STABILIZATION OF SOFT CLAY SOIL BY USING CEMENT AND FLY ASH

By
Hridoye Sarkar
ID 173-47-583
Md. Rahul Hossen
ID 173-47-552
Md. Mehade Hasan Shadin
ID 173-47-568
Syed Arefin Islam
172-47-488

A thesis submitted to the Department of Civil Engineering of Daffodil International University (DIU) in partial fulfillment of the requirements for the degree of

BACHELOR OF SCIENCE IN CIVIL ENGINEERING

Supervised By
Engr. Ahad Ullah
Senior Lecturer

Department of Civil Engineering
Daffodil International University
January 2022

Stabilization of Soft Clay Soil by Using Cement and Fly Ash

By
Hridoye Sarkar
ID 173-47-583
Md. Rahul Hossen
ID 173-47-552
Md. Mehade Hasan Shadin
ID 173-47-568
Syed Arefin Islam
172-47-488

A thesis submitted to the Department of Civil Engineering of Daffodil International University (DIU) in partial fulfillment of the requirements for the degree of

BACHELOR OF SCIENCE IN CIVIL ENGINEERING

Department of Civil Engineering
Daffodil International University
January, 2022

CERTIFICATION OF APPROVAL

This is to certify the thesis title "**Stabilization of Soft Clay Soil by Using Cement and Fly Ash**". Submitted to the Department of Civil Engineering, Daffodil International University by Hridoye Sarkar ID:173-47-583, Md. Rahul Hossen ID:173-47-552, Md. Mehade HasanShadin ID:173-47-568, Syed Arefin Islam ID:172-47-488 have been accepted as satisfactory in partial fulfillment of the requirement for the degree of Bachelor of Science in Civil Engineering in January 2022.

Head

Dr. Mohammad Hannan Mahmud Khan
Assistant Professor & Department Head
Department of Civil Engineering
Daffodil International University

Supervisor

Engr. Ahad Ullah
Senior Lecturer
Department of Civil Engineering
Daffodil International University

BOARD OF EXAMINERS

Dr. Mohammad Hannan Mahmud khan — **Chairman**
Assistant Professor & Head
Department of Civil Engineering
Daffodil International University

Engr. Ahad Ullah — **Internal Member**
Senior Lecturer — (Supervisor)
Department of Civil Engineering
Daffodil International University

Mr. Abu Hasan — **Internal Member**
Senior Lecturer
Department of Civil Engineering
Daffodil International University

Dr. Muhammad Mukhlesur Rahman — **External Member**
Executive Engineer
Roads and Highways Department

AUTHORS DECLARATION

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.

Hridoye Sarkar
ID 173-47-583

Md. Rahul Hossen
ID 173-47-552

Md. Mehade Hasan Shadin
ID 173-47-568

Syed Arefin Islam
172-47-488

Department of Civil Engineering
Daffodil International University

January, 2022

DEDICATION

Dedicated

To

Our Family

ACKNOWLEDGEMENT

All praise to Almighty Allah. Without his help, we cannot finish our work.

Then we have no other words to describe our thankfulness to our beloved and honorable supervisor and Lecturer Mr. Ahad Ullah sir his help, support, and encouragement during our study period are inspired us a lot and improved our work also. We are very much lucky that we have worked with him and we also look forward to our future work with him.

We are also thankful to our lab assistant Md. Julfikar and Md. Mehedi for their endless support during our experiment period.

Special acknowledgment and deep thanks to our parents, their continuous prayers, and encouragement were our real support during studying at Daffodil International University.

ABSTRACT

Soil stabilization has become the main issue in construction. Engineering and researches concerning the effectiveness of exploitation industrial wastes as a stabilizer are gradually increasing. This paper shortly describes the quality of the local ash to be used in the local construction industry in a way to minimize the quantity of waste to be disposed to the environment causing environmental pollution. Many civil engineering laboratory tests are conducted to study the geotechnical properties of fly ash and strength gain mixed with clay samples. a different proportion of fly ash and soil sample cured for fourteen days' results in a strength gain. Understanding of the properties of fly ash is gained from the study and the tests indicates an improved strength and better properties of soft soil sample when stabilized.

Keywords: Soil stabilization, Fly ash, Pollution, Proportion

TABLE OF CONTENTS

LIST OF TABLES

TITLE OF THE FIGURES

List of Abbreviations

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
G_S	Specific Gravity
UCT	Unconfined Compression Test
UCS	Unconfined compressive strength

CHAPTER-1
INTRODUCTION

1.1 General

In the past construction could be done anywhere in the world. Because we had enough space and we could manage the construction work in a good place by avoiding problematic places. But now a day due to lack of space for urbanization we have to build on soft soil. At present with increasing urbanization and industrialization, it is necessary to use marginal areas to develop infrastructural facilities. Soft soils are generally unsuitable for construction because of their high water content. Engineers all over the world are currently using stable techniques to improve the strength properties of soft soils. Cement and fly ash have played a special role in the development of soil components that have been tested in different countries of the world and various studies have been done and satisfactory results have been obtained. A number of researches showed satisfactory results. Several research works have been conducted in Bangladesh to determine the effect of cement as a stabilizer for soft inorganic soil. [1] showed that cement can be used effectively to stabilize the coastal soils so that it fulfills the requirements of road sub-base and base for light traffic. Islam (2004) investigated the effect of lime and fly ash stabilization on coastal soils and found a noteworthy increase in strength. Bangladeshi researcher Md. Zoynul Abedin saw that the effect of cement and fly ash stabilization on the strength properties of organic soil of Dhaka city. Unconfined compression tests were carried out with different percentages of cement and fly ash additives. The effect of the curing period on compressive strength gain was also studied by curing the test specimens for three different curing periods. Since our soil is coastal, we will see how much strength our soil acquires.

1.2 Thesis Background

Clayey soils are usually categorized as expansive soils other names of these soils are soft soils. [2] This soil is very well known for its sudden settling. Normally in construction industries, the structures constructed on clay soils, the soil should be stabilized. This contortion could cause significant failure to foundation and structures. Due to the low strength of clay soil, road construction also has to face some problems.

In this study, we are trying to increase soil strength by mixing cement and fly ash with soil. Soil stabilization is the process of any physical, chemical, mechanical, or combined method that changes and improves the engineering property of the soil and thus making it more stable. Soil stabilization is three broad types there are biological, physical, and chemical. We have to stabilize the soil using admixtures like fly ash. Geo-Technical process of rising the engineering properties of the soil density shear strength, C&O factors are improved whereas improving, settlement, and porosity compressibility reduced and creating it a lot of stable and sturdy. To cause the economy within the value of the road. to improve undesirable properties of soils, like excessive swelling or shrinkage, high physical property, difficulty in compacting, etc. To facilitate compaction and increase the load-bearing capability to scale back compressibility and thereby settlements. To improve permeability characteristics.

1.3 Importance of Soil Stabilization

You need a stable foundation of the latest structure or roadway to ensure the best construction and durability. The foundation itself needs to rest on a strong ground that is able to move a considerable amount of the whole building. If the soil is weak, over time it becomes compact and begins to swell. This swollen soil, which is common with Texas clay soils, transfers the entire structure. The very walls of the building will begin to crack. Significant cracks will be created in the foundation, as a result of which the building will commit suicide to the forces of nature. It’s not just buildings that have stabilized the ground before construction. [3] Many construction companies also designate soil stabilization services when building new roadways, overpasses, parking lots, and even airports. As the soil swells it can create cracks, obstructions, and weak sidewalks which can prove dangerous over time. On the roadway, any noticeable damage can easily lead to an accident. On the runway, the consequences can be more devastating, dangerous, and costly.

Fly ash stabilization is gaining more importance in recent times since it has widespread availability. This method is cheaper and takes less time than any other method. It has a long history of use as an engineering component Successfully employed in geotechnical applications. [4] Fly ash is a generator of coal-fired power generation Opportunity - advantage; It has less cementing properties than this Lime and cement. Most fly ash belongs to secondary binders; These binders cannot produce their own desired effect. However, the presence of a small amount of activator can cause a chemical reaction in the formation of cementation compounds which contributes to the improved strength of the soft soil. However, there are the following limitations to soil stabilization. the soil will have less moisture to be stable; Therefore, dewatering may be required. The soil-fly ash mixture is cured below zero and then soaked. Extremely sensitive to water shaking and energy loss. Sulfur content can form a wide range of minerals in the soil Ash mixture, which reduces long-term strength and durability.

Fly ash

Fly ash provides an economical way of soil stabilization. The method of soil improvement in which fly ash is added to the soil to improve its properties is known as fly ash stabilization. The quantity of fly ashis used in most soil stabilizers is in the range of 5% to 10%. Fly ash modification describes an increase in strength brought by cation exchange capacity rather than cementing effect brought by the pozzolanic reaction. [5] In soil modification, as clay particles flocculate, transforms natural plate-like clay particles into needle-like interlocking metal line structures. Clay soils turn drier and less susceptible to water content changes.

1.4 Scope of the study

In this study soil samples were collected from Cox's bazaar, Kutubdia, and fly ash collected from Thakurgoan. Cement collected from the saver. After collecting all of these mixed these goods with proper ratio and 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, Atterberg limit test, Standard proctor compaction test, Unconfined compression test. These index properties were tested in the laboratory by the laboratory test specimens. After doing all these tests we achieve our goal successfully.

1.5 Objective of the study

1) To determine the increasing strength of the soil by mixing fly ash with the soil.

2) Comparing the strength of soil with different ratios of fly ash.

1.6 Properties and Engineering Index

For engineering purposes, soil index properties are very much important because they identify the soil classifications. Some important properties indexes shortly described given below:

1.6.1 Liquid Limit

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 the liquid state. This is often the soil behaves changes by the water content. This is often the sole methodology adopted by ASTM to see the liquid limit of soft soil. This check is completed by the Casagrande methodology. This device consists of a brass cup and a tough rubber base. It conjointly consists of a groove that divides the soil on the cup before taking the drops onto it. The brass cup drops the number of times and takes reading from the meter. The cup is upraised and born from a height of ten millimeters (0.394 in.). The wetness content, in percent, needed to shut a distance of twelve.5 mm (0.5 in.) on the rock bottom of the groove when blows are going to be the ultimate results of this check. The liquid limit result is going to be determined by this checking procedure.

1.6.2 Plastic Limit

It is that minimum water contains at which soil begins to crumble when it is rolled into a thread of 3mm diameter. Gravel and sand are no plastic soil because the liquid limit and plastic limit almost coincide with each other as a result zone the of the plastic stage doesn’t exist. Clay ansilts are plastic soil in which the liquid limit is always greater than the plastic limit.

1.6.3 Plasticity Index

The plasticity index shows the difference between the liquid limit and the plastic limit of soil.

PI= PL – LL

Plasticity index is the plastic limit subtracted from the liquid limit and directs the size of the range between the two boundaries. The high range of the plastic index determines the high clay content soil.

Fly Ash

Fly ash is ash that contains are Silica (SiO_2) Aluminum Oxide (Al_2O_3) than any other ash. Generally, we found two types of fly ash. We work with class F fly ash. We found this type of fly ash in the brickfields and Arc furnaces. [6]

Chemical component	Typical Fly ash	
	Class C	Class F
Silica (SiO_2)	40%	55%
Alumina (Al_2O_2)	16%	26%
Ferric oxide (Fe_2O_2)	6%	7%
Calcium oxide (CaO)	24%	9%
Magnesium oxide (MgO)	2%	2%
Sulfate oxide(SO_2)	3%	1%
Loss of ignition (LOI)	6%	6%

CHAPTER-2
LITERATURE REVIEW

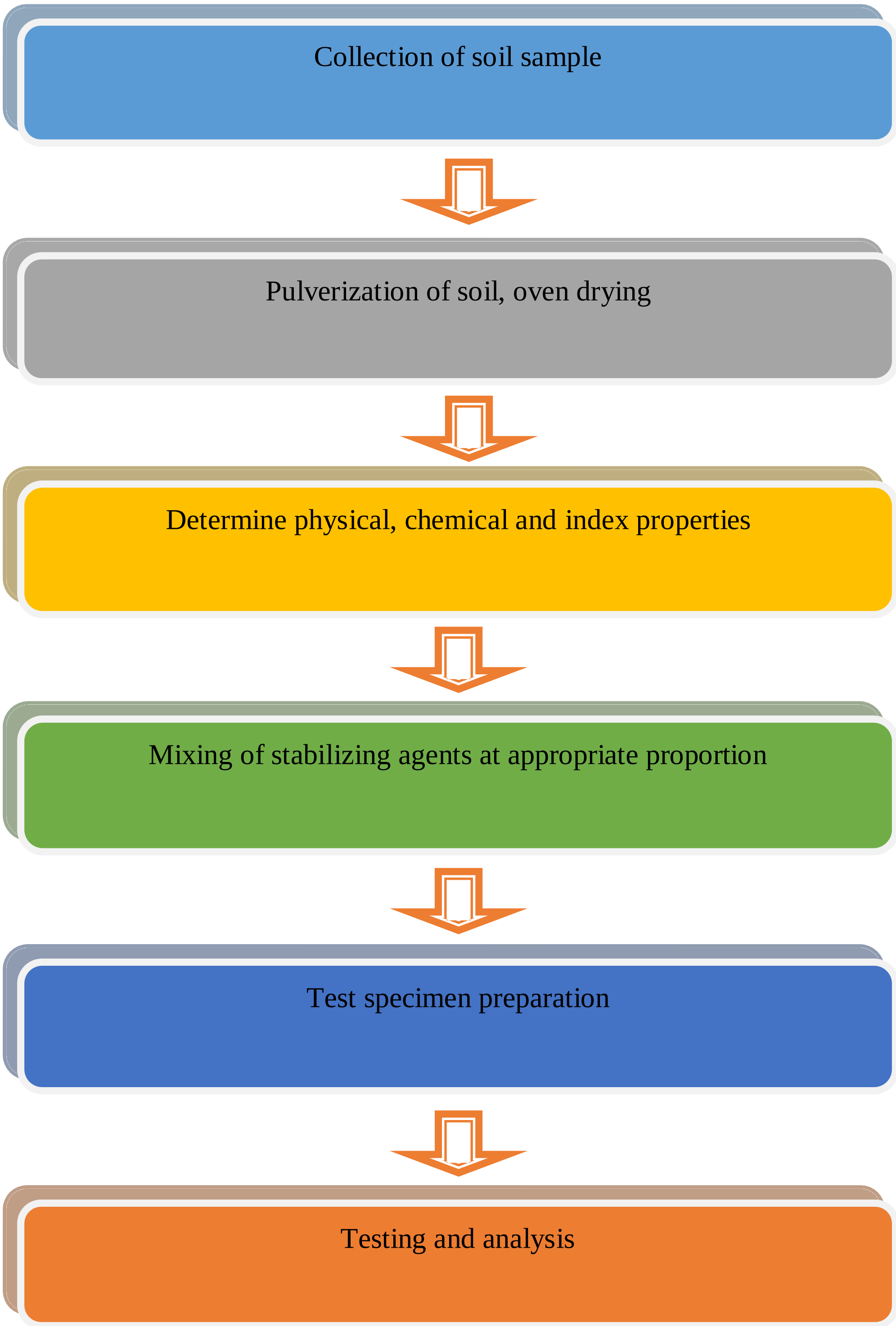
2.1 Introduction

The review of the literature regarding previous research on the strength properties of clay has been presented in this chapter. The published results of geotechnical investigations on strength of clay properties have been reviewed and presented in order to clarify the state of current knowledge and 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.

In earlier research, Magdi M.E. Zumrawi experimented in his study (Stabilization of pavement subgrade by using fly ash activated by cement), Expansive soil treated with varying percentages of fly ash, 0, 5, 10, 15, and 20 percent combined with 5% cement content were studied. Consistency limits, compaction, CBR, swell potential, and swell pressure tests were conducted on treated and untreated soils. The experimental results show that the addition of cement-fly ash admixture to the soil has a great influence on its properties. It was found that the optimum dosage of fly ash is 15% mixed with 5% cement revealed in significant improvement in strength and durability. [7] (Gyanen. Takhelmayum, Savitha. A.L, krishna Gudi) looked at their investigation is to evaluate the compaction and unconfined compressive strength of stable black cotton soil using fine and coarse ash mixtures. the proportion of fly ash mixtures that are used in black cotton soil varied from five to thirty. The study concludes that with proportion addition of fine and coarse fly ash improves the strength of stable black cotton soil and exhibits a comparatively well-defined moisture density relationship. it had been found that the peak strength attained by the fine fly ash mixture was 25% more when compared to coarse fly ash. [8] Ankit Singh Negi, Mohammed Faizan, Devashish Pandey Siddharth, Rehanjot Singh (Dept. of Civil Engineering, University of Petroleum and Energy Studies, Dehradun,India) they used lime to stabilization of soil. They found in their study that using 6% lime makes the soil 4 to 10 times higher stable than untreated soil. [9] From these experiments it is clear that mixing lime or fly ash in different proportions increases soil strength.

CHAPTER-3
METHODOLOGY

- We have completed our study by following bellow's steps.



3.1 Overview:

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 workflow chart is given below.

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. [10]

3.3 Soil Collection

We found the value of soil under four after testing the soil in the laboratory. We collect the soil from the laboratory.

3.4 Laboratory Test

All the soil sample contains some laboratory test they 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
- Pan
- Lead

- Brush
- Spoon
- Bowel
- Balance
- Drying oven
- Moisture can
- Gloves
- Liquid limit device
- Spatula
- Molds
- Manual Hammer
- Unconfined Compressive Test Machine

3.6 Grain Size Analysis (Sieve Analysis)

3.6.1 Introduction

Grain size analysis is performed to determine soil particle size which is examined by sieve analysis. In this laboratory experiment ASTM standard sieve which are #4 , #16 , #30 , #40 , #50 , #100 , #200 and a pan. We follow the ASTM C136 standard.

3.6.2 Test Procedure

- Firstly, 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 we have to pour soil in the sieve
- Shake properly for the passing the soil sample
- Record retained soil sample and weight
- Record retained soil sample from pan

3.7 Specific Gravity Test

3.7.1 Introduction

How much heavier an object or soil is than water is called Specific Gravity. The result for clay soil varies from 2.65 to 2.80. The coarser soil has lower specific gravity than finer soil. We follow the ASTM D854 standard.

3.7.2 Test procedure

Here,

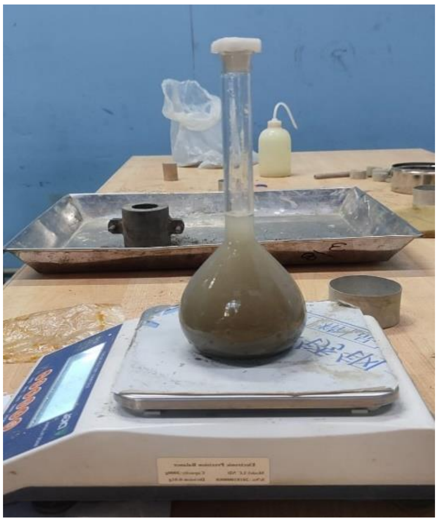
M_1=Weight of Pycnometer

M_2=Weight of Pycnometer+Soil

M_3=Weight of Pycnometer+Soil+Water

M_4=Weight of Water + Pycnometer

G_T=Specific gravity of distilled water (varies with temperature).



3.8 Atterberg Limit Test

3.8.1 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. We flow ASTM-D4318 Standard Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils.

3.8.2 Test procedure

Plastic index, PI= PL – LL

Liquid index, LI = (W-PL)/ (LL-PL)

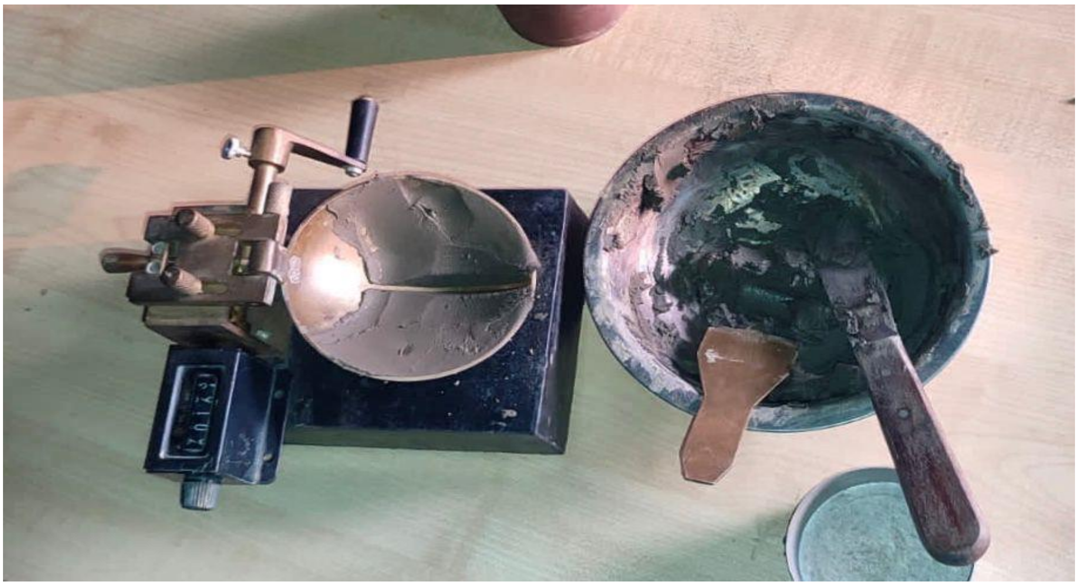
Where "W" is the natural water content

3.9 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 the liquid state.

3.9.1 Test procedure

- Put 200 gm dry soil pass through the #40 sieve
- Add distilled water into the soil and mix it properly to form a uniform paste
- Place the brace cup at least 10 mm up and Set the meter and grooving tool
- 1/3 of the brace cup should be filled with soil and divided by the grooving tool.
- Trials shall be requiring 30 to 35 drops, second between 25 and 30 drops, and third trial requiring 20 to 25 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 note down for the analysis



3.10 Plastic Limit of Soil

It is that minimum water contains at which soil begins to crumble when it is rolled into a thread of 3mm diameter. Gravel and sand are non-plastic soil because the liquid limit and plastic limit almost coincide with each other as a result zone of the plastic stage does not exist. It is also followed by ASTM standards.

3.10.1 Test procedure

- 50 gm #40sieve passing oven-dry soil has to be taken for this test
- Water mix with the soil and observe at least 1 hour for proper water soil mix up
- After that soil should be divided into ur parts to take several readings.
- Then roll the soil 3.2 mm on the flat surface
- Repeatedly rolling until it breaks into pieces
- Then the soil stories on the moisture cans for oven drying.

3.11 Proctor Compaction Test

3.11.1 Introduction

Compaction could be an artificial method within which expulsion of air is done by means that of mechanical means that. The dry density is maximum at a certain moisture content that is called optimum water content. The water content and dry density to obtain the maximum dry density and the optimum water contents and we follow the ASTM D698 standard.

3.11.2 Test procedure

- At first we need #4 sieve passing 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 a moister can.
- Weight moisture can with soil.
- Place the soil to oven dry.

3.12 Grain size analysis test by hydrometer

3.12.1 Introduction

A hydrometer is an instrument used to measure the relative density of liquids based on the concept of buoyancy. Relative density means the density of a substance relative to the density of a reference substance. We follow the ASTM D422 standard.

3.12.2 Test Procedure

- When beginning the check, the suspension is mixed once more victimization the maker or tipping technique, and a timer tracks the period once admixture is complete.
- 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. Take readings of the hydrometer in suspension at elapsed times of 1, 2, 4, 15, 30, 60, 240, and 1440 minutes. Additional readings are optional to define particle size distribution
- 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.

3.13 Unconfined compression test

3.13.1 Introduction

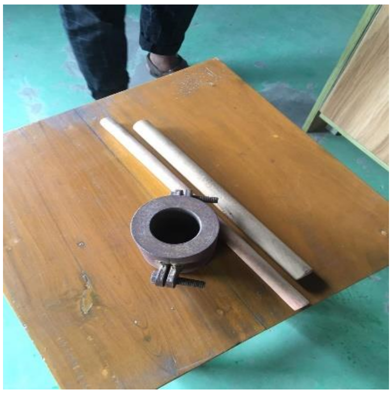
The maximum load that can be transmitted to the subsoil by a foundation depends upon the soil resistance of the underline soil to seeding deformation and compressibility. An axial load is applied at a constant rate of strain without any lateral support to the soil specimen and increases until failure occurs. The compressive load per unit area required to fail the soil specimen under such conditions is called unconfined compression. We follow ASTM D 2166 standard.

3.13.2 Test Procedure

- Add required quantity of water W_w to this soil.

$$W_w = W_S \times W/100 \text{ gm}$$

- Mix the soil thoroughly with water.
- Place the wet soil in an exceedingly 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.






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	Weight of dry soil	Water content %
13	25	128.57	112.3	16.27	87.3	18.63688431 %
19	24.03	147.33	127.31	20.02	103.28	19.3841983 %
18	25.21	138.76	120.92	17.84	95.71	18.63964058 %
12	22.79	142.87	124.28	18.59	101.49	18.31707557 %
Average Water content 18.74 %						

Table 4.2 Specific Gravity

Specimen number	Test 1	Test 2	Fly ash
Temperature	31	31	31
Pycnometer bottle number	1	1	2
Weight of Pycnometer, M1	110.1	110.1	107.4
Weight of Pycnometer + Soil, M2	147.49	147.7	158.01
Weight of Pycnometer + Soil +Water, M3	379.72	379.61	382.16
Weight of Pycnometer + Water, M4	355.93	355.94	356.07
The specific gravity of distilled water, GT	0.9954	0.9954	0.9954
The specific gravity of the Soil, GS	2.73	2.69	2.05
Soil Average2.71			

4.3 Grain Size Analysis

Table 4.3.1 Sieve Analysis Wash

Sieve Analysis Wash						
Sieve No	**Sieve opening (mm)**	**Weight of container (gm)**	**Weight of soil retained (gm)**	**Percent of soil retained**	**Cumulative percent retained**	**Percent finer**
4	4.76	500.29 gm	0 gm	0.00 %	0.00 %	100.00 %
8	2.38	292.86 gm	0.2 gm	0.10 %	0.10 %	99.90 %
16	1.19	288.53 gm	0.12 gm	0.06 %	0.16 %	99.84 %
30	0.6	295.26 gm	0.13 gm	0.07 %	0.23 %	99.78 %
50	0.287	292.95 gm	0.28 gm	0.14 %	0.37 %	99.64 %
100	0.15	249.88 gm	5.9 gm	2.95 %	3.32 %	96.69 %
200	0.075	259.74 gm	5.8 gm	2.90 %	6.22 %	93.79 %
Pan	0	231.46 gm	187.57 gm	93.79 %	100.00 %	0.00 %
			200 gm	100.00 %		
FM 0.04 %						

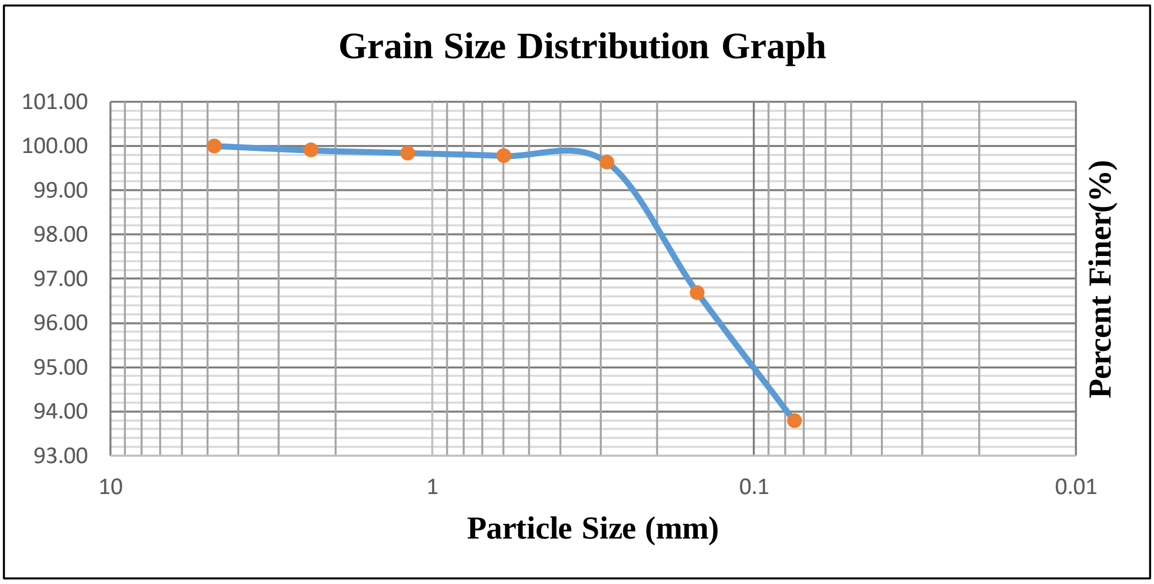


Figure 4.1: Grain Size Distribution (wash)

Table 4.3.2 Sieve Analysis

Sieve Analysis						
Sieve No	**Sieve opening (mm)**	**Weight of container (gm)**	**Weight of soil retained (gm)**	**Percent of soil retained**	**Cumulative percent retained**	**Percent finer**
4	4.76	500.29 gm	0 gm	0.00 %	0.00 %	100.00 %
8	2.38	292.86 gm	9.6 gm	4.80 %	4.80 %	95.20 %
16	1.19	288.53 gm	18.5 gm	9.25 %	14.05 %	85.95 %
30	0.6	295.26 gm	20.95 gm	10.48 %	24.53 %	75.48 %
50	0.287	292.95 gm	41.15 gm	20.58 %	45.10 %	54.90 %
100	0.15	249.88 gm	28.41 gm	14.21 %	59.31 %	40.70 %
200	0.075	259.74 gm	23.15 gm	11.58 %	70.88 %	29.12 %
Pan	0	231.46 gm	58.24 gm	29.12 %	100.00 %	0.00 %
			200 gm	100.00 %		
FM 1.48						

Table 4.3.3 Hydrometer Analysis

Input Parameters	
The viscosity of water at 25°C Temperature	0.00000922gs/cm^2
The specific gravity of soil	71
Weight of dry soil	50 gm
Zero correction	3
Meniscus correction	1

Time (MIN)	Ra	T	Tc=-4.85+0.25T	Rc =Ra-Zc+Tc	%finer =(Rcxa)/Ws	Recorrected For meniscus	L=16.3-0.164 Ra	K	D (mm)	Actual % finer wt. to total fines in soil mass
1	29	27	1.9	27.9	55.242	30	11.38	0.0127183	0.0429	16.086
2	25	27	1.9	23.9	47.322	26	12.036	0.0127183	0.0312	13.780
4	19	27	1.9	17.9	35.442	20	13.02	0.0127183	0.0229	10.321
8	16.5	27	1.9	15.4	30.492	17.5	13.43	0.0127183	0.0165	8.879
15	15	28	2.15	14.15	28.017	16	13.676	0.0127183	0.0121	8.159
30	11.5	28	2.15	10.65	21.087	12.5	14.25	0.0127183	0.0088	6.141
60	10	28	2.15	9.15	18.117	11	14.496	0.0127183	0.0063	5.276
120	8	28	2.15	7.15	14.157	9	14.824	0.0127183	0.0045	4.123
240	6.8	28	2.15	5.95	11.81	7.8	15.0208	0.0127183	0.0032	3.431
480	6.2	27	1.9	5.1	10.098	7.2	15.1192	0.0127183	0.0023	2.941
1440	6	27	1.9	4.9	9.702	7	15.152	0.0127183	0.0013	2.825
2880	5.6	28	2.15	4.75	9.405	6.6	15.2176	0.0127183	0.0009	2.883
4320	5.1	28	2.15	4.25	8.415	6.1	15.2996	0.0127183	0.0008	2.450

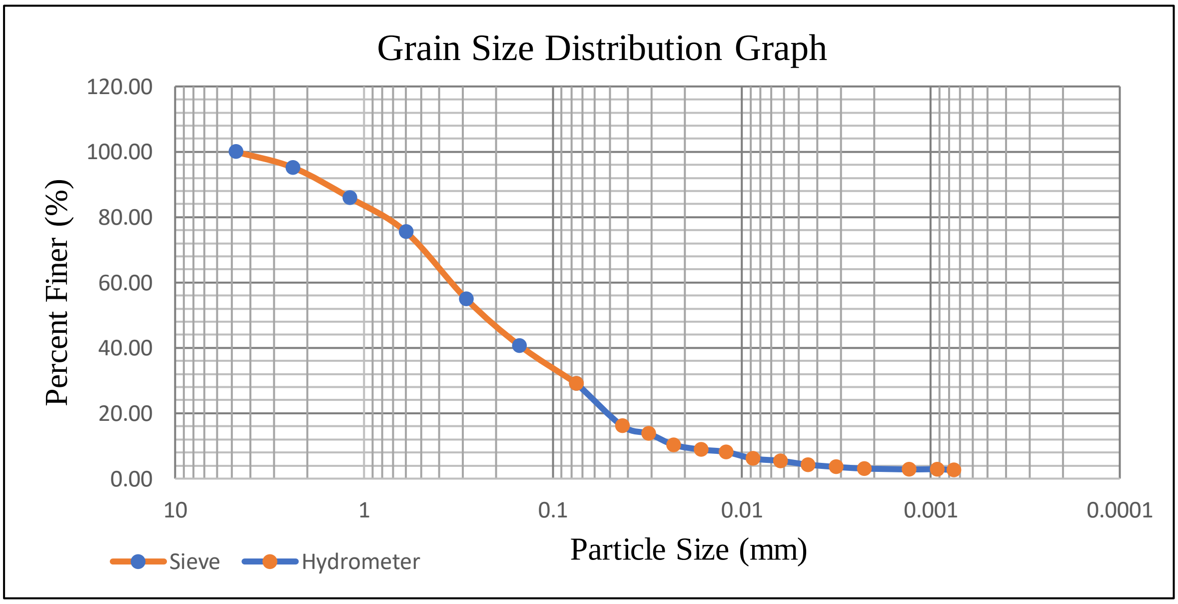


Figure 4.2: Grain Size Distribution (by Hydrometer)

Table 4.4 Atterberg Limits Test

Liquid Limit Test			
Moisture can ID	56	91	101
W_c = Wt of can (gm)	19.6 gm	20.63 gm	20.44 gm
W_{cms} = Wt of can + wet soil (gm)	38.39 gm	42.36 gm	44.28 gm
W_{cds} = Wt of can+dry soil (gm)	33.98 gm	37.15 gm	38.42 gm
W_s = Weight of soil solids = W_{cds} –Wc(gm)	14.38 gm	16.52 gm	17.98 gm
W_w = Weight of pure water = Wcms –Wcds (gm)	4.41 gm	5.21 gm	5.86 gm
w = Water content % ((Ww/Ws) *100)	30.67 %	31.54 %	32.59 %
No Of Drop	37	23	17
25 Blow = 31.6			
Plastic Limit Test			
Moisture can ID	15(2)	17	58
W_c = Wt of can (gm)	20.7 gm	24.85 gm	18.84 gm
W_{cms} = Wt of can + wet soil (gm)	27.48 gm	30.89 gm	24 gm
W_{cds} = Wt of can+dry soil (gm)	26.34 gm	29.93 gm	23.11 gm
W_s = Weight of soil solids = W_{cds} – Wc (gm)	5.64 gm	5.08 gm	4.27 gm
W_w = Weight of pure water = Wcms – Wcds (gm)	1.14 gm	0.96 gm	0.89 gm
w = Water content % ((Ww/Ws) *100)	20.21 %	18.90 %	20.84 %
Average = 19.98			

Plasticity Index: LL-PL= 11.62

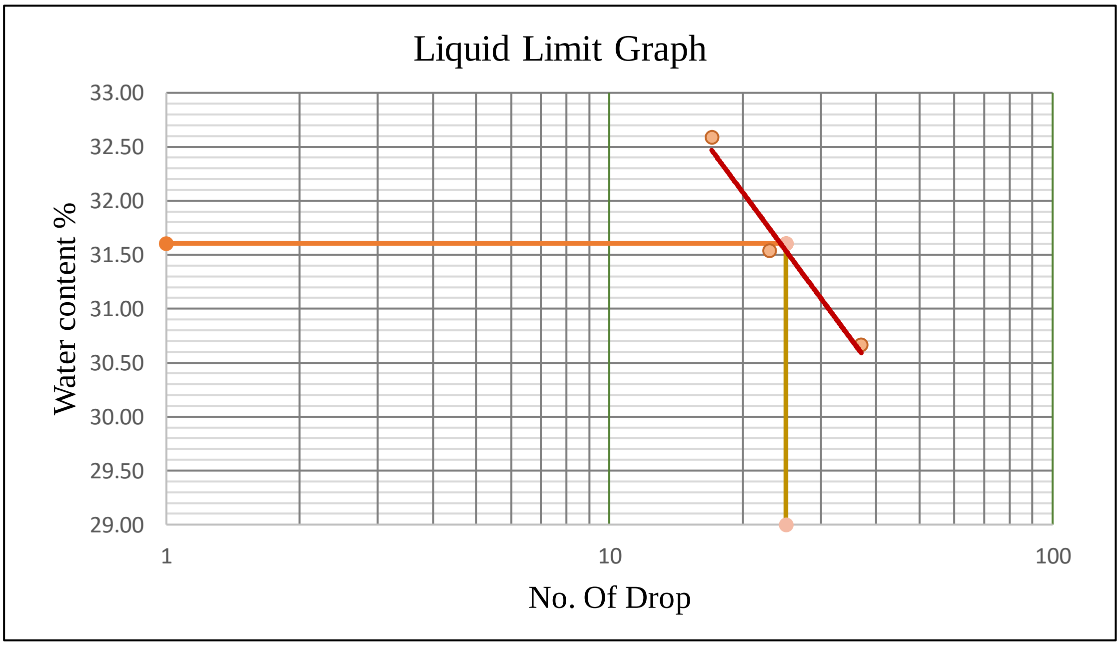


Figure 4.3: In the above figure, we see No. of Blow 25 = 31.6

4.5 Standard Proctor Test

Table 4.5.1 Standard Proctor Test (Only Soil)

Water Content Determination (Only Soil)						
Sample no	1	2	3	4	5	6
Moisture can no	56	76	101	54	52	50
Mass of empty clean can	19.65	21.46	20.4	20.35	21.71	20.25
Mass of can + wet soil	95.7	97.9	88.05	85.9	91.97	88.15
Mass of can + dry soil	89.35	89.63	79.74	76.14	79.76	75.63
Mass of soil solid	69.7	68.17	59.34	55.79	58.05	55.38
Mass of pore water	6.35	8.27	8.31	9.76	12.21	12.52
Water content w%	9.11	12.13	14.00	17.49	21.03	22.61
Density Determination (Only Soil)						
Compacted soil sample no	1	2	3	4	5	6
Volume of the mold, (V),(ft^3)	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
Mass of compacted soil and mold (lb.)	10.274	10.516	10.648	10.803	10.692	10.63
Mass of compacted soil, (lb.)	3.80	4.05	4.18	4.33	4.22	4.16
Wet density,r = (M/V),(lb./ft^3)	115.26	122.61	126.62	131.29	127.95	125.95
Dry density, rd. = [r/(1+w/100)],(lb./ ft^3)	105.63	109.34	111.06	111.74	105.72	102.72

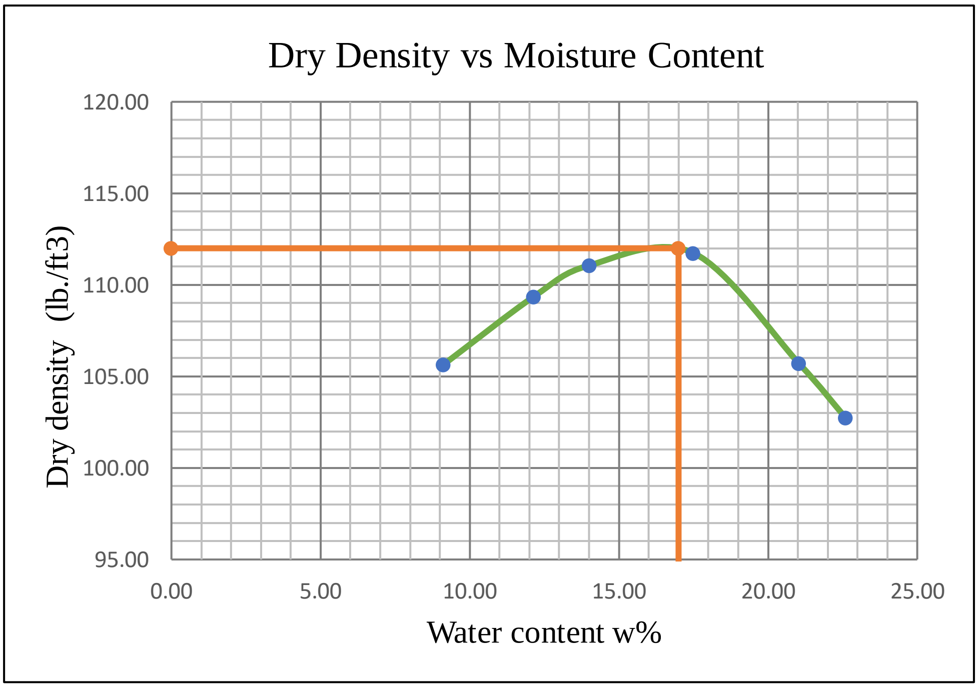


Figure 4.4: In the above figure, we see maximum dry density is 112 (lb./ft^3), and optimum Moisture content is 17 %

Table 4.5.2 Standard Proctor (7% Fly Ash & 3% Cement)

Water Content Determination (7% Fly Ash & 3% Cement)						
Sample no	1	2	3	4	5	6
Moisture can no	13	18	14	15 (2)	11	20
Mass of empty clean can	20.02	25.12	24.1	20.65	24.41	23.97
Mass of can + wet soil	88.78	120.47	114.76	100.72	119.92	123.81
Mass of can + dry soil	83.53	110.53	102.97	89.1	103.85	104.75
Mass of soil solid	63.51	85.41	78.87	68.45	79.44	80.78
Mass of pore water	5.25	9.94	11.79	11.62	16.07	19.06
Water content w%	8.27	11.64	14.95	16.98	20.23	23.59
Density Determination (7% Fly Ash & 3% Cement)						
Compacted soil sample no	1	2	3	4	5	6
The volume of the mold, (V),(ft^3)	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
Mass of compacted soil and mold (lb.)	10.163	10.406	10.604	10.736	10.670	10.52
Mass of compacted soil, (lb.)	3.69	3.94	4.13	4.27	4.20	4.05
Wet density, r = (M/V),(lb./ft^3)	111.92	119.27	125.28	129.29	127.28	122.61
Dry density, rd.=[r/(1+w/100)],(lb./ft^3)	103.37	106.83	108.99	110.53	105.87	99.20

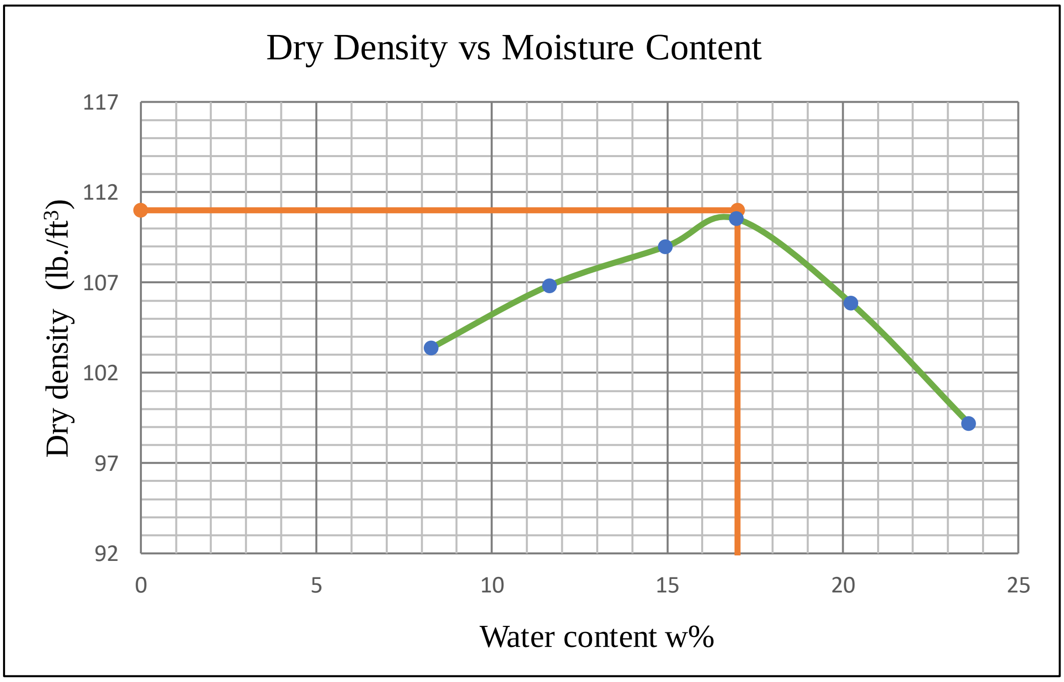


Figure 4.5: We see maximum dry density is 111(lb./ft^3) and optimum Moisture content is 17%

Table 4.5.3 Standard Proctor (12 % Fly Ash & 3% Cement)

Water Content Determination (12 % Fly Ash & 3% Cement)							
Sample no	1	2	3	4	5	6	7
Moisture can no	52	101	54	50	76	58	91
Mass of empty clean can	21.69	20.44	20.3	21.33	21.4	18.84	20.6
Mass of can + wet soil	87.54	87.37	87.65	89.16	92.15	94.7	81.37
Mass of can + dry soil	82.85	80.69	79.8	79.75	80.7	80.62	69.03
Mass of soil solid	61.16	60.25	59.5	58.42	59.3	61.78	48.43
Mass of pore water	4.69	6.68	7.85	9.41	11.45	14.08	12.34
Water content w%	7.67	11.09	13.19	16.11	19.31	22.79	25.48
Density Determination (12 % Fly Ash & 3% Cement)							
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.)	10.009	10.207	10.406	10.604	10.648	10.52	10.41
Mass of compacted soil, (lb.)	3.54	3.74	3.94	4.13	4.18	4.05	3.94
Wet density, r = (M/V),(lb./ft^3)	107.24	113.25	119.27	125.28	126.62	122.61	119.27
Dry density, rd.= [r/(1+w/100)],(lb./ft^3)	99.60	101.95	105.37	107.90	106.12	99.85	95.05

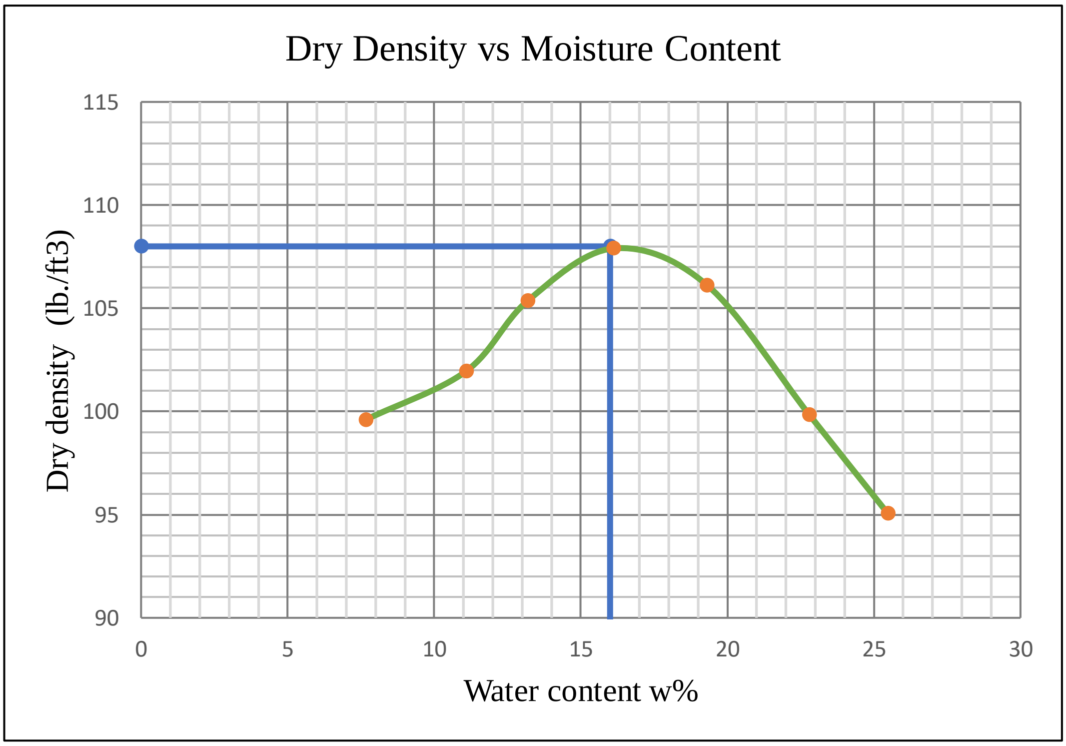


Figure 4.6: We see maximum dry density is 108(lb./ft^3) and optimum moisture content is 16%

Table 4.5.4 Standard Proctor (17 % Fly Ash & 3% Cement)

Water Content Determination (17 % Fly Ash & 3% Cement)						
Sample no	1	2	3	4	5	6
Moisture can no	56	16	12	20	18	15(1)
Mass of empty clean can	19.66	25.53	22.8	23.57	25.12	24.59
Mass of can + wet soil	73.39	98.05	100.78	98.16	88.85	105.12
Mass of can + dry soil	69.6	91.3	91.61	87.77	78.68	90.44
Mass of soil solid	49.94	65.77	68.81	64.2	53.56	65.85
Mass of pore water	3.79	6.75	9.17	10.39	10.17	14.68
Water content w%	7.59	10.26	13.33	16.18	18.99	22.29
Density Determination (17 % Fly Ash & 3% Cement)						
Compacted soil sample no	1	2	3	4	5	6
Volume of the mold, (V), (ft^3)	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
Mass of compacted soil and mold (lb.)	10.031	10.163	10.384	10.604	10.560	10.45
Mass of compacted soil, (lb.)	3.56	3.69	3.91	4.13	4.09	3.98
Wet density, r = (M/V), (lb./ft^3)	107.91	111.92	118.60	125.28	123.94	120.60
Dry density, rd = [r/(1+w/100)], (lb./ft^3)	100.30	101.50	104.65	107.83	104.16	98.62

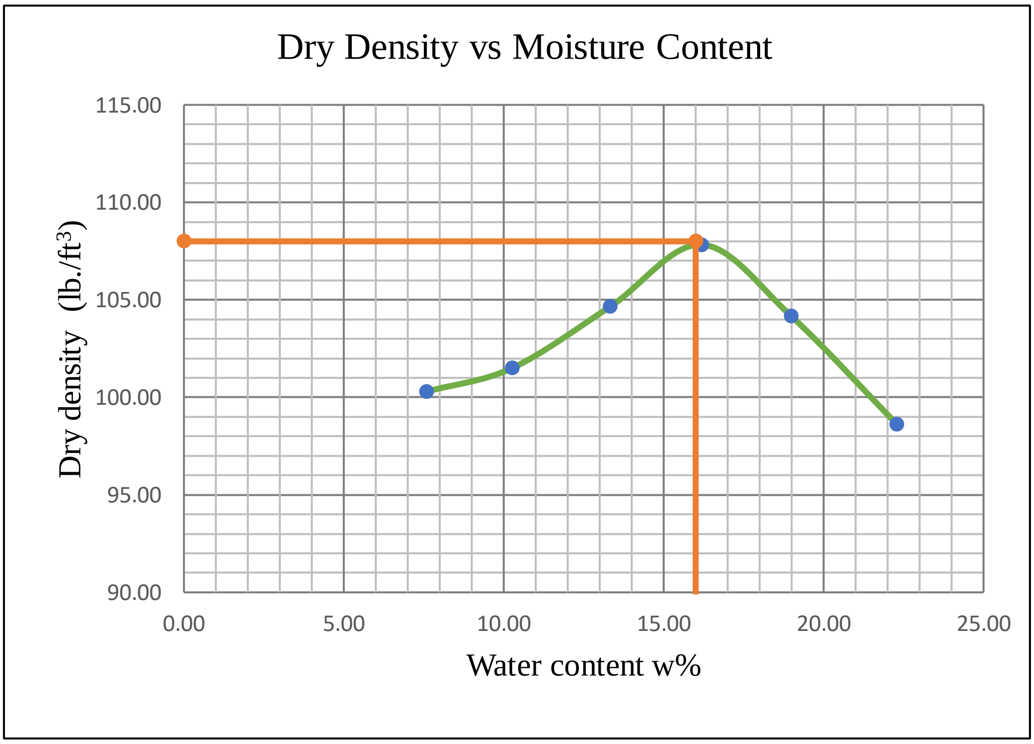


Figure 4.7: We see maximum dry density is 108(lb./ft^3) and optimum Moisture content is 16%

Table 4.6 Unconfined Compression Test

Table 4.6.1 The calculation for unconfined compressive strength of Day-3 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
100	1	1.316	11.491	47	0.098	85.7192
200	2	2.632	11.647	90.5	0.189	163.003
300	3	3.947	11.806	127.5	0.2675	226.622
400	4	5.263	11.97	161.5	0.338	283.166
500	5	6.579	12.139	195.5	0.410	338.042
600	6	7.895	12.312	229	0.480	390.432
700	7	9.211	12.49	258.5	0.542	434.467
800	8	10.526	12.674	289.5	0.607	479.525
900	9	11.842	12.863	276.5	0.580	451.255

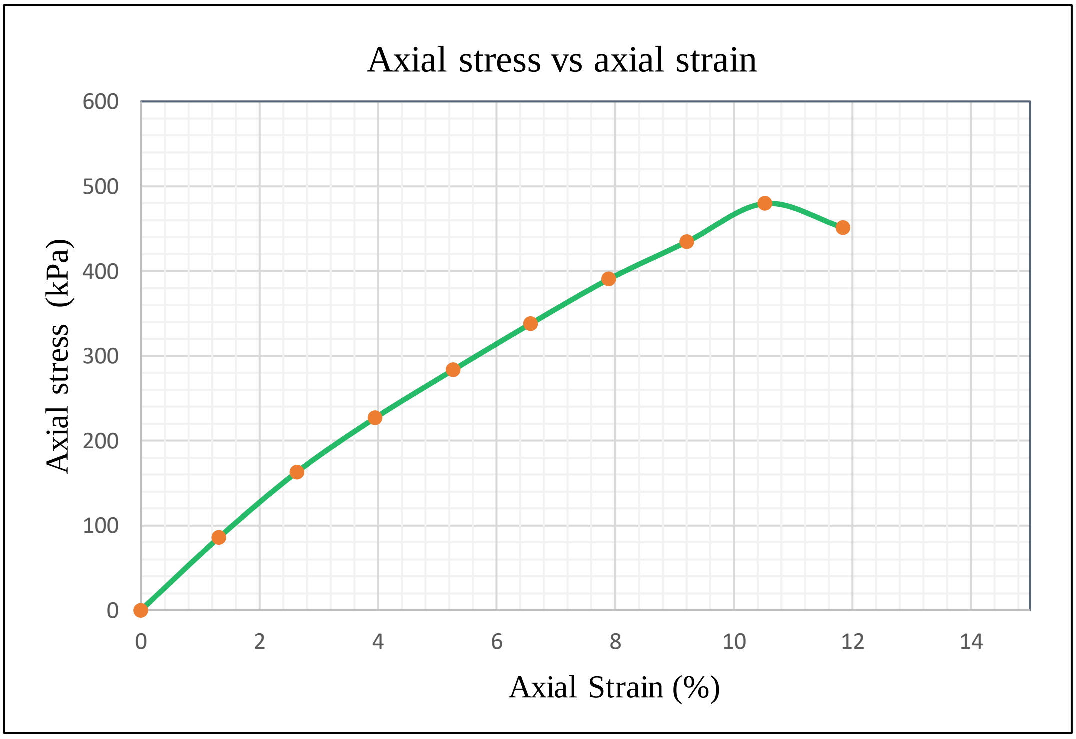


Figure 4.8: We see axial stress and axial strain Day-3 (only soil)

Table **4.6.2** The calculation for unconfined compressive strength of Day-3 Cement 3% Fly ash 7%

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
100	1	1.316	11.491	70.5	0.147	128.665
200	2	2.632	11.647	153.5	0.322	276.594
300	3	3.947	11.806	225.5	0.473	400.940
400	4	5.263	11.97	298.5	0.626	523.517
500	5	6.579	12.139	365.5	0.767	632.136
600	6	7.895	12.312	438.5	0.920	747.766
700	7	9.211	12.49	501.5	1.052	843.034
800	8	10.526	12.674	559.5	1.174	926.897
900	9	11.842	12.863	535	1.123	873.279

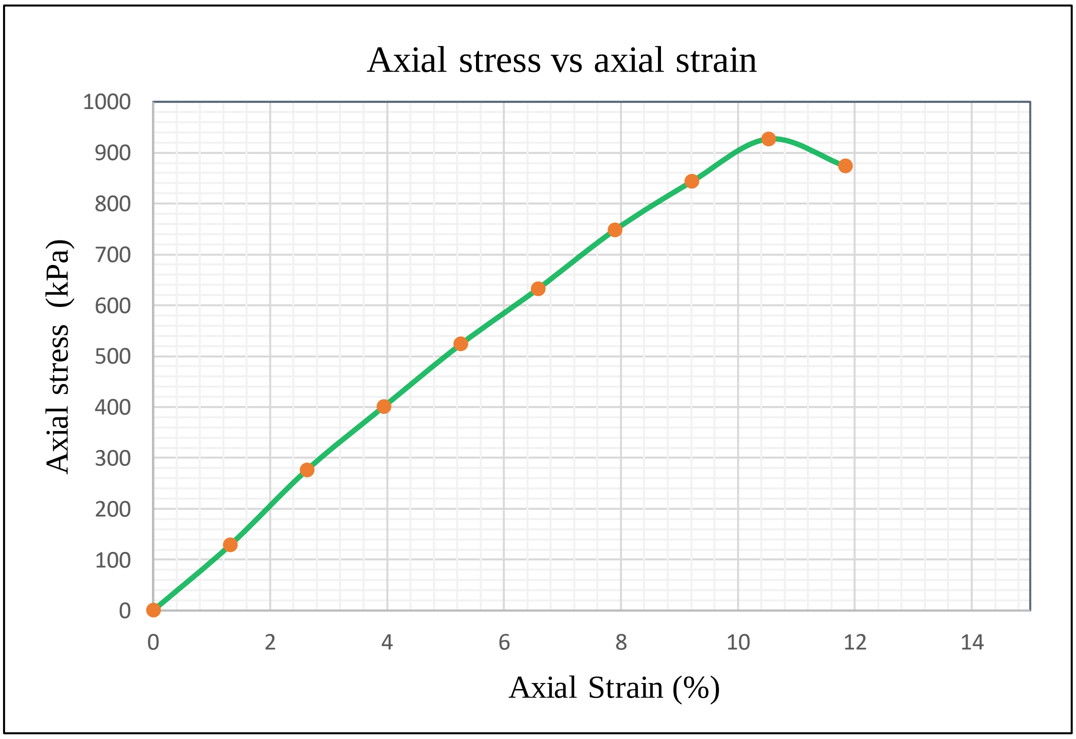


Figure 4.9: We see axial stress and axial strain Day-3 (3% cement & 7% fly ash)

Table 4.6.3 The calculation for unconfined compressive strength of Day-3 Cement 3% Fly ash 12%

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
100	1	1.316	11.491	51	0.106	93.029
200	2	2.632	11.647	133.5	0.280	240.534
300	3	3.947	11.806	215.5	0.452	383.152
400	4	5.263	11.97	293.5	0.616	514.745
500	5	6.579	12.139	368	0.772	636.460
600	6	7.895	12.312	443.5	0.931	756.294
700	7	9.211	12.49	514	1.079	864.051
800	8	10.526	12.674	578	1.213	957.550
900	9	11.842	12.863	551	1.156	899.401

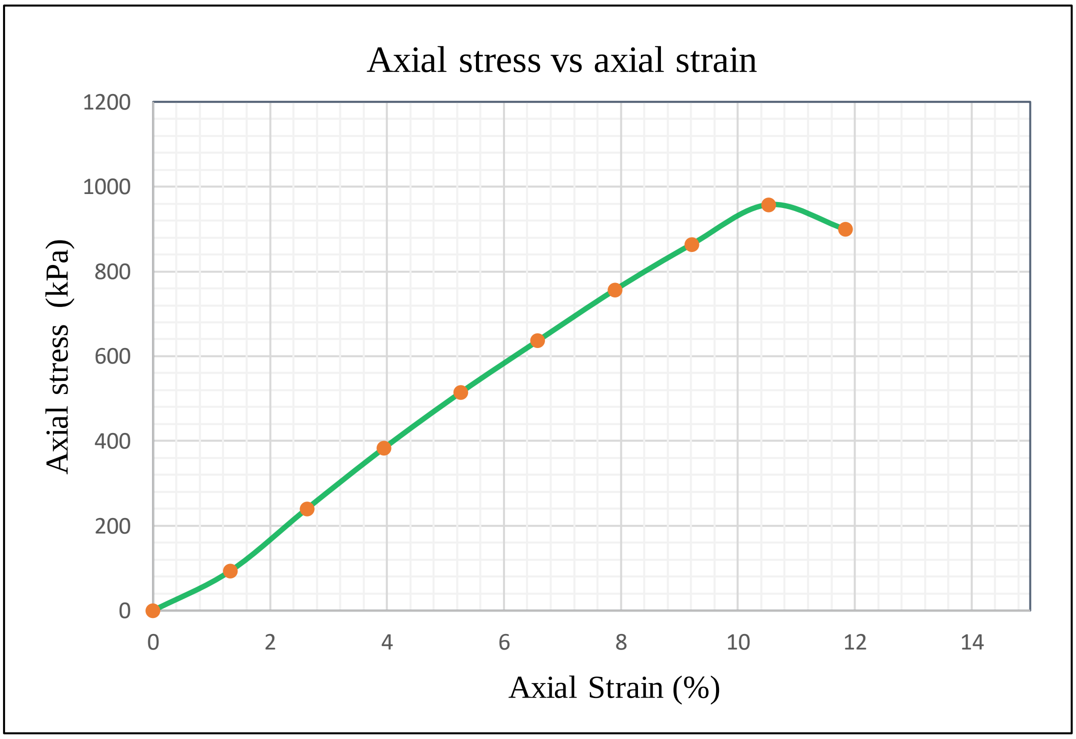


Figure 4.10: We see axial stress and axial strain Day-3 (3% cement & 12% fly ash)

Table 4.6.4 The calculation for unconfined compressive strength of Day-3 Cement 3% Fly ash 17%

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
100	1	1.316	11.491	78.5	0.164	143.286
200	2	2.632	11.647	166	0.348	299.132
300	3	3.947	11.806	244	0.512	433.847
400	4	5.263	11.97	326.5	0.685	572.639
500	5	6.579	12.139	402	0.844	695.279
600	6	7.895	12.312	477.5	1.002	814.286
700	7	9.211	12.49	545.5	1.145	917.013
800	8	10.526	12.674	603	1.266	998.974
900	9	11.842	12.863	573	1.203	935.318

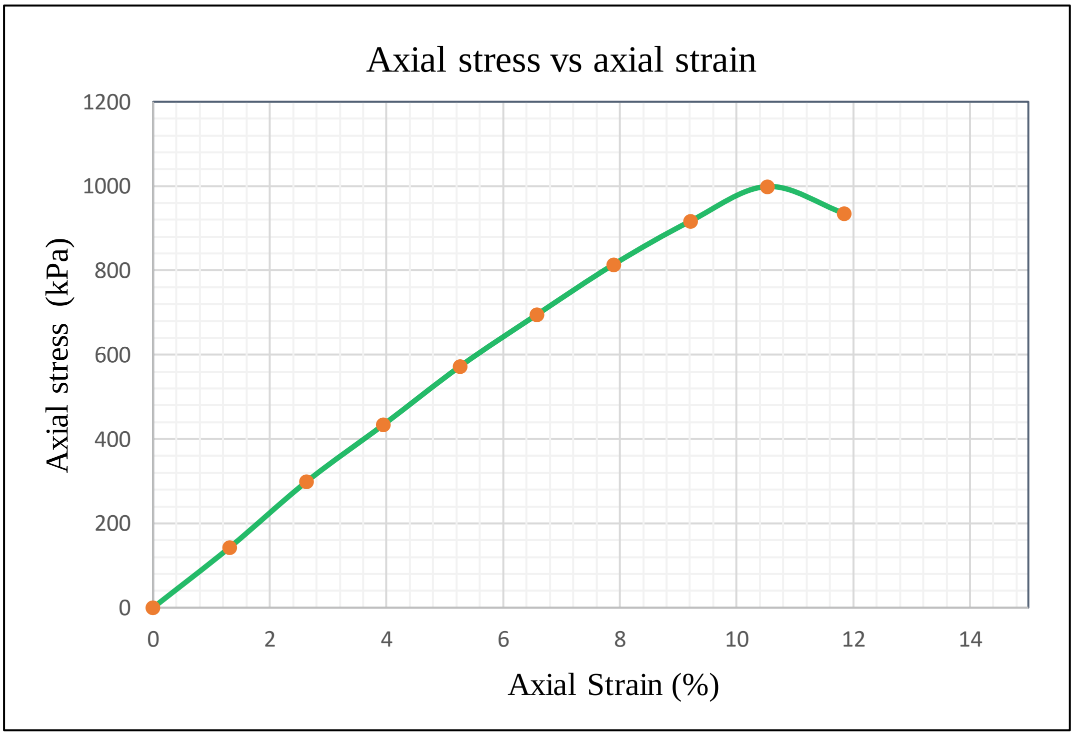


Figure 4.11: We see axial stress and axial strain Day-3 (3% cement & 17% fly ash)

Table 4.6.5 The calculation for unconfined compressive strength of Day-7 only soil

Deformation	Deformation ΔL (mm)	Axial Strain % (ϵ)	Corrected Area (cm^2)	Load Dial Reading (Proving ring)	Corr Day-3 ected Load (KN)	Stress (kPa)
0	0	0	11.34	0	0	0
100	1	1.316	11.491	50	0.104	91.201
200	2	2.632	11.647	114.5	0.240	206.276
300	3	3.947	11.806	172	0.361	305.776
400	4	5.263	11.97	222	0.466	389.306
500	5	6.579	12.139	269	0.564	465.194
600	6	7.895	12.312	305.5	0.641	520.914
700	7	9.211	12.49	342	0.718	574.859
800	8	10.526	12.674	317.5	0.666	525.919

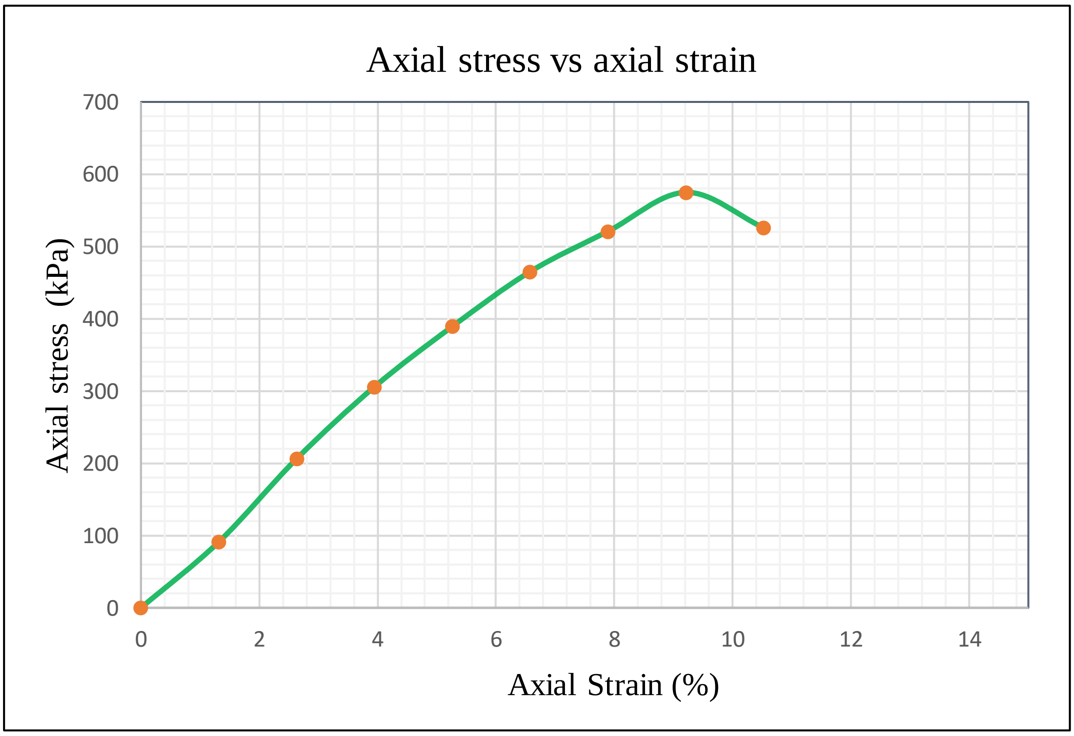


Figure 4.12: We see axial stress and axial strain Day-7 (only soil)

Table 4.6.6 The calculation for unconfined compressive strength of Day-7 Cement 3% Fly ash 7%

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
100	1	1.316	11.491	63.5	0.133	115.873
200	2	2.632	11.647	138.5	0.290	249.549
300	3	3.947	11.806	210.5	0.441	374.258
400	4	5.263	11.97	289.5	0.607	507.727
500	5	6.579	12.139	366	0.768	633.001
600	6	7.895	12.312	445.5	0.935	759.705
700	7	9.211	12.49	521.5	1.094	876.661
800	8	10.526	12.674	574	1.205	950.923
900	9	11.842	12.863	544	1.142	887.973

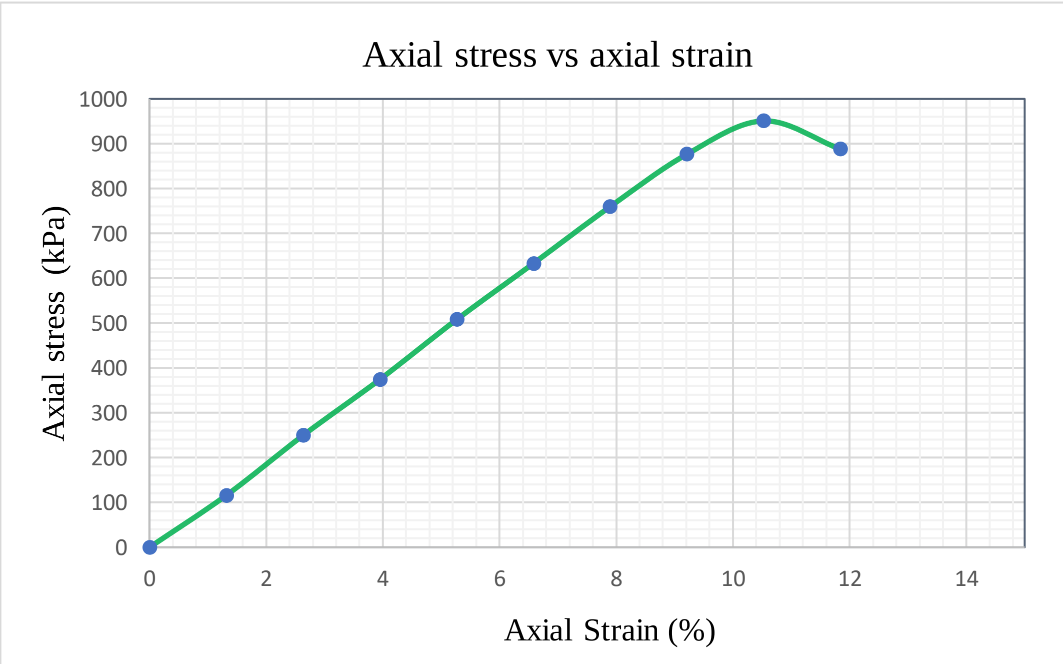


Figure 4.13: We see axial stress and axial strain Day-7 (3% cement & 7% fly ash)

Table 4.6.7 The calculation for unconfined compressive strength of Day-7 Cement 3% Fly ash 12%

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
100	1	1.316	11.491	55.5	0.116	101.253
200	2	2.632	11.647	128.5	0.269	231.518
300	3	3.947	11.806	205	0.430	364.475
400	4	5.263	11.97	289	0.606	506.850
500	5	6.579	12.139	371	0.778	641.650
600	6	7.895	12.312	456.5	0.958	778.468
700	7	9.211	12.49	537.5	1.128	903.562
800	8	10.526	12.674	614.5	1.290	1018.029
900	9	11.842	12.863	686.5	1.441	1120.617
1000	10	13.158	13.058	753.5	1.582	1211.632
1100	11	14.474	13.259	718	1.507	1137.038

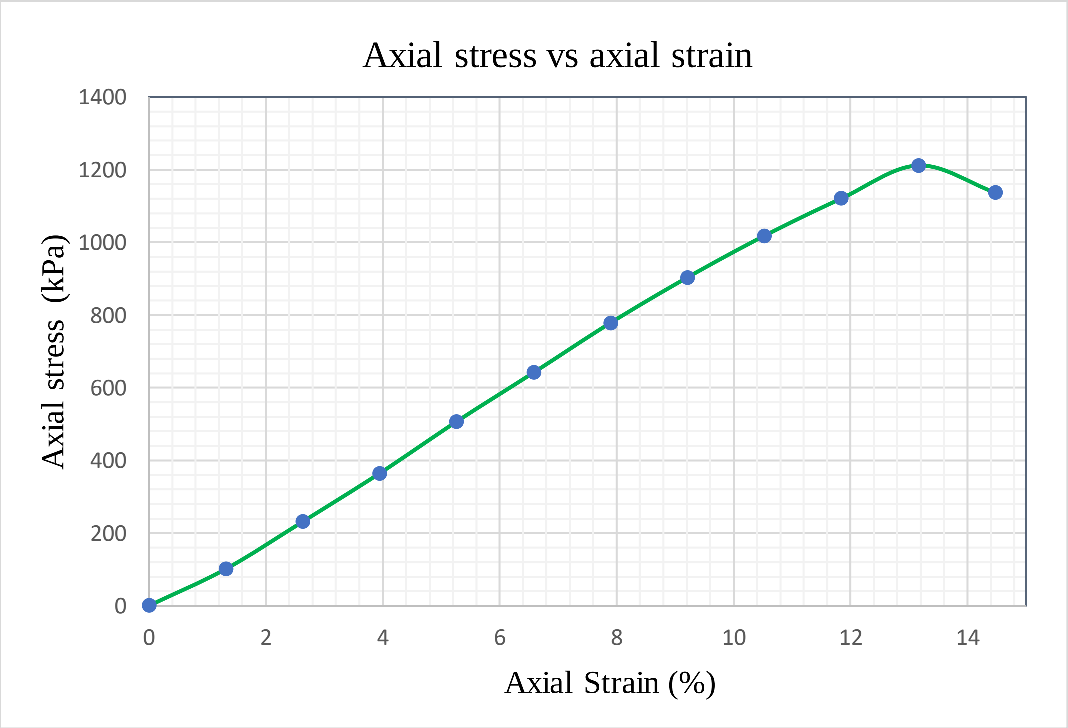


Figure 4.14: We see axial stress and axial strain Day-7 (3% cement & 12% fly ash)

Table 4.6.8 The calculation for unconfined compressive strength of Day-7 Cement 3% Fly ash 17%

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
100	1	1.316	11.491	52	0.109	94.856
200	2	2.632	11.647	128	0.268	230.617
300	3	3.947	11.806	211.5	0.443	376.037
400	4	5.263	11.97	298	0.625	522.639
500	5	6.579	12.139	380.5	0.798	658.085
600	6	7.895	12.312	465.5	0.977	793.819
700	7	9.211	12.49	548.5	1.151	922.057
800	8	10.526	12.674	629.5	1.321	1042.883
900	9	11.842	12.863	710.5	1.491	1159.799
1000	10	13.158	13.058	665	1.396	1069.306

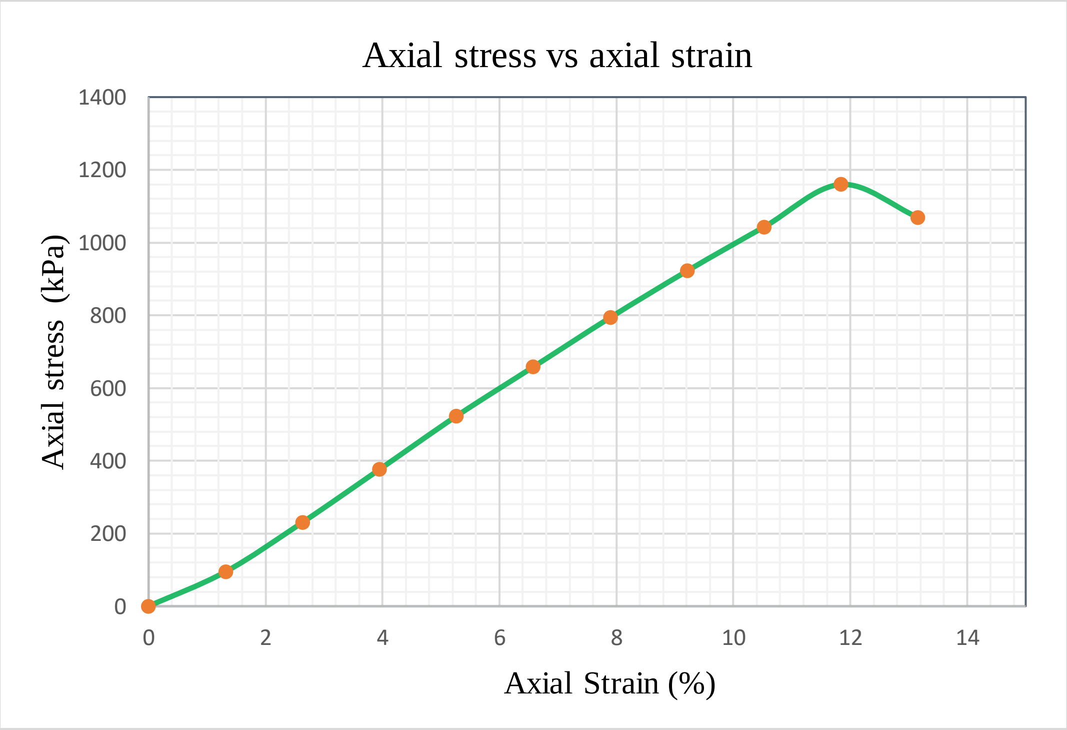


Figure 4.15: We see axial stress and axial strain Day-7 (3% cement & 17% fly ash)

Table 4.6.9 The calculation for unconfined compressive strength of Day-14 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
100	1	1.316	11.491	56.5	0.118	103.080
200	2	2.632	11.647	117.5	0.246	211.685
300	3	3.947	11.806	177	0.371	314.670
400	4	5.263	11.97	232.5	0.488	407.727
500	5	6.579	12.139	281.5	0.590	486.819
600	6	7.895	12.312	325	0.682	554.174
700	7	9.211	12.49	358	0.751	601.761
800	8	10.526	12.674	378.5	0.794	626.992
900	9	11.842	12.863	364	0.764	594.107

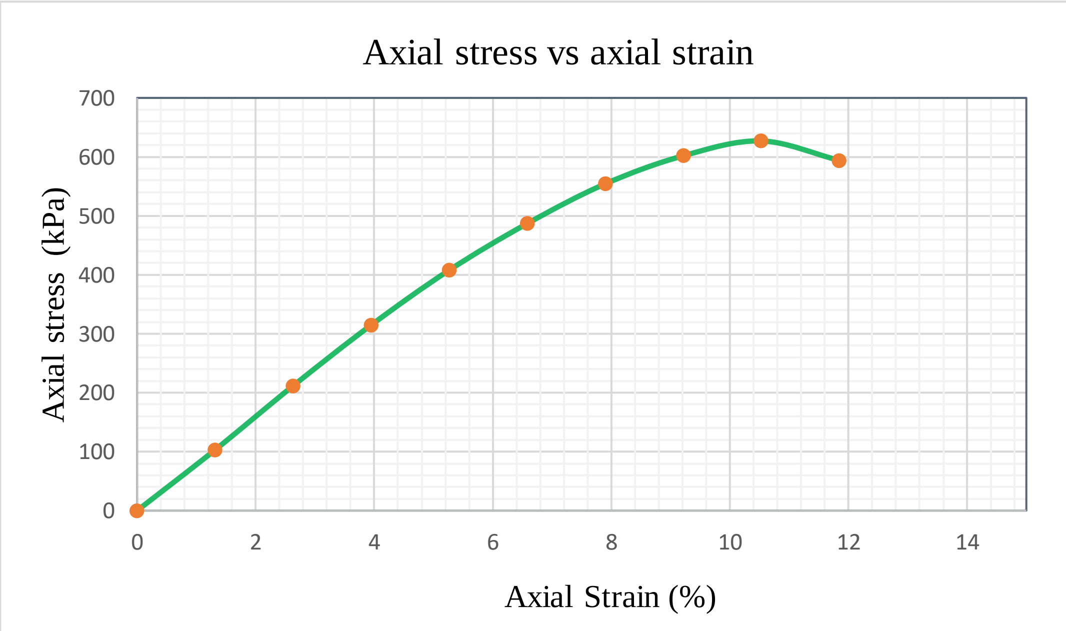


Figure 4.16: We see axial stress and axial strain Day-14 (only soil)

Table 4.6.10 The calculation for unconfined compressive strength of Day-14 Cement 3% Fly ash 7%

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
100	1	1.316	11.491	59.5	0.124	108.563
200	2	2.632	11.647	141	0.295	254.056
300	3	3.947	11.806	227.5	0.477	404.497
400	4	5.263	11.97	313.5	0.658	549.832
500	5	6.579	12.139	392.5	0.824	678.845
600	6	7.895	12.312	475.5	0.998	810.875
700	7	9.211	12.49	552	1.159	927.942
800	8	10.526	12.674	633.5	1.330	1049.510
900	9	11.842	12.863	585	1.228	954.909

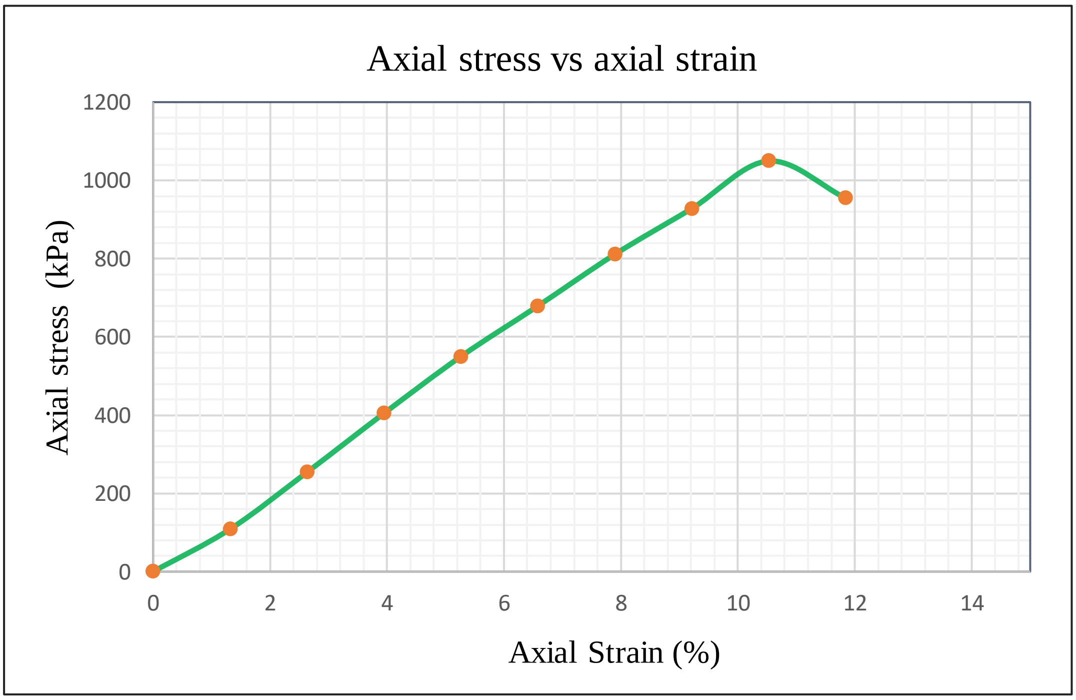


Figure 4.17: We see axial stress and axial strain Day-14 (3% cement & 7% fly ash)

Table 4.6.11 The calculation for unconfined compressive strength of Day-14 Cement 3% Fly ash 12%

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
100	1	1.316	11.491	68.5	0.143	125.010
200	2	2.632	11.647	154	0.323	277.496
300	3	3.947	11.806	241	0.505	428.510
400	4	5.263	11.97	328	0.688	575.271
500	5	6.579	12.139	417	0.875	721.229
600	6	7.895	12.312	506.5	1.063	863.750
700	7	9.211	12.49	589	1.236	990.152
800	8	10.526	12.674	670	1.406	1109.988
900	9	11.842	12.863	748	1.570	1221.021
1000	10	13.158	13.058	828.5	1.739	1332.248
1100	11	14.474	13.259	769	1.614	1217.814

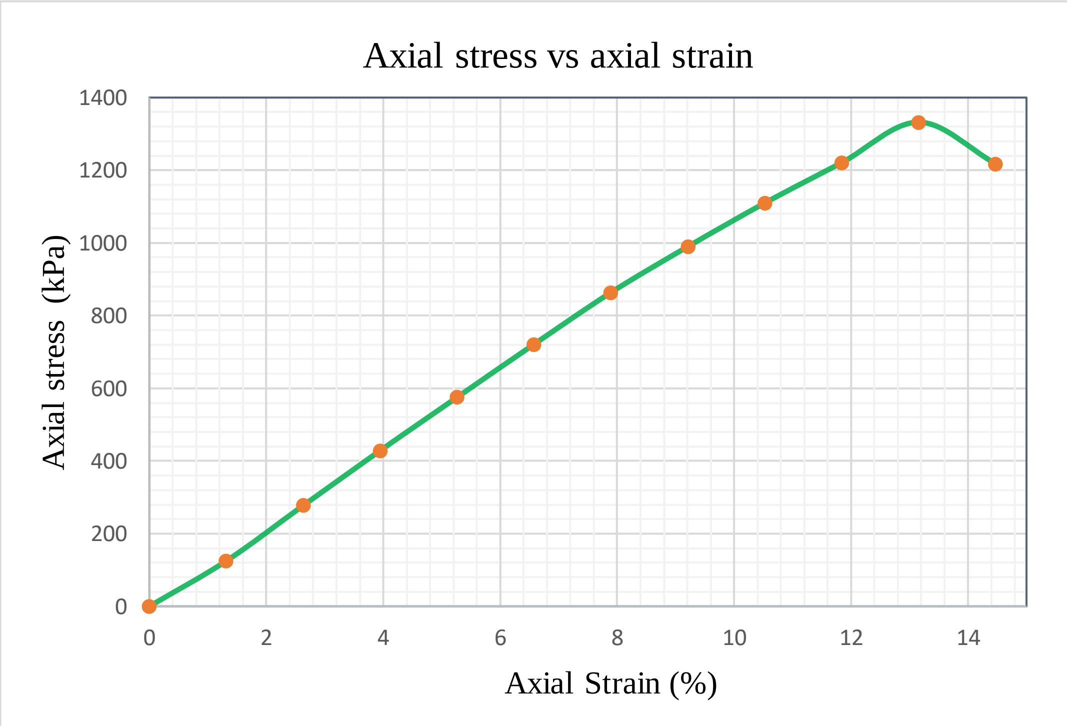


Figure 4.18: We see axial stress and axial strain Day-14 (3% cement & 12% fly ash)

Table 4.6.12 The calculation for unconfined compressive strength of Day-14 Cement 3% Fly ash 17%

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
100	1	1.316	11.491	68.5	0.143	125.010
200	2	2.632	11.647	154	0.323	277.496
300	3	3.947	11.806	235.5	0.494	418.727
400	4	5.263	11.97	321	0.673	562.990
500	5	6.579	12.139	402.5	0.845	696.144
600	6	7.895	12.312	488.5	1.0256	833.049
700	7	9.211	12.49	569.5	1.195	957.365
800	8	10.526	12.674	648.5	1.361	1074.364
900	9	11.842	12.863	725	1.522	1183.471
1000	10	13.158	13.058	692.5	1.454	1113.531

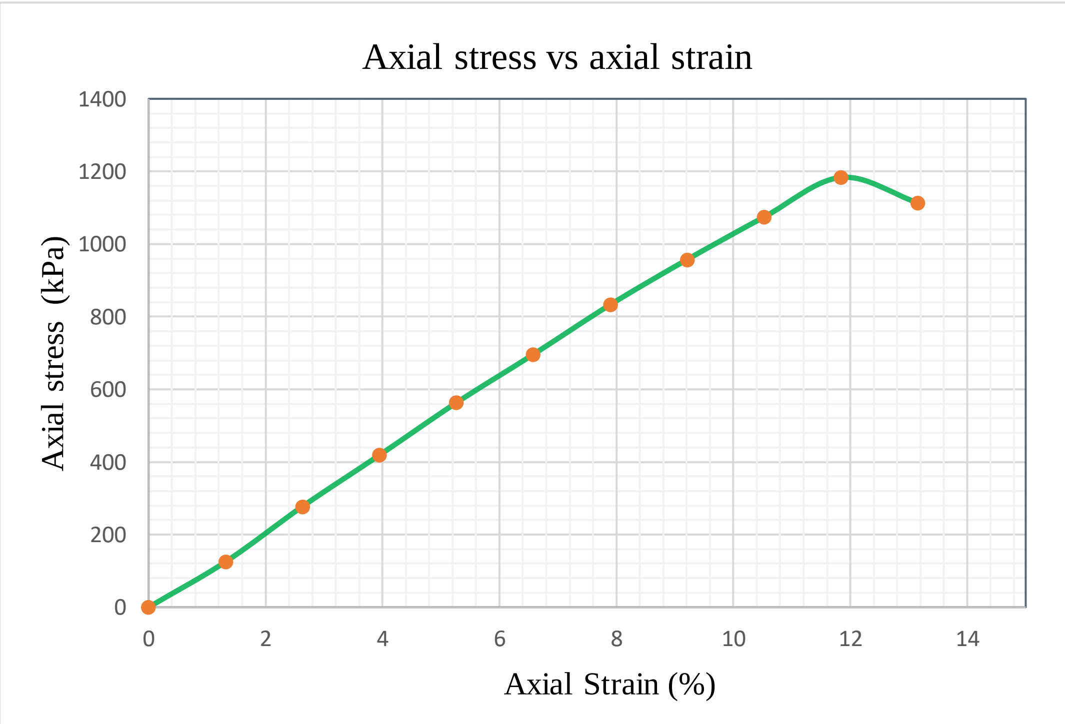


Figure 4.19: We see axial stress and axial strain Day-14 (3% cement & 17% fly ash)

CHAPTER-5
RESULTS AND DISCUSSION

5.1 General

In this research, a total of sixteen unconfined compression tests are conducted. We tested the quality for 3,7,14,28 days using fly ash and cement in four proportions with soil. From this study, we also found that if we add cement and fly ash at a certain limit it starts to settle and how it behaves.

5.2 Results and Discussion

The unconfined compression test was conducted for clay with cement and fly ash various ratios and the result are presented in [Figure 5.1]. It was found that the unconfined compressive strength of clays goes on increasing with 12% fly ash and 3% cement between four ratios.

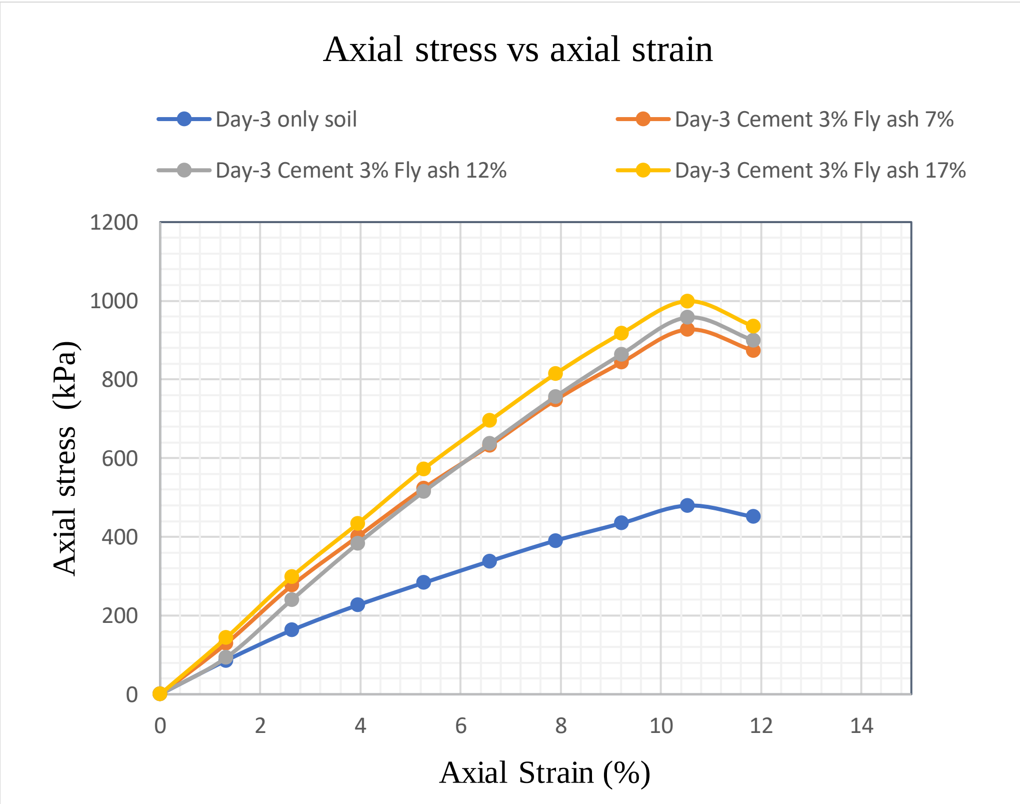


Figure 4.20: Combine axial stress vs axial strain (day -3)

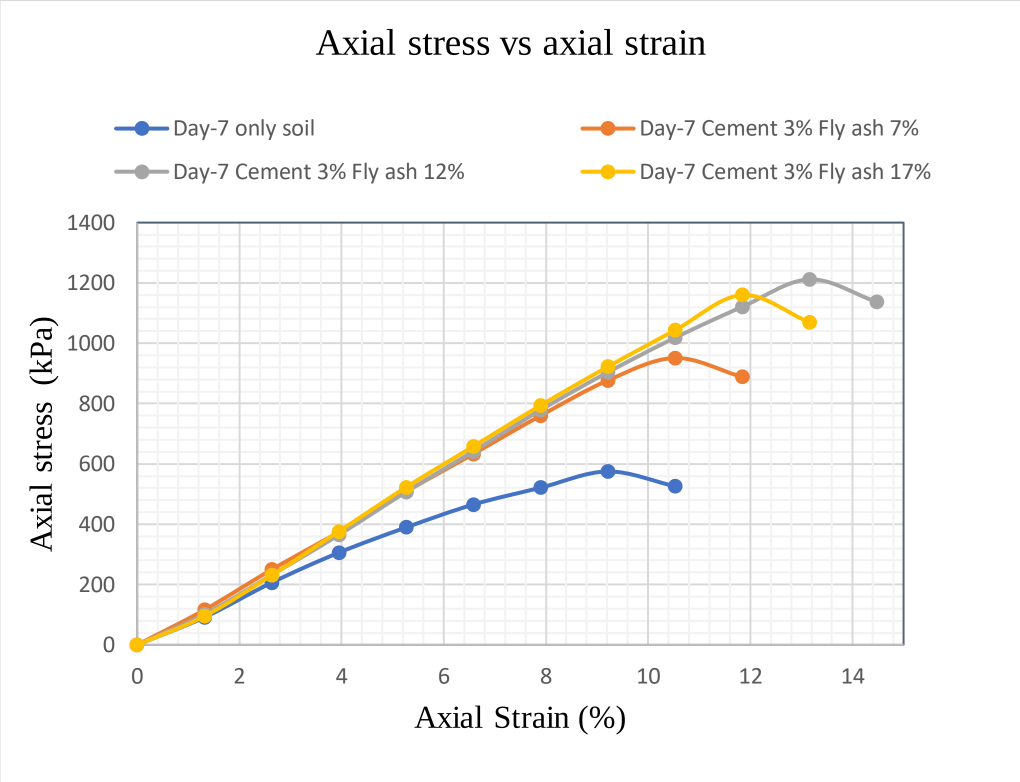


Figure 4.21: Combine axial stress vs axial strain (day -7)

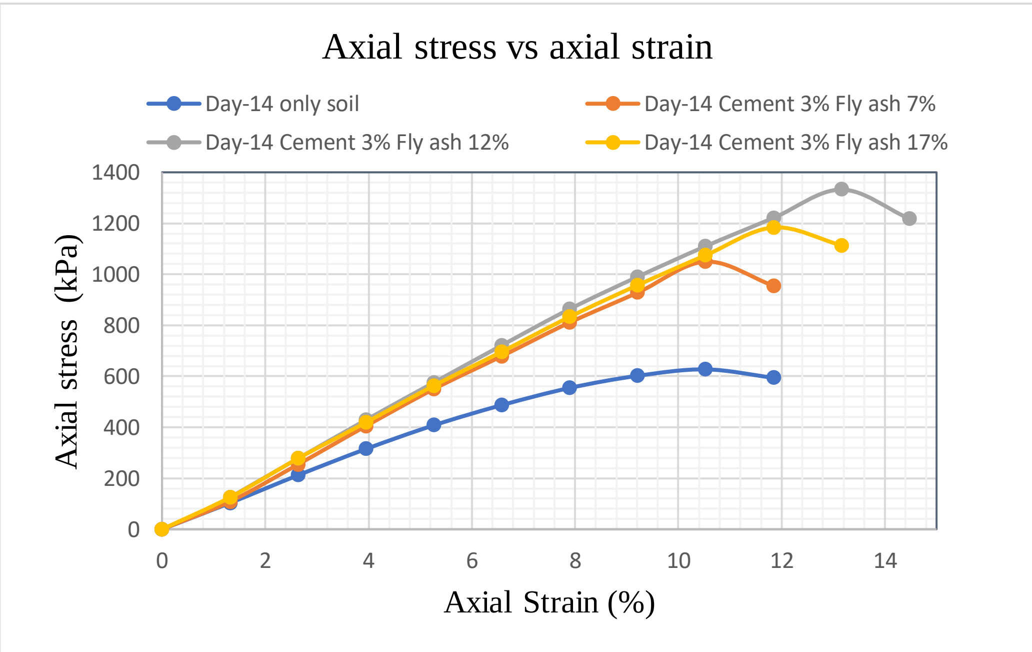


Figure 4.22: Combine axial stress vs axial strain (day -14)

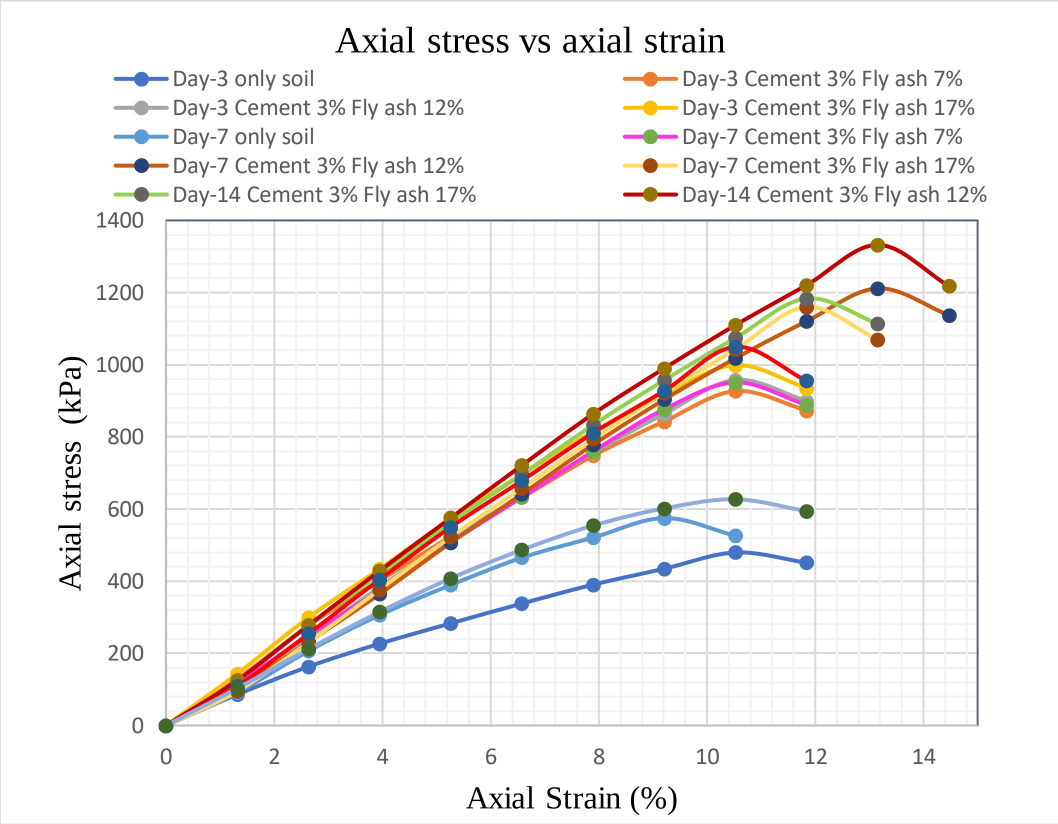


Figure 4.23: Combine axial stress vs axial strain (all)

CHAPTER-6

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The conclusions drawn from this research may be summarized follow as a result, when we mix fly ash with soil, the strength of soil increases. It was found that clay soils strength varies with the variation of fly ash and cement ratio. From this study, we also found that if we add fly ash and cement at a certain limit it starts to settle. When 12% fly ash and 3% cement are mixed with soil, the soil will not settle anymore but if more than or less than this mix of fly ash and cement the soil will get less energy or absorb more energy which is harmful to the soil.

6.2 Significance of Research

There is a specific reason behind doing this test. Very little research has already been done on soft soils. And mixing fly ash with soft soil has made the work even less. Fly ash is produced in large quantities in factories all over the world. But fly ash is harmful to the environment. Fly ash is harmful to the atmosphere but if we can use fly ash properly, it is possible to protect the atmosphere. And so we are realizing the importance of using engineering components as fly ash. Most parts of Bangladesh are made of soft soil, so if fly ash is used, the environment will be free from pollution and proper use of fly ash.

6.3 Recommendations

When cement and fly ash is mixed with soil, it behaves 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 we can run more different experiments on the soil. Also, this research suggests the following point should be studying for further study-

- The proportions of cement can be changed
- Different soil samples can be worked with

References

[1] M. Z. A. a. M. Z. U. A. I. N. Chowdhury1, "Stabilization of Organic Soil from Bangladesh with Cement and Fly Ash," *Stabilization of Organic Soil from Bangladesh with Cement and Fly Ash,* p. 95, 30 May 2016.

[2] R. Rajapakse, "Expansive Soil," *Pile Design and Construction Rules of Thumb (Second Edition),* no. 2016, pp. 110-117, 2019.

[3] V. K. A. Anjali Gupta, "Contaminated dredged soil stabilization," *International journal of Geo-Engineering,* pp. 1-13, 2017.

[4] S. K. G. Gyanen. Takhelmayum, "Laboratory Study on Soil Stabilization," *Laboratory Study on Soil Stabilization Using Fly,* vol. 2, no. 1, January 2013, pp. 478-480, 2013.

[5] E. I. Prof. Magdi Zumrawi, "Stabilization of Pavement Subgrade by Using Fly ash," *Stabilization of Pavement Subgrade by Using Fly ash Activated by cement,* vol. 3, no. 2015, pp. 223-225, 2015.

[6] b. L. J. M. a. L. R. Lenke, "Efficiency of Fly Ash in Mitigating Alkali-Silica Reaction Based on Chemical Composition," *ACI Materials Journal,* no. 2006, p. 320, September-October 2006.

[7] M. M. E. Zumrawi, "Stabilization of Pavement Subgrade by Using Fly Ash," *American Journal of Civil Engineering and Architecture,* vol. 3, pp. 218-219, 2015.

[8] S. K. G. Gyanen. Takhelmayum, "Laboratory Study on Soil Stabilization Using Fly," *International Journal of Engineering Science and Innovative Technology,* vol. 2, pp. 477-478, 2013.

[9] M. F. D. P. S. R. s. Ankit Singh Negi, "SOIL STABILIZATION USING LIME," *International Journal of Innovative Research in Science, Engineering and Technology,* vol. 2, no. 2, pp. 448-449, 2013.

[10] B.M.D, Principles of Geotechnical Engineering 8th edition, India: Cengage Learning India Privet Limited., 1, January 2013.

[11] N. Ural, The Importance of Clay in Geotechnical Engineering, September 2018.

[12] A. N. N. I. A. M. V. Y. M. a. V V Kramarenko, "Determination of water content in clay and organic soil using microwave oven," *Earth and Environmental Science,* vol. 10, 2016.