CHAPTER 1

1.1 Introduction

For any type of structure, the foundation is very important and has to be strong enough to support the entire structure and carry the super imposed load safely. For the foundation to be strong, the soil around the foundation plays a very critical role. So, to deal with soils, we should have proper knowledge about the type of soil and their properties and on factors which affect their properties and behaviour. The method of soil stabilization is important to achieve the required properties in a soil which is required for the construction work.

From the starting of construction work, the necessity of knowledge of soil properties has come to the light. Ancient civilizations of the Chinese, Romans and Incas used various methods to improve soil properties and its strength, some of these process were so effective that their constructions, buildings and roads still exist.

Soil stabilization can be used in nearly every or all type of problem related to soil . When the geotechnical engineers are to be deal with clay soils, the engineering properties of those soils must be improve to make the soil suitable for construction.

Silica fume is a mineral admixture, made up of submicron particles of silica dioxide, produced as a by- product from the production of silicon and ferrosilicon metal. After various studies we made a conclusions that the addition of silica fume plays a very vital role in improvement or transformation of chemical properties and physical properties of soil, especially sulfate soils.

When civil engineers faced the problem of construction damage, there is a need for improving the geotechnical properties of the soil by using some process or methods of stabilization. Stabilization or improvement of subgrade of pavements has traditionally depend on treatment with cement, silica fume, fly ash and several additives such as pozzolanic materials. Pozzolanic materials, such as Fly ash, lime, and cement, which are considered as wastes may be used for soil stabilization . The Silica Fume is considered to be 40% cheaper than that of Portland cement.

Cement is widely app;ied to stabilize soil especially in highway construction and earth dam or embankment construction. Cement can be applied to stabilize or pick up sandy and clay soils mainly in the areas where level of ground water is very high. Almost all the fine-grained soils can be improved with cement and silica fume except for some mineral soils. The quantity of cement required to stabilize soils mostly rely upon their physical properties. All most more fine-grain soil or plastic (higher value of plasticity) a soil is, the more quantity of cement is required to stabilize or improve it. cement stabilization of silty soil is more helpful when the soil's liquid limit , varies from 40 to 50 and its plasticity index is small than 20. The reduction in liquid limit of soil by addition of cement is depends on the soil used and its type. so by this we can not make a general claim that there is always decrease in value of liquid limit of all fine-grain soils.

1.2 Objectives of Study

Generally,the objective of the study is to determine the behaviour of soil on addition of silica fume and cement.The more specific objectives of the study are:-

- To determine the basis engineering properties of the soil,cement and silica fume.
- To prepare mixes of soil with various proportions of silica fume and cement.
- To determine all the geotechnical properties of mixes.
- To find the unconfined compressive strength of the mixes at their OMC
- To obtain a optimal mix for maximum UCS value.

1.3 Scope of Study

This study is focused on identifying the engineering properties of soil and shear strength of soil. The sample used in this study is silty soil, laboratory test that will be performed include Atterberg limit, compaction test ,unconfined compressive strength test. The compaction methods will be used for this experiment is standard proctor. Unconfined compressive strength(ucs) will be used to determine the shear strength of the soil after compaction.

.

CHAPTER 2

LITERATURE REVIEW

Soil stabilization is the process of improving some engineering properties of soil by different methods, mechanical ,physical or chemical.The main purpose of stabilization is to produce an improved soil material which will have all the desired engineering or geotechnical properties. Soils are generally stabilized or improved to get the desired properties or increase in strength and to prevent erosion and formation dust in soils. The main aim is to get a soil material or system that can sustain under the design conditions and for the entire designed life of the engineering project. The properties of soil may vary a lot at different places or even at one place in certain cases; the success of soil stabilization widely depends on testing of soil samples. Various methods are used to improve the properties of soil or to stabilize it and the process must be tested in the standard soil lab with the soil material before practising it on the field.

2.1 Principles of Soil Stabilization

• To find out the soil properties of the area which are under consideration.

• To find out the properties of soil which needs to be improved to get the design value and to select the effective and more economical methods for its stabilization.

• To design the stabilized soil mix sample and test it in the soil lab for better stability and its durability values.

2.2 Advantages of Soil Stabilization

The properties of soil varies at different location and construction of structures on soil depends a lot on the bearing capacity of the soil, hence, we have to stabilize or improve the properties of soil which makes it easy to know the load bearing capacity of the soil and even increase the load bearing capacity. The soil gradation is plays a very important property to keep in mind while stabilizing the soils. The soils must be well-graded which is needed for better work as it has less number of voids or uniformly graded soil which is considered to be stable but has more voids in it. Thus, it is good for us to mix different types of soils together in order to improve the strength and engineering properties. It is very much costly to replace the weak soil entirely and hence, soil stabilization is to be used in to order to get desired strength.

- Stabilization improves the soil strength, thus, increases the bearing capacityof soil.

- Stabilization is very much economical in terms of both cost and energy to increase the soil bearing capacity rather than going for raft foundation or deep foundation at site.

- It also gives more stability to the soil at site in slopes or other such places.

- Sometimes it may be also used to prevent erosion of soil or dust formation, which is very useful especially in arid and dry weather.

- It is also done for soil water-proofing,which prevents water from entering into the soil and hence helps the soil from losing its shear strength.

- Stabilization helps in minimizing the volume change of soil due to change in temperature or variation in moisture content.

- Stabilization helps in improving the durability and the workability of the soil.

2.3 Review of Some Previous Works

Various research have been done to improve the strength of soil by adding Silica Fume and Cement.

The effect of adding silica fume on the engineering behavior of soil subgrades which has inadequate stability was examined [1]. They compacted the clay soil and clayey soil-silica fume samples at the optimum moisture content and then implemented to laboratory tests. Test results gives a considerable upgrading on swelling pressure and unconfined compressive strength of soil mixture with silica fume. It was found that the swelling pressure of soil samples gets reduced by 87% when the contents of silica fume increased from 5% to 15% and the unconfined compressive strength of soil specimen gets improved by 4% when the contents of silics fume increased from 5% to 10% and after then the value gets reduced. It was found that the permeability of soil samples increases when the contents of silica fume is increased. The coefficient of permeability gets increased by 100% when contents of silica fume is 15%. Also, the test results gives that the presence of silica fume reduces the cracks development on the surface of compacted soil samples by minimizing the crack width by 75%. The study revealed that the silica fume is a important material to change the engineering properties of soil and make them suitable for construction purpose.

The effect of cement and silica fume with cement on the geotechnical or engineering properties of the clayey soil was studied [2].He carried a numerous of laboratory experiments and prepare a lot of soil samples by adding both cement and silica fume with cement . He took four different percentages of cement (2%, 4%, 6% and 8%) and three different percentages of silica fume (2%, 4% and 6%) to use as a materials for stabilization . Results from tests reveals that mixing cement and silica fume with cement to the soil minimize the maximum dry density and increases the optimum moisture content of the samples. Tests results showed that the unconfined compressive strength of the soil increases significantly with increase in the content of cement and silica fume with cement especially.

The effect of silica fume on geotechnical properties of expansive clay like black cotton soil was examined [3].They carried lots of laboratory experiments and put their conclusions. Varities of soil specimens were made by adding black cotton soil with silica fume varying from 5% to 20% by weight of dry soil.The tests results gives a significantly increase in California bearing ratioof soil samples and unconfined compressive strength of soil.There is decrease in differential free swell of the clay soil from 50% to 7% with increase in content of silica fume from 5% to 20% respectively.The Proctor compaction test results gives a small decrease in Maximum dry density of soil samples and increase in optimum moisture content of soil.From his study we can conclude that the silica fume has a potential to improve the engineering properties of black cotton soil.

The effect of cement and lime on the engineering properties of clay soil was examined [4].After conducting various laboratory test they concluded that mixing cement and lime to ssamples does not give a fixed change in the liquid limit of the soil samples. Tests result showed that the liquid limit values either gets increased or reduced , but does not give a certain pattern of increasing or decreasing. However,tests results showed that the soil samples with plasticity indices between 25 and 30, the liquid limit values of soil samples gives an rough pattern by adding 9 % lime or cement but then gives an increasing pattern in the soil samples with over 9 % lime or cement. Tests results revealed that there is increase in plastic limit and optimum moisture content of soil by adding cement/lime to soil specimens. Soil samples with 1-3 % lime or cement content, the values of plasticity adopted a gradually increasing pattern. soil samples with over 5 % lime or cement content, there is a increasing pattern in the values of plasticity limit.

Test results revealed that there is increase in shrinkage limit of soil samples by adding cement/lime and decrease in plasticity index of the soil samples. It was concluded that the reduction was significant to the soil samples with Plasticity index equal to30 and Plasticity index equal to 35 when 3 % lime or cement was added. After conducting various laboratory test it was found that the most suitable quantity of lime and cement in the clay-lime and clay-cement mixes was 13%, where the reduction in volume of the soil samples was minimum. The less volume change was observed in the soil samples with Plasticity index equal to 35, and with the 9 % of lime and cement mixtures. while in the soil samples with Plasticity index equal to40, the reduction in volume was observed minimum when there was with 5 % lime in the clay-lime mixes.

The effect of lime and micro silica fume mix on the soft soil properties was examined [5].He carried a series of laboratories experiment on soft soil samples with (0,3,6,9,12)% lime and(0,6,12,18)% micro silica fume. It was found that the liquid limit of soil mixtures gets reduced to 33% for 12% lime, and 0% micro silica fume. Test results shows that there is increase in the plastic limit to 41% for 9% lime, and 18% micro silica fume. Test result shows that with 9% lime and 16% silica fume the max dry density gets reduced to 1.32gm/cm^3. The optimum moisture content of soil mix gets increased to 28.66% with 12% lime. It was found with 18 % silica fume and 6 % cement that the California Bearing Ratio (CBR) values gets increased to13.5%.With this study it can be concluded that micro silica fume and lime can be used to stabilized subgrade layers and to perk up soil properties to make suitable them for engineering projects.

The effect of adding cement kiln dust on clay soil was studied.[6].He carried various experiment to know the geotechnical properties of soil samples.after performing experiments it was found that properties of soil gets improved,permeability of soil samples decreases and compressibility of soil gets improved. He found that unconfined compressive strength of soil increases and plasticity of soil gets decreased. It was found that cement kiln improves the texture of soil and reduced the swell characteristics of soil samples.It was found for light construction purpose 12 to 30 % of cement kiln dust is sufficient.

The effects of engineering properties of clayey soil of Iraq was studied.[7].the clayey soil was blended with lime and silica fume.He carried a series of experiment to get the geotechnical properties of soil. The soil samples were prepared by mixing 2.5 %,5%,7.5%,and 10% lime and 2%,4% and 6% for silica fume.After performing various experiments it was found the liquid limit and plasticity index of soil gets reduced by 41.4% and52% by mixing lime and silica fume.The specific gravity of soil was decreased by 5.5 % by mixing 2.5% lime and 6%silica fume but it decreses by 3% adding only lime(10%).The maximum dry density of soil samples gets decreased whereas o.m.c of soil samples gets increased, the best combination was found to be 2.5 % lime and 6% silica fume.The ucs value of the samples gets increased from 21 to 69 kPa by adding 6% silica fume and 2.5 % lime, however on addition of 5% lime only ucs values increases to 42 kPa only.

On the basis of literature review the objective are defined and thereafter the experiments have been performed in the succeeding chapters.

CHAPTER 3

EXPERIMENTAL INVESTIGATIONS

3.1 Purpose

The purpose of this experimental study is to investigate the effects of the addition of Silica Fume and Cement on Specific Gravity,Consistency limits,Compaction and Shear Strength of the Soil.All the experiments are performed as per IS code 2720(part 1-40)

The experimental work consists of the following steps:

1. XRD Analysis of soil,silica fume and cement.

2. Preparation of samples mixes.

3.Specific Gravity of soil and its mixes.

4. Determination of Index properties of the soil and its mixes.

i) Liquid Limit by Casagrande's Apparatus

ii) Plastic Limit

5. Particle size distribution by sieve analysis and hydrometer analysis.

6. Determination of the maximum dry density (MDD) and the corresponding optimum moisture content (OMC) of the soil by Proctor compaction test

7. Determination of the shear strength by Unconfined compression test (UCS).

3.2 Materials

3.2.1 Natural Soil

The stabilization of has to be implemented in soft soils like (silty, clayey peat or organic soils) in order to accomplish pleasing engineering or geotechnical properties. A clay soil has a more surface area than others soil,the reason is that it has elongated and flat shaped particle .The soil used in this study is taken from DTU CAMPUS,Bawana Delhi. The soil has been classified as silty soil as per IS code 1498:1970 (Reprint 2000).

3.2.2 Silica Fume

Silica fume is also termed as micro-silica, which is obtained as a waste product of the high-purity quartz.silica fume is produced in electric furnaces by silicon and ferrosilicon alloys. SF is also obtained as a by product in the manufacturing of other silicon alloys such as ferrochromium,ferromagnesium, ferromanganese and calcium silicon. It consists of very fine particles which can be measured by various techniques such as nitrogen absorbtion.This technique is used when the particles of silica fume is very less say 100 times lesser as compared to cement particle. As the contents of silica is more and has very fineness it is widely used and a more effective pozollanic material.In concrete it is widely used to fulfil the desired properties.The most important property of silica fume is that it improves the strength of the material with which it is mixed and develop a good bond with the soil.silica fume is also used to minimize the permeability of soil minimize and used in preventing the steel from corrosion. The chemical composition of silica fume used is given below which contains high amount of silica and oxygen.

Table-3.1 Chemical Composition of Micro Silica Fume

(Supplied by manufacturer)

Composition	Value (%)
SiO_2	98.2
Al_2O_3	0.02
Na_2O	0.01
K_2O	0.10
MgO	0.06
CaO	0.60

The specific gravity of silica fume was found to be 2.23.

3.2.3 Cement

Cement is the oldest binding agent and it is widely used for soil improvement or stabilization. Cement is generally used as primary or main stabilizing agent or hydraulic controller because it has the capability to hold the particles and acts as stabilizer agents.the reaction which took place after mixing with soil does not depends upon minerals of soil and it has a very important property that it reacts with water in any soil. This is the reason cement is widely used to stabilize or improve a wide range of soils. The types of cement available to us are ordinary Portland cement,high alumina cement,sulphate resistant cement, blast furnace cement.The types of cement to be used for stabilization process depends on type of soil to be used and the amount of strength to be achieved.Generally very less amount of cement is required to enhances the geotechnical or engineering properties of soil of the soil.Cement stabilized soils have the following improved properties:

- Decreased cohesiveness (Plasticity)
- Decreased volume expansion or compressibility
- Increased strength (PCA-IS 411, 2003).

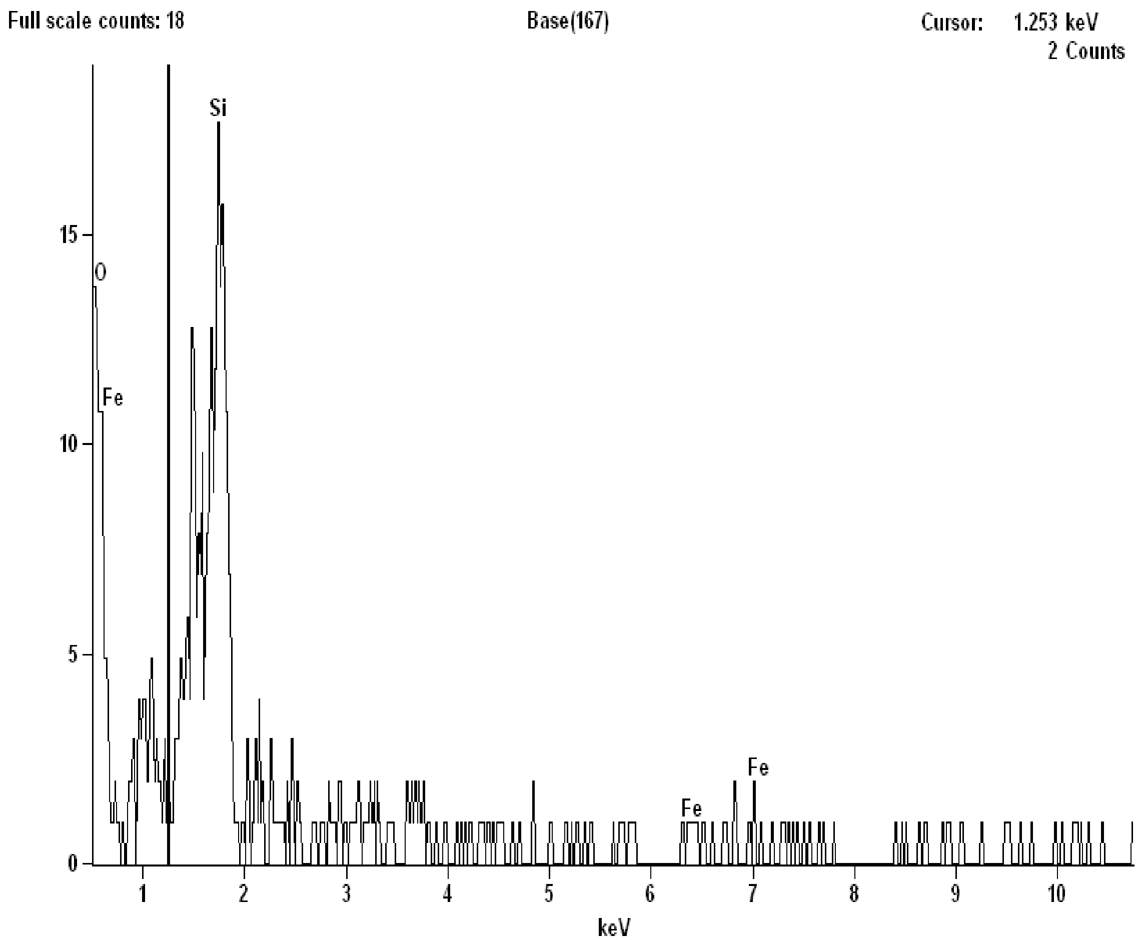
Ordinary Portland cement was classified into three grades,say 33 grades,43 grades and 53 grades depending upon the strength of cement when tested after 28 days of curing by IS4031-1988.

In this study ordinary Portland cement of 43 grade was taken whose specific gravity is 3.15. The initial setting time was found to be 30 minute and the final setting time found to be 600 minutes. The fineness of cement was found to be 230 m^2/kg.The soundness test was performed by Le chatelier apparatus and it was found to be 10 mm.The compressive strength of ordinary Portland cement after 3 days of curing was 23 MPa and after 7 days of curing ,it was 33 MPa but after 28 days of curing ,it was 43 MPa.

3.3 XRD Analysis

X-ray diffraction technique is non-destructive analytical technique which gives information about the crystal structure,physical and chemical composition as well as properties of material and thin film.this technique is based on observing the scattered intensity of an x-ray beam hitting a sample as a function of incident and scattered angle,polarization and wavelength or energy.

3.3.1 XRD Pattern of Soil



Acc.Voltage: 15.0 kV Take Off Angle: 81.1 deg.

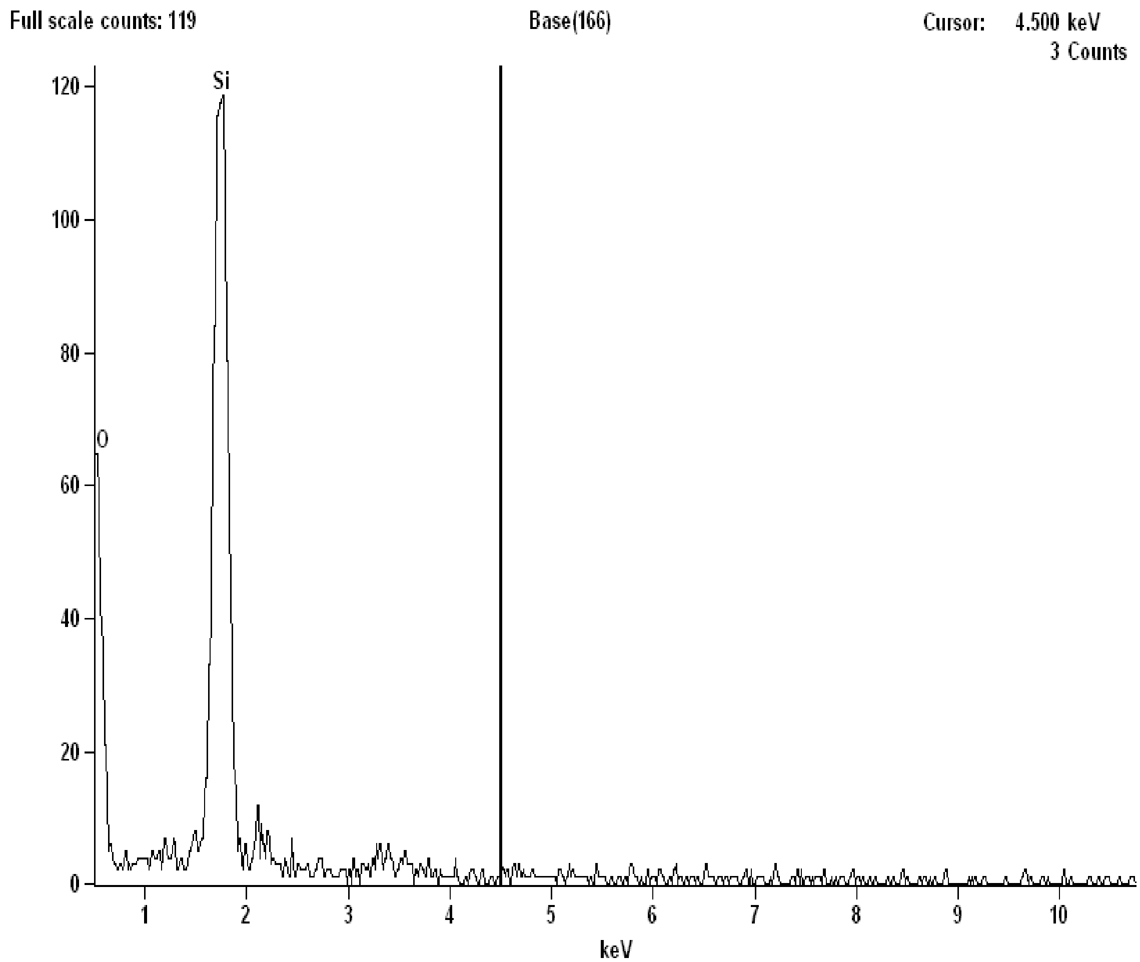
Quantitative Results for: Base(167)

Element Line	Net Counts	Int. Cps/nA	Weight %	Weight % Error	Atom %	Atom % Error	Formula	Standard Name
O K	416	0.000	70.76	+/- 7.48	83.04	+/- 8.78	O	
Si K	186	0.000	21.43	+/- 2.30	14.33	+/- 1.54	Si	
Si L	0	0.000	---	---	---	---		
Fe K	11	0.000	7.81	+/- 4.26	2.63	+/- 1.43	Fe	
Fe L	268	0.000	---	---	---	---		
Total			100.00		100.00			

Fig. 3.1 XRD Pattern of Plain Soil

The XRD analysis of Soil gives the information about the chemical composition and physical properties of natural Soil. Soil contain high amount of Oxygen and Silica and little amount of Iron and Potassium.

3.3.2 XRD Pattern of Silica Fume



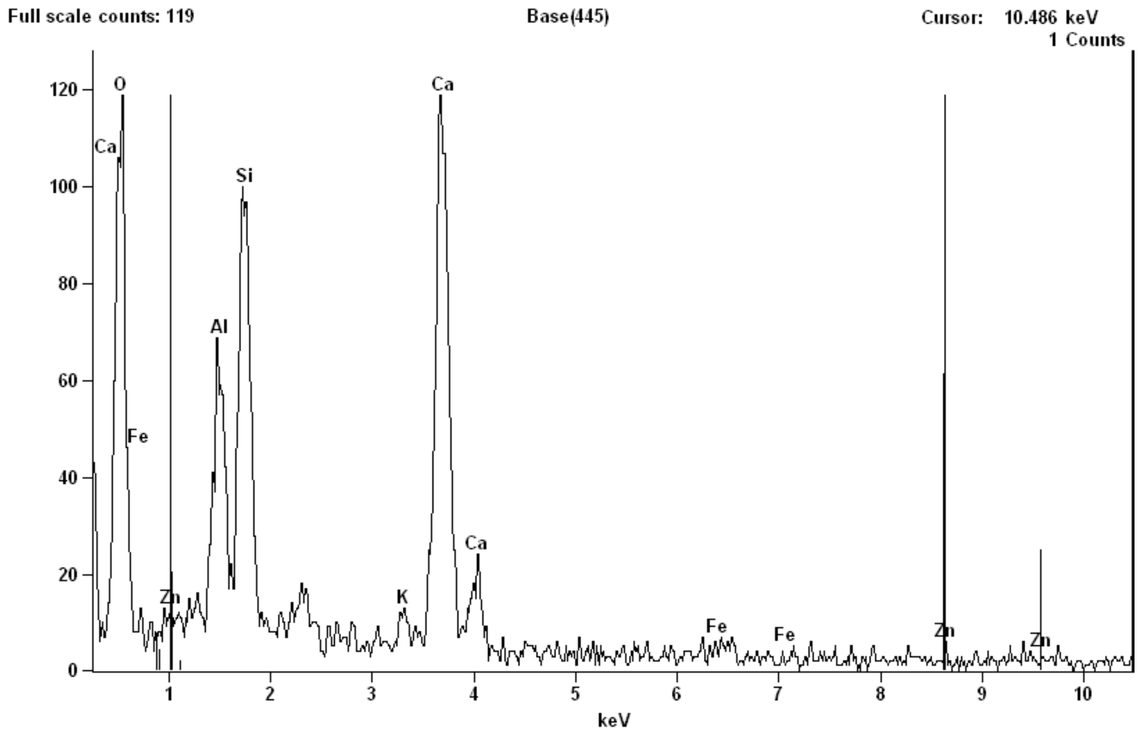
Acc.Voltage: 15.0 kV Take Off Angle: 42.6 deg. Quantitative Results for: Base(166)

Element Line	*Net Counts*	*Int. Cps/nA*	*Weight %*	*Weight % Error*	*Atom %*	*Atom % Error*	*Formula*	*Standard Name*
O K	1158	0.000	59.36	+/- 2.51	71.94	+/- 3.04	O	
Si K	1866	0.001	40.64	+/- 1.48	28.06	+/- 1.02	Si	
Si L	0	0.000	---	---	---	---		
Total			100.00		100.00			

Fig.3.2 XRD Pattern of Silica Fume

The XRD analysis of Silica Fume gives the information about the chemical composition and physical properties of Silica Fume. Silica Fume contains high amount of oxygen and silica.

3.3.3 XRD Pattern of Cement



Acc.Voltage: 15.0 kV Take Off Angle: 81.0 deg.

Quantitative Results for: Base(445)

Element Line	Net Counts	Int. Cps/nA	Weight %	Weight % Error	Atom %	Atom % Error	Formula	Standard Name
O K	1801	---	50.52	+/- 1.74	69.56	+/- 2.39	O	
Al K	595	---	5.26	+/- 0.52	4.29	+/- 0.43	Al	
Si K	1160	---	10.67	+/- 0.60	8.37	+/- 0.47	Si	
Si L	0	---	---	---	---	---		
K K	69	---	0.96	+/- 0.25	0.54	+/- 0.14	K	
K L	0	---	---	---	---	---		
Ca K	1723	---	28.89	+/- 1.31	15.88	+/- 0.72	Ca	
Ca L	0	---	---	---	---	---		
Fe K	33	---	1.77	+/- 1.02	0.70	+/- 0.40	Fe	
Fe L	375	---	---	---	---	---		
Zn K	12	---	1.93	+/- 2.41	0.65	+/- 0.81	Zn	
Zn L	0	---	---	---	---	---		
Total			100.00		100.00			

Fig.3.3 XRD Pattern of Cement

The XRD analysis of Cement gives the information about the chemical composition and physical properties of Cement. Cement contains high amount of oxygen and Calcium and little amount of Silica,Potassium,Aluminium,Iron and Zinc.

3.4 Samples Preparation

The natural soil used in this study was dried, mixed with different percentage of silica fume and cement .Samples were made by mixing both Cement and Cement with silica fume . Three different percentages of Silica Fume (3%, 5%, and 7%) and four different percentages of cement (0%,3%,5%and 7%)were used for study. The percentages were calculated in terms of dry weight of the soil. The samples of the Unconfined Compressive Strength tests were prepared with optimum moisture content and to a maximum dry density of the soil.

3.5 Experimentations:-

3.5.1 Specific gravity of the soil [IS:2720(partII)]

The specific gravity of soil is the ratio between the weight of the soil solids and weight of equal volume of water. It is measured by the help of a volumetric flask in a very simple experimental setup where the volume of the soil is found out and its weight is divided by the weight of equal volume of water. Specific gravity of a substance denotes the number of times that substance is heavier than water. In simpler words we can define it as the ratio between the mass of any substance of a definite volume divided by mass of equal volume of water. In case of soils, specific gravity is the number of times the soil solids are heavier than equal volume of water.

$$\text{Specific Gravity } G = \frac{W_2 - W_1}{(W_4 - W1) - (W3 - W2)}$$

W1 = Weight of bottle in gms

W2 = Weight of bottle + Dry soil in gms

W3 = Weight of bottle + Soil + Water

W4 = Weight of bottle + Water

Table 3.2 Values of G for different Types of Soils

S.No.	Type of soil	Range of G value
1.	Sands	2.65-2.67
2.	Silty Sands	2.67-2.70
3.	Inorganic Clays	2.70-2.80
4.	Soils with mica or iron	2.75-2.90
5.	Organic Soils	Quite variable, as low as 2.2

3.5.2 Hydrometer test [IS:2720 (Part IV)]:-

The hydrometer method is based on the measurement of velocity of soil particles in a sedimentation solution and the dry mass of soil in the solution in different intervals of time. The velocity of falling particles and dry mass of soil at a specific depth are measured by a hydrometer. The results are combined with Stokes' law, which gives the relation between velocity of a spherical particle and its diameter while settling within its solution. The tests are carried out according to procedure mentioned in IS2720 Part 4 1985

Picture 1 Hydrometer test apparatus

3.5.3 Liquid limit[IS:2720(part V)]

It is the water content of the soil between the liquid state and plastic state of the soil. It can be defined as the minimum water content at which the soil, though in liquid state, shows small shearing strength against flowing. It is measured by the Casagrande's apparatus and is denoted by w_l.

The Casagrande tool cuts a groove of size 2mm wide at the bottom and 11 mm wide at the top and 8 mm high. The number of blows used for the two soil samples to come in contact is noted down. Graph is plotted taking number of blows on a logarithmic scale on the abscissa and water content on the ordinate. Liquid limit corresponds to 25 blows from the graph.

When enough and sufficient water is added to a fine soil, it achieves a liquid state; i.e. the soil behaves like a liquid without having any shear strength. However, when we reduce the water content of the soil gradually, the soil changes from the liquid state of the plastic state. In the plastic state, the soil gains a lot of shear strength. A plastic soil (i.e. a soil in plastic state) is a sticky soil and can be moulded into different shapes and hence used for making clay toys, etc.

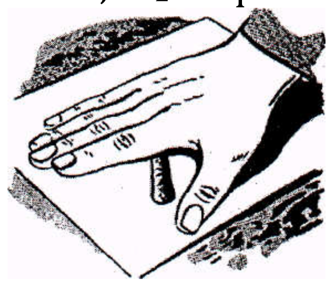
Picture 2 Liquid limit apparatus

3.5.4 Plastic limit [IS:2720(part X)]

This is determined by rolling out soil till its diameter reaches approximately 3 mm and measuring water content for the soil which crumbles on reaching this diameter. Plasticity index (Ip) was also calculated with the help of liquid limit and plastic limit;

$$I_P = W_L - W_P$$

Where, W_L- Liquid limit, W_P- Plastic limit



Picture 3 Plastic liquid method

Plasticity index

Plasticity index (Ip) was also calculated with the help of liquid limit and plastic limit;

$I_P = W_L – W_P$

W_L- Liquid limit

W_P- Plastic limit

3.5.5 Particle Size Distribution

Soil at any place is composed of particles of a variety of sizes and shapes, sizes ranging from a few microns to a few centimeters are present sometimes in the same soil sample. The distribution of particles of different sizes determines many physical properties of the soil such as its strength, permeability, density etc.

Particle size distribution is found out by two methods, first is sieve analysis which is done for coarse grained soils only and the other method is sedimentation analysis used for fine grained soil sample. Both are followed by plotting the results on a semi-log graph. The percentage finer *N* as the ordinate and the particle diameter i.e. sieve size as the abscissa on a logarithmic scale. The curve generated from the result gives us an idea of the type and gradation of the soil. If the curve is higher up or is more towards the left, it means that the soil has more representation from the finer particles; if it is towards the right, we can deduce that the soil has more of the coarse grained particles.

The soil may be of two types- well graded or poorly graded (uniformly graded). Well graded soils have particles from all the size ranges in a good amount. On the other hand, it is said to be poorly or uniformly graded if it has particles of some sizes in excess and deficiency of particles of other sizes. Sometimes the curve has a flat portion also which means there is an absence of particles of intermediate size, these soils are also known as gap graded or skip graded.

For analysis of the particle distribution, we sometimes use D10, D30, and D60 etc. terms which represents a size in mm such that 10%, 30% and 60% of particles respectively are finer than that size. The size of D10 also called the effective size or diameter is a very useful data. There is a term called uniformity coefficient Cu which comes from the ratio of D60 and D10, it gives a measure of the range of the particle size of the soil sample.

As per provisions of IS 460-1972 (revised), soils having particles of size larger than 75 micron (0.075 mm) are termed as coarse grain soils. Thus, sand, gravel, cobble and boulder do fall within the definition of coarse grained soils. The size range of different types of these soils, is as under:

I. Boulder- (more than 300 mm)

II. Cobble- (80 mm to 300 mm)

III. Gravel- (4.75 mm to 80 mm)

IV. Sand – (0.075 mm-4.75 mm)

Soils finer than 0.075 mm (75μ) are classified as silts and clays; and hence are called fine grained soils.

3.5.6 Proctor Compaction Test [IS:2720(part VII)]

This experiment gives a clear relationship between the dry density of the soil and the moisture content of the soil. The experimental setup consists of (i) cylindrical metal mould (internal diameter- 10.15 cm and internal height-11.7 cm), (ii) detachable base plate, (iii) collar (5 cm effective height), (iv) rammer (2.5 kg). Compaction process helps in increasing the bulk density by driving out the air from the voids. The theory used in the experiment is that for any compactive effort, the dry density depends upon the moisture content in the soil. The maximum dry density (MDD) is achieved when the soil is compacted at relatively high moisture content and almost all the air is driven out, this moisture content is called optimum moisture content (OMC). After plotting the data from the experiment with water content as the abscissa and dry density as the ordinate, we can obtain the OMC and MDD.

$$\text{Wet density} = \frac{\text{weight of wet soil in mould (gms)}}{\text{volume of mould(cc)}}$$

$$\text{Moisture content \%} = \frac{\text{weight of water (gms)}}{\text{weight of dry soil (gms)}} \text{X } 100$$

$$\text{Dry density } \gamma_d \text{ (gm/cc)} = \frac{\text{wet density}}{1+\frac{\text{moisture content}}{100}}$$

Picture 4 Standard proctor test apparatus

3.5.7 Unconfined Compression Test[IS:2720(part VII)]

This experiment is used to determine the unconfined compressive strength of the soil sample which in turn is used to calculate the unconsolidated, undrained shear strength of unconfined soil. The unconfined compressive strength (q_u) is the compressive stress at which the unconfined cylindrical soil sample fails under simple compressive test. The experimental setup constitutes of the compression device and dial gauges for load and deformation. The load was taken for different readings of strain dial gauge starting from ε = 0.005 and increasing by 0.005 at each step. The corrected cross-sectional area was calculated by dividing the area by (1- ε) and then the compressive stress for each step was calculated by dividing the load with the corrected area. Q_U= load/corrected area (A')

Q_U= compressive stress

A'= cross-sectional area/ (1- ε)

Picture 5 Unconfined compressive strength test apparatus

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Engineering Properties of Soil

4.1.1 Specific Gravity of the Soil.

M_1 = Mass of empty bottle = 696.63 gm

M_2= Mass of bottle + mass of dry soil = 858.22 gm

M_3 = Mass of bottle + mass of dry soil + mass of water = 1669.42 gm

M_4 = Mass of bottle + mass of water = 1567.53 gm

$$G = \frac{M2 - M1}{[(M2 - M1) - (M3 - M4)]}$$

$$G = \frac{161.59}{(161.59 - 101.89)}$$

G = 2.706

The Specific gravity of the soil is obtained as 2.706.

4.1.2 Grain Size Distribution

Hydrometer reading

Calibration of hydrometer:

Initial reading = 760mL

Final reading = 850mL

Volume of hydrometer, V_H = 90mL

Area of cross section of the cylinder, A = $\frac{(700-600)}{2.8}$ = 35.71 cm^2

Height of bulb, h = 15.5 cm

Table 4.1 Observation for Calibration of Hydrometer

Actual Hydrometer reading (R_H)	Distance between neck to each mark on hydrometer (H) in cm	Effective depth $H_e = H + \frac{1}{2}(h - \frac{V_h}{A})$ in cm
25(1025)	1.7	8.2
20(1020)	3.4	9.9
15(1015)	5.1	11.6
10(1010)	6.8	13.3
5(1005)	8.5	15
0(1000)	10.2	16.7
-5(995)	11.9	18.4

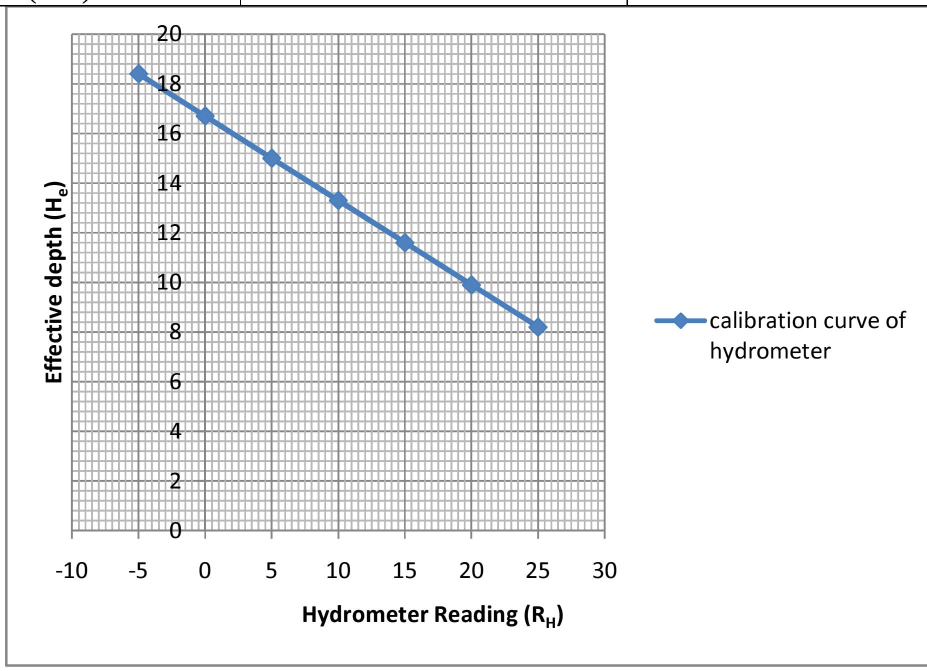


Fig 4.1 Calibration Curve of Hydrometer

Mass of dry soil (M_s) = 50g; Meniscus correction (C_m) = +0.5

Percentage finer $N = \frac{100G}{M_d(G-1)} R$

Where R = hydrometer reading corrected for composite correction

M_d= dry mass of soil sample.

Factor M = $\sqrt{\frac{0.3\eta}{g(G-1)\rho_w}}$

$\eta = 8.85 \times 10^{-3}$ poise, g=981cm/s^2

G=2.706, ρ_w=1 gm/cc at 27^0c.

M=0.01258.

Sl. No.	Observations				Calculations					
	Elapsed time (t)	Hydrometer reading (R_H)	Temperature	Composite correction (C)	Corrected hydrometer reading $R_H' = R_H + C_m$	Height H_e (cm)	Reading $R = R_H + C$	Factor M	Partice size (mm) $D = M\sqrt{\frac{H_e}{t}}$	Percentage finer (N)
1	0.5 min	10	27^0C	-0.5	10.5	13.3	9.5	0.01258	0.0639	30.24
2	1 min	9.75	27^0C	-0.5	10.25	13.39	9.25	0.01258	0.0453	29.44
3	2 min	9.5	27^0C	-0.5	10	13.47	9	0.01258	0.0322	28.65
4	4 min	8.75	27^0C	-0.5	9.25	13.73	8.25	0.01258	0.0229	26.26
5	8 min	7.75	27^0C	-0.5	8.25	14.07	7.25	0.01258	0.0164	23.07
6	15 min	7.25	27^0C	-0.5	6.75	14.24	6.75	0.01258	0.0120	21.49
7	30 min	6.75	27^0C	-0.5	7.25	14.41	6.25	0.01258	0.00859	19.89
8	1hr	6	27^0C	-0.5	6.5	14.67	5.5	0.01258	0.00436	17.5
9	2 hr	5.5	25^0C	-0.5	6	14.83	5	0.01258	0.0031	15.9
10	4 hr	5	25^0C	-0.5	5.5	15	4.5	0.01258	0.00281	14.32
11	8 hr	4	25^0C	-0.5	4.5	15.33	3.5	0.01258	0.00224	11.14
12	12 hr	3	25^0C	-0.5	3.5	15.56	2.5	0.01258	0.00185	7.96
13	24 hr	1.5	25^0C	-0.5	3	15.73	1	0.01258	0.00131	3.18

Table 4.2 Observation and Calculation of Hydrometer

Table 4.3 Partical Size Distribution

Sl. No.	Sieve size	Mass of soil retained in each sieve (g)	Percentage retained (%)	Cumulative percentage retained (%)	Percentage finer
1	4.75mm	3.3	0.33	0.33	99.67
2	2.36mm	10.4	1.04	1.37	98.63
3	1.18mm	18	1.8	3.17	96.83
4	600µ	62.1	6.21	9.38	90.62
5	300µ	45.1	4.51	13.89	86.11
6	180µ	108.2	10.82	24.71	75.29
7	75µ	185.1	18.51	43.22	56.78
8	Pan	567.8	56.78	100	0

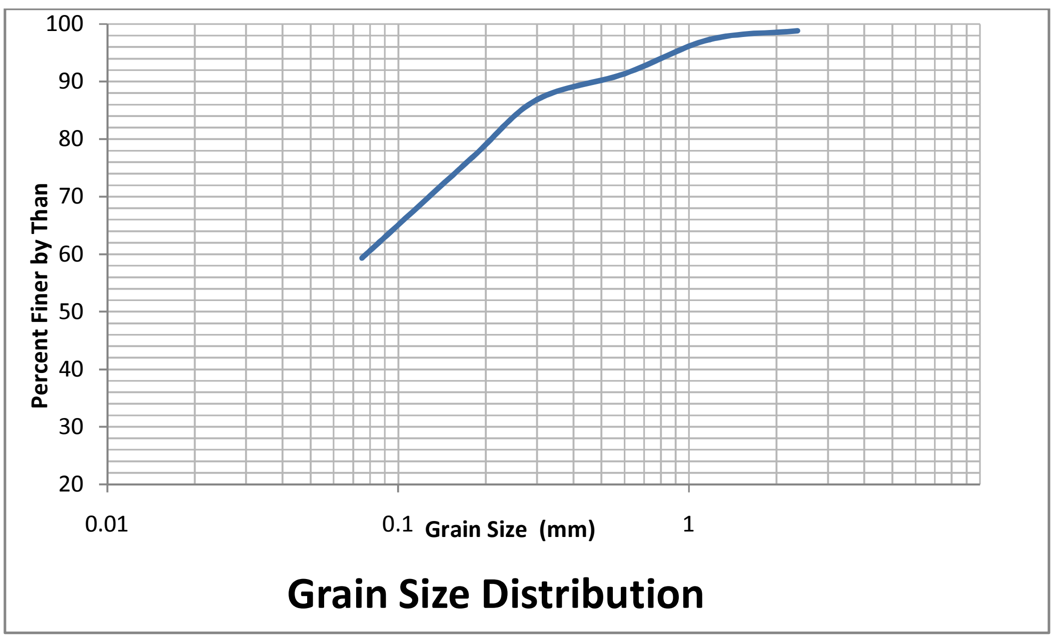


Fig 4.2 Grain Size Distribution Curve

4.1.3 Consistency Limit Determination

Table 4.4 Observation for Water Content

Sl. No.	No. of blow	Mass of sampler (M_e) in gm	Mass of Sampler + Moist soil ($M_e + M_m$) in gm	Mass of Sampler + Dry soil ($M_e + M_s$) in gm	Mass of moist soil (M_m) in gm	Mass of Dry soil (M_m) in gm	Mass of water (M_w) in gm	Water content W= (M_w/M_m) *100 %
1	14	5.46	11.79	9.98	6.39	4.58	1.81	39.52
2	21	5.39	11.51	9.90	6.12	4.51	1.61	35.69
3	29	15.63	26.17	23.77	10.54	8.14	2.40	29.48
4	41	5.36	13.84	12.39	8.48	7.63	1.45	20.63

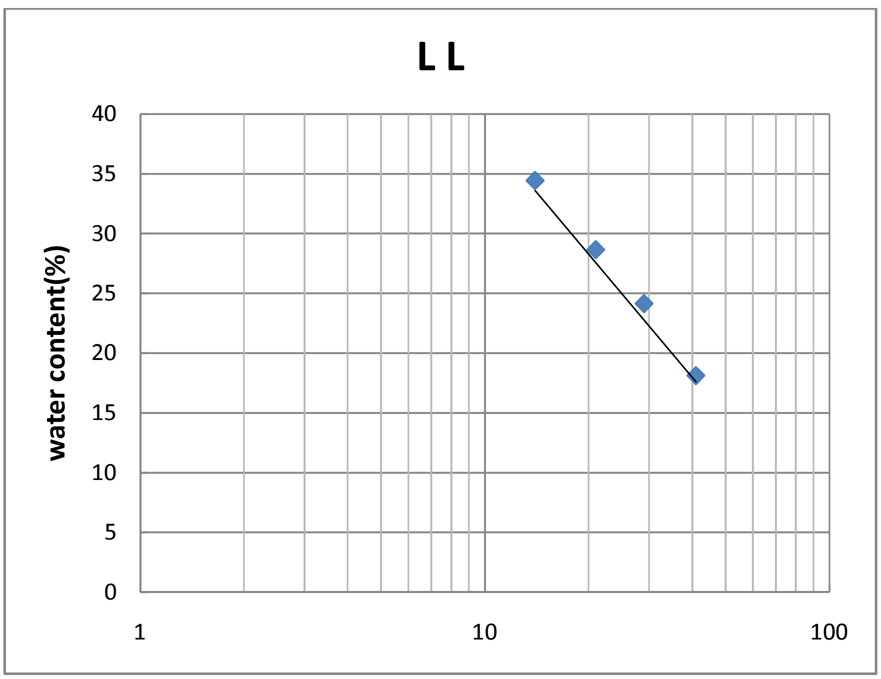


Fig 4.3 Liquid Limit Curve of Soil

The Liquid Limit of Soil is 25.80 %.

Table 4.5 Observation for Plastic Limit

Sl. No.	Mass of sampler (M_e) in gm	Mass of Sampler + Moist soil ($M_e + M_m$) in gm	Mass of Sampler + Dry soil ($M_e + M_s$) in gm	Mass of moist soil (M_m) in gm	Mass of Dry soil (M_m) in gm	Mass of water (M_w) in gm	Water content W= (M_w/M_m)*100 %
1	5.39	9.13	8.48	3.75	3.09	0.66	21.35
2	6.04	9.14	8.3	2.74	2.26	0.48	21.23
3	5.61	8.57	8.04	2.96	2.43	0.53	21.77

The average value of Plastic Limit of Soil is 21.45%

P.I=LL-PL

P.I =4.35.

4.1.4 Results of Proctor Compaction Test

Weight of Mould (M_m) = 4.260 kg and,

Volume of Mould (V) = 0.960 m^3

Table 4.6(a) Observation for Bulk density

Sl. No	% Water added	Mass of water added	Mass of mould + Mass of soil ($M_m + M_s$) in kg	Mass of soil in mould (M_s) in kg	Bulk density (ρ) = (M_s / V) (kN/m^3) .
1	4	120	5.940	1.680	17.50
2	7	210	6.040	1.780	18.54
3	10	300	6.130	1.870	19.47
4	13	390	6.212	1.952	20.33
5	16	480	6.140	1.880	19.58

Table 4.6(b) Observation for Water Content

Sl. No.	Mass of sampler (M_e) in gm	Mass of Sampler + Moist soil ($M_e + M_m$) in gm	Mass of Sampler + Dry soil ($M_e + M_s$) in gm	Mass of moist soil (M_m) in gm	Mass of Dry soil (M_m) in gm	Mass of water (M_w) in gm	Water content W= $(M_w/M_w)*100$ %
1	5.39	15.26	15.18	10.37	9.79	0.58	5.92
2	5.61	16.48	15.56	10.87	9.95	0.92	9.25
3	17.46	28.44	27.31	10.98	9.85	1.13	11.47
4	6.56	22.08	20.08	15.52	13.52	2.00	14.79
5	6.52	20.68	18.62	14.16	12.10	2.06	17.03

Table 4.6(c) Observation for Dry density

Sl. No.	Bulk Density (ρ) (kN/m^3).	Water content (w %)	Dry density ρ_d=(ρ/(1+w)) in kN/m^3.
1	17.50	5.92	16.52
2	18.54	9.25	16.97
3	19.47	11.47	17.46
4	20.33	14.79	17.71
5	19.58	17.03	16.73

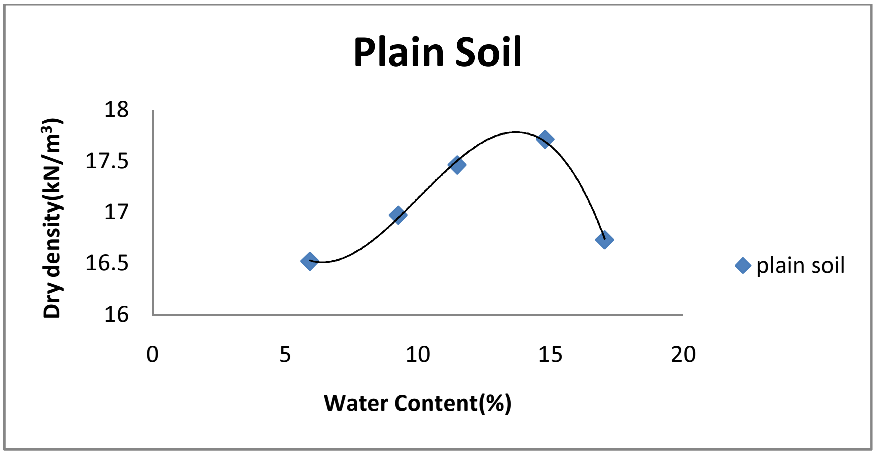


Fig.4.4 Relation between Dry density and Water Content

O.M.C of Soil is 13.80 %

M.D.D of Soil is 17.78 kN/m^3.

4.1.5 Unconfined Compressive Strength (UCS)

Table 4.7 Observation for Unconfined Compressive Strength of soil

UCS Value after 28 days of curing		UCS Value after 7 days of curing		UCS Value after 1 days of curing	
Axial Stress (MPa)	Axial Strain (%)	Axial Stress (MPa)	Axial Strain (%)	Axial Stress (MPa)	Axial Strain (%)
0.025	0.006	0.017	0.006	0.008	0.006
0.042	0.013	0.034	0.132	0.023	0.013
0.067	0.019	0.059	0.026	0.046	0.019
0.084	0.026	0.075	0.035	0.062	0.026
0.100	0.032	0.100	0.039	0.084	0.032
0.124	0.039	0.116	0.046	0.107	0.039
0.156	0.046	0.139	0/054	0.136	0.046
0.179	0.052	0.171	0.065	0.158	0.052
0.203	0.059	0.194	0.072	0.172	0.059
0.225	0.065	0.217	0.078	0.163	0.065
0.248	0.072	0.19 2	0.081	0.147	0.072
0.262	0.078	0.167	0.085		
0.284	0.085				
0.266	0.092				
0.241	0.098				

After 1 days of curing

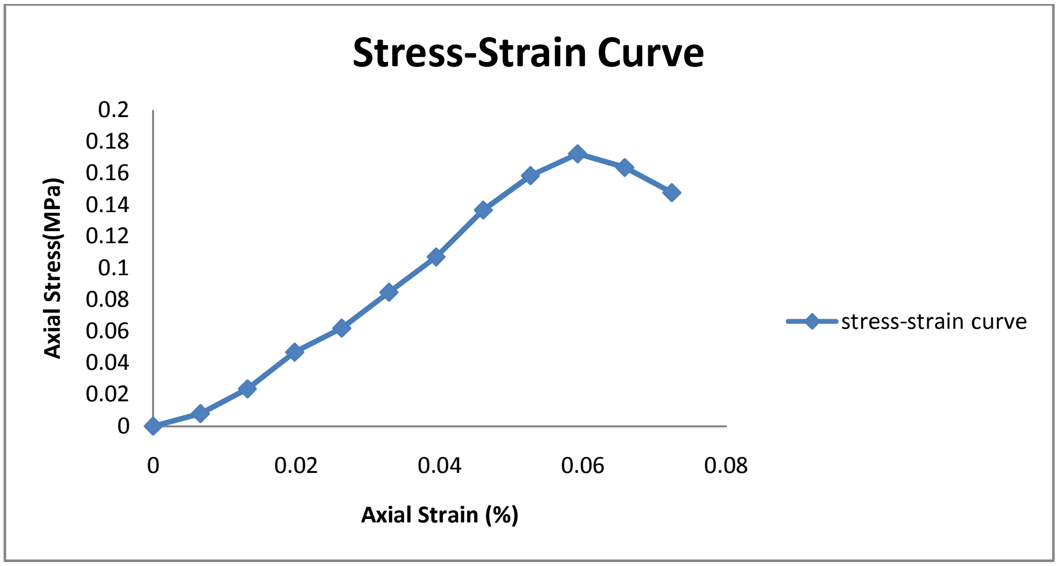


Fig 4.5 Stress strain curve of soil after 1 day

The Unconfined Compressive Strength Value of Soil is 0.172MPa.

After 7 days of curing

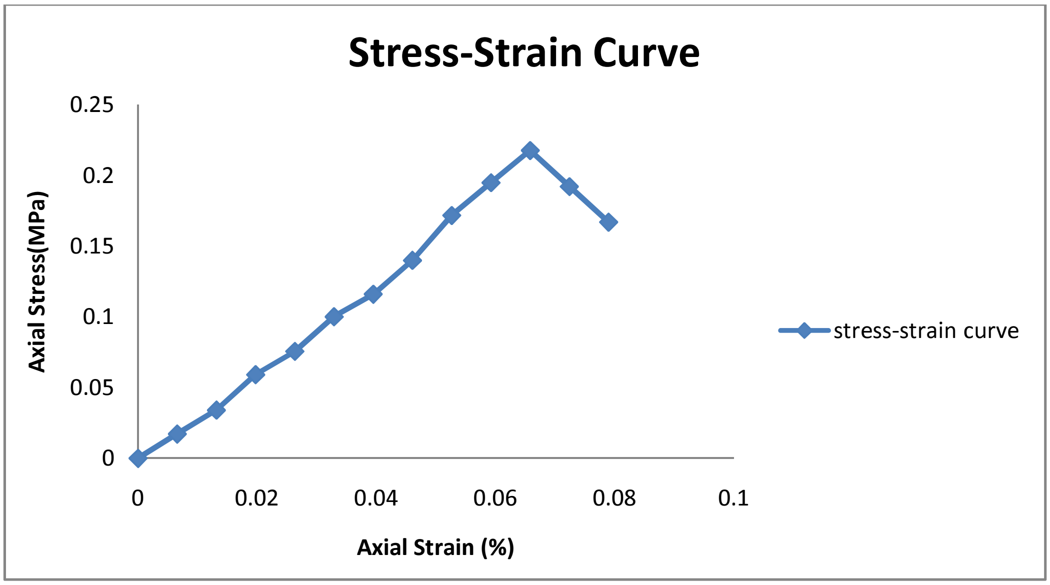


Fig 4.6 Stress strain curve of soil after 7 days

The Unconfined Compressive Strength Value of Soil is 0.217MPa.

After 28 days of curing

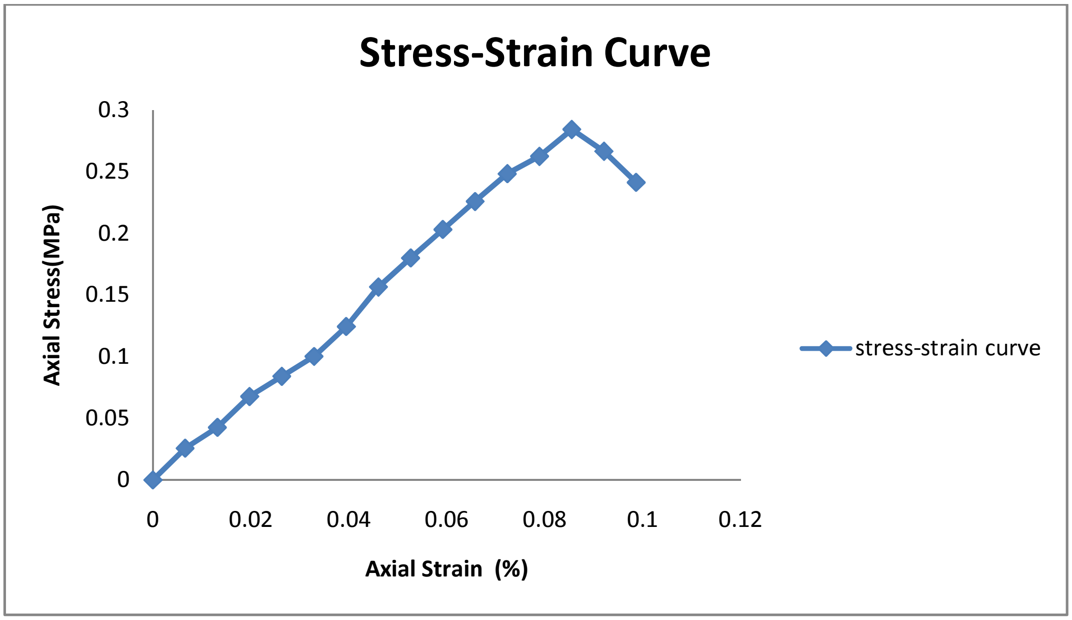


Fig 4.7 Stress strain curve of soil after 28 days

The Unconfined Compressive Strength Value of Soil is 0.284MPa.

4.2 Engineering Properties of Various Mixes

Table 4.8 Mix Designation

Mix	Soil(%)	Silica Fume(%)	Cement(%)
M0	100	0	0
M1	100	0	3
M2	100	0	5
M3	100	0	7
M4	100	3	0
M5	100	3	3
M6	100	3	5
M7	100	3	7
M8	100	5	0
M9	100	5	3
M10	100	5	5
M11	100	5	7
M12	100	7	0
M13	100	7	3
M14	100	7	5
M15		7	7

The % of silica fume and cement is in by weight addition to soil.

4.2.1 Engineering Properties of M1

4.2.1.1 Specific Gravity of M1 is 2.720

4.2.1.2 Consistency Limits

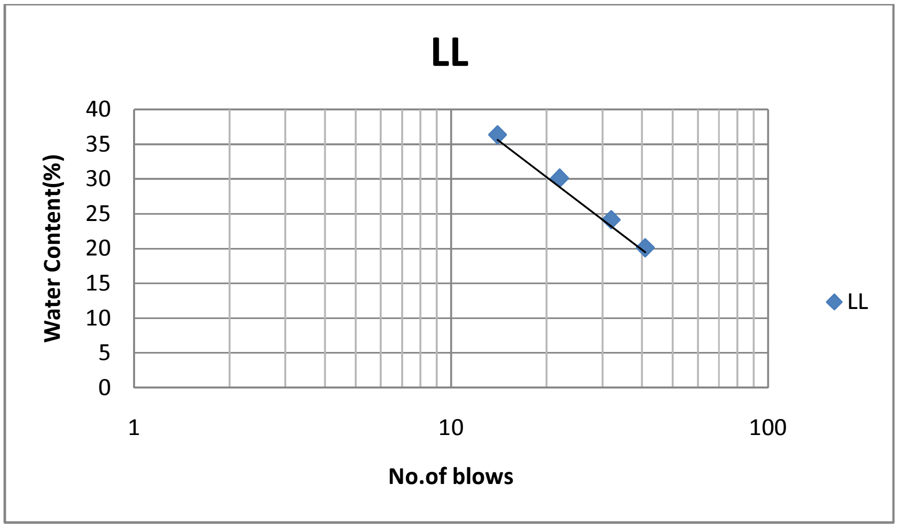


Fig 4.8 Liquid Limit Curve of M1

The Liquid Limit of M1 is 28.20 %.

The Plastic Limit of M1 is 23.74 %.

P.I=4.46.

4.2.1.3 Results of Proctor Compaction Test

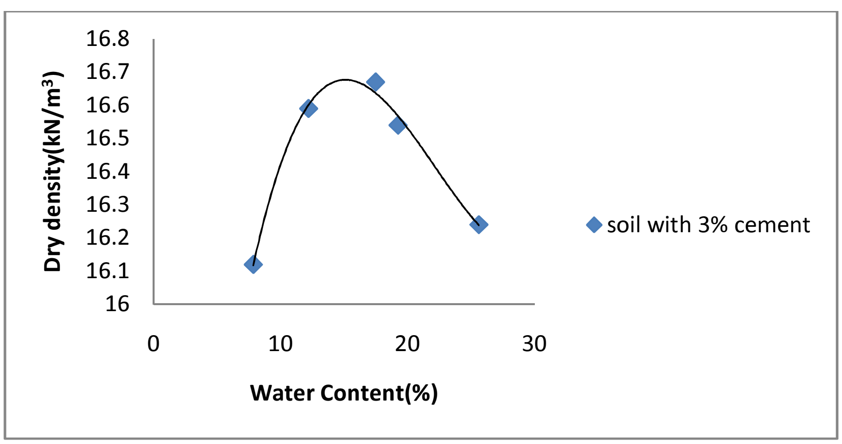


Fig 4.9 Relation between Dry density and Water Content of M1

O.M.C of M1 is 17.20%.

M.D.D of M1 is 16.64 $kN/m^{3.}$

4.2.1.4 Unconfined Compressive Strength (UCS)

After 1 days of curing

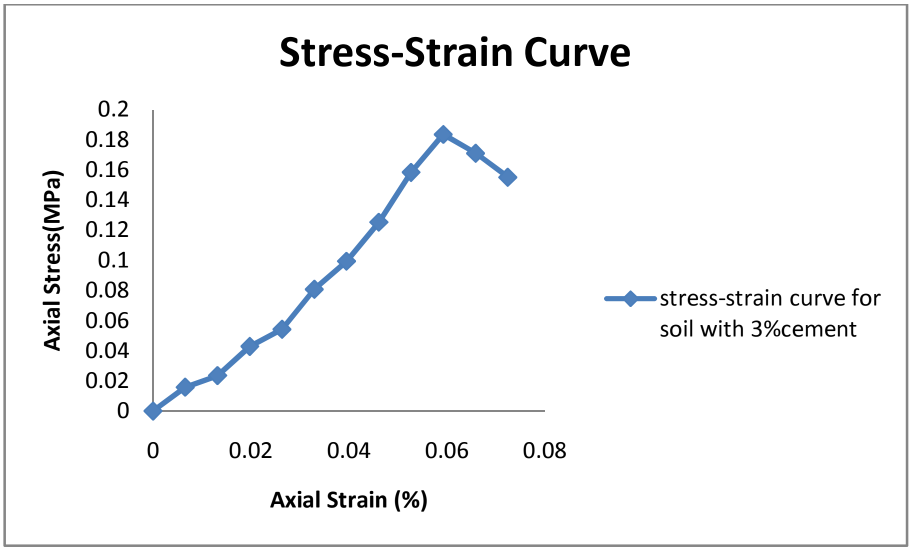


Fig 4.10 Stress strain curve of M1 after 1 day

The Unconfined Compressive Strength Value of M1 is 0.183MPa.

After 7 days of curing

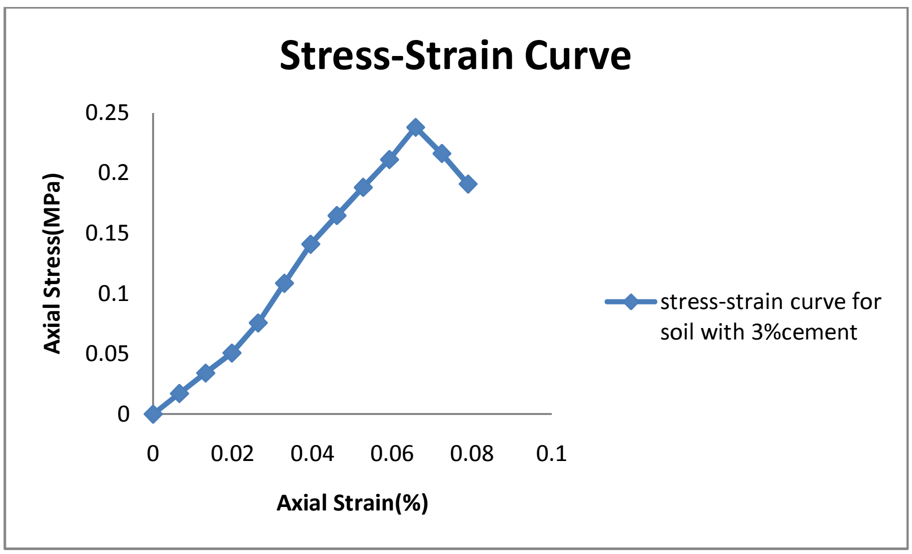


Fig 4.11 Stress strain curve of M1 after 7 day

The Unconfined Compressive Strength Value of M1 is 0.237MPa.

After 28 days of curing

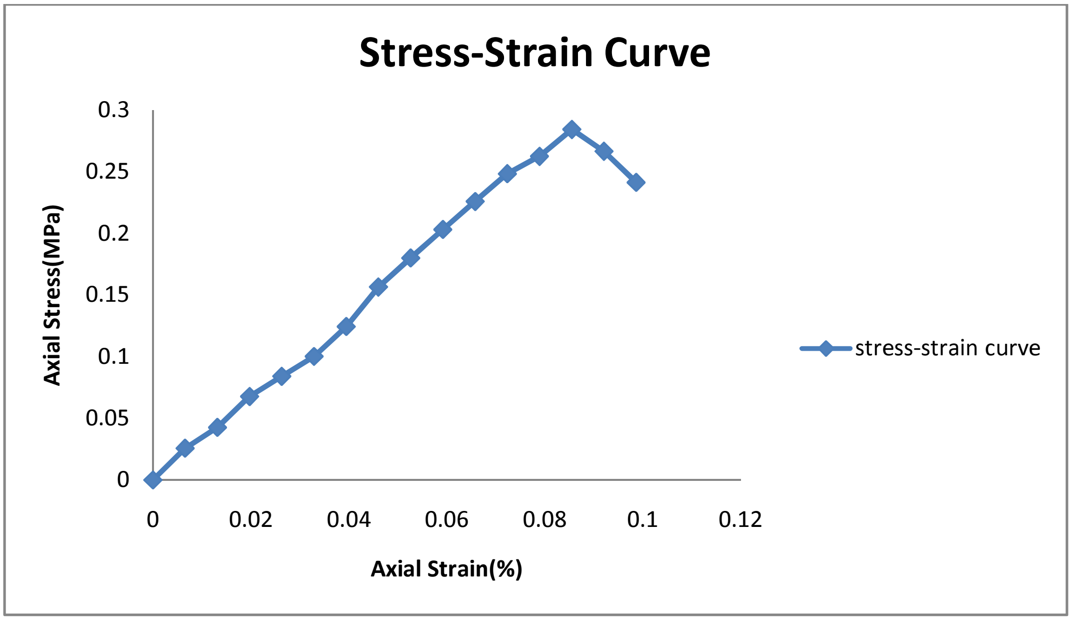


Fig 4.12 Stress strain curve of M1 after 28 day

The Unconfined Compressive Strength Value of M1 is 0.309MPa.

4.2.2Engineering Properties of M2

4.2.2.1 Specific Gravity of M2 is 2.728.

4.2.2.2 Consistency Limits

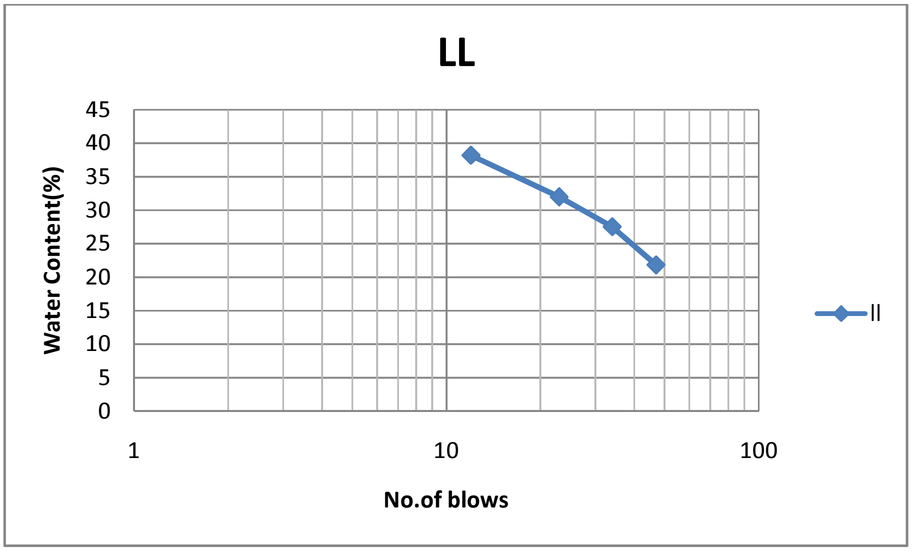


Fig 4.13 Liquid limit Curve of M2

The Liquid Limit of M2 is 31.20 %.

The Plastic Limit of M2 is 26.14 %.

P.I=5.06.

4.2.2.3 Results of Proctor Compaction Test

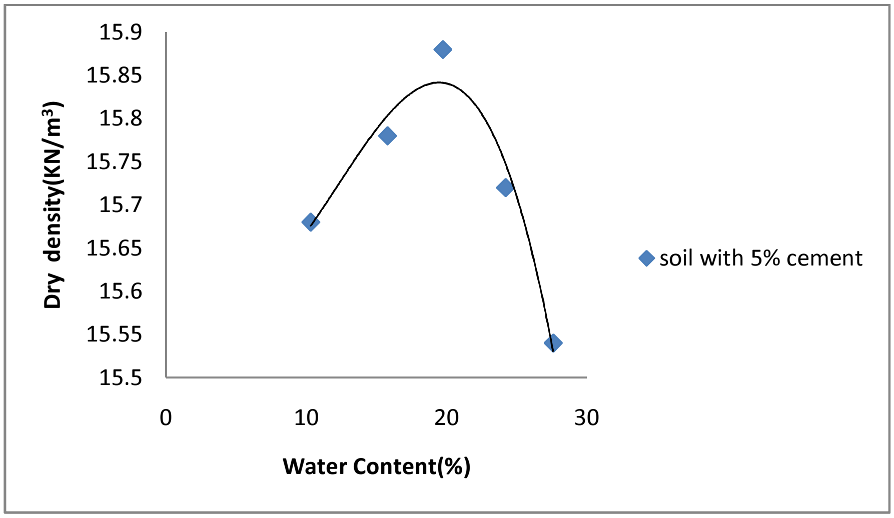


Fig 4.14 Relation between Dry density and Water Content of M2

O.M.C of M2 is 20.80%

M.D.D of M2 is 15.84 kN/m^3

4.2.2.4 Unconfined Compressive Strength (UCS)

After 1 days of curing

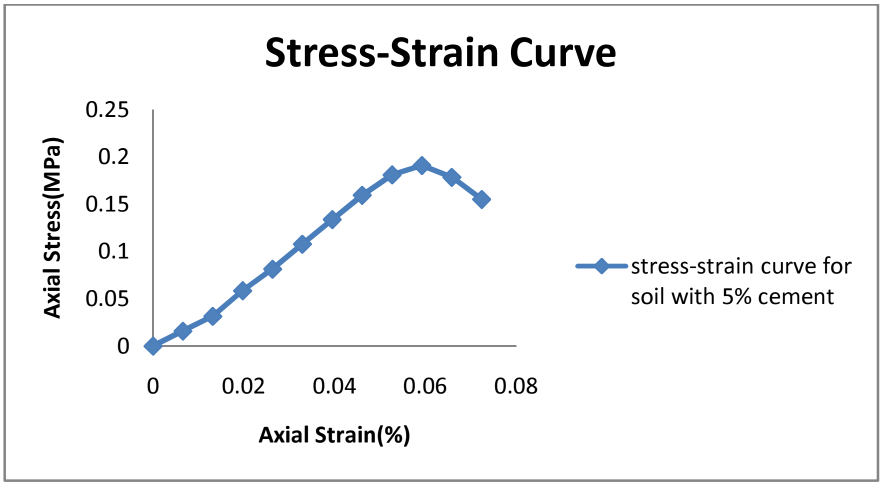


Fig 4.15 Stress strain curve of M2 after 1 day

The Unconfined Compressive Strength Value of M2 is 0.194MPa.

After 7 days of curing

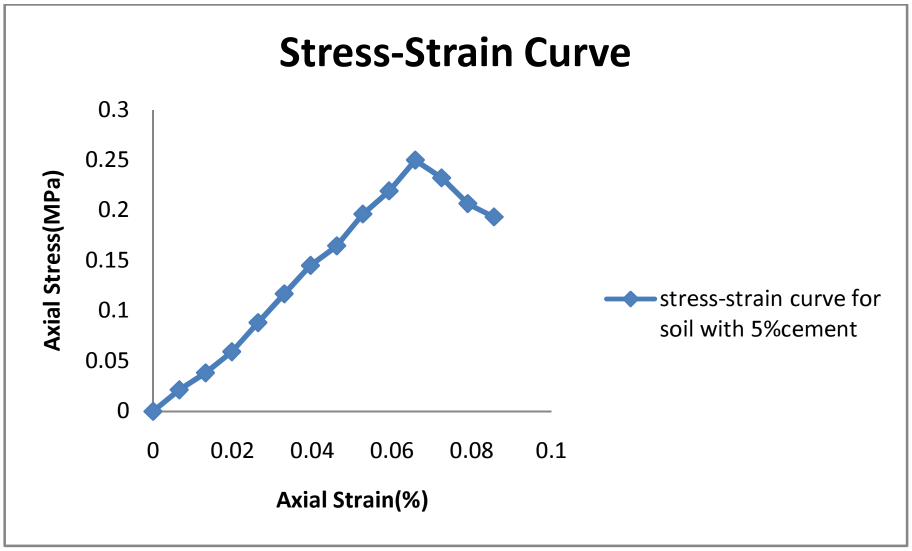


Fig 4.16 Stress strain curve of M2 after 7 day

The Unconfined Compressive Strength Value of M2 is 0.249MPa.

After 28 days of curing

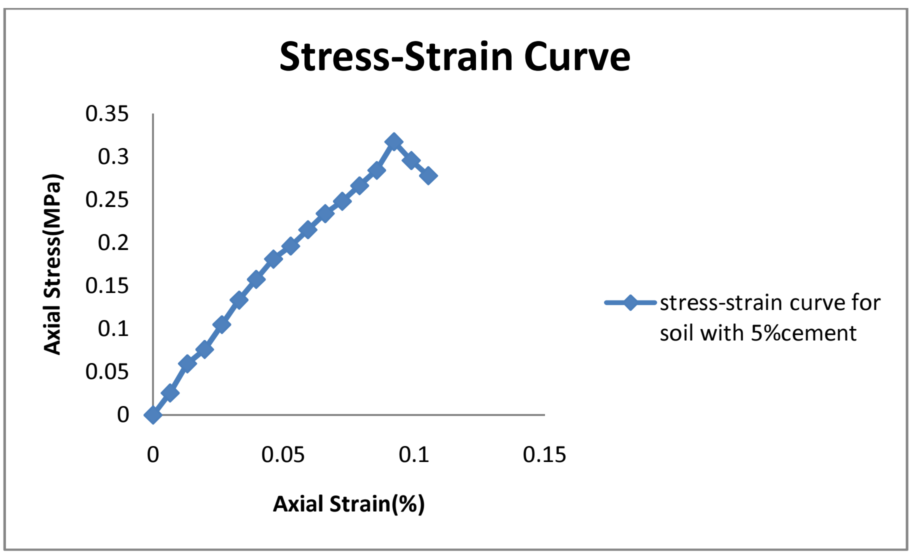


Fig 4.17 Stress strain curve of M2 after 28 day

The Unconfined Compressive Strength Value of M2 is 0.317MPa.

4.2.3Engineering Properties of M3

4.2.3.1 Specific Gravity of M3 is 2.728

4.2.3.2 Consistency Limits

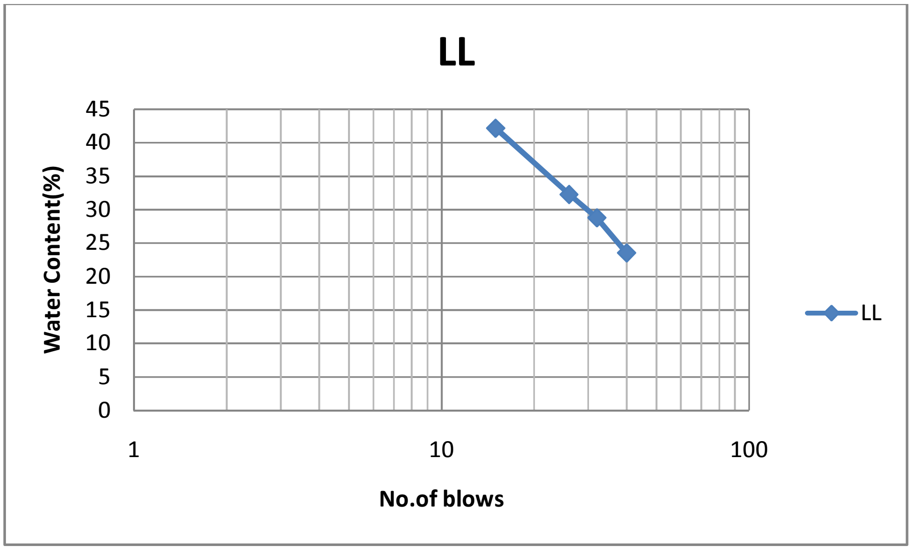


Fig 4.18 Liquid limit curve of M3

The Liquid Limit of M3 is 33.10 %.

The Plastic Limit of M3 is 28.42 %.

P.I=4.68.

4.2.3.3 Results of Proctor Compaction Test

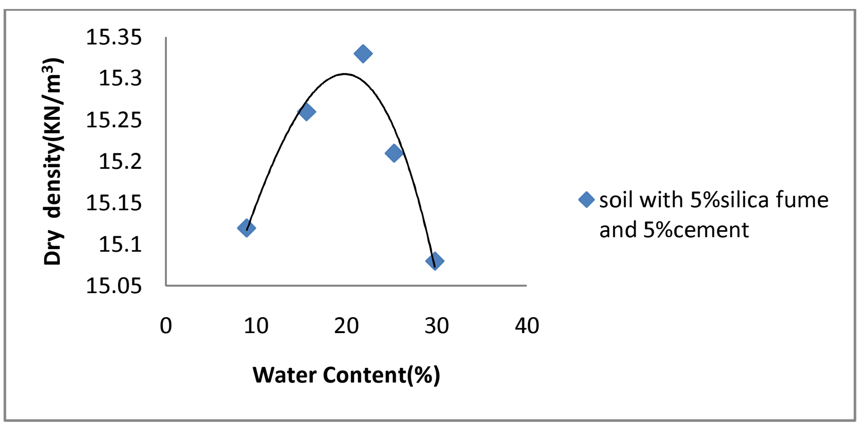


Fig 4.19 Relation between Dry density and Water Content of M3

O.M.C of M3 is 22.10%

M.D.D of M3 is 15.28 kN/m^3

4.2.3.4 Unconfined Compressive Strength (UCS)

After 1 days of curing

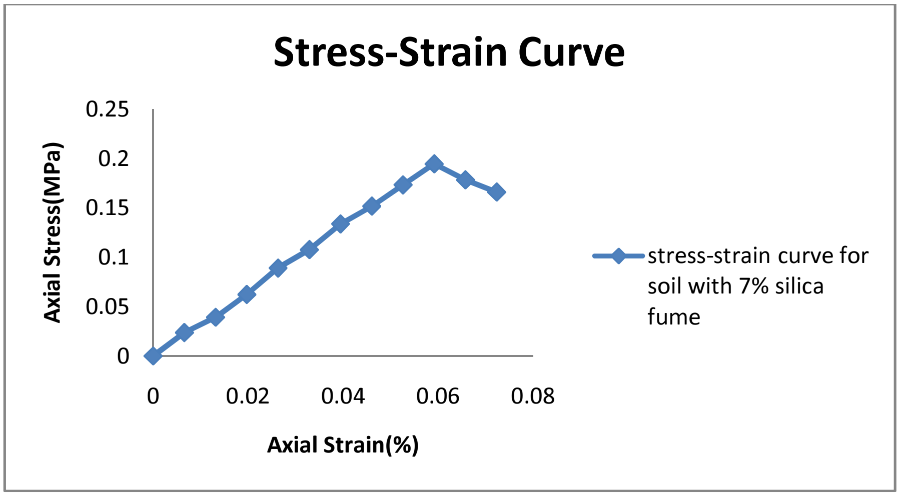


Fig 4.20 Stress strain curve of M3 after 1 day

The Unconfined Compressive Strength Value of M3 is 0.209MPa.

After 7 days of curing

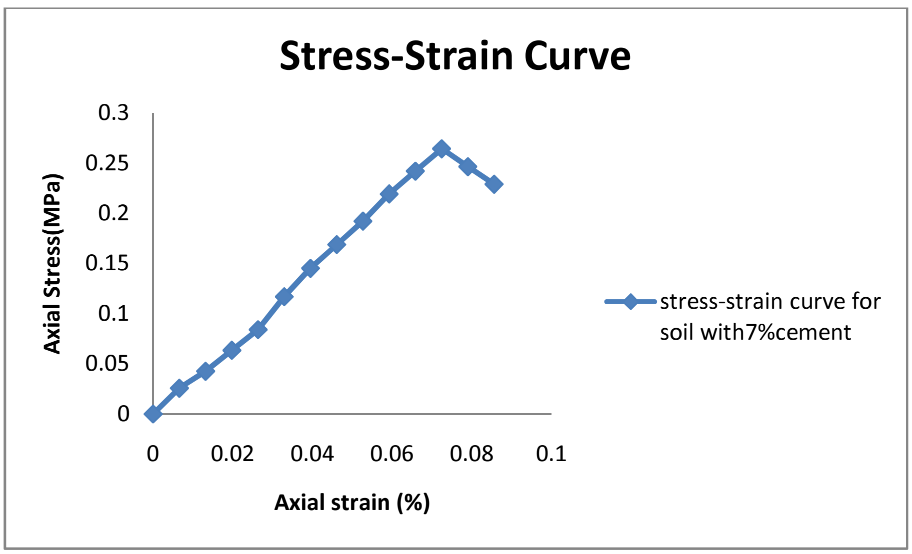


Fig 4.21 Stress strain curve of M3 after 7 day

The Unconfined Compressive Strength Value of M3 is 0.264MPa.

After 28 days of curing

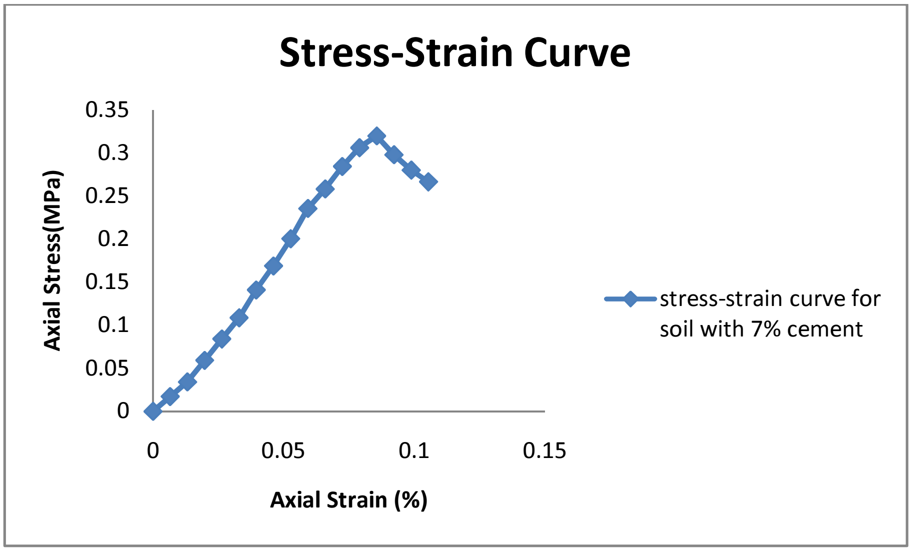


Fig 4.22 Stress strain curve of M3 after 28 day

The Unconfined Compressive Strength Value of M3 is 0.339MPa.

4.2.4 Engineering Properties of M4

4.2.4.1 Specific Gravity of M3 is 2.691

4.2.4.2 Consistency Limits

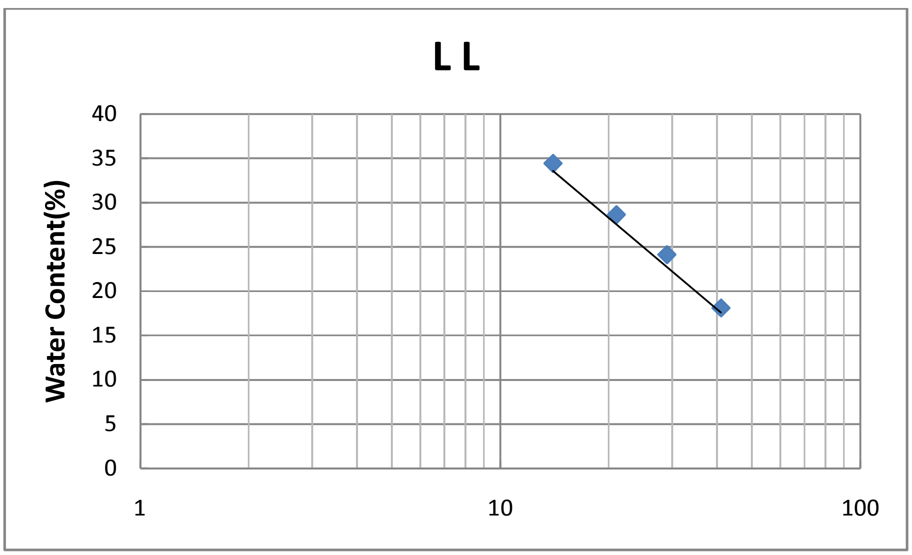


Fig 4.23 Liquid Limit Curve of M4

The Liquid Limit of M4 is 27.30 %.

The Plastic Limit of M4 is 23.24%.

P.I=4.16.

4.2.4.3 Results of Proctor Compaction Test

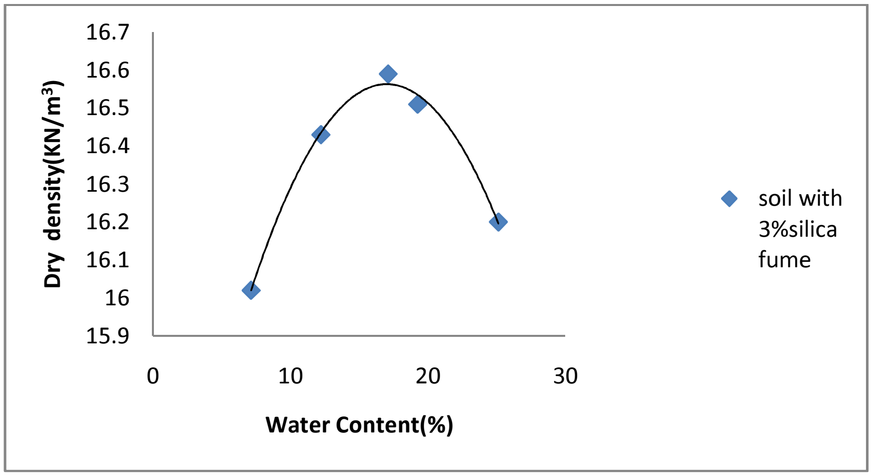


Fig 4.24 Relation between Dry density and Water Content of M4

O.M.C of M4 is 16.40%

M.D.D of M4 is 16.58 kN/m^3

4.2.4.4 Unconfined Compressive Strength (UCS)

After 1 days of curing

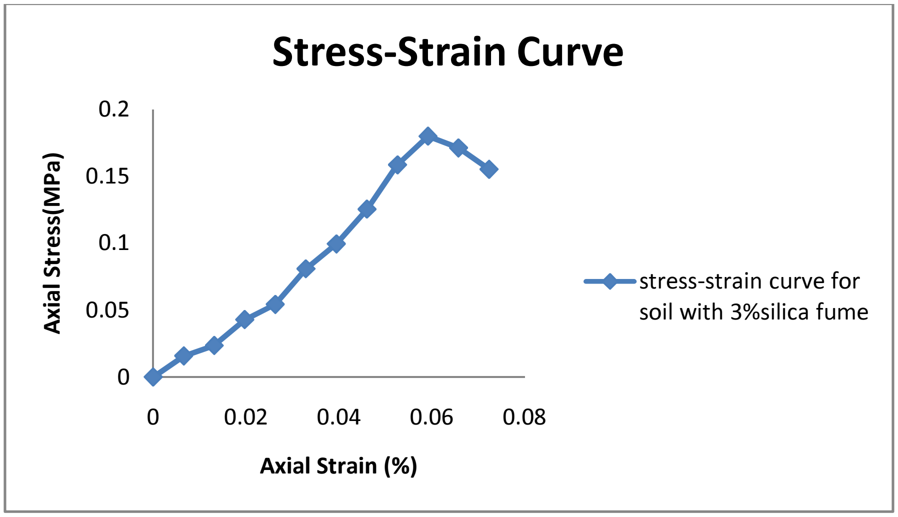


Fig 4.25 Stress strain curve of M4 after 1 day

The Unconfined Compressive Strength Value of M4 is 0.179MPa.

After 7 days of curing

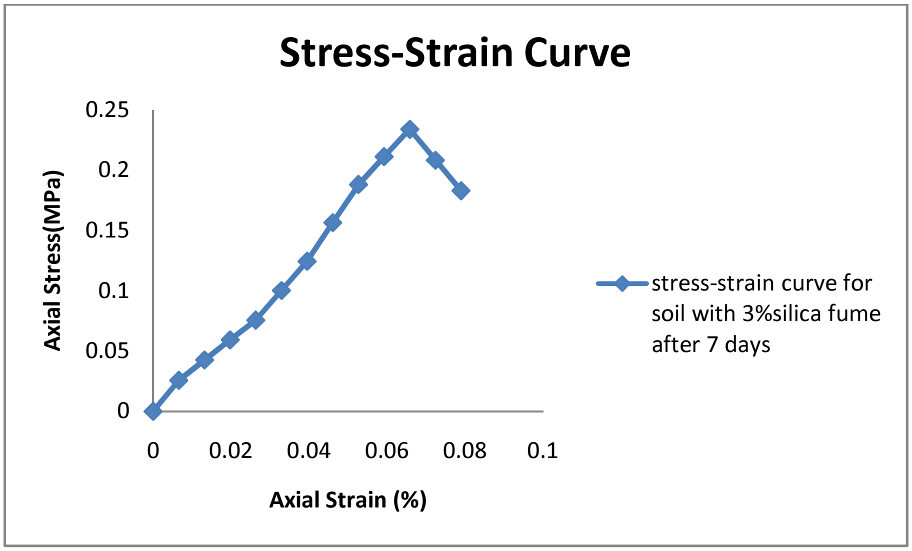


Fig 4.26 Stress strain curve of M4 after 7 day

The Unconfined Compressive Strength Value of M4 is 0.233MPa.

After 28 days of curing

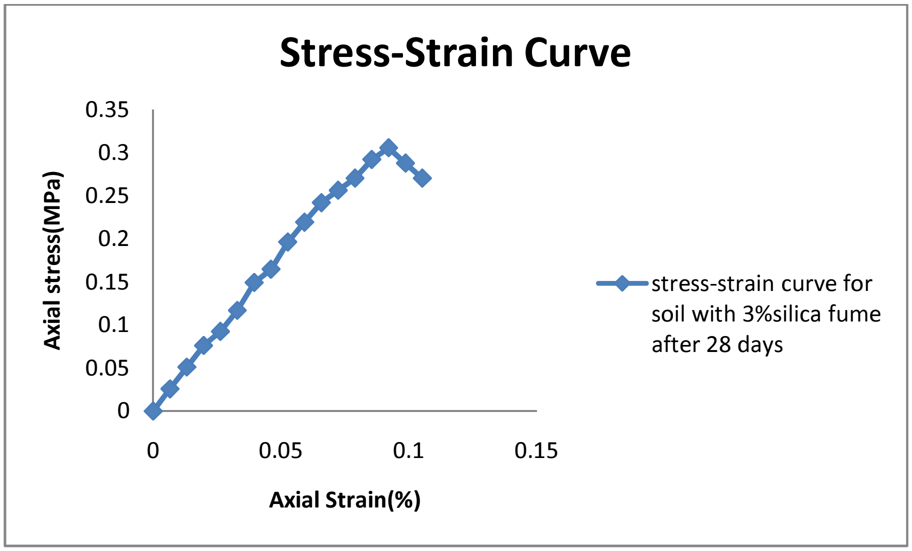


Fig 4.27 stress strain curve of M4 after 28 day

The unconfined Compressive strength value of M4 is 0.305MPa.

4.2.5 Engineering Properties of M5

4.2.5.1 Specific Gravity of M5 is 2.702

4.2.5.2 Consistency Limits

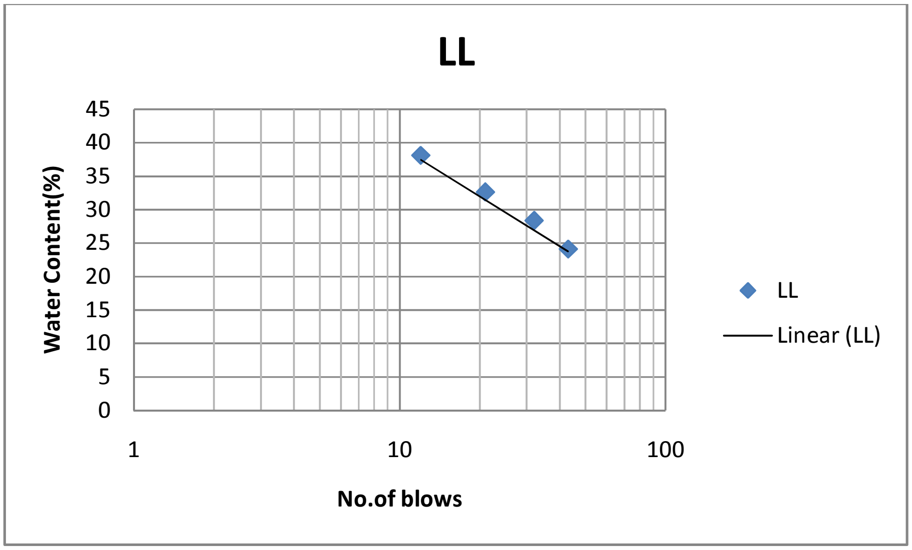


Fig 4.28 Liquid Limit Curve of M5

The Liquid Limit of M5 is 29.60 %.

The Plastic Limit of M5 is 25.46%.

P.I=4.14.

4.2.5.3 Results of Proctor Compaction Test

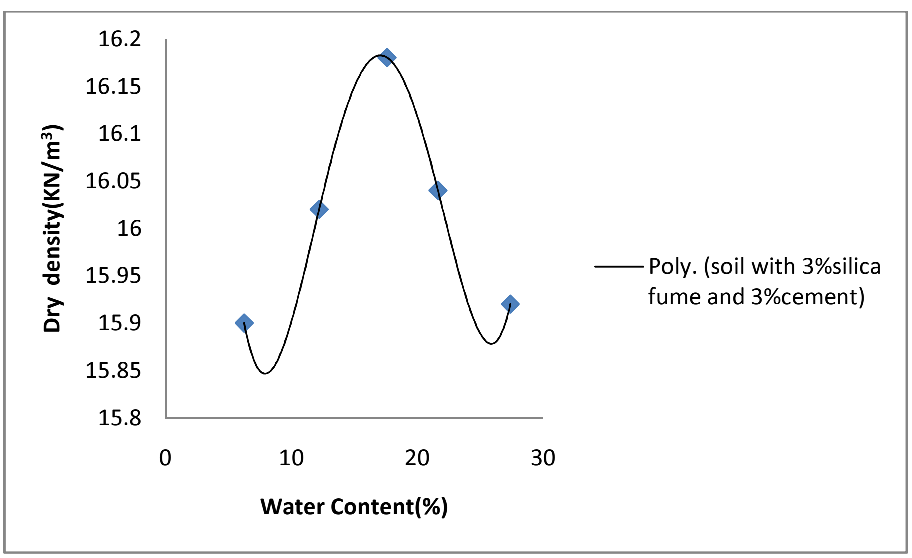


Fig 4.29 Relation between Dry density and Water Content of M5

O.M.C of M5 is 18.20%

M.D.D of M5 is 16.18 kN/m^3

4.2.5.4 Unconfined Compressive Strength (UCS)

After 1 days of curing

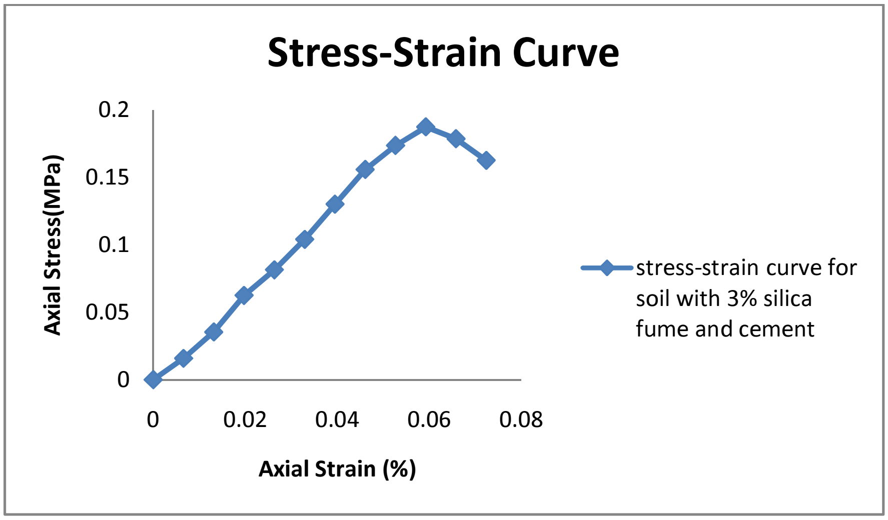


Fig 4.30 Stress strain curve of M5 after 1 day

The Unconfined Compressive Strength Value of M5 is 0.187MPa.

After 7 days of curing

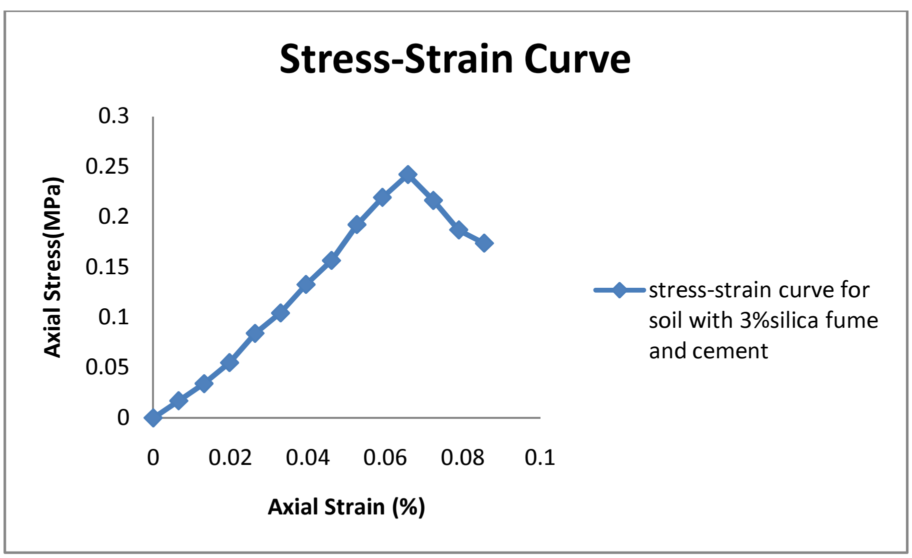


Fig 4.31 Stress strain curve of M5 after 7 day

The Unconfined Compressive Strength Value of M5 is 0.241MPa.

After 28 days of curing

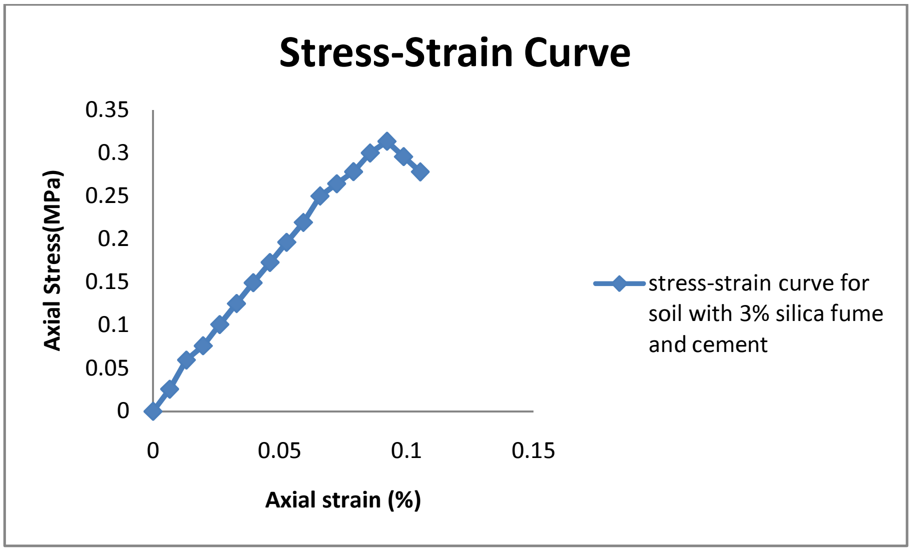


Fig 4.32 Stress strain curve of M5 after 28 day

The Unconfined Compressive Strength Value of M5 is 0.313MPa.

4.2.6 Engineering Properties of M6

4.2.6.1 Specific Gravity of M6 is 2.710

4.2.6.2 Consistency Limits

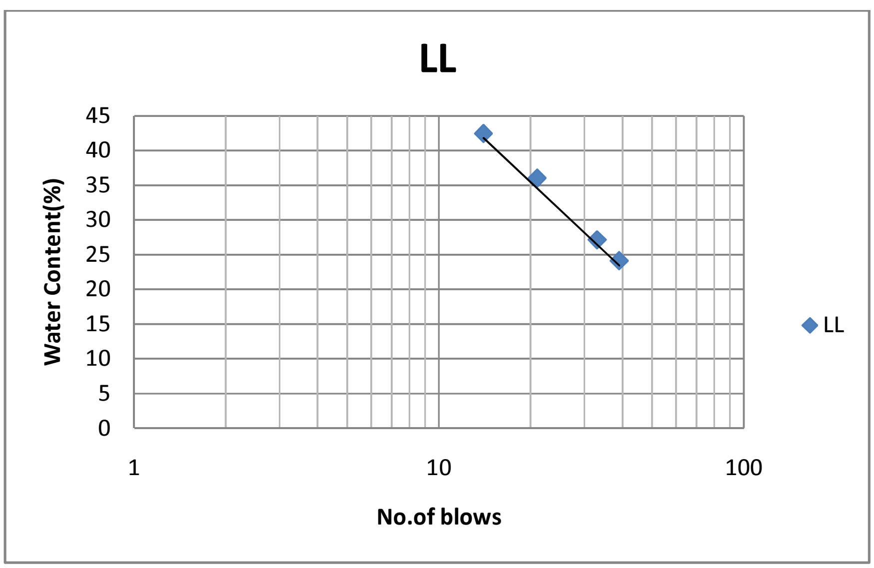


Fig 4.33 Liquid Limit Curve of M6

The Liquid Limit of M6 is 31.20 %.

The Plastic Limit of M6 is 27.10%.

P.I=4.1.

4.2.6.3 Results of Proctor Compaction Test

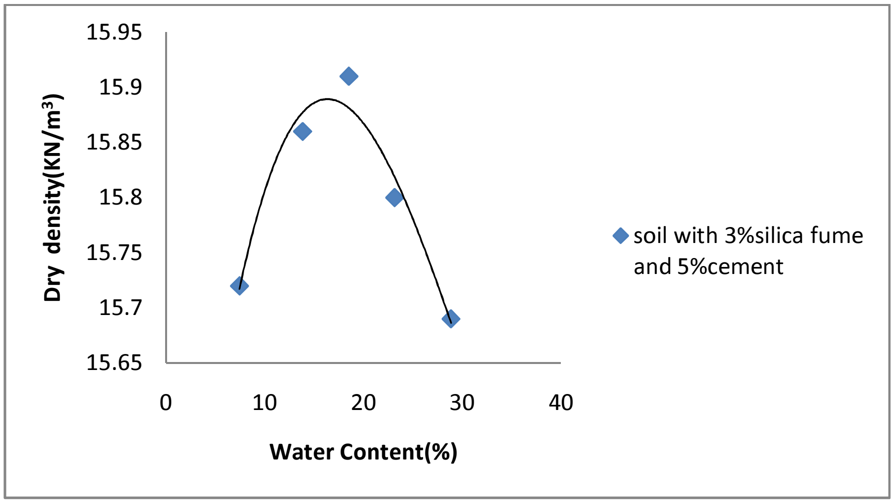


Fig 4.34 Relation between Dry density and Water Content of M6

O.M.C of M6 is 19.40%

M.D.D of M6 is 15.88kN/m^3

4.2.6.4 Unconfined Compressive Strength (UCS)

After 1 days of curing

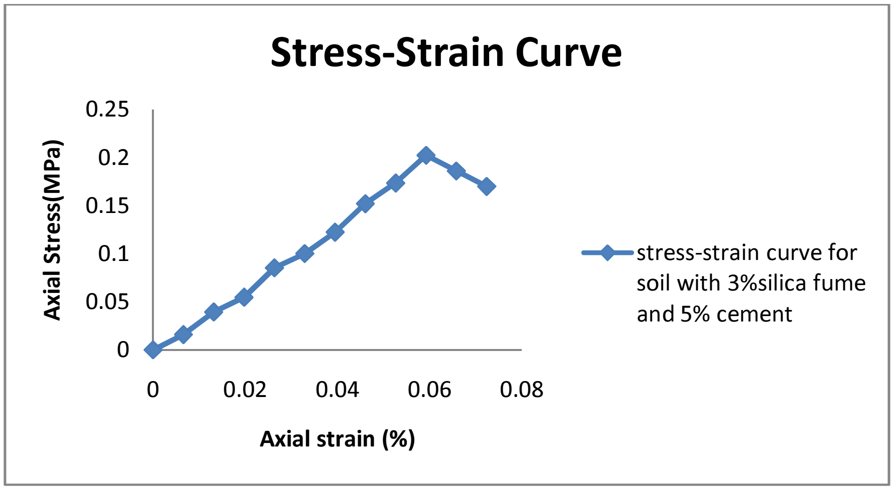


Fig 4.35 Stress strain curve of M6 after 1 day

The Unconfined Compressive Strength Value of M6 is 0.202MPa.

After 7 days of curing

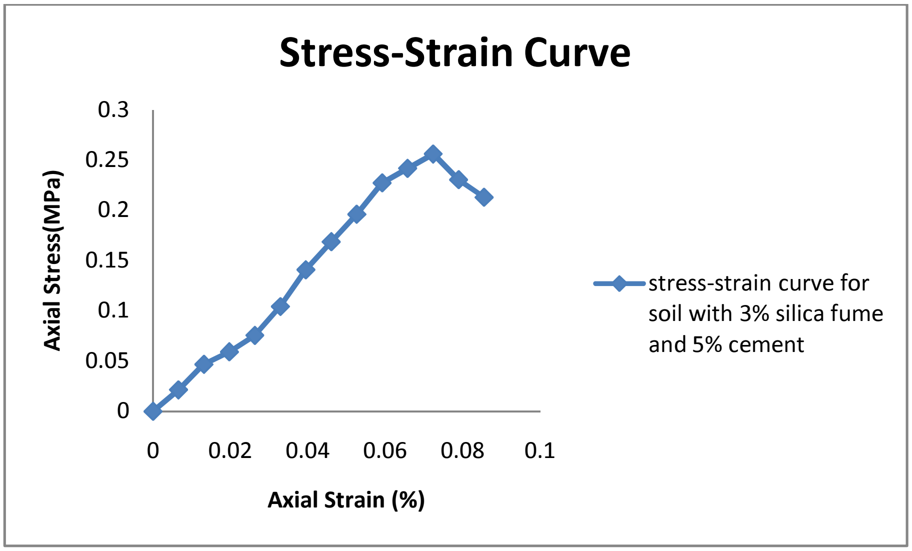


Fig 4.36 stress strain curve of M6 after 7 day

The unconfined Compressive strength value of M6 is 0.256MPa.

After 28 days of curing

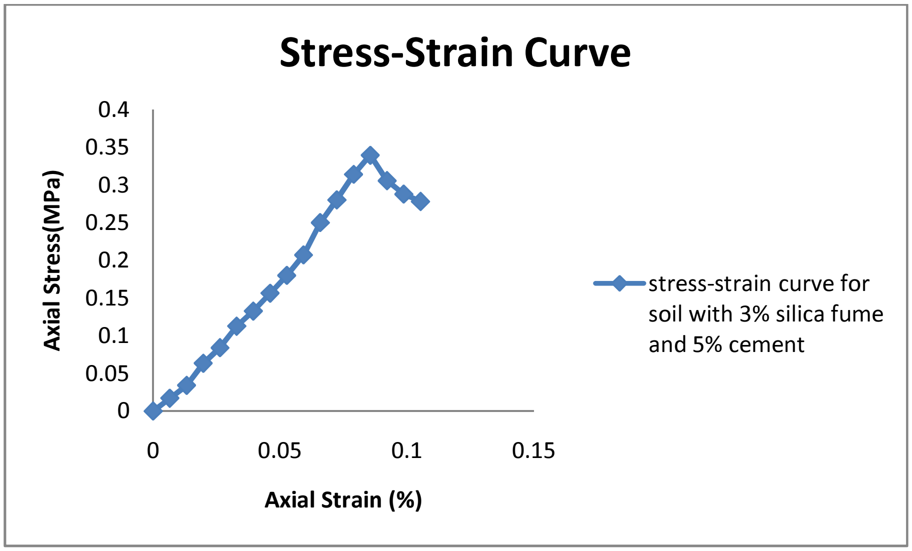


Fig 4.37 Stress strain curve of M6 after 28 day

The Unconfined Compressive Strength Value of M6 is 0.339MPa.

4.2.7 Engineering Properties of M7

4.2.7.1 Specific Gravity of M7 is 2.718

4.2.7.2 Consistency Limits

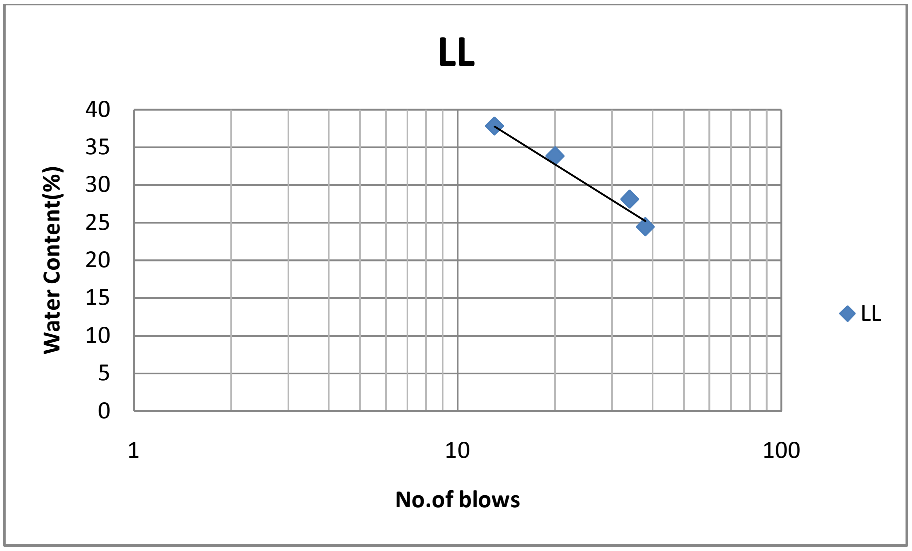


Fig 4.38 Liquid Limit Curve of M7

The Liquid Limit of M7 is 30.40 %.

The Plastic Limit of M7 is 26.34 %.

P.I=4.06.

4.2.7.3 Results of Proctor Compaction Test

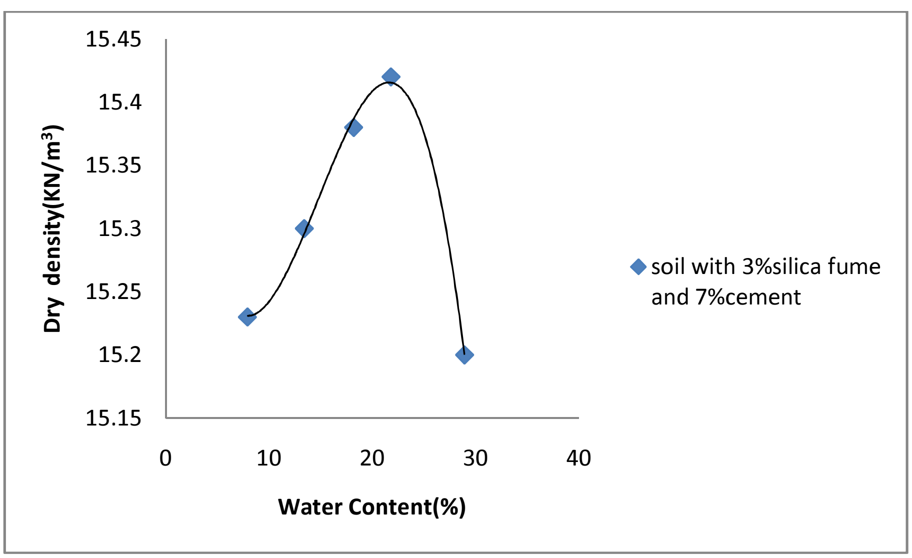


Fig 4.39 Relation between Dry density and Water Content of M7

O.M.C of M7 is 21.20%

M.D.D of M7 is 15.43kN/m^3

4.2.7.4 Unconfined Compressive Strength (UCS)

After 1 days of curing

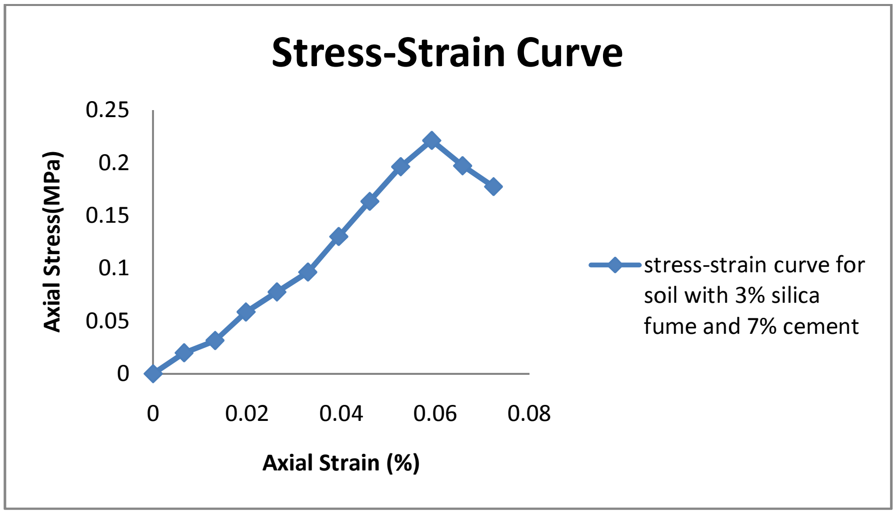


Fig 4.40 Stress strain curve of M7 after 1 day

The Unconfined Compressive Strength Value of M7 is 0.221MPa.

After 7 days of curing

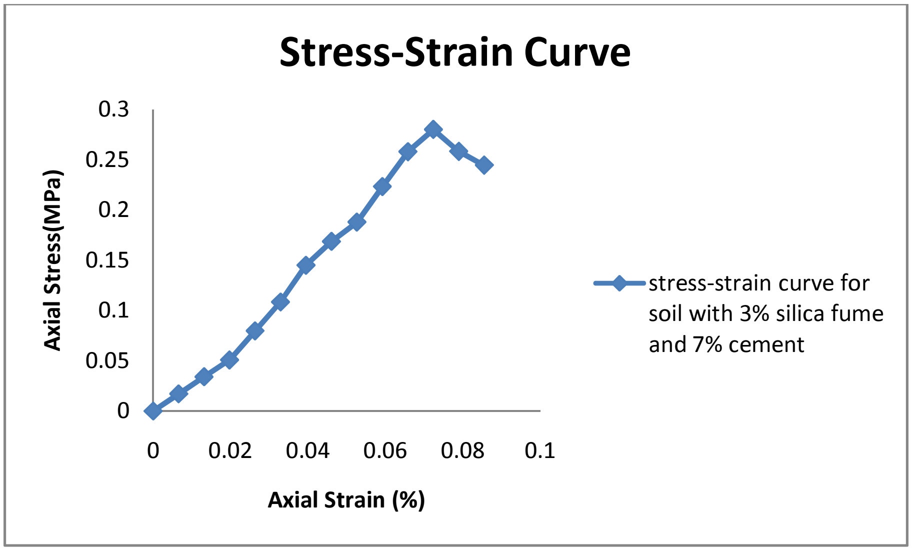


Fig 4.41 Stress strain curve of M7 after 7 day

The Unconfined Compressive Strength Value of M7 is 0.280MPa.

After 28 days of curing

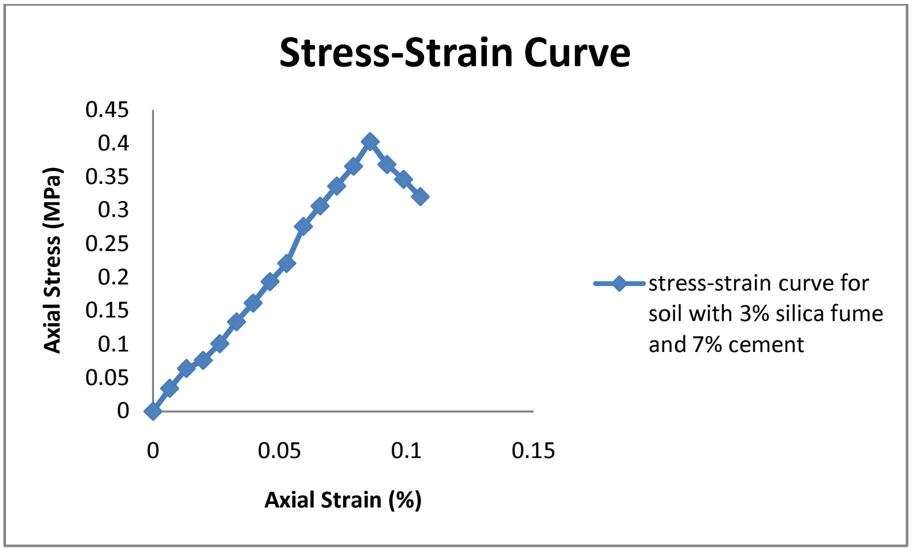


Fig 4.42 Stress strain curve of M7 after 28 day

The Unconfined Compressive Strength Value of M7 is 0.402MPa.

4.2.8 Engineering Properties of M8

4.2.8.1 Specific Gravity of M8 is 2.680

4.2.8.2 Consistency Limits

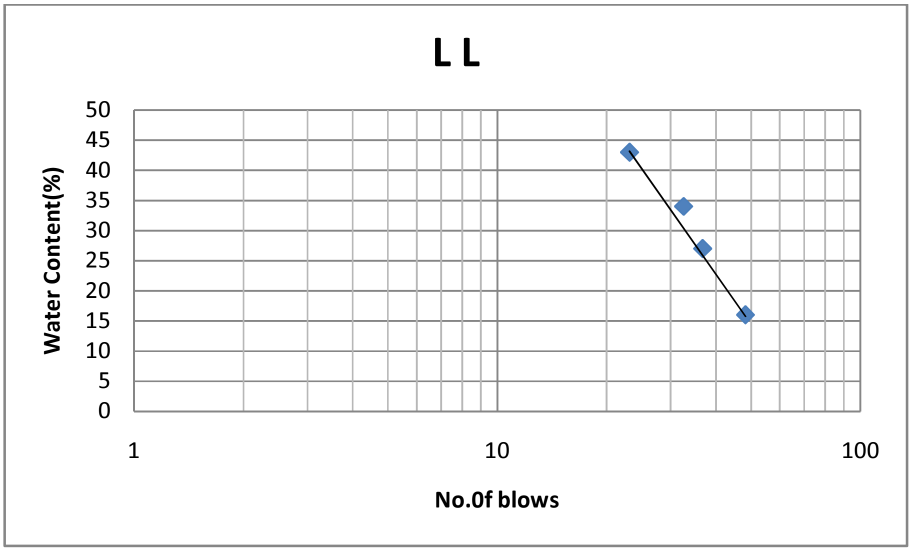


Fig 4.43 Liquid Limit Curve of M8

The Liquid Limit of M8 is 30.10 %.

The Plastic Limit of M8 is 25.63%.

P.I=4.47.

4.2.8.3 Results of Proctor Compaction Test

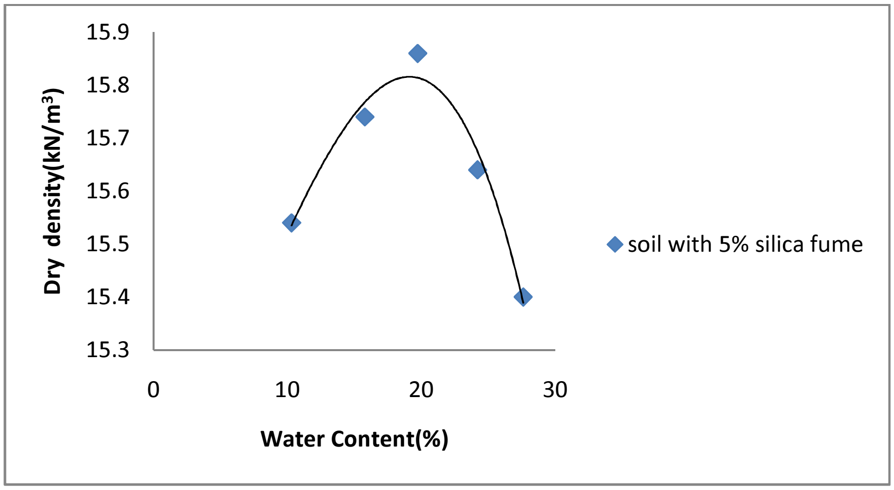


Fig 4.44 Relation between Dry density and Water Content of M8

O.M.C of M8 is 20.20%

M.D.D of M8 is 15.82kN/m^3

4.2.8.4 Unconfined Compressive Strength (UCS)

After 1 days of curing

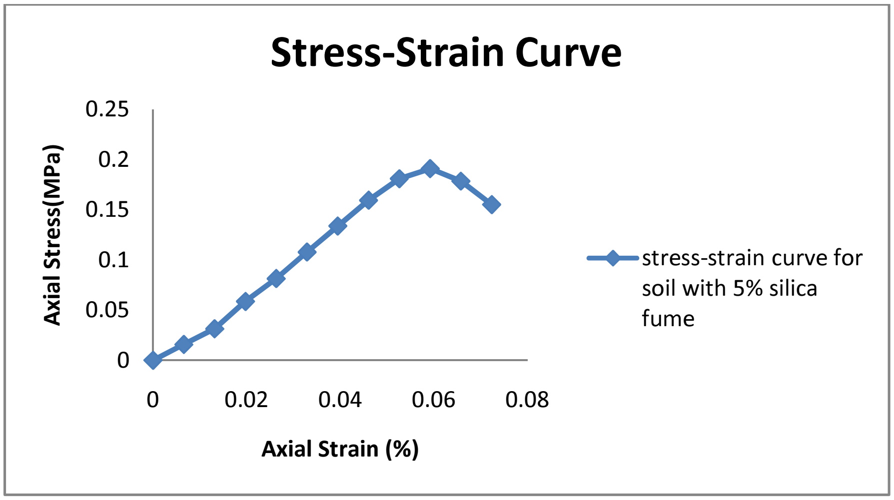


Fig 4.45 Stress strain curve of M8 after 1 day

The Unconfined Compressive Strength Value of M8 is 0.191MPa.

After 7 days of curing

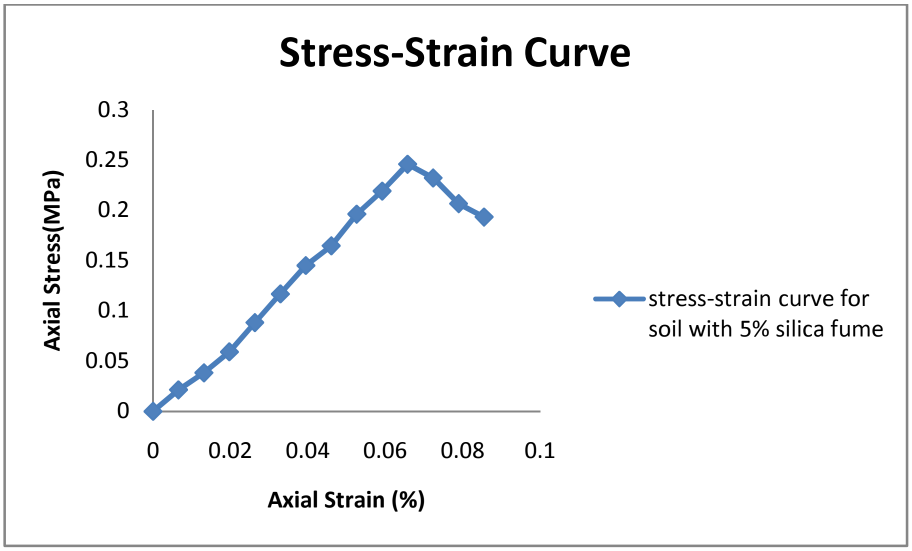


Fig 4.46 Stress strain curve of M8 after 7 day

The Unconfined Compressive Strength Value of M8 is 0.245MPa.

After 28 days of curing

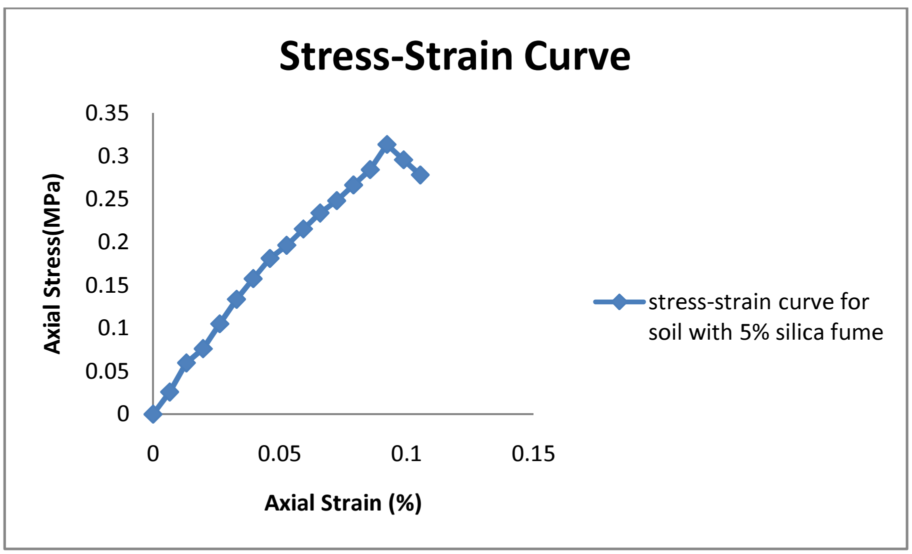


Fig 4.47 Stress strain curve of M8 after 28 day

The Unconfined Compressive Strength Value of M8 is 0.313MPa.

4.2.9 Engineering Properties of M9

4.2.9.1 Specific Gravity of M9 is 2.689

4.2.9.2 Consistency Limits

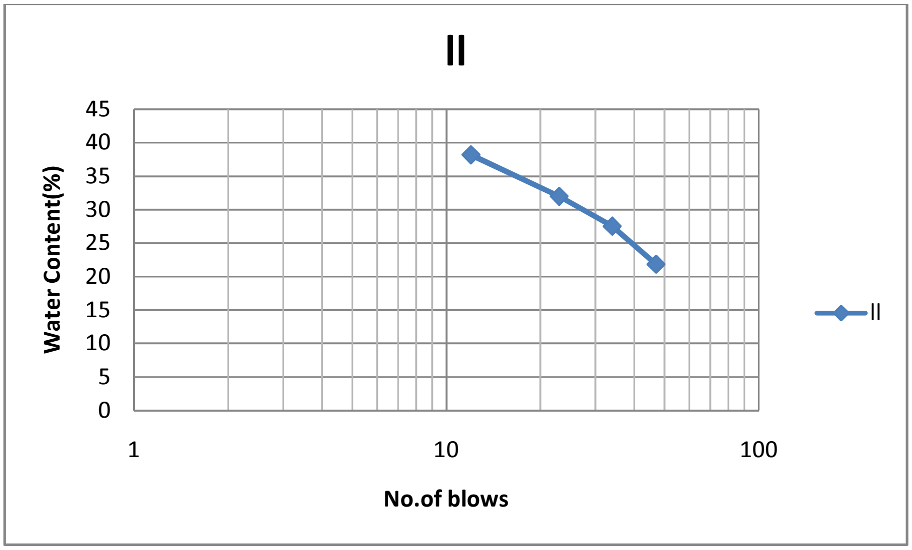


Fig 4.48 Liquid Limit Curve of M9

The Liquid Limit of M9 is 31.80 %.

The Plastic Limit of M9 is 27.14 %.

P.I=4.66.

4.2.9.3 Results of Proctor Compaction Test

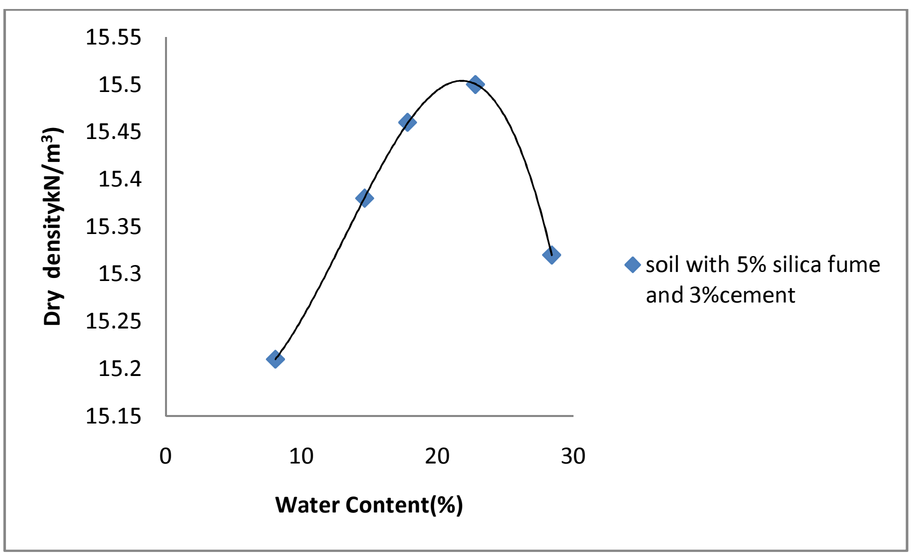


Fig 4.49 Relation between Dry density and Water Content of M9

O.M.C of M9 is 21.40%

M.D.D of M9 is 15.5 kN/m^3

4.2.9.4 Unconfined Compressive Strength (UCS)

After 1 days of curing

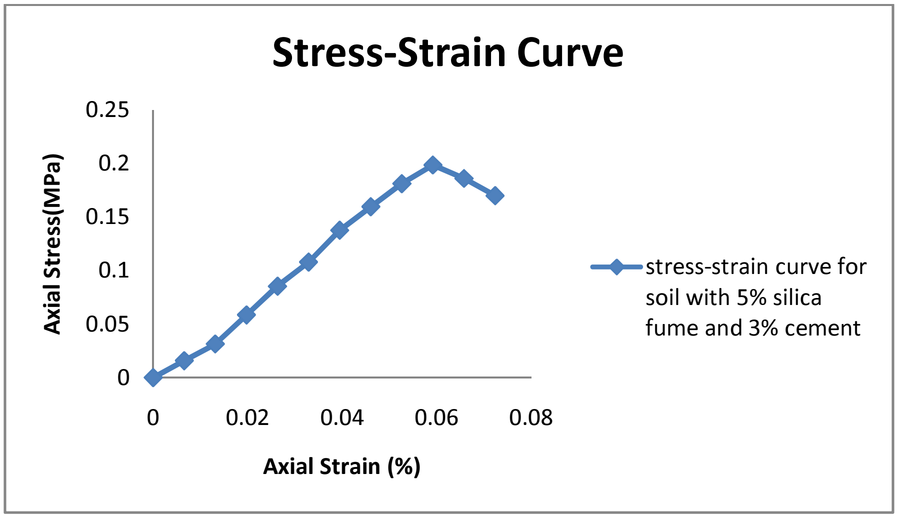


Fig 4.50 Stress strain curve of M9 after 1 day

The Unconfined Compressive Strength Value of M9 is 0.198MPa.

After 7 days of curing

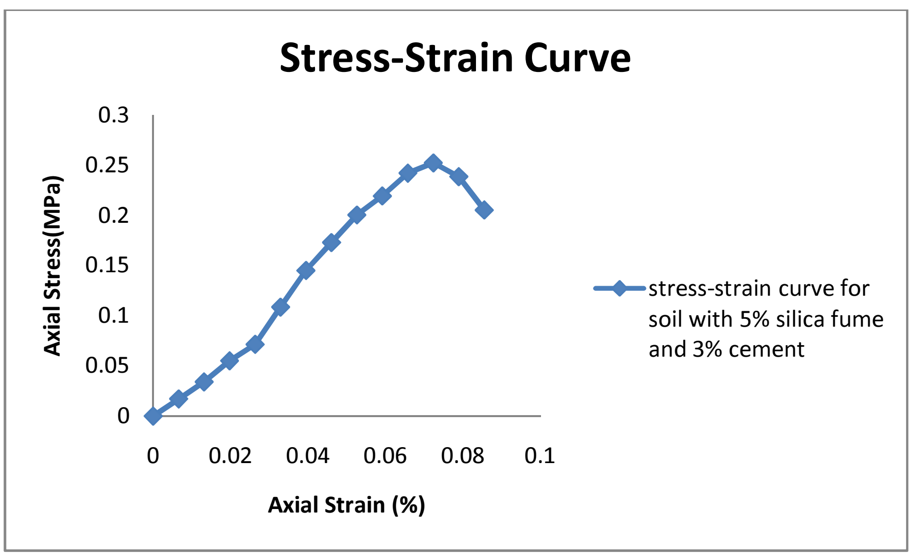


Fig 4.51 Stress strain curve of M9 after 7 day

The Unconfined Compressive Strength Value of M9 is 0.252MPa.

After 28 days of curing

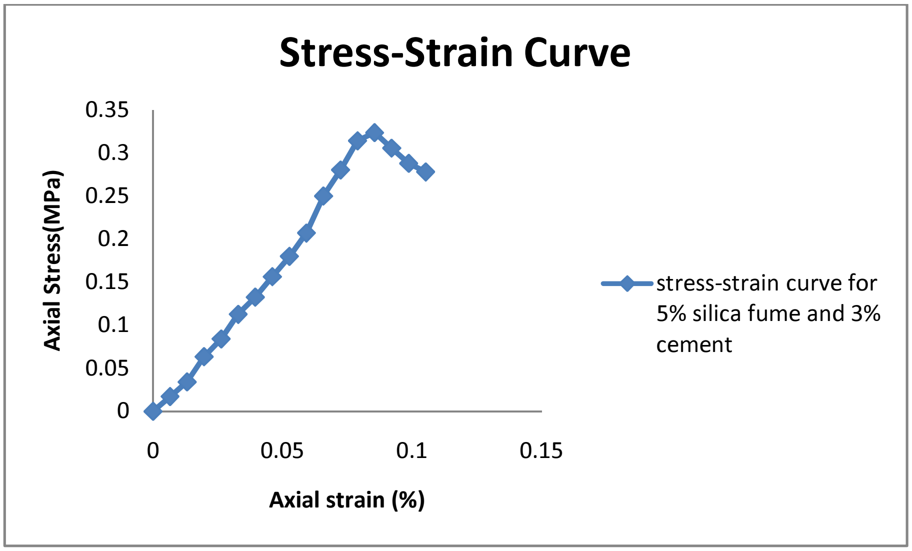


Fig 4.52 Stress strain curve of M9 after 28 day

The Unconfined Compressive Strength Value of M9 is 0.323MPa.

4.2.10 Engineering Properties of M10

4.2.10.1 Specific Gravity of M10 is 2.698

4.2.10.2 Consistency Limits

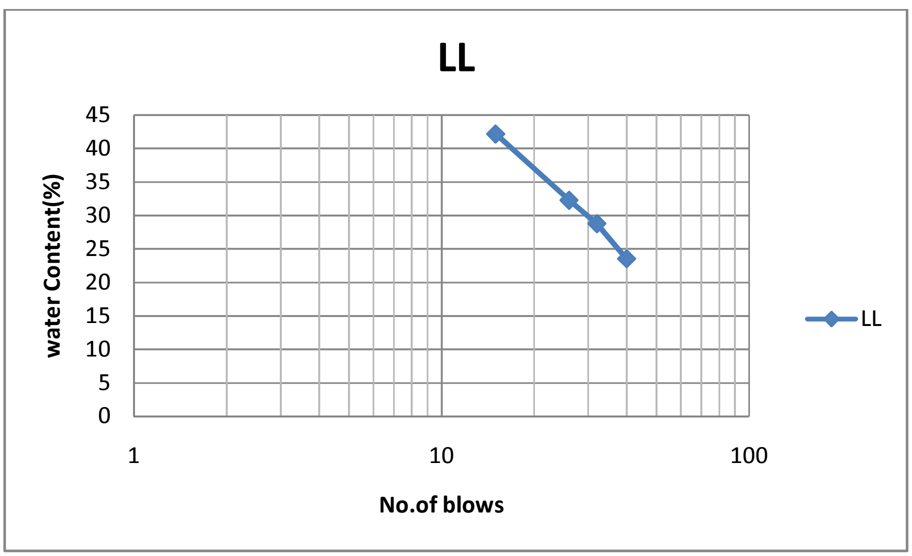


Fig 4.53 Liquid Limit Curve of M10

The Liquid Limit of M10 is 33.20 %.

The Plastic Limit of M10 is 29.02%.

P.I=4.18.

4.2.10.3 Results of Proctor Compaction Test

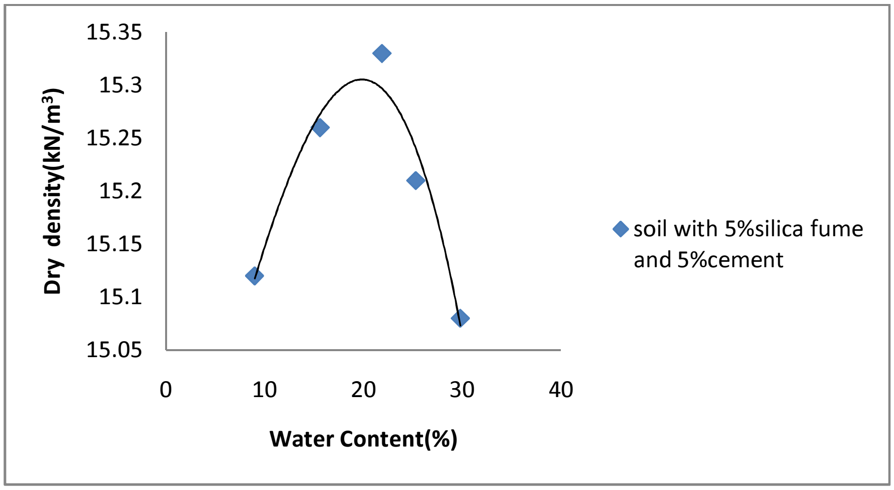


Fig 4.54 Relation between Dry density and Water Content of M10

O.M.C of M10 is 22.20%

M.D.D of M10 is 15.31kN/m^3

4.2.10.4 Unconfined Compressive Strength (UCS)

After 1 days of curing

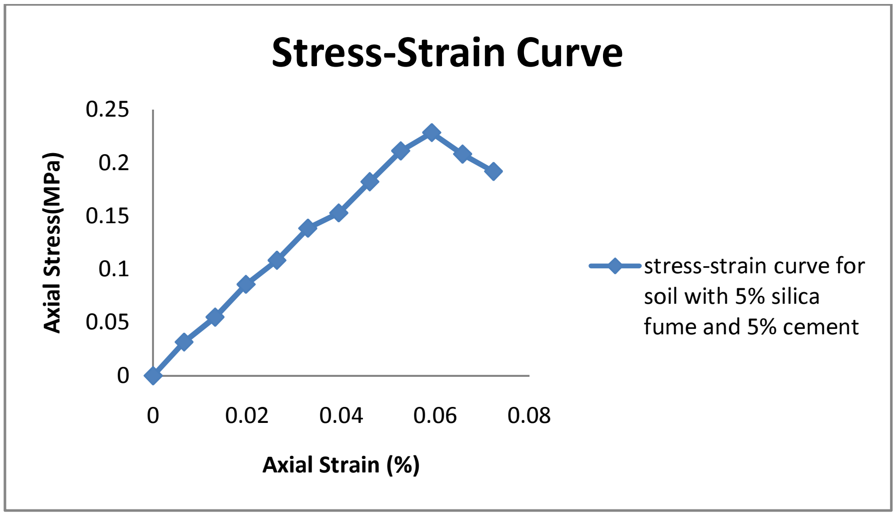


Fig 4.55 Stress strain curve of M10 after 1 day

The Unconfined Compressive Strength Value of M10 is 0.228MPa.

After 7 days of curing

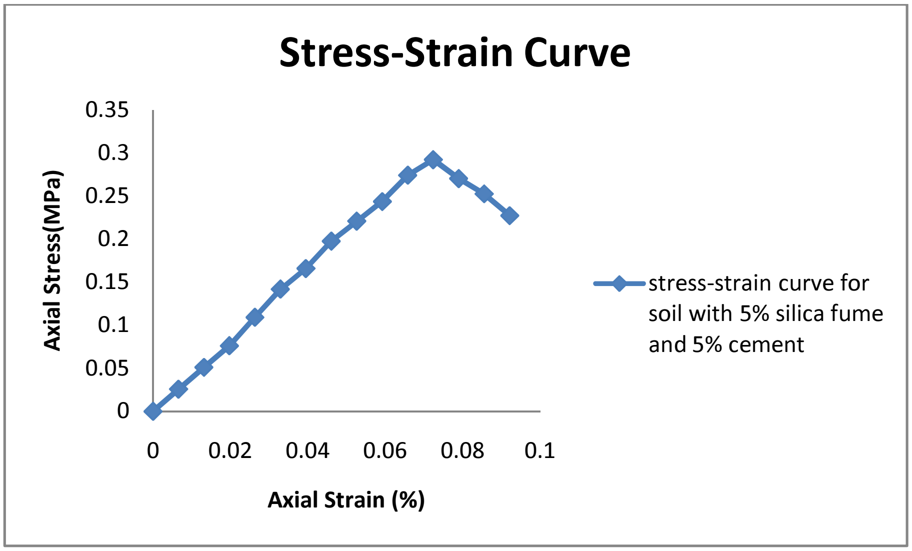


Fig 4.56 Stress strain curve of M10 after 7 day

The Unconfined Compressive Strength Value of M10 is 0.292MPa.

After 28 days of curing

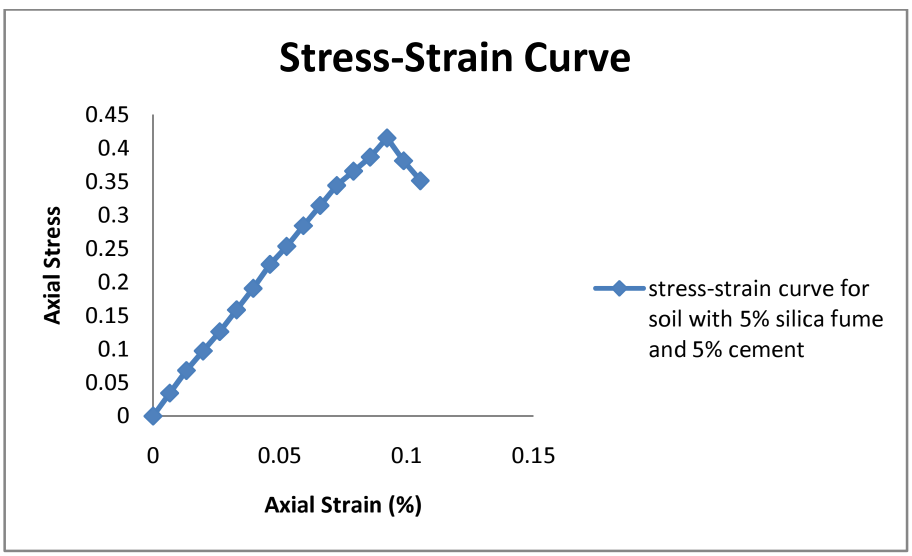


Fig 4.57 Stress strain curve of M10 after 28 day

The Unconfined Compressive Strength Value of M10 is 0.415MPa.

4.2.11 Engineering Properties of M11

4.2.11.1 Specific Gravity of M11 is 2.706

4.2.11.2 Consistency Limits

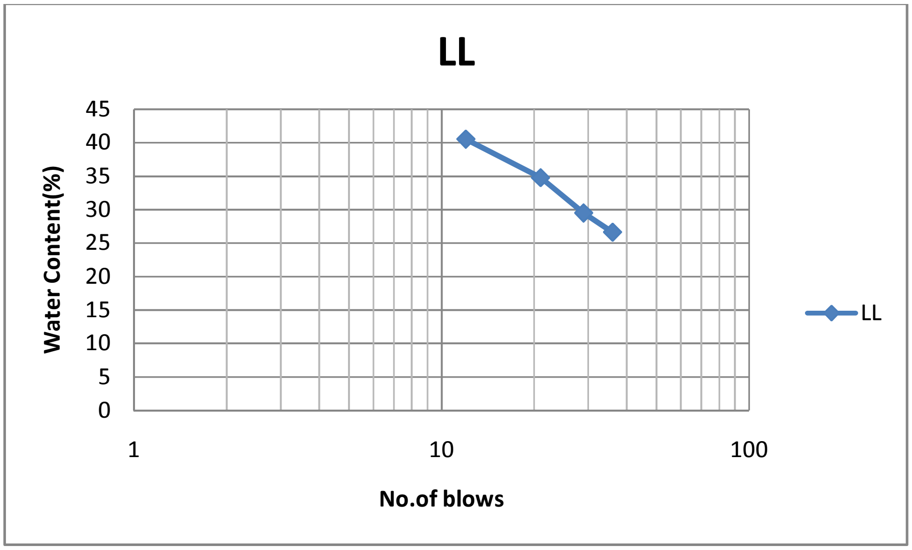


Fig 4.58 Liquid Limit Curve of M11

The Liquid Limit of M11 is 32.40 %.

The Plastic Limit of M11 is 28.3%.

P.I=4.1.

4.2.11.3 Results of Proctor Compaction Test

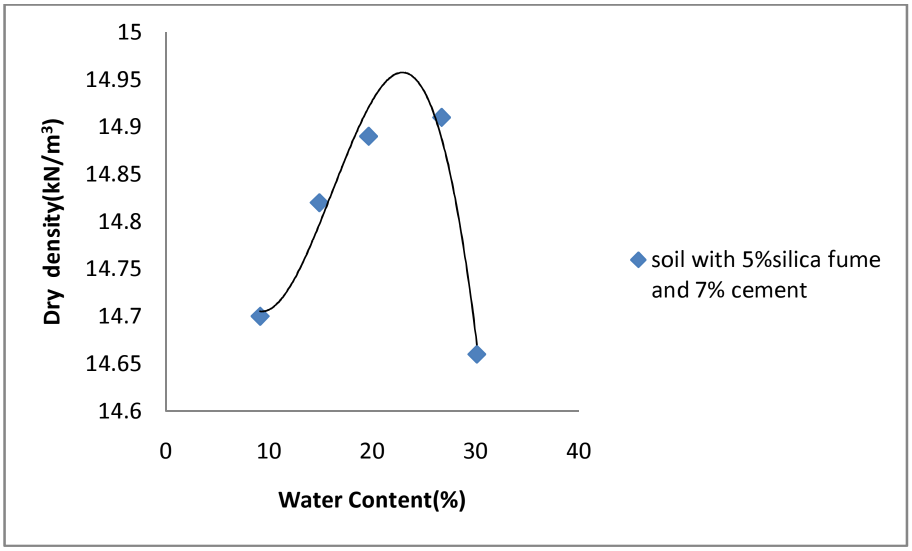


Fig 4.59 Relation between Dry density and Water Content of M11

O.M.C of M11 is 24.80%

M.D.D of M11 is 14.95 kN/m^3

4.2.11.4 Unconfined Compressive Strength (UCS)

After 1 days of curing

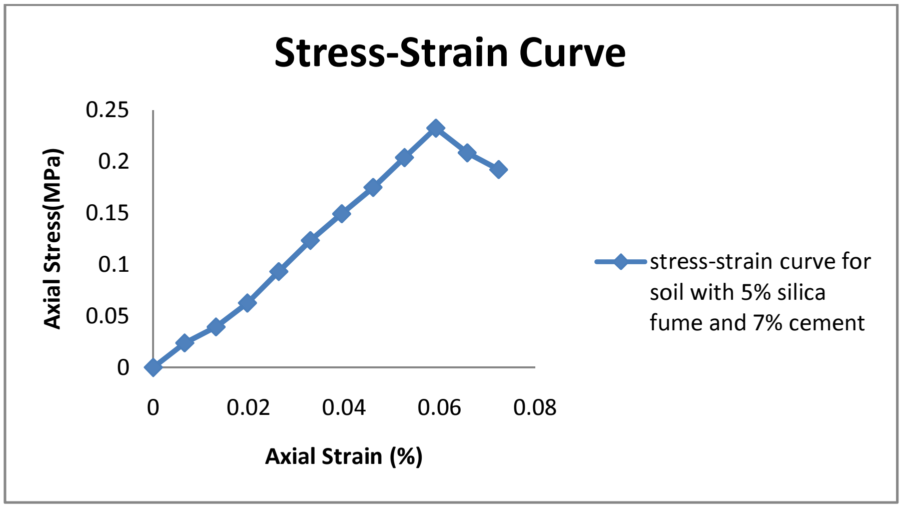


Fig 4.60 Stress strain curve of M11 after 1 day

The Unconfined Compressive Strength Value of M11 is 0.232MPa.

After 7 days of curing

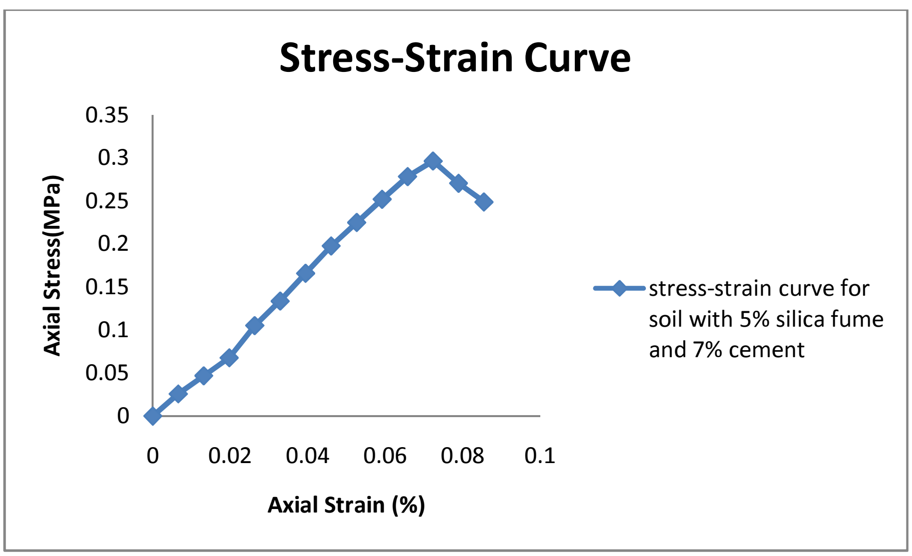


Fig 4.61 Stress strain curve of M11 after 7 day

The Unconfined Compressive Strength Value of M11 is 0.296MPa.

After 28 days of curing

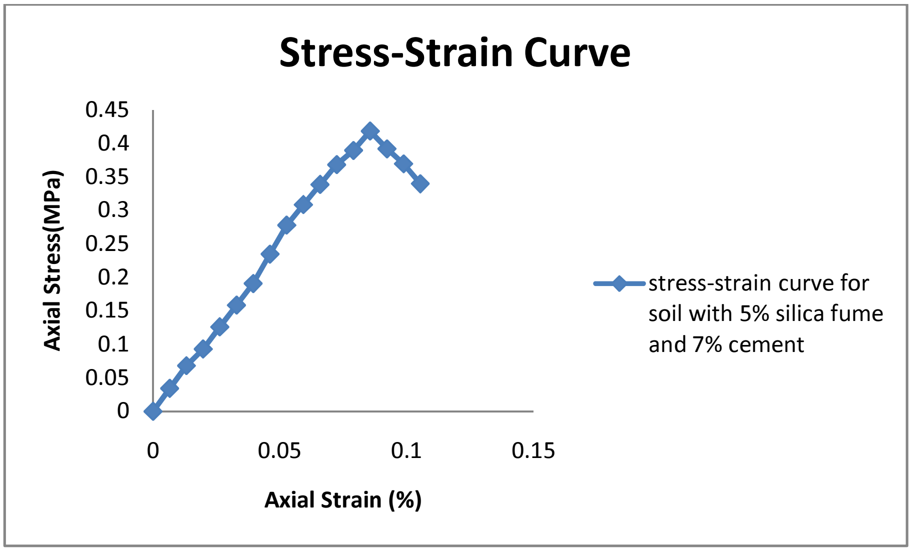


Fig 4.62 Stress strain curve of M11 after 28 day

The Unconfined Compressive Strength Value of M11 is 0.418MPa.

4.2.12Engineering Properties of M12

4.2.12.1 Specific Gravity of M12 is 2.668

4.2.12.2 Consistency Limits

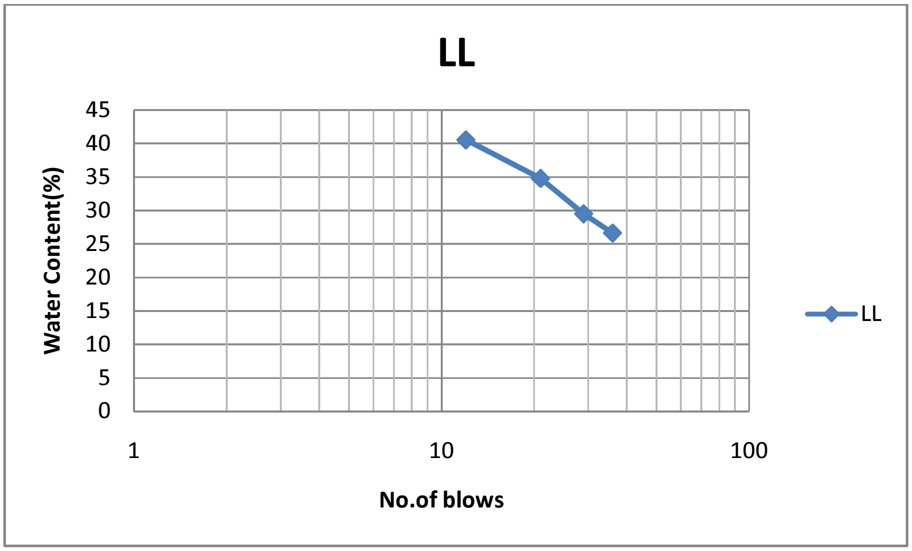


Fig 4.63 Liquid Limit Curve of M12

The Liquid Limit of M12 is 32.20 %.

The Plastic Limit of M12 is 27.32%.

P.I=4.88.

4.2.12.3 Results of Proctor Compaction Test

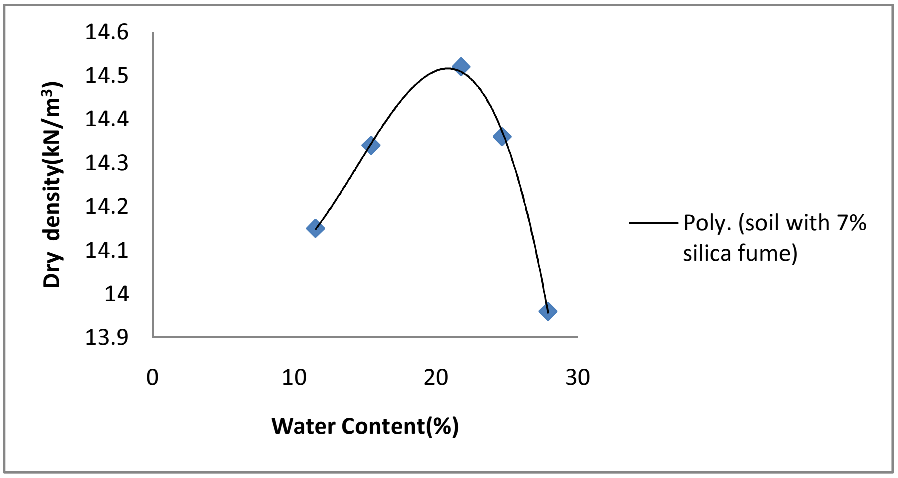


Fig 4.64 Relation between Dry density and Water Content of M12

O.M.C of M12 is 21.60%

M.D.D of M12 is 14.51kN/m^3

4.2.12.4 Unconfined Compressive Strength (UCS)

After 1 days of curing

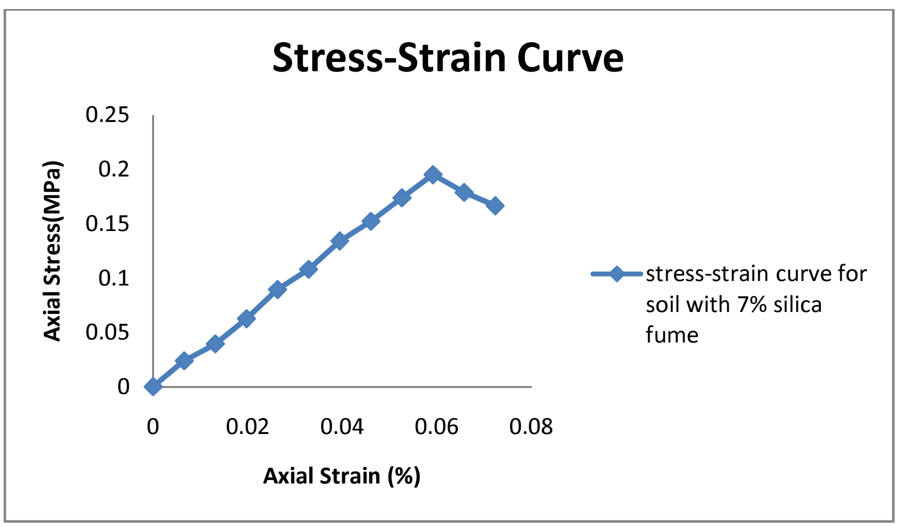


Fig 4.65 Stress strain curve of M12 after 1 day

The Unconfined Compressive Strength Value of M12 is 0.194MPa.

After 7 days of curing

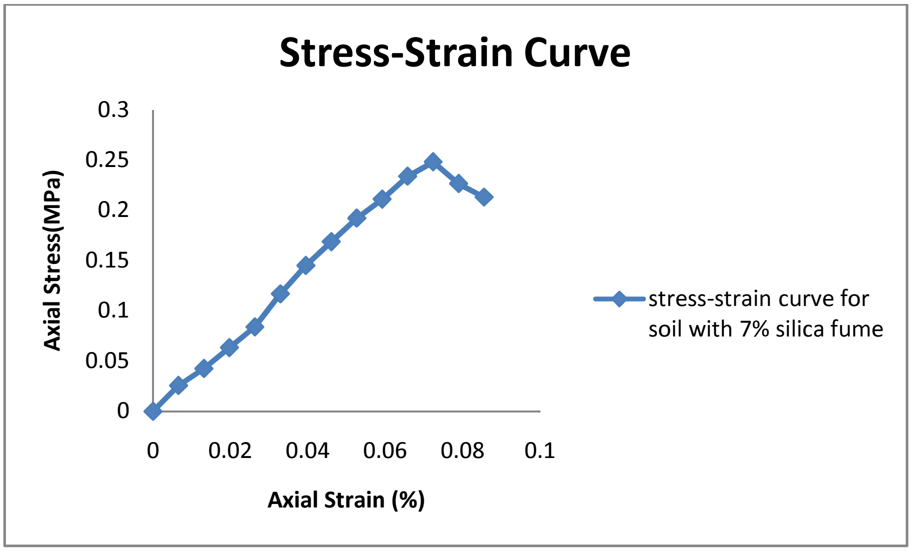


Fig 4.66 Stress strain curve of M12 after 7 day

The Unconfined Compressive Strength Value of M12 is 0.248MPa.

After 28 days of curing

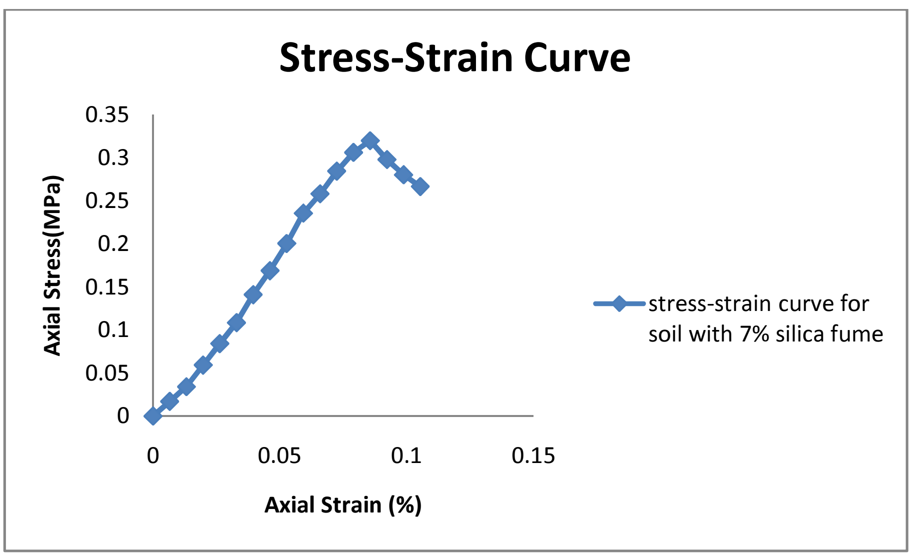


Fig 4.67 Stress strain curve of M12 after 28 day

The Unconfined Compressive Strength Value of M12 is 0.319MPa.

4.2.13 Engineering Properties of M13

4.2.13.1 Specific Gravity of M13 is 2.691

4.2.13.2 Consistency Limits

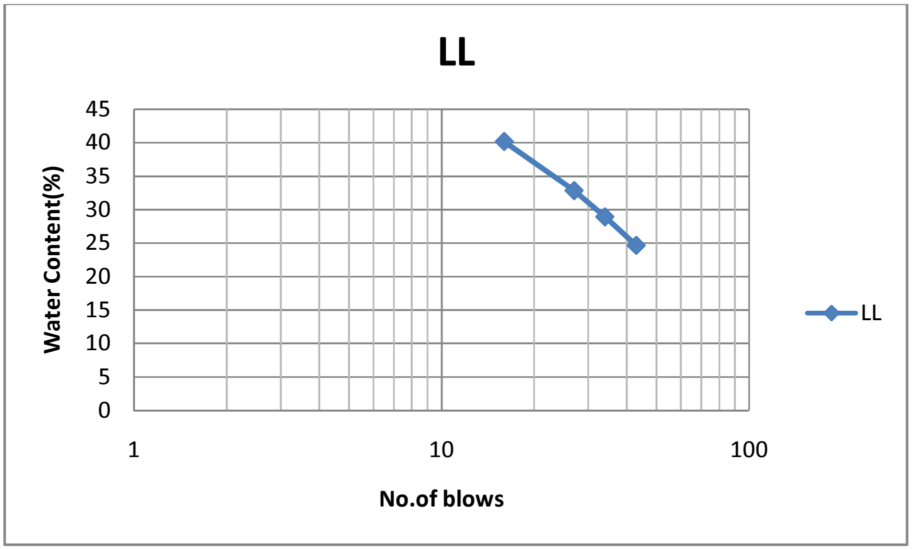


Fig 4.68 Liquid Limit Curve of M13

The Liquid Limit of M13 is 34.10 %.

The Plastic Limit of M13 is 29.06%.

P.I=5.04.

4.2.13.3 Results of Proctor Compaction Test

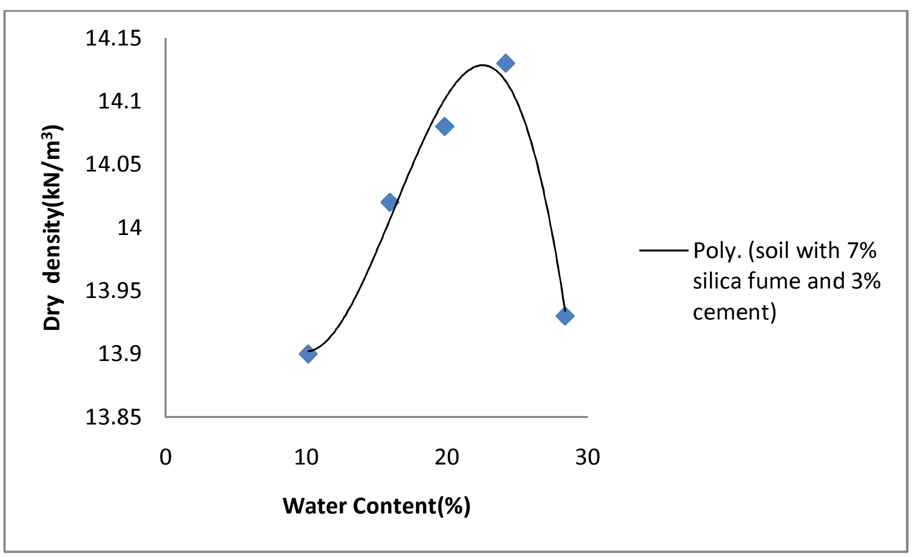


Fig 4.69 Relation between Dry density and Water Content of M13

O.M.C of M13 is 23.20%

M.D.D of M13 is 14.13kN/m^3

4.2.13.4 Unconfined Compressive Strength (UCS)

After 1 days of curing

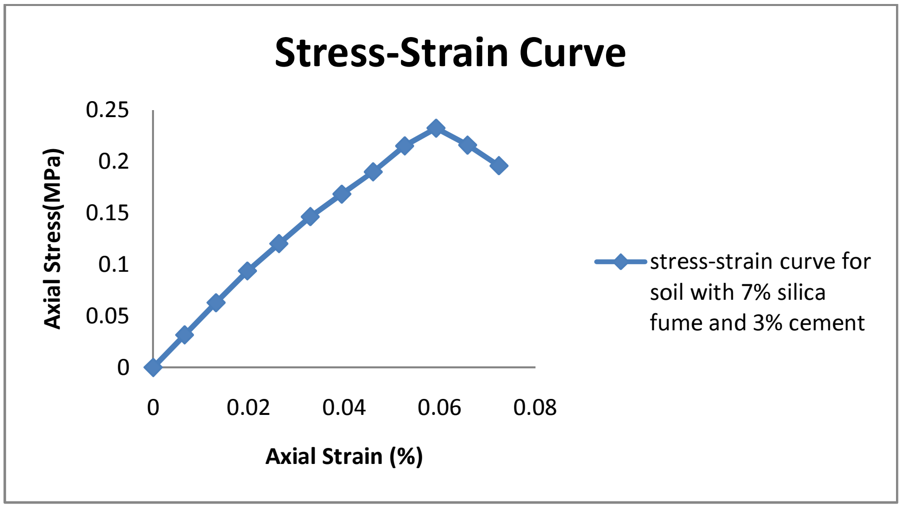


Fig 4.70 Stress strain curve of M13 after 1 day

The Unconfined Compressive Strength Value of M13 is 0.232MPa.

After 7 days of curing

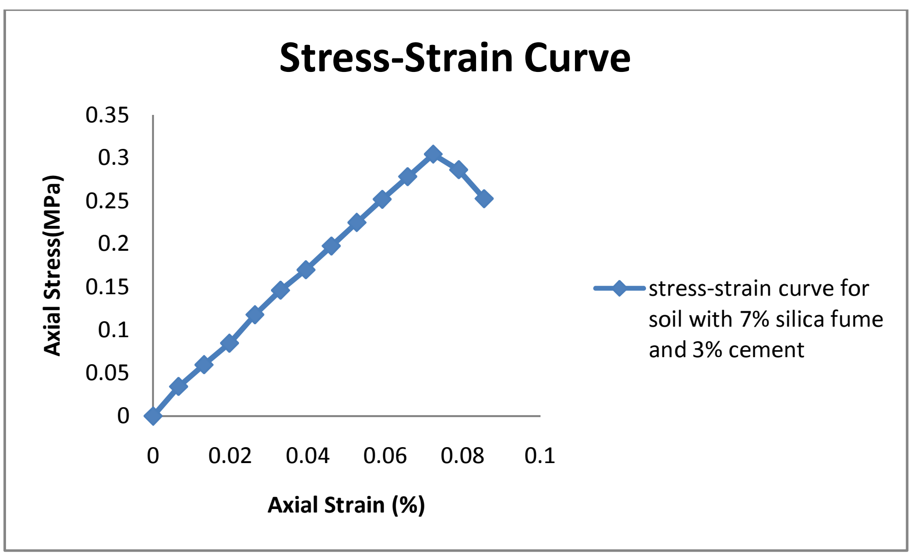


Fig 4.71 Stress strain curve of M13 after 7 day

The Unconfined Compressive Strength Value of M13 is 0.304MPa.

After 28 days of curing

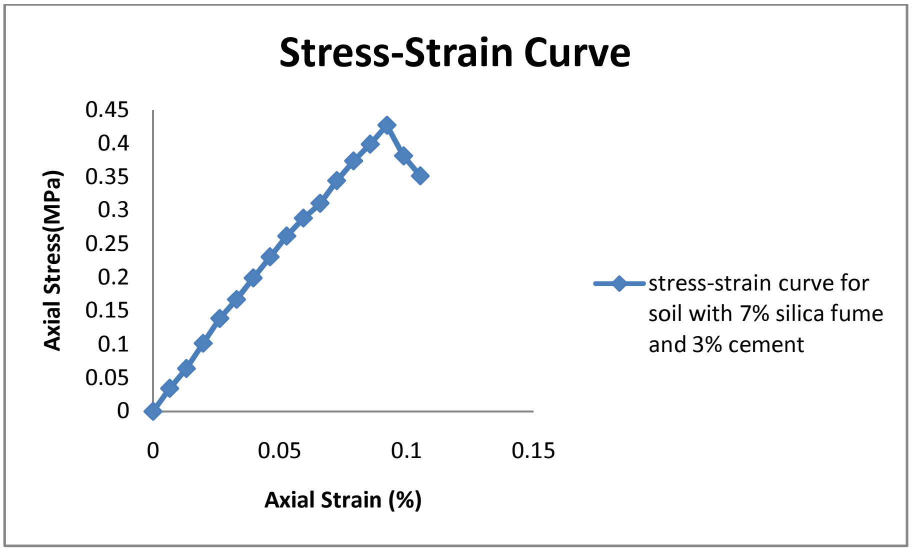


Fig 4.72 Stress strain curve of M13 after 28 day

The Unconfined Compressive Strength Value of M13 is 0.427MPa.

4.2.14 Engineering Properties of M14

4.2.14.1 Specific Gravity of M14 is 2.687

4.2.14.2 Consistency Limits

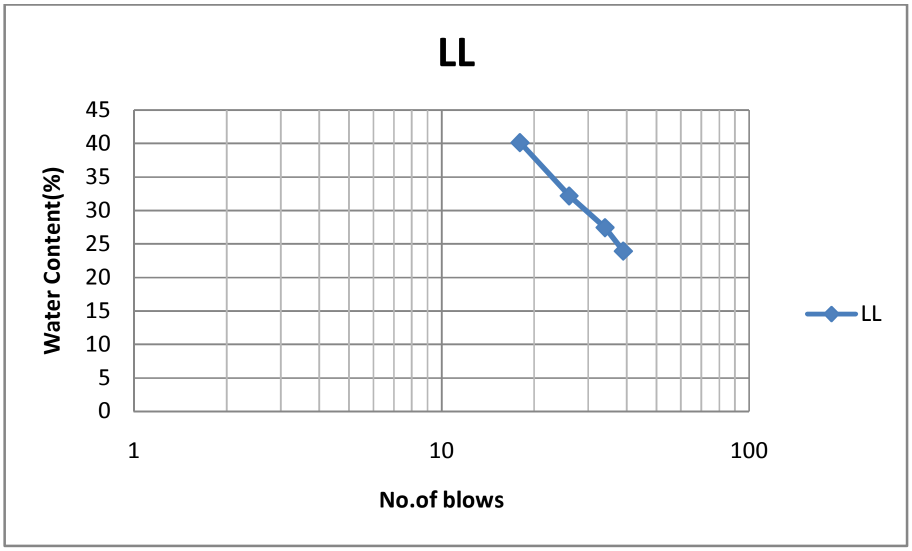


Fig 4.73 Liquid Limit Curve of M14

The Liquid Limit of M14 is 33.60 %.

The Plastic Limit of M14 is 28.61%.

P.I=4.99.

4.2.14.3 Results of Proctor Compaction Test

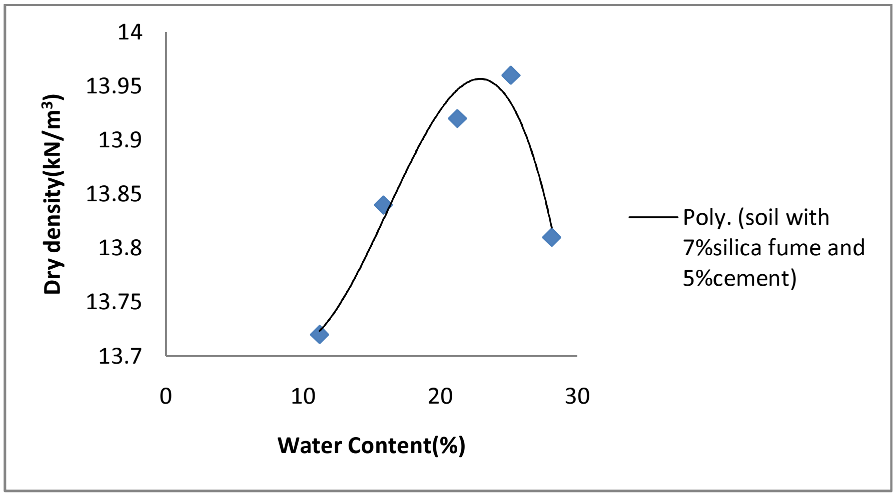


Fig 4.74 Relation between Dry density and Water Content of M14

O.M.C of M14 is 24.80%

M.D.D of M14 is 13.96kN/m^3

4.2.14.4 Unconfined Compressive Strength (UCS)

After 1 days of curing

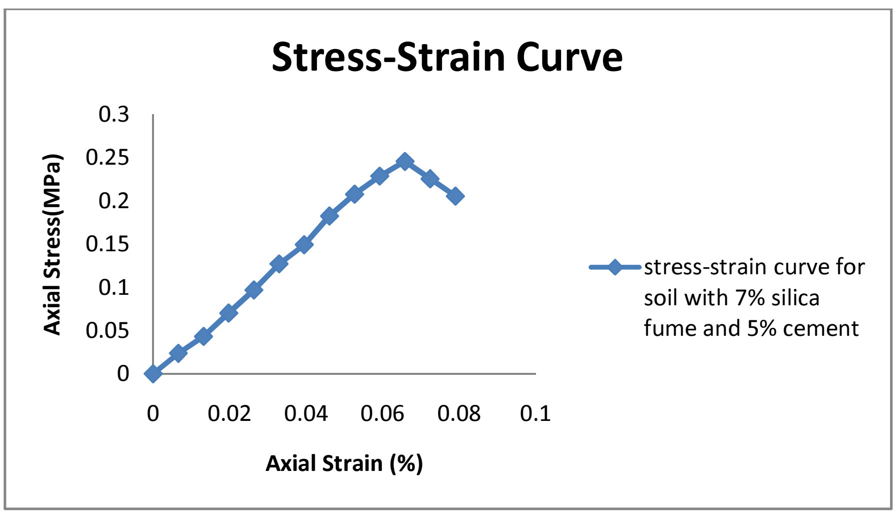


Fig 4.75 Stress strain curve of M14 after 1 day

The Unconfined Compressive Strength Value of M14 is 0.245MPa.

After 7 days of curing

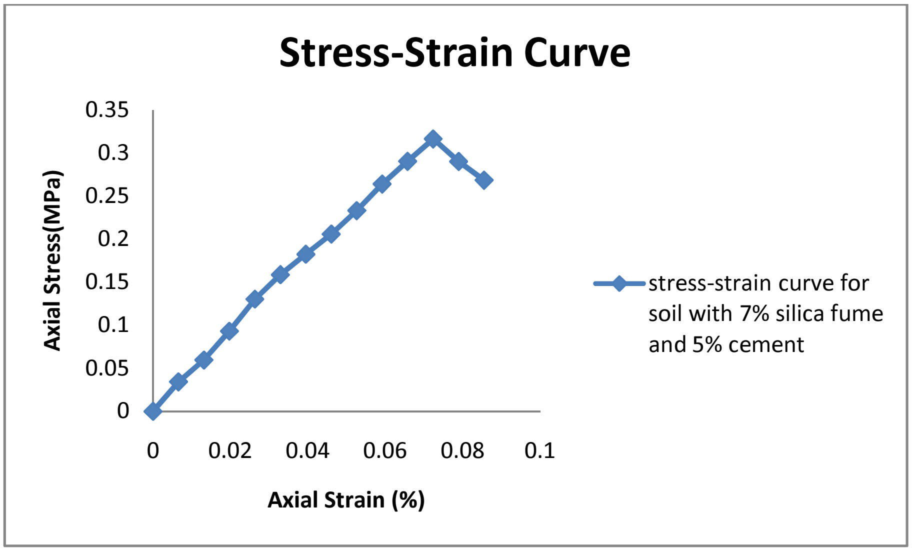


Fig 4.76 stress strain curve of M14 after 7 day

The Unconfined Compressive Strength value of M14 is 0.316MPa.

After 28 days of curing

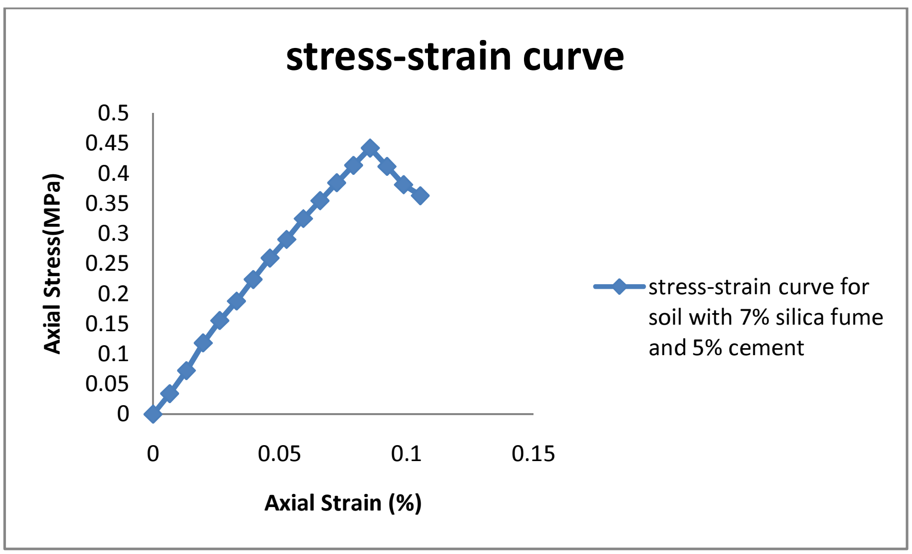


Fig 4.77 Stress strain curve of M14 after 28 day

The Unconfined Compressive Strength Value of M14 is 0.442MPa.

4.2.15 Engineering Properties of M15

4.2.15.1 Specific Gravity of M15 is 2.694

4.2.15.2 Consistency Limits

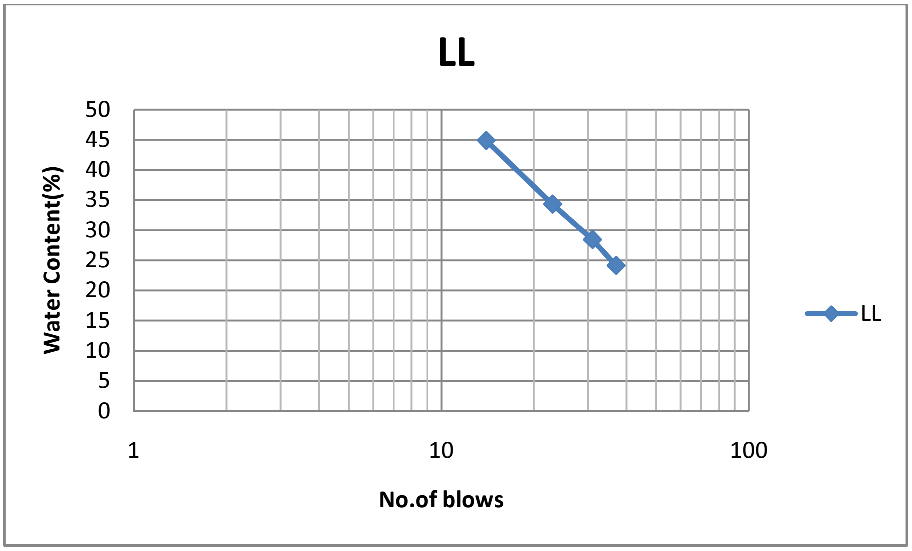


Fig 4.78 Liquid Limit Curve of M15

The Liquid Limit of M15 is 32.40 %.

The Plastic Limit of M15 is 27.86%.

P.I=4.54.

4.2.15.3 Results of Proctor Compaction Test

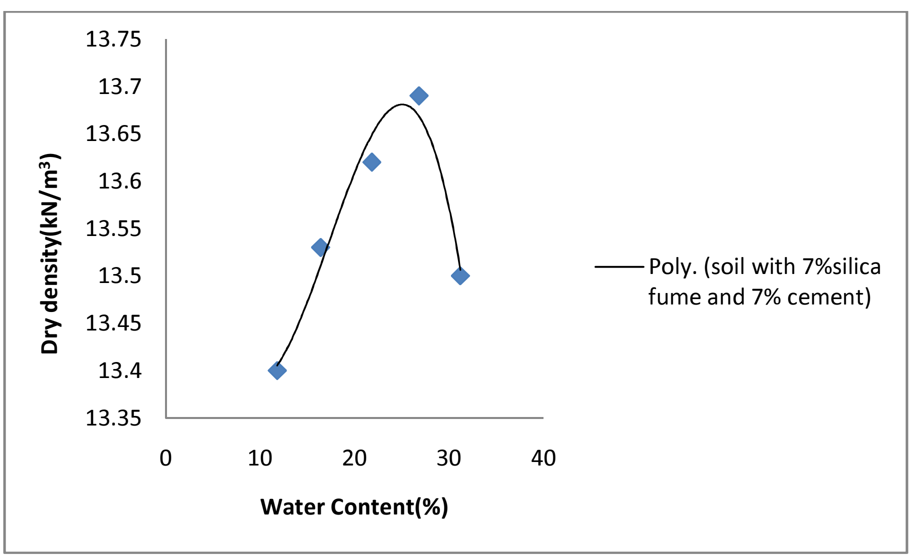


Fig 4.79 Relation between Dry density and Water Content of M15

O.M.C of M15 is 26.20%

M.D.D of M15 is 13.68 kN/m^3

4.2.15.4 Unconfined Compressive Strength (UCS)

After 1 days of curing

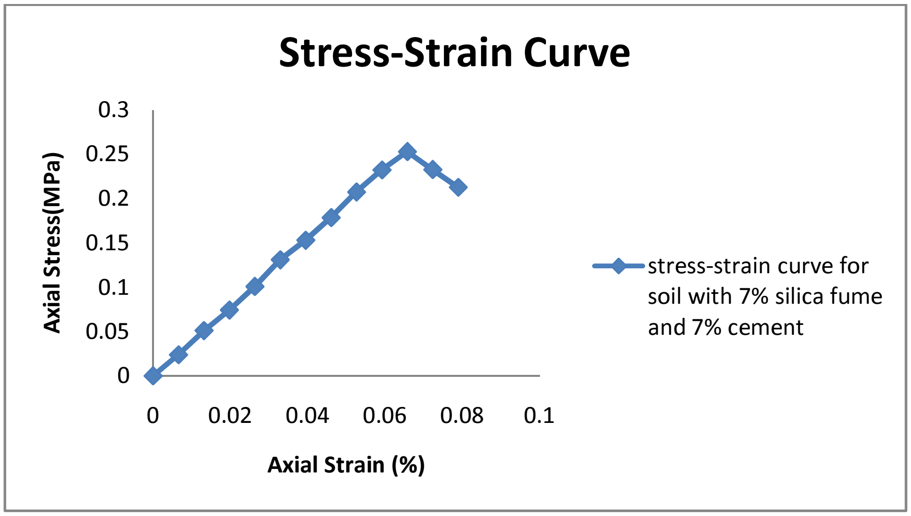


Fig 4.80 Stress strain curve of M15 after 1 day

The Unconfined Compressive Strength Value of M15 is 0.252MPa.

After 7 days of curing

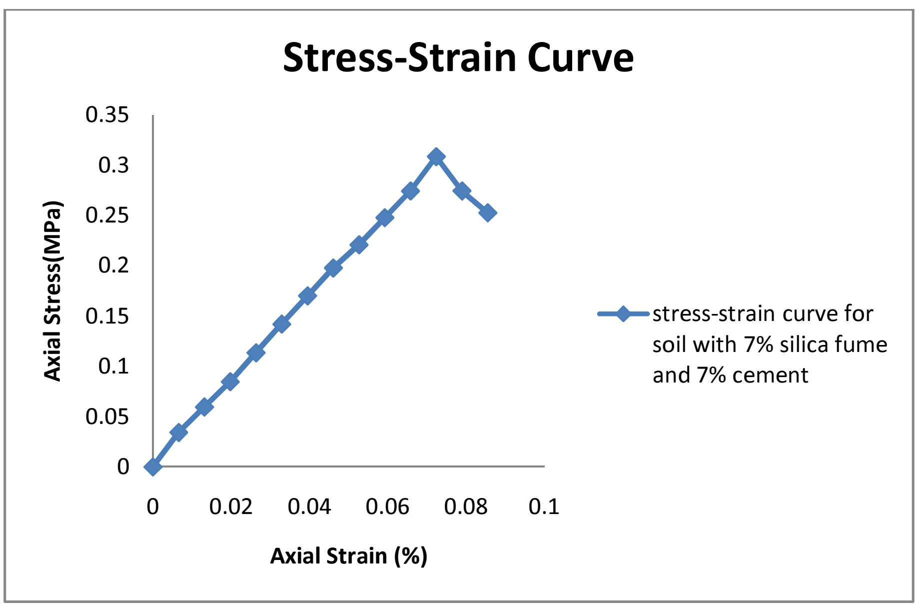


Fig 4.81 Stress strain curve of M15 after 7 day

The Unconfined Compressive Strength Value of M15 is 0.308MPa.

After 28 days of curing

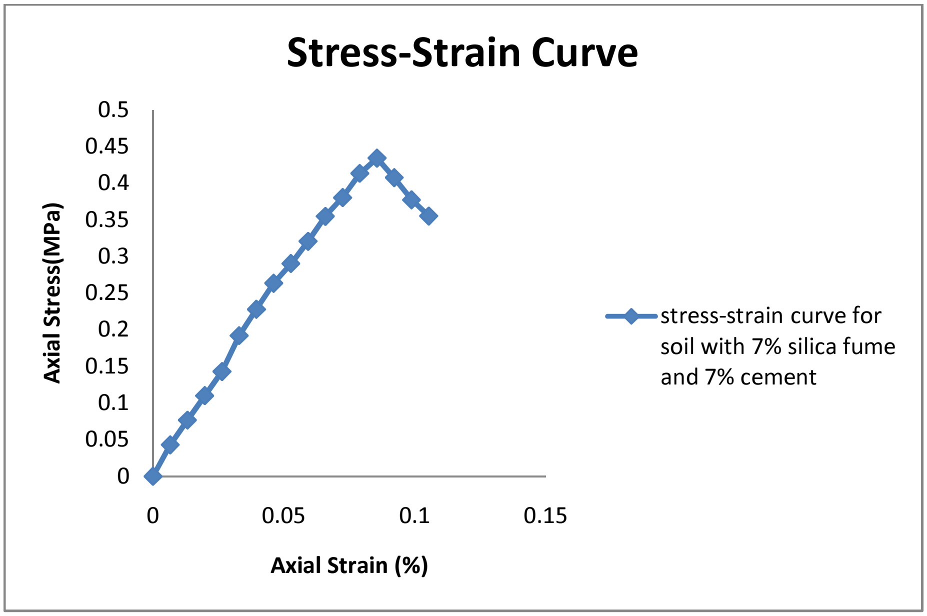


Fig 4.82 Stress strain curve of M15 after 28 day

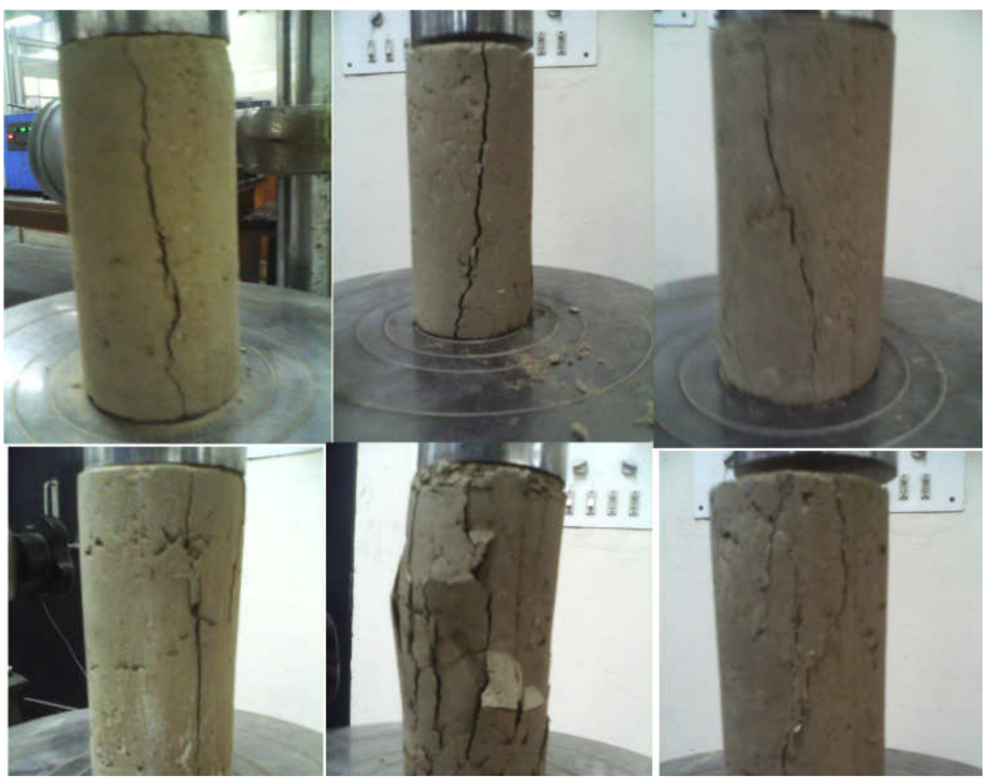
The Unconfined Compressive Strength Value is of M15 0.434MPa.

Picture 6 UCS Test Samples

Picture 7 UCS Test Apparatus With Sample

Picture 8 Failure of Sample

Picture 9 Failure Pattern of Sample



Picture 10 Failure Pattern of Sample

4.3 Compilation of Results

Table 4.9 Variation of Engineering Properties of different Mixes

MIX	**G**	**LL (%)**	**PL (%)**	**PI (%)**	**O.M.C (%)**	**M.D.D. kN/ m^3**	**UCS (MPa)**		
							1 day	7 day	28 day
M0	2.706	25.80	21.45	4.35	13.80	17.78	0.172	0.217	0.284
M1	2.720	28.20	23.74	4.46	16.80	16.92	0.183	0.237	0.309
M2	2.728	31.20	26.14	5.06	18.20	16.46	0.194	0.249	0.317
M3	2.735	33.10	28.42	4.68	20.80	16.04	0.209	0.264	0.339
M4	2.691	27.30	23.24	4.16	16.40	16.58	0.179	0.233	0.305
M5	2.702	29.60	25.46	4.14	18.30	16.18	0.187	0.241	0.313
M6	2.710	31.30	27.10	4.10	19.40	15.88	0.202	0.256	0.339
M7	2.718	30.40	26.34	4.06	21.20	15.43	0.221	0.280	0.402
M8	2.680	30.10	25.63	4.47	20.20	15.82	0.191	0.245	0.313
M9	2.689	31.80	27.14	4.66	21.40	15.50	0.198	0.252	0.323
M10	2.698	33.20	29.02	4.18	22.20	15.31	0.228	0.292	0.415
M11	2.706	32.40	28.30	4.10	24.80	14.95	0.232	0.296	0.418
M12	2.668	32.20	27.32	4.88	21.60	14.51	0.194	0.248	0.319
M13	2.680	34.10	29.06	5.04	23.20	14.13	0.230	0.304	0.427
M14	2.687	33.60	28.61	4.99	24.80	13.96	0.245	0.316	0.442
M15	2.694	32.40	27.86	4.54	26.20	13.68	0.252	0.308	0.434

4.4 Discussion

4.4.1 Effects on Specific Gravity by addition of Silica Fume and Cement with Soil.

The effect of silica fume with cement content on specific gravity of soil samples is presented in Fig.4.83 which shows that as the cement content increases, the specific gravity of soil increases.The specific gravity of any material depends on its mineralogical composition.The specific gravity of soil is 2.706 ,which is blended with various percentages of silica fume with specific gravity 2.23 and cement with specific gravity 3.15.This is why with the increase in cement content in the mixture the overall specific gravity of the mix increases. This indicates that the Soil-Silica Fume mixture is lighter than that of the natural conditions because the Silica Fume and Cement fills the voids between soil particles.

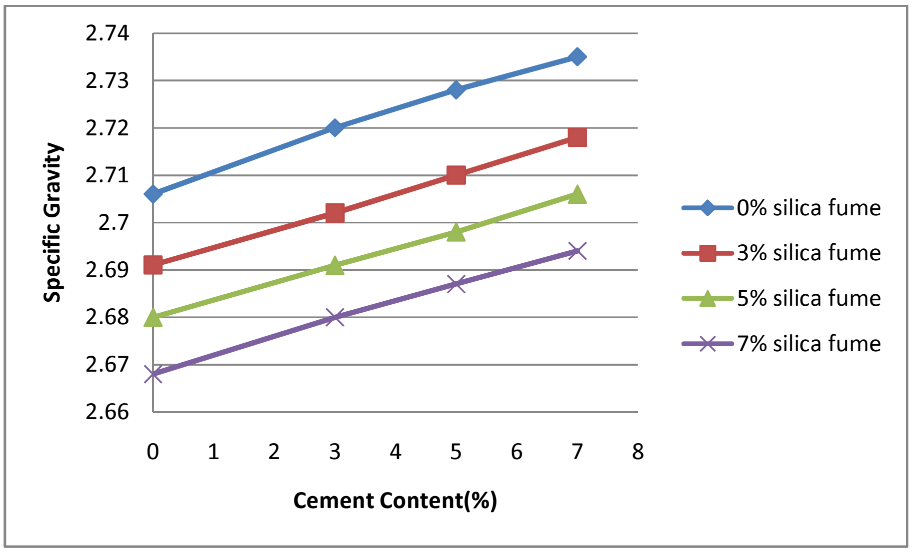


Fig 4.83 Variation of specific gravity of different mixes

4.4.2 Effect on Consistency Limits by addition of Silica Fume and Cement with Soil.

The effects of silica fume and cement on the consistency limits are given in Fig.4.84 to Fig.4.87. Liquid limit and Plastic limit values of soil samples with 0% silica fume increases on increasing cement content.However Liquid and Plastic limits of soil samples with 3% silica fume and 5% silica fume increases with increasing cement content (upto 5%) then decreases on increasing cement content for all soil samples.But the changes in plasticity index is almost negligible.Liquid limits and Plastic limits values for soil samples with 7 % silica fume increases with increasing cement content(upto 3%) then decreases on increasing cement content.The reason for the above changes may be due to type of soils and amount of silicate clay mineral present in the soil samples and associated exchangeable cat-ions .

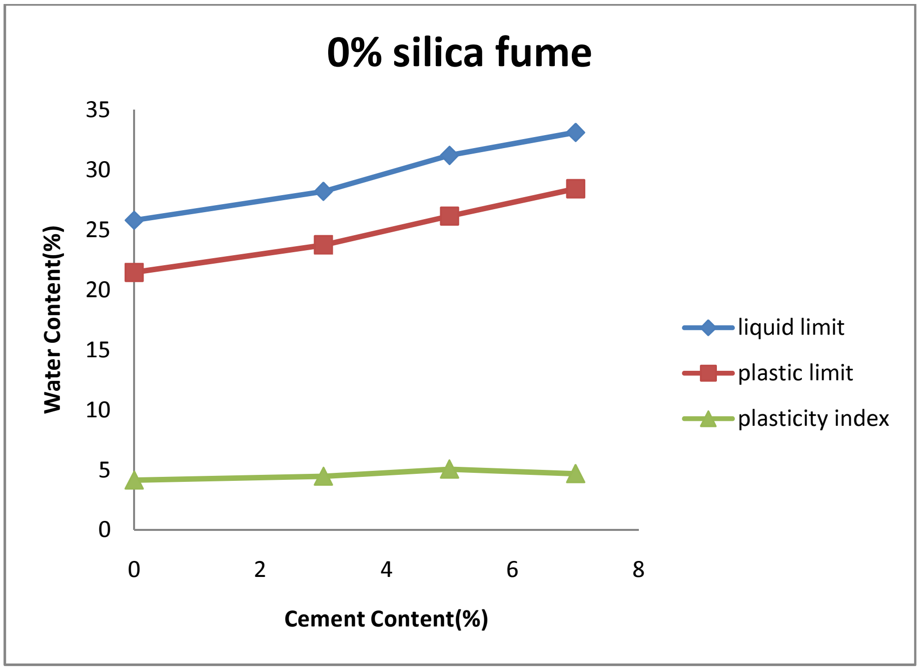


Fig 4.84 Variation of Consistency Limit of Soil mixes with 0% Silica Fume

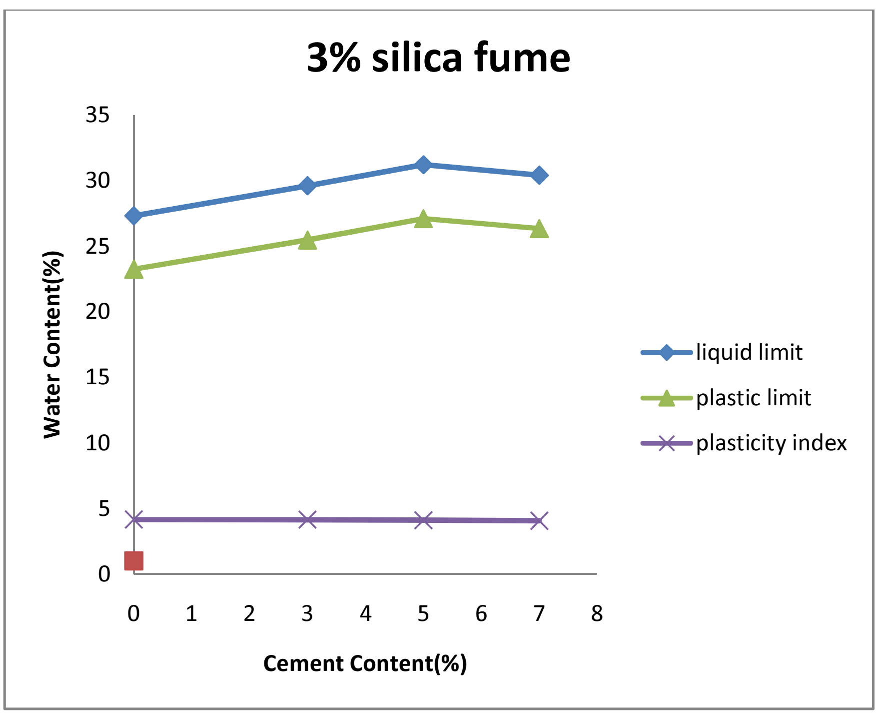


Fig 4.85 Variation of Consistency Limit of Soil mixes with 3% Silica Fume

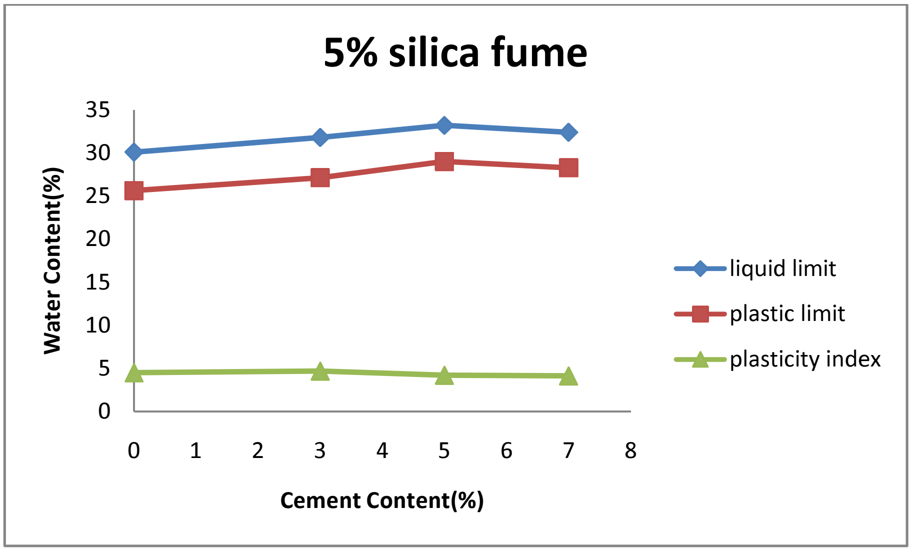


Fig 4.86 Variation of Consistency Limit of Soil with 5% Silica Fume

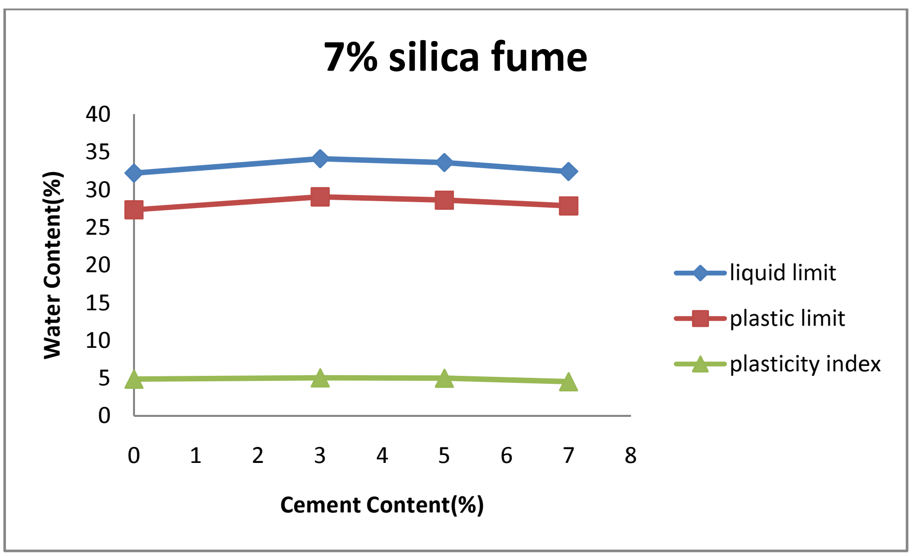


Fig 4.87 Variation of Consistency Limit of Soil with 7% Silica Fume

4.4.3 Effect on Compaction Parameters by addition of Silica Fume and Cement with Soil.

Fig.4.88 and Fig.4.89 shows the variation of optimum moisture content and maximum dry density values of soil samples on addition of silica fume and cement. From the fig it is observed that O.M.C of soil increases whereas MDD of soil mixes decreases by adding silica fume and cement at all different percentages. There is increase in O.M.C of soil mixes may be due to the increase in surface area of composite soil mixes. The fineness of cement and silica fume is much more higher as compared to that of soil.There is change in the surface area and particle size distributionof soil mixes by adding silica fume and cement.The decrease in MDD of soil mixes on addition of silica fume and cement is due to the fact thatit fills the void of the soil mixes..

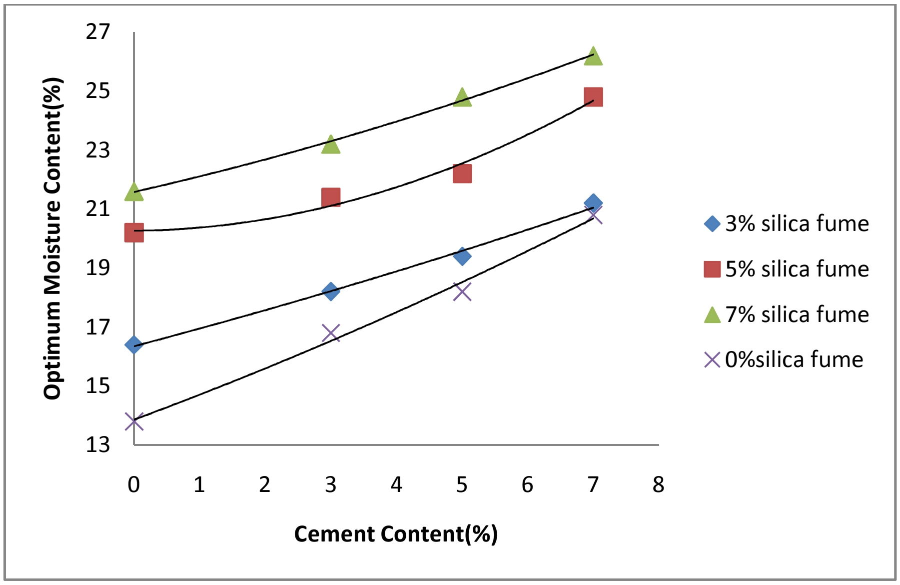


Fig 4.88 Variation of OMC for different mixes

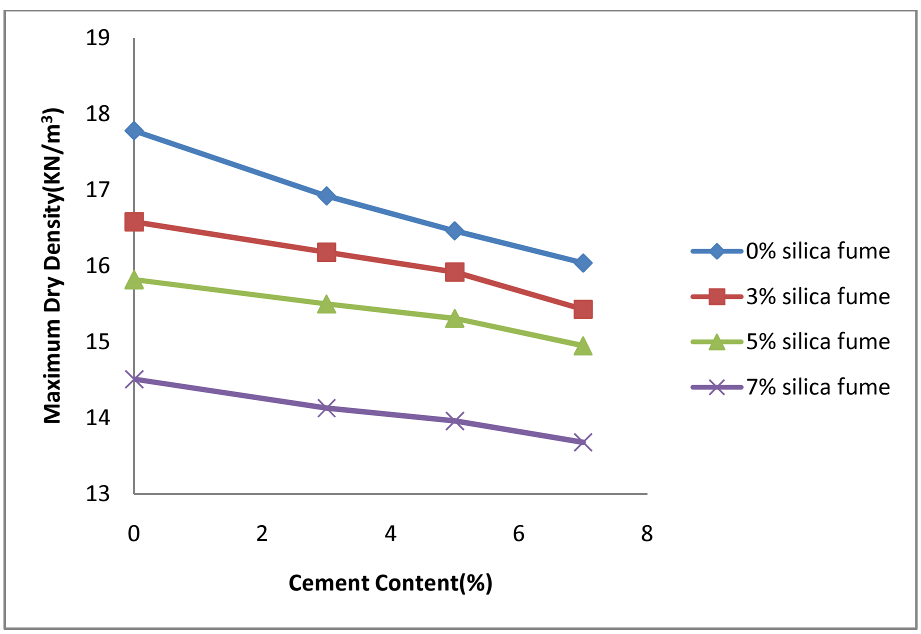


Fig 4.89 Variation of MDD for different mixes

4.4.4 Effect on Unconfined Compressive Strength by addition of Silica Fume and Cement with Soil

The effects of silica fume and cement contents on the unconfined compressive strength for silty soil samples are presented in Fig.90 to Fig.93.The unconfined compressive strength of soil samples with 0%and 3% silica fume significantly increases with increasing cement content from 0% to 7% (increases from 0.172MPa to 0.221MPa after 1 days of curing,0.217MPa to 0.280MPa after 7 days of curing and 0.284 MPa to 0.402 MPa after 28 days of curing). The unconfined uompressive strength of soil samples with 5% silica fume increases with increasing cement content from 0% to 7% (increases from 0.191MPa to 0.232MPa after 1 days of curing,0.245MPa to 0.296MPa after 7 days of curing and 0.305 MPa to 0.418 MPa after 28 days of curing). The unconfined compressive strength of soil samples with 7% silica fume increases with increasing cement content from 0% to 3% (increases from 0.194MPa to 0.232 MPa after 1 days of curing,0.248MPa to 0.304 MPa after 7 days of curing and 0.319 MPa to 0.427 MPa after 28 days of curing). After that, the unconfined compressive strength is minutely changed on increasing cement content. The maximum unconfined compressive strength of the silty soil samples is found to be at the 7% silica fume and 5 % cement content.The increment in the unconfined compressive strength may be because of the internal friction of cement and silica fume particles and also due to the chemical reaction took place between cement and soil. As there is increase in content of cement and silica fume in soil samples the soil becomes more brittle that the plain soil.

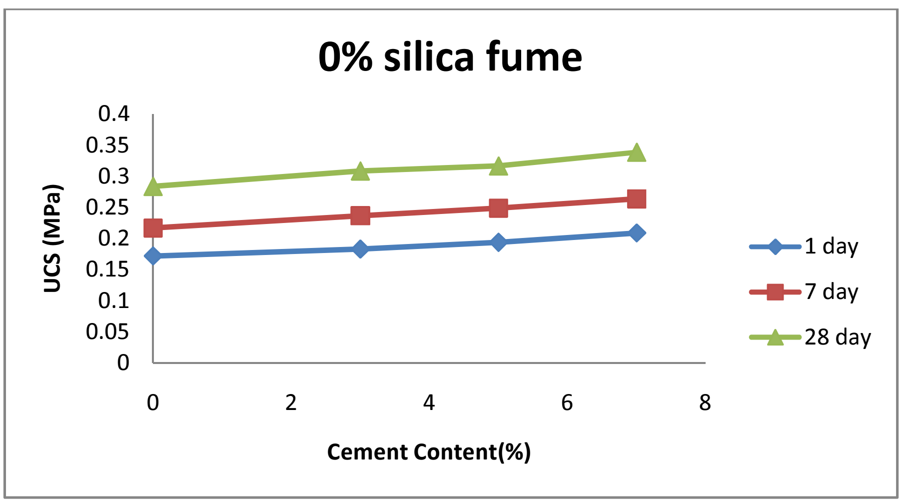


Fig 4.90 Variation of UCS of soil mixes with 0% silica fume

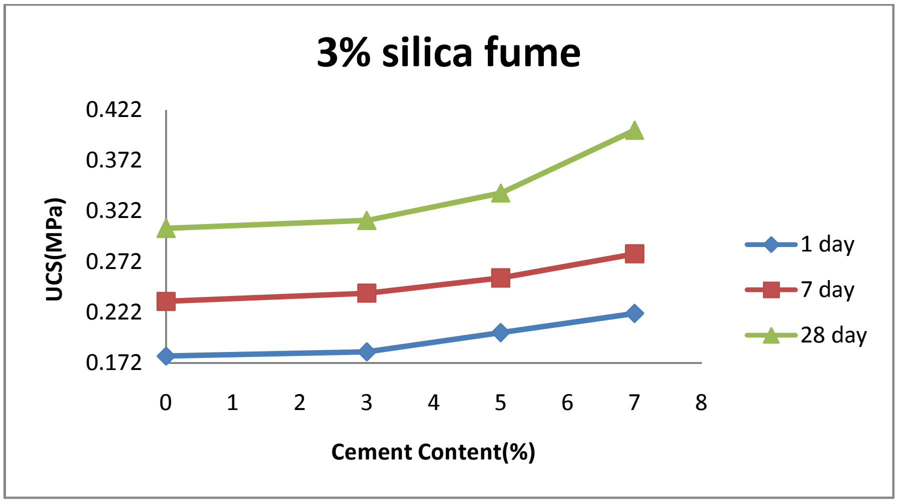


Fig 4.91 Variation of UCS of soil mixes with 3% silica fume

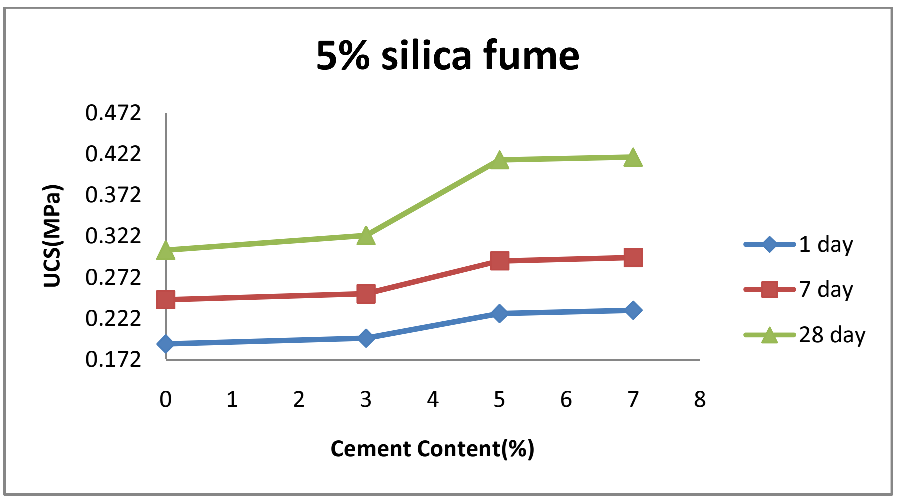


Fig 4.92 Variation of UCS of soil mixes with 5% silica fume

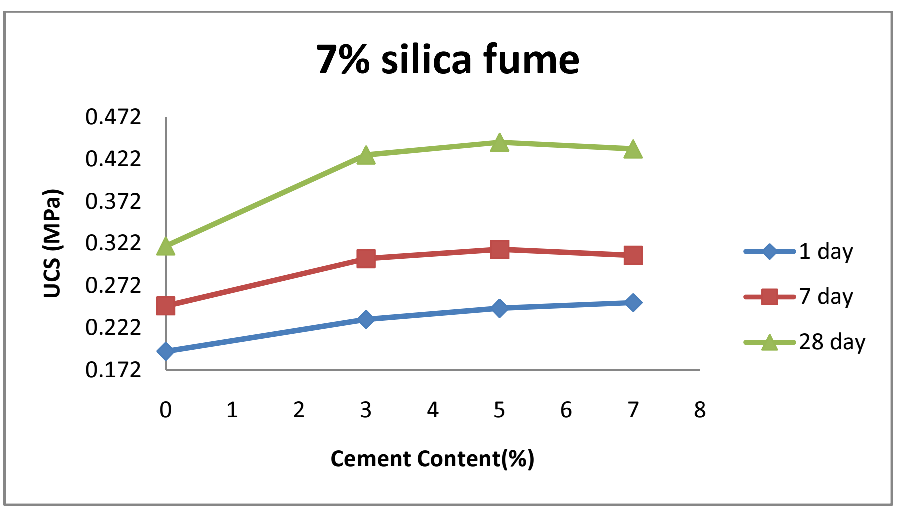


Fig 4.93 Variation of UCS of soil mixes with 7% silica fume

CHAPTER 5

Conclusions and Recommendations for the Future Work

5.1 conclusions:-

According to the results obtained in above study ,the following conclusions are drawn:

(1) Adding cement and cement with silica fume decreases the maximum dry density and increases the optimum moisture content of the soil.

(2) The Atterberg limits i.e.liquid limit and plastic limit increases on addition of cement and cement with silica fume initially then decreases on further addition to the soil.

(3) The unconfined compressive strength of the soil increases significantly with increase in cement content with silica fume especially after a long curing period.

(4) However on addition of more cement(upto 5%) with silica fume(upto 7%) the unconfined compressive strength of the soil decreases. The unconfined compressive strength of the soil on addition of 5% cement with 7% silica fume(28 days of curing peroid) increases from 0.319MPa to 0.442MPa.

(5) The optimal dose of silica fume was 7 % and that of cement was 5 % to be added with soil to get an improvement of 55 % UCS value.

5.2 Recommendations for Future work:-

(1) The XRD and SEM analysis of all the mixes may be carried out to get a compositions of various elements.

(2) The Triaxial test on each mixes may be conducted to get the value of cohesion and angle of internal friction for different drainage condition.

(3) In order to use these mixes as a subgrade material for the construction of road,CBR test may be conducted to evaluate the strength of the road.

(4) The tests for the hydraulic conductivity may be conducted to use these mixes for the construction of dam/embankment.

(5) The swelling and consolidation behaviour of these mixes may be checked before using them for the construction material.

(6) All the tests may be repeated for different combinations and the material other than cement and silica fume also.

REFERENCES

(1) Dr. Adel A. Al-Azzawi, Khalida A. Daud ,Muhammed A. Abdul Sattar "Effect of Silica Fume Addition on the Behavior of Silty-Clayey Soils" Journal of Engineering and Development, Vol. 16, No.1, March 2012.

(2) Al-Zairjawi Khachi,"Effect of adding cement and silica fume on compaction properties and shear strength of soil", Al-Qadisiya Journal For Engineering Sciences,vol.2 no.1,2009.

(3) Chhaya Negi ,R.K.Yadav,A.K.Singhai "Effect of Silica Fume on Engineering Properties of Black Cotton Soil",International Journal of Computational Engineering Research,vol.3,issue 7.

(4) Mehdi Gharib,Hamidreza Saba,Arash Barazesh "The Effects of Additives on Clay Soil Properties using Cement and Lime" International Journal of Basic Sciences and Applied Research.vol.,1(3),66-78,2012.

(5) Hassan Mosa Jafer,Hayder Abbas Obaid,Ahmad Hassan Hadi "Stabilization of Soft Soil Subgrade layers by using Lime Micro-Silica Fume Mixture" Eupharates Journal of Agriculture Science-5(1),44-53,(2013).

(6) Y.keerthi ,P.Divya Kanthi,N.Tejashwi "Stabilization of Clayey Soil using Cement Kiln Dust" International Journal of Advanced Structure and Geotechnical Engineering. ISSN 2319-5347,Vol.02,No.02,April 2013.

(7) Ishraq Khudhair Abass "Studying Some of the Geotechnical Properties of Stabilized Iraqi Clayey Soils" Eng.and Tech. Journal,vol.31,Part (A),No.6,2013.

(8) Kalkan,E. and Akbulut,S., "The Positive Effects of Silica Fume on the Permeability,Swelling Pressure and Compressive Strength of Natural Clay Liners",Journal of Engineering Geology,Vol. 73,2004,pp. 145-156.

(9) Chen, F.H., "Foundation on Expansive Soil, Development in Geotechnical Engineering", Elsevier Scientific Publishing Company, New York, USA, 1988, p. 463.

(10) Cokça, E., " Effect of Fly Ash on Swell Pressure of an Expansive Soil", Electronic Journal of Geotechnical Engineering, Paper 9904. Oklahoma State University, USA, 1999, www.ejge.com/1999/Ppr9910.htm.

(11) Abd El-Aziz M. , Abo-Hashema M., and El-Shourbagy M., " The effect of Lime-Silica Fume Stabilizer on Engineering Properties of Clayey. Subgrade", Fourth Mansoura International Engineering Conference (4th IEC), Faculty of Engineering, Mansoura University, Egypt, April 2004.

(12) Kalkan, E. ,"Influence of Silica Fume on the Desiccation Cracks of Compacted Clayey Soils", Journal of Applied Clay Science, Vol. 43, 2009, pp. 296-302.

(13) Choudhary AK, Gill KS & Jha KN (2011), "Improvement in CBR values of expansive soil subgrade using geosynthetics,"Proc. Indian Geotechnical Conference, 569-572.

(14) M Karimi & Ali G."Stabilization of silty sand soils with lime and micro silica admixture in pressure of sulphates".Pan –Am CGS ,Geotechnical Conference 2011.

(15) IS: 2720(Part 2), 1973 Methods of Test for Soils, Determination of water content.

(16) IS 2720(III/SEC-I): 1980 Methods of Test for Soils, Determination of specific gravity.

(17) IS 2720(VII):1980 Methods of Test for Soils, Determination of water content, dry density relation using light compaction.

(18) IS 2720(X):1991 Methods of Test for Soils, determination of unconfined compression test.

(19) IS 2720(IV):1985 Methods of Test for Soils, determination of grain size analysis.

(20) IS 15388 (2003) Specification for silica fume.

(21) IS 8112:1989 43 grade ordinary Portland cement.

(22) Lamb,T.W and Whitman,R.V, "Soil Mechanics" Paperback,New York 1969.

(23) Singh,A, "Soil Engineering in Theory and Practice",Asia Publishing House,1981.

BIO-DATA

Name:-Jay Shanker

D.O.B:-21/03/1990

Address:-Adarsh nagar
P.O-Harnaut
Dist.-Nalanda
Bihar-803110

Mobile No.-9650236025

E mail:- tanish1999@gmail.com

Educational qualification:-

(1) M.TECH (Geotechnical Engineering)
(2) B.TECH (Civil Engineering)
(3) 10th and 12th (Science Stream)

Hobbies:-Playing and watching cricket, exploring new places and reading story books.