STRENGTH CHARACTERISATION
OF
FLY ASH COMPOSITE MATERIAL

A THESIS SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF

BACHELOR OF TECHNOLOGY
IN
MINING ENGINEERING
BY

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DEPARTMENT OF MINING ENGINEERING
NATIONAL INSTITUTE OF TECHNOLOGY
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CERTIFICATE

This is to certify that the thesis entitled **"STRENGTH CHARACTERISATION OF FLY ASH COMPOSITE MATERIAL"** submitted by **Sri Abhisek Das** in partial fulfillment of the requirements for the award of Bachelor of Technology degree in Mining Engineering at the National Institute of Technology, Rourkela (Deemed University) is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University/Institute for the award of any Degree or Diploma.

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ABSTRACT

Coal is one of the primary sources of energy, accounting for about 67% of the total energy consumption in the country. India has some of the largest reserves of coal in the world. Indian coal has high ash content and low calorific value. However, with the present rate of around 0.8 million tons average daily coal extraction in the country, the reserves are likely to last over a 100 years. 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. Nearly 73% of the country’s total installed power generation capacity is thermal of which coal-based generation is 90%. Some 85 thermal power stations, besides several captive power plants use bituminous and sub-bituminous coal and produce large quantities of fly ash. High ash content (30% - 50%) coal contributes to these large volumes of fly ash. The country’s dependence on coal for power generation has unchanged. Thus fly ash management is a cause of concern for the future.

This project report is an attempt to find a suitable utilization for a particular fly ash sample depending upon its geotechnical properties and thus reduce the need for vast areas for disposal of fly ash which in turn causes considerable damage to the environment.

Around 110 million tonnes of fly ash get accumulated every year at the thermal power stations in India. Internationally fly ash is considered as a by product which can be used for many applications. Fly Ash Mission was initiated in 1994 to promote gainful and environment friendly utilization of the material. One of the areas identified for its bulk utilization was in construction of roads and embankments.

In this project various geotechnical experiments are performed on fly ash samples. Some of them are Standard Procter Compaction test, Liquid limit test, Permeability study, Unconfined compressive strength study etc. Based on the results obtained from these experiments, a suitable end use for the fly ash based on the characteristics of the sample is ascertained.
The results from the geotechnical experiments help in determining the potential of the fly ash for use, in highway embankments, in construction of bricks, as an aggregate material in Portland cement, filling of low lying areas etc.

The term “fly ash‟ is often used to describe any fine particulate material precipitated from the stack gases of industrial furnaces burning solid fuels. The amount of fly ash collected from furnaces on a single site can vary from less than one ton per day to several tons per minute. The characteristics and properties of different fly ashes depend on the nature of the fuel and the size of furnace used. Pulverization of solid fuels for the large furnaces used in power stations creates an immediate, urgent problem; dry fly ash has to be collected from the stack gases and disposed of quickly and safely. Fly ashes generally fall into one of two categories, depending on their origin and their chemical and mineralogical composition. Combustion of anthracite or bituminous coal generally produces low-calcium fly ashes; high-calcium fly ashes result from burning lignite or sub-bituminous coal. Both types contain a preponderance of amorphous glass.

Composite material made of fly ash is used in many ways and is subject to a variety of different loading conditions, and so different types of stress develop. The compressive strength of concrete, one of its most important and useful and one of the most easily determined properties, is indicated by the unit stress required to cause failure of a specimen. In addition to being a significant indicator of load-carrying ability, strength is also indicative of other elements of quality concrete in a direct or indirect manner. In general, strong concrete will be more impermeable, better able to withstand severe exposure, and more resistant to wear. On the other hand, strong concrete may have greater shrinkage and susceptibility to cracking than a weaker material. Finally, the concrete-making properties of the various ingredients of the mix are usually measured in terms of the compressive strength.

From the results obtained it was found that the fly ash can be compacted over a large moisture content range thus it has a potential to be used in fills and embankments. Also since fly ash is having low permeability thus it further benefits the use in fills and embankments by reducing the chances of damage to the ground water resources. The low specific gravity of fly and the pozzolanic activity of fly ash aids for its use along-with cements for construction purposes and also in manufacturing of bricks.

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Chapter 1

INTRODUCTION

BACKGROUND

OBJECTIVE

EXPERIMENTAL STUDY PLAN

CHAPTER: 01

INTRODUCTION

Whether used in buildings, bridges, pavements, or any other of its numerous areas of service, composite must have strength, the ability to resist force. The forces to be resisted may result from applied loads, from the weight of the concrete itself or, more commonly, from a combination of these.

Therefore, the strength of concrete is taken as an important index of its general quality. Hence, tests to determine strength are the most common type made to evaluate the properties of hardened concrete, because (a) the strength of concrete. in compression, tension, shear, or a combination of these, has in most cases a direct influence on the load-carrying capacity of both plain and reinforced structures; (b) of all the properties of hardened concrete, those concerning strength usually can be determined most easily; and (c) by means of correlations with other more complicated tests, the results of strength tests can be used as a qualitative indication of other important properties of hardened concrete.

The results of tests on hardened concrete usually are not known until it would be very difficult to replace any concrete which is found to be faulty. These tests, however, have a policing effect on those responsible for construction and provide essential information in cases where the concrete forms a vital structural element of any building. The results of tests on hardened concrete, even if they are known late, help to disclose any trends in concrete quality and enable adjustments to be made in the production of future concrete.

1.1 BACKGROUND

Fly ash was recognized as pozzolanic ingredient for use in concrete as early as in 1914. However, the earliest comprehensive study on the use of fly ash in concrete was conducted by Davis (1937), Abdun Nur (1961) compiled data on the properties. Much of the literature concerning use of fly ash in concrete before 1980 dealt with fly ashes resulting from the burning of bituminous coal, designated as Class F pozzolans in ASTM specifications.

During the early period of 1940 to 1960, usefulness of only Class F fly ash was investigated since that was the generally available ash at that time.

Uses of fly ash were established for a number of applications and the advantages and disadvantages were identified. Co-operative tests were conducted by ASTM Committee C-9 (1962) and studies on the fundamental characteristics of Class F fly ashes were reported by Minnick (1959) during this period. The early studies concluded that substantial amount of the Portland cement in concrete could he replaced with fly ash without adversely affecting the long term strength of concrete (Timms and Grieb, 1956).

These were basically sub-bituminous ashes. Since 1970s a number of studies have been reported dealing with the characteristics of the fly ashes from sub-bituminous. These self hardening fly ashes generally contained larger amounts of calcium as compared to the bituminous ashes. A new class of ash was therefore added to the ASTM specifications which included ashes with more than 15% calcium oxide and combined silica, alumina, and iron oxide content less than 75%. These ashes exhibit many other useful properties.
The most use and, therefore, most research have been on the use of fly ash in cement and concrete.

1.2 GOAL

The basic aim is to evaluate the strength potential of fly ash with addition of additives like gypsum, lime, surfactant & water. The aim has to be achieved through addressing the following specific objectives.

1.3 SPECIFIC OBJECTIVES: The above goal was achieved with the following specific objectives.

- Investigation into the engineering properties and characteristics of the fly ash samples collected.
- Investigation into the strength gain of composite material aspects associated with the one of the fly ash specimen collected.
- Establishment of better suited combinations of fly ash- lime- surfactant compositions for compressive strength test under laboratory scale/conditions.

1.4 EXPERIMENTAL STUDY PLAN

In order to achieve the objectives outlined, the study plan is divided into the following stages.

- **Collection of the fly ash samples**: samples were collected from ROUKELA STEEL PLANT.

- **Collection of data:** for the fulfillment of the objectives mentioned above & to carry out proper investigation into the strength characteristics of fly ash, various necessary data & literatures were collected from different books, journals & internet.

- **Preparation of the samples to be tested:** samples of size 108 mm. × 54 mm. were prepared taking mixtures of fly ash, lime & gypsum.

- **Tests to be performed:** For the samples collected, various strength experiments e.g. Brazillian test, UCS, permeability test, Slake Durability test, was carried out in the laboratory.

- **Results & discussions:** Characterization of the fly ash samples with respect to the engineering properties of composite material based on the results.

LAYOUT:

This project report consists of a total of five chapters each dealing with a specific part. Chapter 1 gives the general outline of the problem, aim and specific objectives of the study, and methodology adopted. Chapter 2 gives a thorough review of the available literature collected over the period. Chapter 3 deals with the various technical experiments adopted to investigate into the strength characteristics of the fly ash composite materials. After that the results obtained in the corresponding experiments are discussed in the chapter 4. At last the important conclusions drawn from the various results are discussed in the last chapter i.e. chapter 5

Chapter 2

LITERATURE REVIEW

Characterization of fly ash

Collection of fly ash

Types and properties of fly ash

CHAPTER: 02
LITERATURE REVIEW

This chapter focuses on important factors affecting strength gain in lime- gypsum - fly ash composite columns and on laboratory procedures for preparing test specimens and determining the strength of lime-cement- gypsum - fly ash composite mixtures. The following topics are covered: properties of the fly ash, preparation prior to mixing, stabilizing agents, dose rates and proportions of stabilizer, mixing of the fly ash with additives and stabilizer, sample production, curing, sample extraction, and strength testing.

2.1 CHARACTERIZATION OF FLY ASH

2.1.1 ORIGIN OF COAL

Coal is a complex, heterogeneous material, in widespread use as an energy source throughout the world. It is the end product of a series of biological and physicochemical processes which have resulted in the wide variety of minable materials currently utilized in industry.

When pulverized coal is burnt to generate electrical power, extremely large quantities of fly ash and bottom ash are produced. Fine grade fly ash has acquired considerable importance in the building materials sector.

Coals are formed in the earth's interior over periods in the order of 300 to 400 million years. Over such long periods, the different kinds of plant material from which coal is formed undergo complex transformations, so that the nature and properties of the great variety of coals we now utilize are dependent on the class of plants which have been transformed and on the depth to which these have been buried. Together with the depth of burial, high temperatures and pressures play an important role in determining coal composition and characteristics.

Coal attains its final stale in combination with a range of different compounds, and can he sub-divided into various classes or groups such as peat, lignite, sub-bituminous and bituminous coals and anthracite. The quantity of water present in these different classes of coal decreases in proportion to their ascending rank, ranging from 90 % for peats to 1.5 % for anthracites.

Characterization of coals demands knowledge of the following parameters:

Moisture,
Ash content,
Volatile matter,
fixed carbon,
sulphur content (organic, pyritic and sulphatic sulphur),
Calorific or heating value.

2.1.2 BURNING CONDITIONS

Coal is burned in power stations in order to generate the heat required to turn water into steam which can be used to drive steam turbines. The energy of the coal is finally converted into electrical power. In accordance with the ranking noted above, anthracite has the highest and lignite the lowest calorific value of the coals used as power station fuels. Three different processes are employed for the combustion of pulverized coal in power station boilers:

High temperature combustion: here combustion occurs at furnace temperatures of some 1500 - 1700 °C. The resulting ash melts and falls into water, where it collects in the form of solid, mainly vitreous particles. Only a small quantity of fine particles escapes to electrostatic precipitators in the form of fly ash. Furnaces of this type are generally referred to as slag-tap furnaces.

Dry combustion: in this case, the pulverized coal is burnt at furnace temperatures of 1100 to 1400 °C. Roughly 90 % of the ash collected from the process is in the form of ultra-fine particles retained by electro filters or precipitators. Since the temperature decreases slowly, the percentage of vitreous particles is low.

Fluidized-bed combustion: the furnace temperature in the fluidized beds is less than 900^0 C, excluding melting. Ashes are irregularly shaped, with a high percentage of crystalline particles. These are not genuine fly ashes, and are of little interest for building material applications. Coal is used as fuel for about 40 to 50% of electric power generation all over the world.

2.2 COLLECTION OF FLY ASH

During the combustion of pulverized coal in suspension-fired furnaces of modern thermal power plants, the volatile matter is vaporized and the majority of the carbon is burned off. The mineral matter associated with the coal, such as clay, quartz and feldspar disintegrate or slag to varying degree.

The slagged particles and unburned carbon are collected as ash. The coarser particles fall in the bottom of the furnace and are collected as bottom ash or boiler slag. The finer particles that escape with flue gases are collected as fly ash using cyclone separators, electrostatic precipitators or bag houses.

Depending upon the collection system varying from mechanical to electrical precipitators or bag houses and fabric filters, about 85 to 99.9% of the ash from the flue gases is retrieved in the form of fly ash. Fly ash, accounts for 75 to 85% of the total coal ash, and the remainder is collected as bottom ash or boiler slag.

Fly ash because of its mineralogical composition, fine particle size and amorphous character is generally pozzolanic and in some cases also self cementitious. The bottom ash and boiler slag are much coarser and are not pozzolanic in nature. It is thus important to recognize that all the ash is not fly ash and the fly ashes produced by different power plants are not equally pozzolanic and, therefore, are not always suitable for use as mineral admixture in concrete.

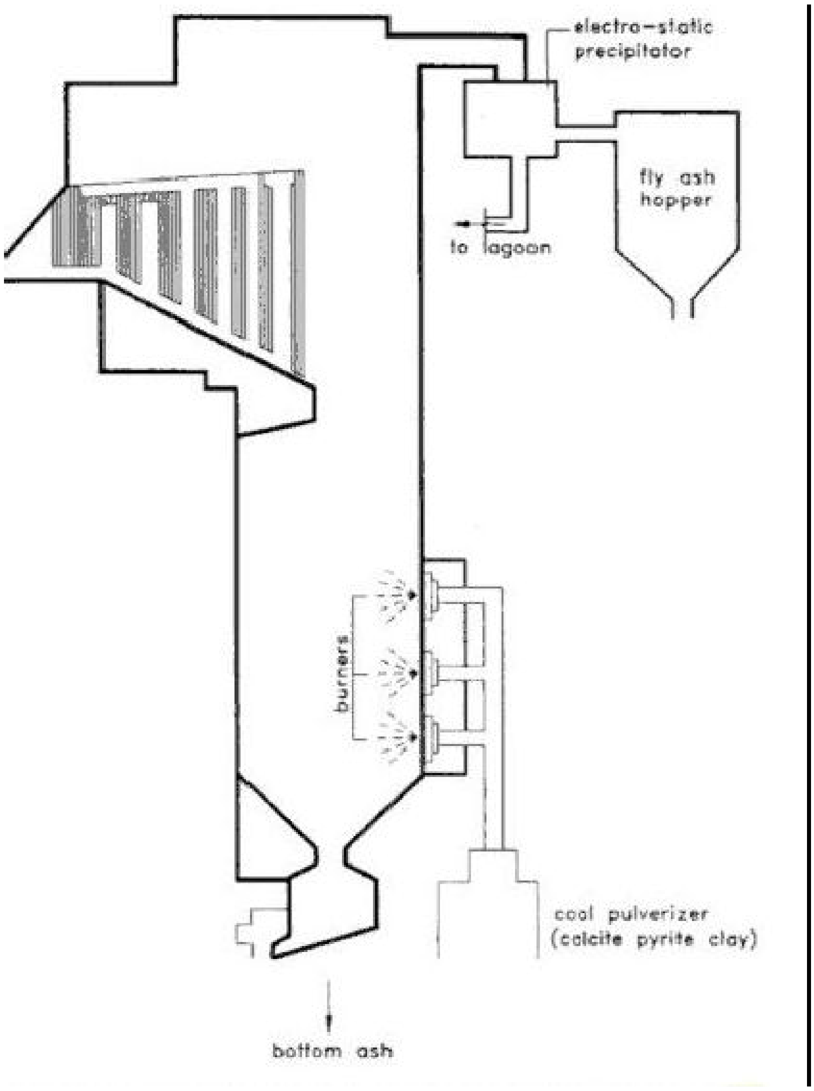

Figure No 2.1 - A typical layout of fossil fuel furnace and fly ash collection system

Fly ash generated in coal burning power plants is an inherently variable material because of several factors. Among these are the type and mineralogical composition of the coal, degree of coal pulverization, type of furnace and oxidation conditions including air-to-fuel ratio, and the manner in which fly ash is collected, handled and stored before use. Since no two utilities or plants may have all of these factors in common, fly ash from various power plants is likely to be different.

The fly ash properties may also vary within the same plant because of load conditions over a twenty four hour period. Non uniformity of fly ash is a serious disadvantage and sometimes is the main hurdle in the effective and wide scale utilization of fly ash as a pozzolan or a cementitious component in cement and concrete.

For collection of the fly ash in a requisite amount from near by steel plant 12-15 plastic bags were arranged. The mouth of the fly ash hopper was opened & the fly ash was allowed to directly fall into the plastic bag. After that the bag of ash was closed & tied with a rope tightly so that the ash inside should not come in contact with the external moisture. The bags were transported from the plant to laboratory & further care was taken to prevent the ash from coming in contact with the other chemicals & moisture.

2.3 TYPES AND PROPERTIES OF FLY ASH

2.3.1 DEFINITIONS AND SPECIFICATIONS

Pozzolans are siliceous and aluminous materials which, though themselves possessing little or no cementitious value, will, in finely divided form and in the presence of moisture, react chemically with calcium hydroxide at ambient temperature to form compounds with cementitious properties (ASTM Standard C618-80).

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. The term fly ash is not applied to the residue extracted from the bottom of boilers.

Fly ashes capable of reacting with $Ca(OH)_2$ at room temperature can act as pozzolanic materials. Their pozzolanic activity is attributable to the presence of SiO_2 and Al_2O_3 in amorphous form. According to ASTM C618-93 specification (1993) for “F1y Ash and Raw or Calcined Natural Pozzolan “for use as Mineral Admixture in Portland Cement Concrete,” pozzolans are defined as “siliceous and aluminous materials which in themselves possess little or no cementitious value but will, in finely divided form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties.”

2.3.2 CLASSIFICATION

As according to ASTM C-618, two major classes of fly ash are recognized. These two classes are related to the type of coal burned and are designated Class F and Class C in most of the current literature. Class F fly ash is normally produced by burning anthracite or bituminous coal while Class C fly ash is generally obtained by burning sub-bituminous or lignite coal. The important characteristics of these two types of ashes are discussed below.

Presently, no appreciable amount of anthracite coal is used for power generation. Therefore, essentially all Class F fly ashes presently available are derived from bituminous coal. Class F fly ashes with calcium oxide (CaO) content less than 6%, designated as low calcium ashes, are not self hardening but generally exhibit pozzolanic properties. These ashes contain more than 2% unburned carbon determined by loss on ignition (LOI) test. Quartz, mullite and hematite are the major crystalline phases identified fly ashes, derived from bituminous coal. Essentially, all the fly ashes and, therefore, most research concerning use of fly ash in cement and concrete are dealt with Class F fly ashes.

In the presence of water, the fly ash particles produced from a bituminous coal react with lime or calcium hydroxide to form cementing compounds similar to those generated on the hydration of Portland cement. Previous research findings and majority of current industry practices indicate that satisfactory and acceptable concrete can be produced with the Class F fly ash replacing 15 to 30% of cement by weight.

When Class F fly ash is used for producing air entrained concrete to improve freeze-thaw durability, the demand for air entraining mixtures is generally increased. Use of Class F fly ash in general reduces water demand as well as heat of hydration. The concrete made with Class F fly ash also exhibits improved resistance to sulphate attack and chloride ion ingress.

Class C fly ashes, containing usually more than 15% CaO and also called high calcium ashes, became available for use in concrete industry only in the last 20 years in the 1970s. Class C fly ashes are not only pozzolanic in nature but are invariably self cementitious.

2.3.3 SPECIFIC GRAVITY

The specific gravity of fly ash is reported to be related to shape, colour as well as chemical composition of fly ash particle. It is adopted as an indirect performance parameter for determining the performance of fly ash in concrete. In ASTM C618, for quality control of fly ash, the uniformity of the fly ash is monitored by limiting the variability of the specific gravity and fineness as measured by the amount retained on 45 µm mesh sieve. The requirement is that any sample tested shall not deviate from the average of 10 previous tests or the total of all tests if the number is less than 10, by more than 5%.

In general specific gravity of fly ash may very from 1.3 to 4.8 (Joshi 1968). However, the Canadian fly ashes have specific gravity ranging from 1.91 to 2.94 whereas those of the American ashes have specific gravity between 2.14 and 2.69. Coal particles with some minerallic impurities have specific gravity between 1.3 and 1.6. Opaque spherical magnetite (ferrite spinel) and hematite particles, light brown to black in colour, when present in sufficient quantity in fly ash increase the specific gravity to about 3.6 to 4.8. As the amount of quartz and mullite increases, the specific gravity decreases. Fly ash pulverization releases some of the gases trapped, during quenching inside the large hollow spherical particles, and increases the bulk specific gravity of the fly ash (Joshi 1968, 1979).

2.3.4 DENSITY

The particle density of fly ash is typically 1.5 - 2.5 mg/m^3; the lower density associated with a high a LOI .There is some variability in the density of particles, with smaller ones having higher densities. This is due to air voids within many of the particles, and between 1% and 5% contains sufficiently large voids that they float on water. The variation in particle density means that sedimentation techniques for determining the particle size distribution are not suitable and more appropriate methods arc now used, e.g. laser scattering. The heavy compaction will give higher maximum dry densities and lower optimum moisture content values, but they are only slightly different from the light compaction; the latter produces more realistic target values for site control.

2.4 EFFECTS OF FLY ASH ON THE PROPERTIES OF FRESH CONCRETE

The present state of knowledge recognizes the usage of fly ash in cement and concrete as raw material in cement production, as an ingredient in blended cement, and as mineral admixture in concrete. Sometimes fly ash is also used as partial replacement of fines. Based on laboratory investigations as well as field applications of fly ash concrete over the last 50 years, several comprehensive reviews and other publications present the accepted views related to the advantages and disadvantages of incorporating fly ash in concrete.

The majority of the recognized effects of fly ash on concrete properties tend to improve concrete performance in field use. The addition of fly ash to concrete affects its properties both in the fresh and hardened states favorably. The nature and degree of effect on a specific concrete property however, depends upon several factors such as type and amount of fly ash, mix proportion, chemical admixtures, curing conditions, and other job requirements including construction practices. In fresh concrete, fly ash plays an important role in the fluidity of concrete which is commonly expressed in such phenomenological measurements as workability, pump ability, compactability, water demand, bleeding and segregation and finish-ability. Addition of fly ash has significant influence on the rate of hydration reactions as well as on the effectiveness of the chemical admixtures, particularly air entraining agent and water reducer or super plasticizer.

Low calcium Class F fly ash normally acts as a fine aggregate of spherical form in early stages of hydration whereas high calcium Class C fly ash may contribute to the early cementing reactions in addition to its presence as fine particulate in the concrete mix Hydration of cement is an exothermic reaction and the released heat causes a rise of temperature of fresh concrete. For producing high strength concrete, high range water reducer or super plasticizer is added to maintain the given workability of concrete at a low water-cement ratio.

Chapter 3

METHODS and MATERIALS

CHAPTER: 03
METHODS and MATERIALS

The purposes of this research are to identify factors that contribute to strength gain in composite specimen. This section summarizes the procedures and materials used in performing the investigation. The sections are the fly ash characterization methods and the method for preparing lime-cement- gypsum-fly ash mix specimens.

3.1 FLY ASH CHARACTERIZATION

Fly ash characterization test were performed on the fly ashes that were investigated in this project. Tests included compressive strength, tensile strength, slake durability & permeability.

3.2 PREPARATION OF FLY ASH COMPOSITE MATERIAL

The fly ash is chosen for its low lime content as well as its availability in abundance. On the basis of the literature reviewing, different lime proportions (0, 5, 10, and 15) % of fly ash (by weight) were selected. Similarly, percentages of gypsum were (0, 0.2, 0.4, 0.6, 0.8) % of fly ash (by weight).

The additives selected are commercially available which are lime, gypsum and surfactant. The addition of lime enhances the pozzolanic reactivity of fly ash containing insufficient free lime required for pozzolanic reaction with its reactive silica. Gypsum is chosen for avoiding the interference of impurities because impurities may retard the initial hydration process.

Depending on the sample dimension, required quantities of fly ash (500 gm), lime, gypsum and water quantity (80-90 %) of the weight of fly ash sample and are thoroughly mixed by hand. Then it was kept inside a plastic mould for 24 hour for moisture homogenization. The samples were cast to NX size core i.e. 54 mm diameter and 108 mm length for compressive strength tests. The samples were taken out of mould after 72 hours and kept in moist proof containers that were in turn placed inside humidity control chambers where the temperature was maintained at about 30˚C ±1%.

The following table shows the proportions of the additives taken in preparation of sample.

Table 3.1

ITEM	AMOUNT TO BE TAKEN
Fly ash (A)	500 gm.
Surfactant or Gypsum (B)	B_0= 0 %, B_1= 0.2 %, B_2=0.4%, B_3=0.6%, B_4=0.8%
Lime (C)	C_0=0%, C_1=5%, C_2=10%, C_3=15%

The following matrix shows the different combinations of the samples prepared. The ingredients were fly ash (A), lime (B) and Gypsum (C).

Table 3.2

AB_0C_0	AB_1C_0	AB_2C_0	AB_3C_0	AB_4C_0
AB_0C_1	AB_1C_1	AB_2C_1	AB_3C_1	AB_4C_1
AB_0C_2	AB_1C_2	AB_2C_2	AB_3C_2	AB_4C_2
AB_0C_3	AB_1C_3	AB_2C_3	AB_3C_3	AB_4C_3

3.3 STRENGTH TESTS:

3.3.1 UNIAXIAL COMPRESSION TEST:

Purpose: To determine the uniaxial compressive strength of rock (qu = Fu = F_c).

Procedure: In this test, cylindrical rock specimens are tested in compression without lateral confinement. The test procedure is similar to the unconfined compression test for soils and concrete. The test specimen should be a rock cylinder of length-to-width ratio (H/D) in the range of 2 to 2.5 with flat, smooth, and parallel ends cut perpendicular to the cylinder axis. Originally, specimen diameters of NX size were used (D = 2c in. = 44mm), yet now the standard size is NQ core (D = 1f in. = 47.6 mm).

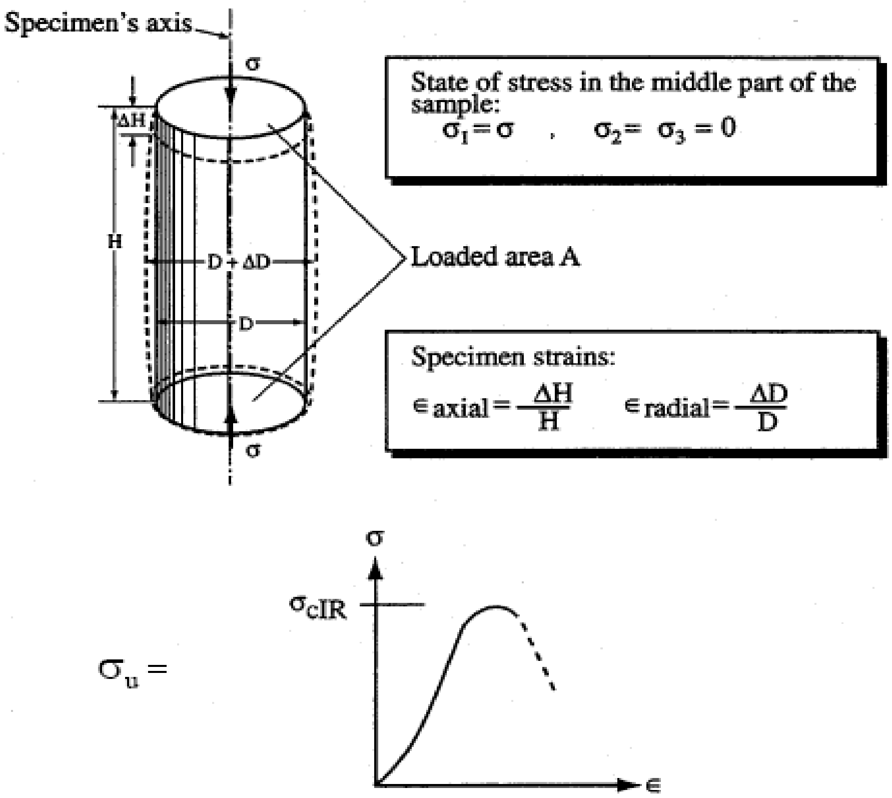

Figure No 3.1 - Uniaxial Compression Test (a) Definitions of stress conditions and strains, (b) Derived stress-strain curve with peak stress corresponding to the uniaxial compressive strength ($q_u = F_u$)

Figure No 3.2 - COMPRESSION TESTING MACHINE

3.3.2 BRAZILLIAN TEST:

Purpose: To evaluate the (indirect) tensile shear of intact rock core, F_T.

Procedures: Core specimens with length-to-diameter ratios (L/D) of between 2 to 2.5 are placed in a compression loading machine with the load platens situated diametrically across the specimen. The maximum load (P) to fracture the specimen is recorded and used to calculate the split tensile strength.

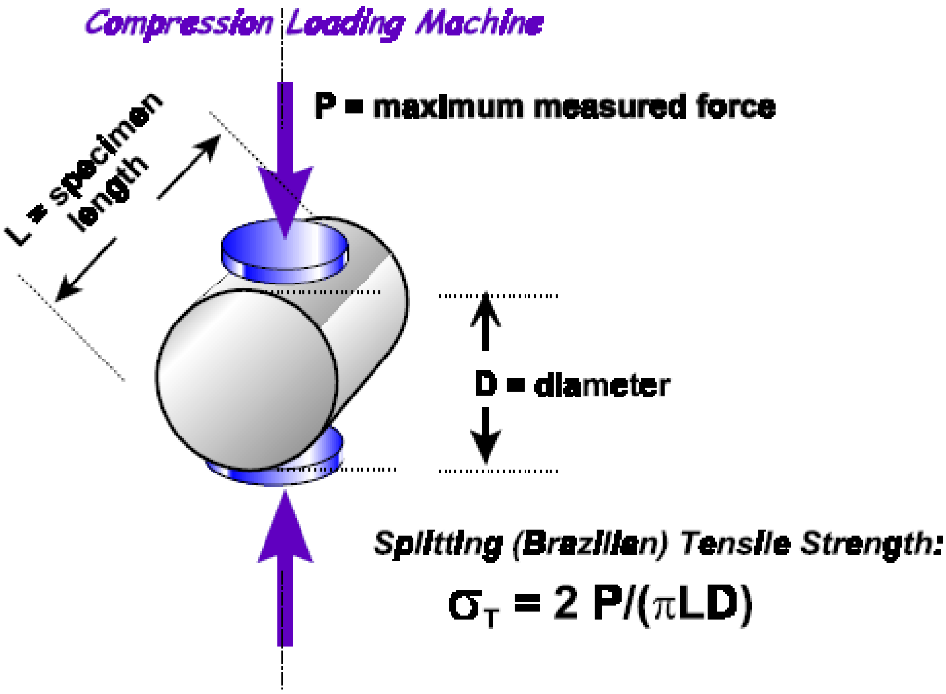

Figure No 3.3 - Setup for Brazilian Tensile Test in Standard Loading Machine.

3.3.3 SLAKE DURABILITY TEST:

Purpose: To determine the durability of shale or other weak or soft rocks subjected to cycles of wetting and drying.

Procedure: In this test dried fragments of rock of known weight are placed in a drum fabricated with 2.0 mm square mesh wire cloth. Figure 3.5 shows a schematic of the test apparatus. The drum is rotated in a horizontal position along its longitudinal axis while partially submerged in distilled water to promote wetting of the sample.

The specimens and the drum are dried at the end of the rotation cycle (10 minutes at 20 rpm) and weighed. After two cycles of rotating and drying the weight loss and the shape and size of the remaining rock fragments are recorded and the Slake Durability Index (SDI) is calculated. Both the SDI and the description of the shape and size of the remaining particles are used to determine the durability of soft rocks.

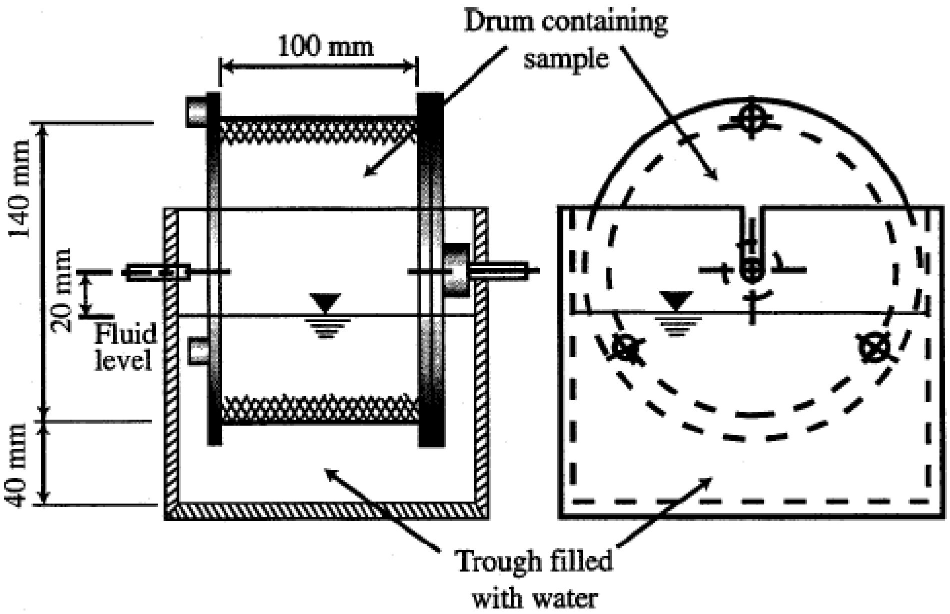

Figure No 3.4 - Rotating Drum Assembly and Setup of Slake Durability

Figure No 3.5 - SLAKE DURABILITY APPARATUS

3.3.4 PERMEABILITY TEST

Objective: to determine the permeability of fly ash using "Miniature high pressure permeameter".

Equipment comprises one each of the following:

- Mould 50 mm diameter x 100 mm high
- Collar for mould
- Top plate
- Base plate with a recess for porous stone
- Porous stone
- Glass stand pipe (indicator pipette) 6 mm x 300 mm long
- Reservoir tank fitted with flow control regulator, valves & two pressure gauges 0- 7 kg/cm^2 , 0 – 10.5 kg/cm^2

The miniature high pressure permeameter is used for studying the permeability characteristics of rock specimens, chemically solidified soils, & industrial products under high pressures. Normally every material can be studied for its permeability characteristics. The small internal dimensions make it possible to perform tests on specimens which have been trimmed from large undisturbed block samples or undisturbed samples obtained by thin wall tube or piston sampling methods or on samples which have been trimmed from larger laboratory compacted specimens.

Pressure type test:

Develop pressure in the water reservoir. Connect the bottom of the permeameter assembly to the water reservoir. Apply required pressure by operating the regulator (10.5 kg/cm^2 pressure gauge indicates the water reservoir pressure & 7.0 kg/cm^2 pressure gauge indicates the test pressure.) when constant flow is established, measure the discharge for a given time.

$$K = (QL / hAt) \text{ cm/ sec}$$

Where Q = discharge in ml.

A = area of specimen in cm^2

t = time of discharge

h = head causing the flow

L = length of specimen

Figure No 3.6 - PERMEABILITY APPARATUS

Chapter 4

RESULTS and DISCUSSIONS

SUMMARY

CHAPTER: 04
RESULTS and DISCUSSIONS

4.1 COMPRESSIVE & TENSILE STRENGTH:

The determination of compression and tensile strength of the prepared samples were carried out as per standard practice. The following table shows the compressive & tensile strengths of various samples after testing.

Table 4.1

Samples			**Date of prep.**	**Date of expt.**	**RESULT**	
type	Curing period				UCS (MPa)	TS (MPa)
AB_0C_0	7D		7.1.09	14.1.09	1.31	0.01
	14D		7.1.09	21.1.09	1.312	0.012
	21D		9.1.09	30.1.09	1.315	0.014
AB_1C_0	7D		12.1.09	19.1.09	1.312	0.011
	14D		12.1.09	26.1.09	1.315	0.012
	21D		12.1.09	2.2.09	1.317	0.013
AB_2C_0	7D		16.1.09	23.1.09	1.32	0.013
	14D		16.1.09	30.1.09	1.325	0.018
	21D		16.1.09	6.2.09	1.328	0.019
AB_0C_1	7D		21.1.09	28.1.09	1.53	0.019
	14D		21.1.09	4.02.09	1.75	0.021
	21D		21.1.09	11.2.09	2.19	0.027
AB_0C_2	7D		2.2.09	9.2.09	1.75	0.021
	14D		2.2.09	16.2.09	2.25	0.034
	21D		2.2.09	23.2.09	2.74	0.038
AB_0C_3	7D		4.3.09	11.3.09	1.8	0.027

	14D		4.3.09	18.3.09	2.26	0.035
	21D		4.3.09	25.3.09	2.89	0.048
AB_3C_0	7D		6.3.09	13.3.09	1.53	0.016
	14D		6.3.09	20.3.09	1.6	0.018
	21D		6.3.09	27.3.09	1.63	0.019
AB_1C_1	7D		9.3.09	16.3.09	1.7	0.019
	14D		9.3.09	23.3.09	1.81	0.023
	21D		9.3.09	30.3.09	1.86	0.029
AB_1C_2	7D		11.3.09	18.3.09	1.9	0.025
	14D		11.3.09	25.3.09	2.1	0.031
	21D		11.3.09	1.4.09	2.56	0.039
AB_1C_3	7D		11.3.09	18.3.09	1.95	0.032
	14D		11.3.09	25.3.09	2.67	0.038
	21D		11.3.09	1.4.09	2.95	0.049
AB_2C_1	7D		16.3.09	23.3.09	1.75	0.02
	14D		16.3.09	30.3.09	1.8	0.024
	21D		16.3.09	6.4.09	1.89	0.03
AB_2C_2	7D		16.3.09	23.3.09	1.91	0.028
	14D		16.3.09	30.3.09	2.35	0.035
	21D		16.3.09	6.4.09	2.57	0.04
AB_2C_3	7D		18.3.09	25.3.09	2.01	0.035
	14D		18.3.09	1.4.09	2.69	0.048
	21D		18.3.09	8.4.09	2.91	0.051
AB_3C_1	7D		18.3.09	25.3.09	1.8	0.023
	14D		18.3.09	1.4.09	1.85	0.028

	21D		18.3.09	8.4.09	1.9	0.032
AB_3C_2	7D		20.3.09	27.3.09	1.92	0.029
	14D		20.3.09	3.4.09	2.23	0.039
	21D		20.3.09	10.4.09	2.59	0.043
AB_3C_3	7D		20.3.09	27.3.09	2.3	0.039
	14D		20.3.09	3.4.09	2.7	0.046
	21D		20.3.09	10.3.09	2.93	0.053
AB_4C_0	7D		21.3.09	28.3.09	1.58	0.019
	14D		21.3.09	6.4.09	1.6	0.02
	21D		21.3.09	13.4.09	1.62	0.021
AB_4C_1	7D		21.3.09	28.3.09	1.81	0.024
	14D		21.3.09	6.4.09	1.9	0.028
	21D		21.3.09	13.4.09	1.95	0.032
AB_4C_2	7D		23.3.09	30.3.09	1.93	0.035
	14D		23.3.09	6.4.09	1.97	0.039
	21D		23.3.09	13.4.09	2.1	0.045
AB_4C_3	7D		25.3.09	1.4.09	2.5	0.045
	14D		25.3.09	8.4.09	2.75	0.049
	21D		25.3.09	15.4.09	2.98	0.056

GRAPHS:

The following graphs are plotted between Uniaxial Compressive strength & Curing Period for various proportions of additives (Gypsum = 0.8%, Lime = 5/ 10/ 15 %)

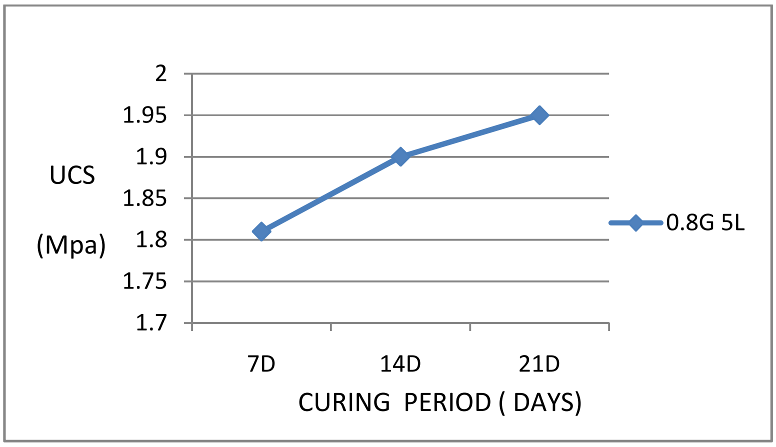

Figure No. 4.1

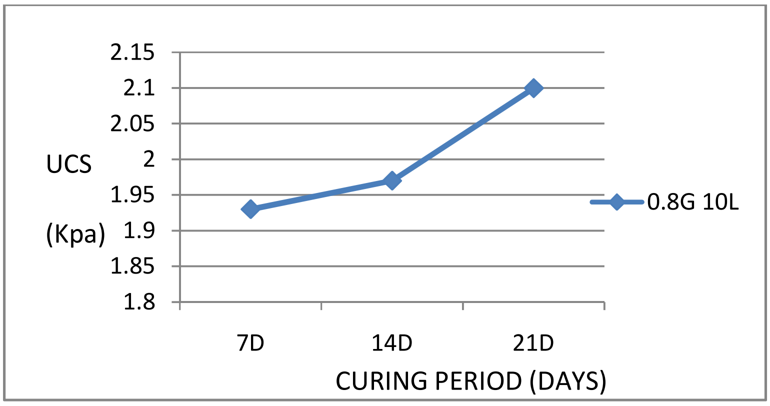

Figure No. 4.2

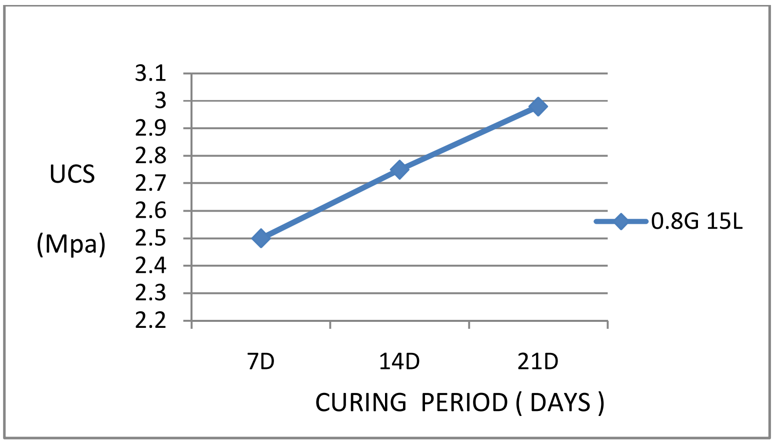

Figure No. 4.3

The following graphs are plotted between Tensile strength & Curing Period taking different proportions of the additives (Gypsum = 0.8%, Lime = 5/ 10/ 15 %)

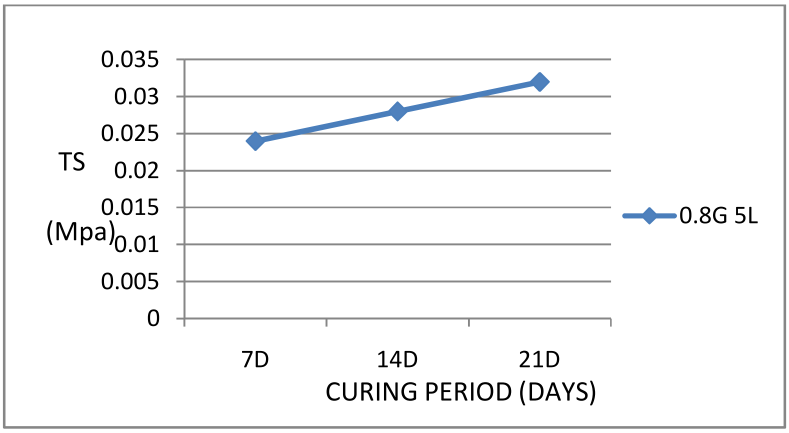

Figure No. 4.4

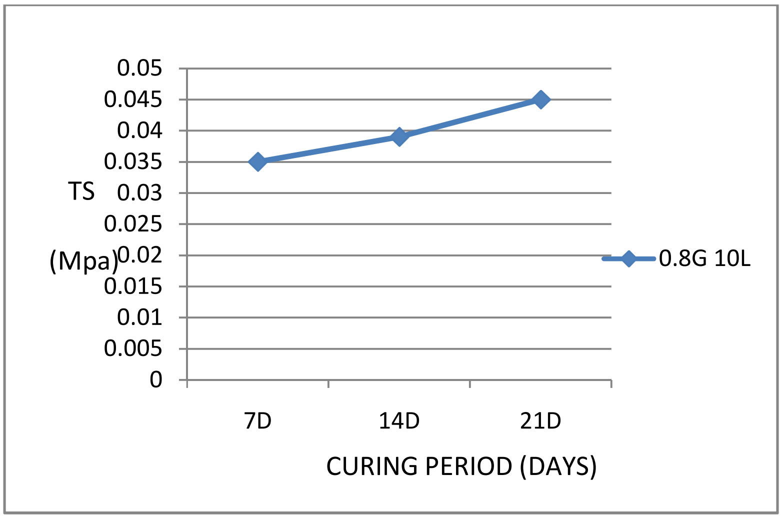

Figure No. 4.5

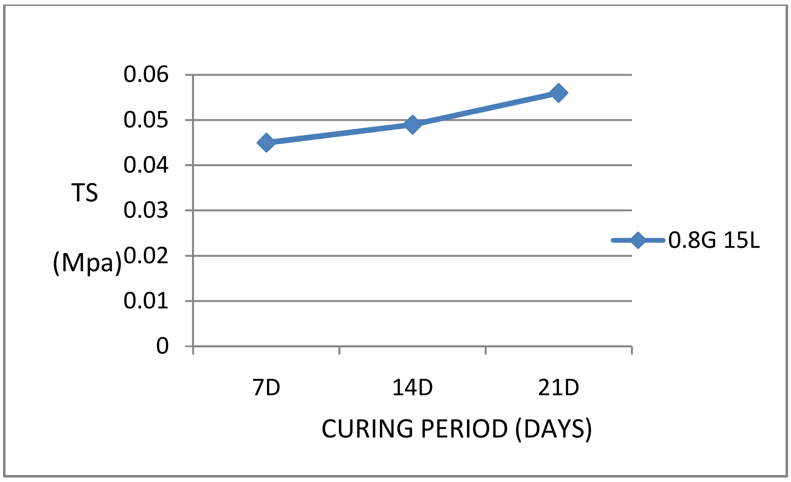

Figure No. 4.6

Compressive strength test is a measure of the resistance of the composites to external loading. UCS tests were conducted on untreated fly ash for 7 days, 14 days and 21 days curing period at room temperature that was about 30 $\pm 3^0$ C. Similar tests were also conducted at the end of 14 days and 21 days of curing time for the fly ash composites. As expected the 7 days cured strength of raw fly ash was very low with only 1.3 MPa and a marginal increase in corresponding values were observed for both 14 days and 21 days of curing periods. Those results are reported in the above table & graphs. The strength of fly ash composite changed with addition of lime, gypsum and temperature and curing period. The 7 days strength of fly ash composites substantially improved with addition of additives. The strength value for composite with 10 % lime was 1.8 MPa and the same for 15 % lime was 2.5 MPa. Addition of 5 % lime increased the strength by about 20 % for both cases. But as the curing period increased to 21 days the strength showed dramatic improvement. The addition of 15 % lime improved the strength of the composite to 2.95 MPa for a 21 days curing period. These observations confirm that addition of lime in excess to fly ash composites may not be beneficial or may even have deleterious effects.

Tensile strength is a measure of resistance of the composite to external tensile forces. Brazilian indirect tensile strength tests were carried out to determine the tensile strength of the fly ash composites in the same testing machine used to find the compressive strength. The samples for the test measured 54 mm in diameter and 27 mm in thickness were cut from the specimen prepared for compressive strength tests. The samples were loaded along the diametrical axis as followed in the method. It was observed that the tensile strength of samples with 10 % lime and

15 % lime were 0.032 and 0.045 MPa respectively, about 3 % of the respective compressive strengths at 7 days curing time. Similar results were also observed for samples without gypsum at 14 days and 21 days curing periods. The tensile strengths were between 10 % and 11.75 % of the compressive strength at respective curing periods. But with the addition of 5 % gypsum the tensile strength improved for all the curing period though at 7 days it was less than 7 % of its compressive strength. The Brazilian tensile strengths almost doubled between 14 days and 28 days curing periods that were more than 15 % and 16 % with 10 % lime and 15 % lime composites respectively.

4.2 PERMEABILTY TEST:

The following table shows various results obtained for the sample containing 10% lime & having curing period of 7, 14, 21 days.

Table 4.2

Curing period	Permeability index (K) in cm/sec
7D	2.8×10^{-4}
14D	2.6×10^{-5}
21D	2.3×10^{-5}

From the above study it is observed that, as the curing period increases, permeability of the sample decreases gradually by a factor of 10 %. This may be due to the reason that as the curing period increases the compaction of sample increases simultaneously & more is the compaction less is possibility of the fractures & pores. Accordingly less is the chance for water to percolate through the sample.

4.3 SLAKE DURABILITY TEST:

Slake durability is defined as the resistance of a rock-like material to wetting and drying cycles. The slake durability indices $I_d(1)$ and $I_d(2)$ after first and second cycles, respectively, are defined as

$$I_d\,(1) = (Y / X) \times 100$$

$$I_d(2) = (Z / X) \times 100$$

Where X = weight of oven dried sample before first cycle started;

Y = weight of oven dried sample retained in mesh drum after one 10 min cycle of rotation; and

Z= weight of oven dried sample retained in mesh drum after two 10 min cycles of rotation. Cured cylindrical specimens of the stabilized mixes of the type

Sample 1:

X = 502 g Y = 241 g Z = 175 g

Sample 2:

X = 498 g Y = 224 g Z = 160 g

Table 4.3

Sample no	$I_d(1)$	$I_d(2)$
1.	48 %	35 %
2.	45 %	32 %

In the present investigations slake durability tests were conducted on each type of composite samples cured for 14 and 21 days. The results of such tests are reported in Table no. 4. It is observed from the tests that the slake durability index for fly ash composite without gypsum vary between 45 % to 32 % during 1st cycle for 14 days curing time and increase marginally for 21 days curing period. The results show considerable increase for both curing periods when 0.8 % gypsum & 10 % lime was added. It indicates that each type of fly ash composite posses low to medium durability as per classifications.

4.4 SUMMARY:

This study was directed toward evaluation of performance of sample specimen incorporating fly ash in addition to proportion of lime, gypsum and surfactant also. Sample mixes; contains 500 g of fly ashes is proportioned to have surfactant replacement of, 10% of lime and 0.8% of gypsum by weight of fly ash sample. The water to cementitious materials ratio was maintained at approximately 0.3, and the desired workability of sample mixes was obtained.

In general, compressive strength increased with age, and decreased with increasing fly ash inclusions in the tested range of variables. However, the specimen containing fly ash in addition to lime, & gypsum is developed to gain maximum compressive strength with age. At an early 7-day age, sample specimen showed a high early compressive strength which is suitable for use in structural concrete.

Based upon data recorded, it can be concluded that specimen containing fly ash with appropriate proportion of certain additives can be proportioned to meet the strength and workability requirement for structural grade concretes.

The chemical, physical and mineralogical properties of fly ash had appreciable effects on performance of fly ash in concrete. Properties of cement influenced the performance of concrete. Therefore, it is necessary to determine the optimum mixture proportions for each cement, lime, gypsum and fly ash source before use.

Chapter 5

CONCLUSIONS and SCOPE

5. CONCLUSION

Based upon data recorded, it can be concluded that specimen containing fly ash with appropriate proportion of certain additives can be proportioned to meet the strength and workability requirement for structural grade concretes.

After conducting all the experiment related to strength development of fly ash based composite materials the following are the factors that affect Strength Gain of Lime-Gypsum-Fly ash composite material:

- Fly ash type (classification, particle size distribution, etc.)
- Fly ash chemistry (pH, cat ion exchange capacity, etc.)
- Types of stabilization agent/agents
- Packing tool / method
- Sample size (mold size)
- Curing time

FUTURE SCOPE:

From the above analysis of samples & based on the results recorded, it can be suggested that the strength of the fly ash composite materials can be further increased by adding the necessary additives in a higher percentage amount & providing them enough curing period for better compaction. For which those composites can meet the requirements for construction purposes.

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WEBSITES:

- www.flyash.info
- en.wikipedia.org/wiki/Fly ash
- www.tifac.org.in/do/fly/fly.htm
- www.flyash.com

STRENGTH CHARACTERISATION OF FLY ASH COMPOSITE MATERIAL:

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Abstract: Coal is one of the major sources of energy, accounting for about 67% of the total energy consumption in the country. Several captive power plants use bituminous and sub-bituminous coal and produce large quantities of fly ash. Thus fly ash management is a cause of concern for the future. The purpose of this project is to find a suitable utilization for a particular fly ash sample depending upon its geotechnical properties and thus reduce the need for vast areas for disposal of fly ash which in turn causes considerable damage to the environment. In this project various geotechnical experiments are performed on fly ash samples. The results from the geotechnical experiments help in determining the potential of the fly ash for use, in highway embankments, in construction of bricks, as an aggregate material in Portland cement, filling of low lying areas etc.

Introduction: Whether used in buildings, bridges, pavements, or any other of its numerous areas of service, composite must have strength, the ability to resist force. The forces to be resisted may result from applied loads, from the weight of the concrete itself or, more commonly, from a combination of these. Therefore, the strength of concrete is taken as an important index of its general quality. Hence, tests to determine strength are the most common type made to evaluate the properties of hardened concrete, because (a) the strength of concrete. in compression, tension, shear, or a combination of these, has in most cases a direct influence on the load-carrying capacity of both plain and reinforced structures; (b) of all the properties of hardened concrete, those concerning strength usually can be determined most easily; and (c) by means of correlations with other more complicated tests, the results of strength tests can be used as a qualitative indication of other important properties of hardened concrete.

Objective: Investigation into the engineering properties and characteristics of the fly ash samples collected & Establishment of better suited combinations of fly ash- lime- surfactant compositions for compressive strength test under laboratory scale/conditions.

Methodology: Fly ash characterization tests were performed on the fly ashes that were investigated in this project. Tests included compressive strength, tensile strength, slake durability & permeability. Following formulae were used to evaluate the strength indices:

- Compressive strength = P / A (where P = max load, A= area of the sample)

- Brazillian Tensile strength = $2P / \pi LD$ (where L= length of the sample)
- Slake durability index = $I_d(1) = (Y / X) \times 100$

  $I_d(2) = (Z / X) \times 100$

Where X = weight of oven dried sample before first cycle started;

Y = weight of oven dried sample retained in mesh drum after one 10 min cycle of rotation

Z= weight of oven dried sample retained in mesh drum after two 10 min cycles of rotation.

- Permeability index : $K = (QL / hAt)$ cm/ sec (where Q = discharge, L= length of specimen, h= head causing flow, t= time of discharge, A = area of specimen)

Results: Compressive strength increased with curing period and decreased with increasing fly ash inclusions in the tested range of variables. However, the specimen containing fly ash in addition to lime and gypsum is developed to gain maximum compressive strength with age. The tensile strength of samples with 10 % lime and 15 % lime were 0.032 and 0.045 MPa respectively, about 3 % of the respective compressive strengths at 7 days curing time. Similar results were also observed for samples without gypsum at 14 days and 21 days curing periods. As the curing period increases, permeability of the sample decreases gradually by a factor of 10 %. Slake durability index for fly ash composite without gypsum vary between 45 % and 32 % during 1st cycle for 14 days curing time and increase marginally for 21 days curing period. It indicates that each type of fly ash composite posses low to medium durability as per classifications.

Conclusion: Based upon data recorded, it can be concluded that specimen containing fly ash with appropriate proportion of certain additives can be proportioned to meet the strength and workability requirement for structural grade concretes.

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