DEVELOPMENT OF STABILIZED FLY ASH COMPOSITE MATERIALS FOR HAUL ROAD APPLICATION

Thesis submitted in partial fulfilment of the requirements for the degree of

Master of Technology

in

MINING ENGINEERING

by

Amit Kumar Jaiswal

Under the guidance of

Prof. Manoj Kumar Mishra

DEPARTMENT OF MINING ENGINEERING
NATIONAL INSTITUTE OF TECHNOLOGY,
ROURKELA – 769 008

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DEPARTMENT OF MINING ENGINEERING
NATIONAL INSTITUTE OF TECHNOLOGY, ROURKELA

June, 2014

Department of Mining Engineering
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CERTIFICATE

This is to certify that the thesis entitled "**Development of stabilised Fly Ash composite materials for Haul Road Application** "Submitted by **Amit Kumar Jaiswal,** Roll **No.** 212MN1465to National Institute of Technology, Rourkela for the award of the degree of M.Tech.in Mining engineering, is a record of bonfire research work under my supervision and guidance.

The research scholar has fulfilled all prescribed requirements for the thesis, which is based on his own work and the thesis my opinion, is worthy of consideration for the award of degree of Master of Technology of the Institute.

The result reported in this thesis has not be submitted to any other University/Institute for the award of any other degree or diploma.

Date:

Prof. Manoj Kumar Mishra
Associate Professor,
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ABSTRACT

Generation of fly ash from the thermal power stations is and will remain a major challenge for the near future. At present out of 140 MT fly ash about 50% are being gainfully used. Rest remain potential environment hazard. Filling of low lying area, underground voids are some of the potential areas of bulk uses. Sub-base of haul road is one such area. An essential attributes of such usage is the strength of fly ash at different period of time. Fly ash does not have any strength. It gains strength in presence of free lime. This investigation is an attempt in that direction. The sub-base of opencast haul road typically suffers from low bearing capacity material as the local material is used. It is envisioned that stabilised fly ash has strong potential to replace the sub-base material and provide adequate resistance to t road degradation. Lime and cement were used as additives to provide reactive lime at different proportions. Laboratory experiments were carried out to evaluate the strength gain in the fly ash. Standard proctor hammer test, unconfined compressive test, Brazilian tensile test and tri-axial test were carried out to determine respective properties. Lime and cement show to be enhancing the strength profiles of the fly ash. Curing periods also has strong influence on the fly ash strength properties. 90 % fly ash and 10% lime shows the maximum strength values at 100 days curing.

Key words-Brazilian tensile test, fly ash, lime, cement, unconfined compressive strength test, Triaxialtest.

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CHAPTER 1

INTRODUCTION

1.1 Introduction and Background

Fly ash is a waste of product from thermal power plant, when coal uses as a fuel. Coal is world's most abundant and widely distributed fossil fuel. An estimate reflects that 75% of India's total installed power is thermal, out of which the share of coal is about 90%. At the present 100 thermal power plant in India produce about 140 million tons of fly ash every year. It is not being used fully for gain full purpose like brick making, cement manufacturing, soil stabilization and as fill materials. Flyash playsan important role for design of road pavement. Haul roads are the life line of any surface mine. Opencast mine economy depends on the cost of haul road design, construction as well as its maintenance in addition to other factor. A stable road base is one of the most important components of road design. Haul road is a multi-layered structure which consists of four layers as surface, base, sub base and sub grade. A typical surface coal mine has about 3 to 5 km of permanent haul road, larger ones having longer lengths and various other branch roads that are constructed either with overburden material or from locally available material found near to the mine property[22].Common surface coal mine haul road construction materialconsists of alluvial soil, crushed rock, sand, gravel, broken shale, sandstone morrum,clay etc. result only in filling the spaces instead of offering total solution to groundstability.

The surface of the road pavement depends on the behaviour of material. Strengthening of the base and sub-base layers beneath, the surface of the surface coal mine, haul road are of vital importance to improve upon mine economics. The materials used in haul road construction are typically sourced locally. It is envisioned that suitable material would address this issue. India produced a large amount of fly ash due to high ash content in its coal reserves and its disposal is a major challenge to power plant operators. However due to technological advances fly ash has found multiple gainful usages in many applications. But those approaches do not address the huge generation completely. Totalnumber of working mine at present is 2628 in 2010-2011.out of which 574 mines deals with coal and lignite, 608 mines deals in metallic minerals, and rest in non metallicminerals. Presently India produces 90 minerals out of which four arefuels minerals, ten are metallic minerals, and fifty are non metallic minerals. Three are atomic minerals andtwenty three are minor minerals. [21]

Table 1. Fly Ash Generation and Its' Utilization in India[43]

SL.NO	Year	Fly ash generation(mtpa)	Fly ash utilization(mtpa)	Percentage utilization
1	2000-01	86.29	13.54	15.70
2	2001-02	82.81	15.57	18.80
3	2002-03	91.65	20.79	22.68
4	2003-04	96.28	28.29	29.39
5	2004-05	98.57	37.49	38.04
6	2005-06	98.97	45.22	45.69
7	2006-07	108.15	55.01	50.86
8	2007-08	116.94	61.98	53
9	2008-09	116.69	66.64	57.11
10	2009-10	123.54	77.33	62.6
11	2010-11	131.09	73.13	55.79

Table 2. Expected Fly Ash Absorption Capacity by Indian Cement Industry [43]

year	**Expected Fly ash absorption(MTPA)**
2015	52.65
2020	73.01
2025	94.63
2030	120.50

1.2 Aim and Objectives-

The goal of the study is to increase the utilisation percentage of fly ash, particularly in geotechnical application. It involves addressing the following specific objectives.

- **a.** Critical review of literature/articles/magazines/books on flyash and its utilisation.
- **b.** Characterisation of the fly ash.
- **c.** Development of stabilised Fly Ash composite materials with additives.
- **d.** Determination of geotechnical properties of fly ash composite materials at different curing period.

1.3 Flow chart of the methodology

The goal and specific objectives of the investigation were achieved by following the steps below.

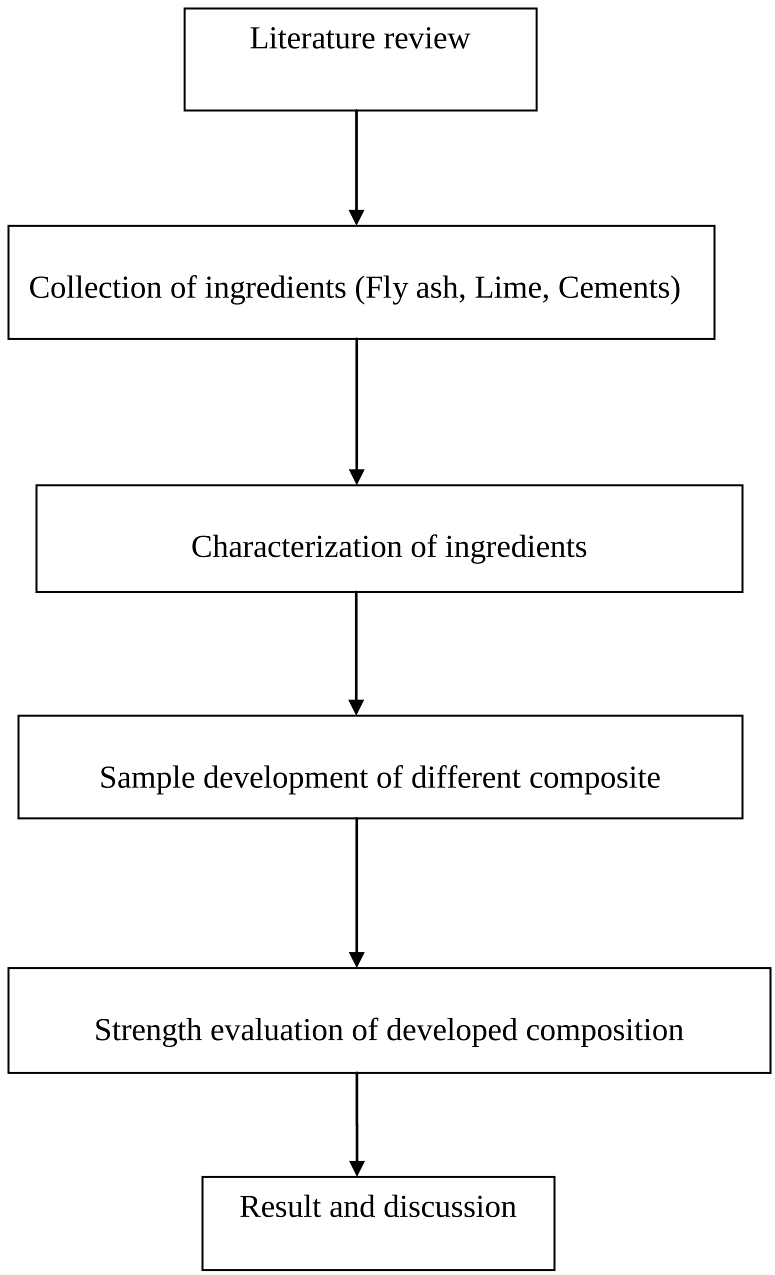

Figure 1: Flow chart of the methodology adopted

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction.

Coal fired power plants produce nearly 90 million tons of fly ash each year. Efforts to use fly ash are highly variable depending upon the coal sources, plant operation, and several other parameters. The different fly ash characteristics are discussed including classification physical features, chemical properties and chemical composition. Electricity generation in India predominantly depends upon coal based power plant. Coal based power plant requires coal of high calorific value to generate electricity. In this process fly ash or coal ash are produced. Indian coal has high ash content. The average ash content in India is 35-38% while imported coal ash content 10-15%. Washingusually reduces the ash content by 7-8%. A large number of coal based thermal power plants provide electric power to sharply growing industries as well as agricultural sectors. In this 70% of electricity is generated by coal based thermal power plant [44].In India the total coal demand was 730 million tonne in 2010-11 and will reach up to approximate 2000 million tonne in 2031-32. It will produce about 600 MT of fly ash annually [3].

2.2 Classification of fly ash-

Various classification schemes have been proposed to organize fly ashes. Each scheme originated with a different purpose in mind. One method widely followed is to identify the suitability of fly ashes as pozzolanic and cementations materials. The two types classified are Type F and Type C fly ash.

2.2.1 Class of F fly ash-

The burning of harder, older anthracite and bituminous coal typically produces Class F fly ash. This fly ash is pozzolanic in nature, and contains less than 20% lime (CaO). Possessing pozzolanic properties, the glassy silica and alumina of Class F fly ash requires a cementing agent, such as Portland cement, quicklime, or hydrated lime, with the presence of water in order to react and produce cementations compounds. Alternatively, the addition of a chemical activator such as sodium silicate (water glass) to a Class F fly ash can lead to the formation of a geopolymer.Typically the silica, iron and aluminium percentage is more than 70% in class “F” type fly ash [23].

2.2.2 Class C fly ash-

Fly ash produced from the burning of younger lignite or sub bituminous coal, in addition to having pozzolanic properties, also has some self-cementing properties. In the presence of water, Class C fly ash will harden and gain strength over time. Class C fly ash generally contains more than 20% lime (CaO). Unlike Class F, self-cementing Class C fly ash does not require an activator. Alkali and sulfate contents are generally higher in Class C fly ashes [23].

2.3Mine haul road and haul trucks-

In open cast coal mine haul road is mainly used for transportation of coal and overburden from one point to another point.

Figure 2.A typical opencast mine [24]

2.4 Problem in haul road: Typically the haul road exhibits the many undesirable features which adversely affect the mine economics. Some of those are as below.

1. Local cracks
2. Sinks
3. Uneven surface
4. Pot holes, etc

The possible solutions are many. Some of those are by making strong base and strong sub-base. It can be achieved by having construction materials in those two layers with sufficient bearing capacity to withstand any vertical and horizontal displacement.

2.5Classification of haul road-

Haul roads are classified in two category depends on traffic the nature of operation on various haul road.

2.5.1 Permanent haul road-

Permanent types of road have a long life and it is the life of mine. The permanenttypes of road is highly expensive and very costly materials are used for design of haul roads.These roads are generally made outside the quarry area. They have to be maintained for a long time in open cast mining[20].

Figure 3. A permanent haul Road [25]

2.5.2 Temporaryhaul roads-

Temporary haul road have a short life,often varying from few weeks to few months depending on production. Ithas minimum road pavement thickness and uses low quality construction materials for design of road pavement. It is usually an inexpensive process[20].

Figure 4. A Temporary haul Road [26]

2.6Design and Fly ash stabilized haul road construction materials-

For the design of haul road pavement is the structure of three or four layers like asphaltic concrete, stabilized fly ash and sub base and sub grade. The main function of haul road pavement is to support the wheel load of the vehicles like dumpers. Pavements are of two broad types i.e. flexible and rigid. The flexible type is popular. Haul road design concerns the ability of the road to carry the imposed loads without need for excessive maintenance.[1]

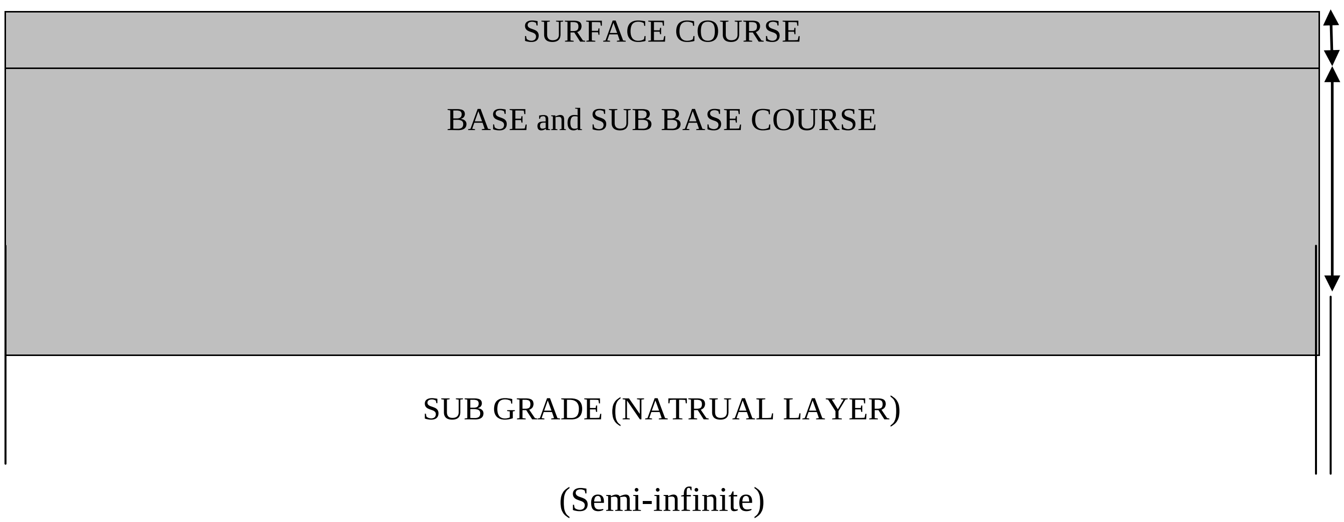

Fig: 5 A typical haul Layer [1]

CHAPTER- 3

METHODOLOGY

3.1 General-

The aim of the investigation was that to enhance the strength properties of surface of coal mine haul road, as well as to achieve the bulk utilization of fly ash. In this chapter the method adopted and materials used to achieve the goal are discussed. The major composition for sample preparation, various methods characterization of ingredient and development of different composite materials are reported.

3.2 Materialsand meathead-

The details of materials used in this investigation are as mentioned in following sections.

3.2.1 Fly ash

Fly ash, a by-product of coal combustions was collected from of Rourkela steel plant (RSP), SAIL; Rourkela is the first integrated steel plant in public sector in India, was set up in German Now its capacity in enhanced to 2 million tons [7].it has a captive thermal power plant that uses electrostatic Precipitator (ESP) to collect the fly ash. The fly ash used had been collected from it and preserved well to retain its characteristics.

Figure6. A local Fly Ash dump site [18]

3.2.2 Lime:

Lime is used as an additive to enhance the strength of fly ash. The lime used was produced from "LobaChemie" India. It is pure Calcium Hydroxide. Its composition is

Table 3.Type Analysis of Lime

$Ca(OH)_2$	M.W. 74.09
Assay (acidimetric)	Min 95.0%
Maximum limit of impurities	
Chloride (Cl)	0.04%
Sulphate (SO_4)	0.4%
Iron (Fe)	0.1%
Heavy metals(as Pb)	0.005%
Substances not precipitated by ammonium oxalate (as Sulphate)	2.50 %

Figure**7.** Collection of lime[27]

3.2.3 Cement:

Cement is a binder. When some percent of cement is used in fly ash its strength increases. Portland cement is the most common types of cement used. It is made by heating lime stone with small quantities of other materials (Such as clay) to 1450°C in a kiln. This process is known as calcinations.The colorof the color of Portland cement is gray or white [9]. The Portland cement used belong to Konarkbrand of OCL,Rajgangpur,India.

Figure8.Portland cement is gray or white [16]

3.3 Method:

3.3.1 Sample preparation:

Before starting sample preparation, the moisture – density relationship was determined for each composite material (% fly ash and % cement or lime). Compaction was achieved by the standard Proctor procedure. Proctor hammer test is mainly used, to predict the quantity of water to be mixed in sample. All the samples tested throughout this study were prepared in accordance to the procedure. The aim of this investigation was not only to increase the haul road strength behavior, but also to maximize fly ash utilization. So different composition are use for evaluating the performance of construction of haul road.

Different types of composition are used as given below.

Table 4. Different types of composition are used for sample preparation

Fly ash (%)	Lime (%)	Cement (%)
90	10	0
92	8	0
95	5	0
97	3	0
92	0	8
95	0	5
97	0	3

The testing of sample are performed,at different daysas 7days, 14 days, 33days, 47days, 60days and 100days. The strength of samples will increases as curing periods increases.

3.4 Standard proctor compaction test-

For construction of road pavement, airports, and other structure, it is very necessary to compact soil to improve its strength. Procter developed a laboratory compaction test procedure to find out maximum dry unit weight of compaction of soil, which can be used for specification of field compaction. Typical equipments used for the test are given below.

Equipment.

1. Compaction mould.
2. Number of U.S sieve.
3. Standard proctor hammer.
4. Large flat pan.
7. Moisture cans.
8. Drying oven.
9. Plastic squeeze bottle with water.

Proctor compaction mould and hammer-

A diagram of aproctor mould and hammer compaction mould isas shown in figure [Figure 9].There isa extension and base plate that can be attached to the top and bottom of the mould, respectively. The inside of mould volume is 1000cc.

Procedure-

- Obtain about 2k.g air dry soil (fly ash and lime/cement) on which the proctor hammer compaction test will be conducted.
- Add enough water (5%, 7%, 9%, 11%)
- Determine the weight of the proctor mould+ base plate,(Not extension), W_1
- Now attach the extension to the top of mould.
- Pour the mould soil into the mould in three equal layers. Each layer should be compacted uniformly by the standard proctor hammer 25 times before the next layer of loose soil is poured into the mould.
- Remove the top attachment(extension)
- Trim the excess soil above the mould

- Determine the weight of mould+base, plate+compacted, moist soil in the mould,W_2.
- Remove the base plate from the mould. Using a jack, extrude the compacted soil from the mould.
- Take the moisture can and determine the mass,W_3(g).
- From the moisture soil extruded and collects a moisture sample in the moisture in above statement and determines the mass of cane+ moisture soil,W_4.
- Placed the moisture can in oven with moist soil in the pan to dry a constant weight.
- Break the rest part of compact soil by hand and mix it and add more water and mix it to raise the moisture content.[10]

Figure9. Proctor compaction Mould and hammer [28]

The different readings of the test are as below.

Table5.Proctor hammer reading for Fly ash-97%, lime-0%, cement 3%

Moisture content	**5%water**	**7%water**	**9%water**	**11%water**
Weight of mould(W_1kg)	3.739	3.739	3.739	3.739
Weight of mould(W_1)+Moisture soil(W_2)	4.9371	5.015	5.108	5.24
Weight of moist soil,(W_2-W_1)	1.198	1.276	1.369	1.501
Moist unit weight=(W_1-WW_1)/10^{-3}(m^3)	1.198*10^3	1.276*10^3	1.369*10^3	1.501*10^3
Mass of moisture can,W_3.(kg)	0.021	0.020	0.019	0.021
Mass of can+moisture soil,(W_4)	0.100	0.073	0.092	0.086
Mass of can+dry soil(W_5.)	0.097	0.072	0.076	0.069
W% = (W_4-W_5)(100)/(W_5-W_3)	3.94%	1.92%	21.66%	35.41%
Dry unit weight=moist weight/1+(w%/100)(Kg/m^3)	1157.5	1251.9	1125.2	1108.48

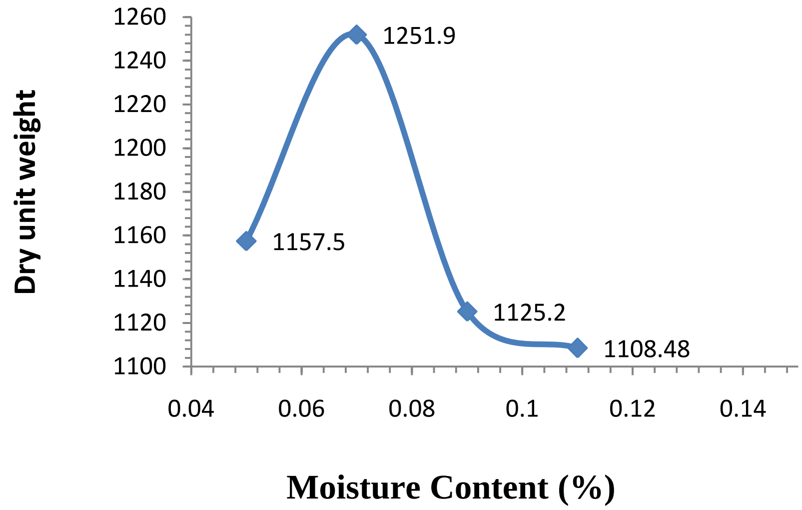

Figure10.Dry unit weight Vs Moisture content

Table6.Proctor hammer reading for Fly ash-95%, lime-0%, cement 5%

Moisture content	**5%water**	**7%water**	**9%water**	**11%water**
Weight of mould(W_1kg)	3.739	3.739	3.739	3.739
Weight of mould(W_1)+Moisture soil(W_2)	4.935	5.042	5.17	5.245
Weight of moist soil, (W_2-W_1)	1.196	1.303	1.431	1.506
Moist unit weight=(W_2-W_1)/10^{-3}(m^3)	1.196*10^3	1.303*10^3	1.431*10^3	1.506*10^3
Mass of moisture can,W_3(kg)	0.019	0.0202	0.0211	0.0212
Mass of can+moisture soil,(W_4)	0.103	0.116	0.115	0.137
Mass of can+dry soil(W_5)	0.102	0.109	0.102	0.113
W% = (W_4-W_5)(100)/(W_5-W_3)	0.0121	0.078	0.160	0.261
Dry unit weight=moist weight/1+(w%/100)(Kg/m^3)	1181.7	1208.7	1234.48	1194.29

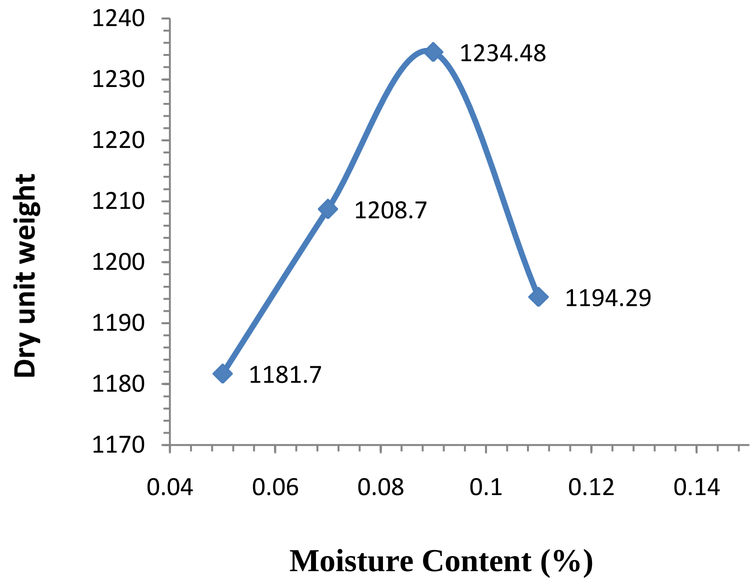

Figure11. Dry unit weight Vs Moisture content

Table7.Proctor hammer reading for Fly ash-92%, lime-0%, cement 8%

Moisture content	**5%water**	**7%water**	**9%water**	**11%wate r**
Weight of mould(W_1kg)	3.739	3.739	3.739	3.739
Weight of mould(W_1)+Moisture soil(W_2)	4.952	5.061	5.179	5.263
Weight of moist soil,(W_2-W_1)	1.213	1.322	1.44	1.524
Moist unit weight=(W_2-W_1)/10^{-3}(m^3)	1.213*10^3	1.322*10^3	1.44*10^3	1.524*10^3
Mass of moisture can,W3(kg)	0.021	0.0202	0.0212	0.019
Mass of can+moisture soil,(W_4)	0.103	0.108	0.111	0.122
Mass of can+dry soil(W_5)	0.100	0.102	0.099	0.100
W% = (W_4-W_5)(100)/(W_5-W_3)	0.038	0.0734	0.154	0.273
Dry unit weight=moist weight/1+(w%/100)(Kg/m^3)	1168.59	1231.6	1247.81	1197.17

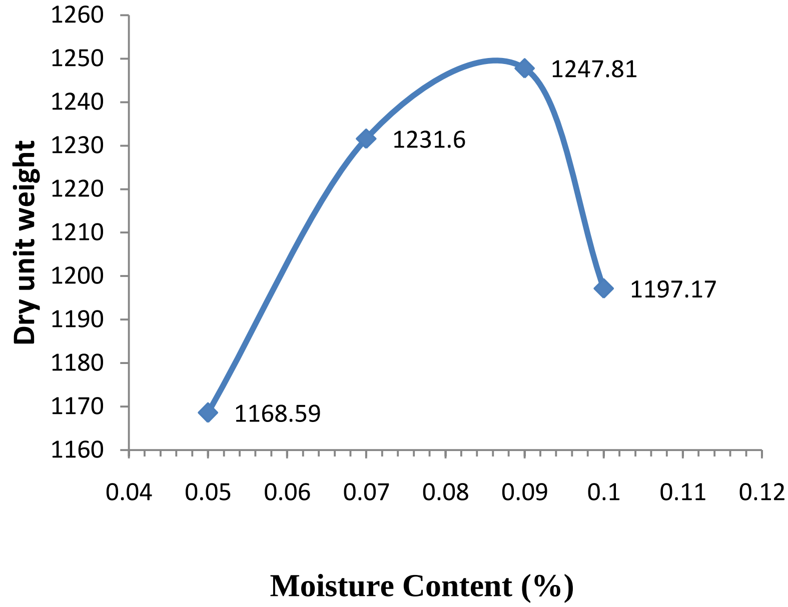

Figure12. Dry unit weight Vs Moisture content

Table8. Proctor hammer reading for Fly ash-97%, lime-3%, cement0%

Moisture content	**5%water**	**7%water**	**9%water**	**11%water**
Weight of mould(W_1kg)	3.739	3.739	3.739	3.739
Weight of mould(W_1)+Moisture soil(W_2)	4.913	5.012	5.175	5.21
Weight of moist soil,(W_2-W_1)	1.174	1.273	1.436	1.471
Moist unit weight=(W_2-W_1)/10^{-3}(m^3)	1.174*10^3	1.273*10^3	1.436*10^3	1.471*10^3
Mass of moisture can,W_3(kg)	0.196	0.02026	0.021	0.0212
Mass of can+moisture soil,(W_4)	0.092	0.097	0.115	0.136
Mass of can+dry soil(W_5)	0.090	0.095	0.104	0.112
W% = (W_4-W_5)(100)/(W_5-W_3)	0.0284	0.02675	0.1326	0.2643
Dry unit weight = moist weight/1+(w%/100)(Kg/m^3)	1141.57	1239.84	1267.87	1163.48

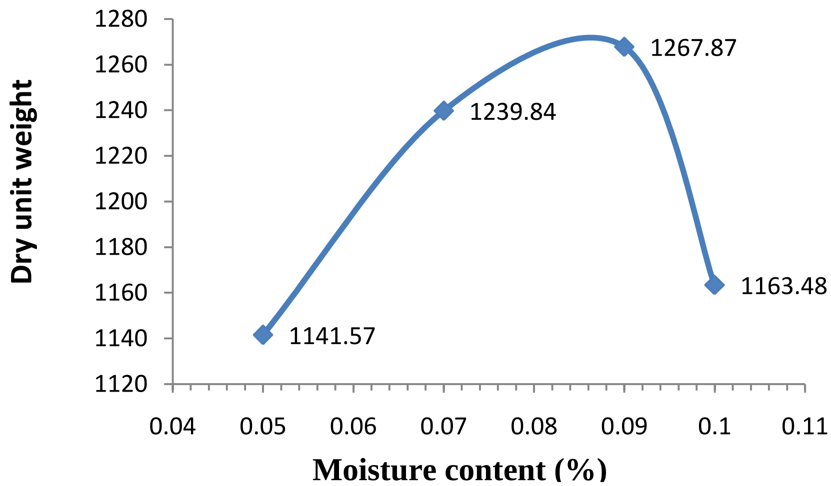

Figure13. Dry unit weight Vs Moisture content

Table9.Proctor hammer reading forFly ash-95%, lime-5%, cement0%

Moisture content	**5%water**	**7%water**	**9%water**
Weight of mould(W_1kg)	3.739	3.739	3.739
Weight of mould(W_1)+Moisture soil(W_2)	4.888	4.97	5.134
Weight of moist soil,(W_2-W_1)	1.149	1.231	1.395
Moist unit weight=(W_2 -W_1)/10^{-3}(m^3)	1.149*10^3	1.231*10^3	1.395*10^3
Mass of moisture can,W_3(kg)	0.0211	0.0212	0.01961
Mass of can+moisture soil,(W_4)	0.079	0.092	0.106
Mass of can+dry soil(W_5)	0.076	0.084	0.082
W% = (W_4-W_5)(100)/(W_5-W_3)	0.0546	0.127	0.384
Dry unit weight=moist weight/1+(w%/100)(Kg/m^3)	1089.5	1092.28	1007.5

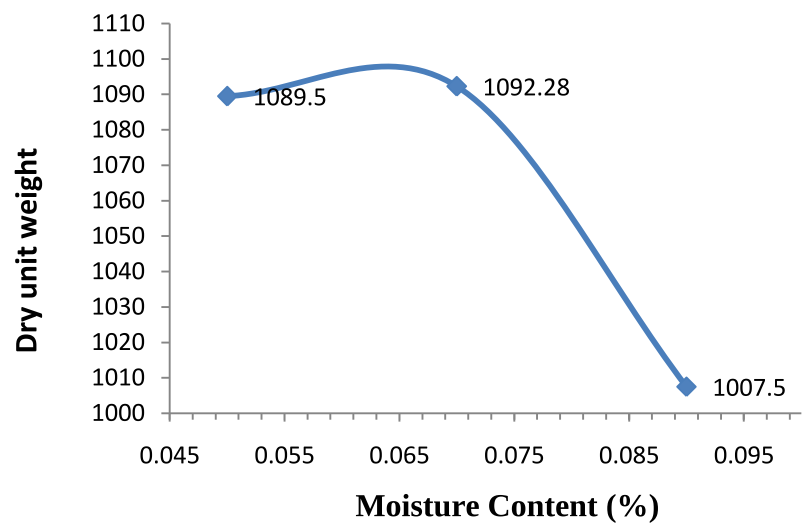

Figure14. Dry unit weight Vs Moisture content

Table10.Proctor hammer reading forFly ash-92%, lime-8%, cement 0%

Moisture content	5%water	7%water	9%water
Weight of mould(W_1kg)	3.739	3.739	3.739
Weight of mould(W_1)+Moisture soil(W_2)	4.908	5.011	5.029
Weight of moist soil,(W_2-W_1)	1.169	1.272	1.281
Moist unit weight=(W_2-W_1)/10^{-3}(m^3)	1.169*10^3	1.272*10^3	1.281*10^3
Mass of moisture can,W_3(kg)	0.0202	0.021	0.019
Mass of can+moisture soil,(W_4)	0.086	0.106	0.127
Mass of can+dry soil(W_5)	0.083	0.097	0.110
W% = (W_4-W_5)(100)/(W_5-W_3)	0.0478	0.1185	0.18807
Dry unit weight=moist weight/1+(w%/100) (Kg/m^3)	1115.67	1137.23	1078.21

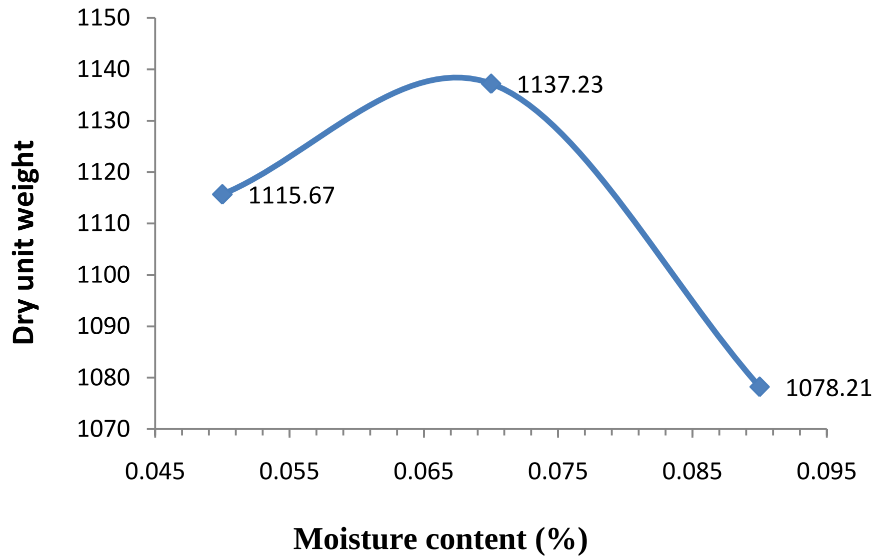

Figure15. Dry unit weight Vs Moisture content

Table11. Proctor hammer reading for Fly ash-90%, lime-10%, cement 0%)

Moisture content	**5%water**	**7%water**	**9%water**	**11%water**
Weight of mould(W_1kg)	3.739	3.739	3.739	3.739
Weight of mould(W_1)+Moisture soil(W_2)	4.909	5.006	5.173	5.236
Weight of moist soil,(W_2-W_1)	1.17	1.267	1.434	1.497
Moist unit weight=(W_2-W_1)/10^{-3}(m^3)	1.17*10^3	1.267*10^3	1.434*10^3	1.497*10^3
Mass of moisture can,W_3(kg)	0.196	0.0212	0.021	0.0202
Mass of can+moisture soil,(W_4)	0.105	0.104	0.134	0.154
Mass of can+dry soil(W_5)	0.101	0.096	0.114	0.123
W% = (W_4-W_5)(100)/(W_5-W_3)	0.0491	0.1069	0.215	0.3017
Dry unit weight=moist weight/1+(w%/100) (Kg/m^3)	1115.24	1144.63	1180.24	1150.03

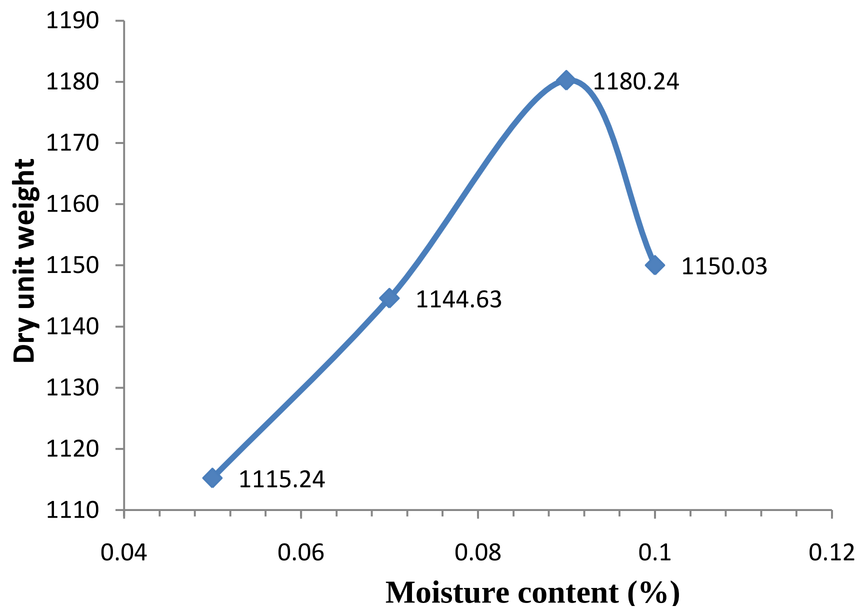

Figure 16. Dry unit weight Vs Moisture content

3.5 Sample preparation for UCS Test-

The purpose of this experiment is to determine the unconfined compressive strength of a cohesive soil sample. A cylinder mould of 13cm length and 6cm diameter was used for preparation of the un-confined compressive strength (UCS) test sample. Sample was prepared with uniform tamping. The final prepared specimen had length to diameter ratio of 2 to 2.5 cm. The typical sample for UCS test is shown in figure 17.

Figure17.Samples for UCS testing

3.6 Sample preparation for Tensile Strength Test-

The Brazilian tensile test make the sample fail under tension though the loading pattern is compressive in nature.This tensile strength is determined as per ASTM D3967.The sample of Brazilian tensile strength test was prepared using the same mould of UCS test sample. For this purpose the circular disk length to diameter ratio was 0.5.The length of circular disk was 3cm and diameter of circular disk was 6 cm. The typical sample for Tensile Strength test is shown in figure 18.

Figure18.Sample for Tensile Strength testing

3.7 Sample preparation of untrained Tri-axial test-

The un-drained, tri-axial compression test was carried out as per IS: 2720-Part 11(1993).

Tri-axial test is more reliable because it can measure both drained and untrained shear Strength. Generally 5cm diameter 10cm long (L/D=2) specimen was used. The purpose of this experiment is calculated the compressive strength and young modulus of fly ash sample.The typical sample for Tri-axial testing test was shown in figure 19.

Figure19.Sample for Tri-axial testing

CHAPTER 4

EXPERIMENTATION

4.1UNCONFINED COMPRESSION TEST (UCS):

The purpose of this experiment is to calculate the unconfined compressive strength of a cohesive soil sample. The unconfined compressive strengths for fine ash are higher than those for the coarser ash specimens [38]. The fraction of lime, present as free lime in the form of calcium oxide or calcium hydroxide, controls self-hardening characteristics of fly ashes [39]. The unconfined compressive strength of fly ashes act as a function of free lime presents [40]. The unconfined compressive strength of fly ash increased exponentially with the free lime content [41]. The major advantage of fly ashes with regard to shear strength in the compacted and saturated condition is that the variation of effective friction angle is negligibly small, irrespective of whether it is obtained from consolidated drained test or consolidated un-drained test [31]. The shear strength of class F fly ash primarily depends on cohesion component when it is in partially saturated. When the sample is fully saturated or dried, it loses its cohesive part of the strength. When densityof fly ash increases its friction also increases. The general relationship between UCS and quality of sub-grade soil are used in pavement construction. (Table 11)

Table12. Relationship between UCS and quality of sub-grade soil [42]

Quality of Sub-grade	UCS(KPa)
Soft sub-grade	25-50
Medium sub-grade	50-100
Stiff sub-grade	100-200
Very stiff sub-grade	200-380
Hard sub-grade	>380

Equipment:

Compression device, Load and deformation dial gauges, Sample trimming equipment, Balance, Moisture can.

Figure20. Sample testing for UCS

Figure21. Specimen after Failure

Calculation:

The results of unconfined compressive strength tests of different composite sample are shown below. The respective young's modulus values are also given. The equation for UCS is

$$\mathbf{S=P/A}$$

Where**P**=load at failure, **A**= cross sectional area, **S**=UCS

$$\mathbf{E}=\frac{S}{\varepsilon}$$

Where **E**=Young's modulus, $\boldsymbol{\varepsilon}=$ Axial strain

Table13. Unconfined Compressive Strength (UCS, MN/m^2) at different curing periods

composition(days)	7	14	33	47	60	100
97%FLY ASH,3%C	0.031	0.047	.05702	0.077	0.175	0.290
95%FLY ASH,5%C	0.041	0.072	.0939	0.145	0.301	0.362
92%FLY ASH,8%C	0.186	0.248	.0290	0.044	0.497	0.518
97%FLY ASH,3%L	0.062	0.082	0.155	0.222	0.290	0.321
95%FLY ASH,5%L	0.082	0.130	0.196	0.238	0.425	0.528
92%FLY ASH,8%L	0.198	0.253	0.312	0.490	0.520	0.611
90%FLY ASH,10%L	0.210	0.290	0.335	0521	0.601	0.715

Table 14. Young's modulus (E, MN/m^2)at different curing periods

composition(days)	7	14	33	47	60	100
97%FLY ASH,3%C	1.82	2.3	2.59	2.99	7.78	10.97
95%FLY ASH,5%C	2.047	3.02	3.61	6.61	13.7	16.62
92%FLY ASH,8%C	6.43	8.58	9.67	18.21	20.57	23.44
97%FLY ASH,3%L	4.78	5.52	6.47	7.42	11.16	27.05
95%FLY ASH,5%L	4.87	6.87	8.95	9.17	18.2	30.08
92%FLY ASH,8%L	7.18	8.95	10.51	20.38	21.95	32.9
90%FLY ASH,10%L	8.86	9.95	11.87	23.23	24.97	34.355

4.2Brazilian tensile strength test

The Brazilian tensile strength was conducted to determine the indirect tensile strength.

Procedure-

- The machine is set on the suitable measuring scale and proper rate of loading with the arrow set to zero.
- The diameter and thickness are measured.
- The specimen is set between the upper and lower platens and they are brought near the specimen.
- The specimen is loaded at the prescribed steady state to the point of failure.
- The fracturing load is recorded.

Figure22. Sample testing for tensile strength

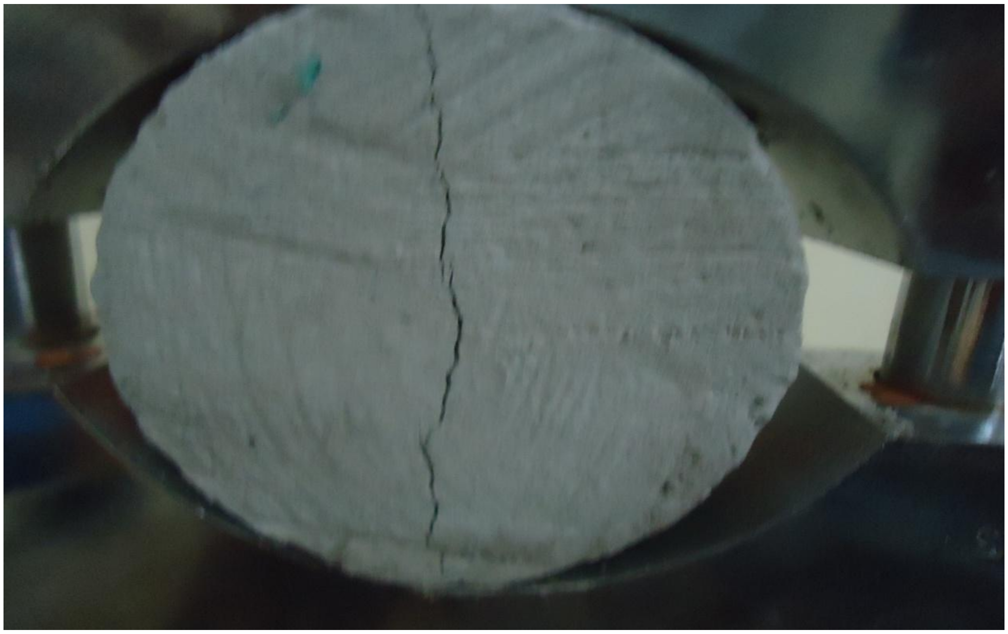

Figure23. Specimen after failure

The result of tensile strength tests are given below,

The tensile equations $\boldsymbol{\sigma_t} = \frac{\boldsymbol{2p}}{\boldsymbol{\pi D t}}$

where

σ_t= Tensile strength

P= Load at failure

D= sample diameter

t=sample thickness

Brazilian tensile strength(BTS(MN/m^2))

Table 15. Tensile Strength (BTS, MN/m^2) at different curing period

composition(days)	7	14	33	47	60	100
97%FLY ASH,3%C	0.0103	0.022	0.0228	0.036.28	0.067	0.108
95%FLY ASH,5%C	0.0586	0.072	0.082	0.134.97	0.185	0.212
92%FLY ASH,8%C	0.093	0.114	0.128	0.202	0.233	0.300
97%FLY ASH,3%L	0.045	0.062	0.072	0.134.78	0.150	0.189
95%FLY ASH,5%L	0.057	0.077	0.103	0.145.36	0.191	0.274
92%FLY ASH,8%L	0.124	0.176	0.196	0.207	0.269	0.383
90%FLY ASH,10%L	0.145	0.188	0.230	0.249	0.310	0.432

4.3 Shear strength of the soil by Undrained Tri-axial test-

Figure24. Antypical Tri-axial Test

The standard integrated untrained test is pressing test, in which the soil pattern is first integrated under all round pressure in the tri-axial cell before failure is brought about by increasing the major principal stress. It may be performing with or without measurement of pore pressure although for most applications the measurement of pore pressure is desirable.

Generally 5cm diameter and 10cm long (L/D=2) specimen is used. Specimen is covered by a thin rubber membrane and set into a plastic cylindrical chamber. Cell pressure is applied in the chamber (which represents σ_3') by pressurizing the cell fluid (generally water).Vertical stress is increased by loading the specimen until shear failure occurs.

Compressive strength by Tri-axial tests-

σ_3=.00689(MN/m^2) **compressive strength (MN/m^2)**

Table 16.Compressive Strength by Unitri-axial tests in MN/m^2at different curing period

composition(days)	7	14	33	47	60	100
97%FLY ASH,3%C	0.0597	0.0895	0.119	0.179	0.191	0.248
95%FLY ASH,5%C	0.179	0.209	0.358	0.447	0.476	0.901
92%FLY ASH,8%C	0.358	0.418	0.537	0.716	0.787	0.1433
97%FLY ASH,3%L	0.179	0.223	0.268	0.328	0.352	0.691
95%FLY ASH,5%L	0.343	0.403	0.492	0.579	0.622	0.746
92%FLY ASH,8%L	0.390	0.462	0.665	0.789	0.912	1.620
90%FLY ASH,10%L	0.597	0.716	1.254	1.285	1.617	2.687

Table 17. Young's modulus (E, MN/m^2)at different curing period

composition(days)	7	14	33	47	60	100
97%FLY ASH,3%C	3.98	4.4	7.96	11.94	12.76	16.58
95%FLY ASH,5%C	7.16	8.3	11.94	14.92	15.89	20.04
92%FLY ASH,8%C	10.23	10.45	13.43	14.33	17.51	28.66
97%FLY ASH,3%L	7.11	8.95	10.74	16.42	23.50	27.64
95%FLY ASH,5%L	11.73	13.51	14.07	17.06	25.73	29.85
92%FLY ASH,8%L	14.87	17.65	21.64	22.57	26.06	46.30
90%FLY ASH,10%L	19.90	20.47	31.35	32.14	35.94	48.86

Undrained Tri-axial Test is mainly used for calculation of cohesion and friction angle. The test reading was used in software code ROCKLAB (www.rocscience.com) to find cohesion and angle of internal of friction.Figures 25, 26, 27, 28, 29, 30, and 31 show the respective results.

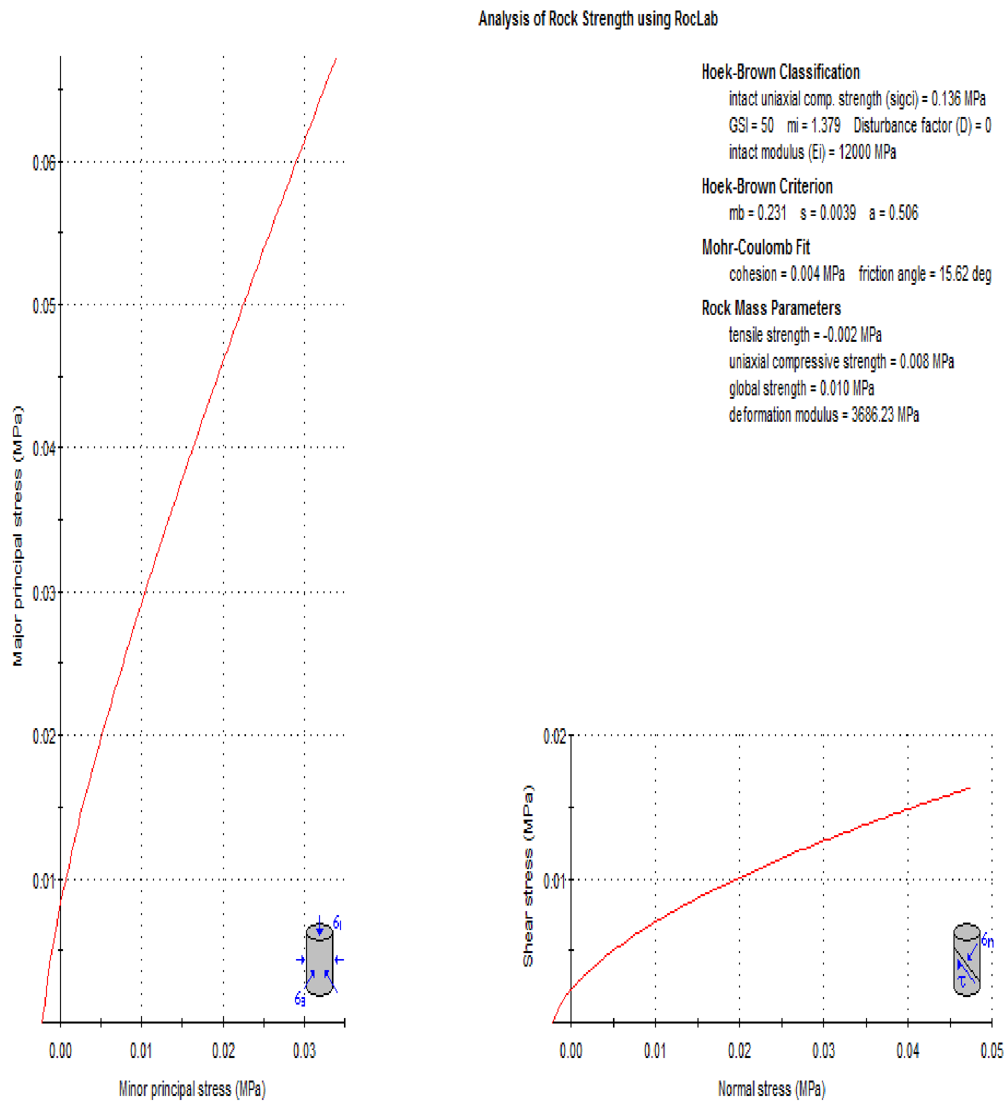

Figure25.Calculation of cohesion and friction angle (97%fly ash and 3% cement).

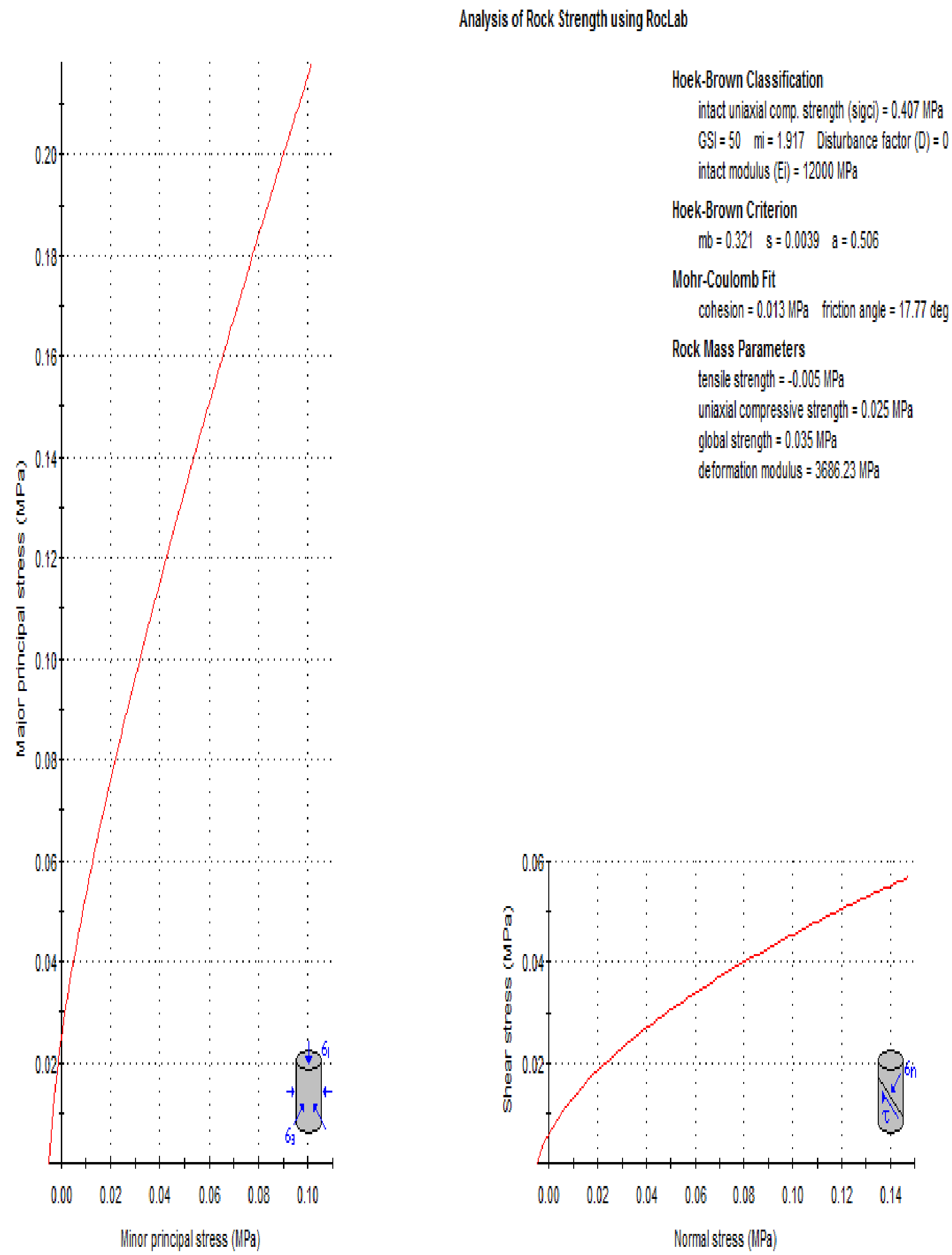

Figure26. Calculation of cohesion and friction angle (95% fly ash and 5% cement).

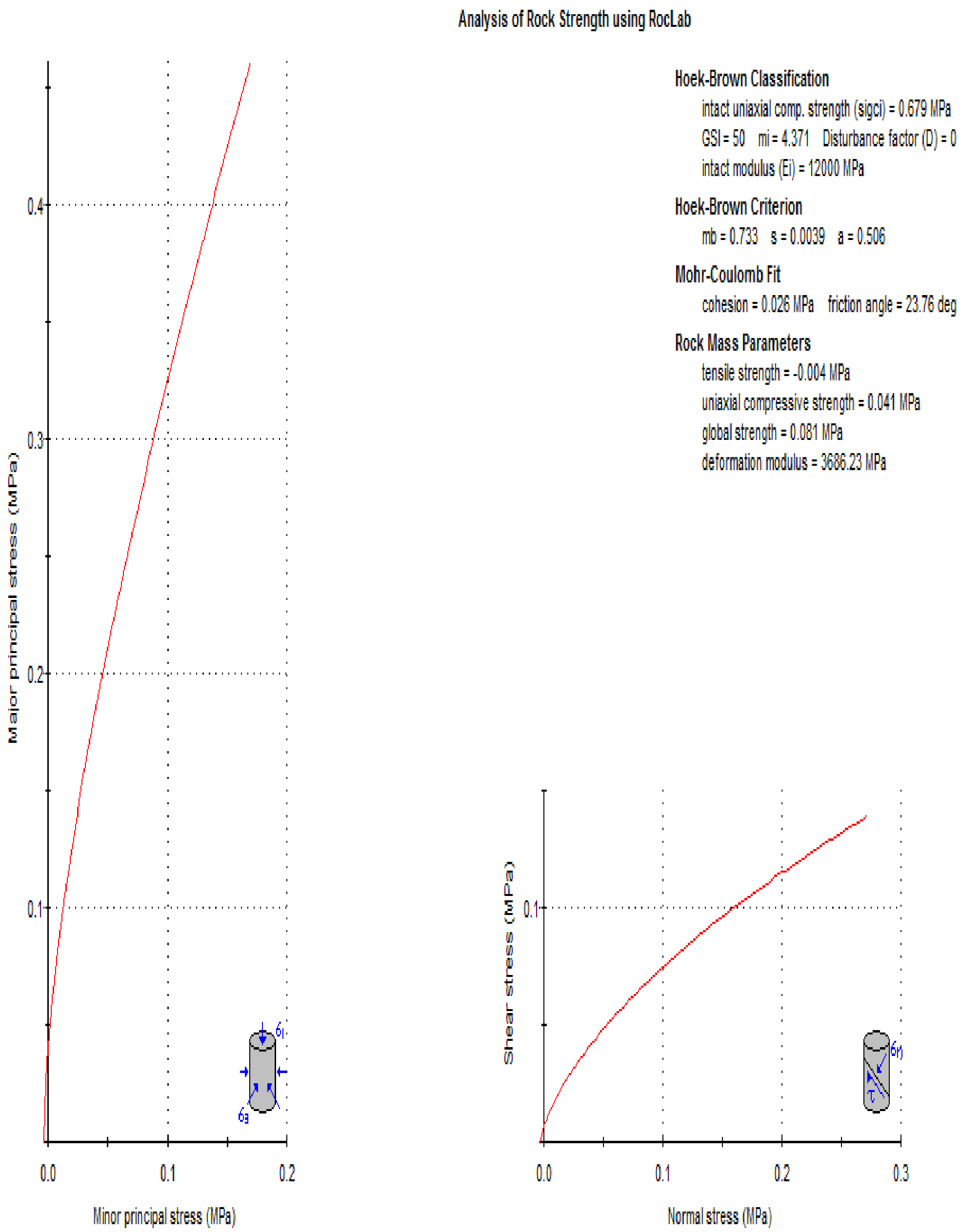

Figure27.Calculation of cohesion and friction angle (92%fly ash and 8% cement)

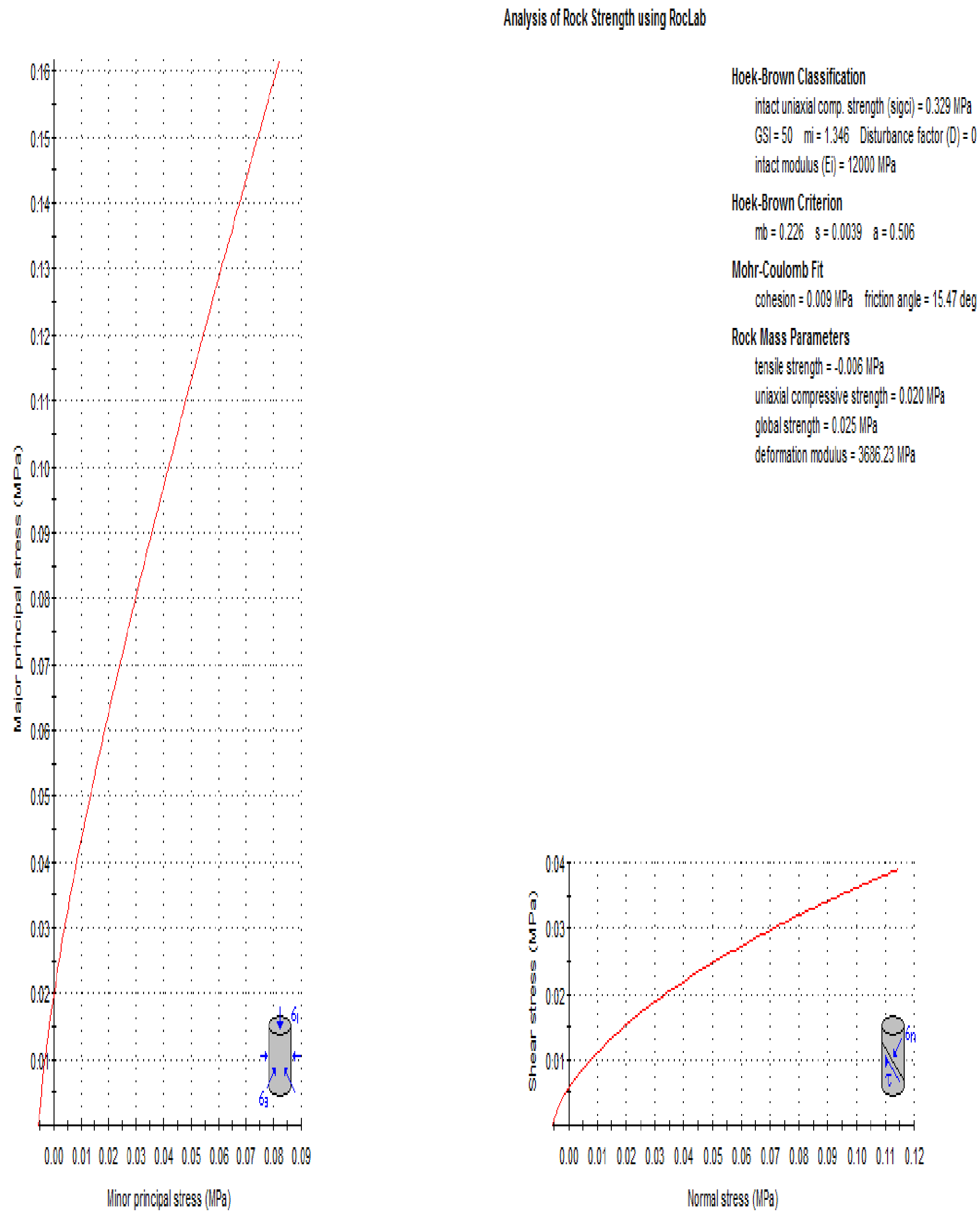

Figure 28.Calculation of cohesion and friction angle (97%fly ash and 3% lime)

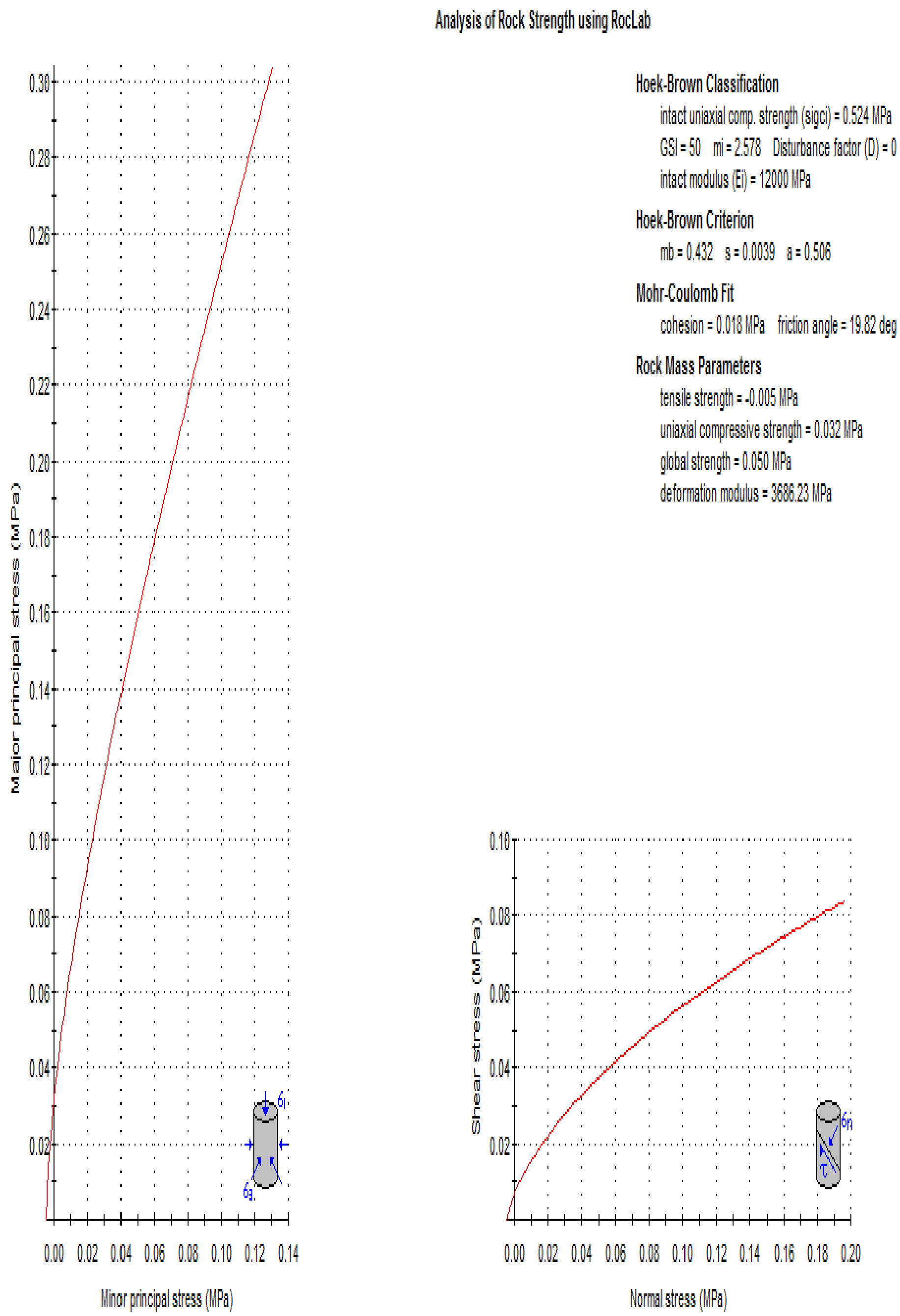

Figure29.Calculation of cohesion and friction angle (95%fly ash and 5% lime)

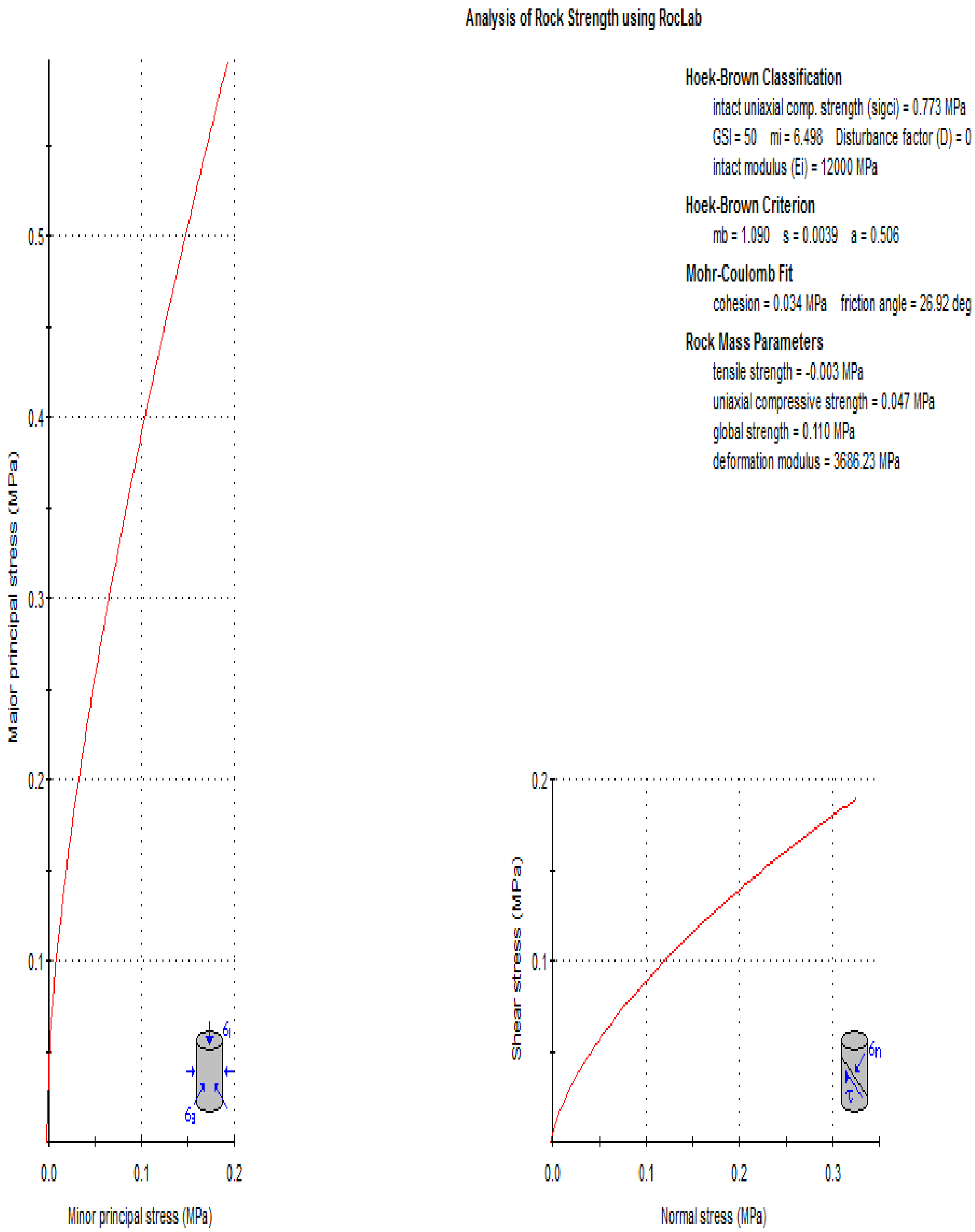

Figure30.Calculation of cohesion and friction angle (92%fly ash and 8% lime)

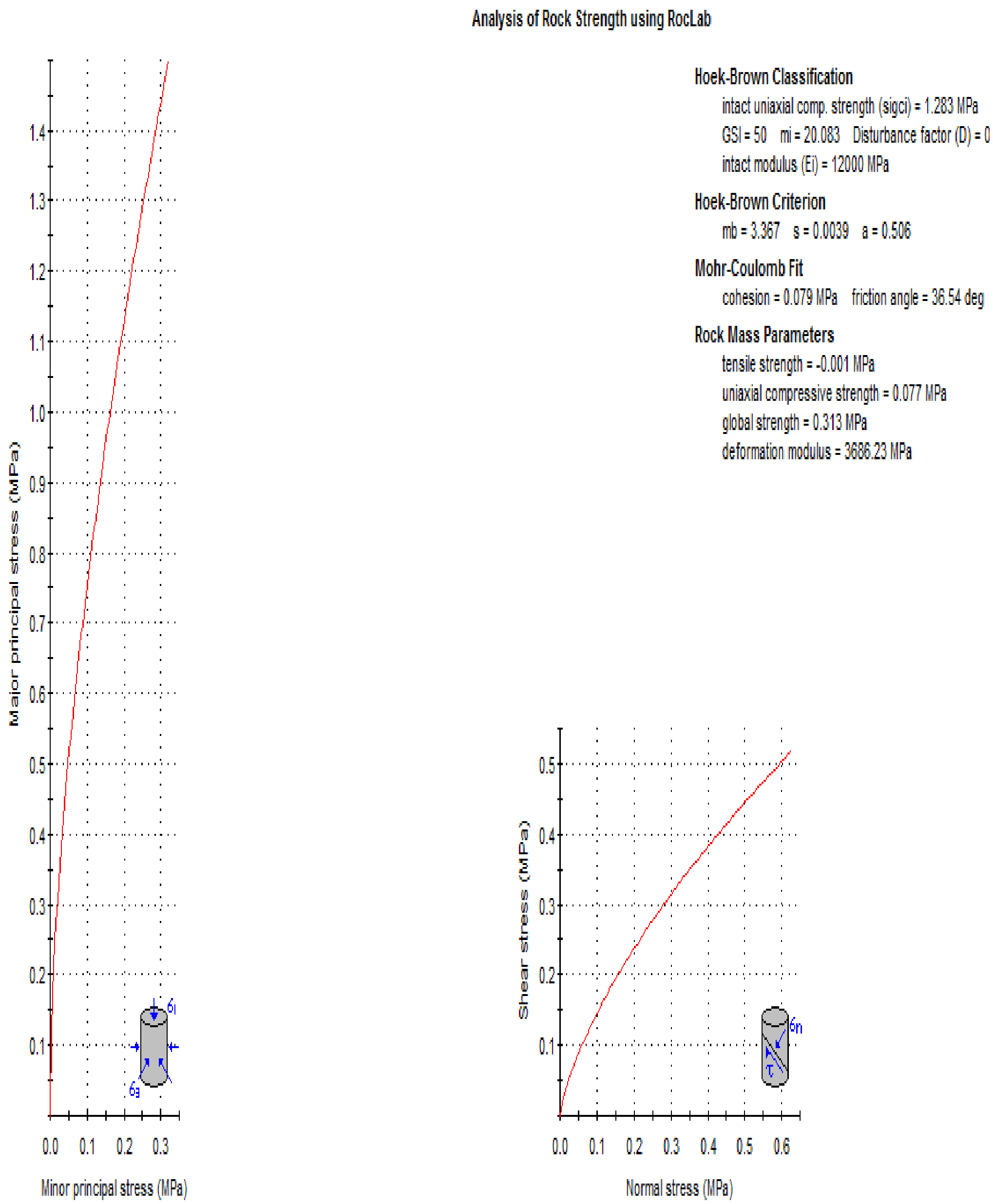

Figure31.Calculation of cohesion and friction angle(90%fly ash and 10% lime)

CHAPTER 5

RESULTS AND DISCUSSION

5.0 Result and Discussion

The investigation focused on evaluation and influence of various parameters on the strength of fly ash materials.Those parameters are discussed below.

5.1 Properties of Fly ash.

The physical and chemical properties of ash vary depending on origin of coal, type of plant, burning process, inorganic chemical composition of coal, degree of pulverization, types of emission control systems, handling and collection systems etc. Fly-ash is of two types i.e. class C and class F. Class F is produced from burning of anthracite and bituminous coal. It contains very small amount of lime (CaO). Class fly ash (pozzolans) has silicon and aluminum material that itself possess little or no Cementationsvalue. It reacts chemically with lime and cement at room temperature to form cementations compounds[23].

5.1.1 Physical Properties

Fly ash is grayish white in color and in powder form [29]. Color of fly ash depends on amount of un-burnt carbon and iron oxide present in ash. The presence of carbon from incomplete combustion of coal gives gray to black color to fly ash. Carbon free ash is blue-gray to brown in color due to presence of iron oxide. The overall colored fly ash is gray.

Fly ash consists of spheroids siliceous glass that varies between 1 to 50μm in diameter. Majority of these periods are considerably finer than Portland cement. Fly ash is a fine grained material consisting of mainly silt size particles with some clay-size particles of uniform gradation [30]. As fly ash is silt sized non-cohesive material, the effect of dispersion agents on particle size distribution of fly ash is negligible. Free swell index differentiate between swelling and non swelling soils and determine the degree of soil expansibility. Nearly 70% of Indian coal ashes exhibit negative free swell index which is due to flocculation, low specific gravity and less quantity of clay size particles [30, 31].Specific gravity is one of the important physical properties required in planning and executing geotechnical applications that involve bulk utilization of fly ash. Specific gravity of fly ash depends on its chemical composition. Fly ash generally possesses low specific gravity compared to that of soil due to the presence of more number of voids from which the entrapped air cannot be removed, or the variation in the chemical composition, iron content in particular, or both [32, 31]. Specific gravity of Indian fly ash varies in the range of 1.60 to 2.65 [31].

Table 18. Physical properties of fly ash

Property	Fly ash
Specific gravity	2.29
Particle size analysis (%)	
Gravel (>4.75 mm)	----
Sand (4.75 mm – 0.075 mm)	23.17
Silt (0.075 mm – 0.002 mm)	73.04
Clay (<0.002 mm)	2.59
Specific Surface Area (m^2/kg)	460
Consistency limits	
Liquid limit (%)	30.65
Plastic limit (%)	Non-plastic
Shrinkage limit (%)	-------
Plasticity index (%)	--------
Free swell index (%)	Negligible

5.1.2 Chemical Properties

Fly ash is a complex inorganic-organic mixture with unique, polycomponent, heterogeneousand variable composition. There are about 188 minerals or mineral groups have been identified in fly ash [33]. The chemical composition is influenced to great extent by the geological and geographical factors related to coal deposit, combustionconditions and removal efficiency of controlling devices [34]. Chemicallycoal is an organic material and primarily contains carbon, hydrogen, nitrogen, oxygen andsulphur.Since combustion of coal is never complete, fly ash also contains varying amount of unborn carbon called loss on ignition. The predominant compounds in fly ash are silica (SiO_2), alumina (Al_2O_3), iron oxide (Fe_2O_3) and calcium oxide (CaO) [35].

Sum of components of silica, alumina, iron oxide, calcium oxide and magnesium oxides more than 85% [37]. Among those silica and alumina comprises 45% to 80%. The fly ash produced from sub-bituminous and lignite coal has relatively higher percentage of calcium oxide and magnesium oxide and lesser percentage of silicon dioxide, aluminum oxide, and iron oxide as compared to fly ash Produced from bituminous coal.

Table 19.Chemical properties andcompositions of fly ash.

Constituents	Fly ash
SiO_2	51.88
Al_2O_3	37.78
Fe_2O_3	6.41
CaO	0.50
K_2O	1.62
MgO	0.48
TiO_2	2.75
Na_2O	0.2
P_2O_5	--
SO_3	--
LOI	2.6

When water or any aqueous medium comes in contact with fly ash, iron, aluminumand manganese oxides sink determine the release of the trace elements associatedwith them into the aqueous medium. The degree of solubility of those oxides in turndepends upon the pH of the aqueous medium [31]. Fly ash with higher free lime and alkaline oxides exhibits higher pH values [31]. About 50% of Indian fly ashes are alkaline in nature [31].

5.2 Geotechnical Properties.

The suitability of fly ash based composite material depends on its various geotechnical properties. The development of geotechnical characteristics depends on time period of reaction, typically the reaction of free lime with available silica, alumina and iron. The following section deals with the influence of curing period, Lime and cement content on the fly ash materials.

5.2.1 Curing periods.

It was observed that composite strength increased as curing period increased. The rise in strength in case of lime addition is more as compare to that in case of cement addition. The initial strength of material at zero days is either nil or negligible to record. The strength at 7^{th} day was also very low when 3 to 5 % cement was used in the fly ash composite materials. At 7th day the sample records"un-confined compressive strength" 0.186 MPa at 8% cement content. From 0 to 14 days the rate was steep for composite materials. At 14-33 days the strength of composite materials was moderate.

Withthe addition of 8% cement the maximum UCS was found to be 0.518MPa at 100 days curing. Similarly values for 8 % lime were 0.611 MPa at 100 days curing. So lime addition affected was higher strength.

The rise in strength in cause of lime addition was more as compare to that in cause of cement addition. The initial strength of material at zero days was either nil or negligible to record. The strength at 7 days was also very low when 3 to 5 % Lime was used in the fly ash composite materials. At 7 days the sample record "un confined compressive strength" 0.21 MPa at 10% Lime content. At 0 to 14 days the rate was steep for composite materials. At 14-33 days the strength of composite materials was moderate.

The addition of 10% Lime maximum UCS of 0.717MPa at 100 days curing. Similarly values for 8 % cement were 0.518MPa at 100 days curing. At 8 % lime and cement, lime addition affected in higher strength value

.

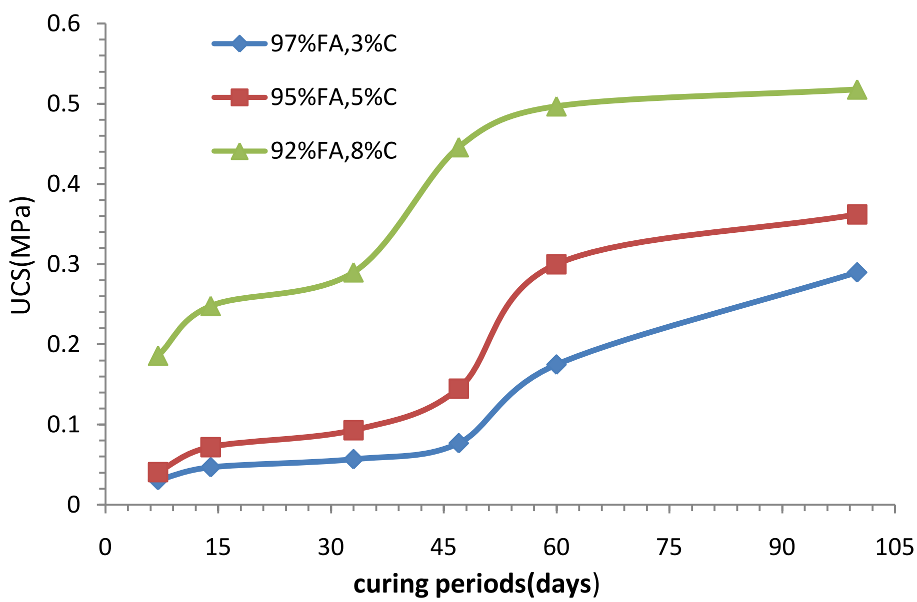

Figure 32.Unconfined compressive strength (MPa) vrs curing periods (days)

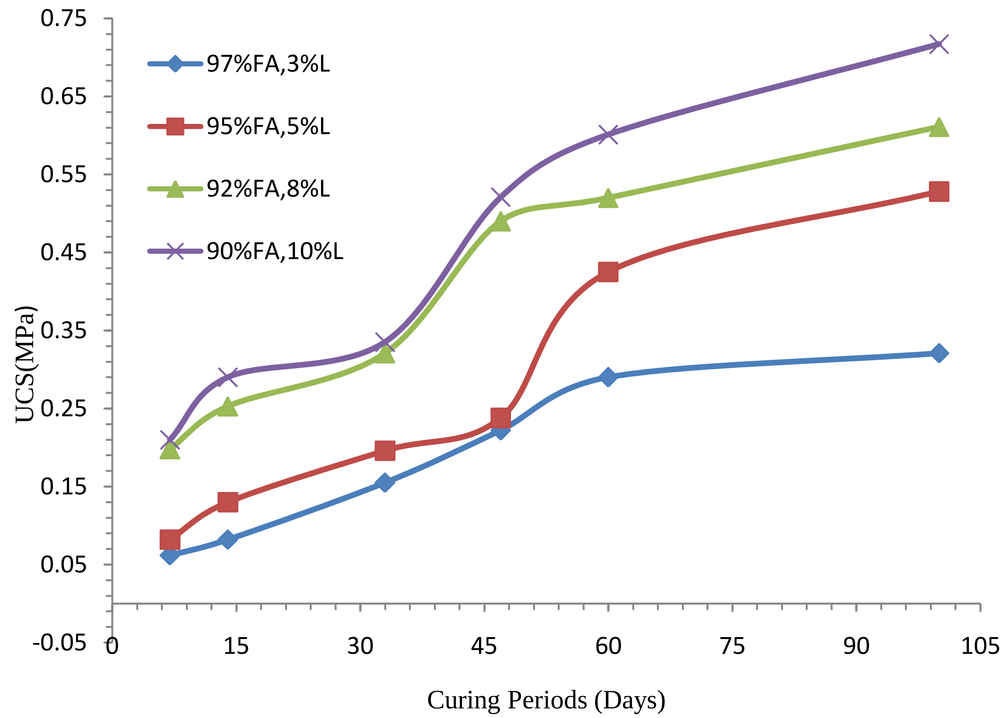

Figure 33.Unconfined compressive strength (MPa) vrs curing periods (days)

Young modulus increased as curing period's increases. The rise in young modulus in case of lime addition was more as compare to that in case of cement addition. The initial young modulus at zero days was negligible to record. The young modulus at 7 days was also low when 3 to 5 % cement are used in the fly ash composite materials. At 7 days the sample record young modulus 6.43 MPa at 8% cements content. At 0 to 14 days the rate was steep for composite materials. At 14-33 days the young modulus was moderate. The addition of 8% cements produced maximum young modulus 23.44 MPa at 100 days curing.

5.2.2 Lime and Cement Content

The rise in young modulus in case of lime addition was more as compare to that incase of cement addition. The initial young modulus at zero days is negligible to record. At 7 days the sample record young modulus 8.86 MPa at 10% Lime content. At 0 to 14 days the rate was steep for composite materials. At 14-33 days the strength of composite materials was moderate.

The addition of 10% Lime resulted in max young modulus of 34.35 MPa at 100 days curing. Similarly values for 8 % cement were 23.44 MPa at 100 days curing.

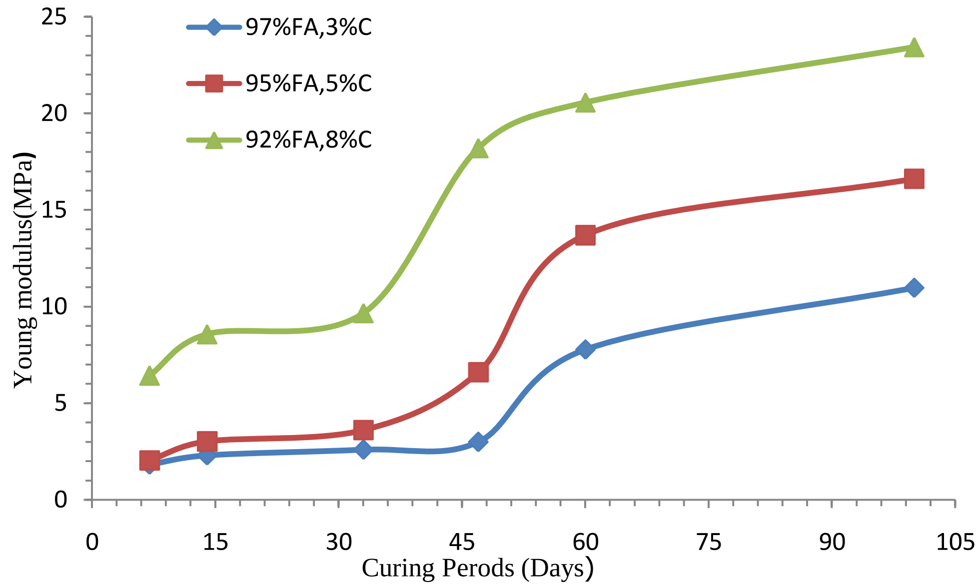

Figure 34. Variation of young modulus (MPa) valuevrs curing periods (days)

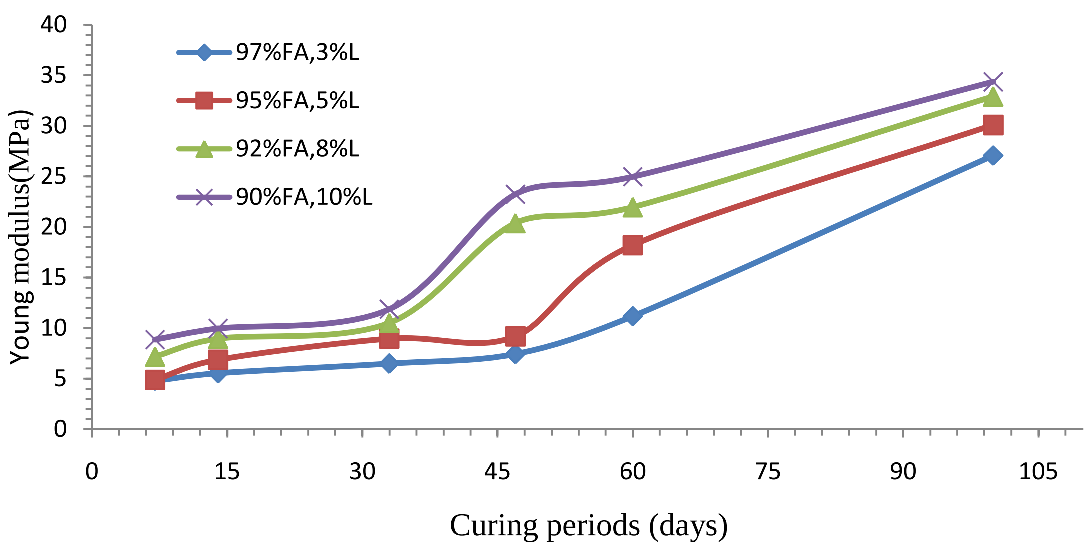

Figure 35. Variation of young modulus (MPa) vrs curing periods(days)

The tensile strength at 7 days was very low when 3 to 5 % cement are used in the fly ash composite materials. At 7 days the sample record Tensile strength 0.093 MPa at 8% cement content. At 0 to 14 days the rate was steep for composite materials. At 14-33 days the strength of composite materials was moderate. After 33 days Tensile strength of sampleincreasedrapidly.The addition of8% cement gavemaximum tensile strength is 0.3 MPa at 100 days curing. Similarly values for 8

% lime were 0.36 MPa at 100 days curing. At 8 % lime and cement, lime addition affected in higher strength value at 0.36MPa.

The respective observation made in respect of cohesion and friction angle are given in (figure 44, figure 45, figure 46, figure 47, figure 48).

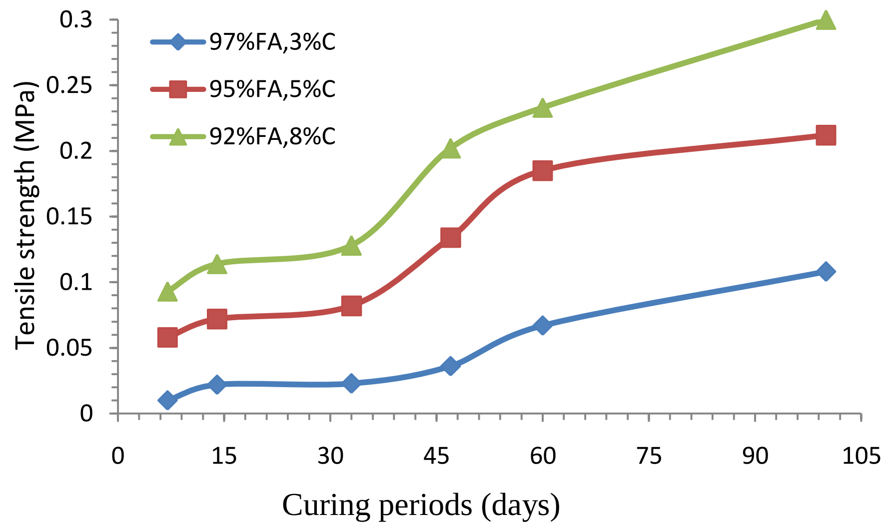

Figure 36. Variation of Brazilian tensile strength vrs curing periods(days)

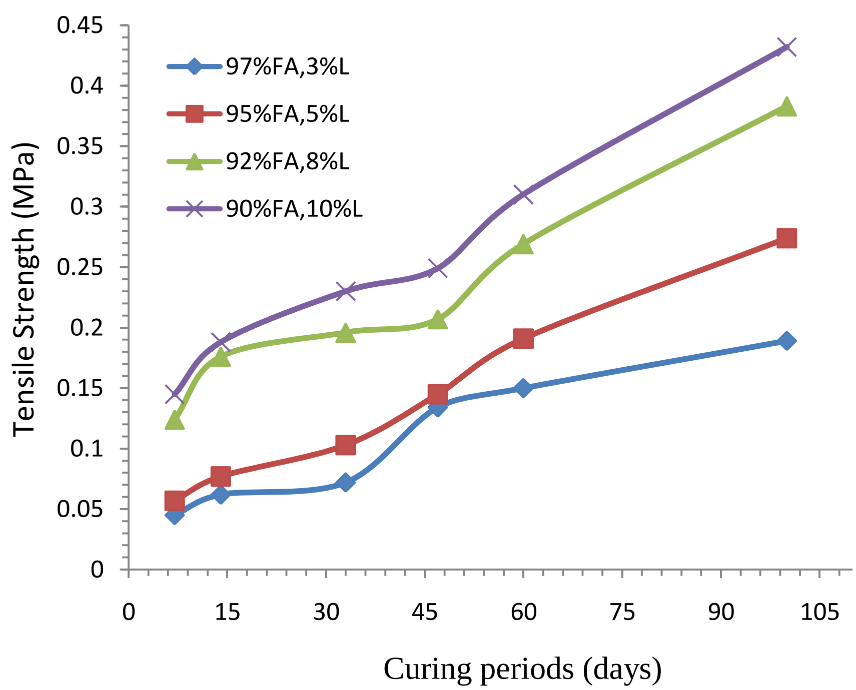

Figure 37. Variation of Brazilian tensile strength value with curing periods (days)

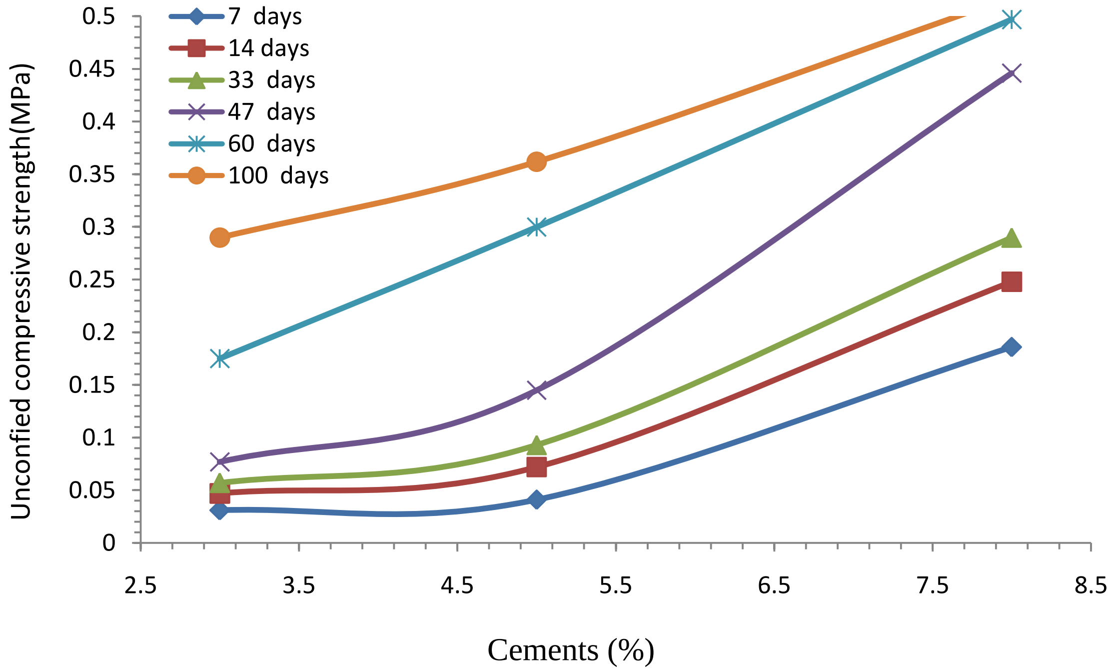

Figure 38. Variation of unconfined compressive strength vrs cement percentage (%)

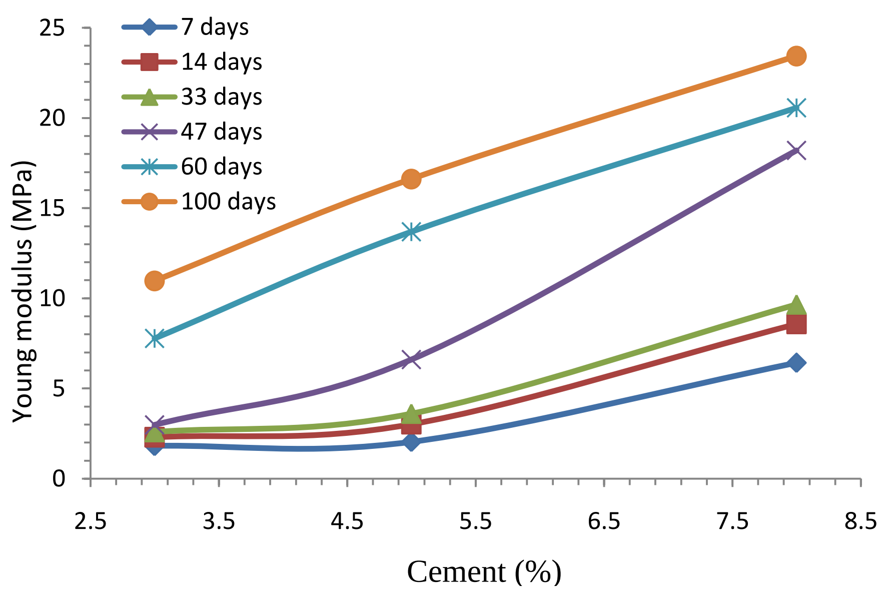

Figure 39. Variation of Young Modulus vrs cement percentage (%)

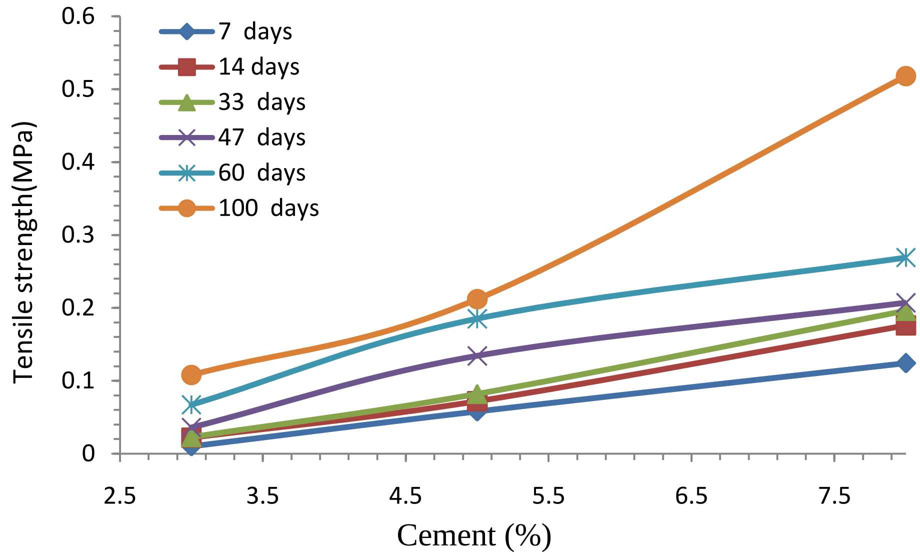

Figure 40.Variation of Brazilian tensile strength (BTS) vrs cement percentage (%)

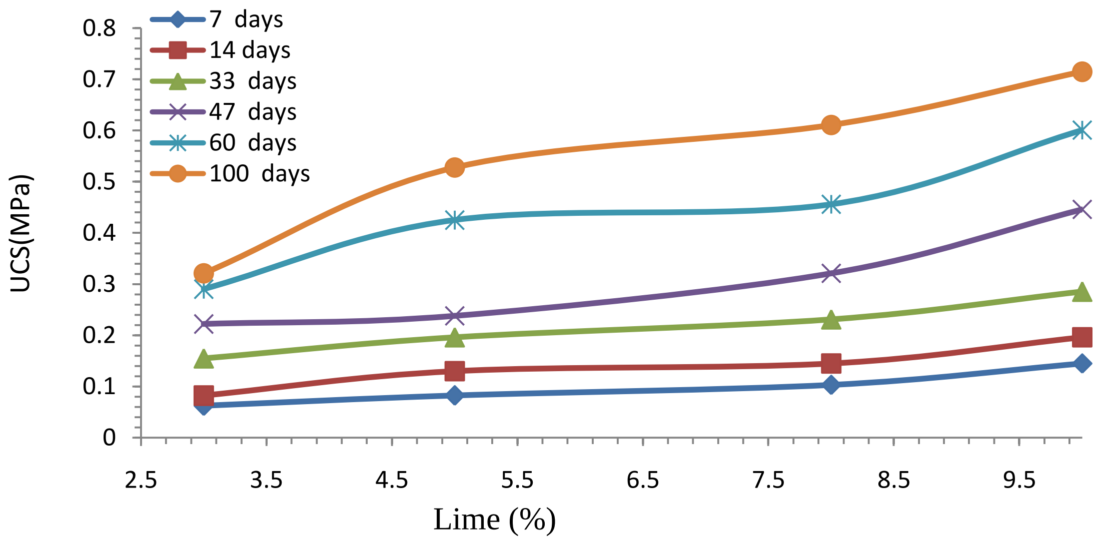

Figure 41.Variation of unconfined compressive strength vrs Lime percentage (%)

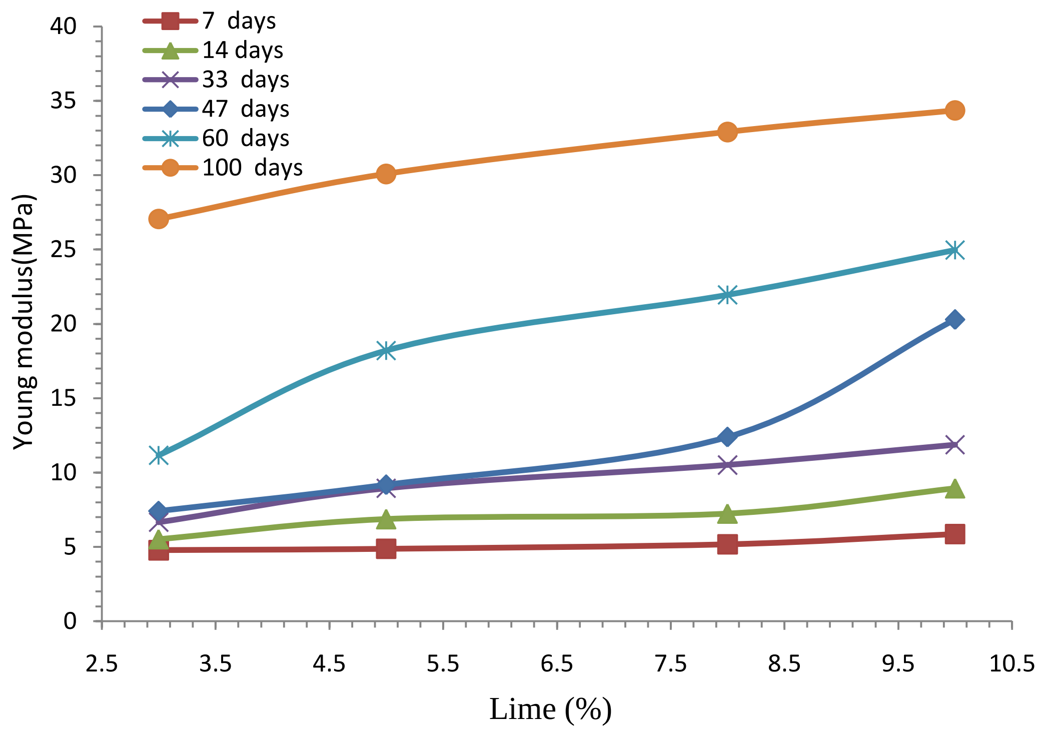

Figure 42. Variation of Young Modulus vrs Lime percentage (%)

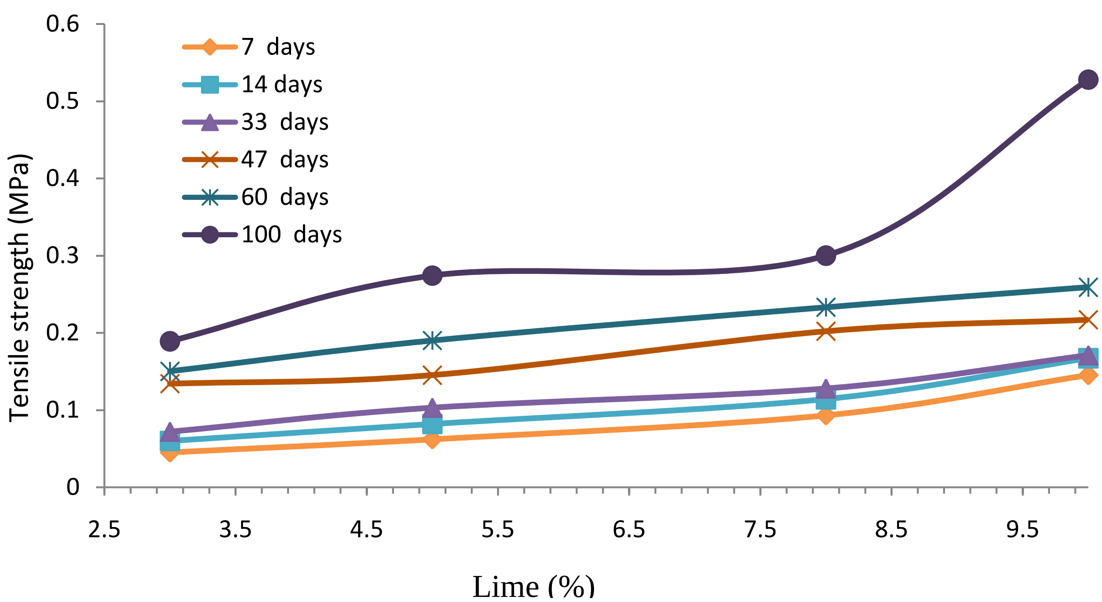

Figure43.Variation ofBrazilian tensile strength vrs Lime percentage (%)

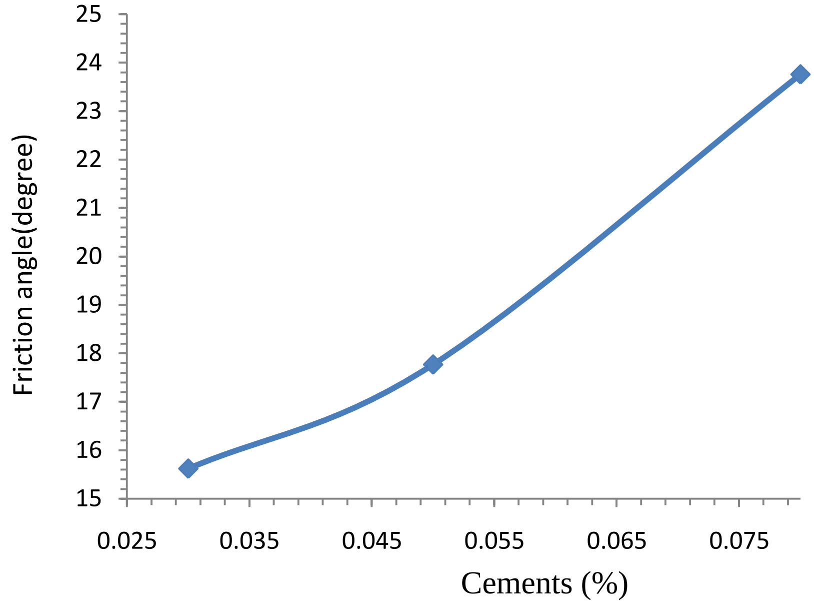

Figure 44.Variation of Friction angle vrs cement percentage (%)

5.2.3 Cohesion and friction angle

Cohesion is the ultimate internal binding force within micro-aggregates or soil particles, Calcium carbonate as well as aluminum and iron oxidesoften impart considerable stability for weak soil.Angle of internal friction is a measure of the ability of a unit of soil to withstand applied shear loading. Lime and cement addition increases cohesion and angle of friction value of the fly ash composite materials. 10 % lime produced maximum cohesion and friction angle values.

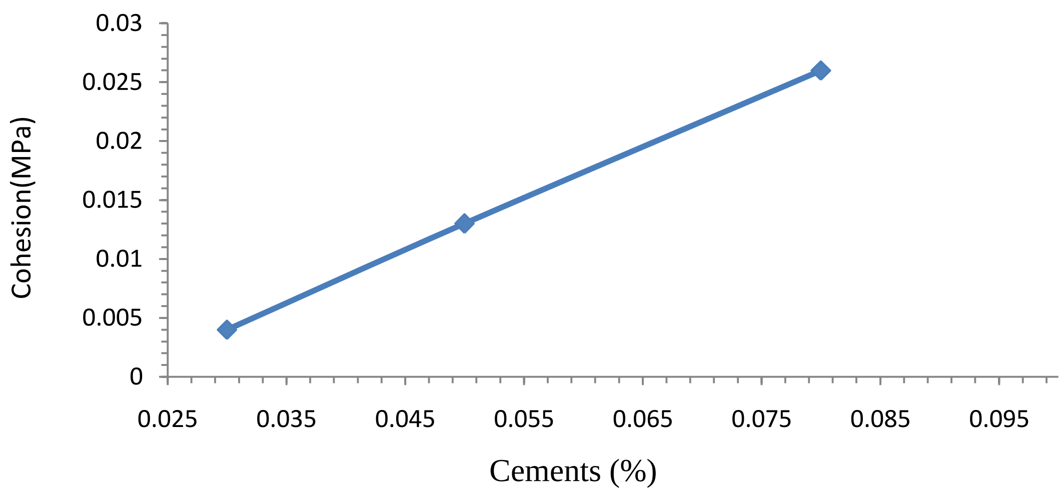

Figure 45.Variation of Cohesion (MPa) vrs cement percentage (%)

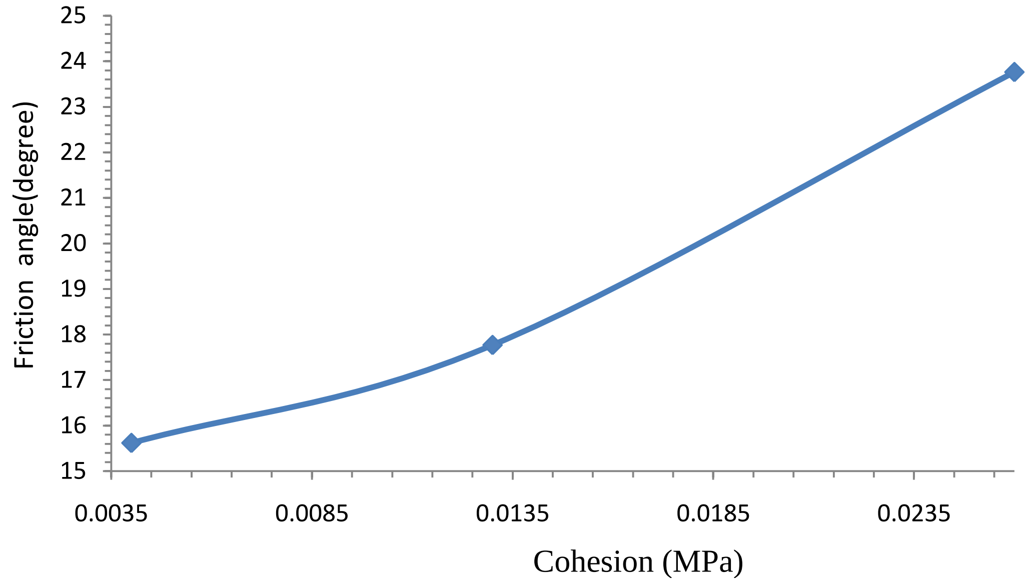

Figure46. Variation of Friction angle (degree) vrs Cohesion (MPa)

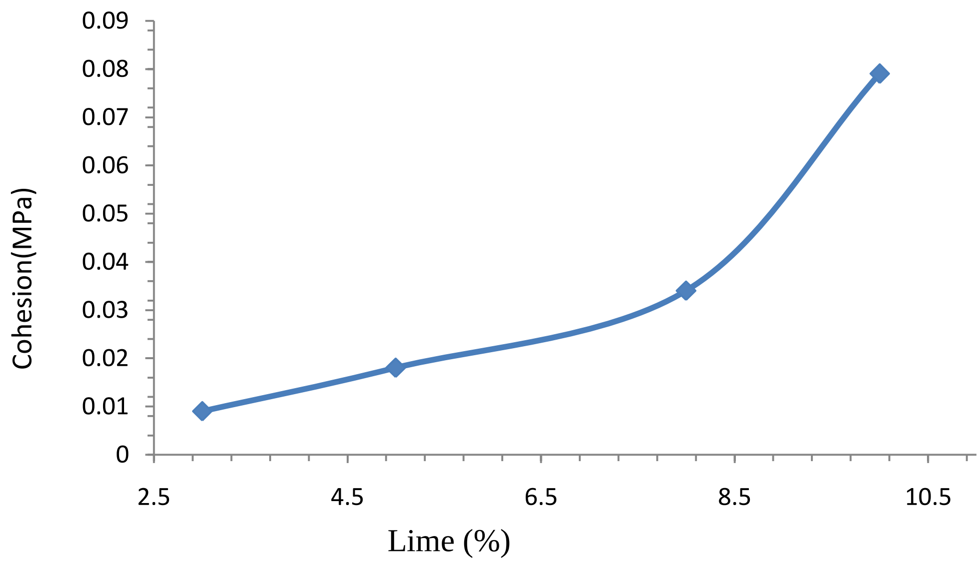

Figure47.Variation of Cohesion (MPa) vrs Lime percentage (%)

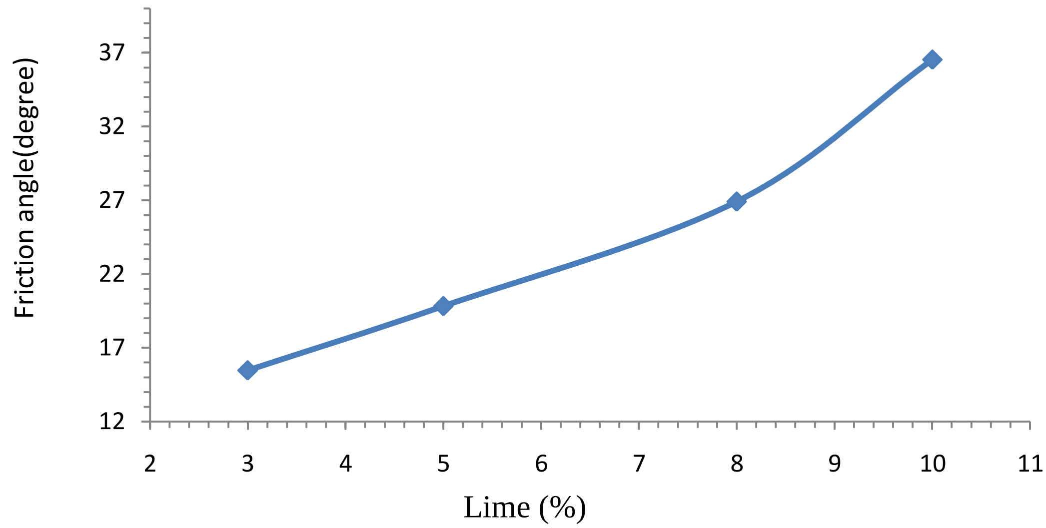

Figure48.Variation of Friction angle (degree) vrs Lime percentage (%)

CHAPTER: 6

CONCLUSIONS

CONCLUSIONS

The present project is an attempt to utilize industrial wastes fly ash in the construction of haul roads. Based on result of Proctor hammer test and unconfined compressive strength, uniaxialtensile strength test and Tri-axial test the following conclusions are drawn. The conclusions are based on the tests carried out on sample selected for study.

(1) Fly ash is class F type.

(2) It has very less CaO% (< 10%)

(3) Fly ash does not have any strength of its own.

(4) Addition of lime and cement enhance bonding between fly ash properties.

(5) The unconfined compressive strength of stabilized sample increased with increases in percentage of Lime or Cement, but the rate of increases is more in case of Lime.

(6) The unconfined compressive strength, Brazilian tensile strength testand tri-axial test of stabilized sample increased as days of curing increase.

(7) The maximum UCS and tensile strength were obtained for 10% lime addition at 100 days.

(8) All the fly ash composite at 30 days curing, reflect better sub base materials in the haul road.

Future scope-

The investigation undertaken was of limited duration with a limited sample. More tests in a large number of samples need to be carried out for establish mutual relation.

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