Unconfined Compressive Strength Comparison Between Cement Stabilized and Lime Stabilized Soil

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CERTIFICATION OF APPROVAL

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It is hereby declared that this dissertation or any part of it has not been submitted elsewhere for the award of any degree or diploma.

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DEDICATION

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To

Our Parents

ACKNOWLEDGMENT

By the name of almighty, we have started and finished our thesis work without any hazard.

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ABSTRACT

Soil stabilization is any process that improves the physical properties of soil, such as increasing shear strength, bearing capacity, etc. Quantitatively the consistency can be expressed by the unconfined compressive strength test (UCT). In this research, the effects of mixing the soil with cement and lime are explored to determine the strength of the unconfined compression of the soil. Clay samples were collected from jionpur, Manikgonj, Bangladesh. The cement used in this experiment is Portland cement. The lime used in this work is limestone. Lime was collected from Narayongonj. Using 3%, 6%, and 9 % lime with normal soil, determined the strength of the soil. Again using 3%, 6%, and 9% cement in the same way, determined the strength of the soil. After finishing this process gradually 3, 7, 14 and 28 days, the molds were carefully placed in the desiccator for curing. Then compared the Unconfined Compressive strength between cement stabilized soil and lime stabilized soil. In this whole study shows the increasing strength of the soil by mixing cement and lime. The best result of cement and lime is found 9% admixture ratio.

Keywords: Cement, Lime, Unconfined Compressive Strength, Atterberg Limits, Index Properties, Strength test.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF THE FIGURES

List of Abbreviations

SCP	Standard proctor test
OMC	Optimum Moisture Content
PL	Plastic Limit
LL	Liquid Limit
ASTM	American Society for Testing and Materials
PI	Plasticity Index
LI	Liquidity Index
MDD	Maximum Dry Density
GS	Specific Gravity
UCT	Unconfined Compression Test
UCS	Unconfined compressive strength
ACI	American concrete institute

Chapter-1

Introduction

1.1 General:

Generally, the Stabilization Concept can be dated 5000 years ago [3]. Its Soil improvement process is improving at more Stable. Treated earth roads were used in ancient Mesopotamia and Egypt. The Greeks and Roman used soil line mixtures. The First experiment on soil stabilization was achieved in the USA with sand /clay mixtures around 1906 [3]. Soft soil improvement techniques like sand compaction pile (SCP); Dynamic compaction (DC), and prefabricated vertical drain (PVD) are very commonly used recently [5]. But Bangladesh or other countries due to low quality of the soil, are considered deep foundation. Construction like buildings, airfields, tunnels, drains, roads, and traffic areas could be cracked. So making soil stabilization is needed. Many constructions are used to complex soil stabilization technic with admixture or chemical like cement and lime. It's a low-cost process and high resistance bearing capacity for any site. For the foundation to be strong, the soil plays a very critical role. Different soil types in other country regions are additional, and their load-bearing capacity is also different. For example, to build multi-storied buildings on low-lying soil there is a need of increasing the capacity of soil. In this paper, we studied the effect of mixing lines and cement to increase soil bearing capacity. The bearing capacity of soil can increase in different ways, such as using lime, cement, plastic, bottles, fiber, geotextile or jute fiber, etc [1]. We studied the effect of mixing limes and cement to increase the bearing capacity of the soil. A lime can play an essential role as it improves the bearing capacity of the soil. The lime is preferable because of its butter durability, high tensile strength and capacity with stand rooting and heat. Porous texture that gives it good drainage and filtration properties. Lime is locally available cheap, ecofriendly, and disinfectant. The reinforcing in soil masses increases its strength, bearing capacity. Conversely, ductility reduces soft cement and lime inhibits lateral deformation. The line stabilized soils show greater extensibility. Minor loss of strength isotropy in strength and absence of weakNess and good compressive strength. The line is a biodegradable and environmental hazard. Soil can be stabilized by adding 3 to 9 percent of cement by volume, and the small percentage is specified to the granular soil while the high percentage is specified to the chosen soil. However, this was mistakenly interpreted to state that any soil can be stabilized with Cement. While there is a type of soil that needs more than 16 percent of cement to be stabilized. (Catton MD.1940) Cement can be used to stabilize any type of soil, without these having organic content greater than 2% or having PH lower than 5.3 (ACI 230.1R-90. 1990) [3].The existence of unstable soil for supporting structures in construction sites, lack of space, and economic motivation are primary reasons for using soil improvement. Ankit Singh Negi, Mohammed Faizan, Devashish Pandey Siddharth, Rehanjot Singh (Dept. of Civil Engineering, University of Petroleum and Energy Studies, Dehradun, India) used lime to stabilize soil. They found in their study that using 6% lime makes the soil 4 to 10 times higher stable than untreated soil. From these experiments, it is clear that mixing lime or cement in different proportions increases soil strength [7].

1.2 Thesis background:

Soil stabilization is being any soil change. The main purpose of soil pavement is to withstand earthquake trembling and water pressure. This can be done through soil stabilization. Soil stabilization is an important issue for civil Engineers. The main goal of most soil stabilization techniques used for reducing liquefaction hazards is to avoid large increases in pore water pressure during earthquake shaking. This can be achieved by densification of the soil. For improvement of its drainage capacity, civil Engineers have been able to play a significant role in this modern world due to soil stabilization, due to which possibility to reduce permanent thickNess in road area Railway or any transportation way with a deep foundation in a construction area or any site. The factors to be considered for this purpose include the soil types, the fine content and size; the soil strengthen de and compressibility, and the area and depth of treatment soil improvement is the most important part of Civil Engineers.

The soil is stabilized in five methods:

- Soil improvement without admixture in coarse-grained soil.
- Soil improvement without admixture in fine-grained soil.
- Soil improvement with replacement.
- Soil improvement with grouting and admixtures.
- Soil improvement with inclusions. It is important to have a fool that can optimize the choice of the soil improvement method for a given situation.

Purpose of soil stabilization:

Soil Improvement main work improving the strength by the composition, Durability, workability, nylon thread, Standard test, unconfined compressive strength, weight-bearing capacity. Higher resistance values and reduced plasticity, pavement thickNess in any construction area week soil is susceptible to the differential settlement. Its low share and high compressibility mitigate the problem, the existing week has to be replaced. Replacing existing was not always be a good option. Because pavement new soil high cost. It is due to the economic consideration for soil improvement or stabilization. Soil using the proper technique can be the best option. Now, foreign civilizations like America, Chinese, Romans, etc., various stabilizations technique to improve soil strength. When any formula or method could not be enhanced soil strength, we are alternative soil strength to replace weak soil in the new soil for the deep foundation.

1.3 Soil stabilization technique:

Three methods are soil stabilization like "SCP., DC, & PVD"[5].

SCP: Sand compaction methods are used for soft soil; the S.C.P. Method mainly improved soft soil ground. It uses vibration to install sand or any similar method using Improved to soil increase density from Bose soil ground or compressibility liquefaction to clay soil.

Dc: Dynamic methods are used for loose dandy soil to reduce liquefaction. Improved soil capacity its method increases the soil's density by dropping a heavy repeatedly on soil ground. Its weight is estimated at 10 to 23 pounds calculation. Gets pressure from the 6 to method space rebinding

PVD: Prepared method installation is used provide the engineer. Its actual work is depending on the engineering requirement of the construction area or site condition. Its technique alternatively can be used to simulate a preload. Now, before the preload, we are using the soil improvement technique. Any foreign country is different from any system like the rammed earth technique clay soil and cement with lime. Soil treatment or stabilization layers depend on green technology, bio-polymer, synthetic-polymer, enzyme surfactants, calcium chloride, sodium chloride, or more technology.

1.4 Cement in soil stabilization:

Cement is the binding material for soil stabilization with its material is generally used for the stabilized range of soil. With added sufficient quantity, its technique is not dependable soil material; soil can be stabilized as an admixture of 7-16% cement by volume cement mixed with water & soil by the special equipment in the area [1]. The stabilizing agent used for this study was ordinary portland cement. The specific gravity is 3.13 and the specific surface is 3790 (cm2 /gm)[8]. Its reaction physical & chemical is by adjustment but it will not change the structure of the soil. Soil cement is an admixture of granular soil and a measured amount of cement and water compacted to the desired density and cured (Liu, 1998) [9]. The role of cement is to improve the engineering properties of available soil such as strength compressibility, permeability, swelling potential, frost susceptibility and sensitivity to changes in moisture content. Soil cement materials range from semi flexible to semi rigid depending on the type of soil and amount of cement used.

Chemical component of cement:

Chemical component	Percentage
Tricalcium silicate ($3CaO$, $SiO_2 - C_3S$)	50%
Dicalcium silicate ($2CaO$, $SiO2 - C_2S$)	25%
Tricalcium aluminate ($3CaO$, $Al_2O_3 - C_3A$)	10%
Tetra-calcium aluminoferrite ($4CaO$, Al_2O_3, Fe_2O_3-C_4AF)	10%
Calcium sulfate ($CaSO_4$)	3%
Clinker (Co_2)	2%

1.5 Lime in soil stabilization:

Short term reactions include hydration for quicklime. Quicklime will immediately react with the water in the soil. Any engineer to & critical section be will be ordered lime provides. Because it's an economical way, its technique concentration for clay stabilization based on achieving target PH vales is economical. With a combination of 5-10% of lime by volume [9]. Lime replaces to normally present on the surface clay mineral. Thus, the clay surface.

Mineralogy is altered, producing the following benefits:

- Plasticity reduction
- reduction in moisture-holding capacity
- Swell reduction
- Improved stability
- Workability for construction platform.

Chemical component of lime:

Chemical component	Percentage
Calcium Oxide (CaO)	60%
Calcium Hydroxide Ca(OH)^2	40%

1.6 Fly ash in soil stabilization:

Fly ash belongs to Secondary binder materials, so it has few cementation properties compared to lime & cement. Fly ash & cement admixture have been used to stabilize agent soil in many parts of the world. Firstly A.S.T.M. requirement gradually sieves we use ding soil cement is used in percentage 1.5,3 & 5 while fly ash uses parentage 5.10 & 20 that is the three-period time respectively 7. 14 & 28 days [2].

1.7 Chemical in soil stabilization:

There are many types of chemical which is used for soil stabilization, such As

- Calcium chloride
- Sodium chloride sodium silicate

Soil stabilization in using thermal: It's a high-cost technology. So, it's a limited method. Here heating or freezing causes changes in its preparation it’s quite an old method of soil stabilization. Soil stabilization deeps a temperature of more than 5000C [2]. Here, this method reduces the plasticity of black cotton soil.

1.8 Soil stabilization perspective in Bangladesh:

By area, the soil of Bangladesh is very weak. The soil properties need to be improved by using cement and lime admixture. Thus, the bearing capacity of the soil and soil stability is increased. So, some measures have to be taken to harden the soil. Cement and lime admixture is commonly used in Bangladesh for soil stabilization. There are also many more ways, but those are readily available and low cost. And it is also a popular technology. Even by adding broken brick aggregates the bearing capacity of the soil is changed. It is also an old and popular technology this method is commonly used in road works.

1.9 Scope of the study:

In this study soil samples were collected from Manikgonj, jionpur, Dhaka and lime were collected from Narayanganj. Cement collected from the saver. After collecting these all soil samples are taken into the laboratory to investigate the engineering and index properties such as field identification test, specific gravity test of the soil, grain size analysis test by sieve, hydrometer test, atterberg limit test, standard proctor compaction test, unconfined compression test. These index properties were tested in the laboratory by the laboratory test specimens. We have successfully attained our aim after completing all of these tests.

1.10 The objective of the study:

- To identify the increasing strength of the soil by mixing cement and lime.
- To compare the unconfined compressive strength comparison between cement stabilization soil & lime stabilization soil.

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Chapter-2

Literature review

2.1 Introduction:

Analysis of the literature concerning previous research on the strength properties of organic clay has been presented. The published consequences of geotechnical investigations on strength of organic clay properties have been studied. Presented to clarify the state of current knowledge of the standard practice. In addition to that, detailed theoretical aspects of the unconfined compressive strength of clay and their applications also the major influencing factors of unconfined compressive strength are addressed in this chapter. Mainly analyzed their bearing capacity using lime and cement.

In villages mud plaster using rice husk is a popular technique to strengthen the soil. Reinforced soil was used by Babylonians more than 3000 years ago to build ziggurats with woven mats of reeds. These have also been used in parts of the Great Wall of China built about 2000 years ago. The Dutch and Romans used willow to reinforce dives and animal hides. Soil improvement with use admixture is a helpful procedure for road, runway, construction development and other major civil engineering projects.

In earlier research, Mohamed Khemissa, Abdelkrim Mahamedi 14 April 2014 published a Paper (cement and lime mixture stabilization of an expansive overconsolidated clay) in the experiment studied with a mixture of various cement and lime content. It can be noted to decrease in plasticity index, increase bearing capacity shear strength, etc. to a bearing percentage of 8% lime & 4% cement basis in CBR value [13].

Bulbul Ahmed, Md. Abdul Alim, Md. Abu Sayeed in 30 Nov 2013 RUET; in published a Paper that (Improvement of soil strength using cement and lime admixtures) the experimental result shows the addition of cement and lime admixture to the soil has great inspiration on its properties. They have five portion of ratio (1%, 3%, 5%, 7%, 9%) cement and lime mix admixture together. After curing the strength is increasing. From these experiments, it is clear that mixing lime or fly ash in different proportions increases soil strength [1].

M.A Asharf in 2018 published a Paper (Stabilization of soil by mixing with different percentages of lime), respectively two types of soli used. They have past recharges that cement performs batter with sandy soil while lime performs batter with silty / clay soil. In the recharge include the admixture, variable percentages of 0%, 2%, 4%, 6%, 8%, 10%, 12%, and 14% were used as stabilizer. The compressive strengths of lime stabilized soil were evaluated for different curing periods: 7 days, 14 days, 28 days and 60 days. It was found that the load bearing capacity of soil increased with the increase in the percentage of lime to a certain limit. It was, also, found that strength increases with an increase in the curing period.

Mr R Prabhakaran in 2019 published a paper that contracts with the comparative study on soil stabilization using lime and cement. He used lime and cement up to 15%. He conducted many tests including liquid limit test plastic limit test, CBR test and unconfined compressive strength test. The findings show that up to 10% substitution is possible beyond 10% the value goes on decreasing in all the tests.

Nivetha babu, Emy poulose in November 2018 resolved that the objective and principle of the soil stabilization is to increase the bearing capacity of soil. And in this paper, the properties have been discussed clearly and the advantages and disadvantages of the lime can be identified very clearly.

LK sharma in 2017 published a paper that deals with the study to inspect the self-governing roles of lime and cement on the stabilization of mountain soil. The test which he perform was the compressive strength test which showed that the compressive strength at 28 days increased 2 to 6 times than that of the untreated sample. It also shows that cement has a comparatively higher influence on the mechanical behavior of soil as compared to lime.

In previous research papers Studied, they treated maximum research papers with different percentage ratios & different curing periods including admixture with soil. In the excrement, the author wanted to include the admixture (cement & lime) same ratio & same curing period with soil, compared to the unconfined compressive strength or stress.

Background of the studied seven Different research papers observed & gathered in the following table bellowed.

Table 2.1: Study gap table

Properties															
SL	Author	Type of soil	Place	Index					Hydrometer	Unconfined test			Best value of Unconfined test	
				Specific	Particle	Maximum dry density	Optimum	Atterber		Cement	Lime	Days curing	Cement	Lime
1	Ahmed, B., Alim, A., & Sayeed, A. (2013).		Rajshahi	√	√	√	√	√	N/A	1%,3%, 5%,7%, 9%	1%,3% ,5%,7 %,9%	3,7	9%	9%
2	Ampera, B., & Aydogmus, T. (2005, March).	Soil with micas or iron	N/A	√	√	√	√	√	N/A	3%,6%, 9%	2%,4% ,6%	3,7,14	6%	6%
3	Chowdhury, M. N., Dev, A., & Noor, M. A.	Silty clay, silty sand.	Chittagong (2 sample)	N/A	√	√	√	√	N/A	3%,6%, 9%,12 %	*	1,7,14,28	9% &12%	*
4	Bhengu, P. H., & Allopi, D. (2017).	Silt soil	South Africa	N/A	√	√	√	√	√	*	2%,4% ,6%,8 %,10%	7	*	10%
5	AYTEKiN, M. (1998).	N/A	Bahrain	N/A	N/A	√	√	√	N/A	5%,10 %	7%,10 %,15%	N/A	5%	10%
6	M A Ashraf, M A Hossen, M A Ali and B P Chakaraborty (9~11 February 2018)	hilly soil, paddy land soil	Khulshi, South Salimpur	√	√	√	√	√	√	*	0%, 2%, 4%, 6%, 8%, 10%12 %, and 14%	7,14, 28,60	*	6% & 8%
7	Md. Zulfikar Ali, Md. Al Imran, Forhad Hossen, Md. Shahidul Islam. (Jnu 2020)	Soft soil	Savar	√	√	√	√	√	N/A	1%, 2%	1%, 2%	N/A	2%	2%

Chapter-3
Methodology

3.1 Summary:

This chapter discusses all soil sample collection, laboratory tests, and the result from the sample for geotechnical purposes which was discussed already in the properties index. All of the laboratory tests will be discussed in this chapter in detail and also show g the predicting and most relatable result through graphical analysis and some related tables. Plotting procedures, correlation methods, and multiple linear regression analyses will be used in this study to examine the interrelationships which exist between the engineering properties and soil index properties. The equation will be provided by the required tests. The tools of error analysis will be used to evaluate the accuracy of both the prediction equations and graphical procedure. Here is our entire flowchart of work is given below:

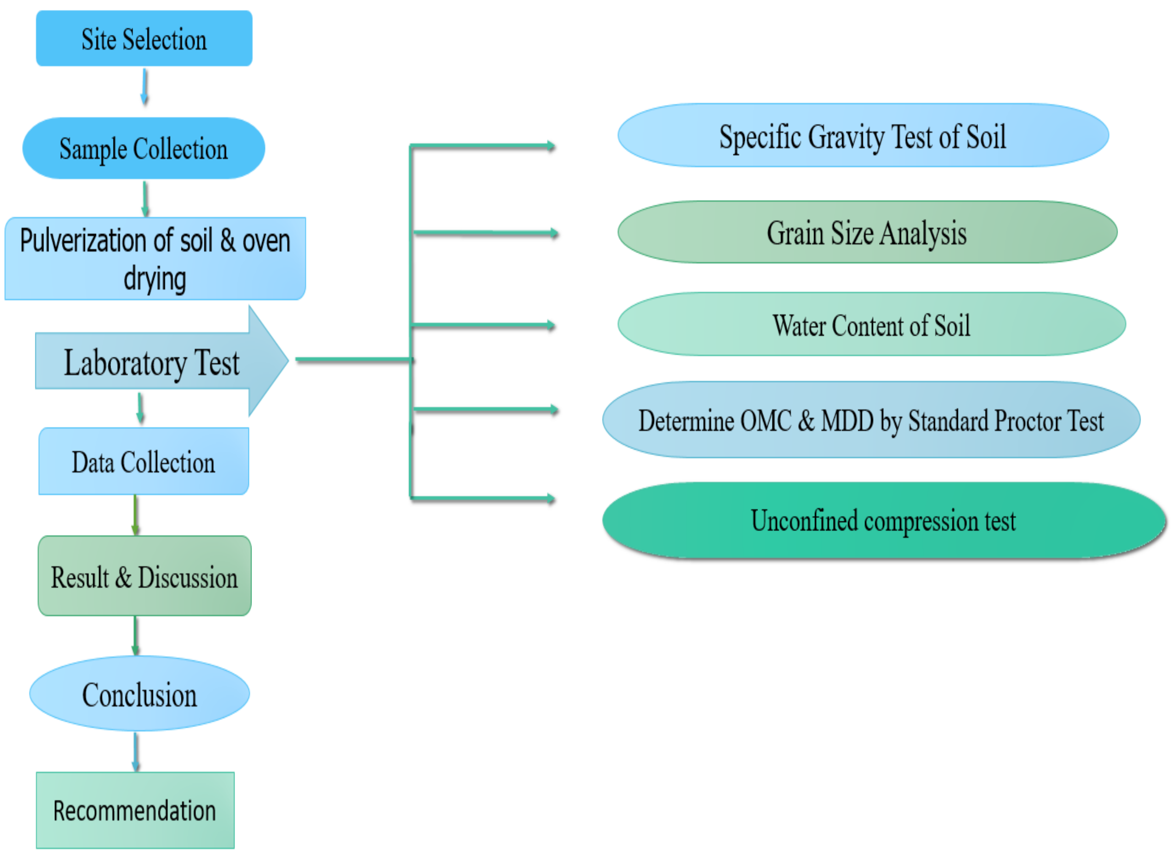


Figure 44: Methodology

3.2 Selection of soil:

Soft soil is defined as soils with large fractions of fine particles such as silt and clayey soils. Which have high moisture content and a large void ratio. Which soil SPT -N value < 4 is called soft soil.

3.3 Soil collection:

The value of soil under 4 (SPT) value after testing the soil in the laboratory. The soil was collected from jionpur, Manikgonj, Bangladesh.

3.4 Laboratory test:

All the soil sample containing some laboratory tests are,

1. Specific gravity test.
2. Atterberg limit test.
3. Proctor compaction test.
4. Grain size analysis test by sieve.
5. Grain size analysis test by hydrometer.
6. Unconfined compression test.

3.5 Instruments:

Following instruments are required to perform various tests in our study:

- ASTM Sieve
- Brush
- Bowel
- Balance
- Drying oven
- Moisture can
- Pycnometer
- Desiccator
- Stopwatch
- Casagrande devices
- Gloves
- Liquid limit device
- Spatula
- Wash bottle
- Standard proctor mold
- Unconfined mold
- Manual hammer
- Unconfined compressive test machine & etc.

Grain size analysis (sieve analysis)

3.6. Introduction:

Grain size analysis is accomplished to determine soil particle size which is tested by sieve analysis. In this laboratory experiment ASTM standard sieve which are #4 , #8 , #16 , #30 , #50 , #100 , #200 and a pan. It follows the ASTM C136 standard.

3.6.1 Test procedure:

- At fast, Note down the weight of all selected sieves.
- After that Note down the weight of the oven dry soil sample.
- All sieve has to be clean from dust.
- Place all sieves according to the sieve number.
- After that, pour the soil into the sieve.
- Shake properly for the passing soil sample, approximately 10 minutes.
- Record retained soil sample and weight.
- Record retained soil sample from pan.

Specific gravity test

3.7 Introduction:

How hefty an object or soil is then water is called specific gravity. The result for organic clay soil varies from 2.58 to 2.62. The coarse soil has lower specific gravity than finer soil. It follows the ASTM D854 standard.

3.7.1 Test procedure:

- Firstly note down the room temperature.
- After that note down M1, M2, M3, M4.
- Get the average value of three test results.
- Then Calculation Gs.

Specific Gravity; Gs (20ºC) = (Ws x GT) / (Ws - Wpsw + Wpw)
When,
Wp = Weight of clean pycnometer (gm)
Wps = Weight of empty pycnometer + dry soil (gm)
Wpsw = Weight of pycnometer + dry soil + water (gm)
Wpw = Weight of pycnometer + water (gm)

Figure 45: Specific gravity test

Atterberg limit test

3.8 Introduction:

Soil liquid limit and plastic limit are determined from atterberg limit test. These two limits are used internationally to determine soil identity, classification, and interrelationships. It follows ASTM-D4318 standard test method for liquid limit, Plastic limit, and plasticity index of soils.

3.8.1 Liquid limit of soil:

Liquid limit defines the soil properties behave and changes plastic to liquid. It shows the behavior of the soil properties by four terms solid states, semi-solid, plastic, and liquid states. When water is poured into the soil it loses its flexibility and becomes a liquid state.

3.8.2 Test procedure:

Plastic index, PI= PL – LL
Liquid index, LI = (W-PL)/ (LL-PL)
Where "W" is the natural water content

- Get, 250 gm oven-dry, #40 sieve passing soil has to be taken for this test.
- Add distilled water into the soil and mix it properly to form a uniform paste.
- The casagrande tool cuts a groove of size 2mm wide at the bottom and 11 mm wide at the top and 8 mm high.
- Trials shall be requiring 25 to 30 drops, the second between 20 and 25 drops, the third trial requiring 15 to 20 drops, and the fourth trial again between 15 to 20 drops.
- Collect a little bit of soil from each test by the moisture can for oven-dry then the soils are fully oven-dried weight should be noted down for the analysis.
- The number of blows used for the soil samples to come in contact is noted down.
- The graph is plotted to take several blows on a logarithmic scale on the abscissa and water content on the ordinate.
- Liquid limit corresponds to 25 blows from the graph.

3.9 Plastic limit of soil:

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. The plasticity index (IP) was also calculated with the help of liquid limit and plastic limit. It is also followed by ASTM standards.

IP=LL-PL

PI = Liquid limit - Plastic limit

3.9.1 Procedure:

Get, 250 gm #40 sieve passing oven-dry soil has to be taken for this test.

- Add distilled water mix with the soil and observe for at least 1 hour for proper water soil mix-up.
- Then, the soil should be divided into parts to take several readings.
- After that, roll the soil 3.0 mm on the flat surface.
- Recurrently rolling until it breaks into pieces.
- Record the wet soil sample and weight.
- After that, the soil on the moisture cans for oven drying.
- Record the dry soil sample and weight.

3.10 Plastic limit test formula:

- Wt. of container: we take the weight of container whose are mentioned by (W)
- Wt. of container + wet soil; We Take the weight of container + weight soil whose are mentioned by (W1)
- Wt. of container + dry soil: Now weight of container + dry soil whose are mentioned by (W2)
- Wt. of water, Ww (gm) and Wt. of dry soil, Ws (gm)
- Water content, $W= (W\text{w}/W\text{s})$ x100%

From the table Plastic Limit (Average of 2 determinations) =23.021%
we kNow,
Plasticity Index (Ip) =Liquid limit -Plastic limit

Ip = 37.1135 -23.21
Ip =13.90

(A) (B)

Figure 46: (A) Plastic limit & (B) Atterberg limit test

Proctor compaction test

3.11 Introduction:

This experiment gives a clear relationship between the dry densities of the soil and the moisture content of the soil. The experimental setup consists of (i) cylindrical metal mold (internal diameter- 10.16 cm and internal height-11.684 cm), (ii) detachable base plate, (iii) removable mold collar (6.35 cm effective height), (iv) hammer (2.5 kg). The Compact fiction 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 compaction 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. The water content and dry density to obtain the maximum dry density and the optimum water contents and it follow the ASTM D698 standard.

3.11.1 Test procedure:

- At first, needed #4 sieve passed oven-dry soil at least 3 kg.
- Add 8% water and mix with soil properly.
- Place sample in the mold in 3 layers.
- Give 25 stocks to each layer.
- Carefully remove the top part the of mold.

- Weight the compacted soil with mold.
- Weight the soil from the middle portion of the mold for the sample.
- Weight a moister can.
- Weight moisture can with soil.
- Place the soil to oven-dry.
- By adding 3% water to the same soil sample continue mixed in the same procedure, the MDD value decreases until then.

Figure 47: Proctor Compaction Test

Grain size analysis test by hydrometer

3.12 Introduction:

The particle size distribution of clay is not possible by using mechanical sieve analysis. This is because the clay particle size is finer than 0.074mm to 0.0002mm. Whereas mechanical sieve analysis limitation has 0.074mm. For that reason, hydrometer analysis is the most broadly used method for obtaining particle size distribution from 0.074mm to 0.0002mm. Hydrometer analysis is accomplished according to ASTM D422.

3.12.1 Test procedure:

Sieve Analysis:

- Record the weight of each sieve before starting the operation.
- Record the weight of the given dry soil sample.
- Put the sieves above the other in ascending order starting from sieve no.200 at the bottom to sieve no.4 on the top. Place the pan below sieve number 200, then carefully pour the soil sample into the top sieve then place the cap over it. Note: make sure all the sieves are clean before starting the analysis test.

- Place the sieve stack in the mechanical shaker and shake for 10 minutes.
- Remove carefully the stack of sieves from the shaker, then record the weight of each sieve with its retained soil, moreover record the weight of the pan with its fine soil retained.

Hydrometer test:

- Get, 50 gm #200 sieve passing oven-dry soil has to be taken for this test.
- Put the admixture mixture into a bottle and make sure it's reached 1L then shake the bottle for 60 seconds after that pour the mixture into the cylinder. After that insert the hydrometer.
- The cylinder is placed back on the bench or within the constant temperature tub and checked to visualize if foam on high of the suspension can inhibit accurately reading the measuring system.
- Immediately after inserting the hydrometer in the cylinder take the reading for 1, 2, and 4, 8, 15, 30, 60 minutes, then 2, 4, 8, 24, 48, 72 hours.
- Read the highest of the meniscus on the hydrometer to the closest ¼ graduation and record it.
- Extract the hydrometer in one steady motion, taking five to ten seconds to get rid of it. If there's a drop of liquid remaining on the tip of the bulb, touch it to the lip of the deposit cylinder and let it flow back to the suspension.
- After taking all the reading records into the hydrometer test paper, then determine how much the percentage of fine soil.

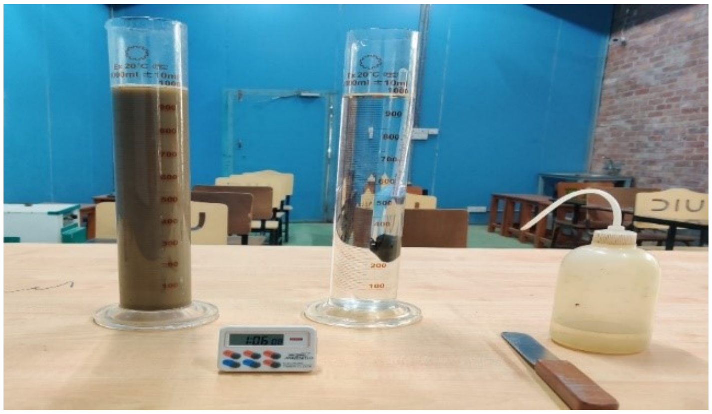


Figure 48: Hydrometer Test

Unconfined compression test

3.13 Introduction:

This experiment is used to determine the unconfined compressive strength of the soil sample which in turn is used to calculate the unconsolidated, under drained shear strength of unconfined soil. The unconfined compressive strength (UCT) is the compressive stress at which the unconfined cylindrical soil sample fails under a simple compressive test. The experimental setup consists 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 passive stress for each step was calculated by dividing the load with the corrected area. It will follow the ASTM D2166 standard test method.

qu = load/corrected area (A')
qu = compressive stress
A’ = cross-sectional area/ (1- ε)

3.13.1 Test procedure:

- Add the required quantity of water Ww to this soil.
  Ww = W_s * W/100 gm
- Mix the soil with water properly.
- Place the wet soil in a hugely tight thick polyethylene bag in an exceeding humidness chamber and place the soil in an exceedingly constant volume mold, having an inter height of 7.6 cm and internal diameter of 3.75 cm.
- After 24 hours take the soil from the humidity chamber and place the soil in a constant volume mold, having an internal height of 7.6 cm and internal diameter of 3.75 cm.
- Place the lubricated molded with plungers in position in the load frame.
- Apply the compressive load till the specimen is compacted to a height of 7.5 cm.
- Eject the specimen from the constant volume mold.
- After that, the specimen should be airtight in a desiccator.

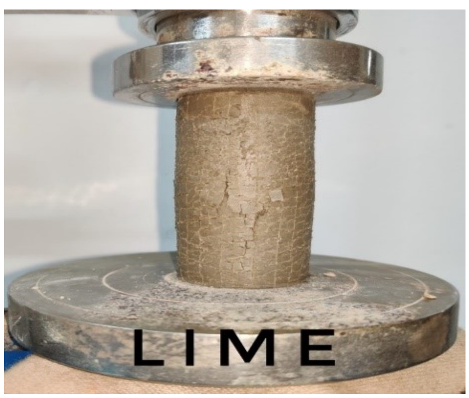
Calibration Formula: y = 0.010x + 0.027

3.13.3 Test figure:



(A) (B) (C)


(D) (E) (F)



(G) (H)

(A) = Mold releaser.

(B) = All molds before test.

(C) = Desiccator.

(D) = Unconfined compression tester.

(E) = Soil mold.

(F) = Cement mold.

(G) = Lime mold.

(H) = All molds after test

Chapter-4
Data Collection & Analysis

Table 4.1 Moisture content

Can no	Can weight W1	Can + Wet soil W2	Can +Dry soil W3	Weight of moisture soil	Weight of dry soil	Water content
58	18.86	67.08	56.5	10.58	37.64	28.10839532
15	20.7	94.15	77.93	16.22	57.23	28.34177879
56	19.61	92.52	75.8	16.72	56.19	29.75618437
Average water content % = 21.55158962						

Table 4.2 Specific gravity

Specimen number	Test 1	Test	Test 3
Temperature	25	25	25
Pycnometer bottle number	1	1	1
Weight of Pycnometer, M1	110.15	110.15	110.15
Weight of Pycnometer + Soil, M2	135.23	140.26	145.16
Weight of Pycnometer + Soil +Water, M3	371.78	375.09	378.08
Weight of Pycnometer + Water, M4	356.35	356.44	356.4
Specific gravity of distilled water, GT	0.9971	0.9971	0.9971
Specific gravity of the Soil, GS	2.59	2.62	
Average = 2.61			

4.3 Grain size analysis table

`Sieve No	Sieve opening (mm)	Sieve opening (mm)	Sieve opening (mm)	Percent of soil retained	Cumulative percent retained	Percent finer
4	4.76	500.29	0	0.00	0.00	100.00
8	2.38	292.86	0	0.00	0.00	100.00
16	1.19	288.53	0	0.00	0.00	100.00
30	0.6	298.32	0.25	0.05	0.05	99.95
50	0.287	293.21	0.44	0.09	0.14	99.86
100	0.15	249.78	1.28	0.26	0.39	99.61
200	0.075	259.77	2.93	0.59	0.98	99.02
pan	0	304.9	494.23	99.02	100.00	0.00
			499.13	100.00		
FM = 0.01 %						

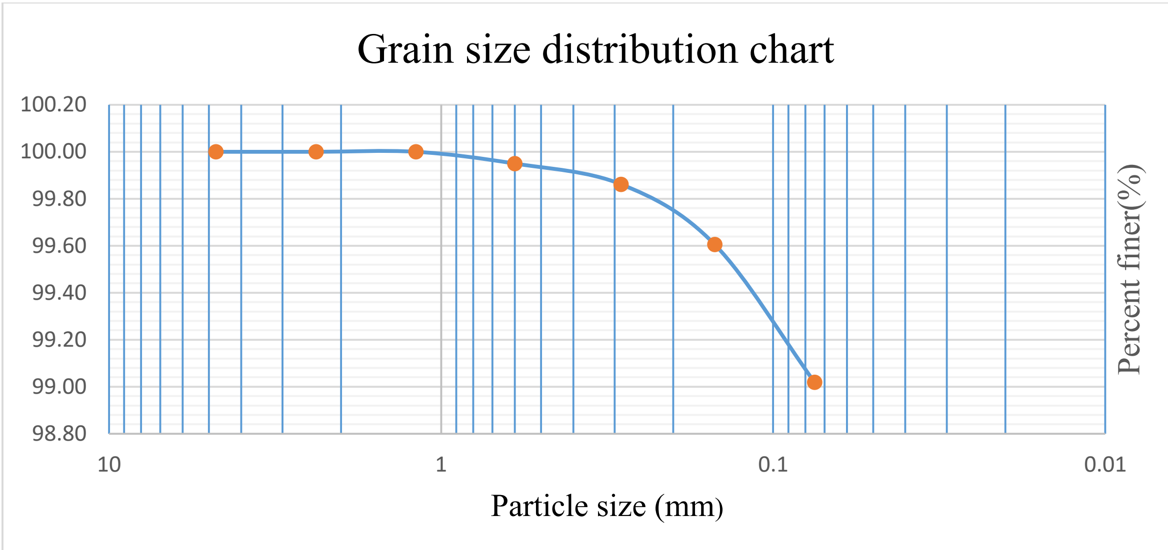


Figure 4.1: Grain size distribution (wash)

Table 4.3.1 Sieve analysis

Sieve No	Sieve opening (mm)	Wt. of container (gm)	Wt. of soil (gm)	Percent of soil retained	Cumulative percent retained	Percent finer
4	4.76	500.29	0			100.00
8	2.38	292.89	0	0.00	0.00	100.00
16	1.19	288.53	0	0.00	0.00	100.00
30	0.6	298.32	0.25	4.91	4.91	95.09
50	0.287	293.21	0.44	8.64	13.56	86.44
100	0.15	249.78	1.12	22.00	35.56	64.44
200	0.075	259.77	2.41	47.35	82.91	17.09
pan	0	304.9	0.87	17.09	100.00	0.00
			5.09	100.00		
FM = 0.54						

4.3.2 Hydrometer analysis

Input Parameters		
Viscosity of water at 25 C temperature	0.00000922	g s/cm2
Specific gravity of soil	2.61	
Weight of dry soil	50	g
Zero Correction	3	g
Meniscus Correction	1	

Time (min)	Ra	T	Tc=-4.85+0.25T	Rc=Ra-Zc+Tc	% finer = (Rcxa)/Ws	Recorrected for meniscus	L=16.3-0.164Ra	K	D (mm)	Actual % finer wrt to total fines in soil mass
									0.075	**17.09**
1	33	21	0.4	30.4	60.19	34	10.724	0.013	0.0429	10.288
2	32	21	0.4	29.4	58.21	33	10.888	0.013	0.0306	9.950
4	31	21	0.4	28.4	56.23	32	11.052	0.013	0.0218	9.611
8	30	21	0.4	27.4	54.25	31	11.216	0.013	0.0155	9.273
15	29	21	0.4	26.4	52.27	30	11.38	0.013	0.0114	8.935
30	27	21	0.4	24.4	48.31	28	11.708	0.013	0.0082	8.258
60	25	21	0.4	22.4	44.35	26	12.036	0.013	0.0059	7.581
120	23	21	0.4	20.4	40.39	24	12.364	0.013	0.0042	6.904
240	20	22	0.65	17.7	34.95	21	12.856	0.013	0.0030	5.973
480	18	23	0.9	15.9	31.48	19	13.184	0.013	0.0022	5.381
1440	17	22	0.65	14.7	29.01	18	13.348	0.013	0.0013	4.958
2880	16	21	0.4	13.4	26.53	17	13.512	0.013	0.0009	4.535
4320	16	22	0.65	13.7	27.03	17	13.512	0.013	0.0007	4.620

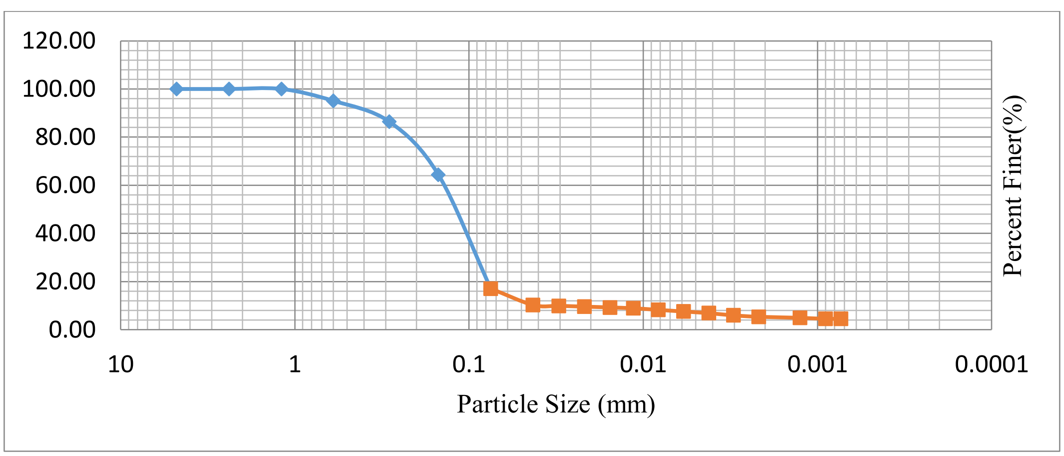


Figure 4.2: Grain size distribution by hydrometer

Table 4.4 Atterberg limits test

Moisture can No	34	36	35	40
W_c = Wt of can (gm)	8.08	7.12	8.41	7.47
W_{cms} = Wt of can + wet soil (gm)	32.51	26.44	32.13	22.49
W_{cds} = Wt of can+dry soil (gm)	25.63	20.93	26.26	18.1
W_s = Weight of soil solids = $W_{cds} – Wc$ (gm)	17.55	13.63	16.85	10.63
W_w = Weight of pure water = $W_{cms} – W_{cds}$ (gm)	6.88	5.51	5.87	4.39
w = Water content % ((Ww/Ws)*100)	39.20	40.43	34.84	41.30
No. of drop	24	20	27	18

Plastic limit test

Moisture can No	182	133
W_c = Wt of can (gm)	7.6	7.26
W_{cms} = Wt of can + wet soil (gm)	12.9	12.63
W_{cds} = Wt of can+dry soil (gm)	11.91	11.61
W_s = Weight of soil solids = $W_{cds} – Wc$ (gm)	4.31	4.35
W_w = Weight of pure water = $W_{cms} – W_{cds}$ (gm)	0.99	1.02
w = Water content % ((Ww/Ws)*100)	22.97	23.45
Average = 23.21		

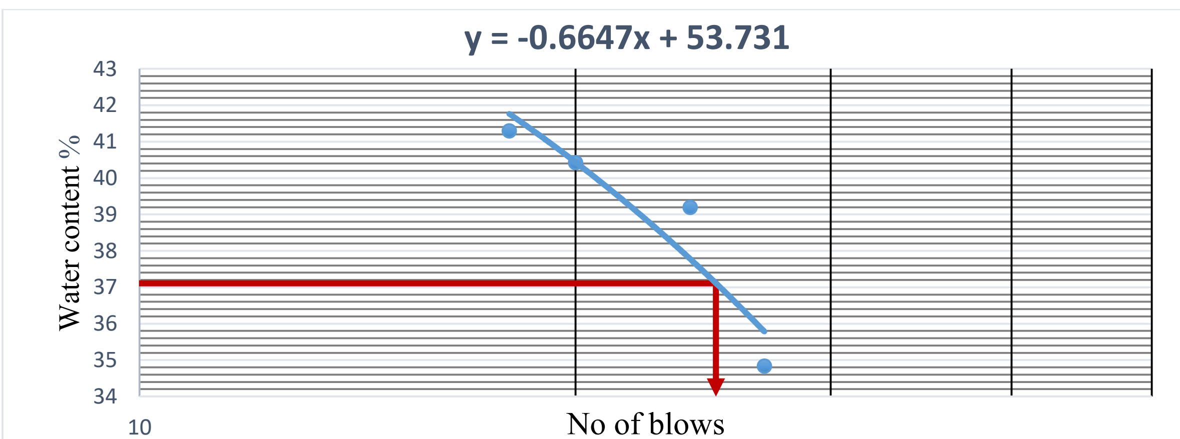


Figure 4.3: Liquid limit chart

In the figure number: 4.3, No. of blow 25 = 37.1135

Standard proctor test

4.5 Standard proctor test table

4.5.1 Standard proctor test only soil

Water content determination of soil only							
Sample no.	1	2	3	4	5	6	7
Moisture can no.	15(2)	56	54	52	58	91	76
Mass of empty clean can	20.26	19.63	20.35	21.68	18.887	20.63	21.47
Mass of can + wet soil	74.53	78.38	74.16	73.78	83.06	58.4	58.25
Mass of can + dry soil	70.13	72.36	67.19	65.92	72	51.25	50.48
Mass of soil solid	49.87	52.73	46.84	44.24	53.113	30.62	29.01
Mass of pore water	4.4	6.02	6.97	7.86	11.06	7.15	7.77
Water content w%	8.82	11.42	14.88	17.77	20.82	23.35	26.78

Dry density determination of soil only							
Compacted soil sample no.	1	2	3	4	5	6	7
Volume of the mold, (V),(ft^3)	0.033	0.033	0.033	0.033	0.033	0.033	0.033
Mass of mold,(lb)	6.470	6.470	6.470	6.470	6.470	6.470	6.470
Mass of compacted soil and mold (lb)	9.921	10.053	10.274	10.472	10.670	10.604	10.494
Mass of compacted soil, (lb)	3.45	3.58	3.80	4.00	4.20	4.13	4.02
Wet density, r = (M/V),(lb/ft^3)	104.57	108.58	115.26	121.27	127.28	125.28	121.94
Dry density, rd = [r/(1+w/100)],(lb/ ft^3)	96.09	97.45	100.33	102.98	105.35	101.56	96.18

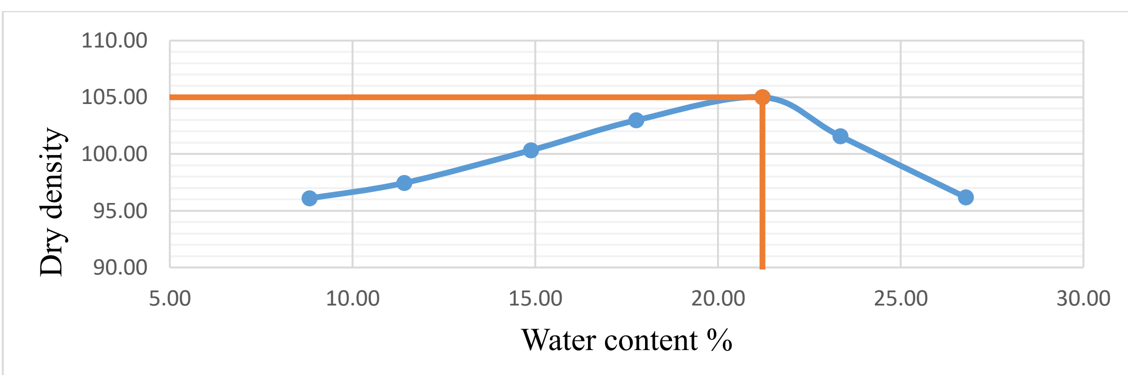


Figure 4.4: Standard proctor test with soil

In the figure number: 4.4, the maximum dry density is 105.35 (lb/ft3) and the optimum moisture content is 20.85 %

4.5.2 Standard proctor test with 3% cement

Water content determination							
Sample no.	1	2	3	4	5	6	7
Moisture can no.	33	70	45	89	22	17	20
Mass of empty clean can	20.26	19.63	20.35	21.68	19.887	20.63	21.47
Mass of can + wet soil	74.53	78.38	74.16	73.78	83.06	58.4	58.25
Mass of can + dry soil	70.13	72.36	67.19	65.92	72	51.25	50.48
Mass of soil solid	49.87	52.73	46.84	44.24	52.113	30.62	29.01
Mass of pore water	4.4	6.02	6.97	7.86	11.06	7.15	7.77
Water content w%	8.82	11.42	14.88	17.77	21.22	23.35	26.78

Dry density determination							
Compacted soil sample no.	1	2	3	4	5	6	7
Volume of the mold, (V),(ft^3)	0.033	0.033	0.033	0.033	0.033	0.033	0.033
Mass of mold (lb)	6.470	6.470	6.470	6.470	6.470	6.470	6.470
Mass of compacted soil and mold (lb)	9.921	10.053	10.274	10.472	10.670	10.604	10.494
Mass of compacted soil, (lb)	3.45	3.58	3.80	4.00	4.20	4.13	4.02
Wet density, r = (M/V),(lb/ft^3)	104.57	108.58	115.26	121.27	127.28	125.28	121.94
Dry density, rd = [r/(1+w/100)],(lb/ ft^3)	96.09	97.45	100.33	102.98	105.00	101.56	96.18

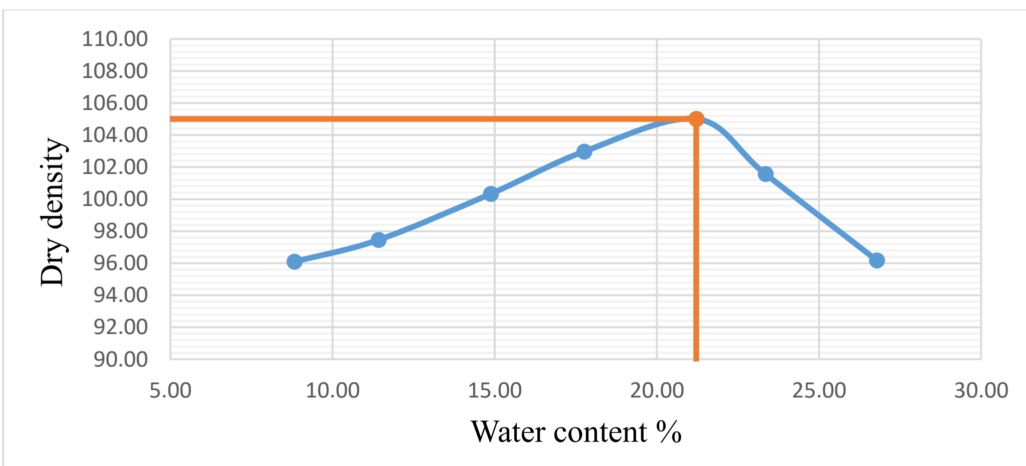


Figure 4.5: Standard proctor test with 3% cement

In the figure number: 4.5, the maximum dry density is 105(lb./ft3) and the optimum moisture content is 21.22%

Table 4.5.3 Standard Proctor with 6 % cement

Water content determination							
Sample no.	1	2	3	4	5	6	7
Moisture can no.	101	18	15(1)	14	12	19	13
Mass of empty clean can	20.43	25.21	24.54	24.08	22.82	24.1	25.03
Mass of can + wet soil	80.96	113.85	120.87	109.09	153.77	115.88	132.11
Mass of can + dry soil	75.02	103.11	106.86	95.01	129.73	97.4	108.33
Mass of soil solid	54.59	77.9	82.32	70.93	106.91	73.3	83.3
Mass of pore water	5.94	10.74	14.01	14.08	24.04	18.48	23.78
Water content w%	10.88	13.79	17.02	19.85	22.49	25.21	28.55

Dry density determination							
Compacted soil sample no.	1	2	3	4	5	6	7
Volume of the mold, (V),(ft^3)	0.033	0.033	0.033	0.033	0.033	0.033	0.033
Mass of mold , lb)	6.470	6.470	6.470	6.470	6.470	6.470	6.470
Mass of compacted soil and mold (lb)	9.943	10.163	10.384	10.560	10.648	10.582	10.472
Mass of compacted soil, (lb)	3.47	3.69	3.91	4.09	4.18	4.11	4.00
Wet density, r = (M/V),(lb/ft^3)	105.24	111.92	118.60	123.94	126.62	124.61	121.27
Dry density, rd = [r/(1+w/100)],(lb/ ft^3)	94.91	98.36	101.35	103.41	103.37	99.52	94.34

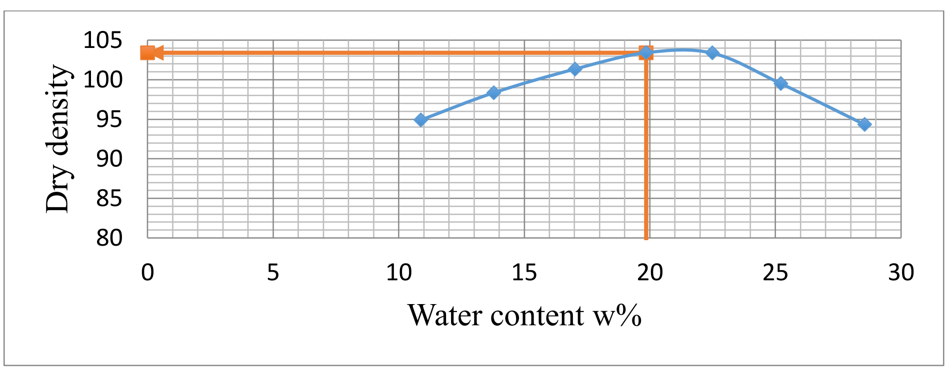


Figure 4.6: Standard proctor test with 6% cement

In the figure number: 4.6, the maximum dry density is 103.41 (lb./ft3) and the optimum moisture content is 19.85 %

Table 4.5.4 Standard Proctor with 9 % cement

Water content determination							
Sample no.	1	2	3	4	5	6	7
Moisture can no.	12	13	14	15	18	77	101
Mass of empty clean can	22.82	25.05	24.12	24.58	25.2	17.2	20.49
Mass of can + wet soil	53.74	64.57	56.69	49.46	58.69	46.46	59.73
Mass of can + dry soil	52.15	60.54	52.64	45.75	52.95	40.93	51.44
Mass of soil solid	18	35.49	28.52	21.17	27.75	23.73	30.95
Mass of pore water	1.59	4.03	4.05	3.71	5.74	5.53	8.29
Water content w%	8.83	11.36	14.20	17.52	20.68	23.30	26.79
Dry density determination							
Compacted soil sample no.	1	2	3	4	5	6	7
Volume of the mold, (V),(ft^3)	0.033	0.033	0.033	0.033	0.033	0.033	0.033
Mass of mold ,(lb)	6.470	6.470	6.470	6.470	6.470	6.470	6.470
Mass of compacted soil and mold (lb)	9.965	10.163	10.340	10.560	10.648	10.60	10.54
Mass of compacted soil, (lb)	3.49	3.69	3.87	4.09	4.18	4.13	4.07
Wet density, r = (M/V),(lb/ft^3)	105.91	111.92	117.26	123.94	126.62	125.28	123.28
Dry density, rd = [r/(1+w/100)],(lb/ ft^3)	97.31	100.51	102.68	105.46	104.91	101.60	97.23

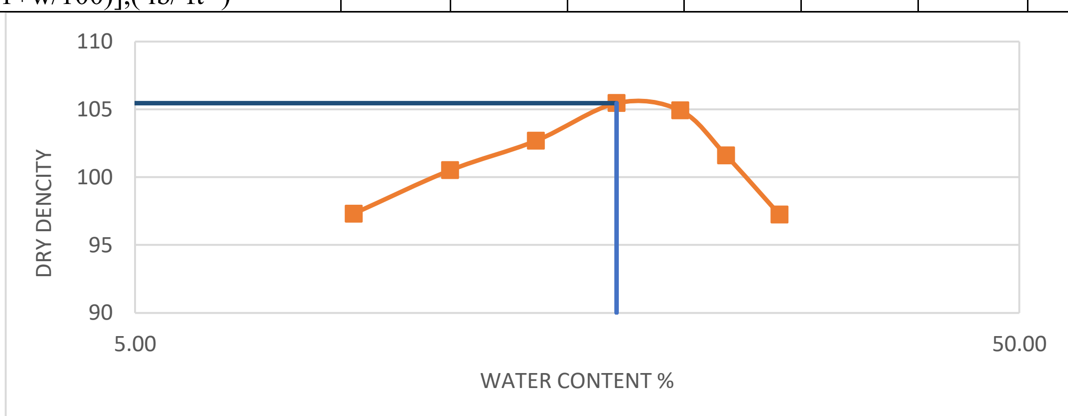


Figure 4.7: Standard proctor test with 9 % cement

In the figure number: 4.7, the maximum dry density is 105.46 (lb./ft3) and the optimum moisture content is 17.52 %

Table 4.5.5 Standard Proctor with 3 % lime

Water content determination with 3 % Lime								
Sample no.	1	2	3	4	5	6	7	8
Moisture can no.	50	20	17	54	58	76	52	11
Mass of empty can	21.49	24.02	24.89	20.37	18.85	21.5	21.67	24.29
Mass of can + wet soil	84.91	126.5	123.5	86.4	86.46	81.9	76.03	84.91
Mass of can + dry soil	79.75	115.8	110.7	76.35	74.53	69.9	64.19	70.53
Mass of soil solid	58.36	91.78	85.76	55.98	55.68	48.4	42.52	46.24
Mass of pore water	5.16	10.72	12.83	10.05	11.93	12	11.84	14.38
Water content w%	8.84	11.68	14.96	17.95	21.43	24.78	27.85	31.10

Density determination								
Compacted soil sample no.	1	2	3	4	5	6	7	8
Volume of the mold, (V),(ft^3)	0.033	0.033	0.033	0.033	0.033	0.03	0.033	0.033
Mass of mold, (lb)	6.470	6.470	6.470	6.470	6.470	6.470	6.470	6.470
Mass of compacted soil and mold (lb)	9.811	9.921	10.053	10.207	10.384	10.47	10.41	10.34
Mass of compacted soil, (lb)	3.34	3.45	3.58	3.74	3.91	4.00	3.94	3.87
Wet density, r = (M/V),(lb/ft^3)	101.23	104.57	108.58	113.25	118.60	121.27	119.27	117.26
Dry density, rd = [r/(1+w/100)],(lb/ ft^3)	93.01	93.63	94.45	96.02	97.67	97.19	93.29	89.45

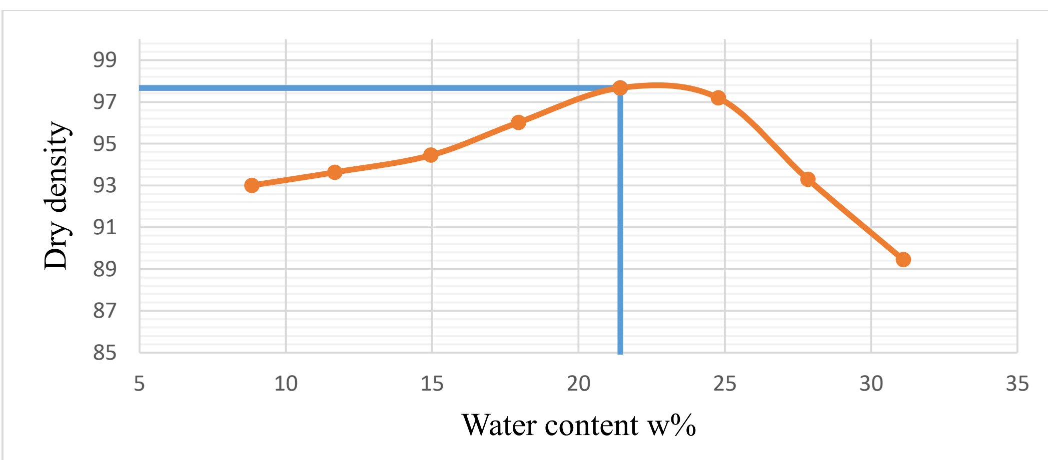


Figure 4.8: Standard proctor test with 3% lime

In the figure number: 4.8, the maximum dry density is 97.67 (lb./ft3) and the optimum moisture content is 21.43 %

Table 4.5.6 Standard Proctor with 6 % lime

Water content determination									
Sample no.	1	2	3	4	5	6	7	8	9
Moisture can no.	2	77	56	101	18	15(1)	14	12	13
Mass of empty clean can	20.66	17.19	19.6	20.43	24.21	24.54	24.08	22.82	25.02
Mass of can + wet soil	70.08	77.78	70.26	89.2	99.23	124.32	100.3	87.73	78.68
Mass of can + dry soil	66.39	71.32	63.71	78.72	86.38	105.79	84.31	72.83	65.44
Mass of soil solid	45.73	54.13	44.11	58.29	62.17	81.25	60.23	50.01	40.42
Mass of pore water	3.69	6.46	6.55	10.48	12.85	18.53	16	14.9	13.24
Water content w%	8.07	11.93	14.85	17.98	20.67	22.81	26.56	29.79	32.76
Density determination									
Compacted soil sample no.	1	2	3	4	5	6	7	8	9
Volume of the mold, (V),(ft^3)	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033
Mass of mold ,(lb)	6.470	6.470	6.470	6.470	6.470	6.470	6.470	6.470	6.470
Mass of compacted soil and mold (lb)	9.700	9.855	9.987	10.141	10.274	10.38	10.47	10.36	10.30
Mass of compacted soil, (lb)	3.23	3.38	3.52	3.67	3.80	3.91	4.00	3.89	3.83
Wet density, r = (M/V),(lb/ft^3)	97.89	102.57	106.57	111.25	115.26	118.60	121.27	117.93	115.93
Dry density, rd = [r/(1+w/100)],(lb/ ft^3)	90.58	91.63	92.79	94.30	95.52	96.57	95.82	90.86	87.32

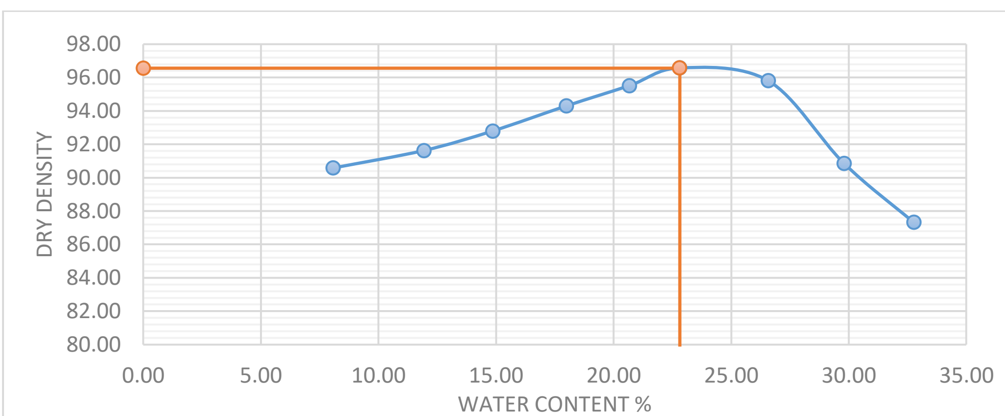


Figure 4.9: Standard proctor test with 6 % lime

In the figure number: 4.9, the maximum dry density is 96.57 (lb./ft3) and the optimum moisture content is 22.81 %

Table 4.5.7: Standard Proctor with 9 % lime

Water content determination									
Sample no.	1	2	3	4	5	6	7	8	9
Moisture can no.	15	13	11	101	18	5	14	12	1
Mass of empty clean can	20.66	17.19	19.6	20.43	24.21	24.54	24.08	22.82	25.02
Mass of can + wet soil	70.18	77.85	70.29	88.89	99.23	125.72	100.4	87.43	78.48
Mass of can + dry soil	66.39	71.32	63.71	78.72	86.38	105.79	84.31	72.83	65.44
Mass of soil solid	45.73	54.13	44.11	58.29	62.17	81.25	60.23	50.01	40.42
Mass of pore water	3.79	6.53	6.58	10.17	12.85	19.93	16.1	14.6	13.04
Water content w%	8.29	12.06	14.92	17.45	20.67	24.53	26.73	29.19	32.26
Density determination									
Compacted soil sample no.	1	2	3	4	5	6	7	8	9
Volume of the mold, (V),(ft^3)	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033
Mass of mold ,(lb)	6.470	6.470	6.470	6.470	6.470	6.470	6.470	6.470	6.470
Mass of compacted soil and mold (lb)	9.700	9.855	9.987	10.141	10.274	10.43	10.47	10.36	10.30
Mass of compacted soil, (lb)	3.23	3.38	3.52	3.67	3.80	3.96	4.00	3.89	3.83
Wet density, r = (M/V),(lb/ft^3)	97.89	102.57	106.57	111.25	115.26	119.93	121.27	117.93	115.93
Dry density, rd = [r/(1+w/100)],(lb/ft^3)	90.40	91.52	92.74	94.72	95.52	96.31	95.69	91.28	87.65

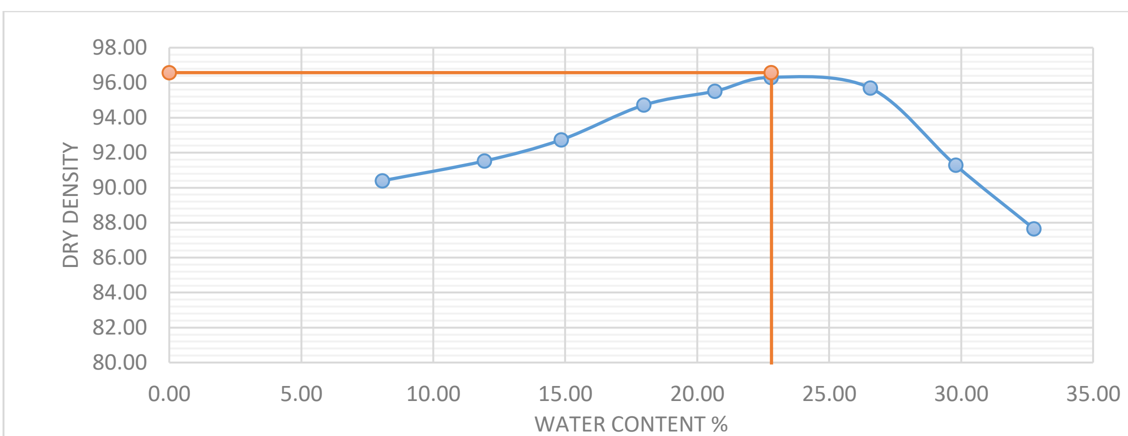


Figure 4.10: Standard proctor test with 9 % lime

In the figure number: 4.10, the maximum dry density is 96.31 (lb./ft3) and the optimum moisture content is 24.53

Unconfined compression test

4.6: Unconfined compression test

Table 4.6.1: Day-3 unconfined compressive strength with soil

Deformation	Deformation ΔL (mm)	Axial Strain = ϵ (%)	Corrected Area (cm^2)	Load Dial Reading (Proving ring)	Corrected Load (kN)	Stress (kPa)
0	0	0	11.34	0	0	0
95	0.95	1.25	11.484	6	0.087	75.758
185	1.85	2.434	11.623	11	0.137	117.870
240	2.4	3.158	11.71	14	0.167	142.613
280	2.8	3.684	11.774	16	0.187	158.825
350	3.5	4.605	11.887	18	0.207	174.140
412	4.12	5.421	11.99	20	0.227	189.324
480	4.8	6.316	12.105	23	0.257	212.309
550	5.5	7.237	12.225	26	0.287	234.765
620	6.2	8.158	12.347	28	0.307	248.643
695	6.95	9.145	12.481	30	0.327	261.998
765	7.65	10.066	12.609	32	0.347	275.200
830	8.3	10.921	12.73	34	0.367	288.295
903	9.03	11.882	12.869	36	0.387	300.723
980	9.8	12.895	13.019	32	0.347	266.534

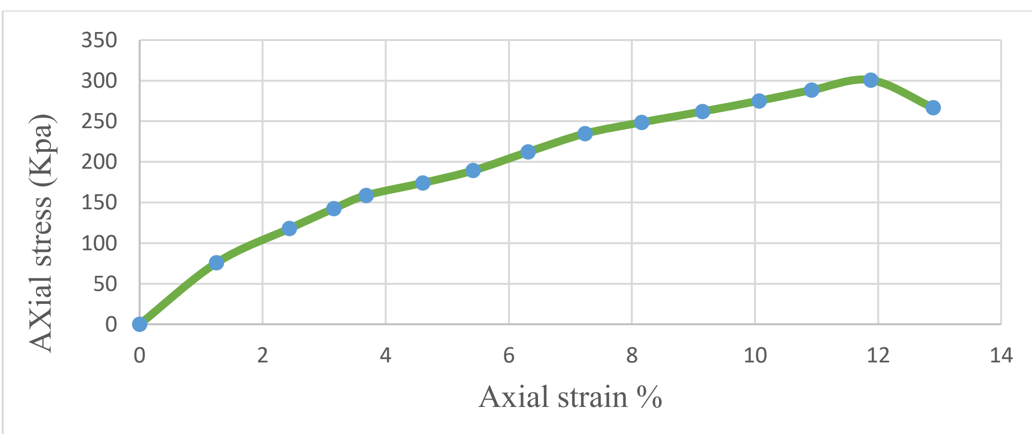


Figure 4.11: Day-3 unconfined compressive strength only soil

In the figure number: 4.6.1, the maximum stress is 300.72 (kpa)

Table 4.6.2: Day-3 unconfined compressive strength with 3% Cement

Deformation	Deformation ΔL (mm)	Axial strain = ϵ (%)	Corrected area (cm^2)	Load dial reading (proving ring)	Corrected load (kN)	Stress (kpa)
0	0	0	11.34	0	0	0
55	0.55	0.724	11.423	10	0.127	111.179
111	1.11	1.461	11.508	25	0.277	240.702
178	1.78	2.342	11.612	34	0.367	316.052
235	2.35	3.092	11.702	42	0.447	381.986
298	2.98	3.921	11.803	48	0.507	429.552
360	3.6	4.737	11.904	53	0.557	467.91
425	4.25	5.592	12.012	58	0.607	505.328
488	4.88	6.421	12.118	62	0.647	533.916
563	5.63	7.408	12.247	64	0.667	544.623
635	6.35	8.355	12.374	58	0.607	490.545

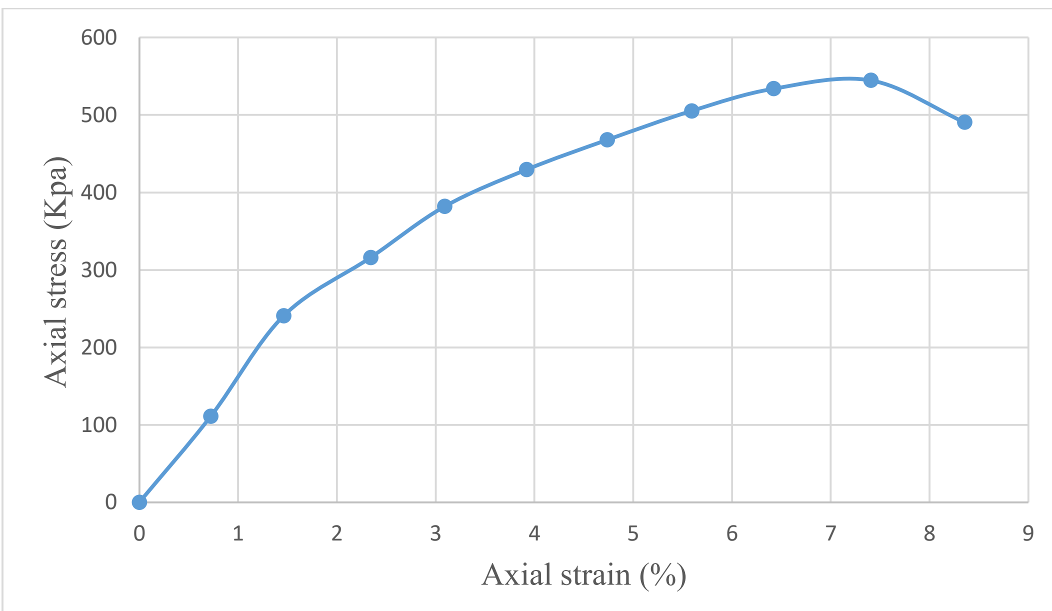


Figure 4.12: Day-3 unconfined compressive strength with 3% cement

In the figure number: 4.6.2, the maximum stress is 544.623 (kpa)

Table 4.6.3: Day-3 unconfined compressive strength with 6% cement

Deformation	Deformation ΔL (mm)	Axial strain = ϵ (%)	Corrected area (cm^2)	Load dial reading (proving ring)	Corrected load (kN)	Stress (kpa)
0	0	0	11.34	0	0	0
45	0.45	0.592	11.408	18	0.207	181.4516
98	0.98	1.289	11.488	36	0.387	336.8733
149	1.49	1.961	11.567	53	0.557	481.5423
200	2	2.632	11.647	68	0.707	607.0233
250	2.5	3.289	11.726	87	0.897	764.9667
300	3	3.947	11.806	99	1.017	861.4264
349	3.49	4.592	11.886	113	1.157	973.4141
408	4.08	5.368	11.983	118	1.207	1007.26
468	4.68	6.158	12.084	110	1.127	932.6382

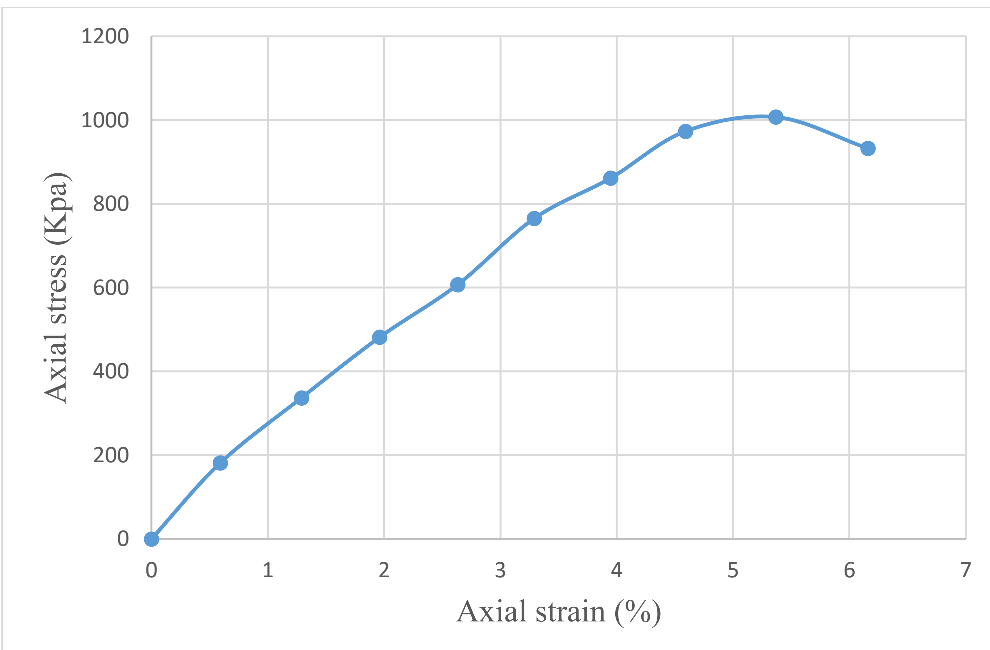


Figure 4.13: Day-3 unconfined compressive strength with 6% cement

In the figure number: 4.6.3, the maximum stress is 1007.26 (kpa)

Table 4.6.4: Day-3 unconfined compressive strength with 9% cement

Deformation	Deformation ΔL (mm)	Axial strain = ϵ (%)	Corrected area (cm^2)	Load dial reading (proving ring)	Corrected load (kN)	Stress (kpa)
0	0	0	11.34	0	0	0
25	0.25	0.329	11.377	28	0.307	269.843
51	0.51	0.671	11.417	49	0.517	452.833
108	1.08	1.421	11.503	81	0.837	727.636
160	1.6	2.105	11.584	97	0.997	860.67
217	2.17	2.855	11.673	113	1.157	991.176
270	2.7	3.553	11.758	127	1.297	1103.08
298	2.98	3.921	11.803	120	1.227	1039.57

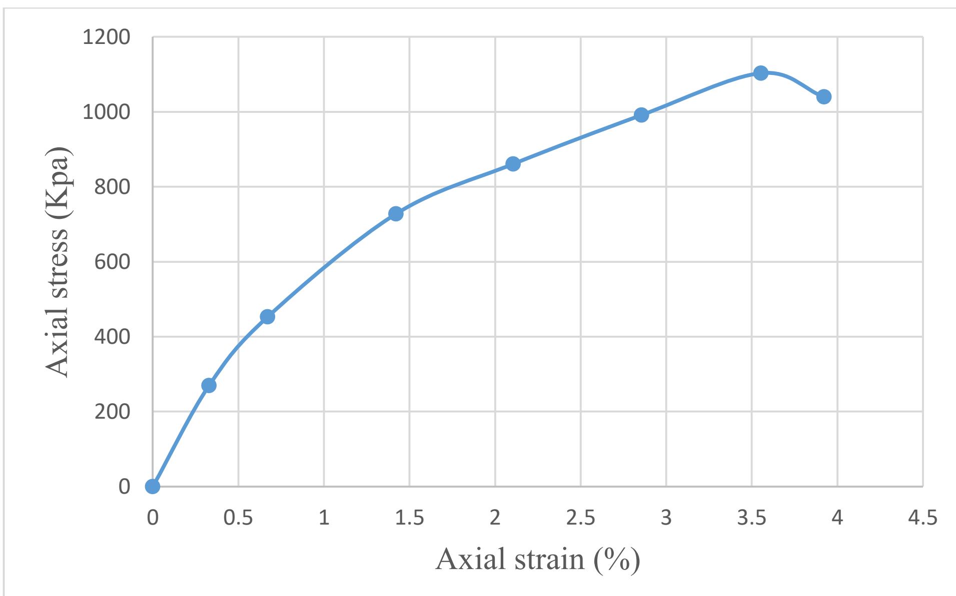


Figure 4.14: Day-3 unconfined compressive strength with 9 % cement

In the figure number: 4.6.4, the maximum stress is 1103.08 (kpa)

Table 4.6.5: Day-3 unconfined compressive strength with 3% lime

Deformation	Deformation ΔL (mm)	Axial strain = ϵ (%)	Corrected area (cm^2)	Load dial reading (proving ring)	Corrected load (kN)	Stress (kpa)
0	0	0	11.34	0	0	0.000
82	0.82	1.079	11.464	5	0.077	67.167
138	1.38	1.816	11.55	8	0.107	92.641
200	2	2.632	11.647	13	0.157	134.799
275	2.75	3.618	11.766	16	0.187	158.933
340	3.4	4.474	11.871	21	0.237	199.646
410	4.1	5.395	11.987	24	0.267	222.741
475	4.75	6.25	12.096	26	0.287	237.269
538	5.38	7.079	12.204	29	0.317	259.751
613	6.13	8.066	12.335	32	0.347	281.313
682	6.82	8.974	12.458	35	0.377	302.617
752	7.52	9.895	12.585	37	0.397	315.455
825	8.25	10.86	12.721	38	0.407	319.943
955	9.55	12.57	12.97	39	0.417	321.511
996	9.96	13.11	13.05	35	0.377	288.889

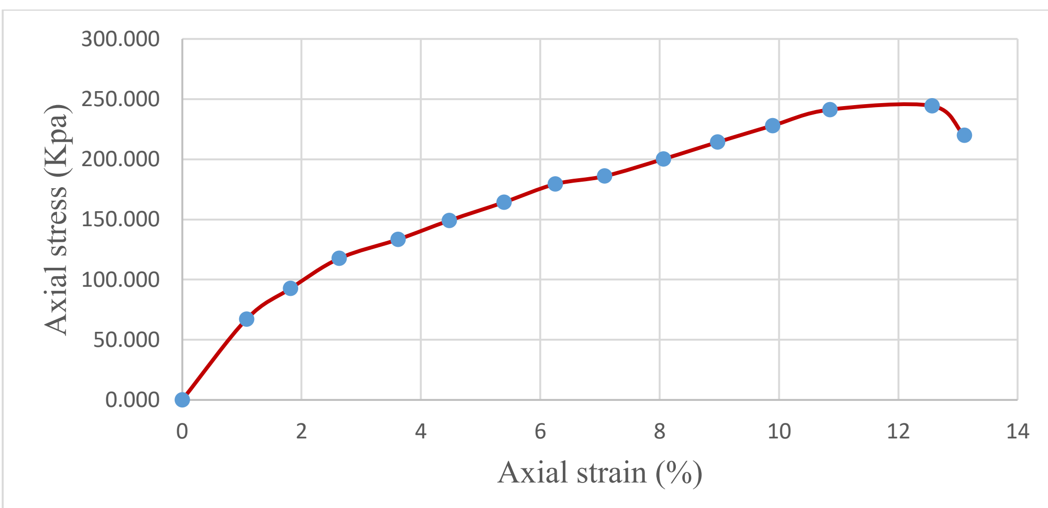


Figure 4.15: Day-3 unconfined compressive strength with 3% lime

In the figure number: 4.6.5, the maximum stress is 321.511 (kpa)

Table 4.6.6: Day-3 unconfined compressive strength with 6% lime

Deformation	Deformation ΔL (mm)	Axial strain = ϵ (%)	Corrected area (cm^2)	Load dial reading (proving ring)	Corrected load (kN)	Stress (kpa)
0	0	0	11.34	0	0	0
74	0.74	0.974	11.452	5	0.077	67.2372
135	1.35	1.776	11.545	9	0.117	101.343
205	2.05	2.697	11.654	12	0.147	126.137
270	2.7	3.553	11.758	15	0.177	150.536
347	3.47	4.566	11.883	18	0.207	174.198
409	4.09	5.382	11.985	23	0.257	214.435
484	4.84	6.368	12.111	27	0.297	245.232
552	5.52	7.263	12.228	32	0.347	283.775
620	6.2	8.158	12.347	35	0.377	305.337
692	6.92	9.105	12.476	39	0.417	334.242
755	7.55	9.934	12.591	41	0.437	347.073
830	8.3	10.921	12.73	42	0.447	351.139
898	8.98	11.816	12.859	42	0.447	347.616
961	9.61	12.645	12.982	39	0.417	321.214

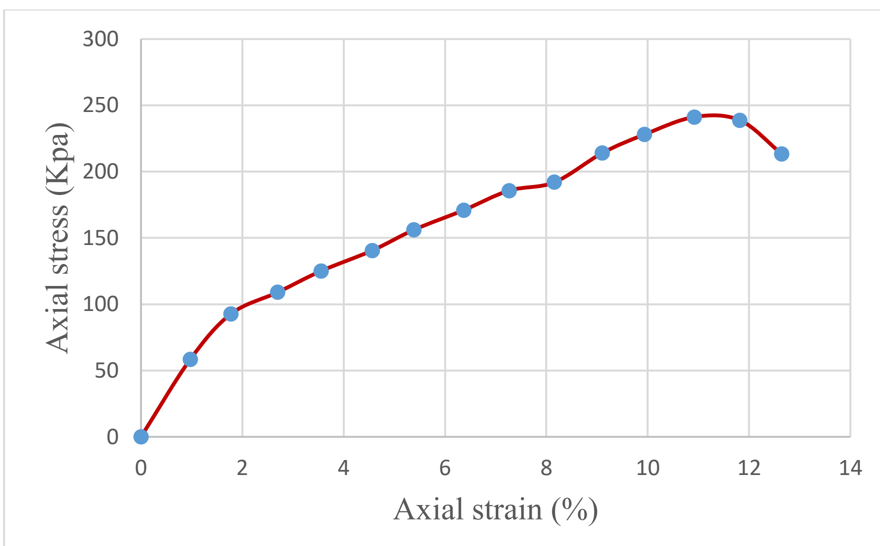


Figure 4.16: Day-3 unconfined compressive strength with 6% lime

In the figure number: 4.6.6, the maximum stress is 347.616 (kpa)

Table 4.6.7: Day-3 unconfined compressive strength with 9% lime

Deformation	Deformation ΔL (mm)	Axial strain = ϵ (%)	Corrected area (cm^2)	Load dial reading (proving ring)	Corrected load (kN)	Stress (kpa)
0	0	0	11.34	0	0	0.000
70	0.7	0.921	11.445	6	0.087	76.016
134	1.34	1.763	11.544	11	0.137	118.676
195	1.95	2.566	11.639	16	0.187	160.667
257	2.57	3.382	11.737	19	0.217	184.885
322	3.22	4.237	11.842	22	0.247	208.580
385	3.85	5.066	11.945	25	0.277	231.896
458	4.58	6.026	12.067	28	0.307	254.413
528	5.28	6.947	12.187	32	0.347	284.730
601	6.01	7.908	12.314	35	0.377	306.156
669	6.69	8.803	12.435	37	0.397	319.260
735	7.35	9.671	12.554	40	0.427	340.131
809	8.09	10.645	12.691	42	0.447	352.218
875	8.75	11.513	12.815	44	0.467	364.417
944	9.44	12.421	12.948	46	0.487	376.120
1012	10.12	13.316	13.082	46	0.487	372.267
1048	10.48	13.789	13.154	40	0.427	324.616

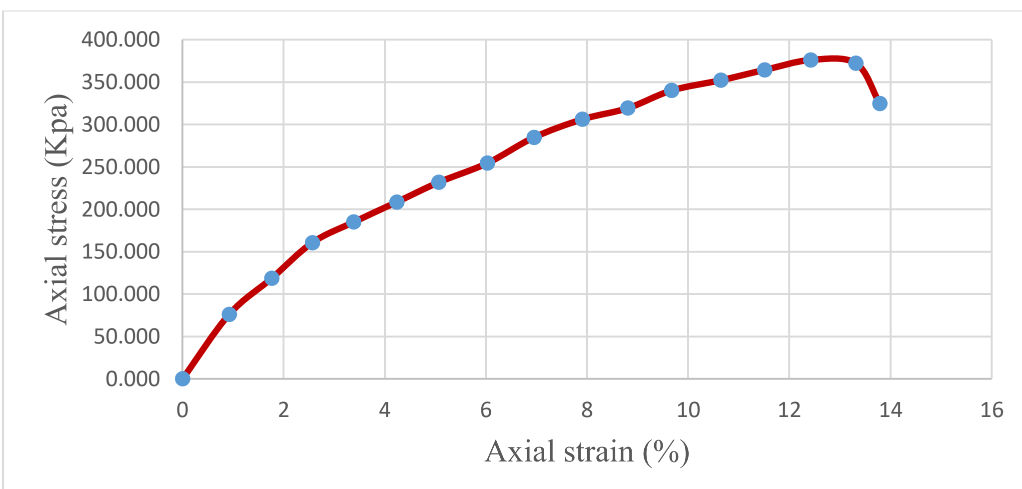


Figure 4.17: Day-3 unconfined compressive strength with 9% lime

In the figure number: 4.6.7, the maximum stress is 372.267 (kpa)

Table 4.6.8: Day-7 unconfined compressive strength with only soil.

Deformation	Deformation ΔL (mm)	Axial strain = ϵ (%)	Corrected area (cm^2)	Load dial reading (proving ring)	Corrected load (kN)	Stress (kpa)
0	0	0	11.34	0	0	0
96	0.96	1.263	11.485	9	0.117	101.872
145	1.45	1.908	11.561	13	0.157	135.801
186	1.86	2.447	11.624	15	0.177	152.271
254	2.54	3.342	11.732	18	0.207	176.441
321	3.21	4.224	11.84	20	0.227	191.723
388	3.88	5.105	11.95	23	0.257	215.063
463	4.63	6.092	12.076	25	0.277	229.381
528	5.28	6.947	12.187	28	0.307	251.908
599	5.99	7.882	12.31	30	0.327	265.638
674	6.74	8.868	12.443	33	0.357	286.908
736	7.36	9.684	12.556	35	0.377	300.255
805	8.05	10.592	12.683	38	0.407	320.902
872	8.72	11.474	12.81	40	0.427	333.333
912	9.12	12	12.886	37	0.397	308.086

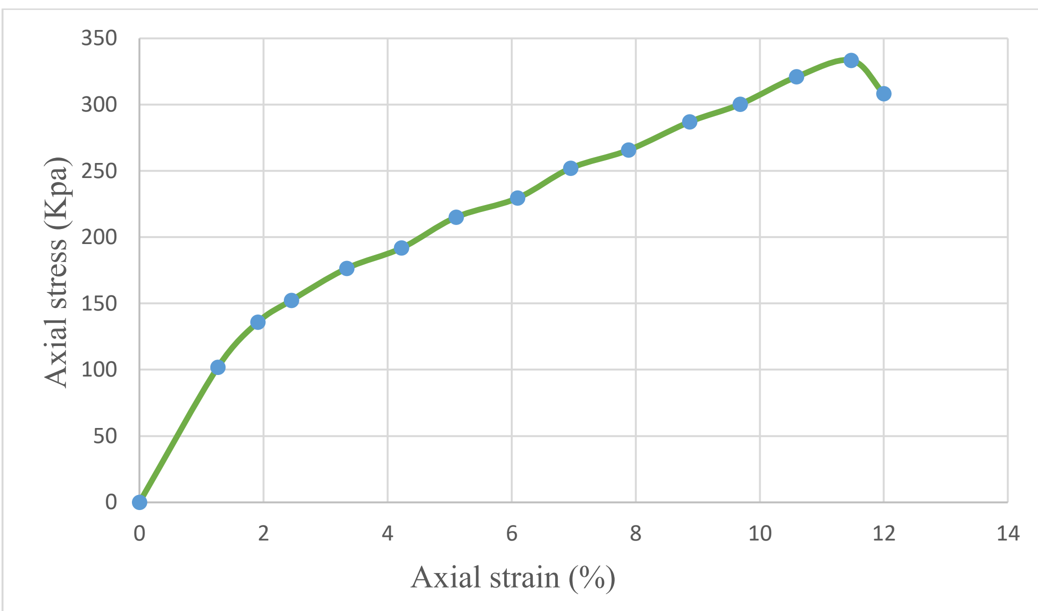


Figure 4.18**:** Day-7 unconfined compressive strength with only soil.

In the figure number: 4.6.8, the maximum stress is 333.333 (kpa)

Table 4.6.9: Day-7 unconfined compressive strength with 3% cement

Deformation	Deformation ΔL (mm)	Axial strain = ϵ (%)	Corrected area (cm^2)	Load dial reading (proving ring)	Corrected load (kN)	Stress (kpa)
0	0	0	11.34	0	0	0
42	0.42	0.553	11.403	11	0.137	120.144
89	0.89	1.171	11.474	28	0.307	267.561
150	1.5	1.974	11.568	42	0.447	386.411
212	2.12	2.789	11.665	50	0.527	451.779
272	2.72	3.579	11.761	58	0.607	516.113
343	3.43	4.513	11.876	65	0.677	570.057
414	4.14	5.447	11.993	66	0.687	572.834
465	4.65	6.118	12.079	61	0.637	527.362

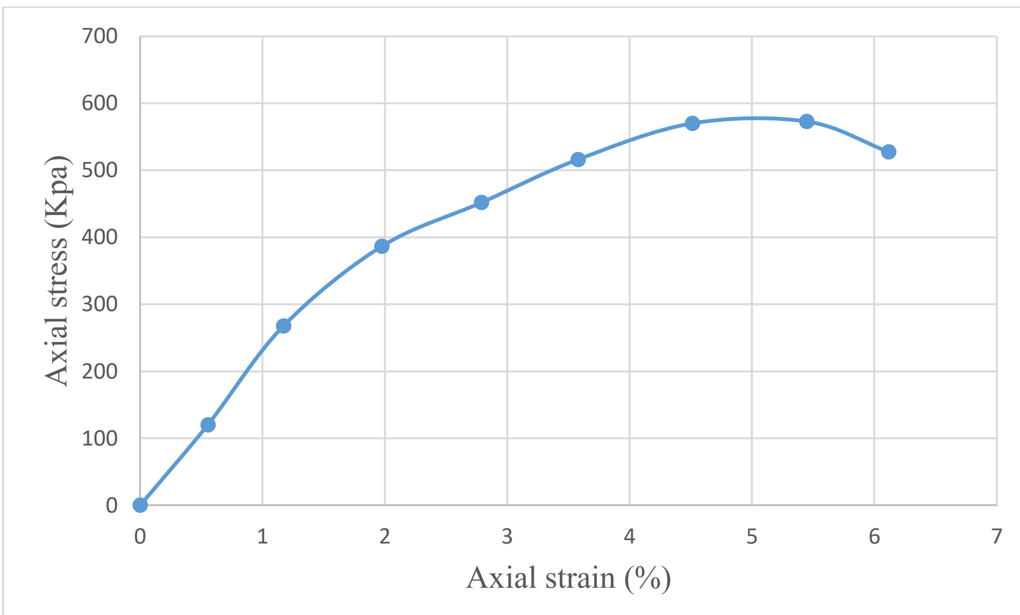


Figure 4.19: Day-7 unconfined compressive strength with 3% cement.

In the figure number: 4.6.9, the maximum stress is 572.834 (kpa)

Table 4.6.10: Day-7 unconfined compressive strength 6% cement

Deformation	Deformation ΔL (mm)	Axial strain = ϵ (%)	Corrected area (cm^2)	Load dial reading (proving ring)	Corrected load (kN)	Stress (kpa)
0	0	0	11.34	0	0	0
38	0.38	0.5	11.397	26	0.287	251.821
76	0.76	1	11.455	58	0.607	529.900
102	1.02	1.342	11.494	79	0.817	710.806
145	1.45	1.908	11.561	102	1.047	905.631
195	1.95	2.566	11.639	120	1.227	1054.214
245	2.45	3.224	11.718	131	1.337	1140.980
265	2.65	3.487	11.75	126	1.287	1095.319

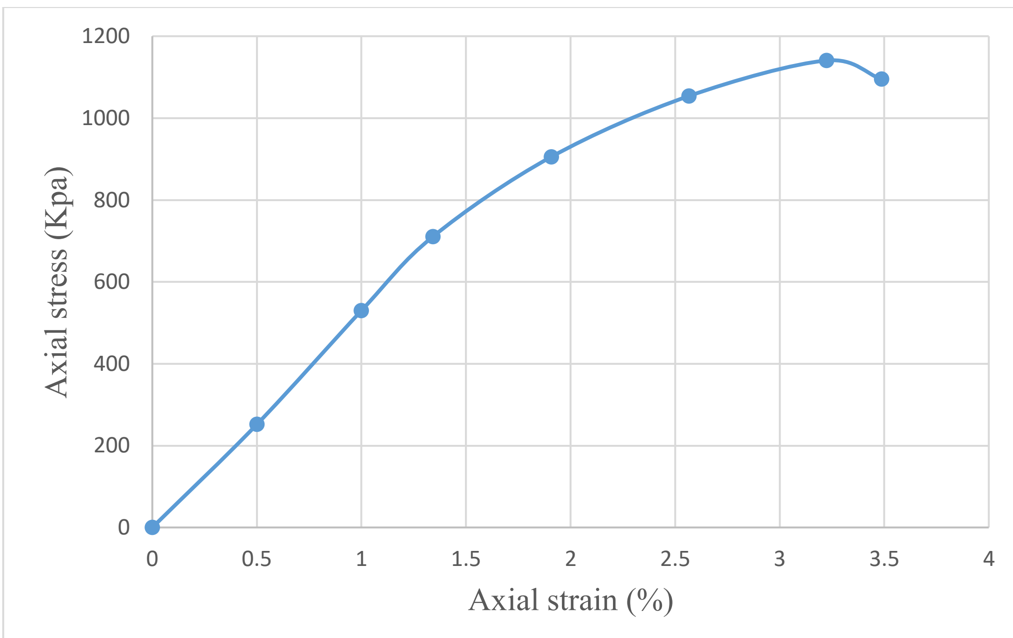


Figure 4.20: Day-7 unconfined compressive strength 6% cement.

In the figure number: 4.6.10, the maximum stress is 1140.980 (kpa)

Table 4.6.11: Day-7 unconfined compressive strength with 9 % cement

Deformation	Deformation ΔL (mm)	Axial strain = ϵ (%)	Corrected area (cm^2)	Load dial reading (proving ring)	Corrected load (kN)	Stress (kpa)
0	0	0	11.34	0	0	0
34	0.34	0.447	11.391	30	0.327	287.069
64	0.64	0.842	11.436	73	0.757	661.945
97	0.97	1.276	11.487	107	1.097	954.993
131	1.31	1.724	11.539	132	1.347	1167.35
185	1.85	2.434	11.623	149	1.517	1305.17
209	2.09	2.75	11.661	143	1.457	1249.46

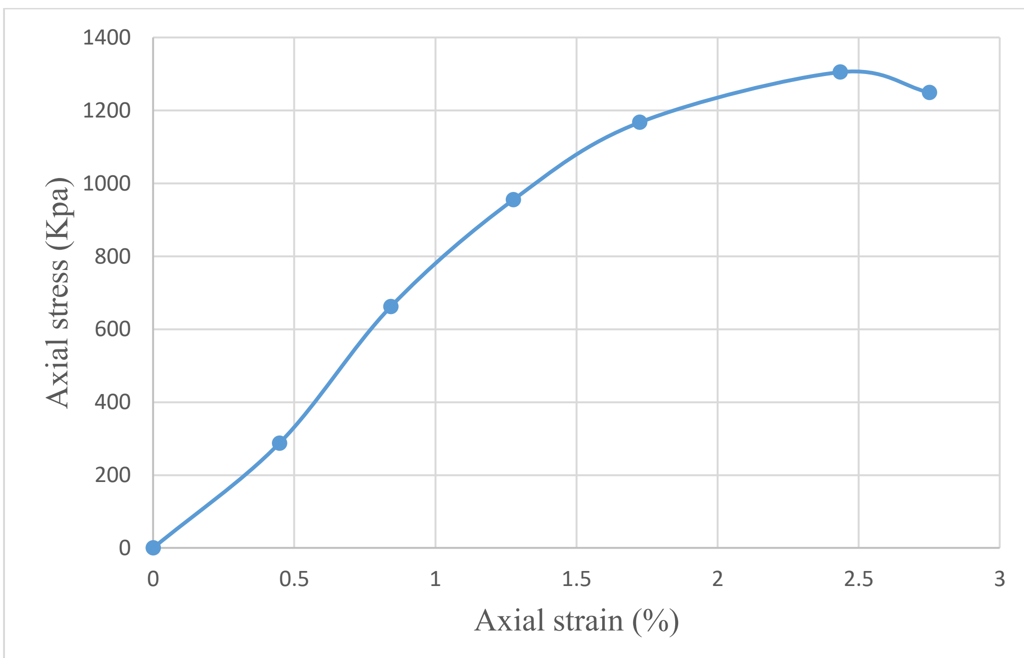


Figure 4.21: Day-7 unconfined compressive strength with 9 % cement.

In the figure number: 4.6.11, the maximum stress is 1305.17 (kpa)

Table 4.6.12: Day-7 unconfined compressive strength with 3% lime

Deformation	Deformation ΔL (mm)	Axial strain = ϵ (%)	Corrected area (cm^2)	Load dial reading (proving ring)	Corrected load (kN)	Stress (kpa)
0	0	0	11.34	0	0	0
77	0.77	1.013	11.456	6	0.087	75.9427
127	1.27	1.671	11.533	11	0.137	118.79
195	1.95	2.566	11.639	16	0.187	160.667
263	2.63	3.461	11.747	20	0.227	193.241
332	3.32	4.368	11.858	24	0.267	225.164
393	3.93	5.171	11.958	28	0.307	256.732
461	4.61	6.066	12.072	30	0.327	270.875
529	5.29	6.961	12.188	34	0.367	301.116
597	5.97	7.855	12.307	37	0.397	322.581
666	6.66	8.763	12.429	40	0.427	343.551
736	7.36	9.684	12.556	37	0.397	316.183

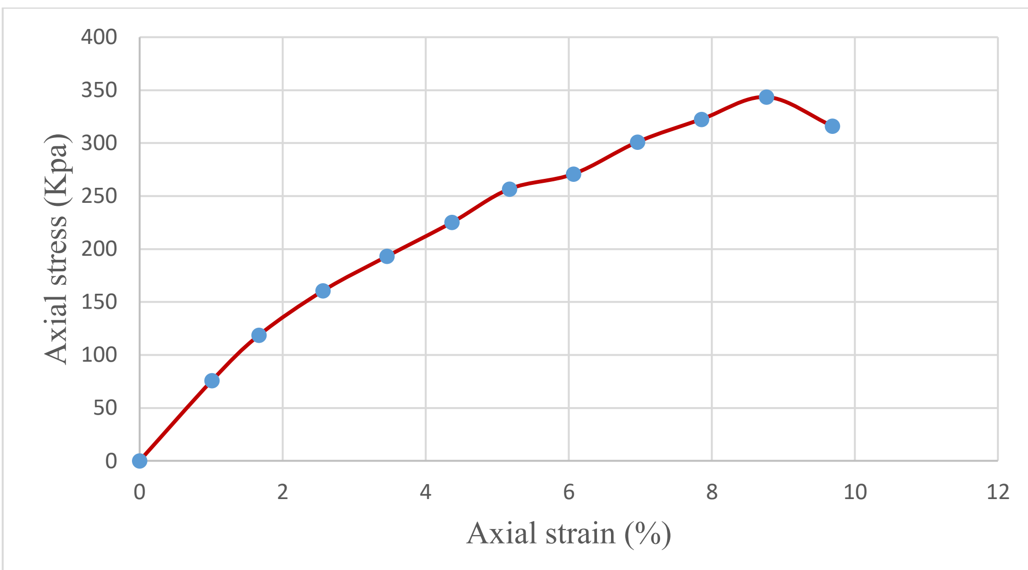


Figure 4.22: A Day-7 unconfined compressive strength with 3% lime.

In the figure number: 4.6.12, the maximum stress is 343.551 (kpa)

Table 4.6.13: Day-7 unconfined compressive strength with 6% lime

Deformation	Deformation ΔL (mm)	Axial strain = ϵ (%)	Corrected area (cm^2)	Load dial reading (proving ring)	Corrected load (kN)	Stress (kpa)
0	0	0	11.34	0	0	0
55	0.55	0.724	11.423	6	0.087	76.1621
116	1.16	1.526	11.516	12	0.147	127.648
193	1.93	2.539	11.635	16	0.187	160.722
245	2.45	3.224	11.718	20	0.227	193.719
311	3.11	4.092	11.824	24	0.267	225.812
380	3.8	5	11.937	28	0.307	257.184
450	4.5	5.921	12.054	31	0.337	279.575
520	5.2	6.842	12.173	35	0.377	309.702
589	5.89	7.75	12.293	38	0.407	331.083
659	6.59	8.671	12.417	40	0.427	343.883
725	7.25	9.539	12.536	36	0.387	308.711

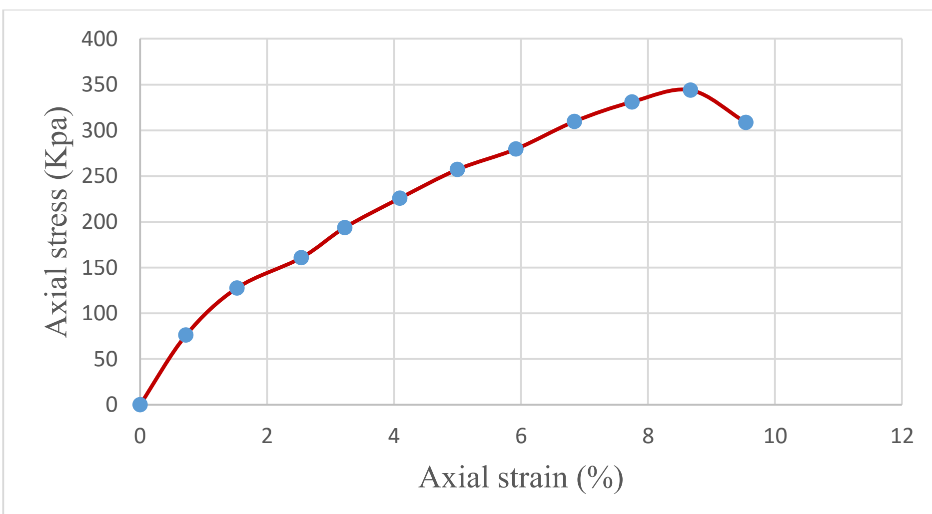


Figure 4.23: Day-7 unconfined compressive strength with 6% lime.

In the figure number: 4.6.13, the maximum stress is 343.883 (kpa)

Table 4.6.14: Day-7 unconfined compressive strength with 9% lime

Deformation	Deformation ΔL (mm)	Axial strain = ϵ (%)	Corrected area (cm^2)	Load dial reading (proving ring)	Corrected load (kN)	Stress (kpa)
0	0	0	11.34	0	0	0
76	0.76	1	11.455	9	0.117	102.139
124	1.24	1.632	11.528	14	0.167	144.865
181	1.81	2.382	11.617	19	0.217	186.795
245	2.45	3.224	11.718	23	0.257	219.321
315	3.15	4.145	11.83	26	0.287	242.604
382	3.82	5.026	11.94	29	0.317	265.494
451	4.51	5.934	12.055	33	0.357	296.143
525	5.25	6.908	12.181	36	0.387	317.708
596	5.96	7.842	12.305	39	0.417	338.887
665	6.65	8.75	12.427	41	0.437	351.654
739	7.39	9.724	12.561	42	0.447	355.863
767	7.67	10.092	12.613	37	0.397	314.755

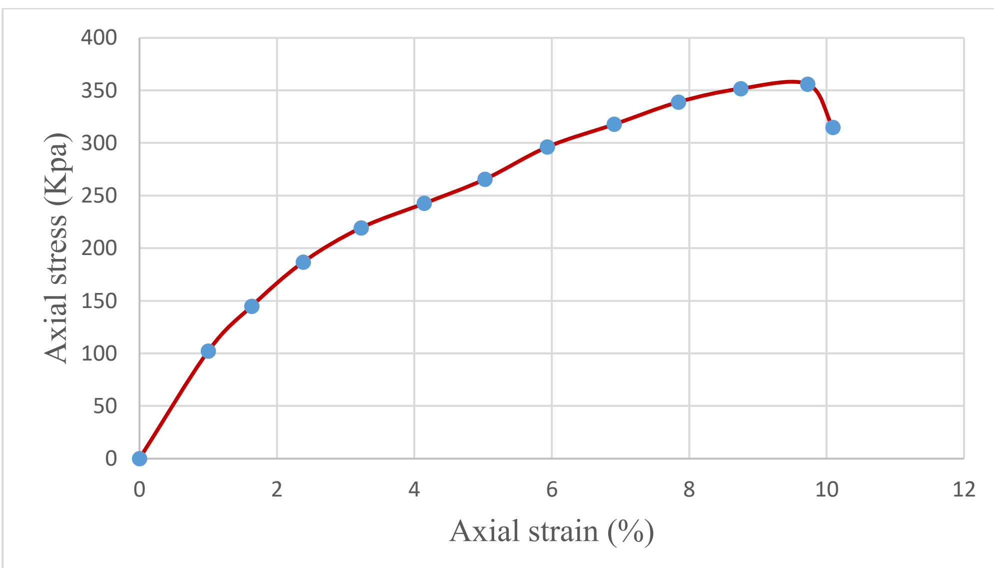


Figure 4.24: Day-7 unconfined compressive strength with 9% lime.

In the figure number: 4.6.14, the maximum stress is 355.863 (kpa)

Table 4.6.15: Day-14 unconfined compressive strength with Soil

Deformation	Deformation ΔL (mm)	Axial strain = ϵ (%)	Corrected area (cm^2)	Load dial reading (proving ring)	Corrected load (kN)	Stress (kpa)
0	0	0	11.34	0	0	0
61	0.61	0.803	11.432	5	0.077	67.355
122	1.22	1.605	11.525	10	0.127	110.195
186	1.86	2.447	11.624	15	0.177	152.271
248	2.48	3.263	11.723	19	0.217	185.106
312	3.12	4.105	11.825	22	0.247	208.879
381	3.81	5.013	11.938	26	0.287	240.409
445	4.45	5.855	12.045	29	0.317	263.180
513	5.13	6.75	12.161	32	0.347	285.338
585	5.85	7.697	12.286	35	0.377	306.853
650	6.5	8.553	12.401	38	0.407	328.199
722	7.22	9.5	12.53	41	0.437	348.763
796	7.96	10.474	12.667	43	0.457	360.780
836	8.36	11	12.742	40	0.427	335.112

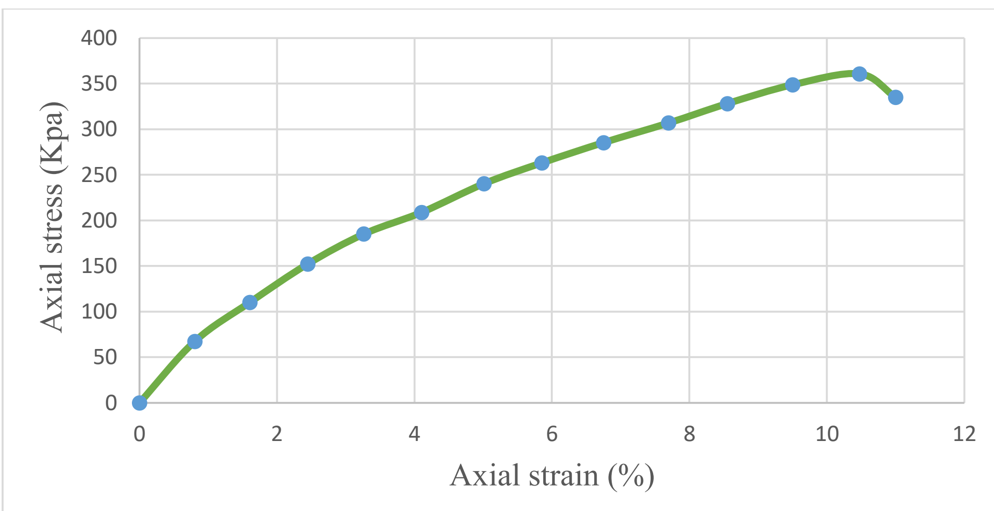


Figure 4.25: Day-14 unconfined compressive strength with Soil.

In the figure number: 4.6.15, the maximum stress is 360.780 (kpa)

Table 4.6.16: Day-14 unconfined compressive strength with 3% cement

Deformation	Deformation ΔL (mm)	Axial strain = ϵ (%)	Corrected area (cm^2)	Load dial reading (proving ring)	Corrected load (kN)	Stress (kpa)
0	0	0	11.34	0	0	0
51	0.51	0.671	11.417	16	0.187	163.791
104	1.04	1.368	11.497	31	0.337	293.120
156	1.56	2.053	11.578	43	0.457	394.714
214	2.14	2.816	11.669	53	0.557	477.333
271	2.71	3.566	11.759	60	0.627	533.209
332	3.32	4.368	11.858	65	0.677	570.923
390	3.9	5.132	11.953	64	0.667	558.019

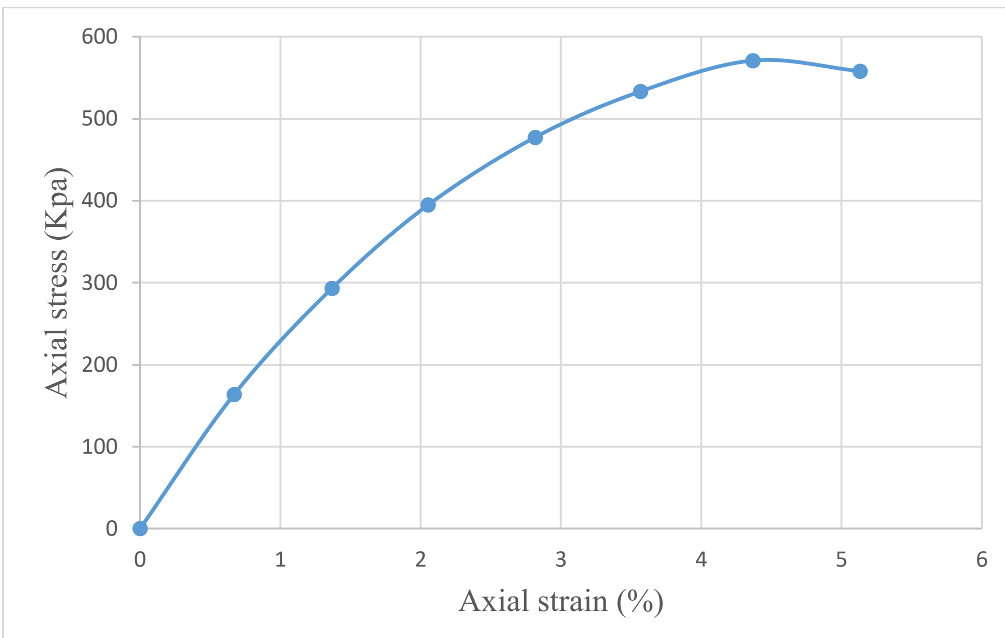


Figure 4.26: Day-14 unconfined compressive strength with 3% cement.

In the figure number: 4.6.16, the maximum stress is 570.923 (kpa)

Table 4.6.17: Day-14 unconfined compressive strength with 6% cement

Deformation	Deformation ΔL (mm)	Axial strain = ϵ (%)	Corrected area (cm^2)	Load dial reading (proving ring)	Corrected load (kN)	Stress (kpa)
0	0	0	11.34	0	0	0
25	0.25	0.329	11.377	22	0.247	217.105
55	0.55	0.724	11.423	47	0.497	435.087
92	0.92	1.211	11.479	78	0.807	703.023
136	1.36	1.789	11.547	102	1.047	906.729
209	2.09	2.75	11.661	112	1.147	983.621
227	2.27	2.987	11.689	109	1.117	955.599

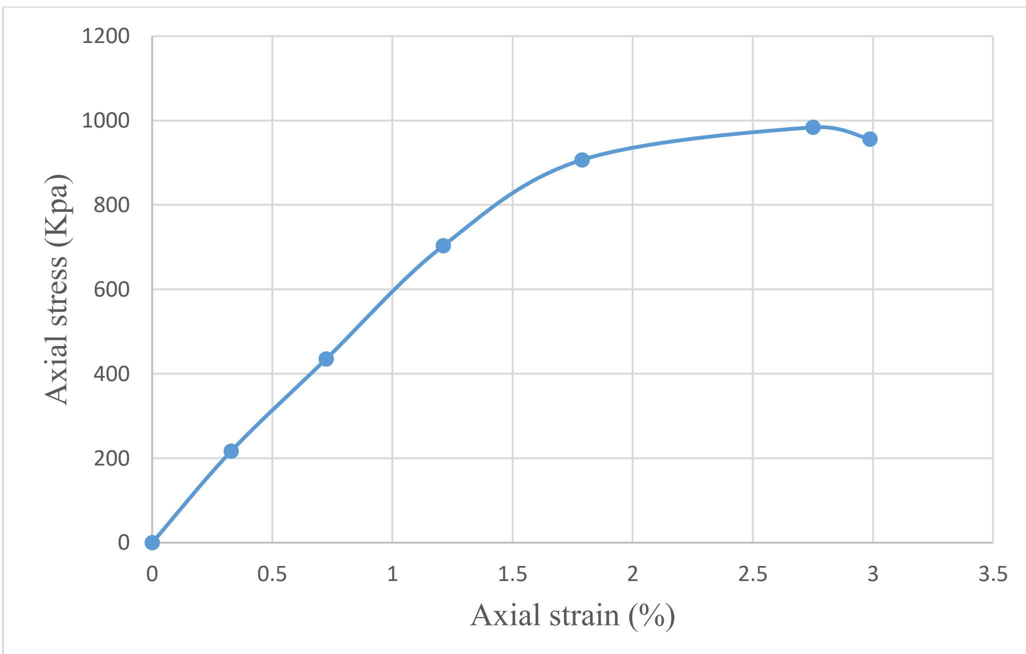


Figure 4.27: Day-14 unconfined compressive strength with 6% cement.

In the figure number: 4.6.17, the maximum stress is 983.621 (kpa)

Table 4.6.18: Day-14 unconfined compressive strength with 9% cement

Deformation	Deformation ΔL (mm)	Axial strain = ϵ (%)	Corrected area (cm^2)	Load dial reading (proving ring)	Corrected load (kN)	Stress (kpa)
0	0	0	11.34	0	0	0
22	0.22	0.289	11.373	41	0.437	384.243
51	0.51	0.671	11.417	82	0.847	741.876
76	0.76	1	11.455	123	1.257	1097.337
112	1.12	1.474	11.51	157	1.597	1387.489
154	1.54	2.026	11.574	183	1.857	1604.458
177	1.77	2.329	11.61	177	1.797	1547.804

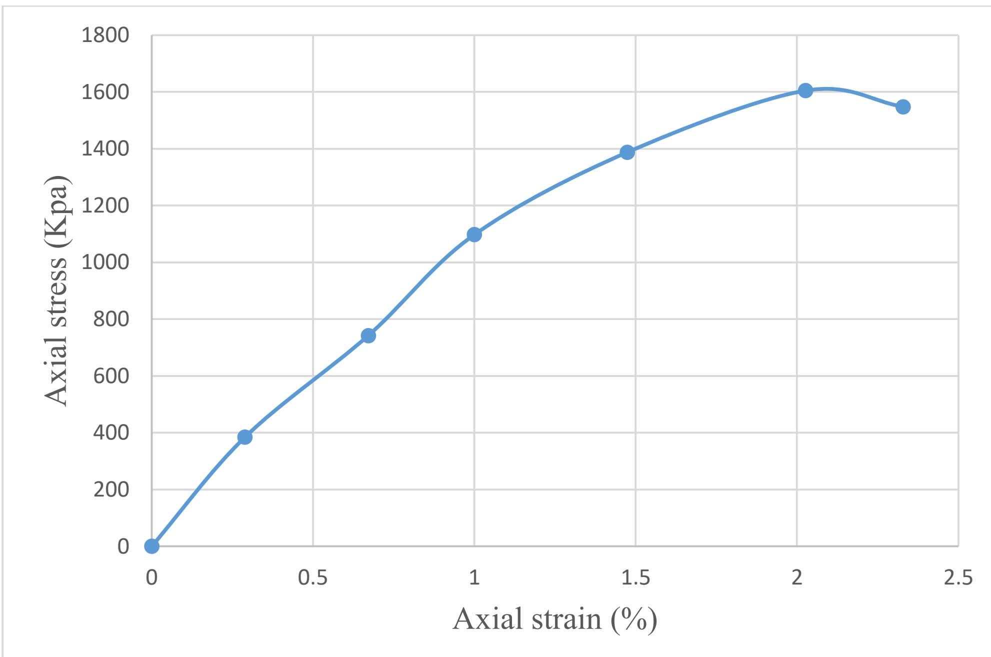


Figure 4.28: Day-14 unconfined compressive strength with 9% cement.

In the figure number: 4.6.18, the maximum stress is 1604.458 (kpa)

Table 4.6.19: Day-14 unconfined compressive strength with 3% lime

Deformation	Deformation ΔL (mm)	Axial strain = ϵ (%)	Corrected area (cm^2)	Load dial reading (proving ring)	Corrected load (kN)	Stress (kpa)
0	0	0	11.34	0	0	0
54	0.54	0.711	11.421	4	0.067	58.664
115	1.15	1.513	11.514	8	0.107	92.930
187	1.87	2.461	11.626	13	0.157	135.042
263	2.63	3.461	11.747	17	0.197	167.702
325	3.25	4.276	11.847	24	0.267	225.374
396	3.96	5.211	11.963	28	0.307	256.625
466	4.66	6.132	12.081	33	0.357	295.505
540	5.4	7.105	12.207	38	0.407	333.415
606	6.06	7.974	12.323	41	0.437	354.621
674	6.74	8.868	12.443	44	0.467	375.311
760	7.6	10	12.6	45	0.477	378.571
823	8.23	10.829	12.717	41	0.437	343.635

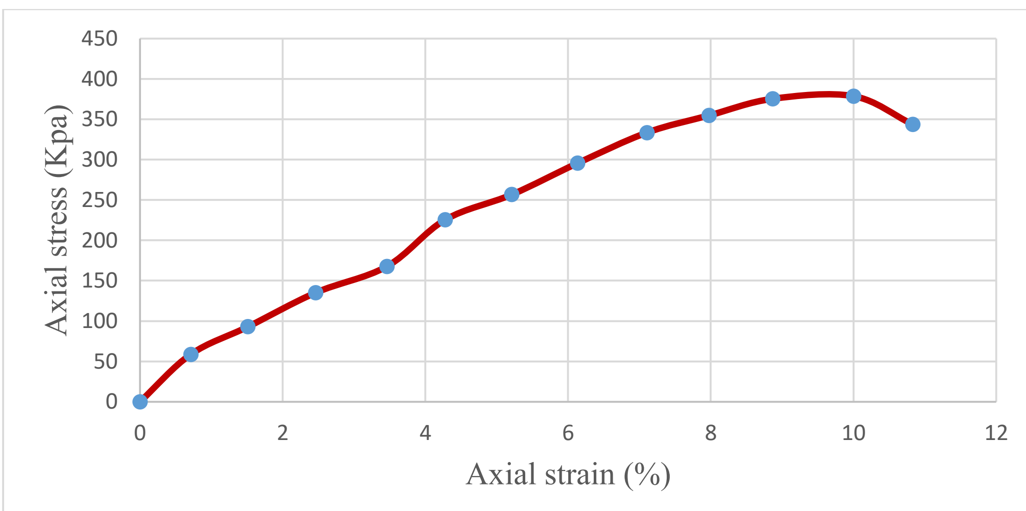


Figure 4.29: Day-14 unconfined compressive strength with 3% lime.

In the figure number: 4.6.19, the maximum stress is 378.571 (kpa)

Table 4.6.20: Day-14 unconfined compressive strength with 6% lime

Deformation	Deformation ΔL (mm)	Axial strain = ϵ (%)	Corrected area (cm^2)	Load dial reading (proving ring)	Corrected load (kN)	Stress (kpa)
0	0	0	11.34	0	0	0
57	0.57	0.75	11.426	6	0.087	76.142
109	1.09	1.434	11.505	10	0.127	110.387
188	1.88	2.474	11.628	16	0.187	160.819
255	2.55	3.355	11.734	21	0.237	201.977
323	3.23	4.25	11.843	25	0.277	233.893
390	3.9	5.132	11.953	29	0.317	265.205
460	4.6	6.053	12.071	33	0.357	295.750
531	5.31	6.987	12.192	38	0.407	333.825
600	6	7.895	12.312	43	0.457	371.183
668	6.68	8.789	12.433	48	0.507	407.786
695	6.95	9.145	12.481	44	0.467	374.169

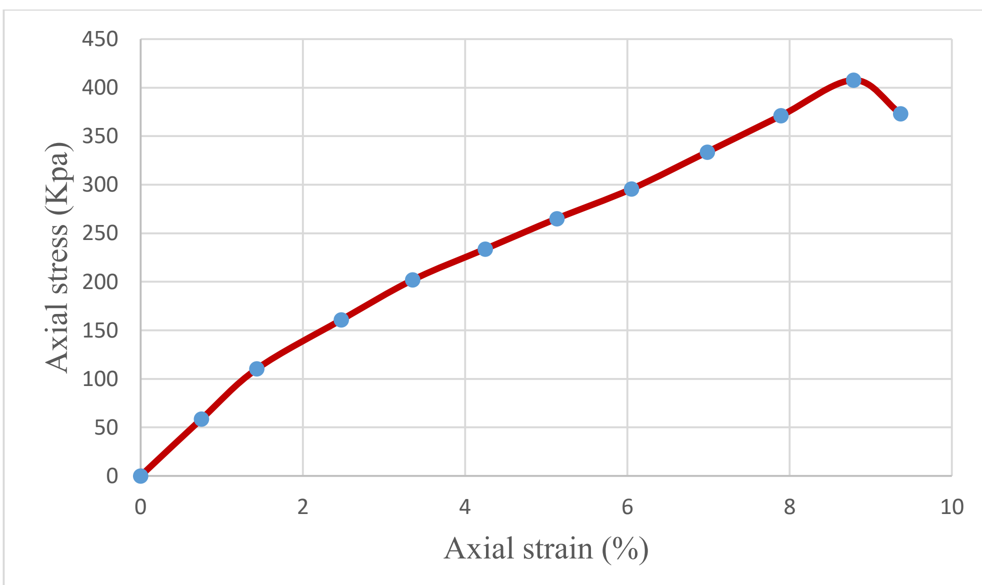


Figure 4.30: Day-14 unconfined compressive strength with 6% lime.

In the figure number: 4.6.20, the maximum stress is 407.786 (kpa)

Table 4.6.21: Day-14 unconfined compressive strength with 9% Lime

Deformation	Deformation ΔL (mm)	Axial strain = ϵ (%)	Corrected area (cm^2)	Load dial reading (proving ring)	Corrected load (kN)	Stress (kpa)
0	0	0	11.34	0	0	0
57	0.57	0.75	11.426	6	0.087	76.142
109	1.09	1.434	11.505	10	0.127	110.387
188	1.88	2.474	11.628	16	0.187	160.819
255	2.55	3.355	11.734	21	0.237	201.977
323	3.23	4.25	11.843	25	0.277	233.893
390	3.9	5.132	11.953	29	0.317	265.205
460	4.6	6.053	12.071	33	0.357	295.750
531	5.31	6.987	12.192	38	0.407	333.825
600	6	7.895	12.312	43	0.457	371.183
668	6.68	8.789	12.433	48	0.507	407.786
695	6.95	9.145	12.481	44	0.467	374.169

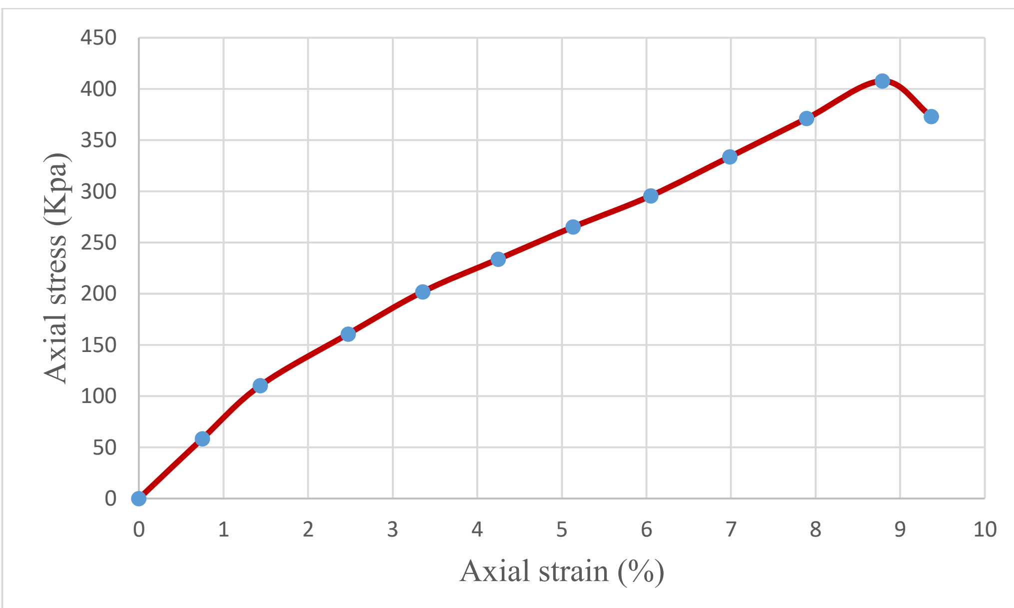


Figure 4.31: Day-14 unconfined compressive strength with 9% lime.

In the figure number: 4.6.21, the maximum stress is 407.786 (kpa)

Table 4.6.22: Day-28 unconfined compressive strength with soil

Deformation	Deformation ΔL (mm)	Axial strain = ϵ (%)	Corrected area (cm^2)	Load dial reading (proving ring)	Corrected load (kN)	Stress (kpa)
0	0	0	11.34	0	0	0
60	0.6	0.789	11.43	4	0.067	58.618
130	1.3	1.711	11.537	9	0.117	101.413
205	2.05	2.697	11.654	12	0.147	126.137
260	2.6	3.421	11.742	14	0.167	142.224
330	3.3	4.342	11.855	17	0.197	166.175
398	3.98	5.237	11.967	19	0.217	181.332
465	4.65	6.118	12.079	21	0.237	196.208
536	5.36	7.053	12.201	24	0.267	218.835
604	6.04	7.947	12.319	26	0.287	232.973
689	6.89	9.066	12.471	28	0.307	246.171
751	7.51	9.882	12.584	30	0.327	259.854
821	8.21	10.803	12.713	31	0.337	265.083
905	9.05	11.908	12.873	29	0.317	246.252

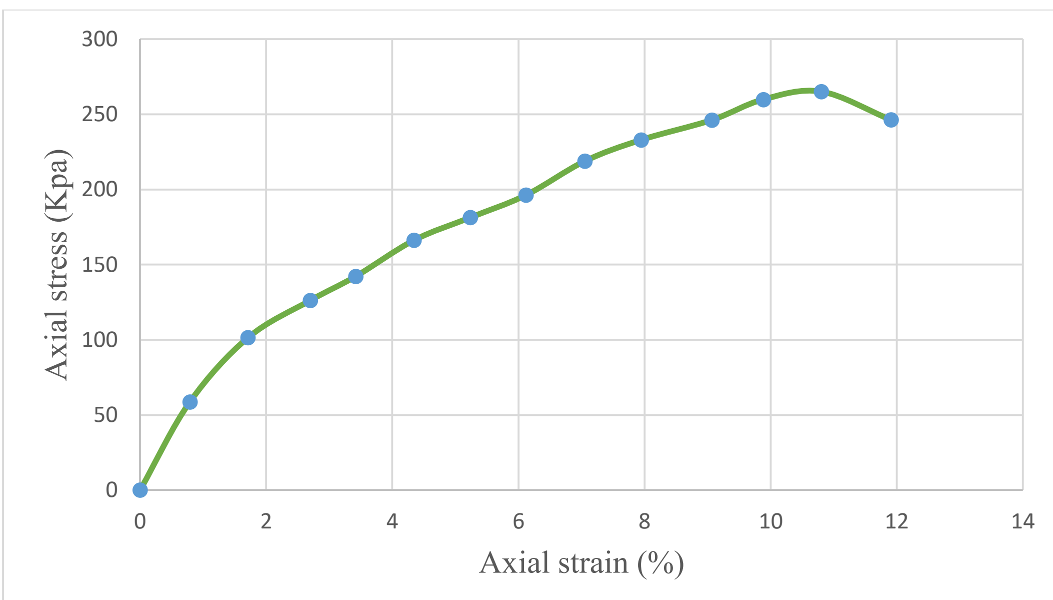


Figure 4.32: Day-28 unconfined compressive strength with soil.

In the figure number: 4.6.22, the maximum stress is 265.083 (kpa)

Table 4.6.23: Day-28 unconfined compressive strength with 3% cement

Deformation	Deformation ΔL (mm)	Axial strain = ϵ (%)	Corrected area (cm^2)	Load dial reading (proving ring)	Corrected load (kN)	Stress (kpa)
0	0	0	11.34	0	0	0
41	0.41	0.539	11.401	16	0.187	164.021
81	0.81	1.066	11.462	40	0.427	372.535
130	1.3	1.711	11.537	58	0.607	526.133
186	1.86	2.447	11.624	71	0.737	634.033
247	2.47	3.25	11.721	82	0.847	722.635
311	3.11	4.092	11.824	90	0.927	783.999
376	3.76	4.947	11.93	96	0.987	827.326
416	4.16	5.474	11.997	92	0.947	789.364

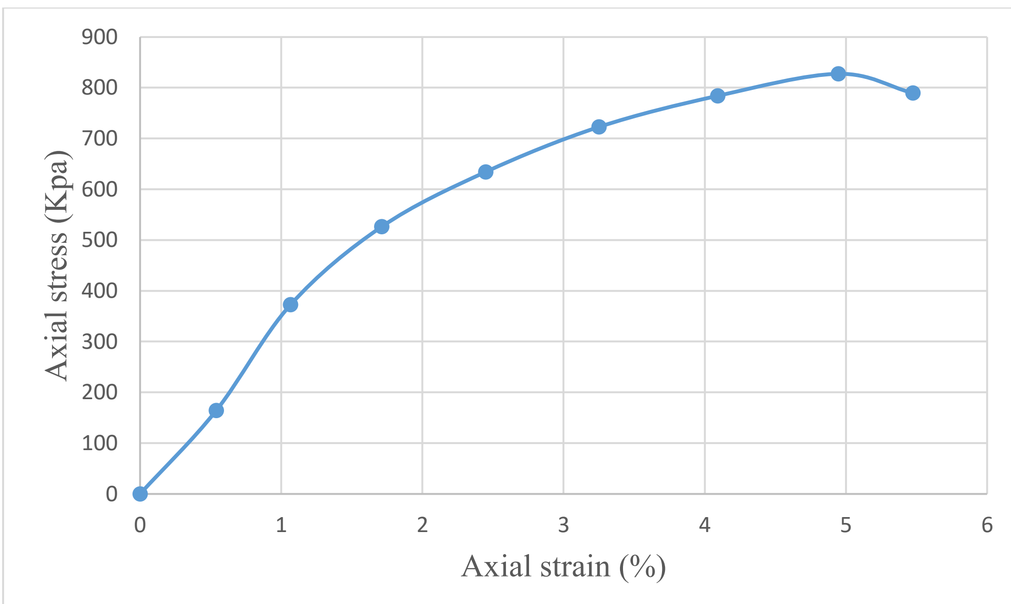


Figure 4.33: Day-28 unconfined compressive strength with 3% cement.

In the figure number: 4.6.23, the maximum stress is 827.326 (kpa)

Table 4.6.24: Day-28 unconfined compressive strength with 6 % cement

Deformation	Deformation ΔL (mm)	Axial strain % (ϵ)	Corrected area (cm^2)	Load dial reading (proving ring)	Corrected load (kN)	Stress (kpa)
0	0	0	11.34	0	0	0
25	0.25	0.329	11.377	38	0.407	357.739
49	0.49	0.645	11.414	82	0.847	742.071
81	0.81	1.066	11.462	117	1.197	1044.320
119	1.19	1.566	11.52	145	1.477	1282.118
160	1.6	2.105	11.584	167	1.697	1464.952
206	2.06	2.711	11.656	181	1.837	1576.012
239	2.39	3.145	11.708	174	1.767	1509.224

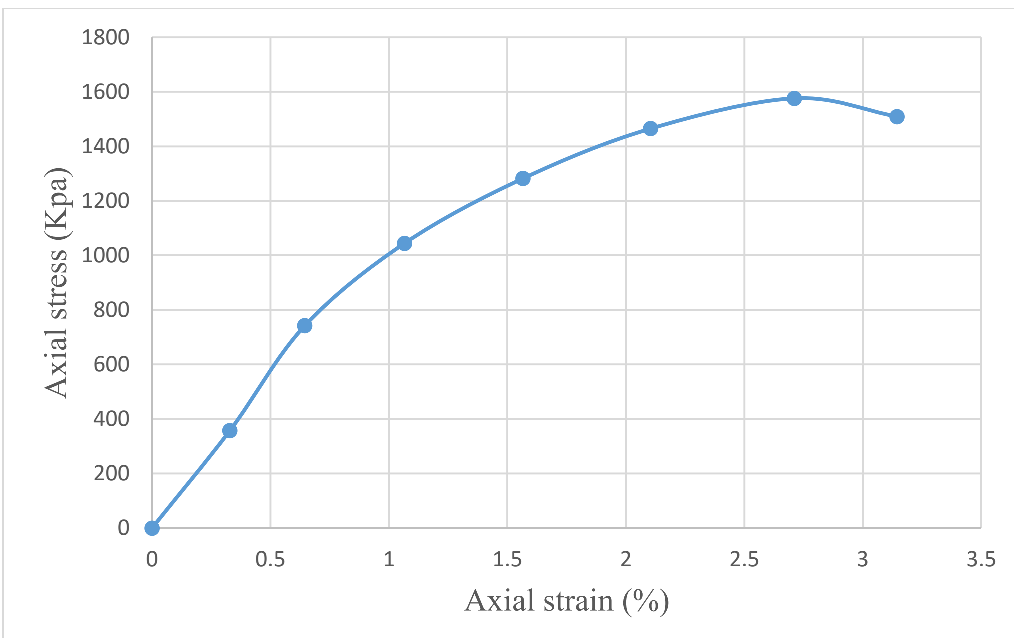


Figure 4.34: Day-28 unconfined compressive strength with 6 % cement.

In the figure number: 4.6.24, the maximum stress is 1576.012 (kpa)

Table 4.6.25: Day-28 unconfined compressive strength with 9 % cement

Deformation	Deformation ΔL (mm)	Axial strain = ϵ (%)	Corrected area (cm^2)	Load dial reading (proving ring)	Corrected load (kN)	Stress (kpa)
0	0	0	11.34	0	0	0
62	0.62	0.816	11.433	35	0.377	329.747
103	1.03	1.355	11.496	63	0.657	571.503
139	1.39	1.829	11.551	96	0.987	854.471
168	1.68	2.211	11.596	128	1.307	1127.113
203	2.03	2.671	11.651	170	1.727	1482.276
234	2.34	3.079	11.7	202	2.047	1749.573
268	2.68	3.526	11.754	211	2.137	1818.104
296	2.96	3.895	11.8	206	2.087	1768.644

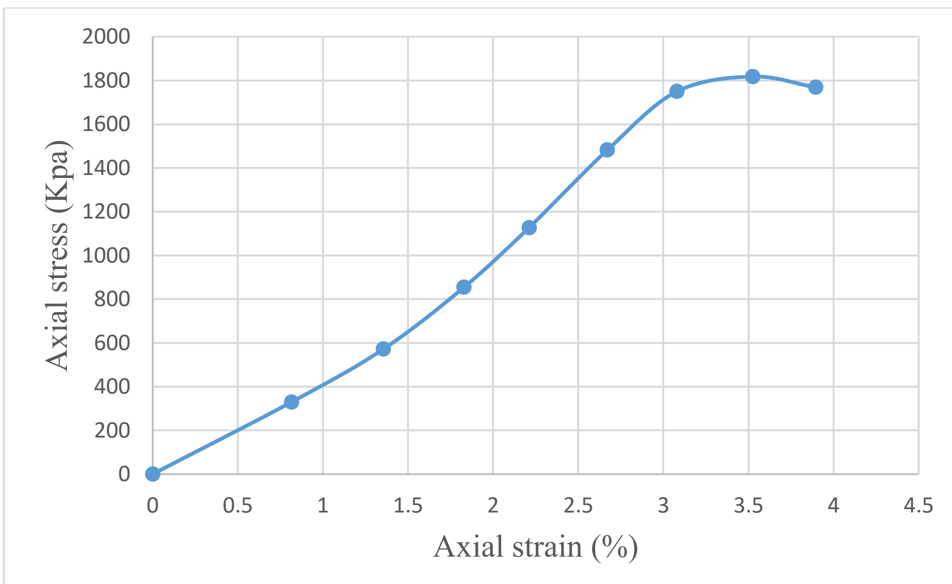


Figure 4.35: Day-28 unconfined compressive strength with 9 % cement.

In the figure number: 4.6.25, the maximum stress is 1818.104 (kpa)

Table 4.6.26: Day-28 unconfined compressive strength 3 % lime

Deformation	Deformation ΔL (mm)	Axial strain = ϵ (%)	Corrected area (cm^2)	Load dial reading (proving ring)	Corrected load (kN)	Stress (kpa)
0	0	0	11.34	0	0	0
55	0.55	0.724	11.423	6	0.087	76.162
123	1.23	1.618	11.526	9	0.117	101.510
193	1.93	2.539	11.635	13	0.157	134.938
258	2.58	3.395	11.739	16	0.187	159.298
345	3.45	4.539	11.879	21	0.237	199.512
493	4.93	6.487	12.127	27	0.297	244.908
560	5.6	7.368	12.242	30	0.327	267.113
630	6.3	8.289	12.365	32	0.347	280.631
693	6.93	9.118	12.478	35	0.377	302.132
767	7.67	10.092	12.613	38	0.417	372.683
841	8.41	11.066	12.751	39	0.467	427.238
909	9.09	11.961	12.881	35	0.377	292.679

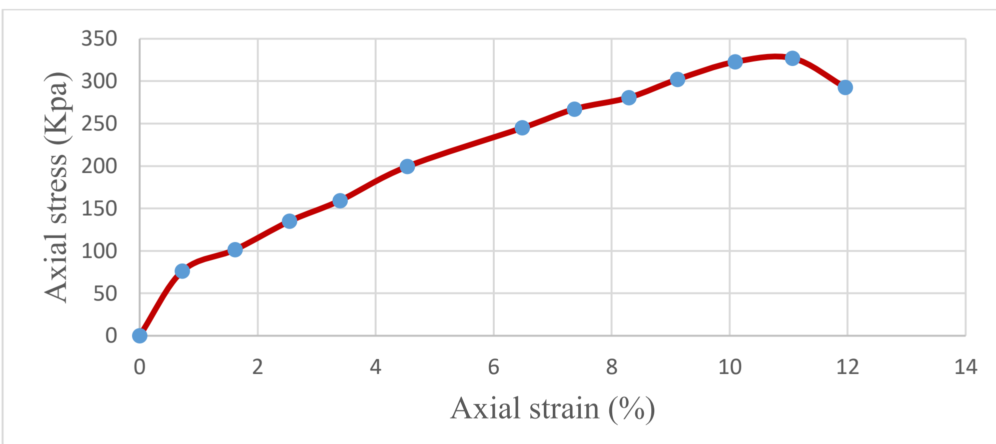


Figure 4.36: Day-28 unconfined compressive strength 3 % lime.

In the figure number: 4.6.26, the maximum stress is 427.238 (kpa)

Table 4.6.27: Day-28 unconfined compressive strength of 6 % lime

Deformation	Deformation ΔL (mm)	Axial strain = ϵ (%)	Corrected area (cm^2)	Load dial reading (proving ring)	Corrected load (kN)	Stress (kpa)
0	0	0	11.34	0	0	0
53	0.53	0.697	11.42	6	0.087	76.182
109	1.09	1.434	11.505	10	0.127	110.387
192	1.92	2.526	11.634	16	0.187	160.736
261	2.61	3.434	11.743	22	0.247	210.338
333	3.33	4.382	11.86	26	0.287	241.990
407	4.07	5.355	11.982	30	0.327	272.909
456	4.56	6	12.064	34	0.367	304.211
489	4.89	6.434	12.12	37	0.397	327.558
529	5.29	6.961	12.188	41	0.467	382.140
579	5.79	7.618	12.275	44	0.507	431.181
609	6.09	8.013	12.328	40	0.427	346.366

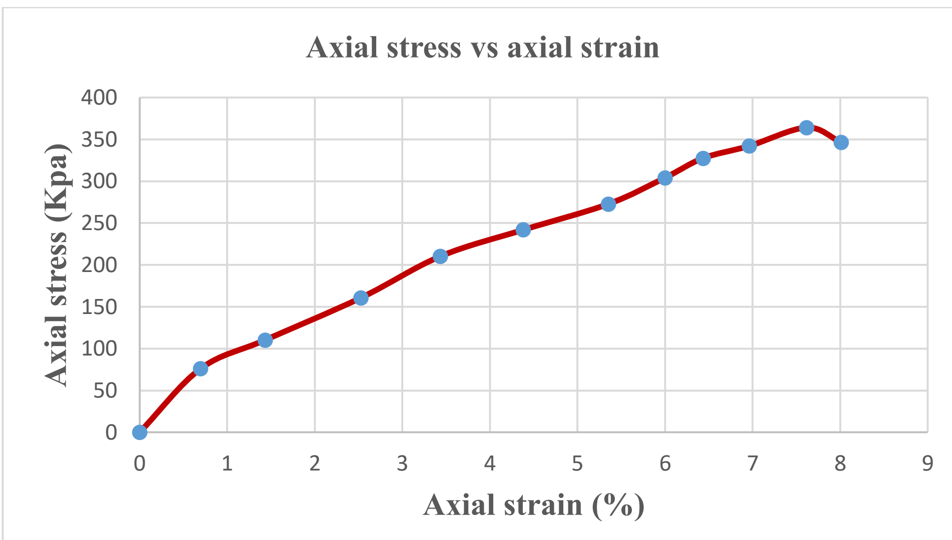


Figure 4.37: Day-28 unconfined compressive strength of 6 % lime.

In the figure number: 4.6.27, maximum stress 431.181 (kpa)

Table 4.6.28: Day-28 unconfined compressive strength with 9 % lime

Deformation	Deformation ΔL (mm)	Axial strain = ϵ (%)	Corrected area (cm^2)	Load dial reading (proving ring)	Corrected load (kN)	Stress (kpa)
0	0	0	11.34	0	0	0
80	0.8	1.053	11.461	9	0.117	102.085
135	1.35	1.776	11.545	15	0.177	153.313
200	2	2.632	11.647	20	0.227	194.900
245	2.45	3.224	11.718	24	0.267	227.855
335	3.35	4.408	11.863	29	0.317	267.217
407	4.07	5.355	11.982	33	0.357	297.947
475	4.75	6.25	12.096	37	0.397	328.208
547	5.47	7.197	12.219	40	0.427	349.456
613	6.13	8.066	12.335	42	0.447	362.383
661	6.61	8.697	12.42	44	0.467	376.006
688	6.88	9.053	12.469	46	0.487	390.569
760	7.6	10	12.6	48	0.517	459.84
807	8.07	10.618	12.687	43	0.457	360.211

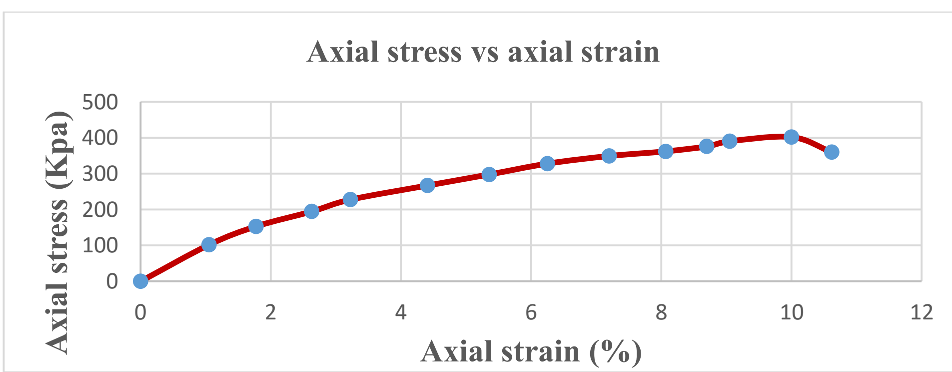


Figure 4.38: Day-28 unconfined compressive strength with 9 % lime.

In the figure number: 4.6.28, the maximum stress is 459.842 (kpa)

Chapter-5
Results and Discussion

5.1 General:

In this thesis, a total of Fifty-six unconfined compression tests are conducted. We tested the quality for 3, 7, 14, 28 days using cement and lime in four proportions with soil. From this research, it’s also found that adding cement and lime at a certain limit it starts to settle and perform.

5.2 Results and discussion:

The unconfined compression test was conducted for organic clay with cement and lime with various ratios and the result is presented in [Figure 4.39, 4.40, 4.41, 4.42]. It was found that the unconfined compressive strength of organic clays goes on increasing with 9% cement and 9% lime between four ratios. Show that the curing period (3, 7, 14 & 28 days) as it grows, serially the value is increasing for cement content. For lime case; in the same process, the value is decreasing from cement. But it was found from this experiment that cement is much more effective than lime.

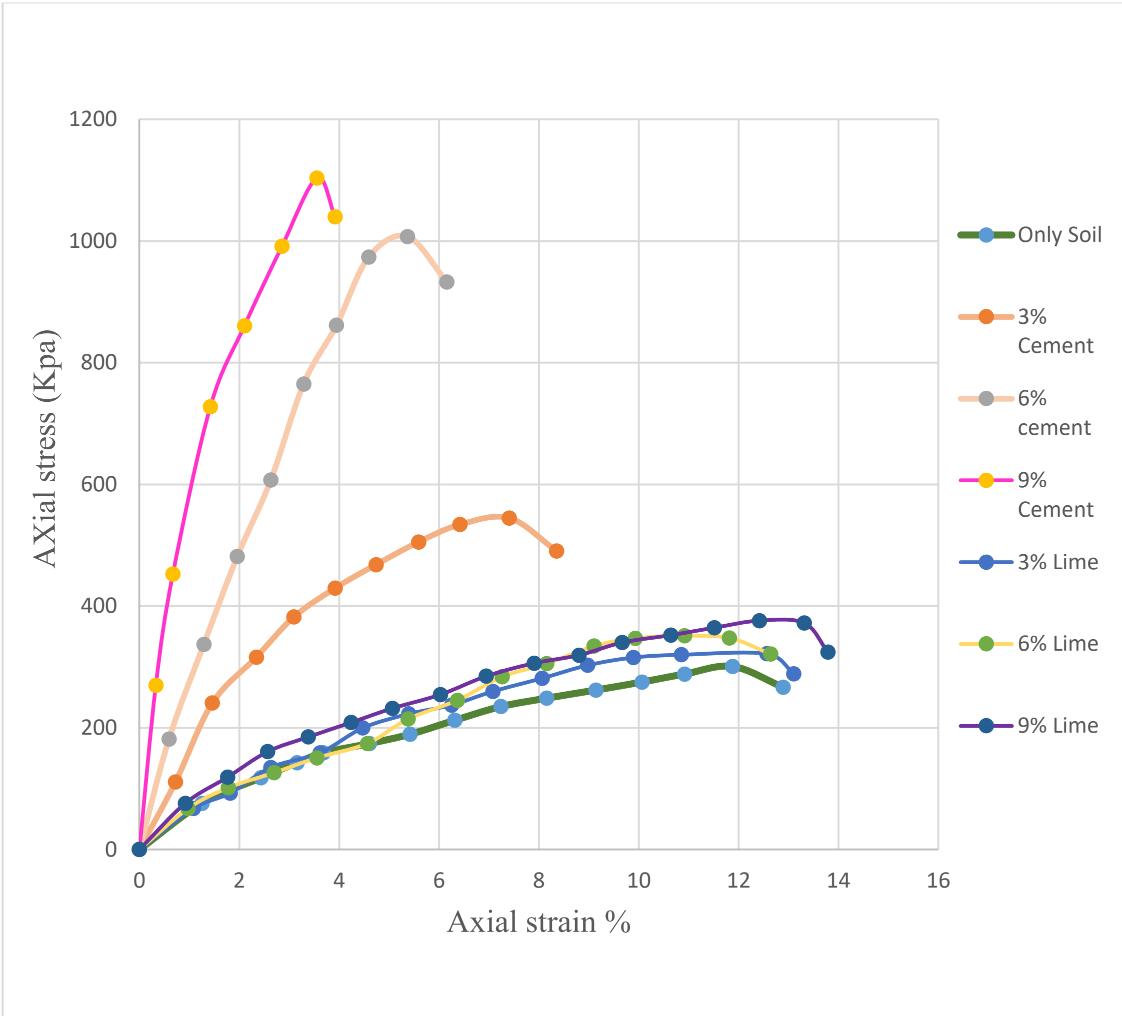


Figure 4.39: Combine cement axial stress vs lime axial stress (day -3)

Above in the figure to included gradually 3%, 6% & 9% cement compare to 3%, 6% & 9% lime respectively soil with 3 days curing period. Determine 9% cement increased high stress 544.623 kpa periodically 6% high stress value 1007.26. & 9% high stress value 1103.0789. But shows that in the curing period, the lime is nearly lower increased respectively soil. Lime high stress 244.41 kpa by 3%, 238.743 kpa by 6% lime and 311.115 kpa by 9% lime. Color has identified the percent of admixture & stress.

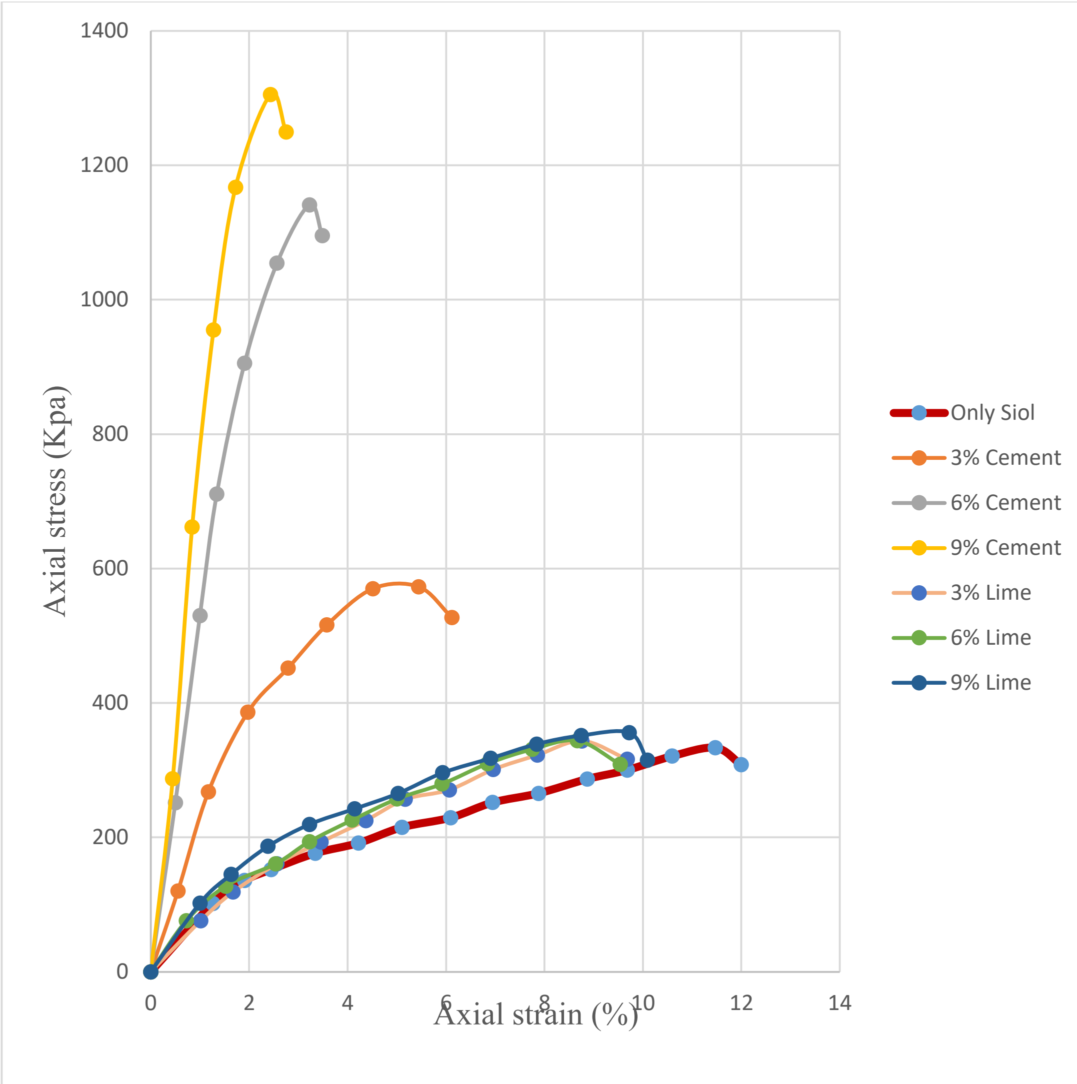


Figure 4.40: Combine cement axial stress vs lime axial stress (day -7)

Above in the figure to included gradually 3%, 6% & 9% cement compare to 3%, 6% & 9% lime respectively soil with 3 days curing period. Determine 3% cement increased high stress 572.834 kpa periodically 6% high stress value 1140.98 & 9% high stress value 1305.17. But shows that in the curing period, the lime is nearly lower increased respectively soil. Lime high stress 343.551 kpa by 3%, 343.883 kpa by 6% lime and 355.863kpa by 9% lime. Color has identified the percent of admixture & stress.

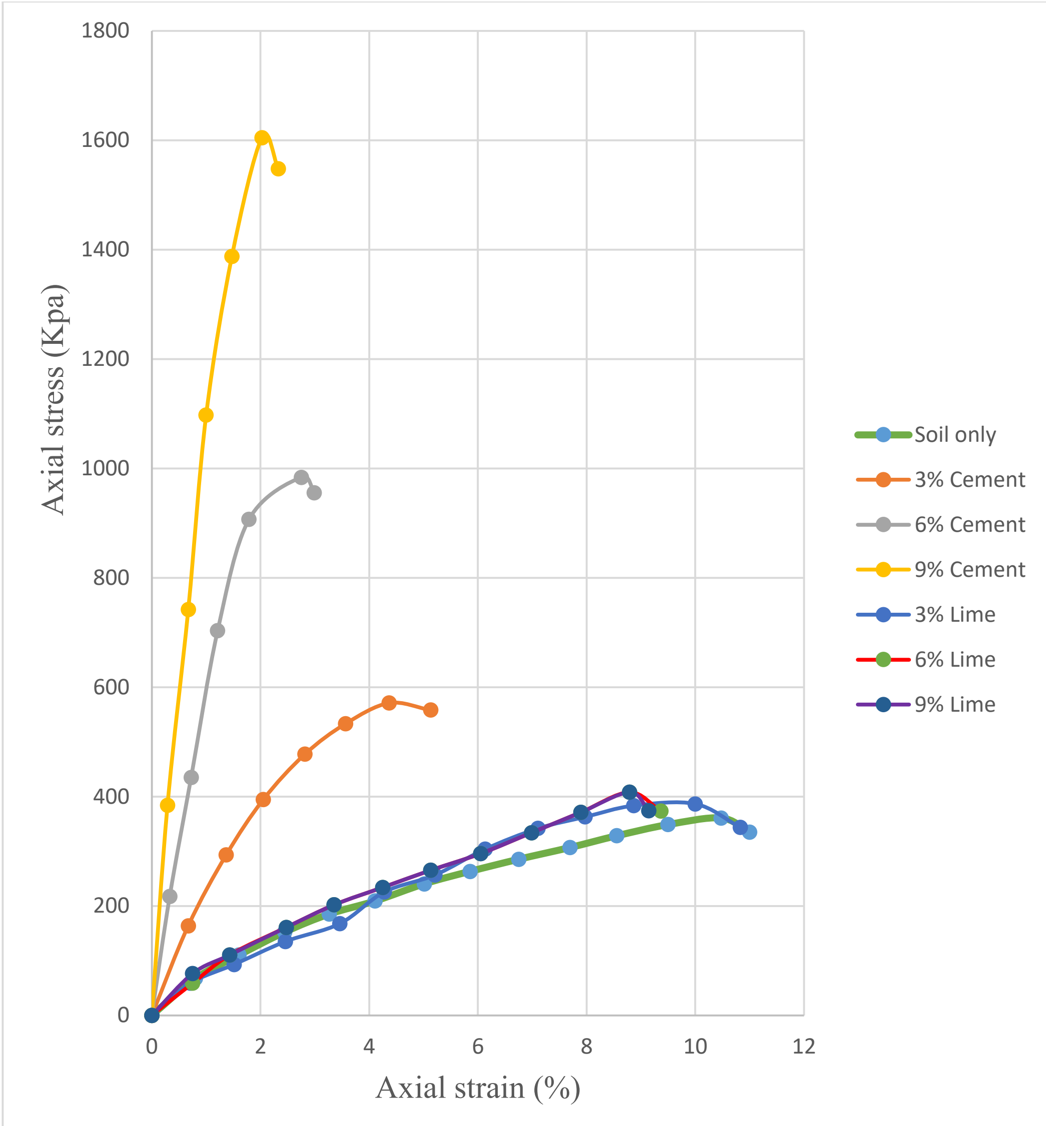


Figure 4.41: Combine cement axial stress vs lime axial stress (day -14)

Above in the figure to included gradually 3%, 6% & 9% cement compare to 3%, 6% & 9% lime respectively soil with 3 days curing period. Determine 3% cement increased high stress 570.923kpa periodically 6% high-stress value 983.621. & 9% high stress value 1604.489. But shows that in the curing period, the lime is nearly lower increased respectively soil. Lime high stress 378.571 kpa by 3%, 407.786 kpa by 6% lime and 407.786 kpa by 9% lime. Color has identified the percent of admixture & stress.

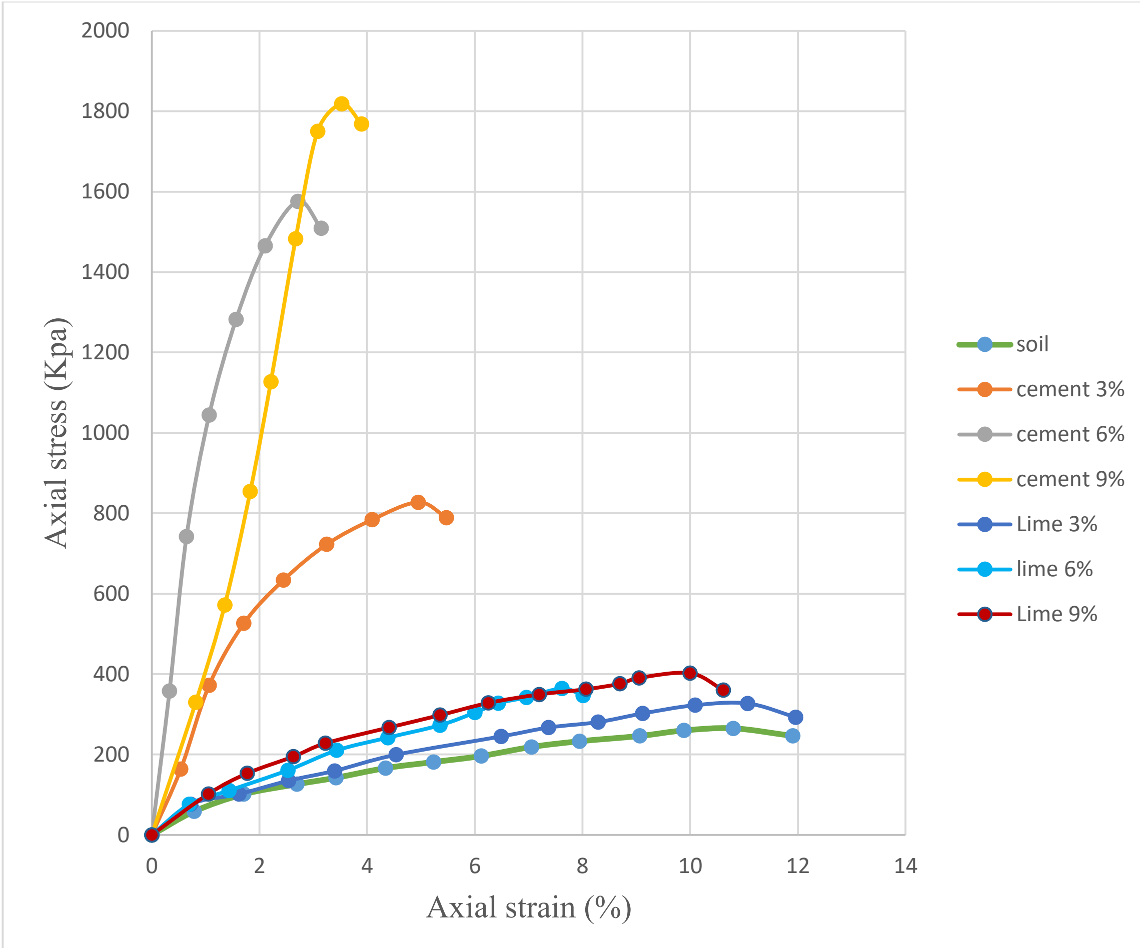


Figure 4.42: Combine cement axial stress vs lime axial strain (day -28)

Above in the figure to included gradually 3%, 6% & 9% cement compare to 3%, 6% & 9% lime respectively soil with 3 days curing period. Determine 3% cement increased high stress 827.326 kpa periodically 6% high stress value 1576.012. & 9% high stress value 1818.104 kpa. But shows that in the curing period, the lime is nearly lower increased respectively soil. Lime high stress 427.238 kpa by 3%, 431.181 kpa by 6% lime and 459.842 kpa by 9% lime. Color has identified the percent of admixture & stress.

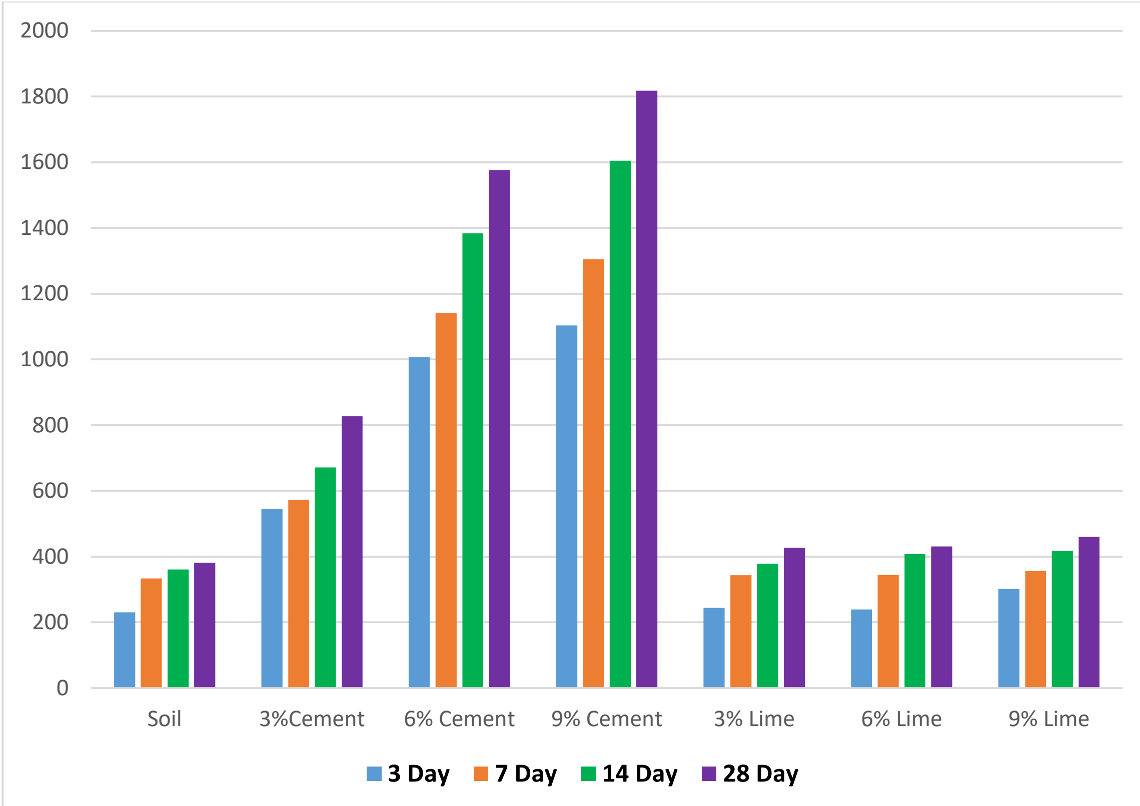


Figure 4.43: Soil with cement stress vs lime stress

Table 4.6.29: Cement stress vs lime stress

Days	Soil	Cement			Lime		
		3% Cement	6% Cement	9% Cement	3% Lime	6% Lime	9% Lime
3	230.376	544.623	1007.26	1103.079	244.41	238.743	301.115
7	333.333	572.834	1140.98	1305.17	343.551	343.883	355.863
14	360.78	670.923	1383.621	1604.489	378.571	407.786	417.786
28	380.87	827.326	1576.012	1818.104	427.238	431.181	459.842

The results are based on descriptions, as shown in figure No. 4.43 and table No. 4.6.29. Here in the study, the soil strength gradually increased the curing period include cement and lime component, 3%, 6%, and 9%, to increase by 3, 7, 14, and 28 days. Color has identified the variable stress.

Table 4.6.30: Comparison table between reference author UCS result vs thesis UCS result

Author reference No & Name	Curing days	Type of Soil	Used Admixture %		Author reference UCS stress (kpa)	
			Cement	Lime	Cement	Lime
[9] Ahmed, B., Alim, A., & Sayeed, A. (2013).	3	Sandy clay	3%	3%	525.72	256.8
			9%	9%	1180.7	488.6
	7		3%	3%	617.63	290.1
			9%	9%	1789.7	660.7
[3] Chowdhury, M. N., Dev, A., & Noor	28	Silty Sand	3%	-	1676.8	-
			6%	-	2406.8	-
			9%	-	3205.2	-
[15] Md. Zulfikar Ali, Md. Al Imran, Forhad Hossen, Md. Shahidul Islam	-	Soil with iron	1%	1%	850	850
			2%	2%	880	960
[11] Basuki Ampera, Taner Aydogmus	28	Clay soil	3%	2%	339.0	162
			6%	4%	524.3	274.5
			9%	6%	719.0	324.8
VS						
Thesis UCS result	3	Organic clay soil	3%	3%	544.62	244.41
			6%	6%	1007.26	238.74
			9%	9%	1103.07	301.11
	7		3%	3%	572.83	343.55
			6%	6%	1140.98	343.88
			9%	9%	1305.17	355.86
	14		3%	3%	670.92	378.57
			6%	6%	1383.62	407.78
			9%	9%	1604.48	417.78
	28		3%	3%	827.32	427.23
			6%	6%	1576.01	431.18
			9%	9%	1818.10	459.84

Above The table chart represents the different author's different types of data like cement and lime stress, soil type, admixture percentage & curing days compared between the thesis results. When it experiments with organic soil sample mixing admixture different curing times, this stress increased relatively low. We studied other different types of soil samples such as silty sand, sandy clay and soil with iron; its type mixing admixture normally its stress was high. Because of that, cement & lime stress is less than thesis cement & lime stress.

Chapter-6

Conclusion and Recommendations

6.1 Introduction:

Geotechnical engineering works for foundation planning. It's, also kNown as geo-technics. The branch of civil engineering is worried about the engineering act of earth materials. It uses the principles and methods of soil and rock mechanics for the solution of engineering problems and the design of engineering works. This study was made of the benefit obtained when organic clay soil is treated with required amount of cement and lime.

Table 6.31: Cement and lime stress increase percentage table

Molds	3 Day		7 Day		14 Day		28 Day	
Admixture %	Stress (kpa)	Stress Increase %	Stress (kpa)	Stress Increase %	Stress (kpa)	Stress Increase %	Stress (kpa)	Stress Increase %
Soil	230.37	Initial	333.33	Initial	360.78	Initial	380.87	Initial
3% Cement	544.62	136.40	572.83	71.85	670.92	85.96	827.32	117.22
3% Lime	238.74	3.64	343.55	3.07	378.57	4.94	427.23	12.17
6% Cement	1007.2	337.23	1140.98	242.30	1383.62	283.50	1576.01	313.79
6% Lime	244.41	6.09	343.88	3.17	407.78	13.03	431.18	13.20
9% Cement	1103.07	378.82	1305.17	291.56	1604.48	344.72	1818.10	377.35
9% Lime	301.11	30.71	355.86	6.75	417.78	15.81	459.84	20.74

Soil respectively higher stress value calculated basic on percentage. Above the figure, 9% admixture used is the best result. Cement percentage result greater than lime percentage result with soil. In the present study, the experimental investigations are carried out in four different mix proportions of soil-cement and soil-lime. From the extension experimental study, the following conclusion may be drawn.

- Strength of soil increases by adding admixtures.
- Strength and stability increase with the increasing amount of admixtures.
- Strength and stability increase with the increase of the curing period.
- Stability improved by cement is much higher than in lime.

6.2 Recommendations:

When cement and lime are mixed with soil, it performs differently, so it can be studied more extensively by mixing it in different proportions. In the future, the environment and the situation may not be the same, so there are more options to run more different experiments on the soil. Also, this research suggests the following points should be studied for further study-

- Different soil samples can be worked.
- Advanced chemicals can be used in the same way.
- Adding more percentage of cement, lime and other ingredients appropriate to the soil for stabilization.
- Effect of compaction on strength of clay with a variation of moisture.

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