# An Experimental Study On Black Cotton Soil Stabilization by Using Terazyme

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# AN EXPERIMENTAL STUDY ON BLACK COTTON SOIL STABILIZATION BY USING TERAZYME

*Thesis Submitted in Partial Fulfilment On*

*The Requirements for The Degree Of*

**MASTER OF TECHNOLOGY**

in

**CIVIL ENGINEERING**

**(**GEOTECHNICAL ENGINEERING**)**

by

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**May2016**

Department of Civil Engineering
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May 30, 2016

# Certificate of Examination

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We the below signed, after checking the dissertation mentioned above and the official record book (s) of the student, hereby state our approval of the dissertation submitted in partial fulfilment of the requirements of the degree of *Master of Technology* in *Civil Engineering (Geotechnical Engineering)* at *National Institute of Technology Rourkela*. We are satisfied with the volume, quality, correctness, and originality of the work.

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May 30, 2016

# Supervisors' Certificate

This is to certify that the work presented in the dissertation entitled *An experimental An Experimental Study On Black Cotton Soil Stabilization By Using Terazyme* submitted by *karnati chakrapani*, Roll Number 214CE1066, is a record of original research carried out by him under my supervision and guidance in partial fulfilment of the requirements of the degree of *Master of Technology* in *Civil Engineering (Geotechnical Engineering)*. Neither this dissertation nor any part of it has been submitted earlier for any degree or diploma to any institute or university in India or abroad.

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# Declaration of Originality

I, karnati chakrapani, Roll Number 214CE1066 hereby declare that this dissertation entitled "*An experimental An Experimental Study On Black Cotton Soil Stabilization By Using Terazyme"* represents my original work carried out as postgraduate student of NIT Rourkela and, to the best of my knowledge, it contains no material previously published or written by another person, not any material represents for the award of any other degree or diploma of NIT Rourkela or any other institution. Any contribution made to this research by others, with whom I worked at NIT Rourkela or elsewhere, is explicitly acknowledged in the dissertation. Works of other authors cited in this dissertation have been duly acknowledged under the section "Bibliography". I have also submitted my original research records to the scrutiny committee foe evaluation of my dissertation.

I am fully aware that in case of any non-compliance detected in future, the Senate of NIT Rourkela may withdraw the degree awarded to me on the basis of the present dissertation.

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ACKNOWLDGEMENTS

*I take it as privilege to express my gratitude towards my supervisor* ***Dr. N. Roy*** *Professor, Department of Civil Engineering, National Institute of Technology, Rourkela, for his continuous help and encouragement. It has been an honour to work under the supervision of Dr. N. Roy, whose valuable guidance and support enriched the quality of work.*

*I express my sincere regards to* ***Prof. S.K. Sarangi****, Director of NIT, Rourkela and* ***Prof. S.K. Sahu,*** *Head of the civil engineering department, NIT, Rourkela for providing facilities in the Geotechnical Engineering laboratory round the clock for research work.*

*I also express my thanks to the staff members of Geotechnical Engineering laboratory for their co-operation during the course of experimentation.*

*I am thankful to* ***Mr. Apoorva Modi****, Avijeet agencies, Chennai for supporting this project by supplying enzyme.*

*I am greatly indebted to my parents for their encouragement and endless support that helped me at every step of life. Their blessings and wishes have enabled me to complete my work successfully.*

*Lastly, I am very much thankful to all those who are directly or indirectly involved in completion of this research work.*

karnati chakrapani

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# LIST OF SYMBOLS

| Notation | Description |
|---|---|
| G | Specific gravity |
| Cu | Coefficient of uniformity |
| Cc | Coefficient of curvature |
| OMC | Optimum Moisture Content |
| MDD | Maximum Dry Density |
| UCS | Unconfined compression test |
| CBR | California Bearing Ratio |
| TZ | Terazyme |
| BC | Black cotton soil |
| $C_V$ | coefficient of consolidation |

# ABSTRACT

In developing countries like India the most important requirement of any project after performance criteria is its economical feasibility and serviceability criteria. The conventional methods are time consuming and are not economically feasible. Hence there is a need to find the other possible ways to satisfy the performance as well as economical criteria. These enzymes have been proven to be very effective and economical. Another advantage of the bio-enzyme is that these are environment friendly. The efficiency of bio enzyme depends upon the amount of dosage, type of soil and curing period. In our country vast areas consist of black cotton soils. As the conventional soil stabilizers like gravel, sand and others are depleting and becoming expensive day by day at a very rapid pace, it becomes necessary to look towards for alternative eco-friendly stabilizers as their substitute. Recently many Bio-enzymes have emerged as cost effective stabilizers for soil stabilization. One such type of bio-enzyme, Terazyme, has been used in the present work. The Terazyme effect on the unconfined compressive strength and on the atterberg limits were studied. The enzyme treated soil showing significant improvement in unconfined compressive strength values. The untreated soil has compressive strength as 71 $kN/m^2$. After treating with Terazyme the soil showed significant improvement in strength. With curing period, the strength is increasing. The strength increment was found to be 300 percent. No significant improvement in liquid and plastic limit values with treatment of Terazyme enzyme. The compression index and coefficient of consolidation values decreasing with enzyme treatment for a prefixing curing period.

# CHAPTER 1

# INTRODUCTION

## 1.1 BLACK COTTON SOILS

Black cotton is one of the expansive soil available in India. Black cotton soil is an expansive soil that generally available in the tropical zones. Their appearance varies from black colour to brown colour. In our country black cotton soil occupies nearly 20% of the available land. Expansive soil major portion generally found in central part and some places in south India. Expansive soils known by black cotton soil are available in the Deccan plateau fields (Deccan Trap) including Madhya Pradesh, Maharashtra, Gujarat, Andhra Pradesh and in some parts of Odisha, in the Indian sub-continent. Black cotton soil available in the valley of river Tapti, Narmada, Godavari and Krishna. The west side of Deccan plateau and in upper portion of Krishna and Godavari basin. In this area the black cotton soil depth is very narrow. These soils formed by the residual action of basalt or trap rocks. The other reason behind formation of these soils is weathering of igneous rocks, after volcanic eruption by the cooling action of lava. These soil shows high plasticity nature. The major clay mineral is montmorillonite. Because of montmorillonite group mineral these clays exhibit more swelling and shrinkage characteristic. The main problem with this type of minerals is instability of earth material. Expansive soils are hard when they lose water content, and the another day if they capture water they become soft in nature.

For a lightly loaded structure it creates problem, under burden and by changing volumetrically alongside regular dampness variety. Subsequently, the superstructures generally counter excessive settlement and differential developments, bringing about harm to establishment frameworks, basic components and structural elements. In a critical number of cases the structure gets to be precarious or dreadful. Notwithstanding when endeavours are made to enhance swelling soil, the absence of proper innovation in some cases results volumetric change that are in charge of billion dollars harm every year. It is because of this that the present work is taken up. The design was to check the extent of enhancing bearing limit esteem and lessen extensiveness by including added substances. These soils are hard in dry state however lose their load carrying strength when once they are permitted water into the clay structure.so we can say that especially expansive soil touchy to changes in environment. These properties have made the soil inadmissible for structural designing purposes either as embankment material or foundation material.

Fig 1.1 Expansive soil

## 1.2 General

A liquid chemical products are actively marketed for stabilizing soils on pavement projects. Normally supplied as concentrated fluids, these additives are mixed with water on the field and splashed on the soil to be dealt with before compaction. Pressure injection is sometimes used to treat deeper soil layers. The concept behind chemical stabilization is to keep the soil properties same, positive effects of the given engineering project with respect to changes of moisture in environment. As known in soil chemistry, clay minerals are arranged in layers with various ions and surrounded by absorbed water molecule. The absorbed water molecule strongly connected to clay surface. The intention is to modify the interaction between clay surface and water in such a way the clay would not absorb water molecule.

In this present study, one type of Bio-enzyme that is Terazyme has been used for alerting the properties of black cotton soil. Detailed laboratory tests were carried out to ascertain the benefits in terms of engineering properties.

## 1.3 Soil stabilization

The mode of alteration and the degree of alteration necessarily depend on the character of the soil and its deficiencies. In general requirement is adequate strength. In the case of a cohesion less soils can be achieved by proper confinement or by mixing the cohesion lees soil with cohesion material. Here the cohesion material act like a cementing agent. In case of cohesive soil, we can improve the soil strength by drying process or make the soil water resistant, changing the soil electrolyte configuration by adding frictional properties. Stabilizing the soil is one of the technique to increase soil strength and maintain atterberg limits within in the specified limit. By chemical alteration we can improve the engineering properties. Stabilization technique can be used to treat extensive variety of soil materials having poor engineering properties. Various types of stabilization techniques are in use. Stabilization can be broadly classified into two type

1.mechanical stabilization

2.chemical stabilization

### 1.3.1 Mechanical Stabilization

In general, weak aggregates are preferred for mechanical stabilization. Mechanical stabilization covers two strategies for changing soil properties

1.the soil particles rearrangement

By improving the gradation of soil

Any material prone to weathering action is suitable for mechanical stabilization.

### 1.3.2 Chemical Stabilization

Chemical stabilization comprises of binding the soil particles by a cementing agent. The binding agent i.e. cementing agent can be produced chemical reaction within in the soil. The chemical reaction does not as a matter of course incorporate the soil particles, although the holding involves intermolecular strengths of the soil.

## 1.4 Soil stabilization by enzyme

An organic catalyst that increases the rate of chemical reaction without being part of end product is called as enzyme. Initially the enzymes are used in treating the horticulture products. For roads to be stabilized by the enzymes require strength and durability. The enzymes are modified by little amount to keep the clay durable. The enzymes react with organic molecules and forms a compound. This compound plays an important role in ions exchange process. First step in ions exchange processes is break down the lattice structure and enzyme act like a surfactant. These surfactants will avoid the clay further gaining the moisture content. After mixing with soil, enzymes are adsorbed by the clay lattice structure. They play a vital role on lattice structure, at first making them to expand and afterwards to tighten. Colloids absorb the enzyme empowering them to be transported through the soil electrolyte media. Generally, soil bacteria release the hydrogen ions. The enzymes are catalyses the process.by chain reaction enzyme are regenerated and goes on reacting.th size of ions is large, so some amount of osmotic migration took place. For this enzyme requires better mixing process. After adding the enzyme to the soil immediately enzyme increases the clay particle wetting and bonding behaviour. For this reason, soil will be compacted to denser that will increase the density of soil Also. Enzymes enhance the chemical bonding. It will help to bind the soil particles more closely. So the clay structure becomes permanent structure; it becomes more durable to weathering conditions.

## 1.5 Scope and objective of research work

There are majorly 4 types of bio-enzymes till date are Renolith, Permazyme, Fujibeton and Terazyme. In the present investigation an attempt is made to stabilize the black cotton soil with bio Enzyme (Terazyme). Detailed laboratory tests were carried out to ascertain the benefits in terms of engineering properties**.**

(a)To evaluate physical properties of Black cotton soil.

(b)To determine the effects of adding enzyme to black cotton soil on its properties.

## 1.6 Outline of the thesis

The present research work consists of six chapters. In each chapter a brief introduction was written. Chapter one contains the about the expansive soils and their availability in our country. Problems related to expansive soils was discussed. After that to stabilize the expansive soil by using enzymes was discussed. Literature review was discussed in second chapter. In this chapter previous works related to enzymes has been discussed. Chapter three consists of materials and methodology. In this chapter the procedure to determine the various properties of i.e. engineering properties and physical properties had been discussed. The fourth chapter consists of detailed laboratory investigation done on the black cotton soil. The enzymatic soil properties with a prefixing reports was mentioned. Chapter 5 focuses on the conclusions drawn from the Laboratory test in what way the black cotton soil is usefull. In which way we can improve the soil behaviour.

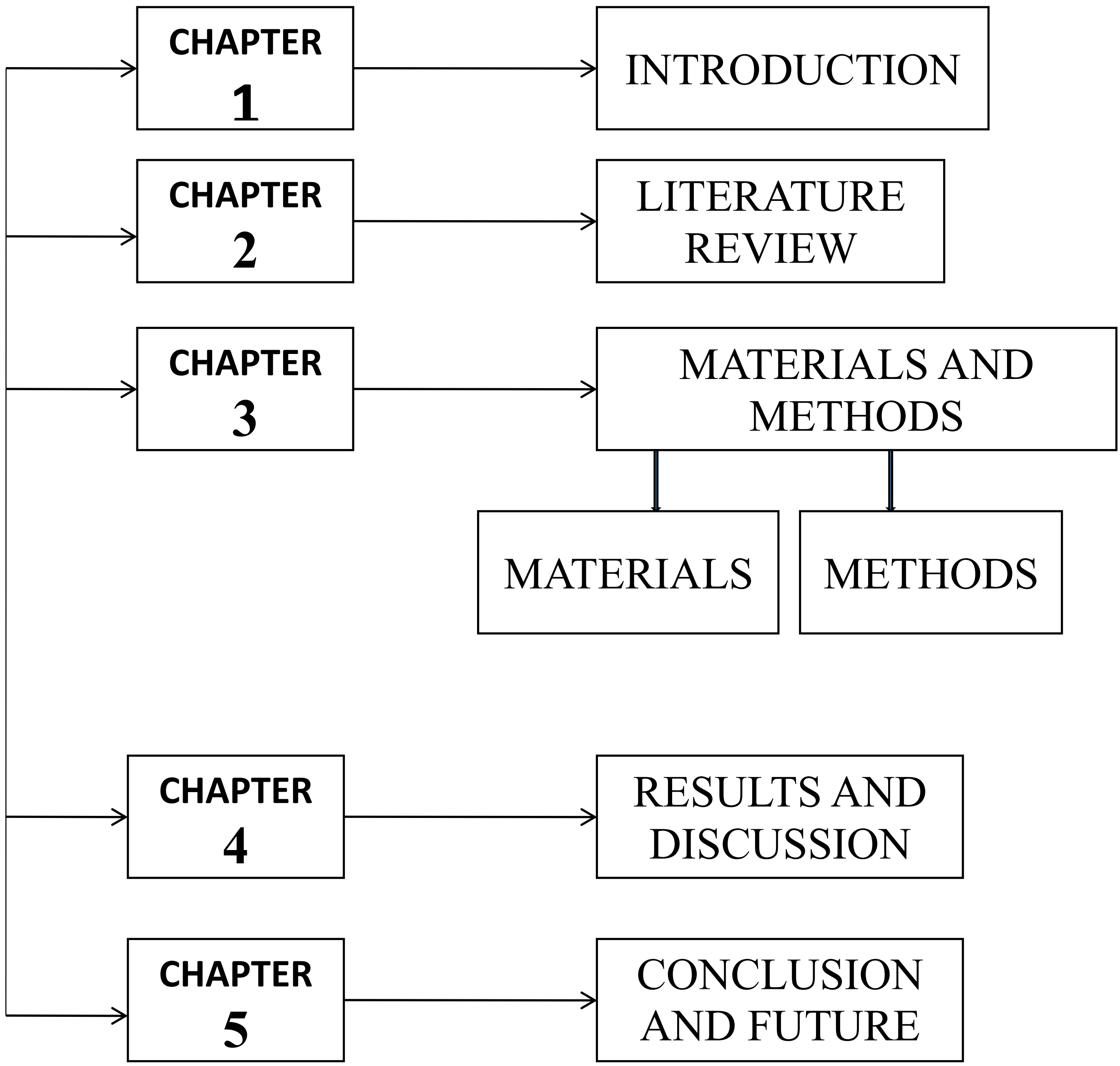



Fig 1.2 Flow chart showing the outline of the thesis

# CHAPTER 2

# LITERATURE REVIEW

As a prelude to begin with a project it is more essential to have general and detailed information regarding the subject content, strategic approaches, available research in the subject area, interpreted results and drawn conclusions. This chapter reviews the attempts made by several researchers to understand the behaviour of Enzymes as reinforcing material in soil.

## 2.1 Literature on liquid chemical stabilizers

**Isaac et al.** (2003) had conducted laboratory study on five types of soil namely CL, OH, CH, CI SX.to improve the five soil properties they mixed with bio enzyme. They conducted CBR test for a pre fixing curing period. From the results it is clear that Terazyme is very effective, economical. most effective in case of silt content is more.

**Velasquez et al.** (2005) studied the enzyme mixing on soil stabilization. they used two types of enzymes namely enzyme A and enzyme B. They conducted chemical analysis of enzyme A before the mechanical testing. After that they conducted resilient modulus and shear strength test on two soils which were stabilized with two different enzymes. Two types of soil are used named as soil 1 and soil 2. soil 1 mechanical properties are not affected by the enzyme A with enzyme B. The stiffness of soil 1 was increased. The resilient modulus of soil 2 increases by the application of both enzymes A and B. With time the enzyme activity on the soil stabilization increases. From the observations minimum four months of time required to get improvement in the shear strength of the soil.

**Shankar et al.** (2009) studied the effect of Terazyme on locally available lateritic soil. The investigated lateritic soil was collected from udipi district region in Karnataka state. The lateritic soil is not full fill the requirements of sub base coarse.so to brought down the atterberg limits they mixed the lateritic soil with locally available river sand. The blended soil is mixed is stabilized by using Terazyme enzyme.

From the observations it has been concluded that if sand amount increases in blended soil the enzyme treated soil cbr value was decreasing. The enzyme is ineffective in improving the consistency limits of lateritic soil. Whereas Terazyme is effective in improving the engineering properties of the lateritic soil. For cohesion less soil Terazyme is not useful to improve its properties.

**Mgangira MB** (2009) conducted laboratory results on the effect of enzyme based liquid chemicals as soil stabilizer. Soil 1 had plasticity index of 35 and the other had PI of 7. Tests – Atterberg limits, Standard proctor and unconfined compressive strength.

1)Treatment with enzyme based products to lead a slight decrease in PI of both soil.

2) Enzyme based chemical treatment of two soils using the two products showed a mixed effect on the UCS. No consistence significant improvement in the UCS could be attributed to treatment.

**Naagesh and Gandgadhara** (2010) made experiments on an expansive soil treated with an organic, non-toxic, eco-friendly bio-enzyme stabilizer in order to assess its suitability in reducing the swelling in expansive soils. They stated that reduction in void ratio of bio enzyme treated specimens with curing period significant reduction in swell properties. The experimental results indicate that the bio enzyme stabilizer used in the present investigation is effective and the swelling of an expansive soil reduces on wet side of OMC.

**Venkatasubramanian and Dhinakaran** (2011) three different soils with four different dosages for 2 and 4 weeks of period after application of enzyme on its strength parameters were studied. It is inferred from the results that addition of bio enzyme significantly improves UCC and CBR values of selected samples.

Unconfined compressive strength: Among three different selected soils, UCC of soil 2 has got higher value compare to two other soils. At the same time, the UCC of soil 1 falls in between values of soil 1 and 3 and soil 3 has got lowest UCC value. This higher rate of increase observed for all the soils treated with bio-enzyme with 4 weeks of duration. For all the soils, soil treated with dosage 3 for a period of 2 weeks’ duration shows descending trend in CBR. For soil 3 except for dosage 1, for other three dosages of bio-enzyme there is descending trend in the rate of increase in CBR

**Faisal A** (2012) studied the three different types of residual soils. These three soils named as soil 1 soil 2 and soil 3. They conducted the tests as per the British institution. To brought down the residual soil atterberg limits, the residual soil is mixed with liquid chemical. The liquid chemical was mixed to the residual soil in four different proportions. The liquid chemical mixed residual soil is tested after 1,7 and 14 days. It has been observed that the atterberg limit values is decreasing pattern. They conducted the proctor test. The liquid chemical soil showing that omc value decreases and dry density value is increasing. The unconfined compression strength is also increasing for liquid chemical mixed soil.

**Greeshma et al.** (2014) conducted experimental work on high liquid limit clay. The liquid limit clay behaviour was investigated by using Bio enzyme Terazyme additive. With treatment of Terazyme the liquid limit is about 30% increase in the first two weeks. After that liquid limit is decreased slightly. However, shrinkage limit was decreased. The ucs value enhanced twelve times the original value.

**Agarwal p and Kaur S** (2014) studied the effect of Terazyme effect on expansive soil. They conducted unconfined strength test to determine the optimum dosage value. To determine the optimum value of dosage totally 5 dosages are mixed to the soil. After that they tested with curing period of 1day and 7 days. From experiments concluded that UCS strength value increases about 200 percent. They give the reason for working mechanism of Terazyme.

**Rajoria V and Kaur S** (2014) presented a research paper on soil stabilization by using enzymes. In this research paper four different types of enzymes were discussed. These enzymes are practised in different countries. The four enzymes are Renolith, Permazyme, Fujibeto and Terazyme. Renolith enzyme was developed in Germany country. Renolith is mixed with water in a predetermined quantity. This water mixture was sprinkled over the soil. This type of enzyme is suitable in cement stabilized soil. By using Renolith enzyme cost reduction is reduced about 20 to 40 percent. This enzyme was helpful in arresting cracks.

The second enzyme discussed is pemazyme.it is very useful in taw freeze types of soil. It increases the compaction effort of clays and soils with silt content is more.

Fujibeton enzyme material was available in japan. Fujibeton is an organic polymer. Fujibeto soil mix is very easy to handle. This enzyme soil mixture requires less skilful workers, with minimum effort we can achieve maximum compaction effort.

The last enzyme discussed was Terazyme enzyme. Which was used in the present investigation to improve the properties of black cotton soil. The main supplier in India is avijeet agencies. The Terazyme is nontoxic eco-friendly material. The Terazyme soil mixture showing the ucs Value increases about 100 times for a curing period of 30 days.

**Thida AN and Than** MS (2014) studied the strength behaviour on enzyme treated soils.
Soil samples are taken at about 3ft depth from Kyarnikan village in Patheingyi township and two places of ASEAN Highway. The soil examined belongs to CL as per the UNIFIED SOIL

CLASSIFICATION SYSTEM. Three enzyme dosages are selected as 0.5 litre, 1 litre and 1.5 litre per 33m3 of soil. The strength tests are conducted after the curing period of one week and four weeks. When soils are stabilized with enzyme, UCS and CBR values are higher than that of natural soil.

**Khan TA and Taha MR** (2015) In this experimental study, three types of bio enzymes from three different countries were used to improve University Kebangsaan Malaysia (UKM)soil. The effect of the three different bio enzymes on Atterberg limits, compaction curves, and unconfined compressive strength was studied. Controlled untreated and treated samples for two dosages at curing times up to three months were prepared and tested after completion of the curing period. From the experiment results, the mixed enzymes did not show any comprehensible improvement in the lab experiment program. that is, Atterberg limits, compaction, and unconfined compression tests. Little improvement, in some cases, could be related to the hypothesis that the enzymes did not produce any chemical change, and they only prevented moisture absorption to bring the particles closer.

**Sen J and Singh JP** (2015) In this study Black cotton soil with varying index properties have been tested for stabilization process. The black cotton soil is mixed with enzyme. The mixed stabilized soil was for a pre fixing period of 0 days, 14days, 21 days and 28 days for various enzyme dosages. The tests which were carried out are the California Bearing Ratio (CBR) test and Unconfined Compressive strength (UCS) test of the soil specimen. The test results indicate that bio-enzyme stabilization improves the strength of BC soil up to great extent, which indicate the bearing capacity and the resistance to deformation increases in stabilized soil.

**Nandini DN and Kumar MT** (2015) conducted experiments on red soil. The red soil is mixed with Terazyme for three different dosages namely D1, D2, D3. They prepared the ucs sample with different moisture content and different density. They made samples for dry side of omc, omc and wet side of omc. From the results they concluded that there is reduction in strength with curing period at omc density. There is significant improvement in ucs was observed at all curing period corresponding to dry side of omc.

**Venika S and Priyanka V** (2015) put an effort to improve the local soil properties. For this they mixed the local soil with Terazyme for different dosages. After addition of enzyme they conducted experiments on specific gravity, atterberg limits, proctor test and cbr test for soaked and un soaked conditions. The results showing that there is no improvement in atterberg limits and improvement was observed in cbr value.

**Ramesh HN and Sagar SR (**2015) studied the effect of Terazyme on black cotton soil and red earth soil separately. They conducted liquid limit, cbr. Unconfined compression strength, free swell index, compressibility and compaction characteristics were studied. The tests were carried for both desiccators dried and air dried samples. The Terazyme showed improvement in air dried than the desiccator dried samples. From the experiments concluded that after 7 days there is a little increment in liquid limit of the soil. Free swell index decreases very rapidly. The ucs value of both soil material is increased very fast.

# CHAPTER3

# MATERIAL AND METHODOLOGY

### 3.1 MATERIALS

For the present research work, black cotton soil was collected from muddurunagar, Kurnool district Andhra Pradesh by method of distributed method of sampling black cotton soil was collected. Before the digging Top soil layer was removed. Because it contains natural vegetation. The soil was taken at a depth of 1.5-meter for the research work. To know the natural moisture content soil was sealed in a polythene bag. Measures were taken for there is no further loss of moisture content. The collected soil was air dried for 1 day. The air dried soil was pulverized using wooden hammer. The pulverized soil was passed through 4.75 mm sieve. Soil passed through 4.75mm sieve was taken in this research work.

### 3.2 SPECIFICGRAVITY

The ratio of a given volume of a material to the equal volume of displaced liquid is defined as specific gravity. In geotechnical field specific gravity plays an important role. Specific gravity test was conducted according to IS: 2720 (Part 3): Sec 1-1980.

About 50 kg of soil was taken for conducting the specific gravity test. Take the empty weight of the pycnometer and report it as $W_{1.}$ Soil was filled in pycnometer. Weigh the pycnometer and report the weight as $W_2$. After that Bottle was filled with distilled water and placed on sand bath to remove air bubbles. After sometime take out the pycnometer from the sand bath and kept cooling fill the pycnometer up to the mark. Weigh the pycnometer (soil and water) and report it as $W_3$. After that fil the water up to the mark. Take the pycnometer and water weight and report it as $W_{4.}$ Now the specific gravity of the soil is calibrated as for the formula.

### 3.3 LIQUIDLIMIT

Liquid limit test was conducted according to IS: 2720 (part5)-1985. The Soil which is passing through 425-micron sieve was used to conducted the test. About 200 gm of soil is taken in a tray. Some amount of water was mixed to the soil. Soil paste was taken into the casagrande apparatus.by the help of groove a cut was made in middle of the soil. The groove divides the soil paste into two parts along the diameter. After that handle of the device was turned. After the some turns the two parts will join together. Take some amount into container for knowing the moisture content. Note down the corresponding blows. Repeat the test two to three times. Draw a graph between blows vs moisture content. Measure the moisture content corresponding to 25 blows. It is reported as liquid of the soil.

### 3.4 PLASTIC LIMIT TEST

For determination of plastic limit of a soil, sieved through 425 IS sieve. About 30 gm of soil is taken, is mixed thoroughly with distilled water. Take 10 gm of water mixed soil into hand and form a ball. Now the ball was rolled against glass plate with fingers. The ball shape turns into thread shape.do the process until the thread is of size 3 mm size. The rate of rolling was about 80 to 90 strokes per minute. Take the soil into the container to know the moisture content. The water content at which soil thread showing cracks that moisture content was known as plastic limit of the soil.

### 3.5 DRY SIEVE ANALYSIS

Take an amount of 2 kg of soil into container. The measured soil was taken sieve by using 75-micron sieve. The 75-micron sieve was so small. For this we adopted wet sieving. Through wet sieving the sieving time reduces. The sieving was done unto clear water comes out of the sieve. After that take the soil into tray and keep it in oven for drying process. After 24 hours take out from the oven. The residue soil was passed through a series of sieves. Measure the weight on each sieve.

### 3.6 HYDROMETER ANALYSIS

For determining the specific gravity of solids hydrometer can be used as the specific gravity of the soil suspension depends upon the particle size, hydrometer can be used for the particle size analysis. About 50 gm of oven dried soil weighed accurately, transferred to an evaporating dish. sodiumhexameta phosphate was added to the soil (2%). For slurry formation water was added. Then the soaked soil was transferred to dispersion cup and Was stirred for 15 minutes. Then the suspension was poured into the standard measuring flask of 1000ml.The suspension mixed thoroughly by placing a bung on the open end of the jar. The jar is placed on the table and a stop watch is started. The hydrometer is inserted in the suspension and the first reading is taken after 30 sec of the commencement of the sedimentation. Further readings are taken after 1,2,4,8, 15.30minutes. The hydrometer is removed from jar and rinsed with distilled water and floated in a comparison cylinder containing distilled water. Further readings were taken after 1,2,4,8,24 hours reckoned from the beginning of sedimentation.

### 3.7 COMPACTION TEST

Compaction test was conducted according to IS: 2720 (Part 7)-1980. For compaction test soil should pass through 4.75 mm sieve. 2500 gm of oven dried measured soil was taken for doing the compaction test. Predicted amount of water was added to the soil. The soil is placed into the compaction mould in three layers. The soil compaction mould volume was about

1000cc.using hammer for each layer is compacted. For each layer compacting to 25 blows of energy was used.in the initial stages soil weight in the mould increases. After certain moisture content the soil weight decreases. At this stage stops the processes. draw a graph between the moisture content and dry density. The top point on the curve was considered to be max dry density and corresponding moisture content was known as OMC.

### 3.8 MODIFIED PROCTOR TEST

Modified proctor test was performed according to IS: 2720 (Part 7)-1980. For modified proctor test soil should pass through 4.75 mm sieve.3000 gm of oven dried measured soil was taken for doing the modified proctor test. predicted amount of water was added to the soil. The soil is placed into the compaction mould in five layers. The soil compacting mould volume was about 1000cc.using hammer for each layer is compacted. For each layer compacting to 25 blows of energy was used. In the initial stages soil weight in the mould increases. After certain moisture content the soil weight decreases. At this stage stops the processes. Draw a graph between the moisture content and dry density. The top point on the curve was considered to be max dry density and corresponding moisture content was known as OMC.

### 3.9 UNCONFINED COMPRESSION TEST

Modified proctor test was conducted according to IS: 2720 (Part 10)-1991. It is a modification to the triaxial test in which unconfined pressure is kept as zero. The soil specimen is placed unconfined compression test machine. The dial gauge and proving ring are set to zero. The compressive load is applied to the specimen by turning handle. As the handle is turned, the upper plate moves downward causes compression. The compressive force is determined from ring reading and the axial strain is found from the dial gauge reading. Force divided with area gives the stress value.

### 3.10 CONSOLIDATION TEST

Consolidation test was performed to know the, a confined soil was subjected to laterally vertical pressure how the soil specimen volume behaviour changes. Consolidation is essentially time dependent process. The parameters obtained from the consolidation test was used to determine the primary consolidation settlement and secondary consolidation settlement respectively. The test procedure as follows. Consolidation test consists of a loading device. Present study contain fixed ring consolidometer was adopted. Load is placed through a loading head that is placed on the top porous stone. Apply the load the magnitude of pressure p, in such a way that present and previous loading pressure should be constant. As $\Delta p/p = 1$ (where $\Delta p =$increase in pressure and p=the pressure before the increase). After end of the experiment values be placed in appropriate formula to get the coefficient of consolidation, coefficient of volume of compressibility.

### 3.11 SWELLING PRESSURE (CONSOLIDOMETER METHOD)

Expansive soils are known to have great swelling ability because of the presence of swelling dominant clay minerals such as the montmorillonite group. Table 4.2 shows the swelling pressure results of black cotton soil for different dosage of Enzyme. The swelling pressure for untreated soil is 180 $kN/m^2$**,** as addition of enzymes (Terazyme) with different dosage lowers the swelling pressure to 160, and 40, kN/m2 for 7 days and 30 days curing period. This implies that as enzyme is added the lesser the swelling pressure of the compacted soil and hence the more stable the material is. After adding the enzyme, it is also consistent that swelling potential decreases with the amount of stabilizer.

Table 3.1 Properties of black cotton soil

| SL.NO | PROPERTIES | CONFIRMING TO IS CODE | VALUE |
|---|---|---|---|
| 1 | Coefficient of uniformity(Cu) | IS: 2720 (Part 4) -1985 | 2.65 |
| **2** | Coefficient of curvature (Cc) | IS: 2720 (Part 4)-1985 | 0.54 |
| **3** | Specific gravity (G) | IS: 2720 (Part 3)-1980 | 2.65 |
| **4** | Maximum dry density (MDD), kN/$m^3$ | IS: 2720 (Part 7)-1980 | 14.10 |
| **5** | Optimum moisture content (OMC), per cent | IS: 2720 ( Part 7)-1983 | 30.00 |
| **6** | Modified proctor test, kN/$m^3$ | IS: 2720 (Part 8)-1983 | 16.70 |
| **7** | Modified proctor moisture content, per cent | IS: 2720 (Part 8)-1983 | 20.00 |
| **8** | Natural moisture content, per cent | IS: 2720 (Part 2)-1973 | 7.00 |
| **9** | Free swell index, per cent | IS: 2720 (Part 25)-1977 | 78.00 |

| | | | |
|---|---|---|---|
| **10** | Liquid limit ,per cent | IS: 2720 (Part 5)-1985 | 83.00 |
| **11** | Plastic limit, per cent | IS: 2720 (Part 5)-1985 | 35.00 |
| **12** | Unconfined compression test, $kN/m^2$ | IS: 2720 (Part 10)-1991 | 71.00 |
| **13** | classification | IS: 2720 (part 4)-1985 | CH |
| **14** | Swelling pressure, $kN/m^2$ | IS: 2720 (part 41)-1977 | 180 |

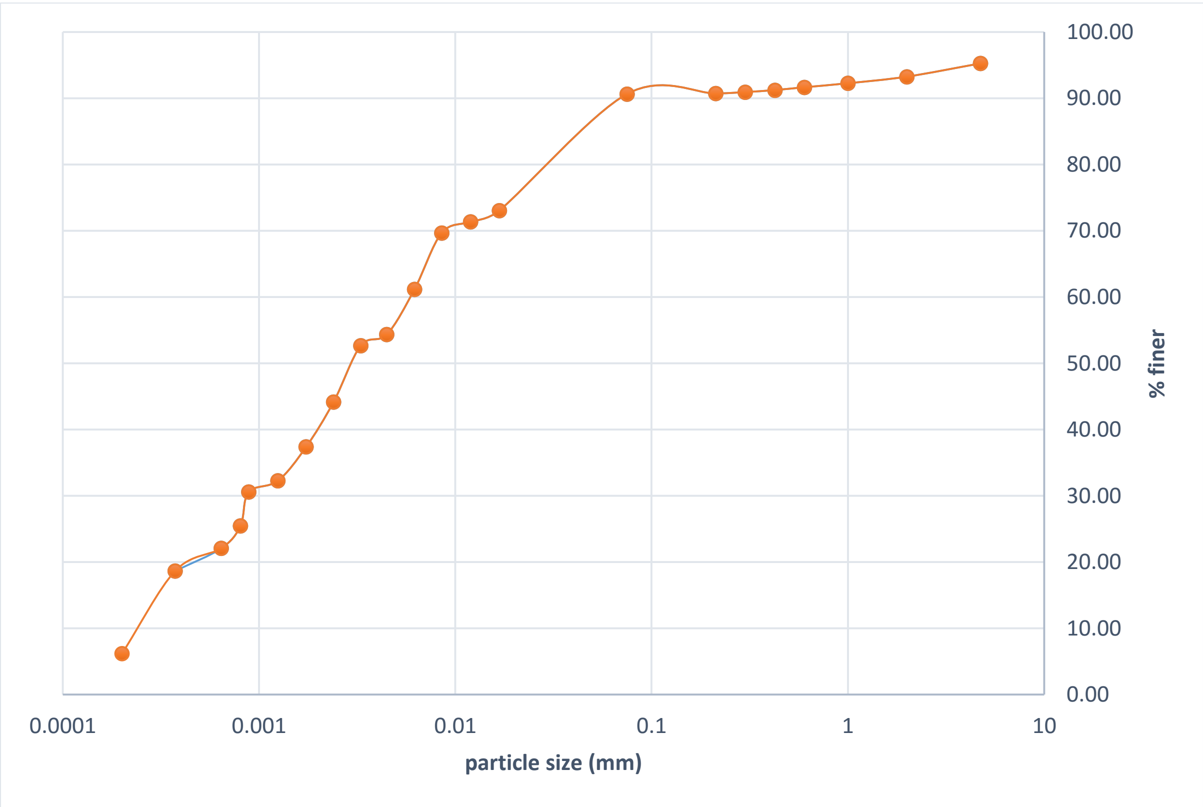



Fig 3.1 Grain size distribution curve

From the graph it is observed that coefficient of uniformity was 2.4 and coefficient of curvature was 0.54

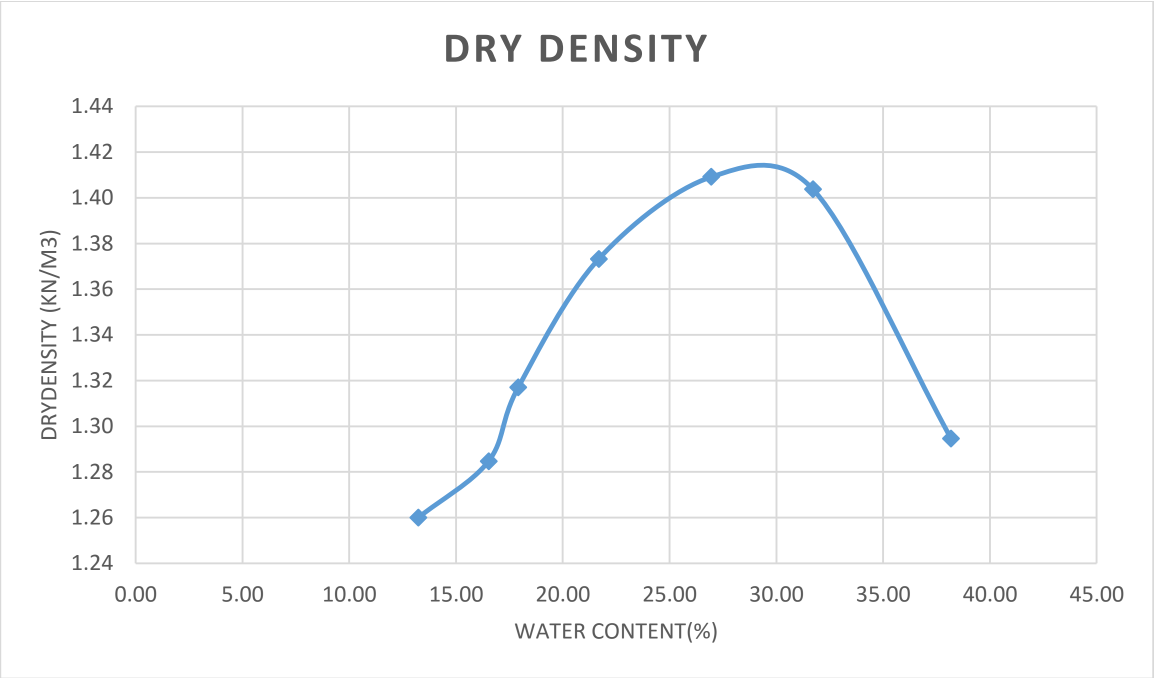



Fig 3.2 Light compaction curve

Maximum dry density (MDD) =14.1kN/m$^3$

Optimum moisture content (OMC) =20%

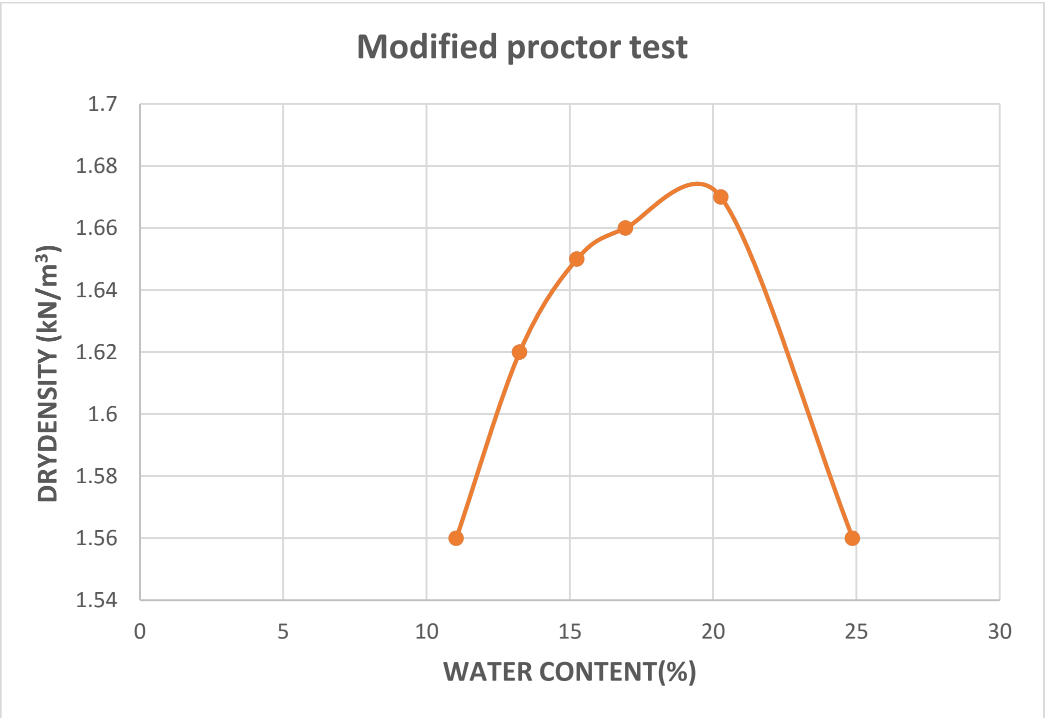



Fig 3.3 water content Vs dry density curve

Maximum dry density (MDD) =16.7kN/m$^3$

Optimum moisture content (OMC) =30%

## Coefficient of Consolidation

The graphical construction suggested by Taylor (1948) has been made use of for computing CV Taylor developed a procedure for evaluating $C_v$, using the square root of time. These data were plotted in Fig 3.4: Usually a straight line can be drawn through the data points in the initial part of the compression curve. The line is projected backward to zero time to define zero time. The common point at R0 may be slightly lower than the initial dial reading (at zero time) observed in the laboratory due to immediate compression of the 1.15 times as large as corresponding values on the first line. The intersection of this second line and the laboratory curve defines R90 and is the point of 90% consolidation. Its time is $T_{90}$.

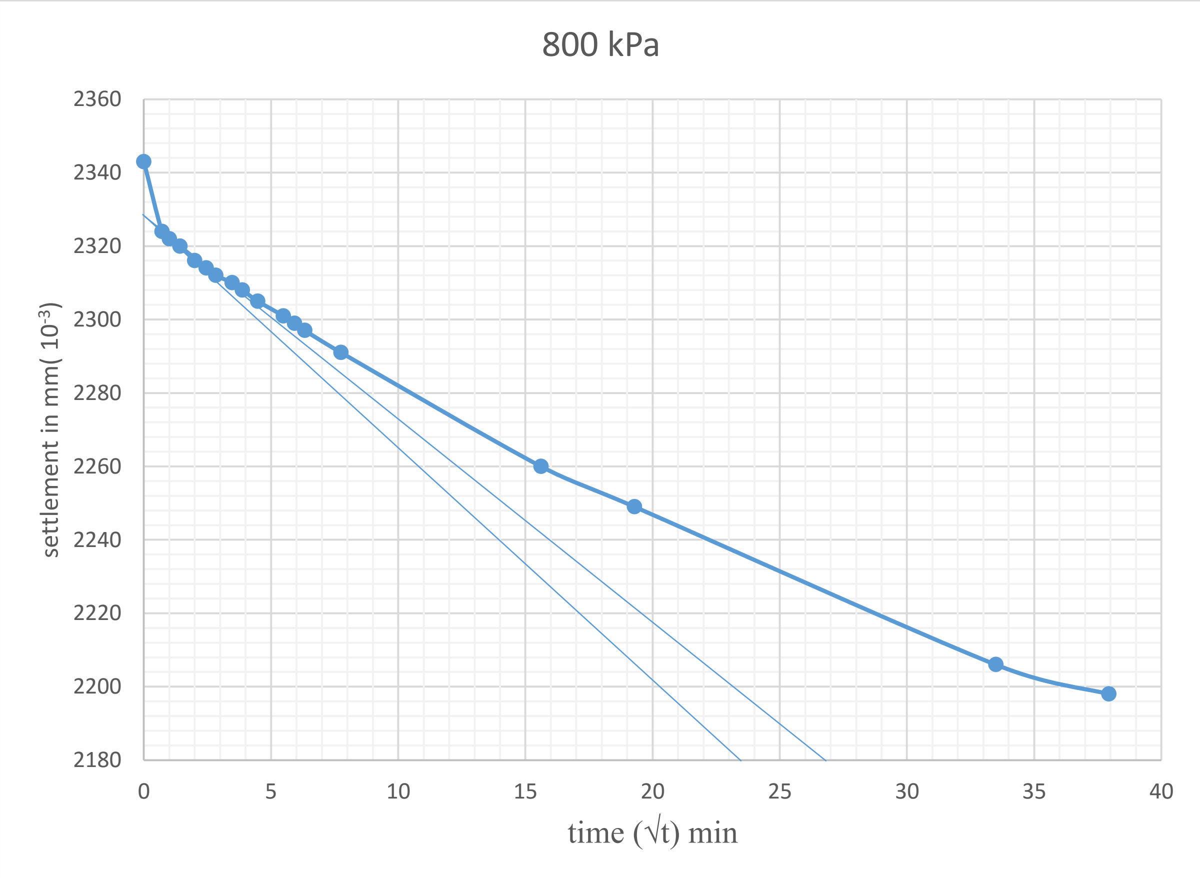



Fig 3.4 Time vs settlement curve for black cotton soil

Coefficient of consolidation signifies the rate at which saturated clay undergoes 1- dimensional analysis when subjected to increase in pressure. Coefficient of consolidation was measured in $cm^2$/sec. From the above graph $\sqrt{t_{90}}$=4 minute consolidation test is carried under double drainage conditions.so drainage path is=1.171 mm. From the above data $c_v$ =33.9$cm^2$/sec.

## Compression index

Compression index curve was plotted stress Vs void ratio. Stress was expressed in kN/m2. Compression indices for untreated and treated enzyme for different curing period discussed below. The compression index of the untreated soil is 0.339, which decreases on treatment with Terazyme

## Untreated soil

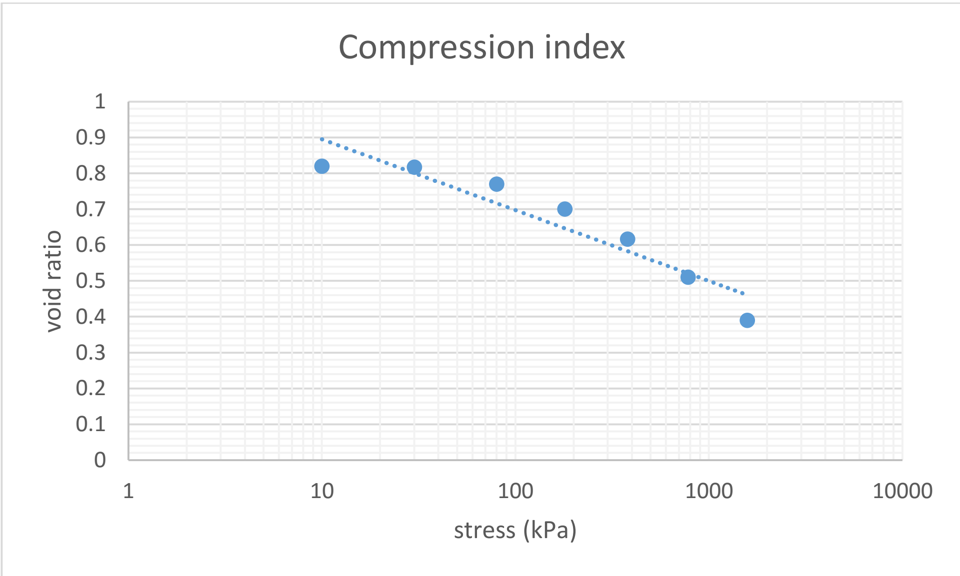



Figure 3.5 compression index curve of untreated soil

From void ratio vs. log ($\sigma$) the coefficient of compressibility =0.335

## 3.12TERAZYME ENZYME

Terazyme is a natural enzyme. Terazyme was prepared from molasses from fermentation process. Terazyme is a nontoxic, eco-friendly non-flammable material. Generally chemical products stored with care. In case of Terazyme no need of special care. While handling Terazyme product no gloves were required. The use of Terazyme in the construction of base and sub-base structures removes the need for the use of a sand/gravel mix, soling or water bound macadam in the construction of road structures. The base and sub-base constructed with Terazyme are built up immediately from the sub-grade level. When compared to conventional structures Terazyme constructed structures showing a much greater flexural strength and a higher CBR % than the conventional structures.

Table3.2 properties of Terazyme

| S.NO | PROPERTY | VALUE OR DESCRIPTION |
|---|---|---|
| 1 | Identity(appeared on label) | N-zyme |
| 2 | Specific gravity | 1.05 |
| 3 | pH value | 3.50 |
| 4 | Appearance/Odour | Dark Brown liquid/ Non-obnoxious |
| 5 | Hazardous components | None |
| 6 | Boiling point | $100^0$c |
| 7 | Evaporation rate | Same as water |
| 8 | Solubility in water | Complete |
| 9 | Melting point | Liquid |
| 10 | Reactivity data | Stable |
| 11 | Materials to avoid | Caustics and strong bases |

The soil was mixed with different dosages of enzyme for different prefixing periods such as 7, 14, 21, 28 and 60 days. With enzymatic soil tests to be performed to know the suitability of enzyme. The dosage of the enzyme was calculated as follows.

Dry density of the present investigated soil was 14.1 kN/$m^3$. Density was defined as the ratio between weight to volume. Asper this

Dry density =weight/volume from this

Weight =volume x dry density

According to manufacture suggested that the Terazyme dosage for 2 $m^3$ to 3$m^3$ .to determine the optimum dosage following dosages are used for conducting test.

From the literature study the dosage were calculated as follows.

For Dosage 1

200 ml for 3.5 $m^3$ of soil = 1.41 x 3.5 x 1000 = 49355 kg of soil

For 1 kg = 0.040 ml of Enzyme

For Dosage 2

200 ml for 3.0 $m^3$ of soil = 1.41x 3.0 x 1000 = 4230 kg of soil

For 1 kg = 0.047 ml of Enzyme

For Dosage 3

200 ml for 2.5 $m^3$ of soil = 1.41 x 2.5 x 1000 = 3525 kg of soil

For 1 kg = 0.056 ml of Enzyme

For Dosage 4

200 ml for 2.0 $m^3$ of soil =1.41 x 2 x1000 =2820 kg of soil

For Dosage 5

200 ml for 1.5 $m^3$ of soil =1.41 x 1.5 x1000 =2115 kg of soil

For 1 kg = 0.094 ml of Enzyme

# CHAPTER4

# RESULTS AND DISCUSSION

Varying quantities of stabilizers can cause different effect in the same soil sample. Insufficient quantity of Enzyme (Terazyme) may lead to less stabilization of the soil where as excess quantities may result the stabilization ineffective and uneconomical. Hence, to determine the optimum quantity of Enzyme for best results, UCS, Swell pressure, consistency limit tests were conducted on each of the soil samples with varying quantity of Enzyme (Terazyme).

## 4.1 CONSISTENCY LIMITS

The effect of Enzyme at different dosage on index properties (Liquid limit, Plastic limit and Plasticity index) of investigating soils have been presented in Table 4.1. From this table 4.1 it is observed that liquid limit decreases marginally and plastic limit also decreases marginally. Terazyme is found to be insignificant for improving consistency limits.

Table 4.1 Consistency limits of enzymatic soil

| **Dosage number** | **Enzyme dosage** | **Liquid limit (%)** | | **Plastic limit (%)** | | **Plasticity index** | |
|---|---|---|---|---|---|---|---|
| **0** | **Un treated Black cotton soil** | 83.50 | | 35.54 | | 47.96 | |
| | | 7 days | 14 days | 7 days | 14 days | 7 days | 14 days |
| **1** | **200 ml/3.0 m$^3$** | 82.80 | 81.50 | 35.00 | 35.00 | 47.80 | 46.50 |
| **2** | **200 ml/3.0 m$^3$** | 82.10 | 80.50 | 34.20 | 33.50 | 47.90 | 47.00 |
| **3** | **200 ml/2.5 m$^3$** | 80.20 | 80.10 | 34.40 | 33.00 | 45.80 | 47.00 |
| **4** | **200 ml/2.0 m$^3$** | 80.00 | 79.00 | 34.50 | 32.00 | 45.50 | 47.00 |
| **5** | **200 ml/1.5 m$^3$** | 79.00 | 77.00 | 34.30 | 31.50 | 44.70 | 45.50 |

## 4.2UNCONFINED COMPRESSIVE STRENGTH (UCS)

For tests of specimen of soil– Terazyme mixtures, specimens were prepared by thoroughly mixing the required quantity of soil and Terazyme as per preselected proportion in dry state and then calculated quantity of water to be sprinkled and mixed thoroughly to get a homogeneous and uniform mixture of soil and Terazyme, and the test results obtained are discussed as follows.

Unconfined compressive strength of black cotton was evaluated by stabilization with variable dosages of enzyme for 0, 7, 14, 21, 28 and 60 days curing. The specimens were prepared and kept in desiccator to retain moisture of the sample so that reaction between soil particle and enzyme would be continued. Numbers of samples were tested with different dosage of enzyme i.e., 200 ml for 1.5, 2.0, 2.5, 3.0, 3.5 $m^3$. The results of the UCS tests for natural and treated soil compacted at maximum dry density and optimum moisture content


Fig 4.1 Experimental setup for UCS

Fig 4.2 Failure pattern of the specimen

Table 4.2 UCS of black cotton soil with curing period

| Dosage number | Dosages | UCS of soil in (kPa) for period of treatment | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0 day Curing | 7 days curing | 14 days curing | 21 days curing | 28 days curing | 56 days curing |
| **0** | **Un Treated** | 71 | | | | | |
| **1** | **200 ml/3.5 $m^3$** | 96 | 120 | 136 | 145 | 165 | 224 |
| **2** | **200 ml/3.0 $m^3$** | 113 | 131 | 135 | 154 | 184 | 242 |
| **3** | **200 ml/2.5 $m^3$** | 117 | 139 | 167 | 177 | 212 | 272 |
| **4** | **200 ml/2.0 $m^3$** | 121 | 186 | 212 | 224 | 277 | 313 |
| **5** | **200 ml/1.5 $m^3$** | 125 | 173 | 201 | 211 | 248 | 262 |

### 4.2.1 Effect of 200 ml/3.5m$^3$ Enzyme on unconfined compressive strength of black cotton soil

The effect on unconfined compressive strength with curing period of 0, 7, 14, 21, 28 and 60 days for addition of 200 ml/3.5m$^3$ Terazyme dosage were illustrated in this section. Below fig 4.3 shows the effect of Terazyme on the stress-strain behaviour of the black cotton soil specimens tested for UCS. From the Fig 4.3 we observe that, the treated black cotton soil specimens failed at a stress of 96, 120, 136, 145, 165 and 224 kPa for 0, 7, 14, 21, 28 and 60 days curing respectively. The 200 ml/3m$^3$ Terazyme dosage treated soil specimen failed at an optimum stress 224 kPa at 60 days curing period where curing has positive effect on unconfined compressive strength ($q_u$).

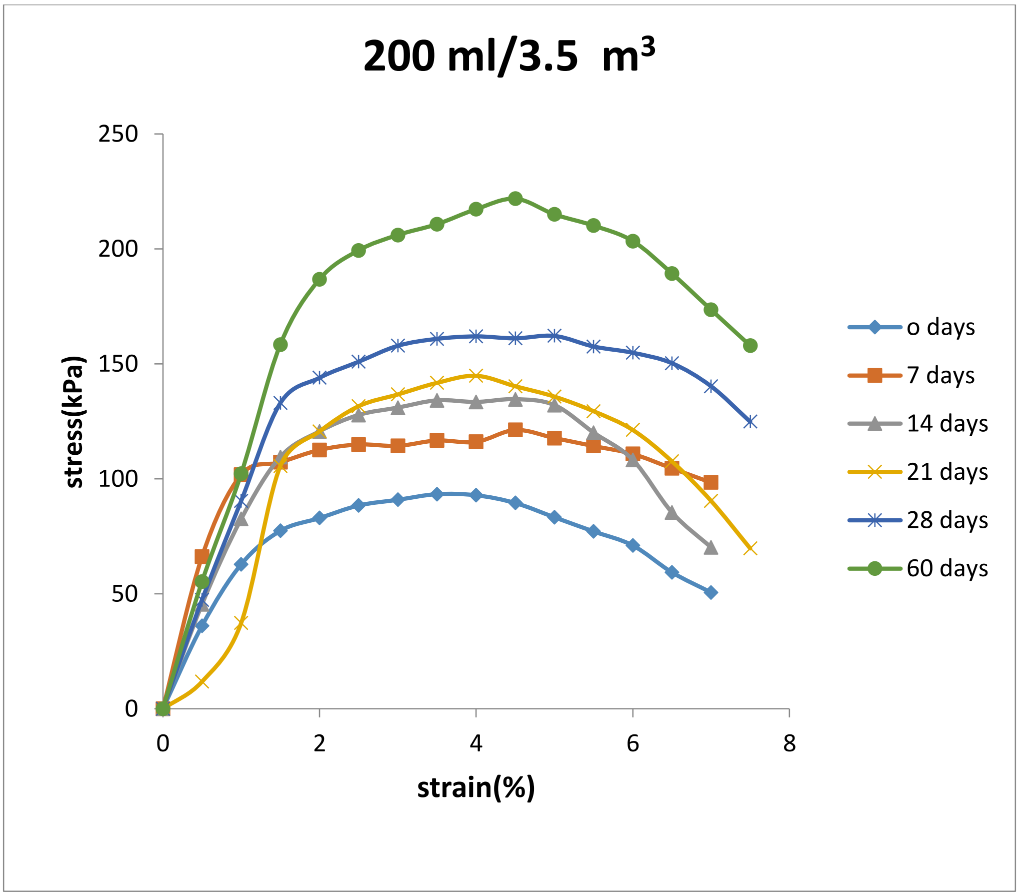



Fig 4.3 Variation in UCS of 200 ml/3.5 m$^3$ enzyme treated BC soil.

### 4.2.2 Effect of 200 ml/3.0m$^3$ Enzyme on unconfined compressive strength of black cotton soil

The effect on unconfined compressive strength with curing period of 0, 7, 14, 21, 28 and 60 days for addition of 200 ml/2m$^3$ Enzyme are illustrated in this topic. Fig 4.4 shows the effect of enzymes on the stress-strain behaviour of the black cotton soil specimens tested for UCS.

(i) From the fig 4.4 we observe that, the treated black cotton soil specimens failed at a stress of 113, 131, 135, 154, 184 and 242 kPa for 0, 7, 14, 21, 28 and 60 days curing respectively.

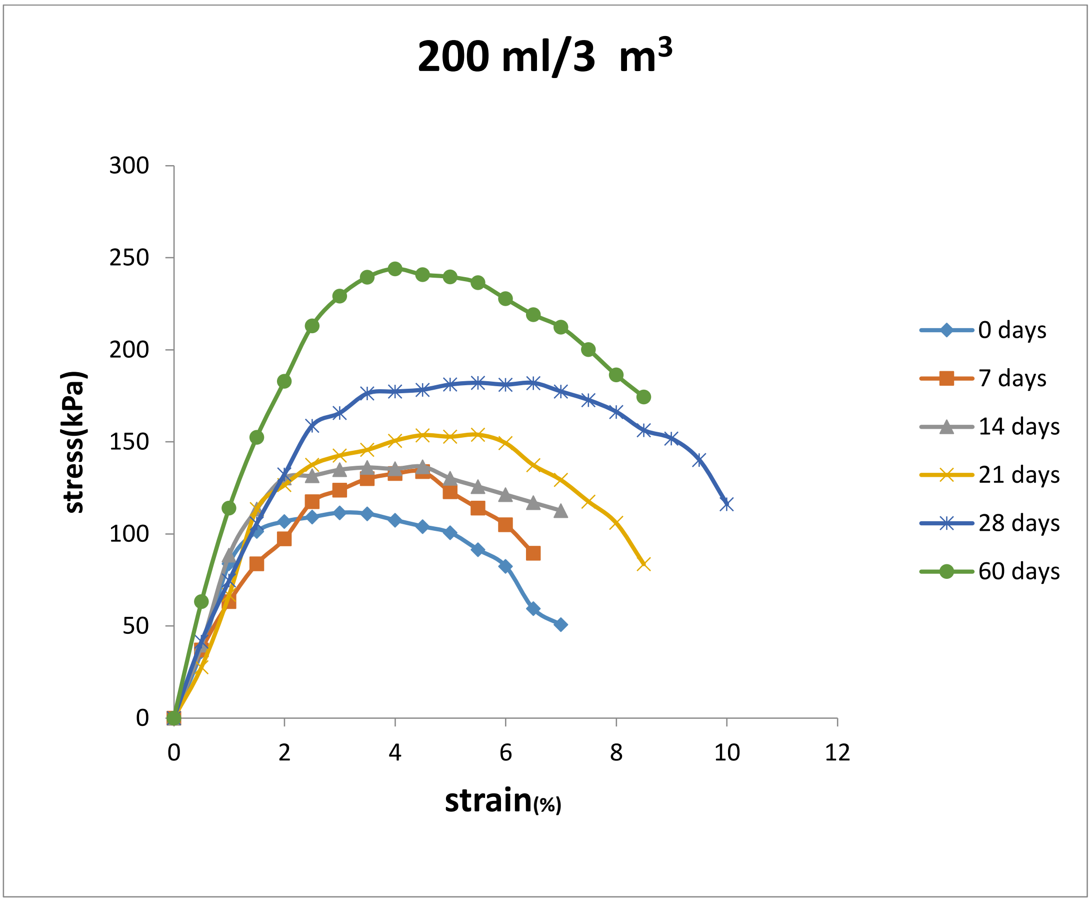



Fig 4.4 Variation in UCS of 200 ml/3.0 m$^3$ enzyme treated BC soil.

### 4.2.3 Effect of 200 ml/2.5m$^3$ Enzyme on unconfined compressive strength of black cotton soil

The effect on unconfined compressive strength with curing period of 0, 7, 14, 21, 28 and 60 days for addition of 200 ml/2.5m$^3$ Enzyme are illustrated in this topic. Fig 4.5 shows the effect of enzymes on the stress-strain behaviour of the black cotton soil specimens tested for UCS.

(i) From the Fig 4.5 we observe that, the treated black cotton soil specimens failed at a stress of 117, 139, 167, 177, 212 and 272 kPa for 0, 7, 14, 21, 28 and 60 days curing respectively.

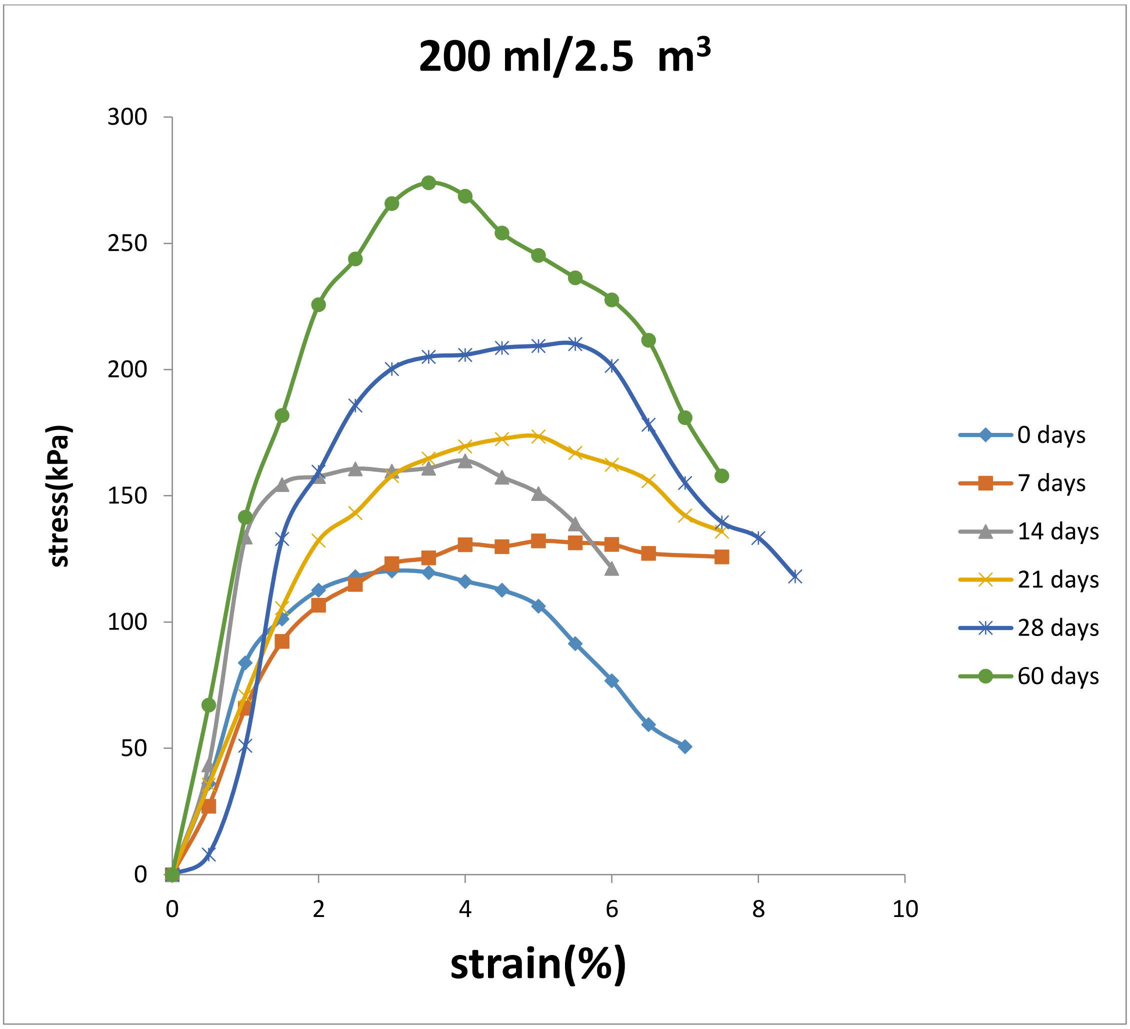



Fig 4.5 Variation in UCS of 200 ml/2.5 m$^3$ enzyme treated BC soil.

### 4.2.4 Effect of 200 ml/2m$^3$ Enzyme on unconfined compressive strength of black cotton soil

The effect on unconfined compressive strength with curing period of 0, 7, 14, 21, 28 and 60 days for addition of 200 ml/2m$^3$ Enzyme are illustrated in this topic. Fig 4.6 shows the effect of enzymes on the stress-strain behaviour of the black cotton soil specimens tested for UCS.

(i) From the Fig 4.6 we observe that, the treated black cotton soil specimens failed at a stress of 121, 186, 212, 224, and 277 and 313 kPa for 0, 7, 14, 21, 28 and 60 day's curing period respectively.

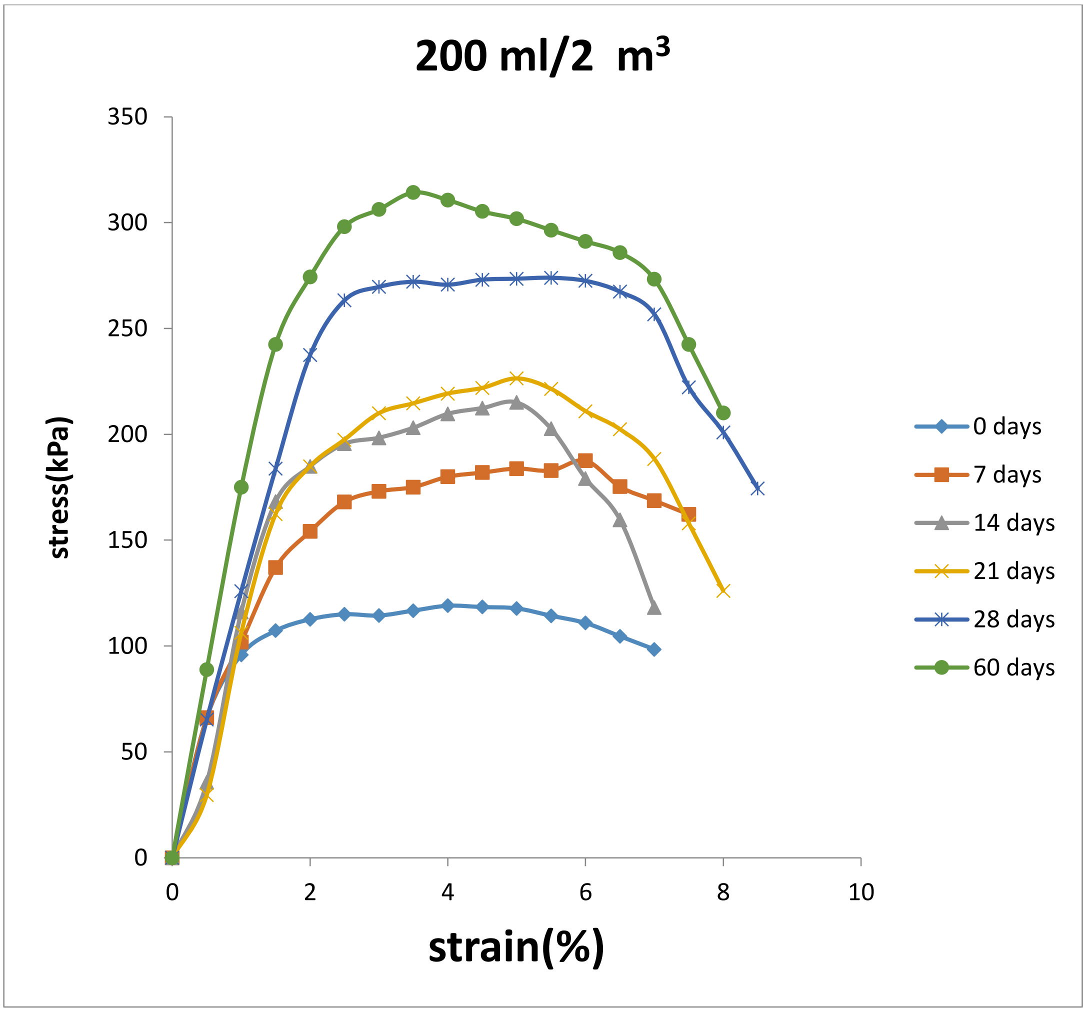



Fig 4.6 Variation in UCS of 200 ml/2 m$^3$ enzyme treated BC soil.

### 4.2.5 Effect of 200 ml/1.5m$^3$ Enzyme on unconfined compressive strength of black cotton soil

The effect on unconfined compressive strength with curing period of 0, 7, 14, 21, 30 and 60 days for addition of 200 ml/1.5m$^3$ Enzyme are illustrated in this topic. Fig 4.7 shows the effect of enzymes on the stress-strain behaviour of the black cotton soil specimens tested for UCS.

From the Fig 4.7 we observe that, the treated black cotton soil specimens failed at a stress of 125, 173, 201, 211, 248 and 262 kPa for 0, 7, 14, 21,30 and 60 days curing respectively.

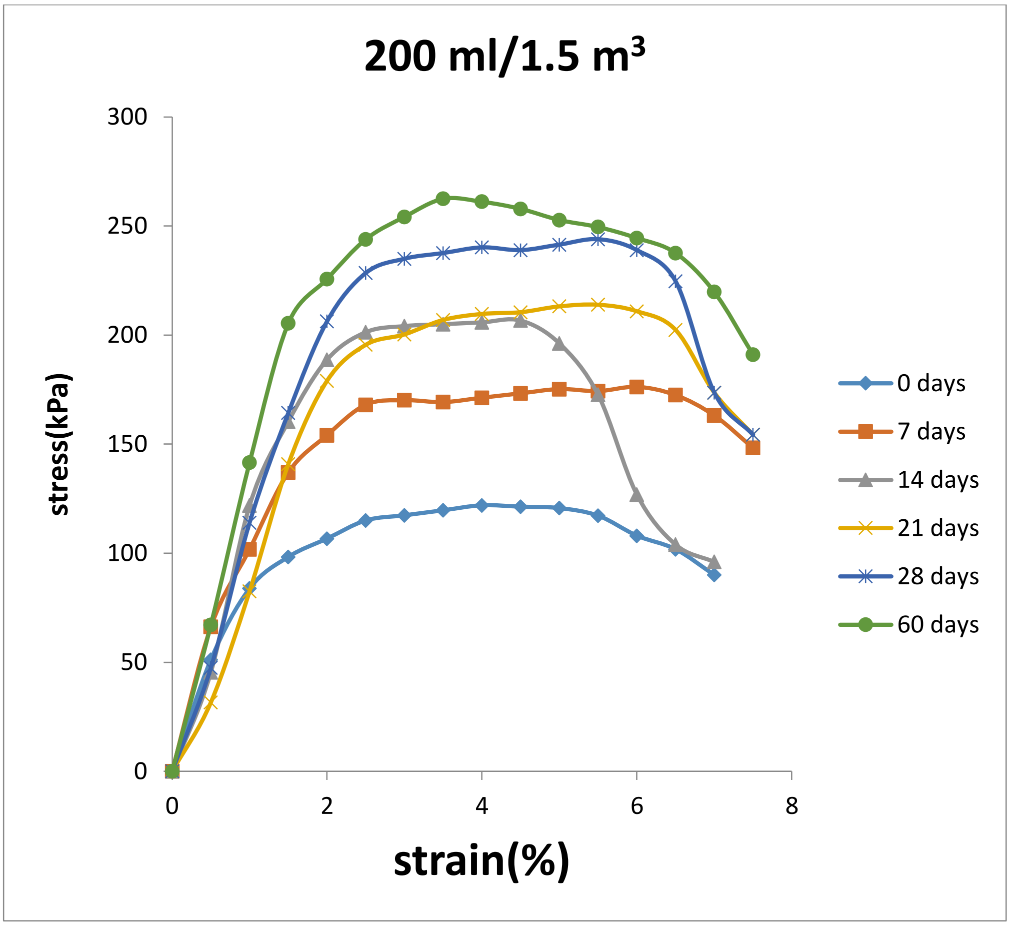



Fig 4.7 Variation in UCS of 200 ml/1.5 m$^3$ enzyme treated BC soil.

### 4.2.6 Effect of different dosage of Terazyme on UCS values for different curing period

Fig 4.8 shows the UCS results of black cotton soil for different curing periods with different dosage of Terazyme. Fig 4.8 shows uniform increment in UCS along with increase in curing period, for untreated soil, UCS value increases as curing period increases up to 60 days for dosage number 1 and 2 there is uniform increase in UCS value along with curing period, and dosage number 3 and 4 shows similar trend along with curing period, strength gains have been much improved for dosage number 3 and 4 compared to dosage 1 and 2.

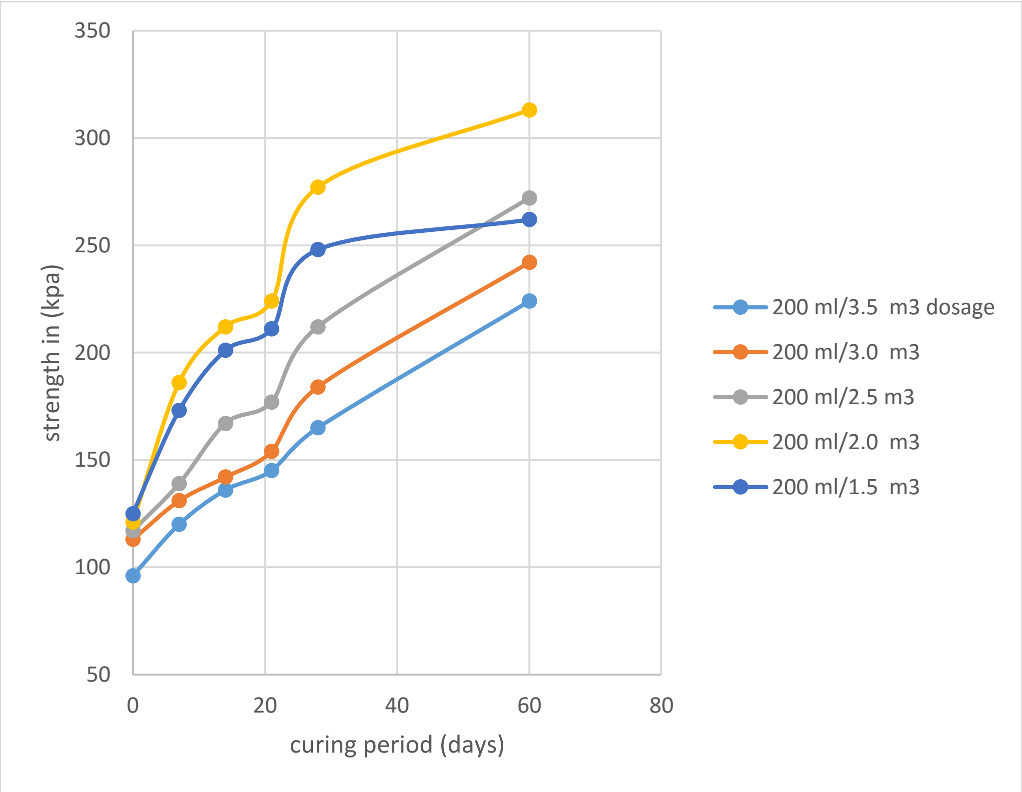



Fig 4.8 Variation of UCS for different curing period on black cotton soil

For zero days of curing with different dosage (1, 2, 3, 4 and 5) indicates the marginal change in the UCS value and similarly for dosage 1 to 2 and 3 to 4 increases in UCS value is not significant for curing period of 7, 14, 21 and 30 days of curing. From the figure 4.8 it can be concluding that for curing period of 60 days is more significant for all dosage of Terazyme.

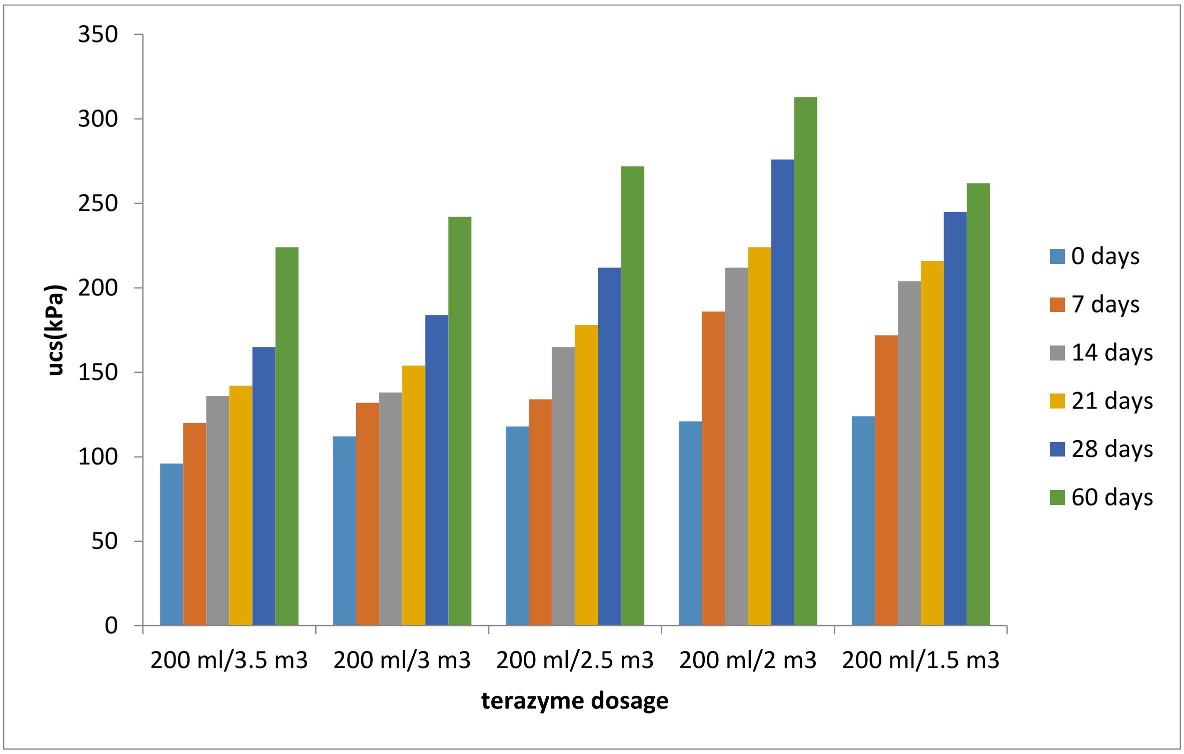



Fig 4.9 Bar chart showing variation of UCS for different curing period on black cotton soil

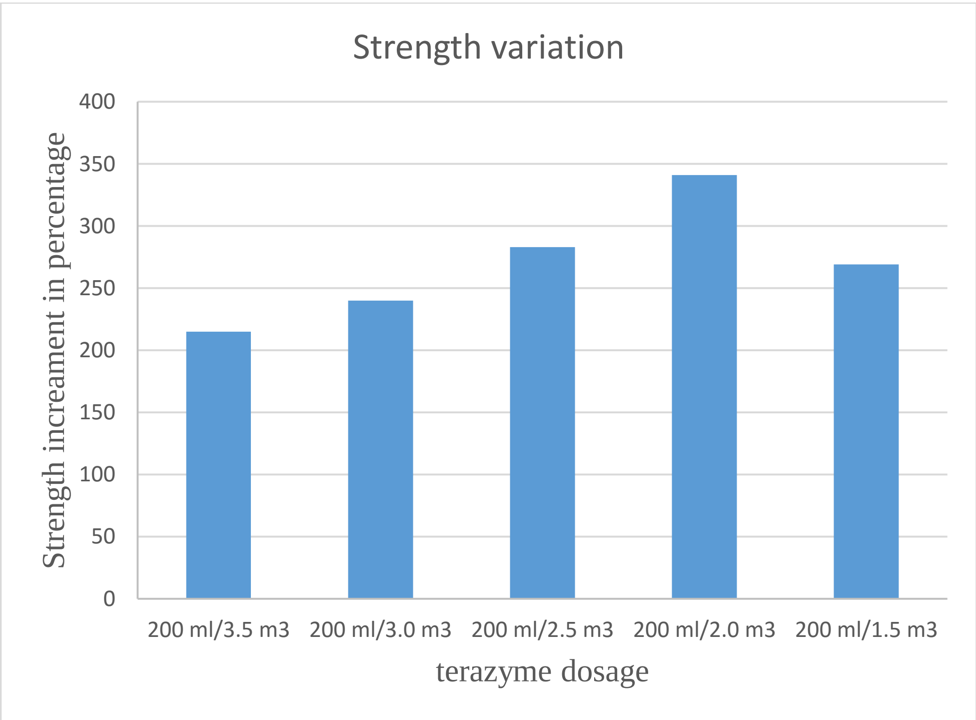



Fig 4.10 Strength increment in percentage

### 4.3 SWELLING PRESSURE (CONSOLIDOMETER METHOD)

Expansive soils are known to have great swelling ability because of the presence of swelling dominant clay minerals such as the montmorillonite group. Table 4.2 shows the swelling pressure results of black cotton soil for different dosage of Enzyme. The swelling pressure for untreated soil is 180 kN/m$^2$**,** as addition of enzymes (Terazyme) with different dosage lowers the swelling pressure to 160 and 40 kN/m$^2$ for 7 days and 14 days curing period. This implies that as enzyme is added the lesser the swelling pressure of the compacted soil and hence the more stable the material is. After adding the enzyme, it is also consistent that swelling potential decreases with the amount of stabilizer.

Table 4.2 Swell pressure test of black cotton soil with different enzyme dosage

| **Dosage number** | **Enzyme dosage** | **Swelling pressure (kN/m$^2$)** | | |
|---|---|---|---|---|
| **0** | **untreated** | 180 | | |
| **1** | **200 ml/2.5 m$^3$** | 7 days | 14days | 30days |
| | | 160 | 120 | 52 |
| **2** | **200 ml/3.5 m$^3$** | 162 | 127 | 64 |

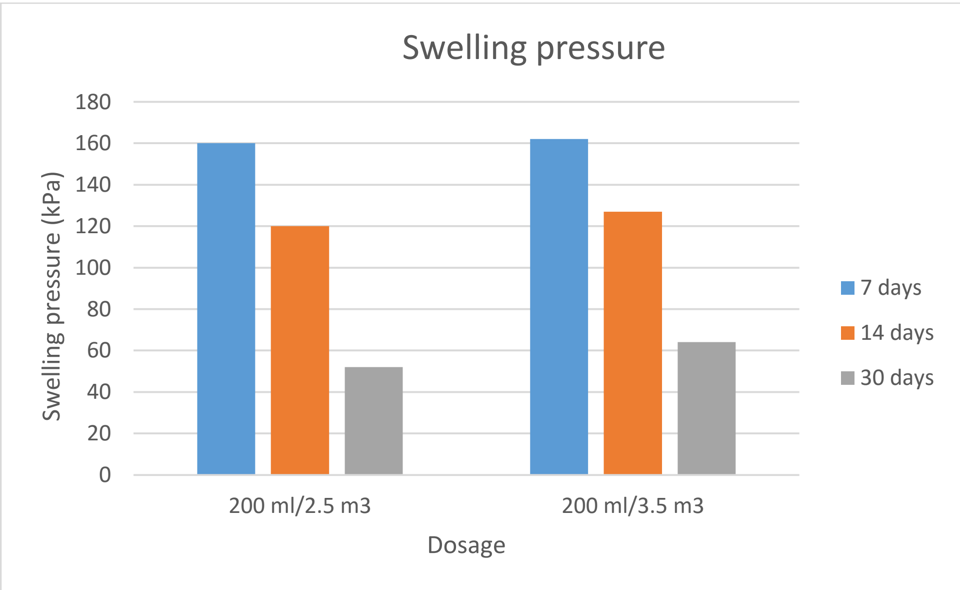



Fig 4.11 Variation in swelling pressure for different curing period

### 4.4 ENZYME TREATED SOIL:

Enzyme was added to the soil and compacted at max dry density at optimum moisture content. The soil was under curing conditions, there is no further loss of moisture content. Below fig 4.12 and fig 4.13 were 7 days curing period

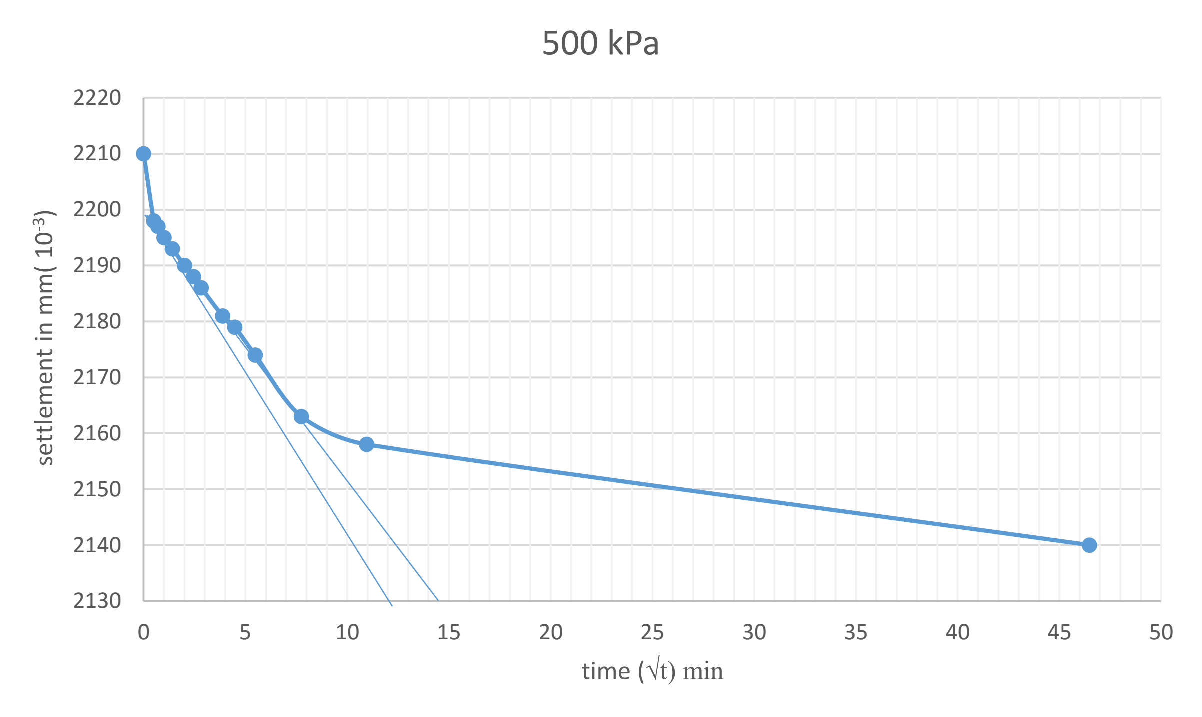


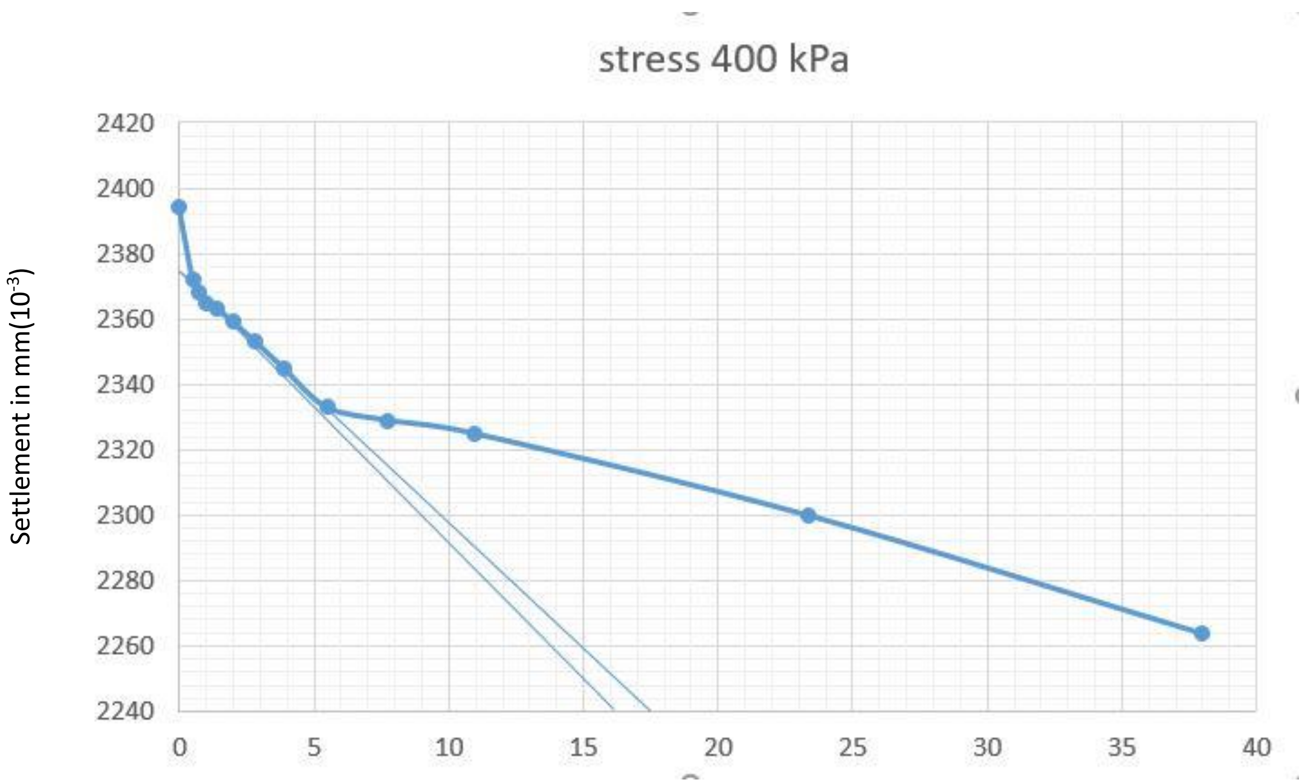

Fig 4.12 Coefficient of consolidation curve of an enzymatic soil for a dosage of 3

From the above graph $\sqrt{t_{90}}$=9.5 min

The consolidation test is carried under double drainage conditions.

drainage path is=13.145 mm

From the above data $c_v$ =2.7 $cm^2$/sec.




time (√t) min

Fig 4.13 Coefficient of consolidation curve of an enzymatic soil for a dosage 1

From the above graph $\sqrt{t_{90}}$=5.45 min

The consolidation test is carried under double drainage conditions.

drainage path is=13.145 mm

From the above data $c_v$ =27 $cm^2$/sec.

## 14 days curing period:

In similar fashion Terazyme is added to the soil and compacted to MDD value, kept for 14 days curing such that no loss of moisture content. For 14 days' experiment program corresponding graph as shown below.

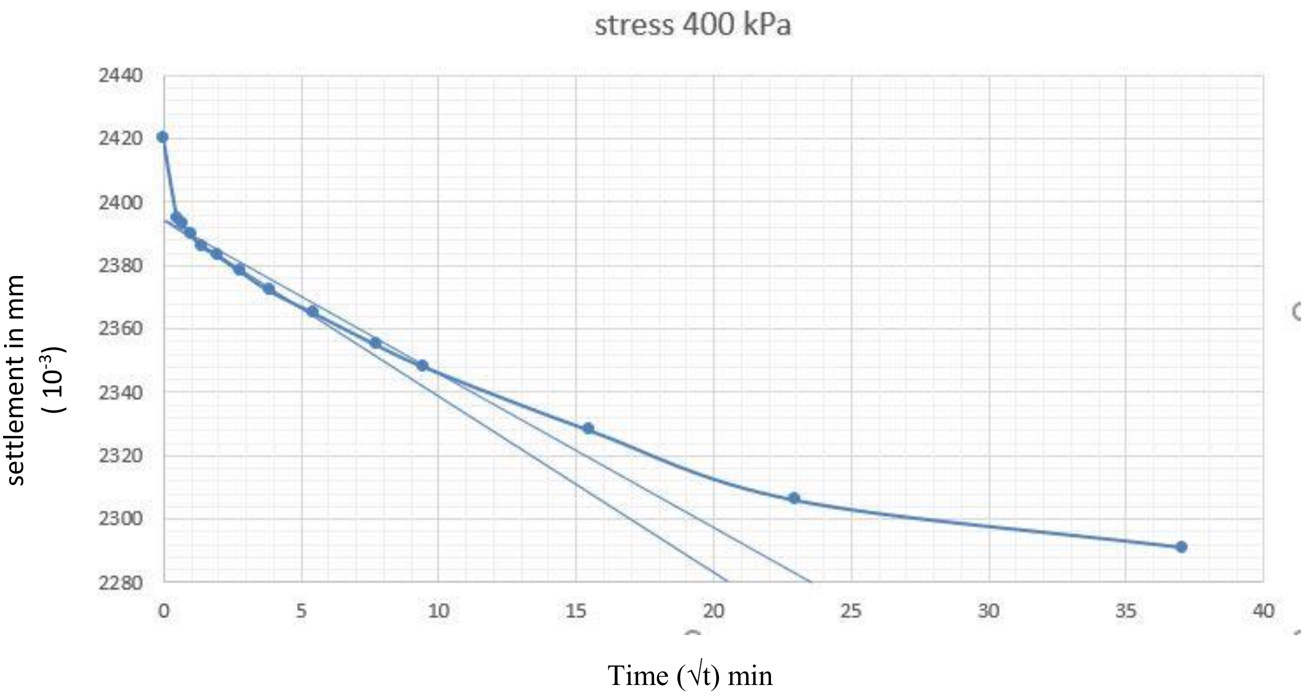



Fig 4.14 Coefficient of consolidation curve of an enzymatic soil for a dosage 3

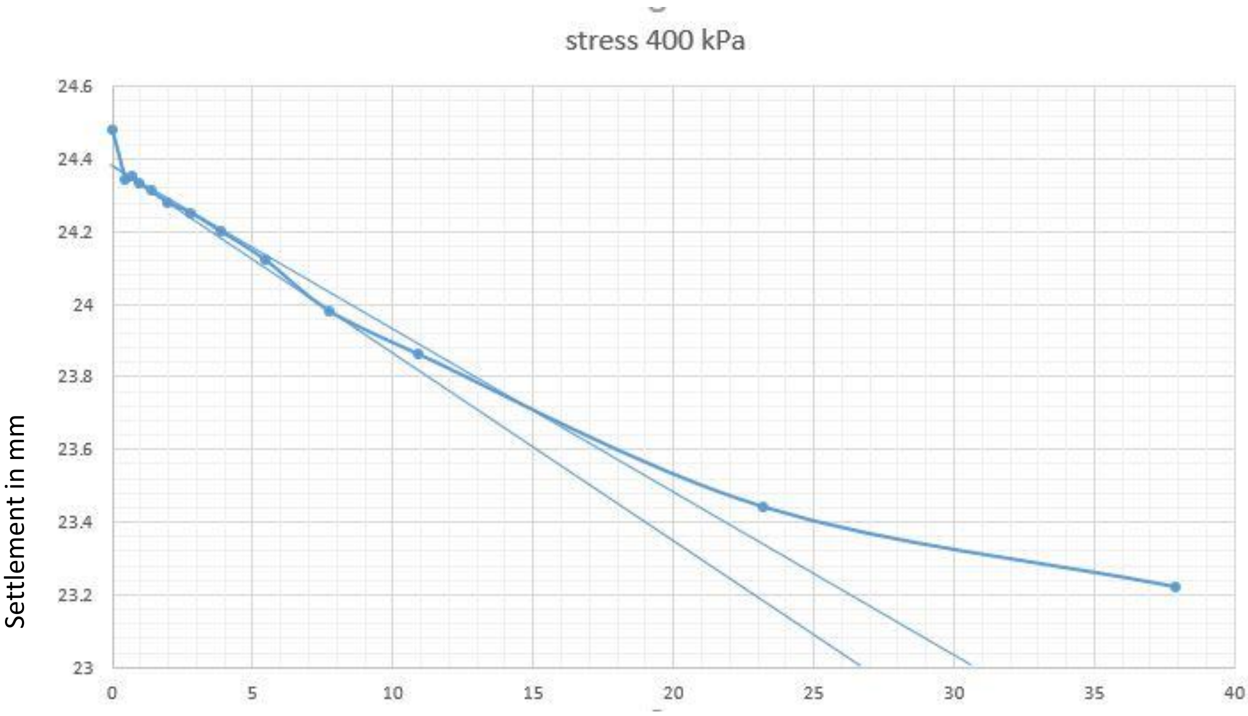
From the above graph $\sqrt{t_{90}}$=9.948 min

The consolidation test is carried under double drainage conditions.

So drainage path is=12.43 mm

From the above data $c_v$ =2.2 $cm^2$/sec.

From above figures it is observed that coefficient of consolidation decreases with the addition of enzyme.




time (√t) min

Fig 4.15 Coefficient of consolidation curve of an enzymatic soil for a dosage 1

From the above graph $\sqrt{t_{90}}$=4.5 min

The consolidation test is carried under double drainage conditions.

The drainage path is=13.1725 mm

From the above data $c_v$ =12.1 $cm^2$/sec.

From above figures it is observed that coefficient of consolidation decreases with the addition of enzyme.

## 30 days curing period:

In similar fashion Terazyme is added to the soil and compacted to MDD value, kept for 17 days curing such that no loss of moisture content. For 14 days' experiment program corresponding graph as shown below.

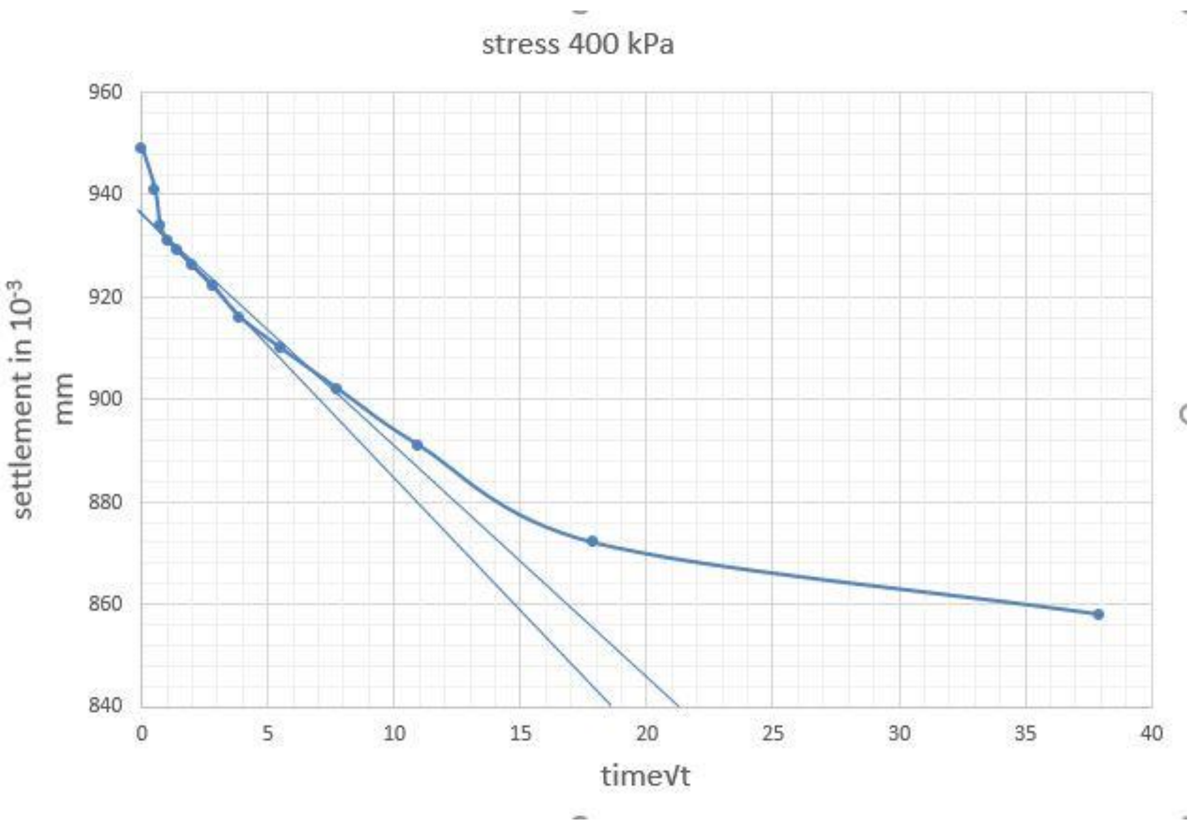



Fig 4.16 Coefficient of consolidation curve of an enzymatic soil for a dosage 3

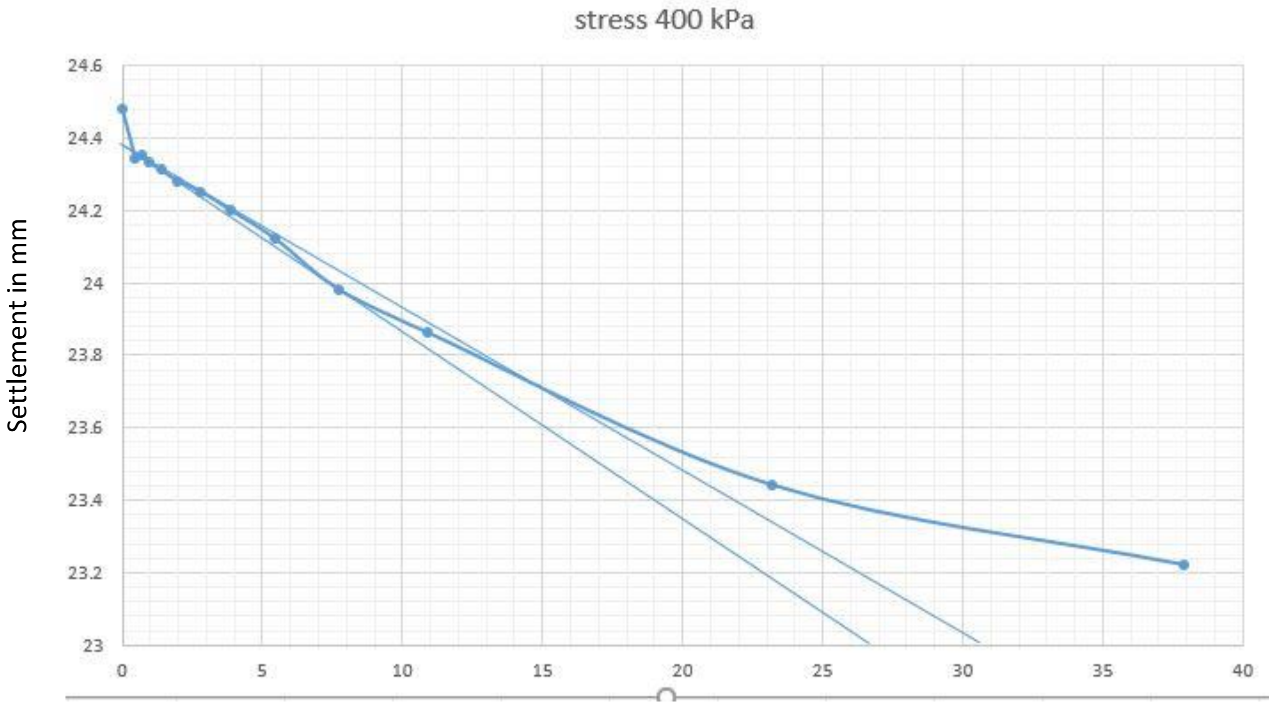
From the above graph $\sqrt{t_{90}}$=7.745 min

The consolidation test is carried under double drainage conditions.

So drainage path is=9.035 mm

From the above data $c_v$ =0.583 cm$^2$/sec.

From above figures it is observed that coefficient of consolidation increases with the curing period.




time (√t) min

Fig 4.17 Coefficient of consolidation curve of an enzymatic soil for a dosage1

From the above graph $\sqrt{t_{90}}$=15 min

The consolidation test is carried under double drainage conditions.

So drainage path is=13.11 mm

From the above data $c_v$ =1 $cm^2$/sec.

From above data it is observed that coefficient of consolidation decreases with the addition of enzyme.

Table 4.3 Coefficient of consolidation values of stabilized soil

| **Sl no** | DOSAGE | **Coefficient of consolidation ($cm^2$/sec)** | | |
|---|---|---|---|---|
| | Untreated | 33.9 | | |
| | Curing period, days | 7 | 14 | 30 |
| 1 | 200 ml/2.5 $m^3$ | 2.7 | 2.2 | 0.583 |
| 2 | 200ml/3.5 $m^3$ | 27 | 12.1 | 1 |

## Compression index:

Compression indices for untreated and treated enzyme for different curing period discussed below. The compression index of the untreated soil is 0.339, which decreases on treatment with Terazyme

**With enzyme:** The soil is treated with enzyme for dosage 200 ml/2.5 $m^3$ and for dosage of 200 ml/3.5 $m^3$ for 7, 14 and 30 days were tested. For dosage 200 ml/2.5 $m^3$ 7 days' compression index is 0.25. For dosage of 200 ml/3.5 $m^3$ 7 days' compression index is 0.27. The graphs corresponding to compression index as shown below.

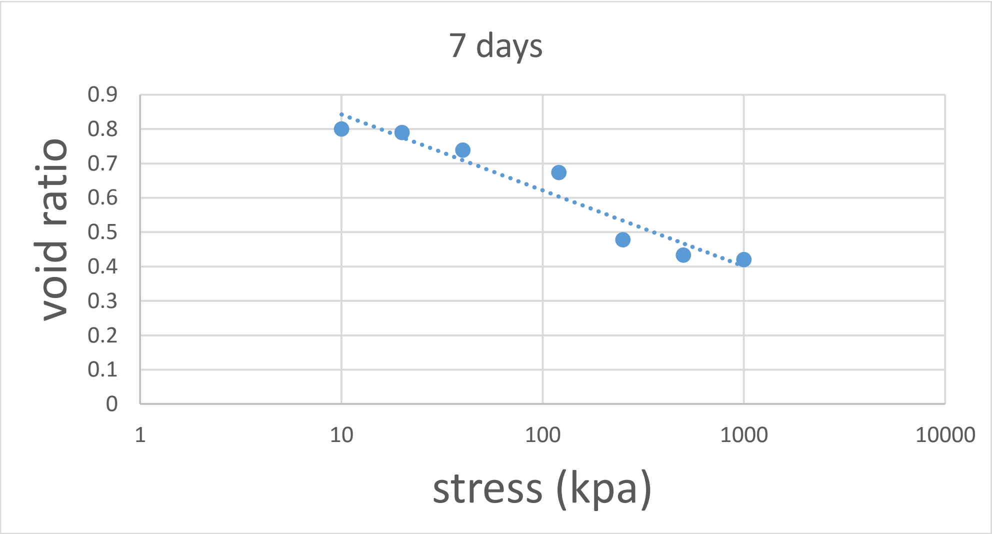



Fig 4.18 Compresiion index curve for a dosage 3

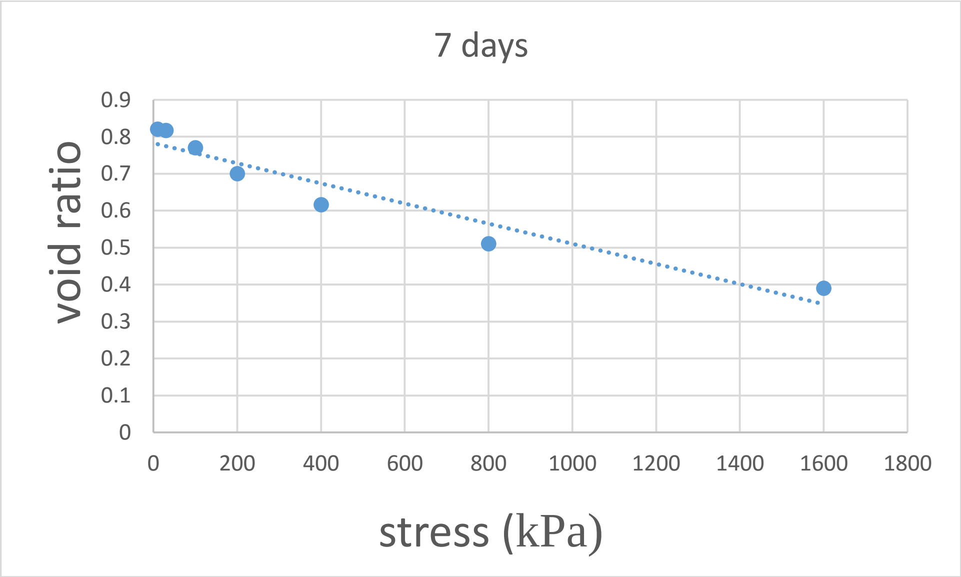



Fig 4.19 Compresiion index curve for a dosage 1

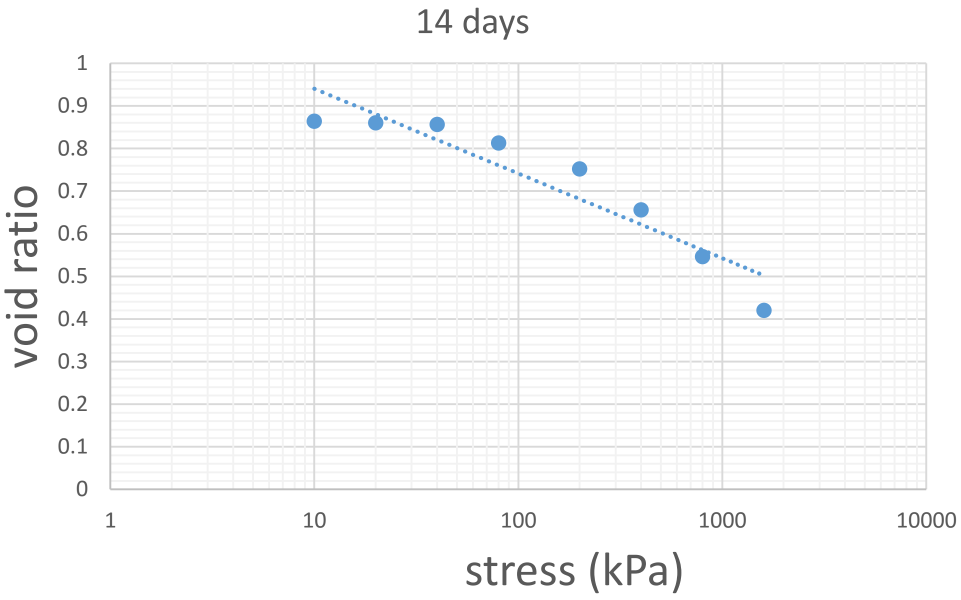



Fig 4.20 Compresiion index curve for a dosage 3

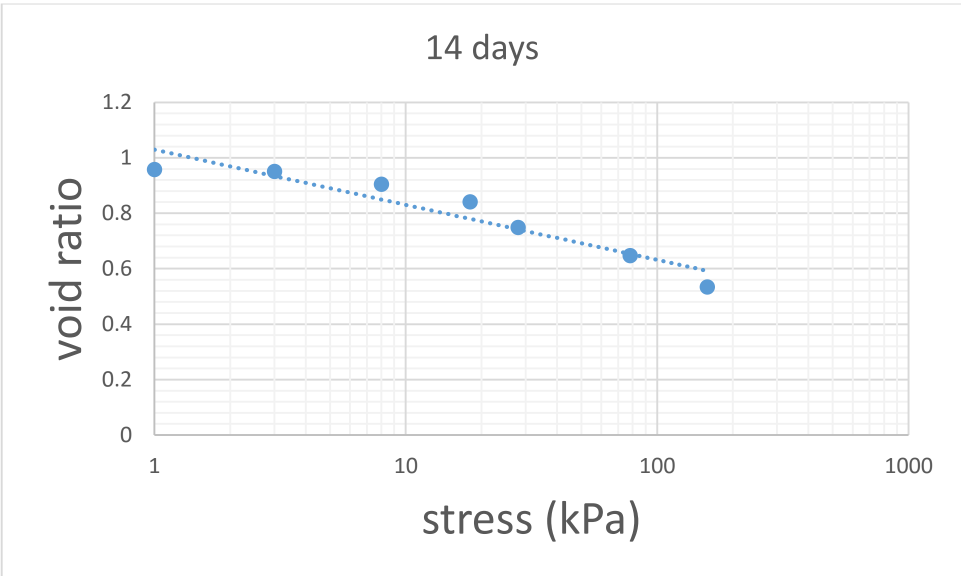



Fig 4.21 Compresiion index curve for a dosage 1

For 14 days the compression index corresponding to dosage 200 ml/2.5 $m^3$ is 0.199 and for dosage of 200 ml/3.5 $m^3$ is 0.23.

30 days

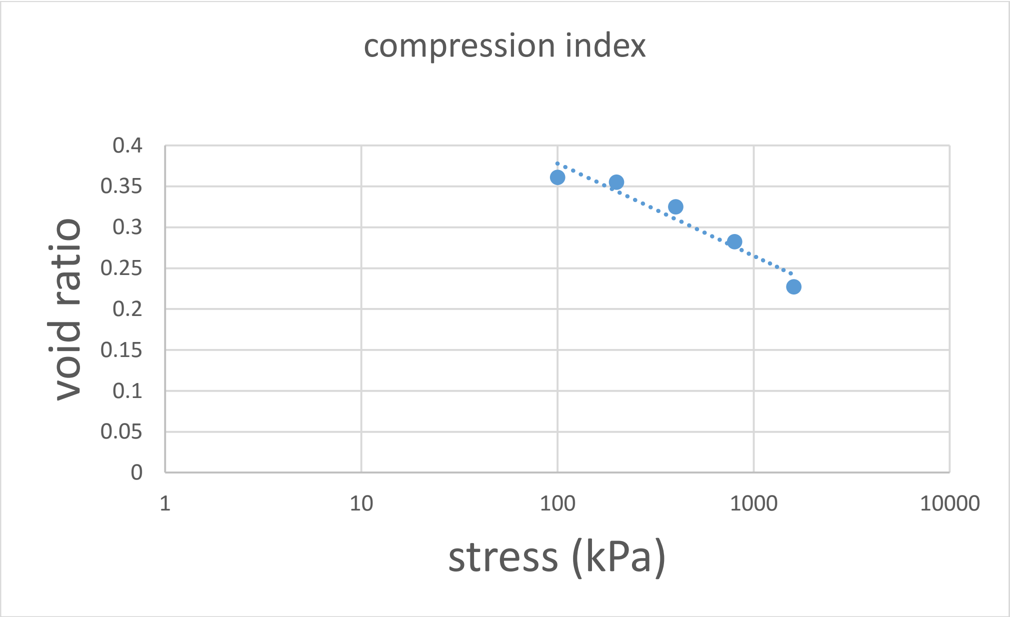



Fig 4.22 Compresiion index curve for a dosage 3

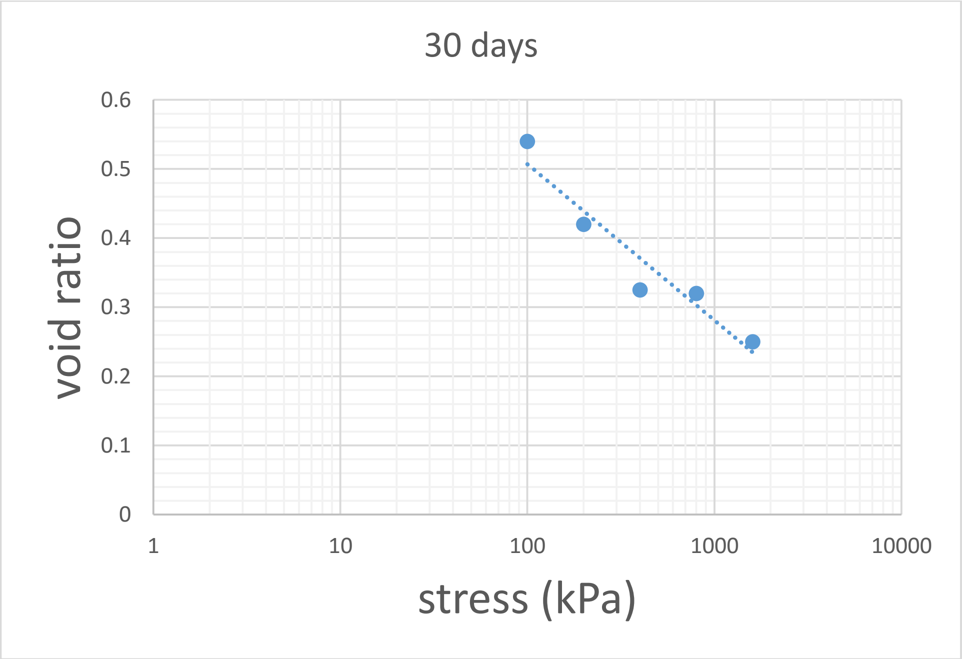



Fig 4.23 Compresiion index curve for a dosage 1

For 30 days the compression index is 0.059. For dosage 1 the compression index was 0.146. From the above data it is clear that with curing period the compression index decreases. So the enzyme treatment is considerable in reducing swelling activity and consolidation activities.

# CHAPTER 5

# CONCLUSION AND FUTURE WORK

The present research work was done to improve the geotechnical properties of black cotton soil. To improve the geotechnical properties a bio enzyme called Terazyme had been used. The Terazyme enzyme was mixed to the soil for different dosage and different curing period were tested. From the experimental investigation and results obtained, the following conclusions are drawn.

1. Untreated black cotton soil has 83.50% liquid limit. After adding the enzyme there is slight change in liquid limit. The overall plasticity index is in between 43.00-48.00
2. The atterberg limits of the treated enzymatic soil not with in the specified limits. Since the enzymatic soil having liquid limit in the range of 83.00%-79.00%. plasticity index is in between 43.00-48.00. The values are not satisfying the subgrade of a pavement. So it is unsuitable to use as sub grade material of the pavement
3. The unconfined compressive strength of enzyme treated soil indicates good improvement with curing period
4. The coefficient of consolidation decreases with curing period. However, there is slight downfall for first week curing period to second week curing period
5. The compression index values decreasing with curing period

## 5.2 A scope for future work

The following aspects may be further investigated

1. Effect of some other additives like fly ash and lime with enzyme product
2. Effect of different bio enzyme products
3. Permeability, shear strength and CBR have to be conducted
4. In the present research work for only black cotton soil was studied. There need to be check the enzyme suitability for different soils with different environmental conditions

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