# AN EXPERIMENTAL STUDY OF SOIL STABILIZATION BY USING CEMENT, LIME AND POTASSIUM HYDROXIDE

Submitted in partial fulfillment of the requirements of the degree of

**Bachelor of Engineering (B.E)**

By

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# CERTIFICATE

This is to certify that **Khan Zishan Mahtab Alam (14CES24), Jamadar Talha Zahid (15DCES67), Kazi Mohd Ismail Zaki (15DCES69)**, **Mulla Abdullatif Jabbar (15DCES78)** have satisfactorily completed and delivered a Project report entitled, **"An Experimental Study on Soil Stabilization by Using Cement, Lime and Potassium Hydroxide"** in partial fulfillment for the completion of the **B.E.** in **Civil Engineering** Course conducted by the University of Mumbai in Anjuman-I-Islam's Kalsekar Technical Campus, New Panvel, Navi Mumbai, during the academic year 2017-18.

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Guide

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**Dr. Abdul Razzak Honnutagi**

Director of AIKTC

# APPROVAL SHEET

This B. E. Project entitled **"An Experimental Study on Soil Stabilization by Using Cement, Lime and Potassium Hydroxide"** by **Khan Zishan Mahtab Alam (14CES24), Jamadar Talha Zahid (15DCES67), Kazi Mohd Ismail Zaki (15DCES69), Mulla Abdullatif Jabbar (15DCES78)** is approved for the degree of Bachelorof Engineering in Civil Engineering.

Examiner

______________________

Supervisor

______________________

Date:

Place: Panvel

# DECLARATION

We declare that this written submission represents our ideas in our own words and where others' ideas or words have been included, we have adequately cited and referenced the original sources. We also declare that we have adhered to all the principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in our submission. We understand that any violation of the above will be a cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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We take this opportunity to thank all our Professors and non-teaching staff who have directly or indirectly helped for our project. We pay our respects and love to our parents and all other family members for their love and encouragement throughout our career. Last but not the least, we express our thanks to our friends for their cooperation and support.

# ABSTRACT

The use of soil stabilization is ever increasing due to technical, economic and environmental benefits. Soil stabilization methods are commonly used in highway projects where high strength of sub-soil is required. In physical and chemical stabilization, an optimum amount of cement, lime or any chemical is mixed with the soil to improve its quality. A practical and generally accepted approach is used to determine the optimum amount of additive to be added to the soil to get the maximum efficiency.

In this work, an attempt has been made to carry out an experimental work, based on various results with different amount of additives ranging from 4%, 8% and 12%. The additives used are cement, lime and Potassium Hydroxide (KOH). Different properties of soil are determined for the campus soil. The important soil parameters are determined by incorporating different percentages of cement, (cement + lime) and (cement + lime +KOH). The results obtained can be utilized as a guide, as to what percentage and combination of additives is to be added in the soil when a particular soil property needs to be enhanced.

# CONTENT

# LIST OF FIGURES

# LIST OF TABLES

# LIST OF GRAPHS

# CHAPTER 1

# INTRODUCTION

## 1.1 Background

The foundation is very important part and has to be strong enough to support the entire structure. In order for the foundation to be strong, the soil around it plays a very critical role. So, we need to have proper knowledge about their properties and factors which affect their behavior to work with soil. The process of soil stabilization helps to achieve the required properties in a soil needed for the type of construction work.

## 1.2 Problem Statement

The safety of any geotechnical structure is dependent on the strength of soil; if the soil fails, the structure founded on it can collapse. Understanding soil properties is the basic to analyzesoil stability problems like: lateral pressure on earth retaining structure, Slope stability, bearing capacity. While constructing a structure of any form, the basic soil parameters are to be known beforehand& they need to be improved, if necessary. The campus soil is taken for carrying out various experiments in geotechnical engineering laboratory

## 1.3 Proposed Solution

The soil is improved by using chemical (KOH), lime and cement. The soil sample for the project is taken from the AIKTC. The work is carried out by performing different experiments on the soil.

## 1.4 Objectives

The aim of our project is to know the physical properties of soil. The main objective of this experimental study is to improve the properties of soil by adding chemical, cement and lime as stabilizing agents.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Introduction

During the literature review for this work, a reference to various books on Soil Engineering, Technicaland Research papers in various journals was made.

## 2.2 Summaries and Relevant Literature

**Satyendra Mittal**, tried to improve BLACK COTTON SOIL by using additives like Lime, Cement and combination. The result showed that after the addition of only lime the 7-day strength is less than 20.7kg/cm$^2$. On addition of cement, the 28 days strength is increased more than 20.7 kg/cm$^2$, but if lime and cement are added together about 6-12% in which lime is about 2-4% and cement is about 4-10%, the 7-day strength has been increased about 34.5-41.3 kg/cm$^2$.

**B.Kanddulma, N kisku, K Murari, JP. Singh,**in this project soil used is CLAYEY SOIL and materials used are Rice Husk Ash and Lime. The mixture of the Rice Husk Ash and Lime is used in different proportion about 5, 10, 15 and 20% by weight of soil. The results obtained after performing various experiments on soil is that the optimum moisture content increases in the soil and California bearing ratio and unified compressive strength value increases about 15% whereas the Atterberg's limit and permeability decreases.

**Monica Malhotra, Sanjeev Naval,**in this project soil used is EXPANSIVE SOIL and materials used are 5% of Lime and different ratios of fly ash and bottom ash. After performing various experiments on soil, the results obtained is that the liquid limit decreases, plastic limit and

optimum moisture content increases as the percentage of fly ash and bottom ash increases and there is reduction in dry density and free swell index as well.
**Dr. Robert,** In this project soil used is fly-ash of class ‘C’.The results obtainedis that the Unified Compressive Strength and California Bearing Ratios values improved 97% and 47% respectively when fly-ash content was increased from 0 to 12%.

**Naman Agarwal, Ashish Murari,Ajit kumar,**This project is used to modify the Compaction and CBR properties of soil. To do so stone dust were used. Stone dust was used in different proportion like 10,20,30,40 & 50% by weight of soil. Theresult obtained in this project is that the Maximum dry density and optimum moisture content of soil increases and there is also an increase in CBR value after the addition of stone dust about 30%.

**Basit Riyaz, Munib Hilal, Mujtaba Mir, Munib Bashir,**in this project material Cement was used in different percentage. The results obtained is that the atterberg’s limit, plasticity Index, optimum moisture content &cohesion decreases in soil whereas the maximum dry density, California bearing ratio and angle of internal friction increases.

**Md. Shakeel Abid,**in this project soil used is cohesive as well as cohensionless soil.The additive used is sulphuric acid($H_2SO_4$).The results obtained is that the maximum dry density increases in soil when sulphuric acid is added upto 10M concentration and it decreases after the concentration is increased from 10M.The additive used is economical when it is added upto 8-10% after that it becomes uneconomical.

**Nandan A, C.B Mishra and Surabh R.Gautam,**in this project soil used is weak local soil and the additives used are terrasil and zycobond.This chemical is used in road development.

**Norazlan Khalid, Mazidah Mukri, Faizah kamarudin, Mohammad Fadzil Arshad,**in this project soil used is local soil and the material used is waste paper sludge ash (WPSA) which is obtained from paper recycling factories.The waste paper sludge ash is used in different proportion.The results obtained is that the unified compressive strength increases and the CBR value is increased by 1.5 times for unsoaked and 3.6 times for soaked.By using WPSA the problem for disposal will also be solved.

**Indirannana, Dr. CH. Sudharan,**In this project soil used is local soil and the material used is quarry dust.The results obtained after performing the experiment is that the liquid limit, plastic limit and plasticity index decreases with addition of quarry dust in different proportion.There is also an increase in maximum dry density.But, there is decrease in optimum moisture content with increase in proportion of quarry dust.

## 2.3 Conclusion

From this study it is clear that there is a considerable improvement in soil properties due to addition of lime, cement and different chemicals.

# CHAPTER3

# MATERIALS AND METHODOLOGY

## 3.1 General

In this study of Soil Stabilisation, different combinations of additives were added to the soil in different combinations. The various samples of soil thus obtained were then subjected to different laboratory tests. The materials involved in this study and the Methodologies or Laboratory Tests that were used in the study are briefly explained in this chapter.

## 3.2 Materials

The materials or additives used in this study are Cement, Lime and Potassium Hydroxide(KOH). The additives are added to the soil in combinations. The three combinations include "Cement", "Cement+Lime" and "Cement+Lime+Potassium Hydroxide". These combinations are added to the soil in 4%, 8% and 12% by the weight of the soil.

### 3.2.1 Cement

Cement is a binder, a substance used for construction that sets, hardens and adheres to other materials, binding them together. Cement is seldom used on its own, but rather to bind sand and gravel together.

Cement is a building material made by grinding limestone and clay to a fine powder, which can be mixed with water and poured to set as a solid mass or used as an ingredient in making mortar or concrete. Cement can also be used as an additive for soil stabilisation.

Ordinary Portland Cement of 53 grade was used in this study which was provided by

Ambuja Cement Ltd. Specific Gravity value of OPC 53 grade is 3.15 (IS: 12269 -1987)

#### 3.2.1.1 Ordinary Portland Cement:

This type of cement is also called normal cement since its setting is normal when mixed with water. It is general purpose cement suitable for use in general concrete construction work which requires no special consideration. It should satisfy all the requirements as described in IS269-1967 and 1975.

Ordinary Portland cement is the most widely used building material in the world with about 1.56 billion tons produced each year.

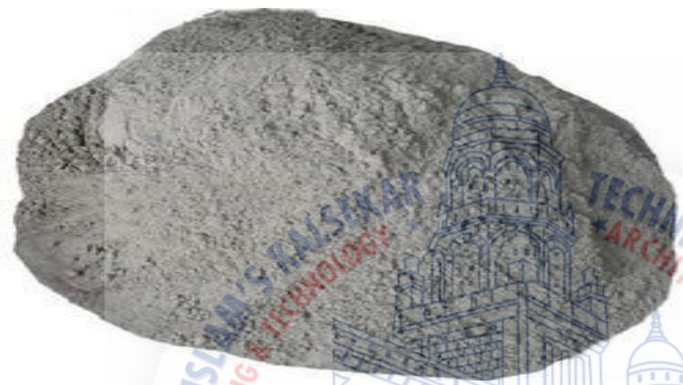


Fig.1 CEMENT

#### 3.2.1.2 Grades of OPC

**33 grade cement**

The 28 day strength is not less than 33N/mm$^2$. This grade of cement has high workability and is mainly used for mortar in masonry work and for plastering work.

**43 grade cement**

The strength of cement is not less than 43N/mm$^2$.This cement is moderately sulphate resisting and has low chloride content. It has good workability and gives smooth surface finishing.

**53 grade cement:**

The strength is not less than 53 N/mm$^2$. This cement is moderately sulphate resisting and has low chloride content.

### 3.2.2 Lime

Lime is a calcium-containing inorganic mineral in which oxides, and hydroxides predominate. In the strict sense of the term, lime is calcium oxide or calcium hydroxide. It is also the name of the natural mineral (native lime) CaO which occurs as a product of coal seam fires and in altered limestone xenoliths in volcanic eject.The word lime originates with its earliest use as building mortar and has the sense of sticking or adhering.

Lime has many complex qualities as a building product including workability which includes cohesion, adhesion, air content, water content, crystal shape, board-life, spreadability, and flowability; bond strength; comprehensive strength; setting time; sand-carrying capacity; hydrolocity; free lime content; vapor permeability; flexibility; and resistance to sulfates. These qualities are affected by many factors during each step of manufacturing and installation, including the original ingredients of the source of lime; added ingredients before and during firing including inclusion of compounds from the fuel exhaust; firing temperature and duration; method of slaking including a hot mix, dry slaking and wet slaking; ratio of the mixture with aggregates and water; the sizes and types of aggregate; contaminants in the mixing water; workmanship; and rate of drying during curing.

Lime is used in combination with "cement" and with "cement & Potassium Hydroxide" for the stabilisation of soil in this study.

Fig.2 LIME

### 3.2.2.1 Types:

Different types of limes are used for building construction. It is not generally found in the Free State. Lime is a product which is obtained by burning lime stone, a raw material, found in lime stone hills or lime stone boulders in the beds of old river, kankar found below ground level, or shells of sea animals.

**1. QUICK LIME**

It is also known as caustic lime. It is obtained by calcination (i.e. heating to redness) of comparatively pure lime stone. It is amorphous in nature, highly caustic and possesses great affinity to moisture.

**2. SLAKED LIME**

It is also known as hydrate of lime. It is obtained by slaking (i.e. chemical combination of quick lime with water) of quick lime. It is ordinary pure lime, in white powder form, available in market. It has got the tendency of absorbing carbonic acid from the atmosphere in the presence of water.

**3. FAT LIME**

It is also known as high calcium lime or pure lime or rich lime or white lime. It is popularly known as fat lime as it slakes vigorously and its volume is increased to about 2 to 2.5 times that of quick lime. This lime is used for various purposes as white washing, plastering of walls, as lime mortar with sand for pointing in masonry work, as a lime mortar with surkhi for thick masonry walls, foundations, etc.

**4. HYDRAULIC LIME**

It is also known as water lime. This lime contains clay and some amount of ferrous oxide. It sets under water and hence also known as water lime. Depending upon the percentage of clay IS has divided hydraulic lime in three classes namely:

Class A – Eminently hydraulic

Class B – Semi Hydraulic

Class C – Non-hydraulic (or Fat lime)

**CLASS A – EMINENTLY HYDRAULIC**

This lime contains about 25% clay content and sets readily under water within a day or so. This lime slakes with difficulty. The mortar and lime concrete prepared from this lime is very useful for construction under water or in damp places.

**CLASS B – SEMI HYDRAULIC**

Semi-hydraulic lime contains about 15% clay content and sets under water at a slower rate within a week or so. The mortar and concrete prepared from this lime is strong and used for superior type of masonry work.

**CLASS C – NON-HYDRAULIC (OR FAT LIME)**

This lime contains about 7.5% of clay content and is prepared from pure lime stone. This slakes vigorously within few minutes but does not set under water. This is used for white washing and colour washing.

## 3.2.3 Potassium Hydroxide:

Potassium hydroxide is an inorganic compound with the formula KOH, and is commonly called caustic potash.

Along with sodium hydroxide (NaOH), this colourless solid is a prototypical strong base. It has many industrial and niche applications, most of which exploit its corrosive nature and its reactivity toward acids. An estimated 700,000 to 800,000 tonnes were produced in 2005. About 100 times more NaOH than KOH is produced annually. KOH is noteworthy as the precursor to most soft and liquid soaps, as well as numerous potassium-containing chemicals.

Fig.3 POTASSIUM HYDROXIDE

### 3.2.3.1 Properties of Potassium Hydroxide:

Potassium hydroxide can be found in pure form by reacting sodium hydroxide with impure potassium. It is usually sold as translucent pellets, which will become tacky in air because KOH is hygroscopic. Consequently, KOH typically contains varying amounts of water (as well as carbonates - see below). Its dissolution in water is strongly exothermic. Concentrated aqueous solutions are sometimes called potassium lyes. Even at high temperatures, solid KOH does not dehydrate readily.

Potassium hydroxide solutions with concentrations around 0.5 to 2.0% are irritating when coming into contact with the skin, while concentrations higher than 2% are corrosive.

### 3.2.3.2 Structure of Potassium Hydroxide:

At higher temperatures, solid KOH crystallizes in the NaCl crystal structure. The OH group is either rapidly or randomly disordered so that the OH− group is effectively a spherical anion of radius 1.53 Å (between Cl− and F− in size). At room temperature, the OH− groups are ordered and the environment about the K+ centres is distorted, with K+ &OH− distances ranging from 2.69 to 3.15 Å, depending on the orientation of the OH group. KOH forms a series of crystalline hydrates, namely the monohydrate KOH·H2O, the dehydrate KOH·2 $H_2O$ and the tetra hydrate KOH·4.

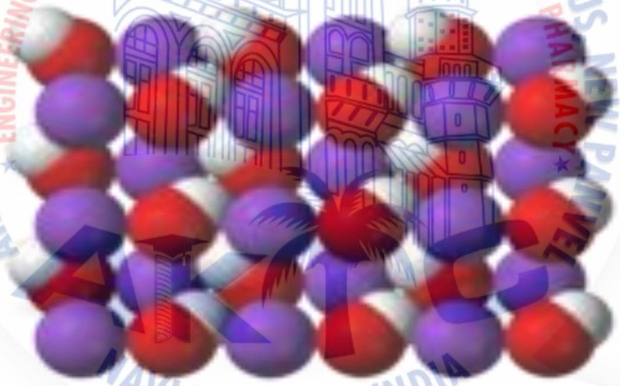


Fig.4 KOH STRUCTURE

### 3.2.3.3 Solubility in Water:

About 121 g of KOH will dissolve in 100 ml of water at room temperature compared with 100 g of NaOH in the same volume (on a molar basis, KOH is slightly less soluble than NaOH).

Because of its high affinity for water, KOH serves as a desiccant in the laboratory. It is often used to dry basic solvents, especially amines and pyridines: distillation of these basic liquids from slurry of KOH yields the anhydrous reagent.

### 3.2.3.4 Manufacture of KOH:

Historically, KOH was made by adding potassium carbonate (potash) to a strong solution of calcium hydroxide (slaked lime), leading to a metathesis reaction which caused calcium carbonate to precipitate, leaving potassium hydroxide in solution:

$Ca(OH)_2 + K_2CO_3 \rightarrow CaCO_3 + 2\ KOH$

Filtering off the precipitated calcium carbonate and boiling down the solution gives potassium hydroxide ("calcinated or caustic potash"). It was the most important method of producing potassium hydroxide until the late 19th century, when it was largely replaced by the current method of electrolysis of potassium chloride solutions.[10] The method is analogous to the manufacture of sodium hydroxide (see chloralkali process):

$2\ KCl + 2\ H_2O \rightarrow 2\ KOH + Cl_2 + H_2$

## 3.3 Methodology

Methodology involves collection of soil sample from ANJUMAN-I-ISLAM'S KALSEKAR TECHNICAL CAMPUS, study of soil properties by conducting various tests like particle size analysis, Atterberg's limits, unconfined compression test, California bearing ratio, standard proctor compaction and specific gravity by addition of Lime, Cement and KOH to the soil and comparison of test results.

### 3.3.1 Classification of Soil

The soil sample is taken from the college campus. The soil samples are used to perform tests to obtain majority of its engineering properties, such as strength, moisture content, etc. The classification of the soil is done according to IS: 2270-1975.

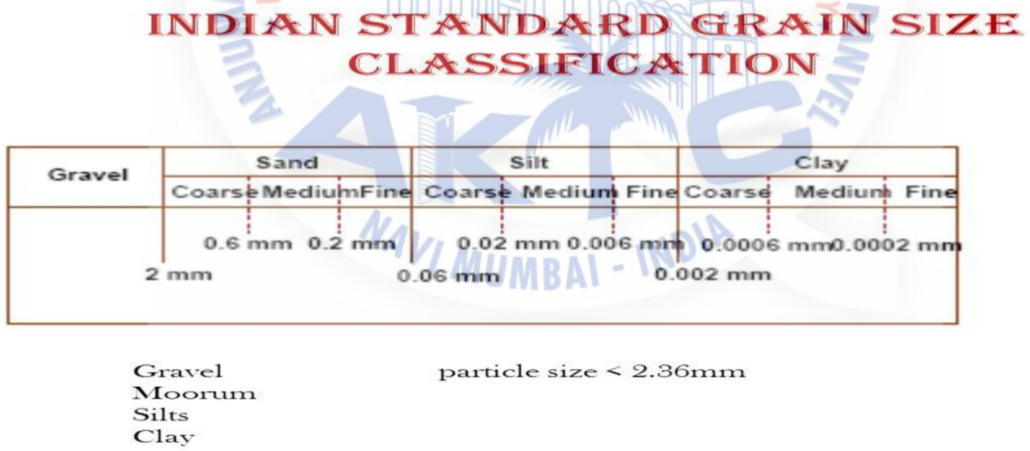



TABLE 1 INDIAN STANDARD GRAIN SIZE CLASSIFICATION

### 3.3.2 Grain size analysis

In accordance with IS 2720 (Part 4):1985.

### 3.3.2.1 Apparatus

Set of fine sieves, 2mm, 1mm, 600micron, 425, 212, 150, and 75 micron, Set of coarse sieves, 100mm, 80mm, 40mm, 10mm, and 4.75mm, Weighing balance with accuracy of 0.1% of the mass of the sample, Oven, Mechanical shaker

Fig.5 MECHANICAL SHAKER

### 3.3.2.2 Procedure

Soil passing 4.75mm I.S. Sieve and retained on 75micron I.S. Sieve contains no fines. Those soils can be directly dry sieved rather than wet sieving.

**Dry Sieving:**

1. Take 500gm of the soil sample after taking representative sample by quartering.
2. Conduct sieve analysis using a set of standard sieves as given in the data sheet.
3. The sieving may be done either by hand or by mechanical sieve shaker for 10 minutes.
4. Weigh the material retained on each sieve.
5. The percentage retained on each sieve is calculated on the basis of the total weight of the soil sample taken.
6. From these results the percentage passing through each of the sieves is calculated.
7. Draw the grain size curve for the soil in the semi-logarithmic graph provided.

**Wet Sieving:**

If the soil contains a substantial quantity (say more than 5%) of fine particles, a wet sieve

analysis is required. All lumps are broken into individual particles.
1. Take 200gm of oven dried soil sample and soaked with water.
2. If deflocculation is required, 2% calgon solution is used instead of water.
3. The sample is stirred and left for soaking period of at least 1 hour.
4. The slurry is then sieved through 4.75 mm sieve and washed with a jet of water.
5. The material retained on the sieve is the gravel fraction, which should be dried in oven and weighed.
6. The material passing through 4.75 mm sieve is sieved through 75 micron sieve.
7. The material is washed until the water filtered becomes clear.
8. The soil retained on 75 micron sieve is collected and dried in oven.
9. It is then sieved through the sieve shaker for ten minutes and retained material on each sieve is collected and weighed 10. The material that would have been retained on pan is equal to the total mass of soil minus the sum of the masses of material retained on all sieves.
11. Draw the curve for the soil in the semi-logarithmic graph in order to obtain grain size distribution curve.

### 3.3.3Determination of water content

In accordance with IS 2710 (Part 2):1973.

#### 3.3.3.1 Apparatus

Cylindrical metal mould shall be either of 100mm diameter and 1000cm3 volume or 150mm diameter and 2250cm3 volume and shall confirm to IS: 10074 – 1982. Balance of capacity 500grams and sensitivity 0.01gram.Balance of capacity 15Kg and sensitivity one gram. Thermostatically controlled oven with capacity up to 250 0C. Airtight containers. Steel straight edge about 30cm in length and having one beveled edge. 4.75mm, 19mm and 37.5mm IS sieves confirming to IS 460 (Part 1).Mixing tools such as tray or pan, spoon, trowel and spatula or suitable mechanical device for thoroughly mixing the sample of soil with additions of water. Heavy compaction rammer confirming to IS: 9189 -1979

#### 3.3.3.2 Test Procedure

Clean the container with lid, dry and weigh (W1). Take the required quantity of the soil specimen in the container crumbled and placed loosely, and weigh with lid (W2). Then keep it in an oven with the lid removed and maintain the temperature of the oven at 110 ± 5°C.Dry the specimen in the oven for 24 h. Every time the container is taken out for weighing. Replace the lid on the container and cool the container in a desiccator. Record the final mass (W3) of the container with lid with dried soil sample**. NOTE**:-Oven-drying at 110 ± 5°C does not result in reliable water content values for soil containing gypsum or other minerals having loosely bound water of hydration or for soil containing significant amounts of organic material. Reliable water content values for these soils can be obtained by drying in an oven at approximately 60 to 80°C.

### Liquid Limit & Plastic Limit Test

In accordance with IS 2720 (Part 5) – 1985.

### 3.3.4 Liquid Limit Test

#### 3.3.4.1 Apparatus

Casagrande's liquid limit device, Grooving tools of both standard and ASTM types, Oven Evaporating dish, Spatula, IS Sieve of size 425 µm, Weighing balance, with 0.01g accuracy.

Fig.6 CASAGRANDE'S LIQUID LIMIT DEVICE

#### 3.3.4.2 Test Procedure

1. Place a portion of the paste in the cup of the liquid limit device.
2. Level the mix so as to have a maximum depth of 1cm.
3. Draw the grooving tool through the sample along the symmetrical axis of the cup, holding the tool perpendicular to the cup.
4. For normal fine grained soil: The Casagrande's tool is used to cut a groove 2mm wide at the bottom, 11mm wide at the top and 8mm deep.
5. For sandy soil: The ASTM tool is used to cut a groove 2mm wide at the bottom, 13.6mm wide at the top and 10mm deep.
6. After the soil pat has been cut by a proper grooving tool, the handle is rotated at the rate of about 2 revolutions per second and the no. of blows counted, till the two parts of the soil sample come into contact for about 10mm length.
7. Take about 10g of soil near the closed groove and determine its water content
8. The soil of the cup is transferred to the dish containing the soil paste and mixed thoroughly after adding a little more water. Repeat the test.
9. By altering the water content of the soil and repeating the foregoing operations, obtain at least 5 readings in the range of 15 to 35 blows. Don't mix dry soil to change its consistency.
10. Liquid limit is determined by plotting a 'flow curve' on a semi-log graph, with no. of blows as abscissa (log scale) and the water content as ordinate and drawing the best straight line through the plotted points

### 3.3.5 Plastic Limit Test

### 3.3.5.1Apparatus

Porcelain evaporating dish about 120mm diameter,Spatula, Container to determine moisturecontent, Container to determine moisture content, Oven, Ground glass plate – 20cm x 15cm, Rod – 3mm dia. and about 10cm long.

Fig.7 PLATIC LIMIT

### 3.3.5.2 Test Procedure

1. Take about 8g of the soil and roll it with fingers on a glass plate. The rate of rollingshould be between 80 to 90 strokes per minute to form a 3mm dia.
2. If the dia. of the threads can be reduced to less than 3mm, without any cracks appearing, it means that the water content is more than its plastic limit. Knead the soil to reduce the water content and roll it into a thread again.
3. Repeat the process of alternate rolling and kneading until the thread crumbles.
4. Collect and keep the pieces of crumbled soil thread in the container used to determine the moisture content.
5. Repeat the process at least twice more with fresh samples of plastic soil each time.

### 3.3.6 Shrinkage Limit Test

In accordance with IS 2720-1972 .

### 3.3.6.1 Apparatus

Oven, Sieve 425 micron, Mercury, Desiccator, Weighing balance, with 0.01g accuracy

Fig.8 SHRINKAGE LIMIT APPARATUS

### 3.3.6.2 Test Procedure

1. 100 gm. of soil sample from a thoroughly mixed portion of the material passingthrough 425 microns IS sieve is taken.
2. About 30 gm. of above soil sample is placed in the evaporating dish and thoroughly mixed with distilled water to make a paste.
3. The weight of the clean empty shrinkage dish is determined and recorded.
4. The dish is filled in three layers by placing approximately 1/3rd of the amount of wet soil with the help of spatula.
5. Then the dish with wet soil is weighed and recorded immediately.
6. The wet soil cake is air dried until the color of the pat turns from dark to light. Then it is oven dried at a temperature of 1050 C to 1100 C for 12 to 16 hours. The weight of the dish with dry sample is determined and recorded. Then the weight of oven dry soil pat is calculated (W0).
7. The shrinkage dish is placed in the evaporating dish and the dish is filled with mercury, till it overflows slightly. Then it is be pressed with plain glass plate firmly on its top to remove excess mercury. The mercury from the shrinkage dish is poured into a measuring jar and the volume of the shrinkage dish is calculated. This volume is recorded as the volume of the wet soil pat (V).
8. A glass cup is placed in a suitable large container and the glass cup removed bycovering the cup with glass plate with prongs and pressing it. The outside of the glasscup is wiped to remove the adhering mercury. Then it is placed in the evaporating dishwhich is clean and empty.
9. Then the oven dried soil pat is placed on the surface of the mercury in the cup andpressed by means of the glass plate with prongs, the displaced mercury being collected in the evaporating dish.
10. The mercury so displaced by the dry soil pat is weighed and its volume (Vo) is calculated by dividing this weight by unit weight of mercury.

## 3.3.7 Standard Proctor Compaction Test

In accordance with IS 2720 (Part 7):1980.

### 3.3.7.1 Apparatus

Cylindrical mould& accessories [volume = 1000cm3], Rammer [2.6 kg], Balance [1gaccuracy], Sieves [19mm], Mixing tray, Trowel, Graduated cylinder [500 ml capacity], Metal container.

Fig.9 S.P.T APPARATUS

### 3.3.7.2 Test Procedure

1. 5 Kg. of soil is taken and the water is added to it to bring its moisture content to about4 % in coarse grained soils and 8% in case of fine grained soils with the help of graduated cylinder
2. The mould with base plate attached is weighed to the nearest 1 gm (M1). The extension collar is to be attached with the mould.
3. Then the moist soil in the mould is compacted in three equal layers, each layer being given 25 blows from the 2.6 Kg rammer dropped from a height of 310 mm. above the soil.
4. The extension is removed and the compacted soil is leveled off carefully to the top of the mould by means of a straight edge.
5. Then the mould and soil is weighed to the nearest 1 gm. (M2).
6. The soil is removed from the mould and a representative soil sample is obtained water content determination.
7. Steps 3 to 6 are repeated after adding suitable amount of water to the soil in an increasing order.

### 3.3.8 Unconfined Compression Test

In accordance with IS 2720 (Part10)-1991.

### 3.3.8.1 Apparatus

Unconfined compressive test, proving ring type.Proving ring , capacity 1 KN , accuracy 1 N ,Dial gauge , accuracy 0.01 mm, Weighing balance,Oven,Stop watch,Sampling tube,Split mould , 38mm diameter , 76mm long, Sample extractor ,Knife ,Verniercaliper,Large mould .

Fig.10 STANDARD PROCTOR TEST

### 3.3.8.2 Test Procedure

1. Soil which is to be tested is mixed with water. This sample is than filled in the mould which is oiled in advance. The mould is having the same internal diameter as that of specimen which is to be tested.
2. The mould is opened carefully and sample is taken out
3. Prepare two or three such samples for testing.
4. Measure the initial length and diameter of the specimen.
5. Put the specimen on bottom of the loading device. Adjust upper plate to make contact with the specimen. Set the dial gauge (compression) at zero. The dial gauge reading provides the deformation in the sample and in turn strain.
6. Compress the specimen until crakes are developed or the strain curve is well past its peak or until a vertical deformation of 20% is reached. Take the dial reading approximately at every 1 mm deformation of the specimen.
7. The proving ring reading provides the corresponding load in- turn axial stress on the sample.
8. Repeat of the specimen.
9. Determine water content of each sample.

### 3.3.9 California Bearing Ratio Test

In accordance with IS 2720 (Part 16) – 1987.

### 3.3.9.1 Apparatus

CBR mould, inside diameter = 150 mm, total height =175 mm, with detachable extension collar, 50 mm high, and detachable base plate, 10 mm thick. Spacer disc, 148 mm diameter,47.7 mm high. Rammers, light compaction, 2.6 kg, drop 310 mm, heavy compaction, 4.89 kg, drop 450 mm. Slotted masses, annular, 2.5 kg each, 147 mm diameter, with a hole of 53 mm diameter in the centre. Cutting collar, steel which can fit flush with the mould both outside and inside. Expansion measuring apparatus, consisting of a perforated plate, 148 mm diameter, with a thread screw in the centre and an adjustable contact head to be screwed over the stem, and a metal tripod. Penetration piston, 50 mm diameter, 100 mm long. Loading device, capacity 50 KN, equipped with a movable head (or base) at a uniform rate of 1.25 mm minute. Two dial gauges, accuracy 0.01 mm. IS sieve, 4.7 mm and 20 mm size.

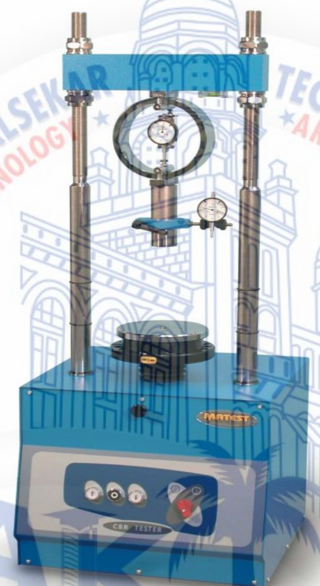


Fig.11 C.B.R APPARATUS

### 3.3.9.2 Test Procedure

## Preparation of test specimen:

**Undisturbed specimen:** Attach the cutting edge to the mould and push it gently into the ground. Remove the soil from the outside of the mould which is pushed in. When the mould is full of soil, remove it from weighing the soil with the mould or by any field method near the spot. Determine the density.

**Remoulded specimen:** Prepare the remoulded specimen at Proctors maximum dry density or any other density at which C.B.R> is required. Maintain the specimen at optimum moisture content or the field moisture as required. The material used should pass 20 mm I.S. sieve but it should be retained on 4.75 mm I.S. sieve. Prepare the specimen either by dynamic compaction or by static compaction.

**Dynamic Compaction:**

1. Take about 4.5 to 5.5 kg of soil and mix thoroughly with the required water.
2. Fix the extension collar and the base plate to the mould. Insert the spacer disc over the base. Place the filter paper on the top of the spacer disc.
3. Compact the mix soil in the mould using either light compaction or heavy compaction. For light compaction, compact the soil in 3 equal layers, each layer being given 55 blows by the 2.6 kg rammer. For heavy compaction compact the soil in 5 layers, 56 blows to each layer by the 4.89 kg rammer.
4. Remove the collar and trim off soil.
5. Turn the mould upside down and remove the base plate and the displacer disc.
6. Weigh the mould with compacted soil and determine the bulk density and dry density.
7. Put filter paper on the top of the compacted soil (collar side) and clamp the perforated base plate on to it.

For soaked test, the filter paper is now placed on the base plate and the mould is turned upside down, so that the top of the sample now placed in water tank for soaking. A filter paper is placed over the sample top along with the perforated plate with the adjustable stem. Over this surcharge weight of 2.5 kg is placed. Soaking is done for 4 days (or for a shorter period if by then soil is thoroughly saturated, showing no further expansion). The initial and final readings of the dial gauge are taken to measure the expansion. The sample is allowed to drain off water in a vertical position for 15 min. The sample along with the mould is again weighed to calculate the % of water absorbed.

**Procedure for Penetration Test**

1. Place the mould assembly with the surcharge weights on the penetration test machine.
2. Seat the penetration piston at the center of the specimen with the smallest possible load, but in no case in excess of 4 kg so that full contact of the piston on the sample is established.
3. Set the stress and strain dial gauge to read zero. Apply the load on the piston so that the penetration rate is about 1.25 mm/min.
4. Record the load readings at penetrations of 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 4.0, 5.0, 7.5, 10 and 12.5 mm. Note the maximum load and corresponding penetration if it occurs for a penetration less than 12.5 mm.
5. Detach the mould from the loading equipment. Take about 20 to 50 g of soil from the top 3 cm layer and determine the moisture content.

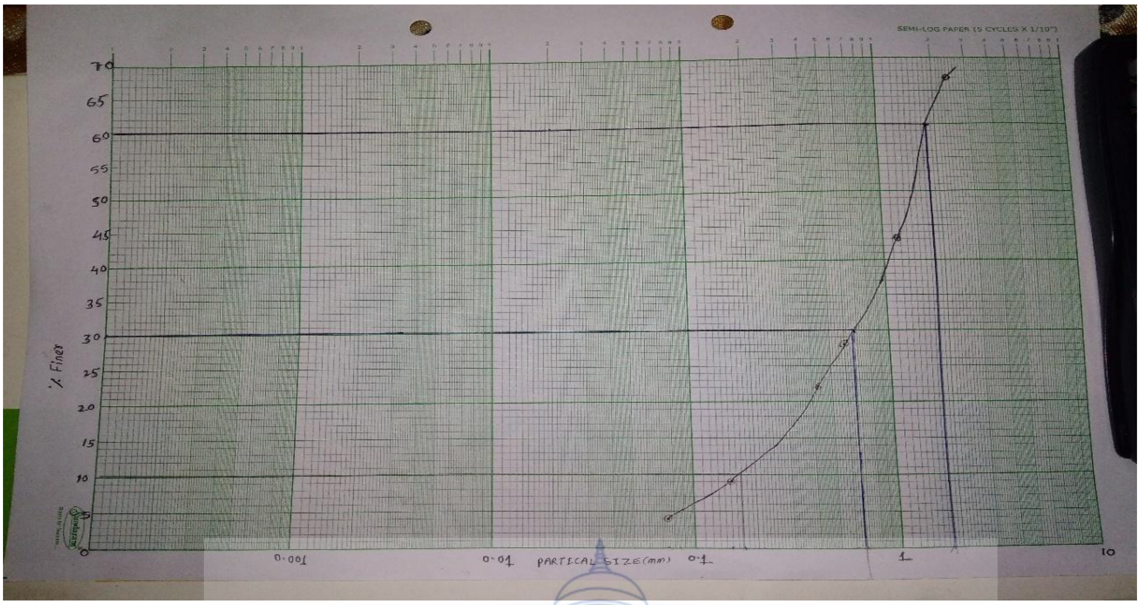
# CHAPTER 4

# ANALYSIS OF SOIL PARAMETERS

## 4.1 SIEVE ANALYSIS

TABLE 2 SIEVE ANALYSIS

| Sieve no | Mass of soil retained | Percentage of mass of soil retained | Cumulative percentage retained | Percent finer |
|---|---|---|---|---|
| 2.36 | 166 | 23 | 33 | 67 |
| 1.18 | 120 | 24 | 57 | 43 |
| 600 | 75 | 15 | 72 | 28 |
| 425 | 30 | 6 | 78 | 22 |
| 150 | 65 | 13 | 91 | 9 |
| 75 | 25 | 5 | 96 | 4 |
| PAN | 20 | 4 | 100 | 0 |
| | 500 | | | |




FROM CALCULATION GRAPH 1 SIEVE ANALYSIS

$C_U$=10.59; CC =1.55

AS PER INDIAN STANDARD

$C_U$ is greater than 6

$C_C$ is between1 to 3

Therefore, our soil is WELL GRADED SAND.

## 4.2 LIQUID LIMIT CALCULATION

TABLE 3 LIQUID LIMIT (CAMPUS SOIL)

| Sample Number | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Number of blows | 16 | 30 | 22 | 18 | - |
| Wt. of container | 15 | 15 | 15 | 15 | - |
| Wt. of container + wet soil | 20 | 25 | 20 | 25 | - |
| Wt. of container + dry soil | 18.6 | 20.5 | 18.1 | 22.9 | - |
| Wt. of water | 1.4 | 5.5 | 1.9 | 2.1 | - |
| Wt. of oven dry soil | 3.6 | 5.5 | 3.1 | 7.9 | - |
| Water content | 38.89 | 81.82 | 61.29 | 26.58 | - |

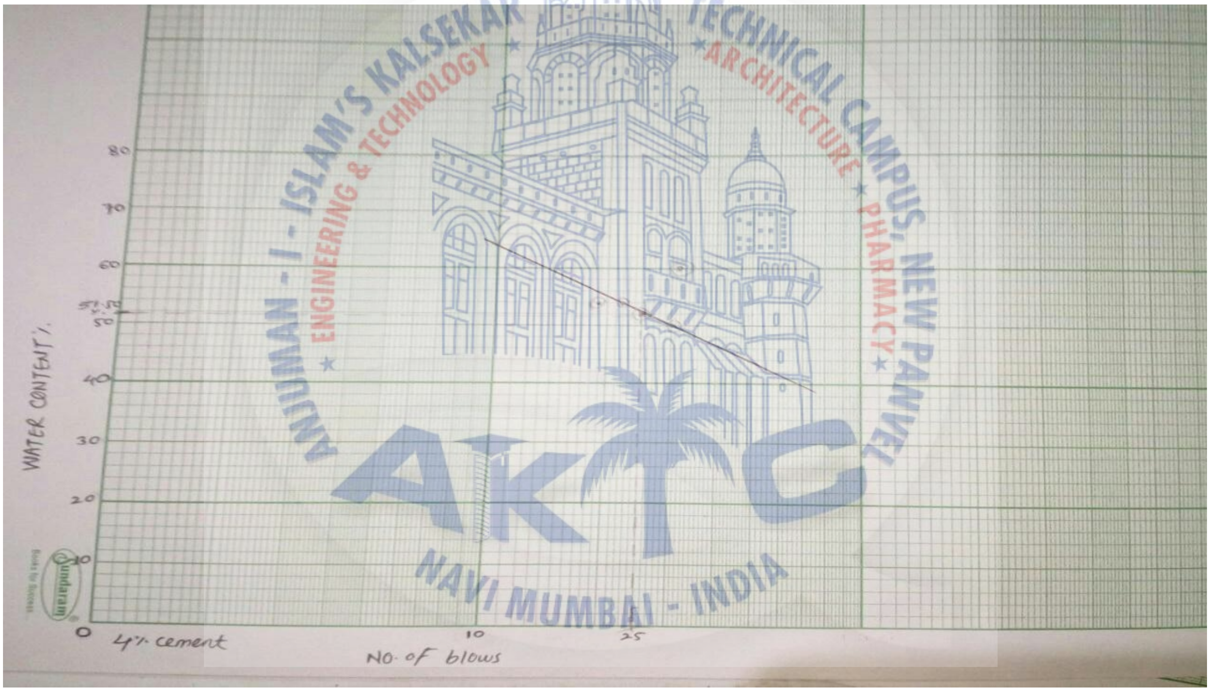

GRAPH 2 LIQUID LIMIT (CAMPUS SOIL)

Liquid limit is 67%

# AT 4% CEMENT

TABLE 4 LIQUID LIMIT (4% CEMENT)

| SampleNumber | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Number of blows | 19 | 26 | 32 | 30 | 22 |
| Wt. of container | 15 | 13.5 | 14.5 | 13.5 | 57.5 |
| Wt. of container + wet soil | 32 | 30.5 | 18.5 | 25.5 | 67.5 |
| Wt. of container + dry soil | 26 | 24.5 | 17 | 21.5 | 64 |
| Wt. of water | 6 | 6 | 1.5 | 4 | 3.5 |
| Wt. of oven dry soil | 11 | 11 | 2.5 | 8 | 6.5 |
| Water content | 54.54 | 52 | 60 | 50 | 53.80 |



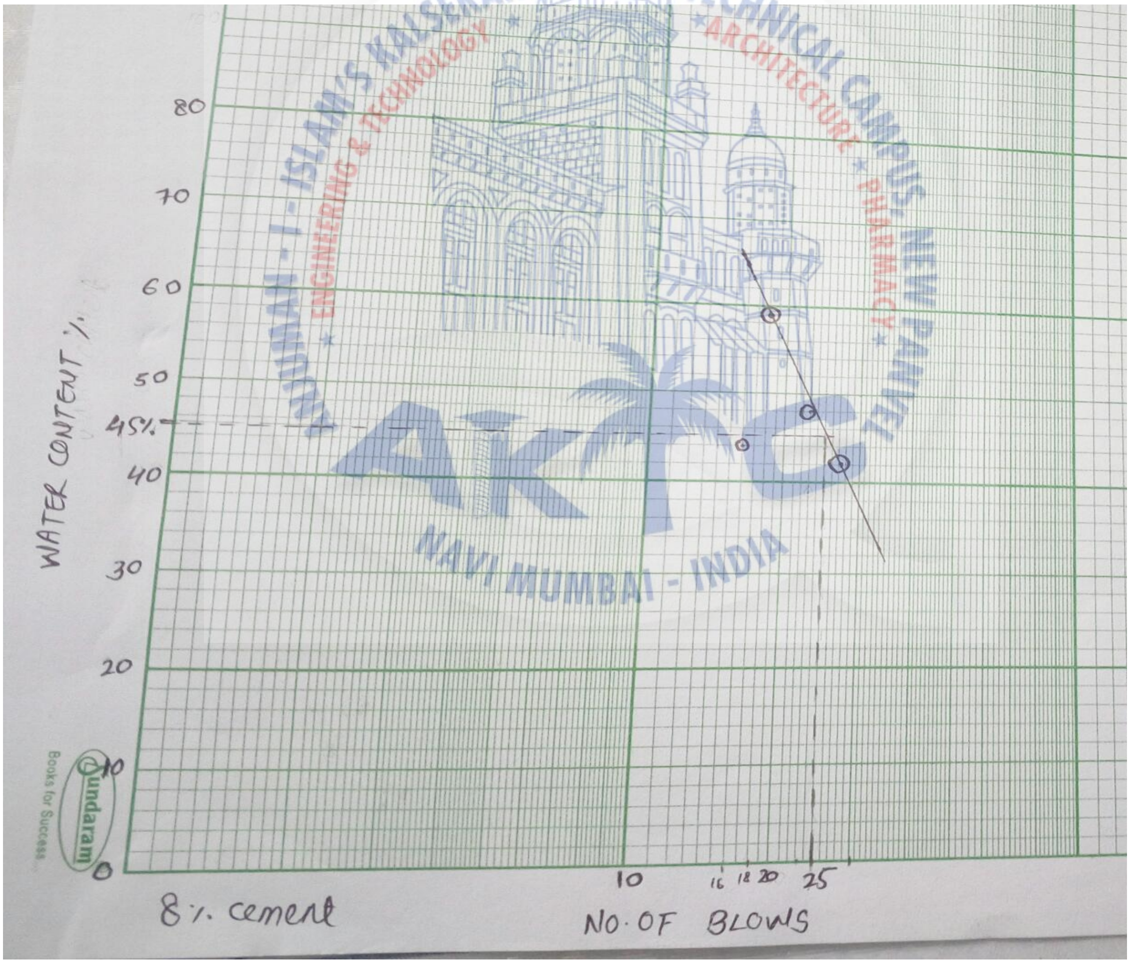

GRAPH 3 LIQUID LIMIT (4% CEMENT)

Liquid limit is 51.50%

AT 8%CEMENT

TABLE 5 LIQUID LIMIT (8% CEMENT)

| Sample Number | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Number of blows | 16 | 23 | 18 | 27 |
| Wt. of container | 8.5 | 14.7 | 13.5 | 13.5 |
| Wt. of container + wet soil | 21.5 | 27 | 23 | 23.3 |
| Wt. of container + dry soil | 17.5 | 23 | 19.5 | 20.5 |
| Wt. of water | 4 | 4 | 3.5 | 2.8 |
| Wt. of oven dry soil | 9 | 8.3 | 6 | 7 |
| Water content | 44.44 | 48 | 58.33 | 42 |



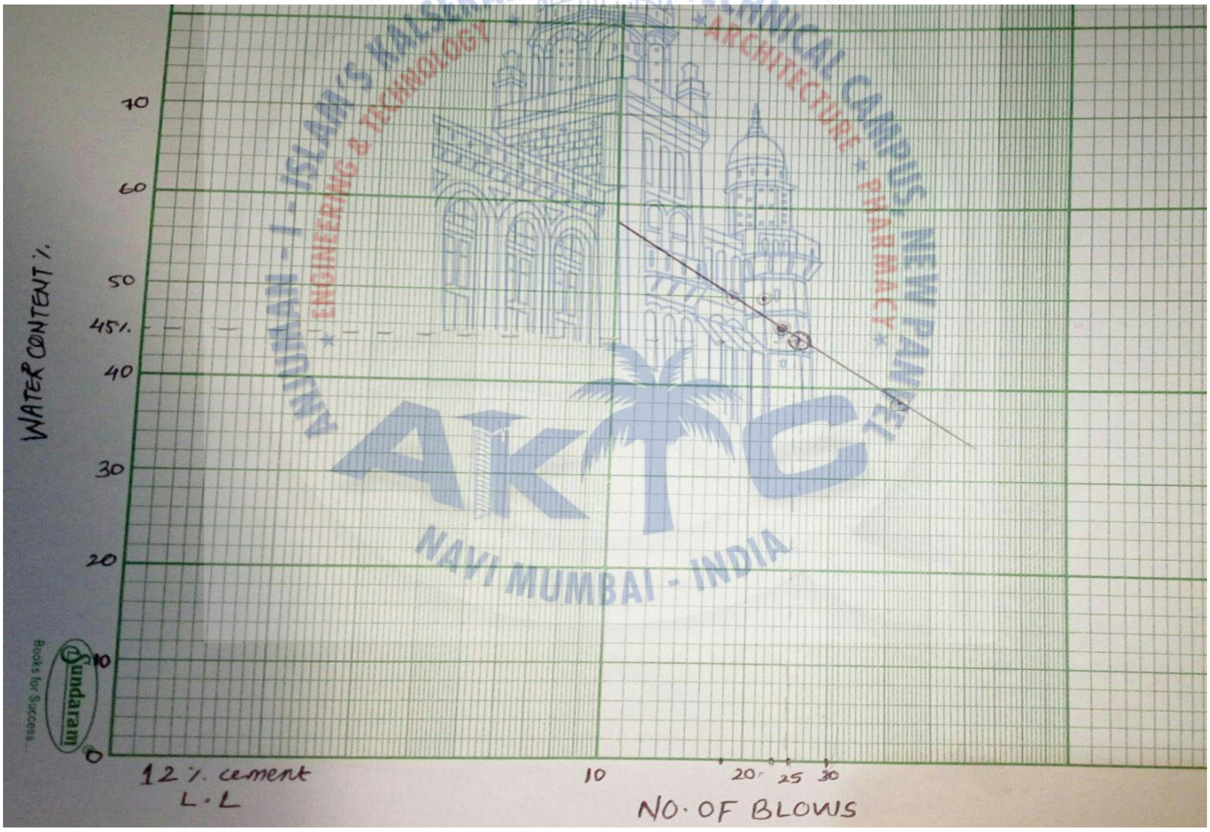

GRAPH 4 LIQUID LIMIT (8% CEMENT)

Liquid limit is 45%

# AT 12% CEMENT

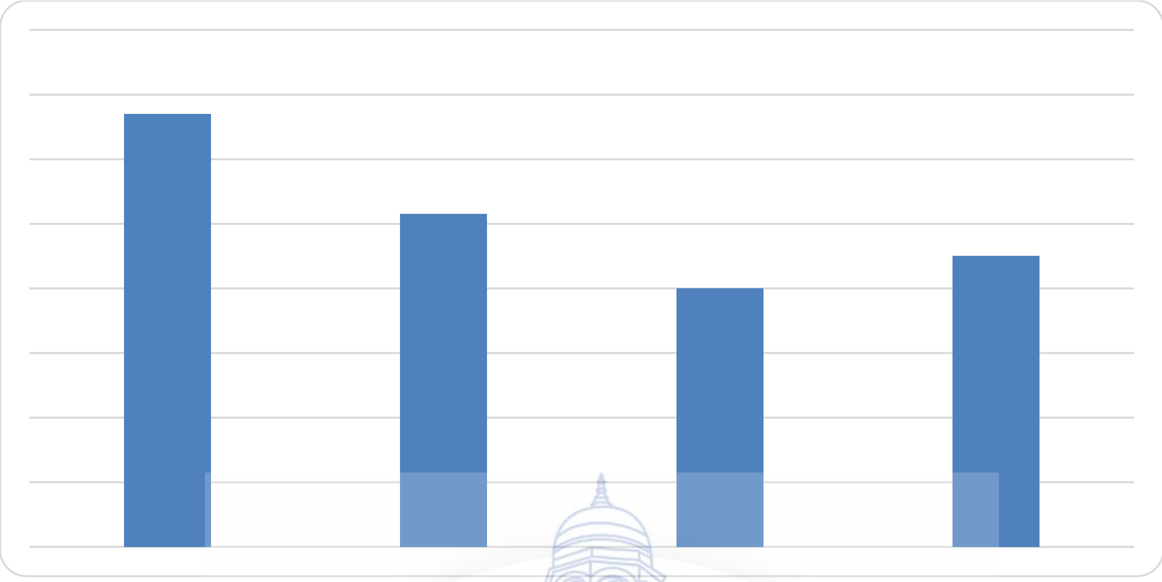
TABLE 6 LIQUID LIMIT (12% CEMENT)

| Sample Number | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Wt. of container | 23 | 21 | 18 | 17 | 34 |
| Number of blows | 13.5 | 8 | 13 | 14 | 12.5 |
| Wt. of container + wet soil | 32.5 | 26 | 22 | 28.5 | 21.5 |
| Wt. of container + dry soil | 26.5 | 16 | 19 | 25 | 19 |
| Wt. of water | 6 | 4 | 3 | 4.5 | 2.6 |
| Wt. of oven dry soil | 13 | 8 | 6 | 11 | 6.5 |
| Water content | 46.15 | 50 | 50 | 45 | 38.40 |




GRAPH 5 LIQUID LIMIT (12% CEMENT)

Liquid limit is 45%



GRAPH 6 COMPARISION BETWEEN LIQUID LIMIT OF CAMPUS SOIL AND 4%, 8% AND 12%CEMENT

## 4.3 PLASTIC LIMIT CALCULATION

CAMPUS SOIL

TABLE 7 PLASTIC LIMIT (CAMPUS SOIL)

| Sample Number | 1 | 2 |
|---|---|---|
| Wt. of container | 10 | 12 |
| Wt. of container + wet soil | 14.2 | 14 |
| Wt. of container + dry soil | 13.0 | 13.5 |
| Wt. of water | 1.2 | 0.5 |
| Wt. of oven dry soil | 3 | 1.5 |
| Water content | 40 | 33.33 |

Average plastic limit is 36.66%

AT 4% CEMENT

TABLE 8 PLASTIC LIMIT (4% CEMENT)

| Sample Number | 1 | 2 |
|---|---|---|
| Wt. of container | 10 | 13.5 |
| Wt. of container + wet soil | 13 | 17 |
| Wt. of container + dry soil | 12 | 16 |
| Wt. of water | 1 | 1 |
| Wt. of oven dry soil | 2 | 2.5 |
| Water content | 50 | 40 |

Average plastic limit is 45%

AT 8% CEMENT

TABLE 9 PLASTIC LIMIT (8% CEMENT)

| Sample Number | 1 | 2 |
|---|---|---|
| Wt. of container | 15.5 | 15 |
| Wt. of container + wet soil | 19 | 18.5 |
| Wt. of container + dry soil | 18 | 17.5 |
| Wt. of water | 1 | 1 |
| Wt. of oven dry soil | 2.5 | 2.5 |
| Water content | 40 | 40 |

Average plastic limit is 40%

AT 12% CEMENT

TABLE 10 PLASTIC LIMIT (12% CEMENT)

| Sample Number | 1 | 2 |
|---|---|---|
| Wt. of container | 15.5 | 15 |
| Wt. of container + wet soil | 22.5 | 20.5 |
| Wt. of container + dry soil | 21 | 19 |
| Wt. of water | 13 | 15 |
| Wt. of oven dry soil | 5.5 | 4 |
| Water content | 27.27 | 37.5 |

Average plastic limit is 32.385%

For Campus Soil

Liquid Limit = 67%

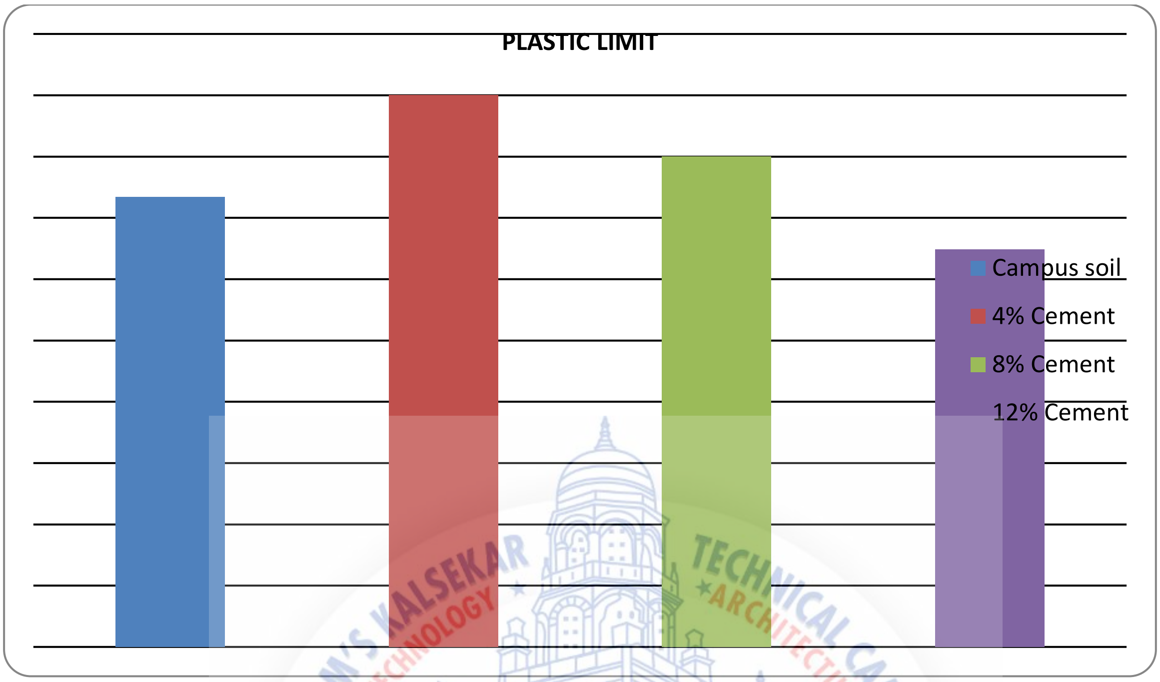
Plastic Limit = 36%

Plasticity Index = 31%

As per IS classification Chart our Soil is MH or OH.

MH (Inorganic silt of high compressibility)

OH (Organic clay of medium to high plasticity)




GRAPH 7 COMPARISON BETWEEN PLASTIC LIMIT OF CAMPUS SOIL, 4%, 8% AND 12% OF CEMENT

## 4.4SPECIFIC GRAVITY CALCULATION

CAMPUS SOIL

TABLE 11 SPECIFIC GRAVITY (CAMPUS SOIL)

| Sr.no. | 1 | 2 |
|---|---|---|
| Empty wt. of pycnometer (Wp) | 0.6150 | 0.6150 |
| Wt. of pycnometer + Dry soil (Wps) | 1.0140 | 1.0160 |
| Wt. of pycnometer + Soil + Water (WB) | 1.7345 | 1.7370 |
| Wt. of pycnometer + Water (WA) | 1.4980 | 1.4980 |
| SPECIFIC GRAVITY (GS) | 2.45 | 2.44 |

Average specific gravity of NORMAL SOIL is 2.45

AT 4% CEMENT

TABLE 12 SPECIFIC GRAVITY (4% CEMENT)

| Sr.no | 1 | 2 |
|---|---|---|
| Empty wt. of pycnometer (Wp) | 0.6120 | 0.6120 |
| Wt. of pycnometer + Dry soil (Wps) | 0.8115 | 0.8140 |
| Wt. of pycnometer + Soil + Water (WB) | 1.5970 | 1.6030 |
| Wt. of pycnometer + Water (WA) | 1.4810 | 1.4810 |
| SPECIFIC GRAVITY (GS) | 2.39 | 2.52 |

Average specific gravity of 4%CEMENT + CAMPUS SOIL is 2.45

AT 8% CEMENT

TABLE 13 SPECIFIC GRAVITY (8% CEMENT)

| Sr.no | 1 | 2 |
|---|---|---|
| Empty wt. of pycnometer (Wp) | 0.6120 | 0.6120 |
| Wt. of pycnometer + Dry soil (Wps) | 0.8140 | 0.8165 |
| Wt. of pycnometer + Soil + Water (WB) | 1.6140 | 1.6120 |
| Wt. of pycnometer + Water (WA) | 1.4810 | 1.4810 |
| SPECIFIC GRAVITY (GS) | 2.92 | 2.85 |

Average specific gravity of 8%CEMENT + CAMPUSSOIL is 2.88

AT 12%CEMENT

TABLE 14 SPECIFIC GRAVITY (12% CEMENT)

| Sr.no | 1 | 2 |
|---|---|---|
| Empty wt. of pycnometer (Wp) | 0.6150 | 0.6150 |
| Wt. of pycnometer + Dry soil (Wps) | 0.8135 | 0.8145 |
| Wt. of pycnometer + Soil + Water (WB) | 1.6155 | 1.6175 |
| Wt. of pycnometer + Water (WA) | 1.4980 | 1.4980 |
| SPECIFIC GRAVITY (GS) | 2.45 | 2.49 |

Average specific gravity of 12%CEMENT+CAMPUSSOIL is 2.47.

AT 4%(CEMENT+LIME)

TABLE 15 SPECIFIC GRAVITY 4% (CEMENT + LIME)

| Sr.no | 1 | 2 |
|---|---|---|
| Empty wt. of pycnometer (Wp) | 0.6135 | 0.6135 |
| Wt. of pycnometer + Dry soil (Wps) | 0.8140 | 0.8145 |
| Wt. of pycnometer + Soil + Water (WB) | 1.6020 | 1.6155 |
| Wt. of pycnometer + Water (WA) | 1.4965 | 1.4965 |
| SPECIFIC GRAVITY (GS) | 2.11 | 2.45 |

Average specific gravity of 4% (CEMENT + LIME) is 2.28.

AT 8% (CEMENT+LIME)

TABLE 16 SPECIFIC GRAVITY 8% (CEMENT + LIME)

| Sr.no | 1 | 2 |
|---|---|---|
| Empty wt. of pycnometer (Wp) | 0.6140 | 0.6140 |
| Wt. of pycnometer + Dry soil (Wps) | 0.8150 | 0.8140 |
| Wt. of pycnometer + Soil + Water (WB) | 1.6120 | 1.6170 |
| Wt. of pycnometer + Water (WA) | 1.4895 | 1.4895 |
| SPECIFIC GRAVITY (GS) | 2.56 | 2.76 |

Average specific gravity of 8% (CEMENT+LIME) is 2.66.

AT 12% (CEMENT+LIME)

TABLE 17 SPECIFIC GRAVITY 12% (CEMENT + LIME)

| Sr.no | 1 | 2 |
|---|---|---|
| Empty wt. of pycnometer (Wp) | 0.6140 | 0.6135 |
| Wt. of pycnometer + Dry soil (Wps) | 0.8175 | 0.8115 |
| Wt. of pycnometer + Soil + Water (WB) | 1.6130 | 1.6090 |
| Wt. of pycnometer + Water (WA) | 1.4895 | 1.4965 |
| SPECIFIC GRAVITY (GS) | 2.54 | 2.32 |

Average specific gravity of 12% (CEMENT+LIME) is 2.43.

AT 4% (CEMENT+LIME+KOH)

TABLE 18 SPECIFIC GRAVITY 4% (CEMENT + LIME + KOH)

| Sr.no | 1 | 2 |
|---|---|---|
| Empty wt. of pycnometer (Wp) | 0.6140 | 0.6140 |
| Wt. of pycnometer + Dry soil (Wps) | 0.7950 | 0.7850 |
| Wt. of pycnometer + Soil + Water (WB) | 1.6020 | 16005 |
| Wt. of pycnometer + Water (WA) | 1.4970 | 1.4970 |
| SPECIFIC GRAVITY (GS) | 2.38 | 2.53 |

Average specific gravity of 4% (CEMENT + LIME + KOH) is 2.46.

AT 8% (CEMENT+LIME+KOH)

TABLE 19 SPECIFIC GRAVITY 8% (CEMENT + LIME + KOH)

| Sr.no | 1 | 2 |
|---|---|---|
| Empty wt. of pycnometer (Wp) | 0.6130 | 0.6130 |
| Wt. of pycnometer + Dry soil (Wps) | 0.7890 | 0.7875 |
| Wt. of pycnometer + Soil + Water (WB) | 1.6120 | 1.6050 |
| Wt. of pycnometer + Water (WA) | 1.4900 | 1.4900 |
| SPECIFIC GRAVITY (GS) | 3.26 | 2.95 |

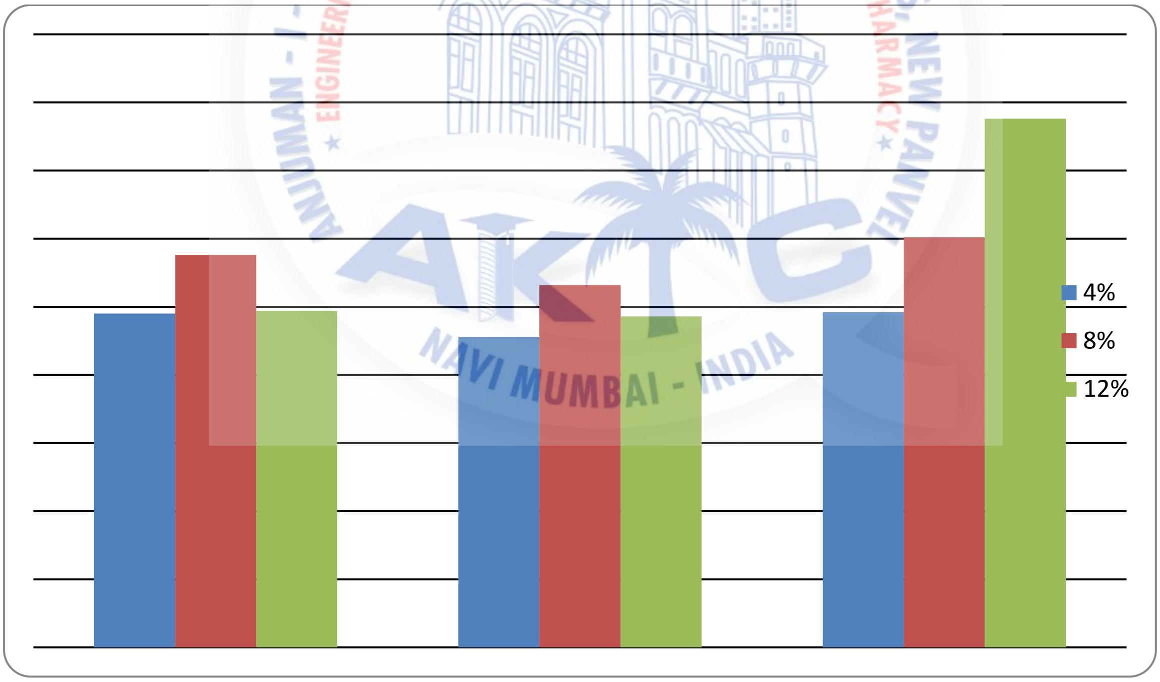
Average specific gravity of 8% (CEMENT + LIME + KOH) is 3.01.

AT 12% (CEMENT+LIME+KOH)

TABLE 20 SPECIFIC GRAVITY 12% (CEMENT + LIME + KOH)

| Sr.no | 1 | 2 |
|---|---|---|
| Empty wt. of pycnometer (Wp) | 0.6130 | 0.6130 |
| Wt. of pycnometer + Dry soil (Wps) | 0.7795 | 0.7810 |
| Wt. of pycnometer + Soil + Water (WB) | 1.6125 | 1.6195 |
| Wt. of pycnometer + Water (WA) | 1.4920 | 1.4920 |
| SPECIFIC GRAVITY (GS) | 3.62 | 4.15 |

Average specific gravity of 12% (CEMENT+LIME+KOH) is 3.88.



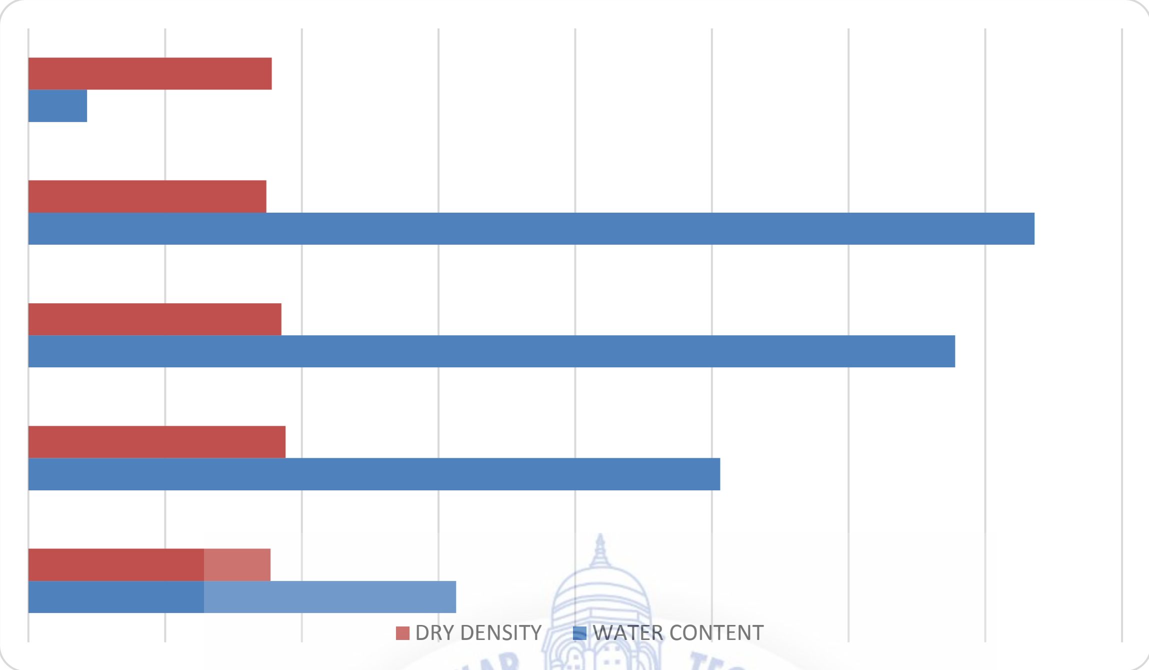

GRAPH 8 COMPARISON BETWEEN SPECIFIC GRAVITY OF 4% CEMENT,8% (CEMENT+ LIME) AND 12% (CEMENT + LIME +KOH)

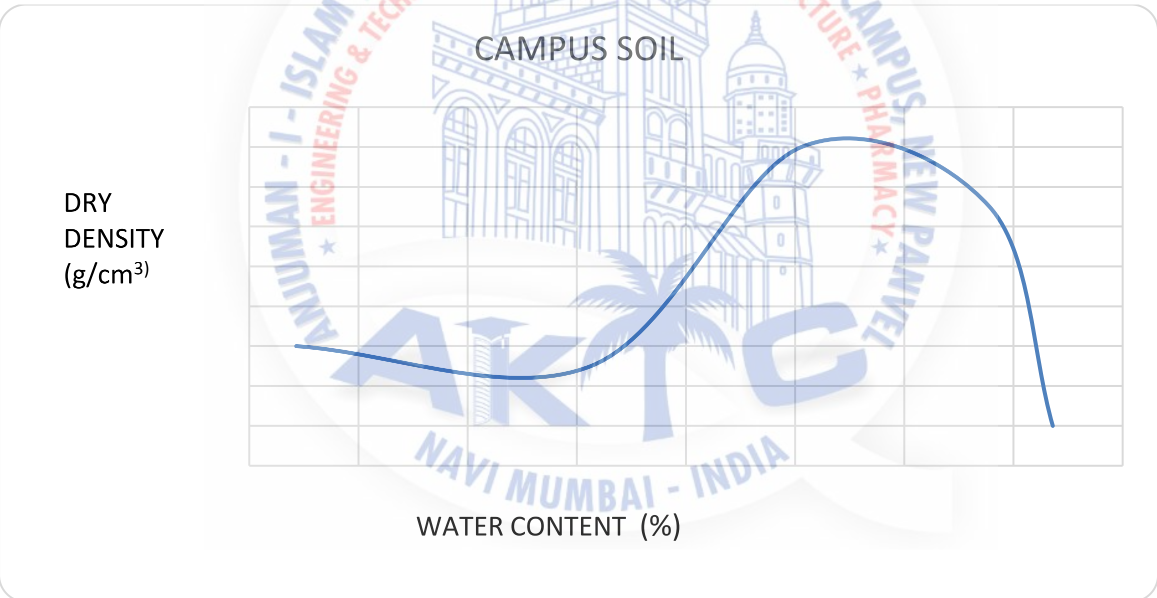
# 4.5 STANDARD PROCTOR TEST CALCULATION

CAMPUS SOIL

TABLE 21 S.P.T (CAMPUS SOIL)

| Sample Number | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Vol. of mould (V) $cm^3$ | 1000 | 1000 | 1000 | 1000 | 1000 |
| Wt of mould (W1) g | 5635.0 | 5635.0 | 5635.0 | 5635.0 | 5635.0 |
| Wt. of mould + compacted soil (W2) g | 7460.0 | 7615.0 | 7610.0 | 7500.0 | 7425.0 |
| Empty wt of container (w1) g | 10 | 15 | 15 | 15 | 15 |
| Wt of container + wet soil (w2) g | 41 | 63.5 | 50 | 61 | 52.79 |
| Wt of container + dry soil (w3) g | 17.5 | 23 | 19.5 | 20.5 | 41.5 |
| Wt of moisture (w2-w3) g | 23.5 | 40.5 | 30.5 | 40.5 | 11.29 |
| wt of dry soil (w3-w1) g | 7.5 | 8 | 4.5 | 5.5 | 26.5 |
| Water content(w) % | 3.13 | 5.06 | 6.78 | 7.36 | 0.43 |
| Wt of compacted soil (W) g | 1825 | 1980 | 1975 | 1865 | 1790 |
| Bulk density($g/cm^3$) | 1.825 | 1.980 | 1.975 | 1.865 | 1.790 |
| Dry density($g/cm^3$) | 1.77 | 1.88 | 1.85 | 1.74 | 1.78 |



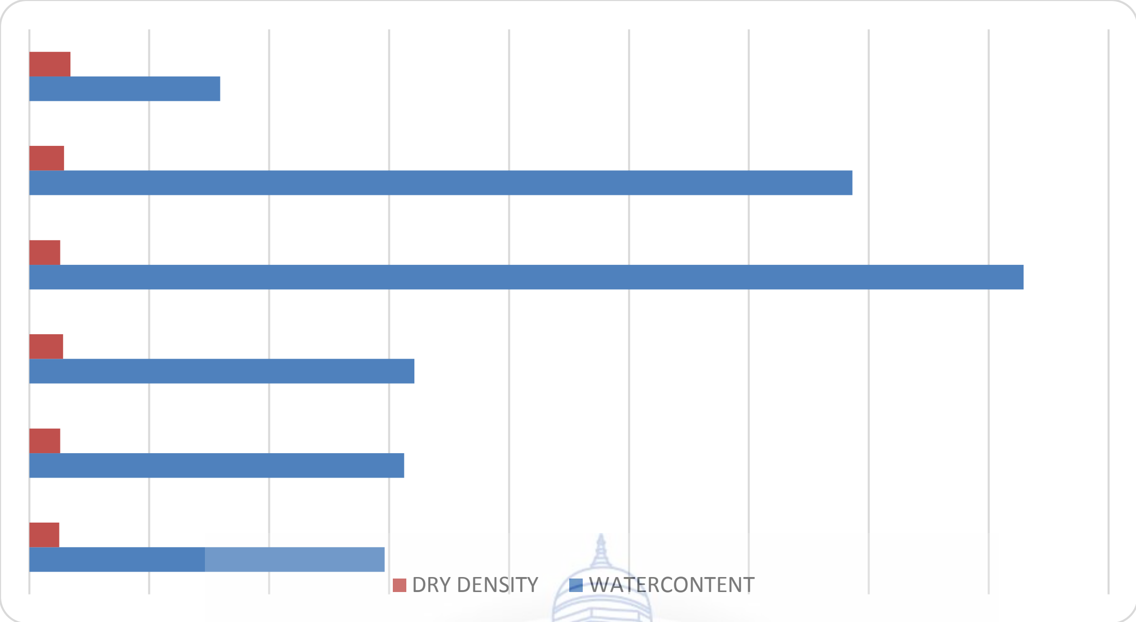



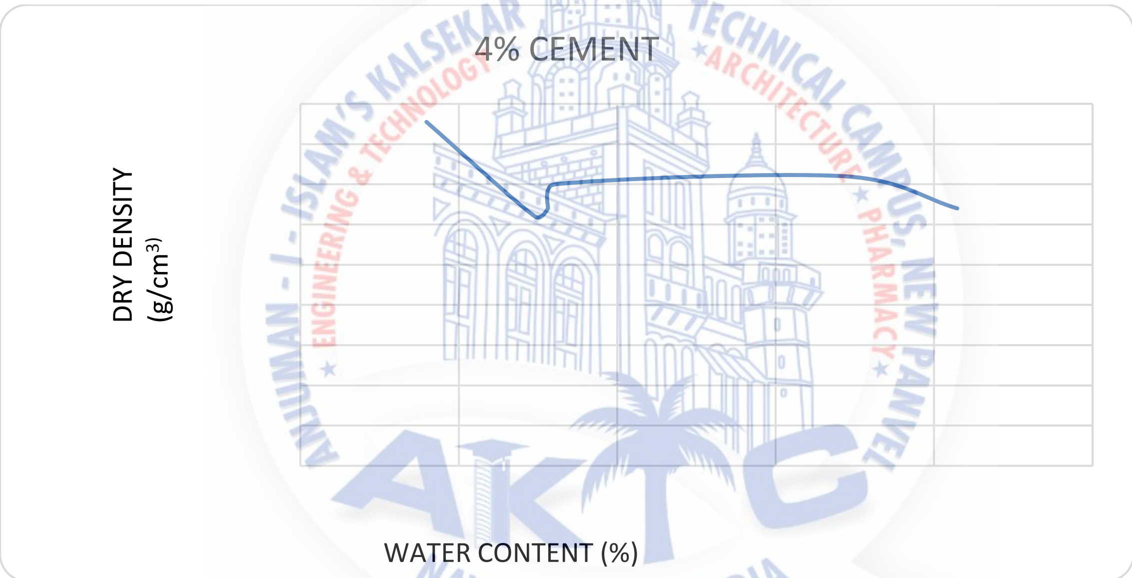

GRAPH 9 S.P.T (CAMPUS SOIL)

AT 4%CEMENT

TABLE 22 S.P.T (4% CEMENT)

| Sample Number | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Vol. of mould (V) | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 |
| Wt of mould (W1) | 5633.5 | 5588.5 | 5633.5 | 5588.5 | 5588.5 | 5588.5 |
| Wt. of mould + compacted soil (W2) | 7065 | 711.5 | 7255 | 7445 | 7570 | 7485 |
| Empty wt of container (w1) | 15 | 15 | 15 | 15 | 15 | 15 |
| Wt of container + wet soil (w2) | 30.5 | 52 | 57 | 44 | 60 | 76 |
| Wt of container + dry soil (w3) | 28.5 | 47 | 51.5 | 35.5 | 48.5 | 71.5 |
| Wt of moisture (w2-w3) | 2 | 5 | 5.5 | 8.5 | 11.5 | 4.5 |
| wt of dry soil (w3-w1) | 13.5 | 32 | 36.5 | 20.5 | 33.5 | 56.5 |
| Water content(w) % | 14.81 | 15.625 | 16.06 | 41.46 | 34.32 | 7.96 |
| Wt of compacted soil (W) | 1430 | 1480 | 1620 | 1810 | 1935 | 1850 |
| Bulk density ($g/cm^3$) | 1.43 | 1.48 | 1.62 | 1.81 | 1.935 | 1.85 |
| Dry density ($g/cm^3$) | 1.24 | 1.28 | 1.40 | 1.28 | 1.44 | 1.71 |



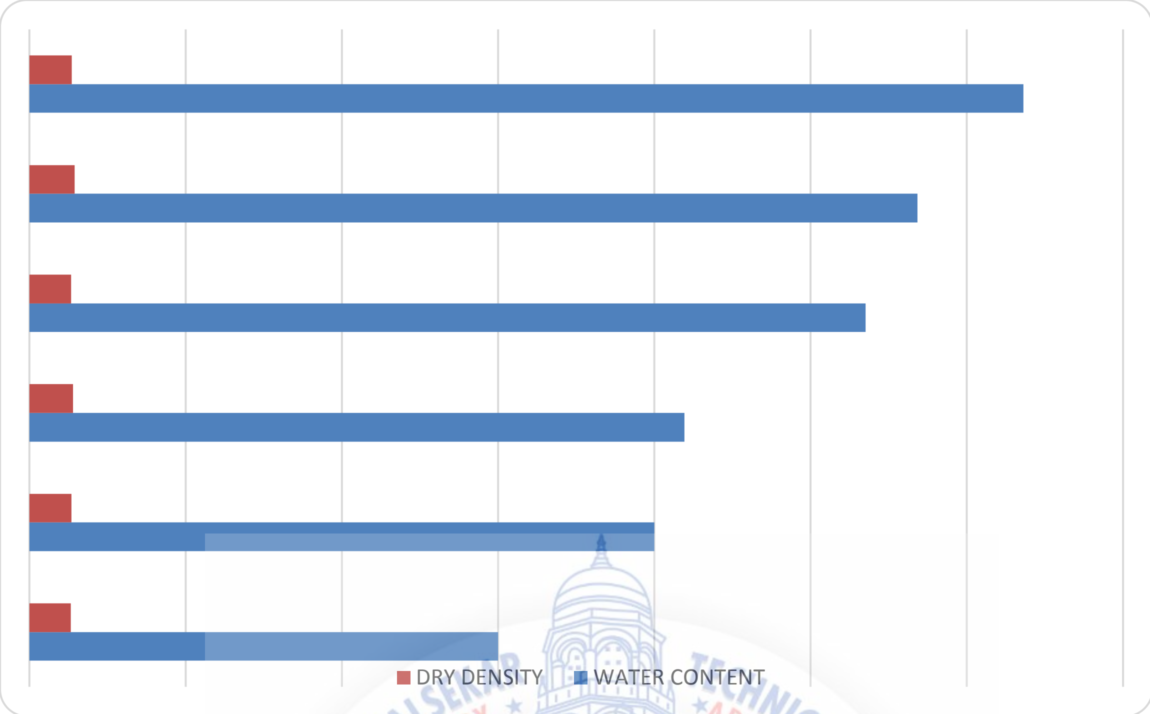



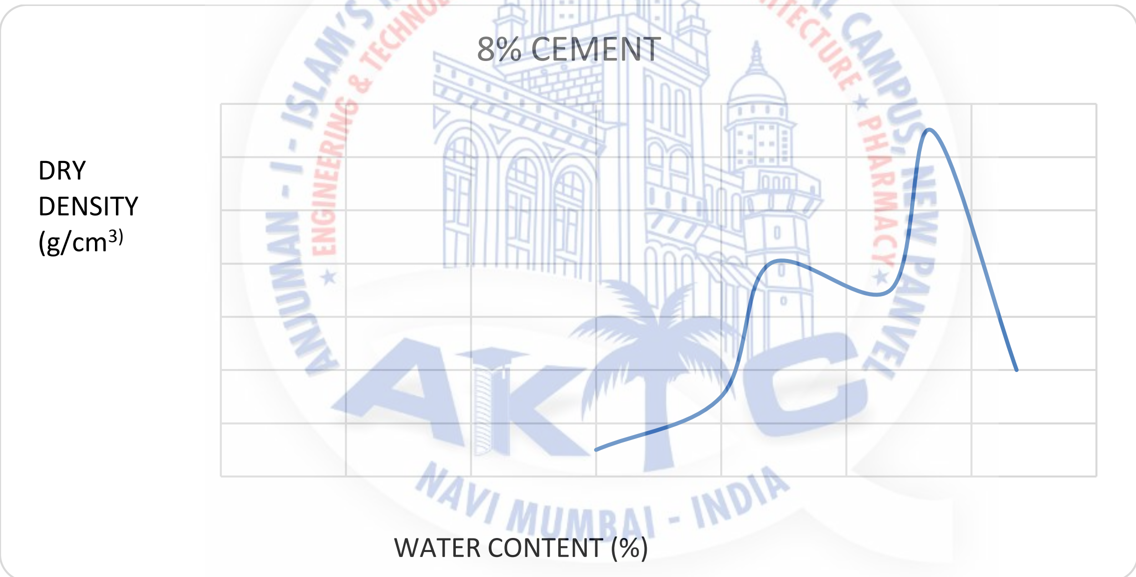

GRAPH 10 S.P.T (4% CEMENT)

AT 8% CEMENT

TABLE 23 S.P.T (8% CEMENT)

| SampleNumber | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Vol. of mould (V) | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 |
| Wt of mould (W1) | 5633.5 | 5588.5 | 5633.5 | 5588.5 | 5588.5 | 5589.5 |
| Wt. of mould + compacted soil (W2) | 7165.0 | 7215.0 | 7335.0 | 7358.0 | 7456.0 | 7398.0 |
| Empty wt of container (w1) | 0.0095 | 0.0150 | 0.0150 | 0.0150 | 0.0150 | 0.0150 |
| Wt of container + wet soil (w2) | 0.0325 | 0.0570 | 0.0525 | 0.0600 | 0.0760 | 0.0440 |
| Wt of container + dry soil (w3) | 0.0295 | 0.0500 | 0.0460 | 0.0505 | 0.0625 | 0.0370 |
| Wt of moisture (w2-w3) | 0.003 | 0.007 | 0.0065 | 0.0095 | 0.0135 | 0.0070 |
| wt of dry soil (w3-w1) | 0.02 | 0.035 | 0.031 | 0.0355 | 0.047 | 0.022 |
| Water content(w) % | 15 | 20 | 20.96 | 26.76 | 28.42 | 31.81 |
| Wt of compacted soil (W) | 1531.5 | 1626.5 | 1701.5 | 1769.5 | 1867.5 | 1808.5 |
| Bulk density (g/cm$^3$) | 1.53 | 1.62 | 1.70 | 1.76 | 1.86 | 1.8 |
| Dry density (g/cm$^3$) | 1.33 | 1.35 | 1.40 | 1.388 | 1.448 | 1.36 |



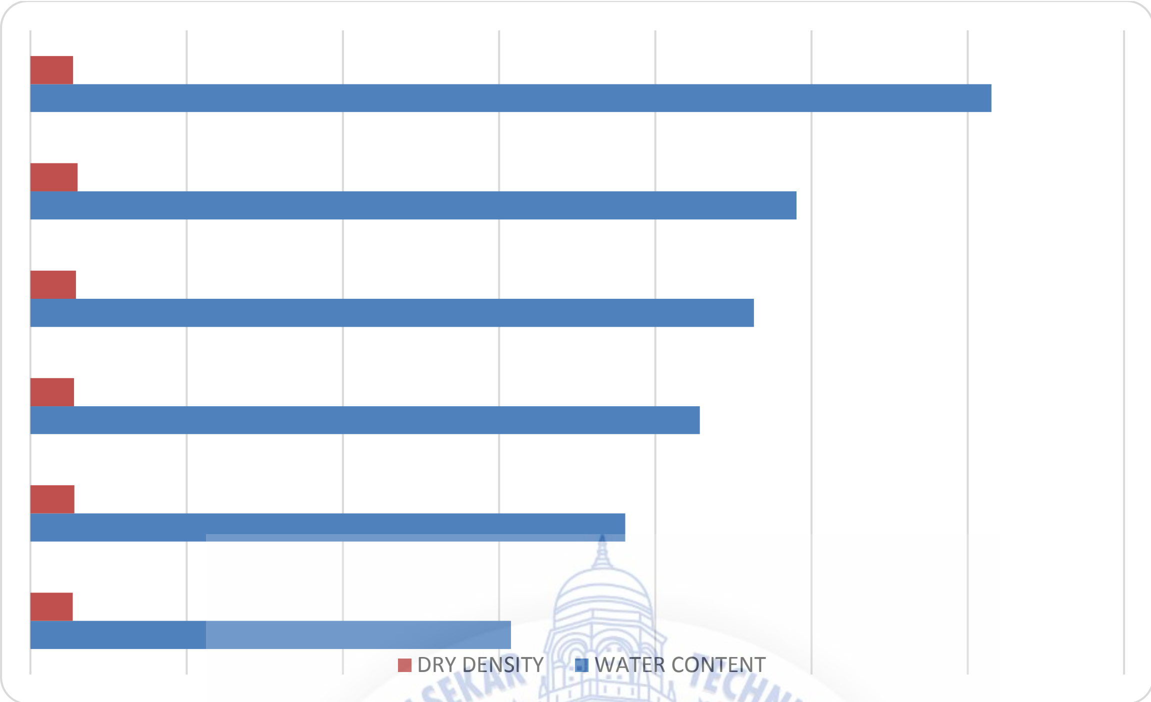



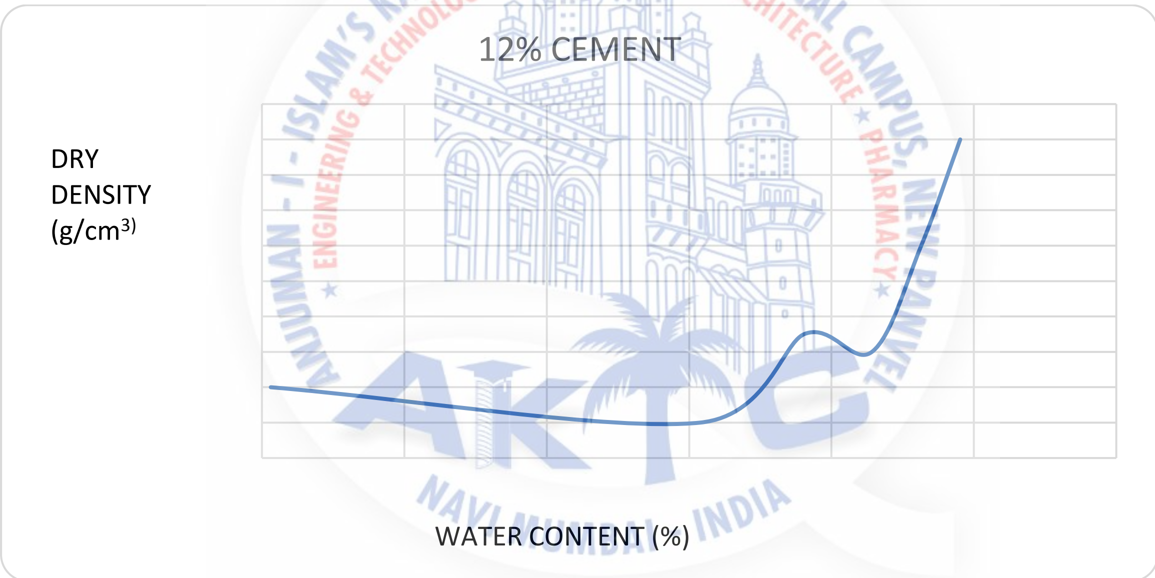

GRAPH 11 S.P.T. (8% CEMENT)

AT 12% CEMENT

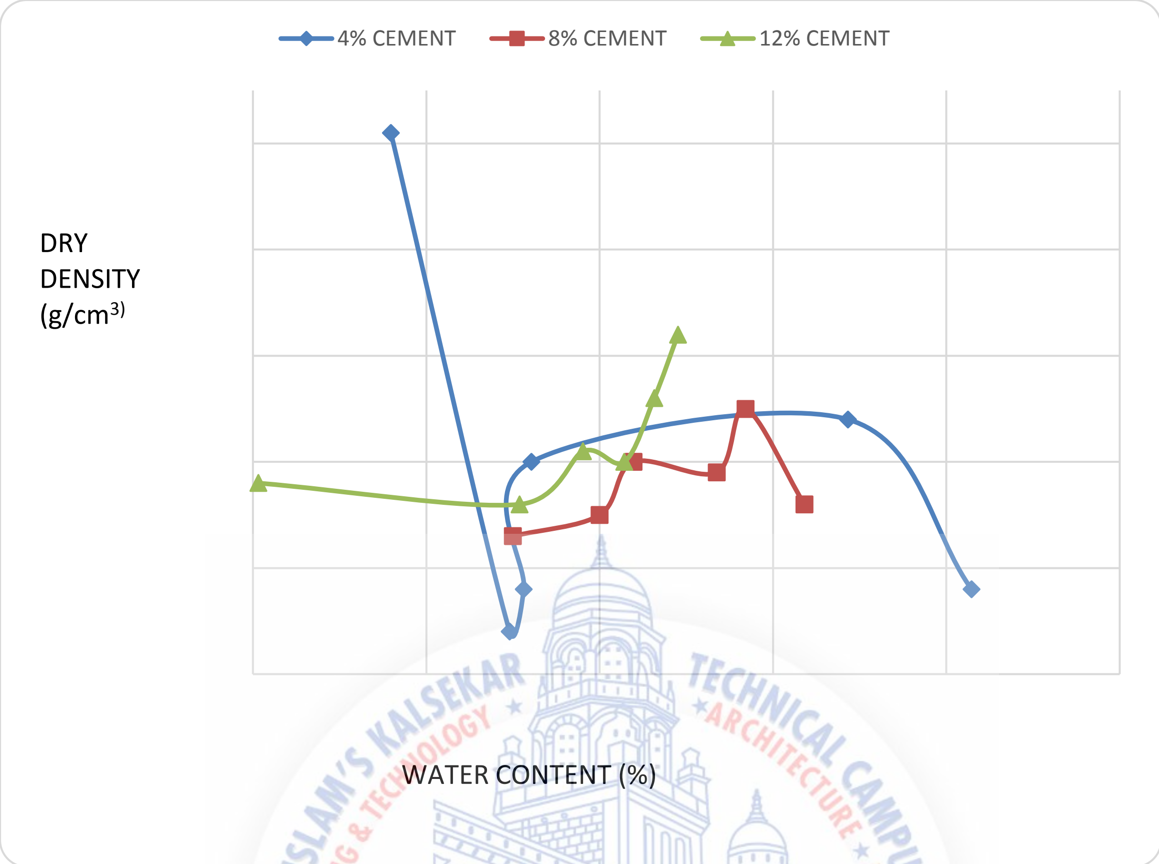
TABLE 24 S.P.T (12% CEMENT)

| Sample Number | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Vol. of mould (V) | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 |
| Wt of mould (W1) | 5633.5 | 5588.5 | 5588.5 | 5633.5 | 5588.5 | 5589.5 |
| Wt. of mould + compacted soil (W2) | 7215.0 | 7279.5 | 7300.0 | 7445.0 | 7481.0 | 7390.0 |
| Empty wt of container (w1) | 0.0125 | 0.0150 | 0.0080 | 0.0145 | 0.0150 | 0.0150 |
| Wt of container + wet soil (w2) | 0.0550 | 0.775 | 0.0335 | 0.0730 | 0.0480 | 0.0490 |
| Wt of container + dry soil (w3) | 0.0450 | 0.0675 | 0.0290 | 0.0620 | 0.0415 | 0.0410 |
| Wt of moisture (w2-w3) | 0.005 | 0.010 | 0.0045 | 0.011 | 0.0065 | 0.0080 |
| wt of dry soil (w3-w1) | 0.0325 | 0.0525 | 0.0210 | 0.0475 | 0.0265 | 0.0260 |
| Water content(w) | 15.38 | 19.04 | 21.42 | 23.15 | 24.52 | 30.76 |
| Wt of compacted soil (W) | 1581.5 | 1691.0 | 1711.5 | 1811.5 | 1892.5 | 1800.5 |
| Bulk density (g/cm$^3$) | 1.58 | 1.69 | 1.71 | 1.81 | 1.89 | 1.80 |
| Dry density (g/cm$^3$) | 1.36 | 1.41 | 1.40 | 1.46 | 1.51 | 1.37 |




GRAPH 12 S.P.T (12% CEMENT)

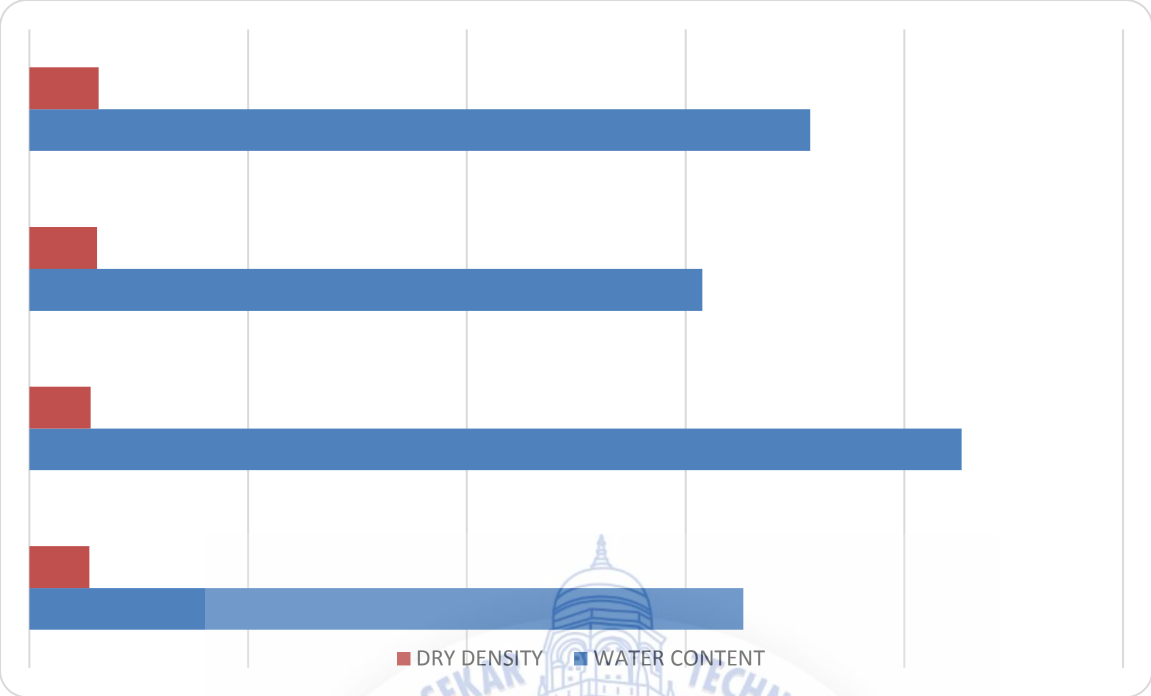


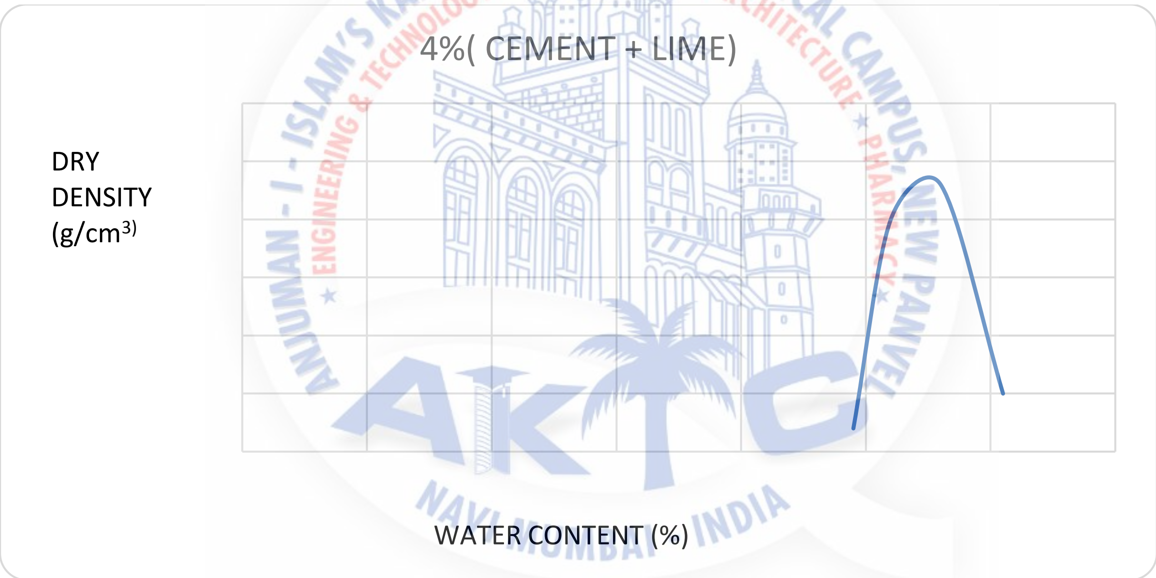

GRAPH 13 COMPARISION BETWEEN 4%, 8% AND 12% OF CEMENT

AT 4% (CEMENT+LIME)

TABLE 25 S.P.T 4% (CEMENT + LIME)

| Sample Number | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Vol. of mould (V) | 1000 | 1000 | 1000 | 1000 |
| Wt of mould (W1) | 5588.5 | 5588.5 | 5588.5 | 5588.5 |
| Wt. of mould + compacted soil (W2) | 7185 | 7290 | 7870 | 7450 |
| Empty wt of container (w1) | 15 | 15.5 | 15 | 15 |
| Wt of container + wet soil (w2) | 43.5 | 52.5 | 45 | 48 |
| Wt of container + dry soil (w3) | 39.5 | 46 | 41 | 43 |
| Wt of moisture (w2-w3) | 4 | 6.5 | 4 | 5 |
| wt of dry soil (w3-w1) | 24.5 | 30.5 | 26 | 28 |
| Water content(w) | 16.32 | 21.31 | 15.38 | 17.85 |
| Wt of compacted soil (W) | 1596.5 | 1701.5 | 1781.5 | 1861.5 |
| Bulk density (g/cm$^3$) | 1.59 | 1.70 | 1.78 | 1.86 |
| Dry density (g/cm$^3$) | 1.37 | 1.40 | 1.55 | 1.58 |



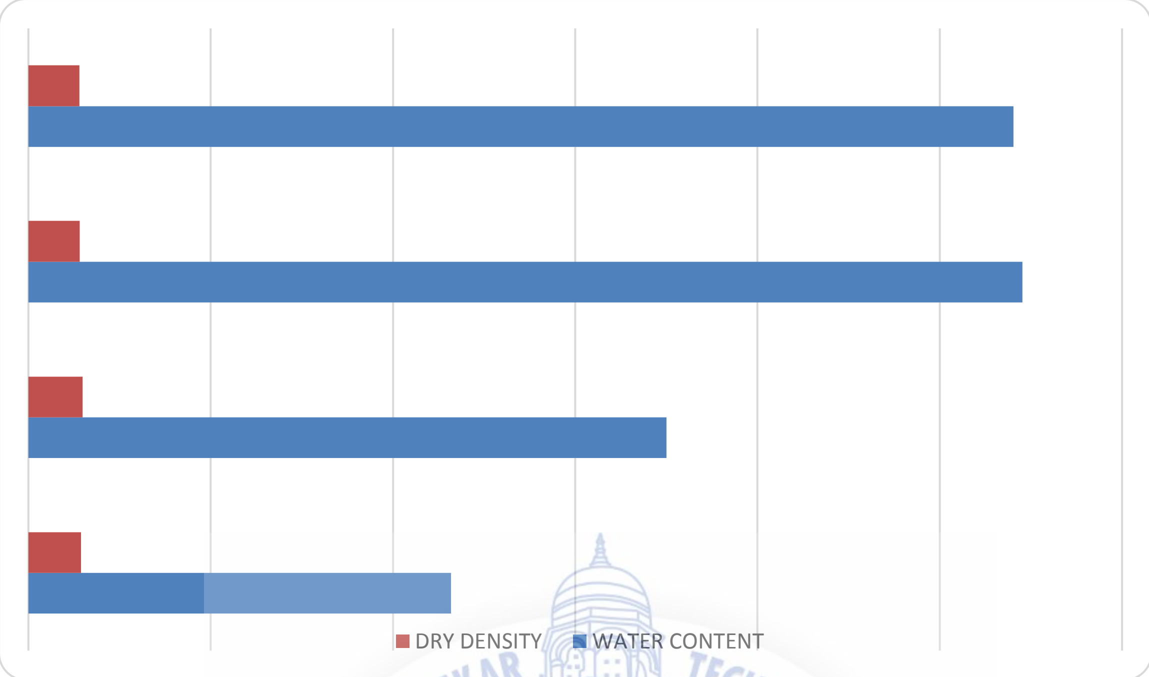



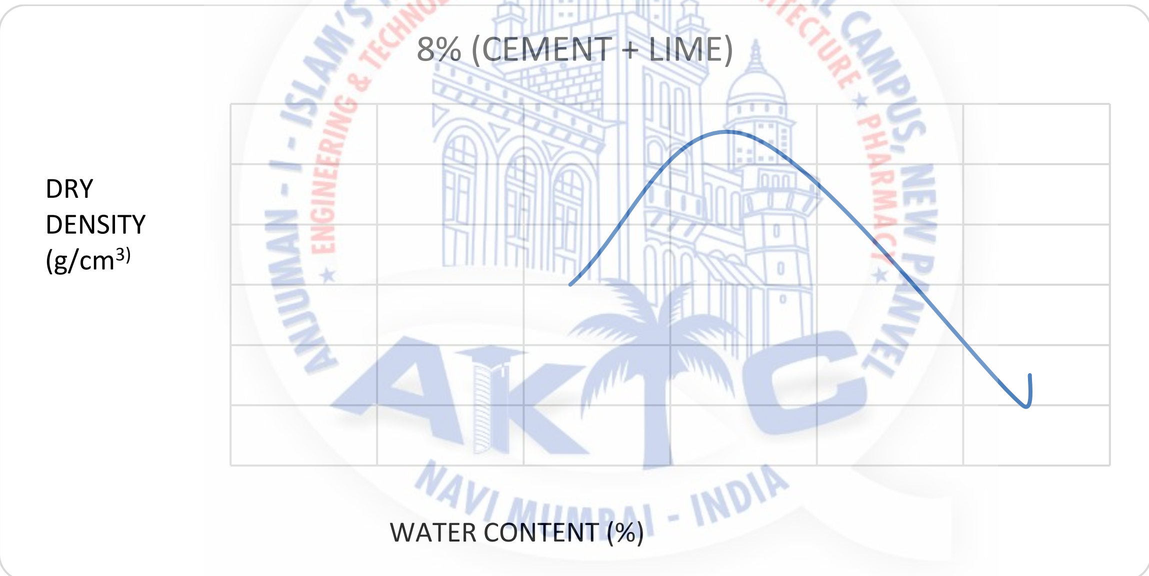

GRAPH 14 S.P.T 4% (CEMENT + LIME)

AT 8% (CEMENT+LIME)

TABLE 26 S.P.T 8% (CEMENT + LIME)

| Sample no. | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Vol. of mould (V) | 1000 | 1000 | 1000 | 1000 |
| Wt of mould (W1) | 5588.5 | 5588.5 | 5632.5 | 5632.5 |
| Wt. of mould + compacted soil (W2) | 7201.0 | 7352.0 | 7437.0 | 7429.5 |
| Empty wt of container (w1) | 15 | 15.5 | 14 | 15 |
| Wt of container + wet soil (w2) | 53.5 | 62.5 | 35 | 38.5 |
| Wt of container + dry soil (w3) | 49.5 | 55.5 | 30.5 | 33.5 |
| Wt of moisture (w2-w3) | 4 | 7 | 4.5 | 5 |
| wt of dry soil (w3-w1) | 34.5 | 40 | 16.5 | 18.5 |
| Water content(w) | 11.59 | 17.5 | 27.27 | 27.02 |
| Wt of compacted soil (W) | 1611.5 | 1762.5 | 1804.5 | 1797.0 |
| Bulk density (g/cm$^3$) | 1.61 | 1.76 | 1.80 | 1.79 |
| Dry density (g/cm$^3$) | 1.44 | 1.49 | 1.41 | 1.40 |



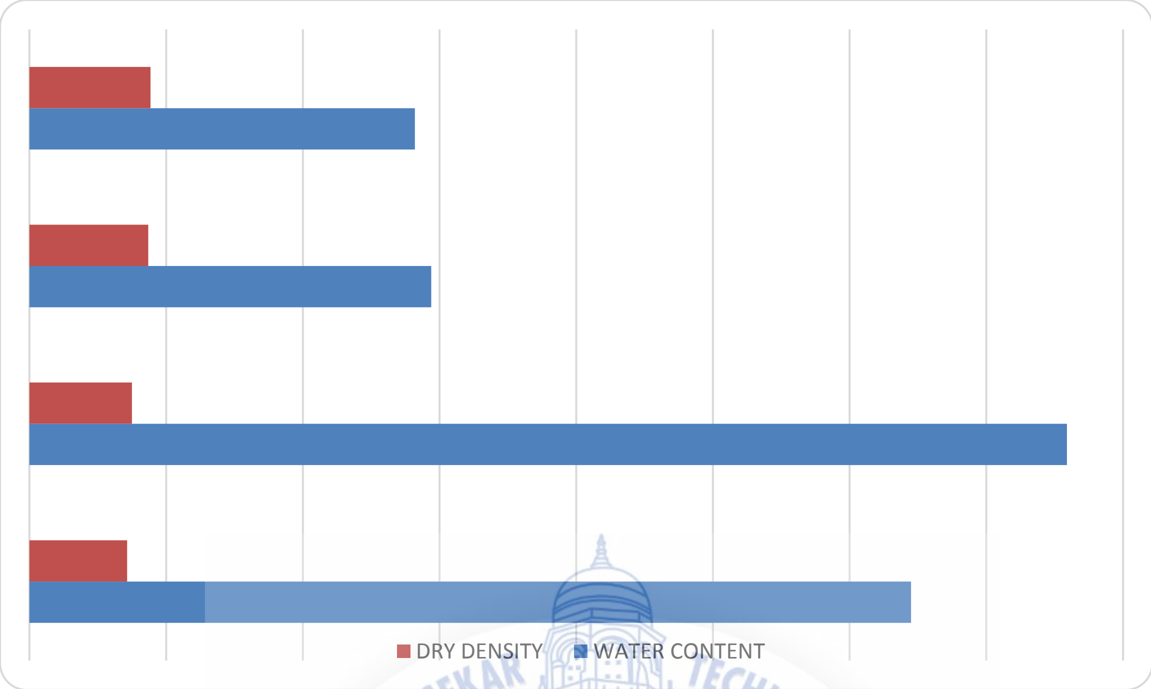



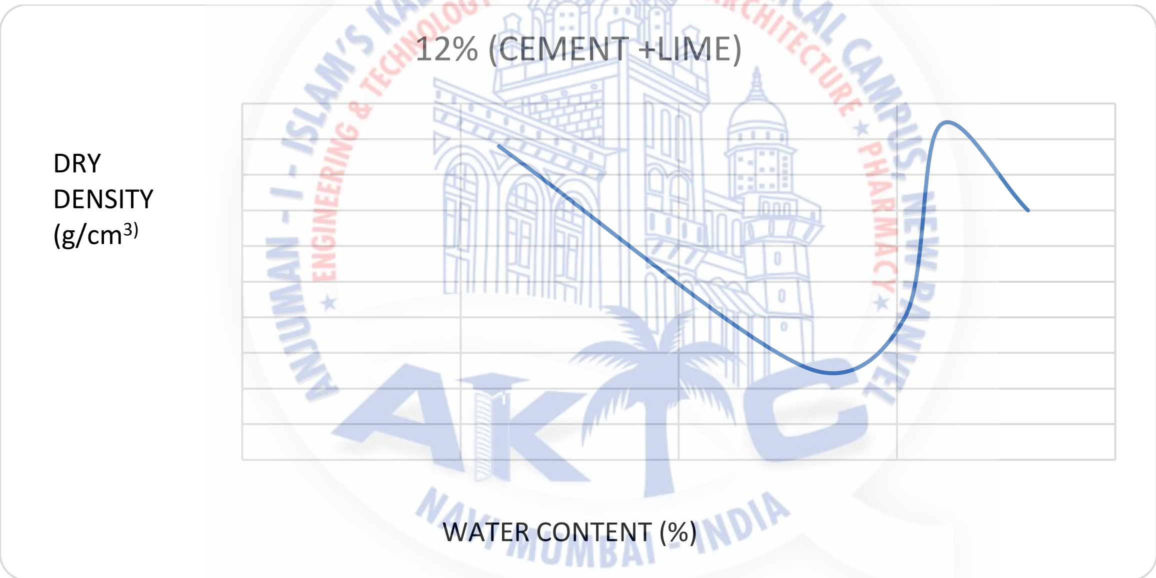

GRAPH 15 S.P.T 8% (CEMENT + LIME)

AT 12% (CEMENT+LIME)

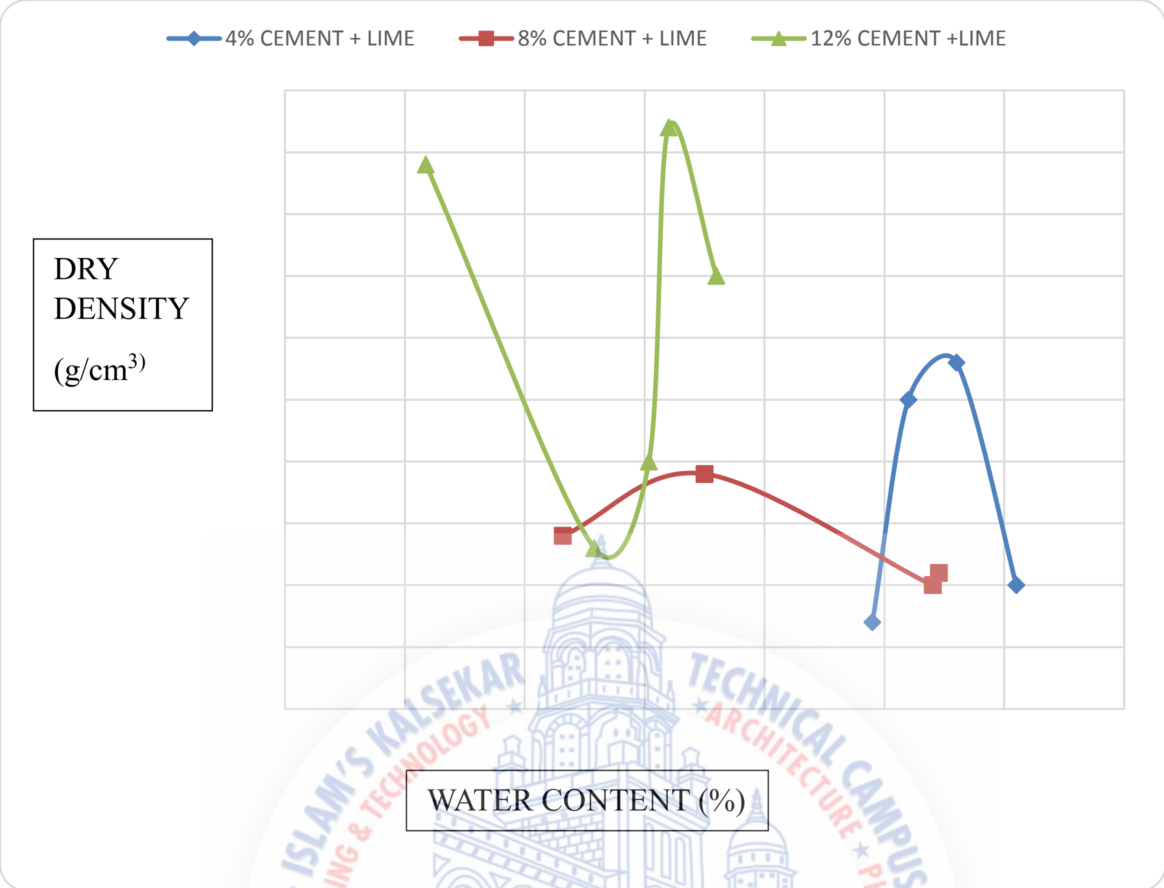
TABLE 27 S.P.T 12% (CEMENT + LIME)

| Sample no. | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Vol. of mould (V) | 1000 | 1000 | 1000 | 1000 |
| Wt of mould (W1) | 5589.5 | 5589.5 | 5589.5 | 5589.5 |
| Wt. of mould + compacted soil (W2) | 7210 | 7320 | 7440 | 7465 |
| Empty wt of container (w1) | 15 | 15 | 15 | 15 |
| Wt of container + wet soil (w2) | 50 | 60.5 | 78 | 80.5 |
| Wt of container + dry soil (w3) | 46 | 54.5 | 74.5 | 77 |
| Wt of moisture (w2-w3) | 4 | 6 | 3.5 | 3.5 |
| wt of dry soil (w3-w1) | 31 | 39.5 | 59.5 | 62 |
| Water content(w) | 12.90 | 15.18 | 5.88 | 5.64 |
| Wt of compacted soil (W) | 1620.5 | 1730.5 | 1850.5 | 1875.5 |
| Bulk density (g/cm$^3$) | 1.62 | 1.73 | 1.85 | 1.87 |
| Dry density (g/cm$^3$) | 1.43 | 1.50 | 1.74 | 1.77 |




GRAPH 16 S.P.T 12% ( CEMENT + LIME)

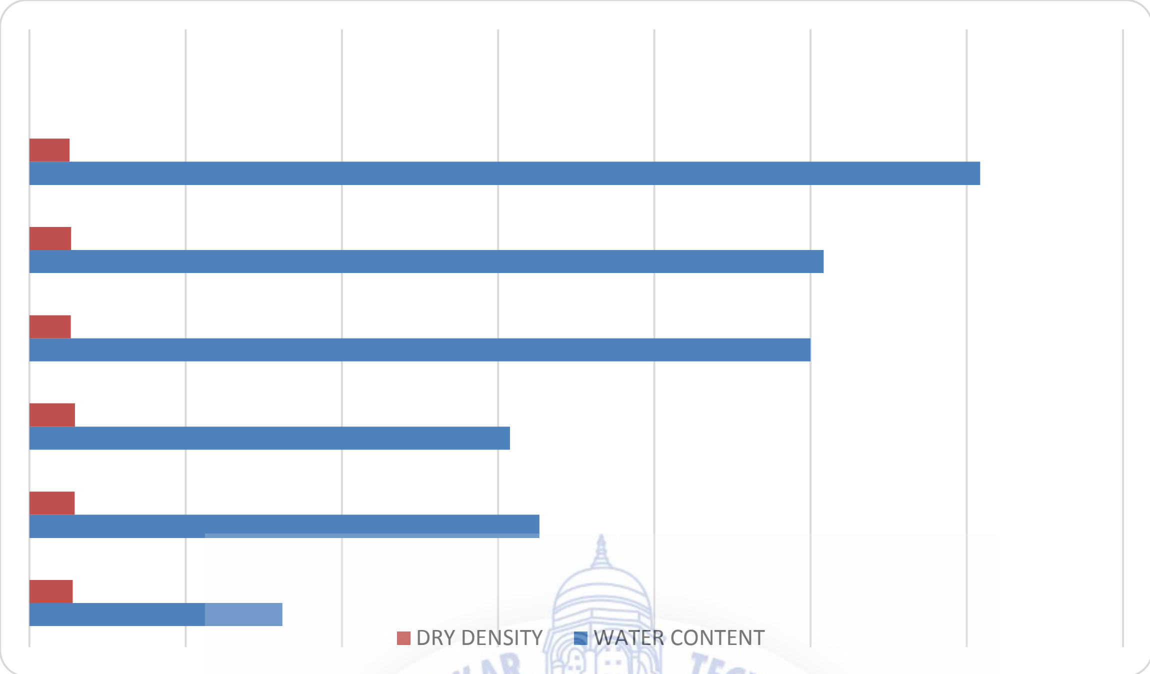


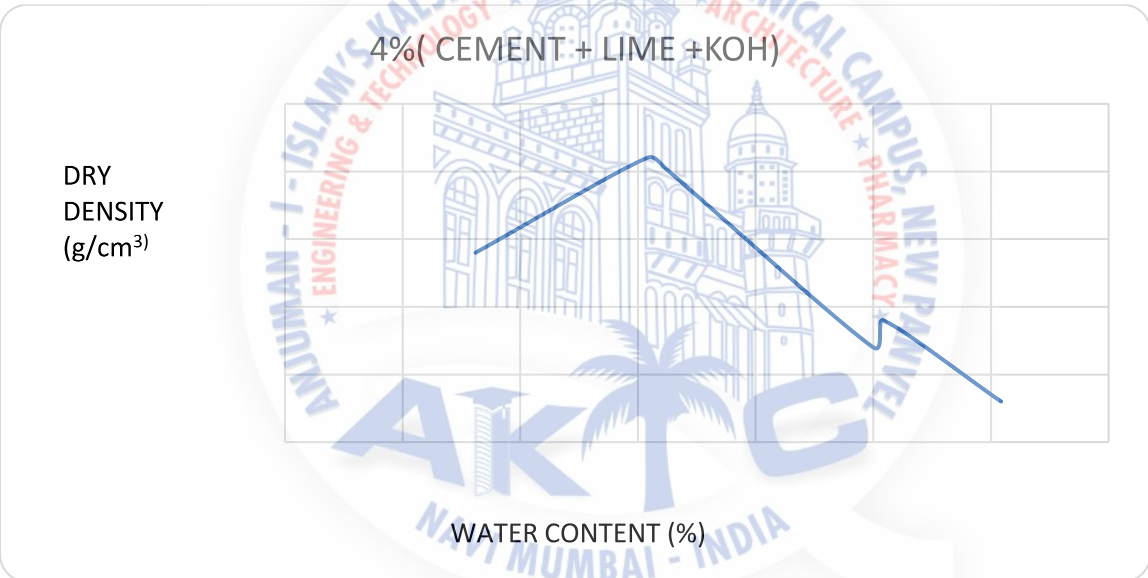

GRAPH 17 COMPARISION BETWEEN 4%, 8% AND 12% OF (CEMENT + LIME)

AT 4% (CEMENT+LIME+KOH)

TABLE 28 S.P.T 4% (CEMENT + LIME + KOH)

| Sample no. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Vol. of mould (V) | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 |
| Wt of mould (W1) | 5640 | 5640 | 5640 | 5589 | 5589 | 5589 |
| Wt. of mould + compacted soil (W2) | 7150 | 7320 | 7335 | 7290 | 7325 | 7310 |
| Empty wt of container (w1) | 15 | 15 | 15 | 15 | 15 | 15 |
| Wt of container + wet soil (w2) | 55 | 43.5 | 45 | 35 | 52 | 60 |
| Wt of container + dry soil (w3) | 52 | 39.5 | 41 | 31 | 44.5 | 49.5 |
| Wt of moisture (w2-w3) | 3 | 4 | 4 | 4 | 7.5 | 10.5 |
| wt of dry soil (w3-w1) | 37 | 24.5 | 26 | 16 | 29.5 | 34.5 |
| Water content(w) | 8.10 | 16.32 | 15.38 | 25 | 25.42 | 30.43 |
| Wt of compacted soil (W) | 1510 | 1680 | 1695 | 1650 | 1685 | 1670 |
| Bulk density (g/cm$^3$) | 1.51 | 1.68 | 1.69 | 1.65 | 1.68 | 1.67 |
| Dry density (g/cm$^3$) | 1.39 | 1.45 | 1.46 | 1.32 | 1.34 | 1.28 |



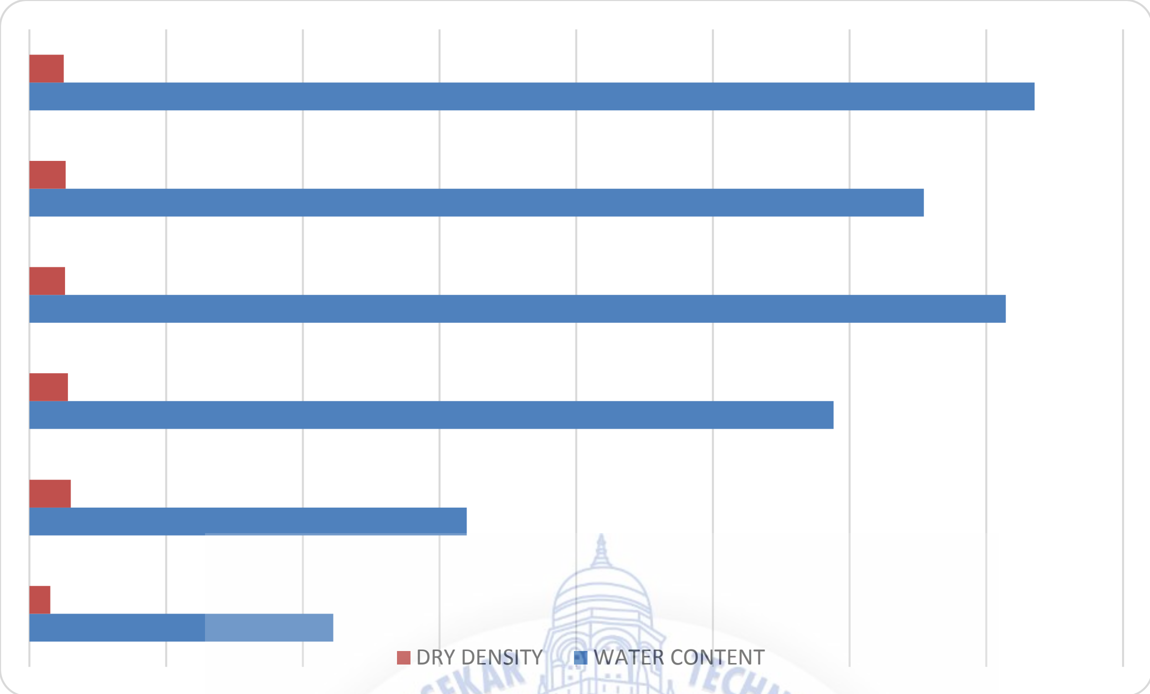



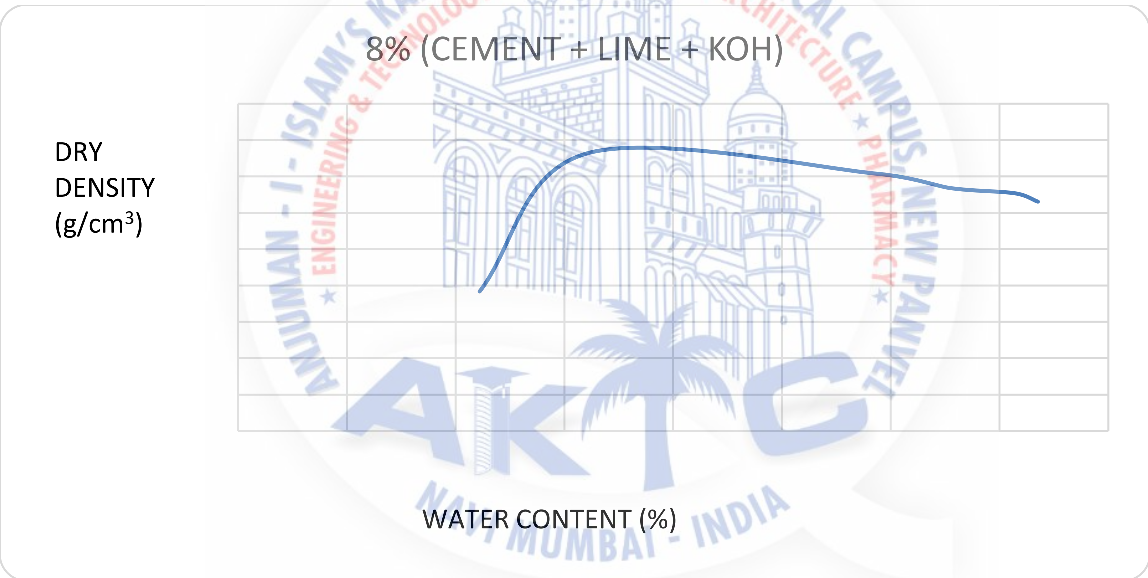

GRAPH 18 S.P.T. 4% (CEMENT + LIME + KOH)

AT 8% (CEMENT+SOIL+KOH)

TABLE 29 S.P.T 8% (CEMENT + LIME + KOH)

| Sample no. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Vol. of mould (V) | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 |
| Wt of mould (W1) | 5640 | 5640 | 5589 | 5589 | 5640 | 5589 |
| Wt. of mould + compacted soil (W2) | 7260 | 7410 | 7420 | 7364 | 7414 | 7314 |
| Empty wt of container (w1) | 15 | 14 | 15 | 13.5 | 8 | 13 |
| Wt of container + wet soil (w2) | 55 | 43 | 37 | 32.5 | 44.5 | 59.5 |
| Wt of container + dry soil (w3) | 51 | 39 | 32 | 27.5 | 35.5 | 47 |
| Wt of moisture (w2-w3) | 4 | 4 | 5 | 5 | 9 | 12.5 |
| wt of dry soil (w3-w1) | 36 | 25 | 17 | 14 | 27.5 | 34 |
| Water content(w) | 11.11 | 16.00 | 29.41 | 35.71 | 32.72 | 36.76 |
| Wt of compacted soil (W) | 1620 | 1770 | 1831 | 1775 | 1774 | 1725 |
| Bulk density (g/cm$^3$) | 1.62 | 1.77 | 1.83 | 1.77 | 1.77 | 1.72 |
| Dry density (g/cm$^3$) | 0.76 | 1.52 | 1.41 | 1.30 | 1.33 | 1.26 |



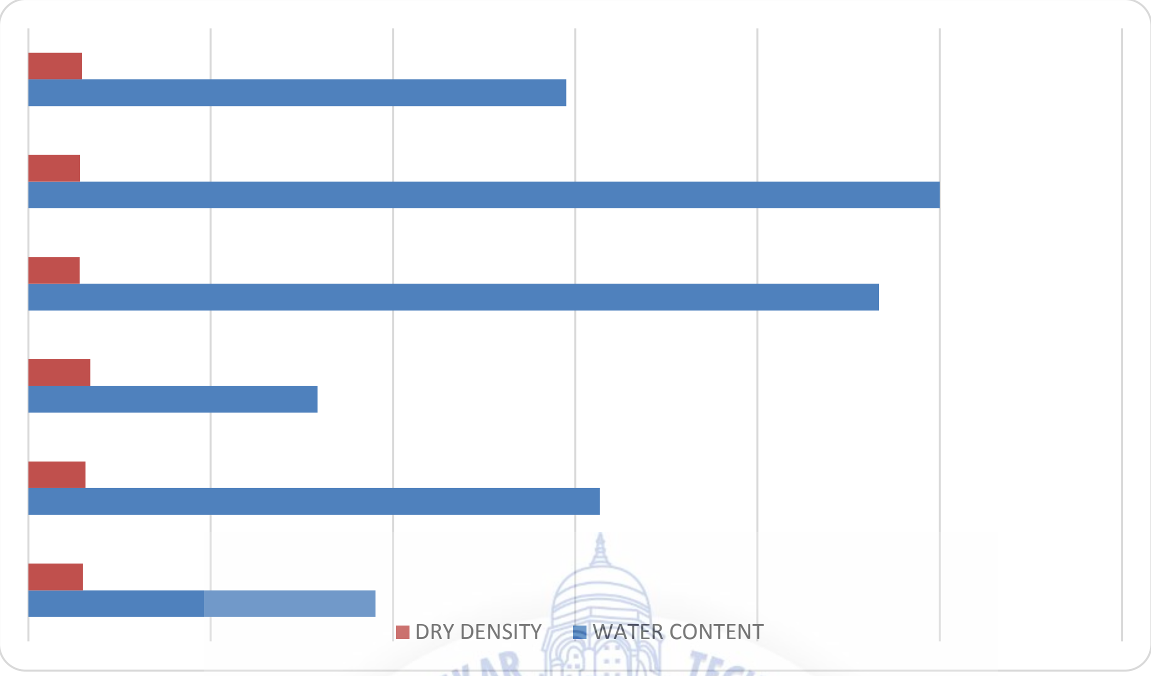



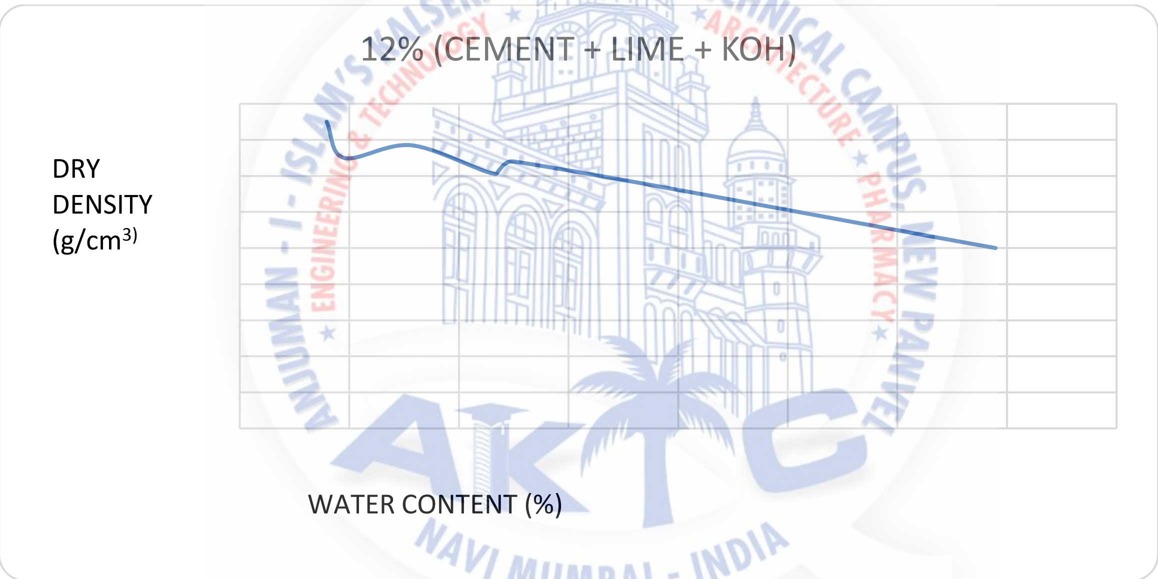

GRAPH 19 S.P.T 8% (CEMENT + LIME + KOH)

AT 12% (CEMENT+LIME+KOH)

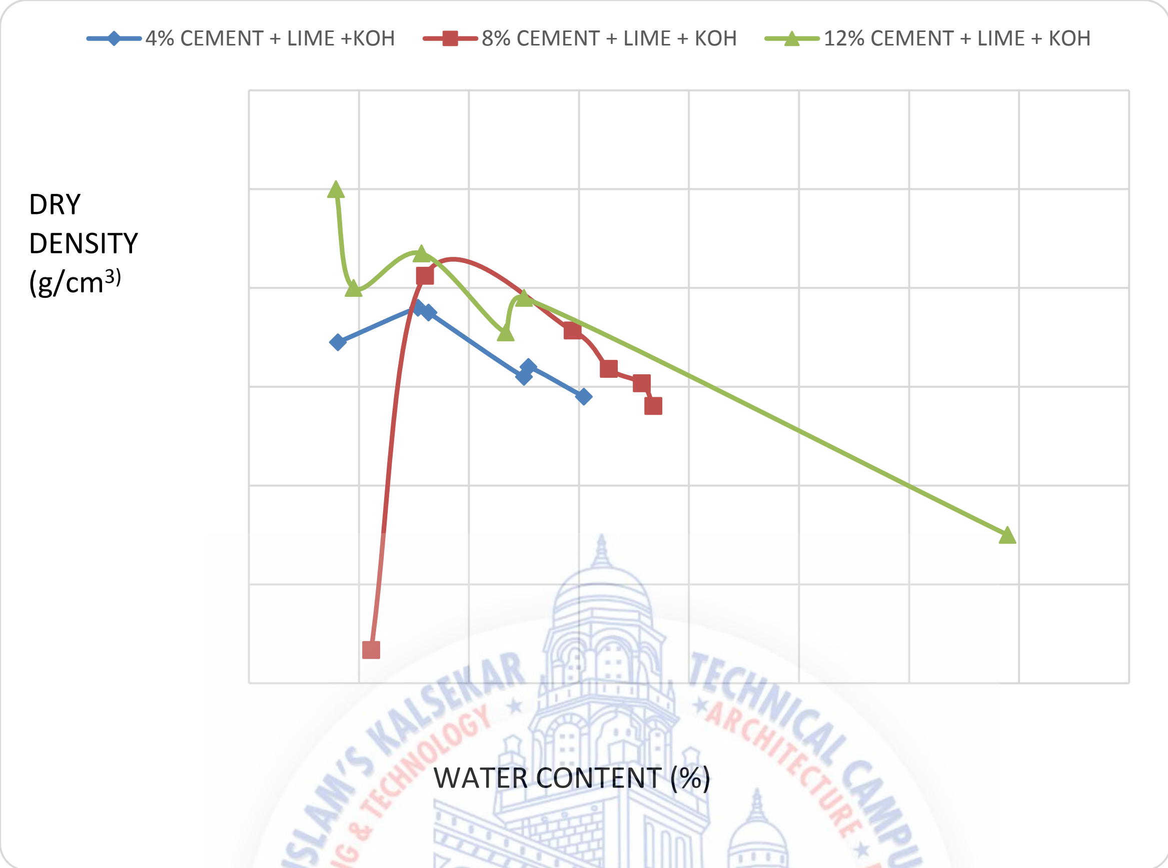
TABLE 30 S.P.T 12% (CEMENT + LIME + KOH)

| Sample no. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Vol. of mould (V) | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 |
| Wt of mould (W1) | 5589 | 5589 | 5589 | 5640 | 5640 | 5640 |
| Wt. of mould + compacted soil (W2) | 7240 | 7410 | 7430 | 7385 | 7425 | 7335 |
| Empty wt of container (w1) | 15.5 | 15 | 15 | 15 | 15 | 15 |
| Wt of container + wet soil (w2) | 50 | 44.5 | 49 | 52 | 60 | 50.5 |
| Wt of container + dry soil (w3) | 47 | 40.5 | 46.5 | 45 | 51 | 45.5 |
| Wt of moisture (w2-w3) | 3 | 4 | 2.5 | 7 | 9 | 4.5 |
| wt of dry soil (w3-w1) | 31.5 | 25.5 | 31.5 | 30 | 36 | 30.5 |
| Water content(w) | 9.52 | 15.68 | 7.93 | 23.33 | 25 | 14.75 |
| Wt of compacted soil (W) | 1651 | 1821 | 1841 | 1745 | 1785 | 1695 |
| Bulk density (g/cm$^3$) | 1.65 | 1.82 | 1.84 | 1.74 | 1.78 | 1.69 |
| Dry density (g/cm$^3$) | 1.50 | 1.57 | 1.70 | 1.41 | 1.42 | 1.47 |




GRAPH 20 S.P.T 12% (CEMENT + LIME + KOH)



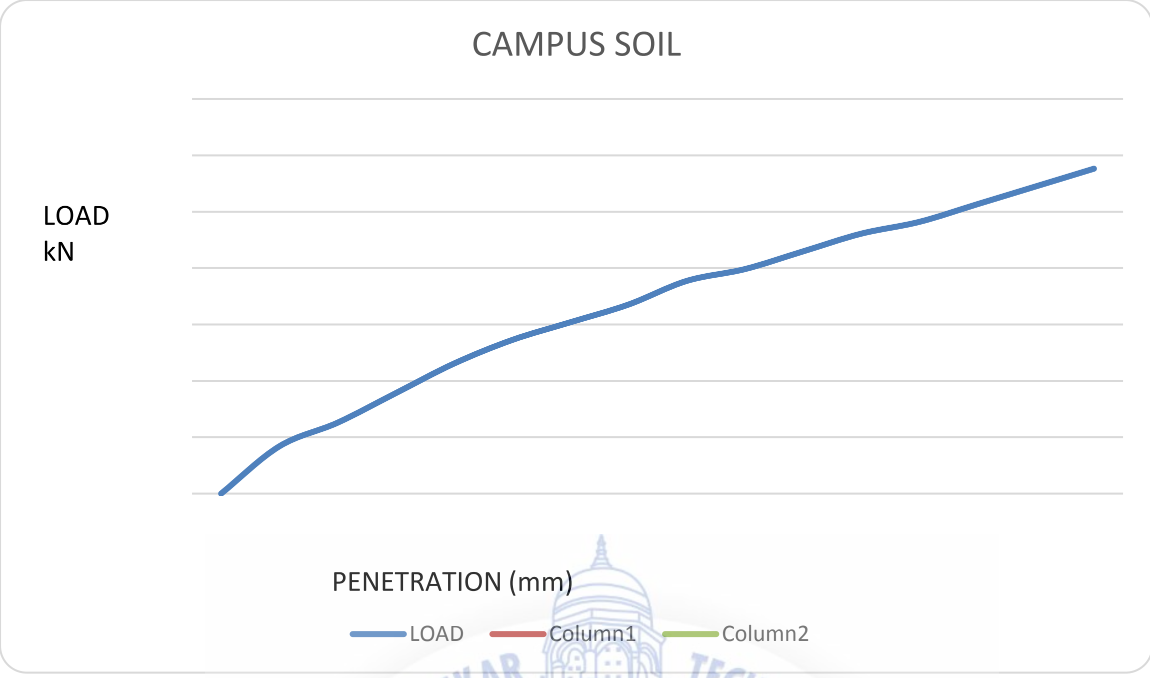

GRAPH 21 COMPARISION BETWEEN 4%, 8% AND 12% OF (CEMENT + LIME +KOH)

## 4.6 CALIFORNIA BEARNG RATIO CALCULATION

CAMPUS SOIL

TABLE 31 C.B.R (CAMPUS SOIL)

| DGR | Penetration DGR*G(mm) | PRR | Load (kN) | Corrected load (kN) |
|---|---|---|---|---|
| 50 | 0.5 | 0.8 | 4.192 | |
| 100 | 1.0 | 1.2 | 6.288 | |
| 150 | 1.5 | 1.7 | 8.908 | |
| 200 | 2.0 | 2.2 | 11.528 | |
| 250 | 2.5 | 2.6 | 13.624 | 11.6 |
| 300 | 3.0 | 2.9 | 15.196 | |
| 350 | 3.5 | 3.2 | 16.768 | |
| 400 | 4.0 | 3.6 | 18.864 | |
| 450 | 4.5 | 3.8 | 19.912 | |
| 500 | 5.0 | 4.1 | 21.484 | 20.8 |
| 550 | 5.5 | 4.4 | 23.056 | |
| 600 | 6.0 | 4.6 | 24.104 | |
| 650 | 6.5 | 4.9 | 25.676 | |
| 700 | 7.0 | 5.2 | 27.248 | |
| 750 | 7.5 | 5.5 | 28.82 | |

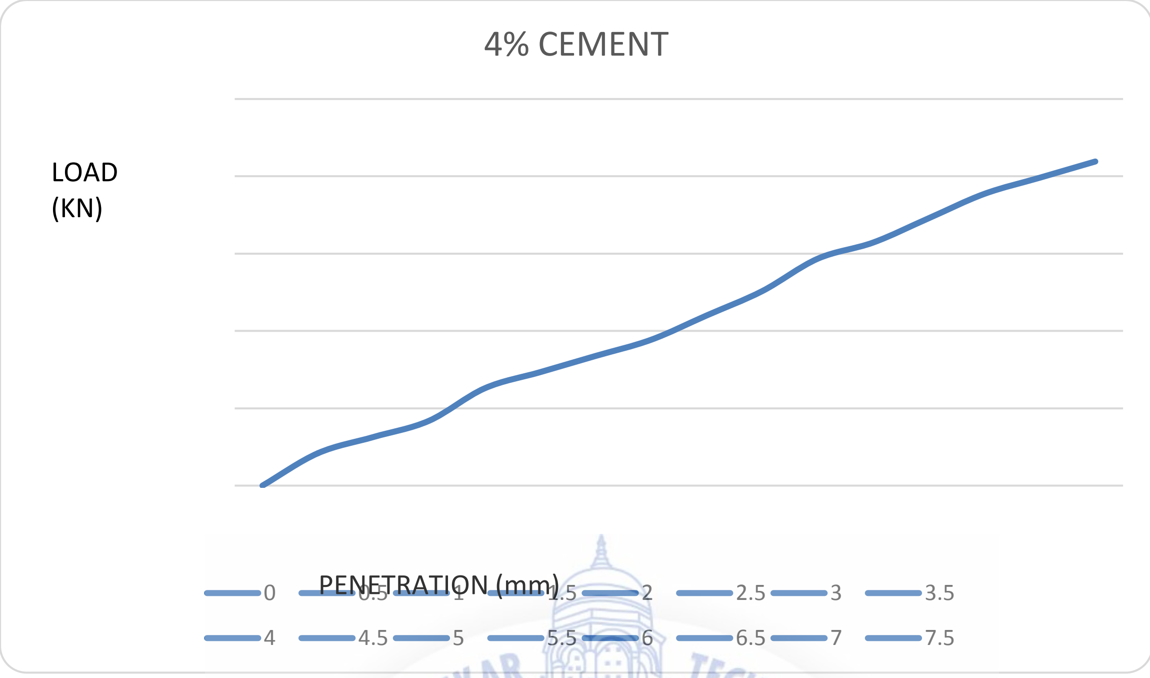



GRAPH 22 C.B.R (CAMPUS SOIL)

AT 4% CEMENT

TABLE 32 C.B.R (4% CEMENT)

| DGR | Penetration DGR*G(mm) | PRR | Load (kN) | Corrected load (kN) |
|---|---|---|---|---|
| 50 | 0.5 | 0.4 | 2.096 | |
| 100 | 1.0 | 0.6 | 3.144 | |
| 150 | 1.5 | 0.8 | 4.192 | |
| 200 | 2.0 | 1.2 | 6.288 | |
| 250 | 2.5 | 1.4 | 7.336 | 7.336 |
| 300 | 3.0 | 1.6 | 8.384 | |
| 350 | 3.5 | 1.8 | 9.432 | |
| 400 | 4.0 | 2.1 | 11.004 | |
| 450 | 4.5 | 2.4 | 12.576 | |
| 500 | 5.0 | 2.8 | 14.672 | 14.672 |
| 550 | 5.5 | 3.0 | 15.720 | |
| 600 | 6.0 | 3.3 | 17.292 | |
| 650 | 6.5 | 3.6 | 18.864 | |
| 700 | 7.0 | 3.8 | 19.912 | |
| 750 | 7.5 | 4.0 | 20.960 | |

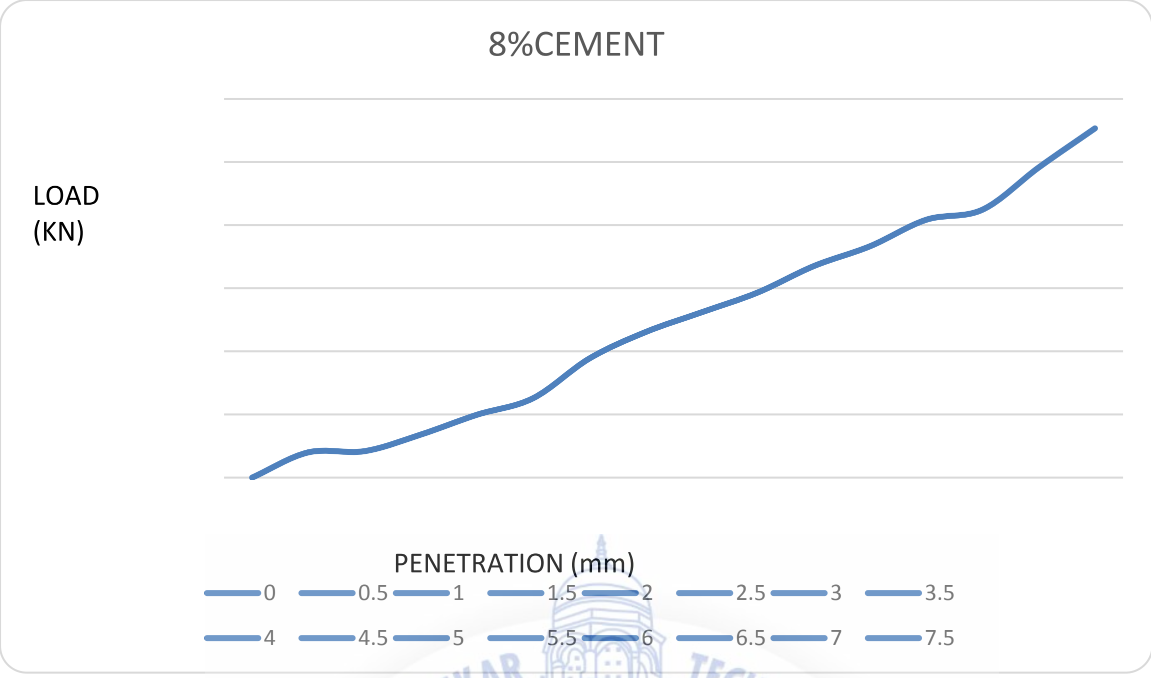



GRAPH 23 C.B.R (4% CEMENT)

AT 8% CEMENT

TABLE 33 C.B.R (8% CEMENT)

| DGR | Penetration DGR*G(mm) | PRR | Load (kN) | Corrected load (kN) |
|---|---|---|---|---|
| 50 | 0.5 | 0.4 | 4.000 | |
| 100 | 1.0 | 0.8 | 4.192 | |
| 150 | 1.5 | 1.3 | 6.812 | |
| 200 | 2.0 | 1.9 | 9.956 | |
| 250 | 2.5 | 2.4 | 12.576 | 12.576 |
| 300 | 3.0 | 3.6 | 18.864 | |
| 350 | 3.5 | 4.4 | 23.056 | |
| 400 | 4.0 | 5.0 | 26.200 | |
| 450 | 4.5 | 5.6 | 29.344 | |
| 500 | 5.0 | 6.4 | 33.536 | 33.563 |
| 550 | 5.5 | 7.0 | 36.680 | |
| 600 | 6.0 | 7.8 | 60.872 | |
| 650 | 6.5 | 8.2 | 42.468 | |
| 700 | 7.0 | 9 | 49.160 | |
| 750 | 7.5 | 9.8 | 55.352 | |

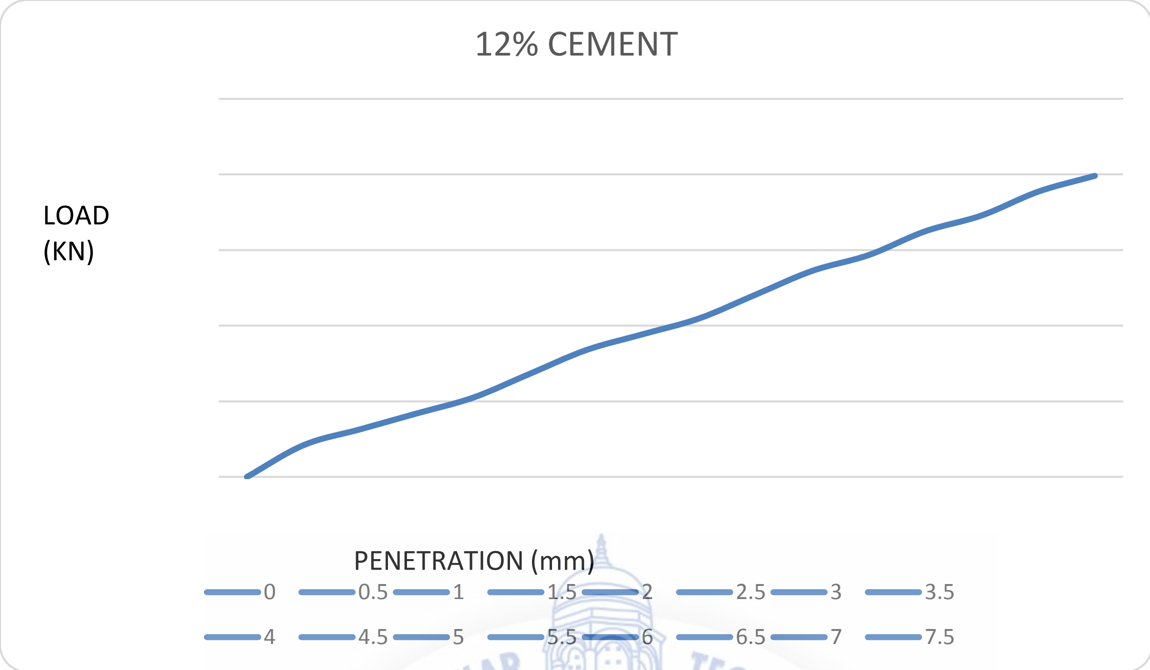



GRAPH 24 C.B.R (8% CEMENT)

AT 12% CEMENT

TABLE 34 C.B.R (12% CEMENT)

| DGR | Penetration DGR*G(mm) | PRR | Load | Corrected load |
|---|---|---|---|---|
| 50 | 0.5 | 0.4 | 2.096 | |
| 100 | 1.0 | 0.6 | 3.144 | |
| 150 | 1.5 | 0.8 | 4.192 | |
| 200 | 2.0 | 1.0 | 5.24 | |
| 250 | 2.5 | 1.3 | 6.812 | 6.812 |
| 300 | 3.0 | 1.6 | 8.384 | |
| 350 | 3.5 | 1.8 | 9.432 | |
| 400 | 4.0 | 2.0 | 10.48 | |
| 450 | 4.5 | 2.3 | 12.052 | |
| 500 | 5.0 | 2.6 | 13.624 | 13.624 |
| 550 | 5.5 | 2.8 | 14.672 | |
| 600 | 6.0 | 3.1 | 16.244 | |
| 650 | 6.5 | 3.3 | 17.292 | |
| 700 | 7.0 | 3.6 | 18.864 | |
| 750 | 7.5 | 3.8 | 19.912 | |

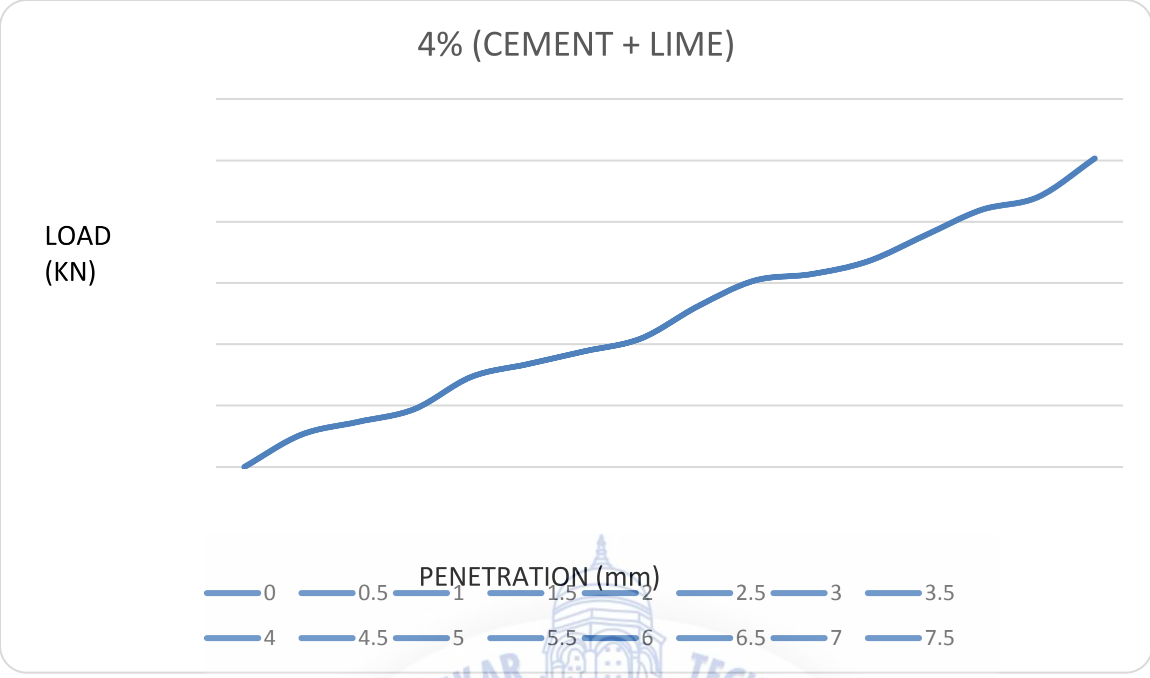



GRAPH 25 C.B.R (12% CEMENT)

AT 4% (CEMENT + LIME)

TABLE 35 C.B.R 4% (CEMENT + LIME)

| DGR | Penetration DGR*G(mm) | PRR | Load (kN) | Corrected load (kN) |
|---|---|---|---|---|
| 50 | 0.5 | 0.5 | 2.620 | |
| 100 | 1.0 | 0.7 | 3.668 | |
| 150 | 1.5 | 0.9 | 4.716 | |
| 200 | 2.0 | 1.4 | 7.336 | |
| 250 | 2.5 | 1.6 | 8.384 | 8.384 |
| 300 | 3.0 | 1.8 | 9.432 | |
| 350 | 3.5 | 2.0 | 10.480 | |
| 400 | 4.0 | 2.5 | 13.100 | |
| 450 | 4.5 | 2.9 | 15.196 | |
| 500 | 5.0 | 3.0 | 15.720 | 15.720 |
| 550 | 5.5 | 3.2 | 16.768 | |
| 600 | 6.0 | 3.6 | 18.864 | |
| 650 | 6.5 | 4.0 | 20.960 | |
| 700 | 7.0 | 4.2 | 22.008 | |
| 750 | 7.5 | 4.8 | 25.152 | |

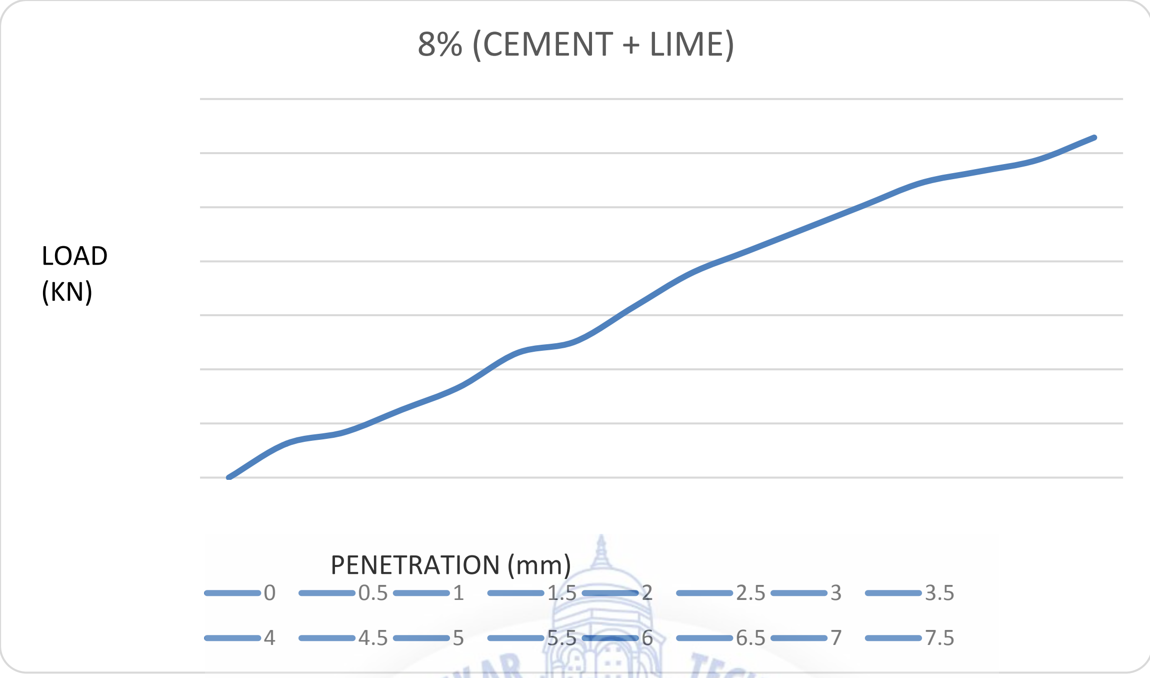



GRAPH 26 C.B.R 4% (CEMENT + LIME)

AT 8% (CEMENT + LIME)

TABLE 36 C.B.R 8% (CEMENT + LIME)

| DGR | Penetration DGR*G(mm) | PRR | Load (kN) | Corrected load (kN) |
|---|---|---|---|---|
| 50 | 0.5 | 0.6 | 03.14 | |
| 100 | 1.0 | 0.8 | 04.19 | |
| 150 | 1.5 | 1.2 | 06.28 | |
| 200 | 2.0 | 1.6 | 08.38 | |
| 250 | 2.5 | 2.2 | 11.52 | 11.52 |
| 300 | 3.0 | 2.4 | 12.57 | |
| 350 | 3.5 | 3.0 | 15.72 | |
| 400 | 4.0 | 3.6 | 18.86 | |
| 450 | 4.5 | 4.0 | 20.96 | |
| 500 | 5.0 | 4.4 | 23.05 | 23.05 |
| 550 | 5.5 | 4.8 | 25.15 | |
| 600 | 6.0 | 5.2 | 27.24 | |
| 650 | 6.5 | 5.4 | 28.29 | |
| 700 | 7.0 | 5.6 | 29.34 | |
| 750 | 7.5 | 6.0 | 31.44 | |

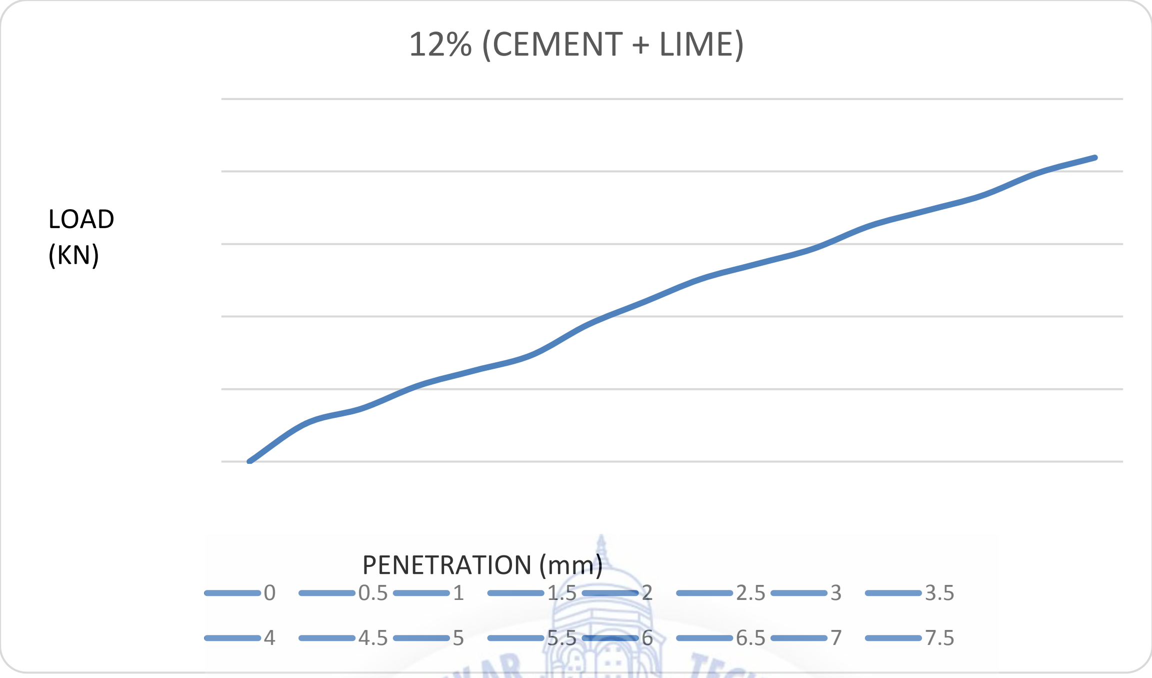



GRAPH 27 C.B.R 8% (CEMENT + LIME)

AT 12% (CEMENT + LIME)

TABLE 37 C.B.R 12% (CEMENT + LIME)

| DGR | Penetration DGR*G(mm) | PRR | Load (kN) | Corrected load (kN) |
|---|---|---|---|---|
| 50 | 0.5 | 0.5 | 2.620 | |
| 100 | 1.0 | 0.7 | 3.668 | |
| 150 | 1.5 | 1.0 | 5.240 | |
| 200 | 2.0 | 1.2 | 6.288 | |
| 250 | 2.5 | 1.4 | 7.336 | 7.80 |
| 300 | 3.0 | 1.8 | 9.432 | |
| 350 | 3.5 | 2.1 | 11.004 | |
| 400 | 4.0 | 2.4 | 12.576 | |
| 450 | 4.5 | 2.6 | 13.624 | |
| 500 | 5.0 | 2.8 | 14.672 | 14.80 |
| 550 | 5.5 | 3.1 | 16.244 | |
| 600 | 6.0 | 3.3 | 17.292 | |
| 650 | 6.5 | 3.5 | 18.340 | |
| 700 | 7.0 | 3.8 | 19.912 | |
| 750 | 7.5 | 4.0 | 20.960 | |

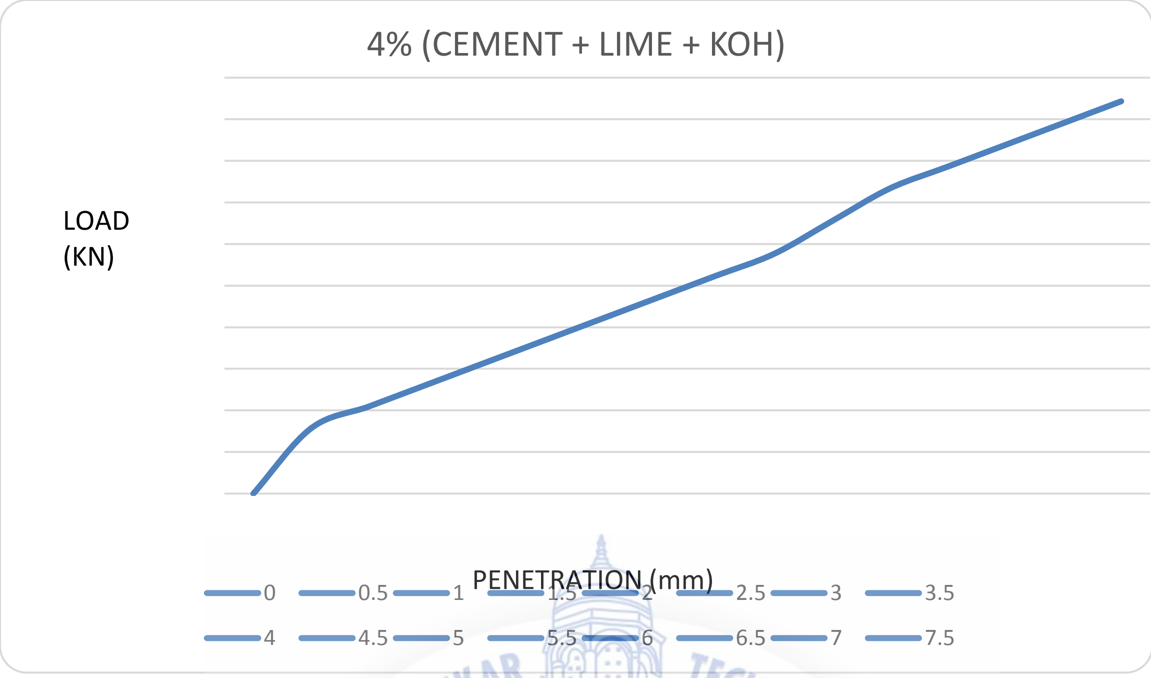



GRAPH 28 C.B.R 12% (CEMENT + LIME)

AT 4% (CEMENT + LIME + KOH)

TABLE 38 C.B.R 4% (CEMENT + LIME + KOH)

| DGR | Penetration DGR*G(mm) | PRR | Load (kN) | Corrected load (kN) |
|---|---|---|---|---|
| 50 | 0.5 | 0.6 | 3.144 | |
| 100 | 1.0 | 0.8 | 4.192 | |
| 150 | 1.5 | 1.0 | 5.240 | |
| 200 | 2.0 | 1.2 | 6.288 | |
| 250 | 2.5 | 1.4 | 7.336 | 8.20 |
| 300 | 3.0 | 1.6 | 8.384 | |
| 350 | 3.5 | 1.8 | 9.432 | |
| 400 | 4.0 | 2.0 | 10.480 | |
| 450 | 4.5 | 2.2 | 11.528 | |
| 500 | 5.0 | 2.5 | 13.100 | 16.00 |
| 550 | 5.5 | 2.8 | 14.672 | |
| 600 | 6.0 | 3.0 | 15.720 | |
| 650 | 6.5 | 3.2 | 16.768 | |
| 700 | 7.0 | 3.4 | 17.816 | |
| 750 | 7.5 | 3.6 | 18.864 | |

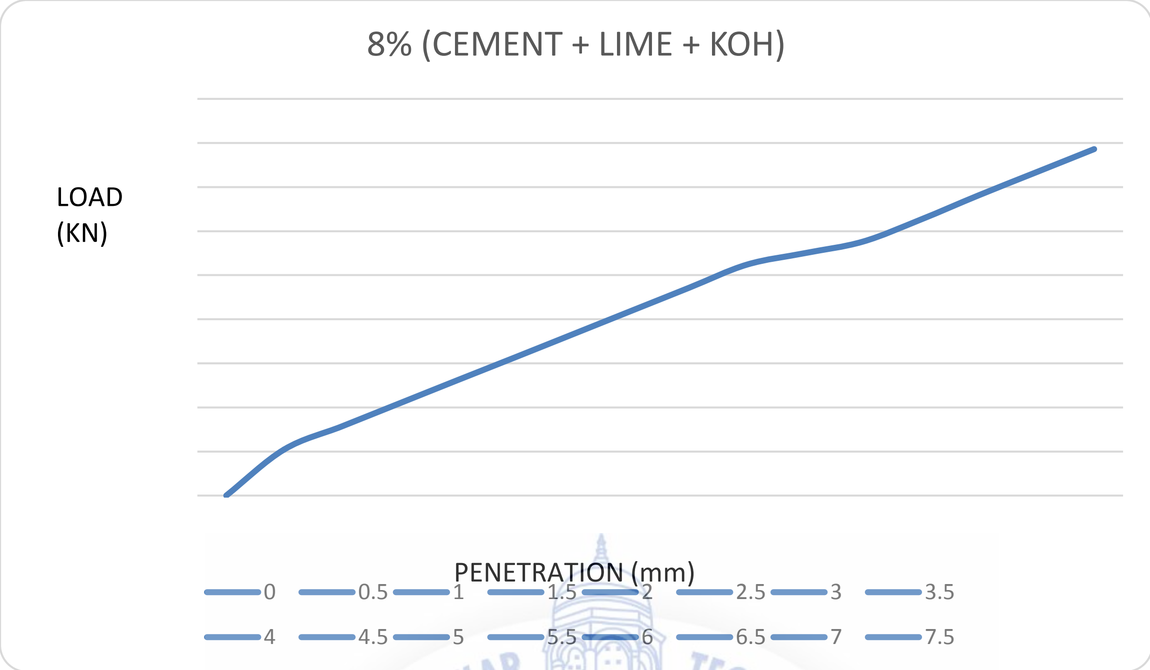



GRAPH 29 C.B.R 4% (CEMENT + LIME + KOH)

AT 8% (CEMENT + LIME + KOH)

TABLE 39 C.B.R 8% (CEMENT + LIME + KOH)

| DGR | Penetration DGR*G(mm) | PRR | Load (kN) | Corrected load (kN) |
|---|---|---|---|---|
| 50 | 0.5 | 0.4 | 02.09 | |
| 100 | 1.0 | 0.6 | 03.14 | |
| 150 | 1.5 | 0.8 | 04.19 | |
| 200 | 2.0 | 1.0 | 05.24 | |
| 250 | 2.5 | 1.2 | 06.28 | 06.28 |
| 300 | 3.0 | 1.4 | 07.33 | |
| 350 | 3.5 | 1.6 | 08.38 | |
| 400 | 4.0 | 1.8 | 09.43 | |
| 450 | 4.5 | 2.0 | 10.48 | |
| 500 | 5.0 | 2.1 | 11.00 | 11.00 |
| 550 | 5.5 | 2.2 | 11.52 | |
| 600 | 6.0 | 2.4 | 12.52 | |
| 650 | 6.5 | 2.6 | 13.62 | |
| 700 | 7.0 | 2.8 | 14.67 | |
| 750 | 7.5 | 3 | 15.72 | |

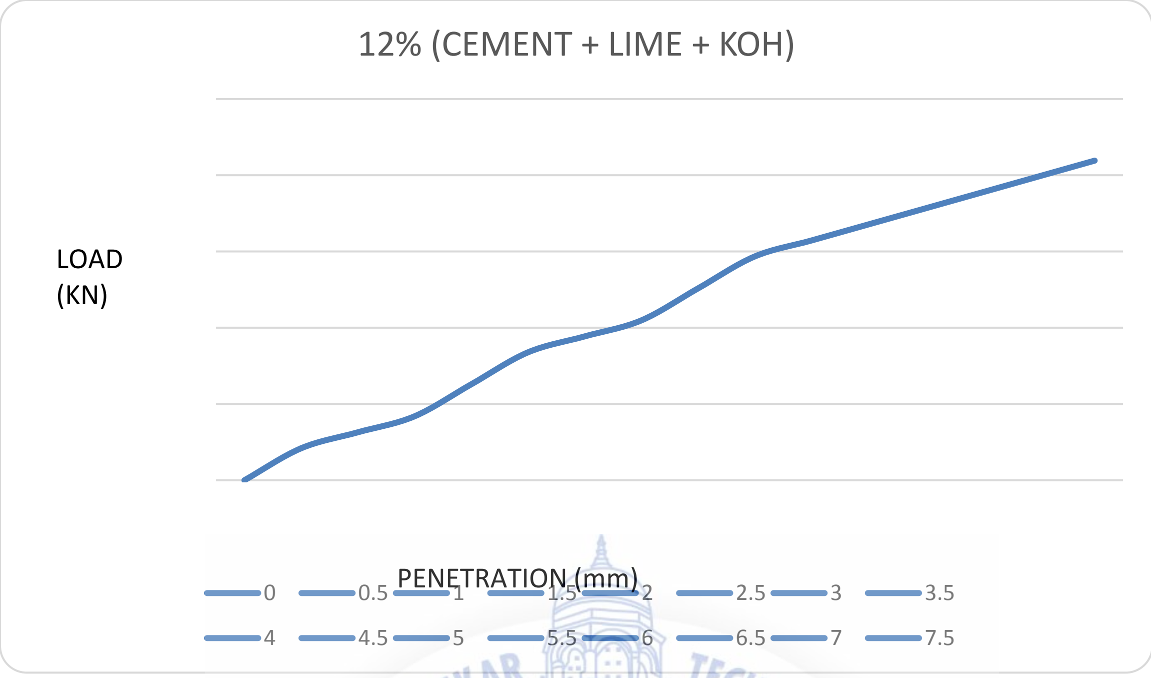



GRAPH 30 C.B.R 8% (CEMENT + LIME + KOH)

AT 12% (CEMENT + LIME + KOH)

TABLE 40 C.B.R 12% (CEMENT + LIME + KOH)

| DGR | Penetration DGR*G(mm) | PRR | Load (kN) | Corrected load (kN) |
|---|---|---|---|---|
| 50 | 0.5 | 0.4 | 2.096 | |
| 100 | 1.0 | 0.6 | 3.144 | |
| 150 | 1.5 | 0.8 | 4.192 | |
| 200 | 2.0 | 1.2 | 6.288 | |
| 250 | 2.5 | 1.6 | 8.384 | 8.40 |
| 300 | 3.0 | 1.8 | 9.432 | |
| 350 | 3.5 | 2.0 | 10.480 | |
| 400 | 4.0 | 2.4 | 12.576 | |
| 450 | 4.5 | 2.8 | 14.672 | 14.80 |
| 500 | 5.0 | 3.0 | 15.720 | |
| 550 | 5.5 | 3.2 | 16.768 | |
| 600 | 6.0 | 3.4 | 17.816 | |
| 650 | 6.5 | 3.6 | 18.864 | |
| 700 | 7.0 | 3.8 | 19.912 | |
| 750 | 7.5 | 4.0 | 20.960 | |




GRAPH 31 C.B.R 12%(CEMENT + LIME + KOH)

# 4.7 UNCONFINED COMPREESSION TEST CALCULATION

CAMPUS SOIL

TABLE 41 U.C.T (CAMPUS SOIL)

SAMPLE 1

| DGR | PRR | ΔL (cm) | LOAD (kg) | € | AREA ($cm^2$) | COMP. STRESS ($kg/cm^2$) |
|---|---|---|---|---|---|---|
| 50 | 13 | 0.05 | 2.99 | 0.00641 | 11.41 | 0.26 |
| 100 | 28 | 0.1 | 6.44 | 0.0128 | 11.49 | 0.56 |
| 150 | 34.2 | 0.15 | 7.866 | 0.0192 | 11.56 | 0.68 |
| 200 | 30.4 | 0.20 | 6.992 | 0.0256 | 11.64 | 0.60 |
| 250 | 21.4 | 0.25 | 4.922 | 0.0320 | 11.71 | 0.42 |
| 300 | 12 | 0.30 | 2.76 | 0.0385 | 11.79 | 0.23 |
| 350 | 7.4 | 0.35 | 1.702 | 0.0449 | 11.87 | 0.14 |
| 400 | 4.8 | 0.40 | 1.104 | 0.0513 | 11.95 | 0.092 |

SAMPLE 2

| DGR | PRR | ΔL (cm) | LOAD (kg) | € | AREA ($cm^2$) | COMP. STRESS ($kg/cm^2$) |
|---|---|---|---|---|---|---|
| 50 | 15 | 0.05 | 3.45 | 0.00641 | 11.41 | 0.30 |
| 100 | 31.2 | 0.1 | 7.17 | 0.0128 | 11.49 | 0.62 |
| 150 | 38.4 | 0.15 | 8.83 | 0.0192 | 11.56 | 0.76 |
| 200 | 32 | 0.20 | 7.36 | 0.0256 | 11.64 | 0.63 |
| 250 | 26.4 | 0.25 | 6.07 | 0.0320 | 11.71 | 0.52 |
| 300 | 18 | 0.30 | 4.14 | 0.0385 | 11.79 | 0.35 |
| 350 | 11 | 0.35 | 2.53 | 0.0449 | 11.87 | 0.21 |
| 400 | 9.4 | 0.40 | 2.16 | 0.0513 | 11.95 | 0.18 |

Average compressive stress is 0.72 $kg/cm^2$.

AT 4%CEMENT

TABLE 42 U.C.T (4% CEMENT)

SAMPLE 1

| DGR | PRR | ΔL (cm) | LOAD (kg) | € | AREA ($cm^2$) | COMP. STRESS ($kg/cm^2$) |
|---|---|---|---|---|---|---|
| 50 | 8.4 | 0.05 | 1.93 | 0.0064 | 11.41 | 0.17 |
| 100 | 20 | 0.10 | 4.60 | 0.0128 | 11.49 | 0.40 |
| 150 | 30 | 0.15 | 6.90 | 0.0195 | 11.56 | 0.60 |
| 200 | 39.4 | 0.20 | 9.10 | 0.0256 | 11.64 | 0.78 |
| 250 | 22.2 | 0.25 | 5.10 | 0.0320 | 11.71 | 0.44 |
| 300 | 12 | 0.30 | 2.76 | 0.0385 | 11.79 | 0.23 |

SAMPLE 2

| DGR | PRR | ΔL (cm) | LOAD (kg) | € | AREA ($cm^2$) | COMP. STRESS ($kg/cm^2$) |
|---|---|---|---|---|---|---|
| 50 | 8 | 0.05 | 1.84 | 0.0064 | 11.41 | 0.16 |
| 100 | 18 | 0.10 | 4.14 | 0.0128 | 11.49 | 0.36 |
| 150 | 30 | 0.15 | 6.90 | 0.0195 | 11.56 | 0.59 |
| 200 | 38.2 | 0.20 | 8.77 | 0.0256 | 11.64 | 0.75 |
| 250 | 16.4 | 0.25 | 3.77 | 0.0320 | 11.71 | 0.32 |
| 300 | 10.4 | 0.30 | 2.39 | 0.0385 | 11.79 | 0.20 |

Average compressive stress is 0.77 $kg/cm^2$.

AT 8%CEMENT

TABLE 43 U.C.T (8% CEMENT)

SAMPLE 1

| DGR | PRR | ΔL (cm) | LOAD (kg) | € | AREA ($cm^2$) | COMP. STRESS ($kg/cm^2$) |
|---|---|---|---|---|---|---|
| 50 | 14.5 | 0.05 | 3.335 | 0.00641 | 11.41 | 0.29 |
| 100 | 31 | 0.1 | 7.13 | 0.0128 | 11.49 | 0.62 |
| 150 | 42.2 | 0.15 | 9.706 | 0.0192 | 11.56 | 0.84 |
| 200 | 51.6 | 0.20 | 11.868 | 0.0256 | 11.64 | 1.02 |
| 250 | 58 | 0.25 | 13.34 | 0.0320 | 11.71 | 1.14 |
| 300 | 65 | 0.30 | 14.95 | 0.0385 | 11.79 | 1.27 |
| 350 | 67 | 0.35 | 15.41 | 0.0449 | 11.87 | 1.29 |

SAMPLE 2

| DGR | PRR | ΔL (cm) | LOAD (kg) | € | AREA ($cm^2$) | COMP. STRESS ($kg/cm^2$) |
|---|---|---|---|---|---|---|
| 50 | 15 | 0.05 | 3.45 | 0.00641 | 11.41 | 0.30 |
| 100 | 31 | 0.1 | 7.13 | 0.0128 | 11.49 | 0.62 |
| 150 | 40 | 0.15 | 9.20 | 0.0192 | 11.56 | 0.79 |
| 200 | 52 | 0.20 | 11.76 | 0.0256 | 11.64 | 1.03 |
| 250 | 58 | 0.25 | 13.34 | 0.0320 | 11.71 | 1.14 |
| 300 | 67 | 0.30 | 15.41 | 0.0385 | 11.79 | 1.29 |
| 350 | 70 | 0.35 | 16.10 | 0.0449 | 11.87 | 1.35 |

Average compressive stress is 1.35 $kg/cm^2$.

AT 12%CEMENT

TABLE 44 U.C.T (12% CEMENT)

SAMPLE1

| DGR | PRR | ΔL (cm) | LOAD (kg) | € | AREA ($cm^2$) | COMP. STRESS ($kg/cm^2$) |
|---|---|---|---|---|---|---|
| 50 | 8.2 | 0.05 | 1.886 | 0.0641 | 11.41 | 0.16 |
| 100 | 17 | 0.1 | 3.91 | 0.0128 | 11.49 | 0.34 |
| 150 | 22.43 | 0.15 | 5.16 | 0.0192 | 11.56 | 0.45 |
| 200 | 27.28 | 0.20 | 6.27 | 0.0256 | 11.64 | 0.54 |
| 250 | 30 | 0.25 | 6.9 | 0.0320 | 11.71 | 0.59 |
| 300 | 32.8 | 0.30 | 7.54 | 0.0385 | 11.79 | 0.63 |
| 350 | 33 | 0.35 | 7.59 | 0.0449 | 11.87 | 0.65 |

SAMPLE 2

| DGR | PRR | ΔL (cm) | LOAD (kg) | € | AREA ($cm^2$) | COMP. STRESS ($kg/cm^2$) |
|---|---|---|---|---|---|---|
| 50 | 10 | 0.05 | 2.30 | 0.0641 | 11.41 | 0.20 |
| 100 | 16 | 0.1 | 3.68 | 0.0128 | 11.49 | 0.32 |
| 150 | 24 | 0.15 | 5.52 | 0.0192 | 11.56 | 0.48 |
| 200 | 29 | 0.20 | 6.68 | 0.0256 | 11.64 | 0.57 |
| 250 | 32 | 0.25 | 7.36 | 0.0320 | 11.71 | 0.63 |
| 300 | 34 | 0.30 | 7.82 | 0.0385 | 11.79 | 0.66 |
| 350 | 35 | 0.35 | 8.05 | 0.0449 | 11.87 | 0.68 |

Average compressive stress is 0.67 $kg/cm^2$.

AT 4% (CEMENT+LIME)

TABLE 45 U.C.T 4% (CEMENT + LIME)

SAMPLE 1

| DGR | PRR | ΔL (cm) | LOAD (kg) | € | AREA ($cm^2$) | COMP. STRESS ($kg/cm^2$) |
|---|---|---|---|---|---|---|
| 50 | 17 | 0.05 | 3.91 | 0.00641 | 11.41 | 0.34 |
| 100 | 35 | 0.1 | 8.05 | 0.0128 | 11.49 | 0.70 |
| 150 | 69 | 0.15 | 15.87 | 0.0192 | 11.56 | 1.37 |
| 200 | 82 | 0.20 | 18.86 | 0.0256 | 11.64 | 1.62 |
| 250 | 91 | 0.25 | 20.93 | 0.0320 | 11.71 | 1.78 |
| 300 | 97 | 0.30 | 22.31 | 0.0385 | 11.79 | 1.89 |

SAMPLE 2

| DGR | PRR | ΔL (cm) | LOAD (kg) | € | AREA ($cm^2$) | COMP. STRESS ($kg/cm^2$) |
|---|---|---|---|---|---|---|
| 50 | 15 | 0.05 | 3.45 | 0.00641 | 11.41 | 0.30 |
| 100 | 29 | 0.1 | 6.67 | 0.0128 | 11.49 | 0.58 |
| 150 | 61 | 0.15 | 14.03 | 0.0192 | 11.56 | 1.21 |
| 200 | 74 | 0.20 | 17.02 | 0.0256 | 11.64 | 1.46 |
| 250 | 83 | 0.25 | 19.09 | 0.0320 | 11.71 | 1.63 |
| 300 | 91 | 0.30 | 20.93 | 0.0385 | 11.79 | 1.78 |

Average compressive stress is $1.84 kg/cm^2$.

AT 8% (CEMENT+LIME)

TABLE 46 U.C.T 8% (CEMENT + LIME)

SAMPLE 1

| DGR | PRR | ΔL (cm) | LOAD (kg) | € | AREA ($cm^2$) | COMP. STRESS ($kg/cm^2$) |
|---|---|---|---|---|---|---|
| 50 | 19 | 0.05 | 4.37 | 0.00641 | 11.41 | 0.38 |
| 100 | 42 | 0.1 | 9.66 | 0.0128 | 11.49 | 0.84 |
| 150 | 76 | 0.15 | 17048 | 0.0192 | 11.56 | 1.51 |
| 200 | 94.4 | 0.20 | 21.71 | 0.0256 | 11.64 | 1.86 |
| 250 | 102.2 | 0.25 | 23.51 | 0.0320 | 11.71 | 2.01 |
| 300 | 106.4 | 0.30 | 24.47 | 0.0385 | 11.79 | 2.08 |

SAMPLE 2

| DGR | PRR | ΔL (cm) | LOAD (kg) | € | AREA ($cm^2$) | COMP. STRESS ($kg/cm^2$) |
|---|---|---|---|---|---|---|
| 50 | 20 | 0.05 | 4.60 | 0.00641 | 11.41 | 0.40 |
| 100 | 45 | 0.1 | 10.35 | 0.0128 | 11.49 | 0.90 |
| 150 | 80 | 0.15 | 18.40 | 0.0192 | 11.56 | 1.59 |
| 200 | 102.2 | 0.20 | 23.50 | 0.0256 | 11.64 | 2.02 |
| 250 | 106.2 | 0.25 | 24.43 | 0.0320 | 11.71 | 2.09 |
| 300 | 108 | 0.30 | 24.84 | 0.0385 | 11.79 | 2.11 |

Average compressive stress is 2.09 $kg/cm^2$.

AT 12% (CEMENT+LIME)

TABLE 47 U.C.T (12% CEMENT + LIME)

SAMPLE 1

| DGR | PRR | ΔL (cm) | LOAD (kg) | € | AREA ($cm^2$) | COMP. STRESS ($kg/cm^2$) |
|---|---|---|---|---|---|---|
| 50 | 4 | 0.05 | 0.92 | 0.00641 | 11.41 | 0.081 |
| 100 | 16.4 | 0.10 | 3.77 | 0.0128 | 11.49 | 0.33 |
| 150 | 26.3 | 0.15 | 6.05 | 0.0192 | 11.56 | 0.52 |
| 200 | 29.6 | 0.20 | 6.81 | 0.0256 | 11.64 | 0.59 |
| 250 | 37 | 0.25 | 8.51 | 0.0320 | 11.71 | 0.73 |

SAMPLE 2

| DGR | PRR | ΔL (cm) | LOAD (kg) | € | AREA ($cm^2$) | COMP. STRESS ($kg/cm^2$) |
|---|---|---|---|---|---|---|
| 50 | 4 | 0.05 | 0.92 | 0.00641 | 11.41 | 0.081 |
| 100 | 16 | 0.1 | 3.68 | 0.0128 | 11.49 | 0.32 |
| 150 | 26 | 0.15 | 5.98 | 0.0192 | 11.56 | 0.52 |
| 200 | 28 | 0.20 | 6.44 | 0.0256 | 11.64 | 0.55 |
| 250 | 36.6 | 0.25 | 8.418 | 0.0320 | 11.71 | 0.72 |

Average compressive stress is 0.73 $kg/cm^2$.

AT 4% (CEMENT+LIME+KOH)

TABLE 48 U.C.T 4% (CEMENT + LIME + KOH)

SAMPLE 1

| DGR | PRR | ΔL (cm) | LOAD (kg) | € | AREA ($cm^2$) | COMP. STRESS ($kg/cm^2$) |
|---|---|---|---|---|---|---|
| 50 | 12 | 0.05 | 2.76 | 0.00641 | 11.41 | 0.24 |
| 100 | 25 | 0.1 | 5.75 | 0.0128 | 11.49 | 0.50 |
| 150 | 52 | 0.15 | 11.96 | 0.0192 | 11.56 | 1.03 |
| 200 | 63 | 0.20 | 14.49 | 0.0256 | 11.64 | 1.24 |
| 250 | 69 | 0.25 | 15.87 | 0.0320 | 11.71 | 1.35 |
| 300 | 72 | 0.30 | 16.56 | 0.0385 | 11.79 | 1.40 |

SAMPLE 2

| DGR | PRR | ΔL (cm) | LOAD (kg) | € | AREA ($cm^2$) | COMP. STRESS ($kg/cm^2$) |
|---|---|---|---|---|---|---|
| 50 | 11 | 0.05 | 2.53 | 0.00641 | 11.41 | 0.22 |
| 100 | 22 | 0.1 | 5.06 | 0.0128 | 11.49 | 0.44 |
| 150 | 47 | 0.15 | 10.81 | 0.0192 | 11.56 | 0.93 |
| 200 | 59 | 0.20 | 13.57 | 0.0256 | 11.64 | 1.17 |
| 250 | 63 | 0.25 | 14.49 | 0.0320 | 11.71 | 1.24 |
| 300 | 70 | 0.30 | 16.10 | 0.0385 | 11.79 | 1.36 |

Average compressive stress is 1.38 $kg/cm^2$.

AT 8% (CEMENT+LIME+KOH)

TABLE 49 U.C.T 8% (CEMENT + LIME + KOH)

SAMPLE 1

| DGR | PRR | ΔL (cm) | LOAD (kg) | € | AREA ($cm^2$) | COMP. STRESS ($kg/cm^2$) |
|---|---|---|---|---|---|---|
| 50 | 17 | 0.05 | 3.91 | 0.00641 | 11.41 | 0.34 |
| 100 | 39 | 0.1 | 8.97 | 0.0128 | 11.49 | 0.78 |
| 150 | 72 | 0.15 | 16.56 | 0.0192 | 11.56 | 1.43 |
| 200 | 82 | 0.20 | 18.86 | 0.0256 | 11.64 | 1.62 |
| 250 | 98 | 0.25 | 22.54 | 0.0320 | 11.71 | 1.92 |
| 300 | 102 | 0.30 | 23.46 | 0.0385 | 11.79 | 1.98 |

SAMPLE 2

| DGR | PRR | ΔL (cm) | LOAD (kg) | € | AREA ($cm^2$) | COMP. STRESS ($kg/cm^2$) |
|---|---|---|---|---|---|---|
| 50 | 18 | 0.05 | 4.14 | 0.00641 | 11.41 | 0.36 |
| 100 | 41 | 0.1 | 9.43 | 0.0128 | 11.49 | 0.82 |
| 150 | 73 | 0.15 | 16.79 | 0.0192 | 11.56 | 1.45 |
| 200 | 86 | 0.20 | 19.78 | 0.0256 | 11.64 | 1.70 |
| 250 | 102 | 0.25 | 23.46 | 0.0320 | 11.71 | 2.00 |
| 300 | 104 | 0.30 | 23.92 | 0.0385 | 11.79 | 2.03 |

Average compressive stress is 2.0 $kg/cm^2$.

AT 12% (CEMENT+LIME+KOH)

TABLE 50 U.C.T 12% (CEMENT + LIME + KOH)

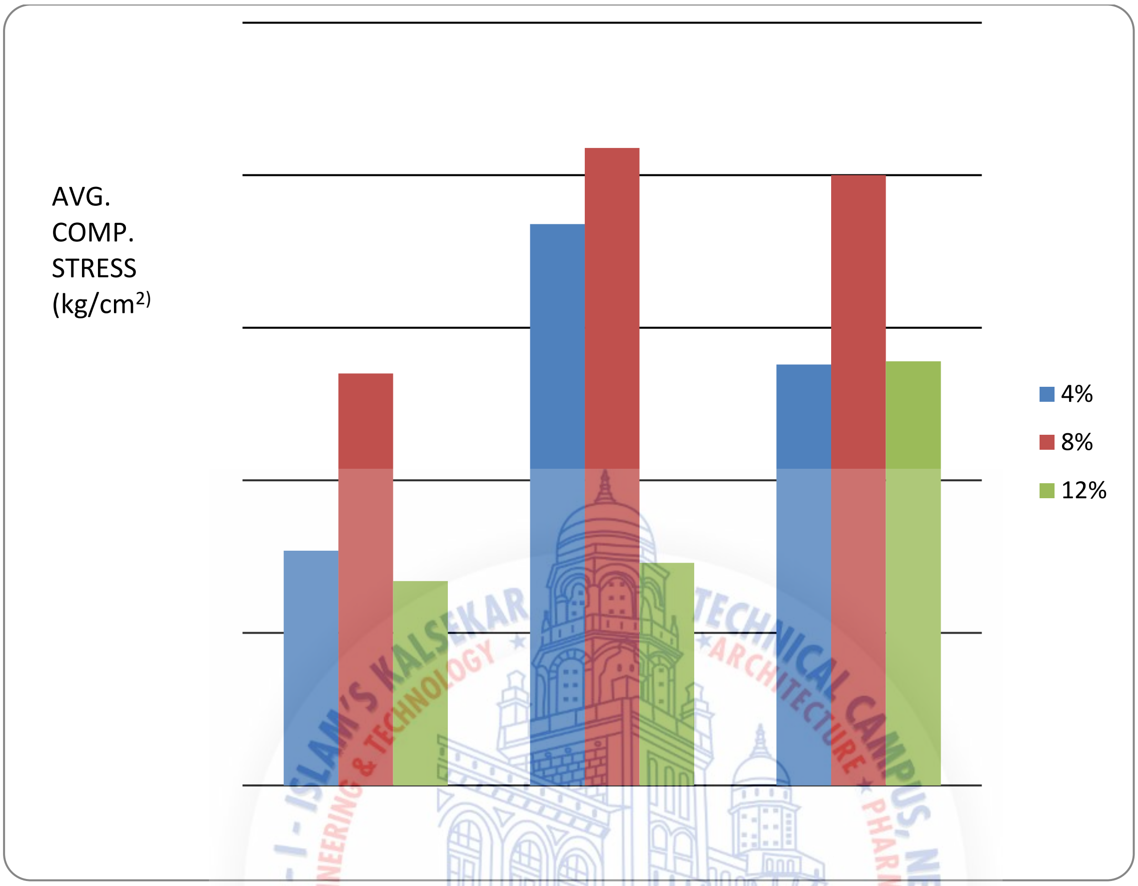
SAMPLE 1

| DGR | PRR | ΔL (cm) | LOAD (kg) | € | AREA ($cm^2$) | COMP. STRESS ($kg/cm^2$) |
|---|---|---|---|---|---|---|
| 50 | 16 | 0.05 | 3.68 | 0.00641 | 11.41 | 0.32 |
| 100 | 38 | 0.1 | 8.74 | 0.0128 | 11.49 | 0.76 |
| 150 | 42 | 0.15 | 9.66 | 0.0192 | 11.56 | 0.83 |
| 200 | 68 | 0.20 | 15.64 | 0.0256 | 11.64 | 1.34 |
| 250 | 74 | 0.25 | 17.04 | 0.0320 | 11.71 | 1.45 |

SAMPLE 2

| DGR | PRR | ΔL (cm) | LOAD (kg) | € | AREA ($cm^2$) | COMP. STRESS ($kg/cm^2$) |
|---|---|---|---|---|---|---|
| 50 | 14 | 0.05 | 3.22 | 0.00641 | 11.41 | 0.28 |
| 100 | 36 | 0.1 | 8.28 | 0.0128 | 11.49 | 0.72 |
| 150 | 41 | 0.15 | 9.43 | 0.0192 | 11.56 | 0.82 |
| 200 | 64 | 0.20 | 14.72 | 0.0256 | 11.64 | 1.26 |
| 250 | 68 | 0.25 | 15.64 | 0.0320 | 11.71 | 1.33 |

Average compressive stress is 1.39 $kg/cm^2$.




GRAPH 32 U.C.T

# CHAPTER5

# RESULTS AND DISCUSSIONS

## 5.1 SIEVE ANALYSIS:

$C_U$=10.59;

$C_C$ =1.55

AS PER INDIAN STANDARD

$C_U$ is greater than 6

$C_C$ is between 1 to 3

Therefore, our soil is WELL GRADED SAND.

## 5.2 LIQUID LIMIT:

| | | |
|---|---|---|
| CAMPUS SOIL | : | 67.00% |
| AT 4% CEMENT | : | 51.50% |
| AT 8% CEMENT | : | 45.00% |
| AT 12% CEMENT | : | 45.00% |
| AT 4% (CEMENT+LIME) | : | - |
| AT 8% (CEMENT+LIME) | : | - |
| AT 12% (CEMENT+LIME) | : | - |
| AT 4% (CEMENT+LIME+ KOH) | : | - |
| AT 8% (CEMENT+LIME+ KOH) | : | - |
| AT 12% (CEMENT+LIME+ KOH) | : | - |

As the cement percentage increases, the liquid limit decreases. This is because the cement particles are non-plastic in nature. They obviously reduce the plasticity characteristic of soil. This can be made use of in highway constructions. However the liquid limit at 8% cement and 12% cement are observed to be same.

# 5.3 PLASTIC LIMIT

| | | |
|---|---|---|
| CAMPUS SOIL | : | 36.66% |
| AT 4% CEMENT | : | 45.00% |
| AT 8% CEMENT | : | 40.00% |
| AT 12% CEMENT | : | 32.38% |
| AT 4% (CEMENT+LIME) | : | - |
| AT 8% (CEMENT+LIME) | : | - |
| AT 12%( CEMENT+LIME) | : | - |
| AT 4% (CEMENT+LIME+ KOH) | : | - |
| AT 8% (CEMENT+LIME+ KOH) | : | - |
| AT 12% (CEMENT+LIME+ KOH) | : | - |

For 4% cement addition, plastic limit shows increase in its value. But, for 8% cement addition, again there is a decline in plastic limit. For 12% cement addition, plastic limit still lowers. The usual trend is plastic limit should go on lowering gradually as the cement (non-plastic material) goes on increasing. Instead, for 4% cement, the plastic limit has increased. This is possibility because of the uncertainty involved in the test method. The test entirely depends on manual judgment. The error might have crept-in due to this.

# 5.4 SHRINKAGE LIMIT:

| | | |
|---|---|---|
| CAMPUS SOIL | : | 42.044% |
| AT 4% CEMENT | : | 12.056% |
| AT 8% CEMENT | : | 0.938% |
| AT 12% CEMENT | : | 28.960% |
| AT 4% (CEMENT+LIME) | : | 16.362% |
| AT 8% (CEMENT+LIME) | : | 22.032% |
| AT 12% (CEMENT+LIME) | : | 29.760% |
| AT 4% (CEMENT+LIME+ KOH) | : | - |
| AT 8% (CEMENT+LIME+ KOH) | : | - |
| AT 12% CEMENT+LIME+ KOH | : | - |

Initially shrinkage limit was high, indicating the shrinking property of soil. However, 4% addition of cement decreased the shrinkage limit considerably. As the cement addition is 8%, it drastically got reduced. But, at 12% cement addition, it again showed an increasing trend. However, as the parentage of (cement +lime) was increased, the shrinkage limit showed the gradual increase.

# 5.5 SPECIFIC GRAVITY:

| | | |
|---|---|---|
| CAMPUS SOIL | : | 2.45 |
| AT 4% CEMENT | : | 2.45 |
| AT 8% CEMENT | : | 2.88 |
| AT 12% CEMENT | : | 2.47 |
| AT 4% (CEMENT+LIME) | : | 2.28 |
| AT 8% CEMENT+LIME | : | 2.66 |
| AT 12% (CEMENT+LIME) | : | 2.43 |
| AT 4% (CEMENT+LIME+ KOH) | : | 2.46 |
| AT 8% (CEMENT+LIME+ KOH) | : | 3.01 |
| AT 12% (CEMENT+LIME+ KOH) | : | 3.88 |

Specific gravity being one of the most important parameters used frequently in Geotechnical calculations, the effect of additives on specific gravity becomes a significant consideration. It can be clearly seen that for 8% & 12% addition of (Cement + Lime + KOH), the specific gravity value goes over 3.00. The addition of KOH has made the considerable difference, as evident from the results.

# 5.6 STANDARD PROCTOR TEST

1. Optimum moisture content

| | | |
|---|---|---|
| CAMPUS SOIL | : | 11.00% |
| AT 4% CEMENT | : | 15.56% |
| AT 8% CEMENT | : | 14.10% |
| AT 12% CEMENT | : | 11.00% |
| AT 4% (CEMENT+LIME) | : | 26.10% |
| AT 8% (CEMENT+LIME) | : | 14.00% |
| AT 12% (CEMENT+LIME) | : | 26.00% |
| AT 4% (CEMENT+LIME+ KOH) | : | 20.00% |
| AT 8% (CEMENT+LIME+ KOH) | : | 24.00% |
| AT 12% (CEMENT+LIME+ KOH) | : | 23.68% |

2. Maximum Dry Density

| | | |
|---|---|---|
| CAMPUS SOIL | : | 1.88g/cm$^3$ |
| AT 4% CEMENT | : | 1.42g/cm$^3$ |
| AT 8% CEMENT | : | 1.40g/cm$^3$ |
| AT 12% CEMENT | : | 1.41g/cm$^3$ |
| AT 4% (CEMENT+LIME) | : | 1.58g/cm$^3$ |
| AT 8% (CEMENT+LIME) | : | 1.49g/cm$^3$ |
| AT 12% (CEMENT+LIME) | : | 1.77g/cm$^3$ |
| AT 4% (CEMENT+LIME+ KOH) | : | 1.46g/cm$^3$ |
| AT 8% (CEMENT+LIME+ KOH) | : | 1.52g/cm$^3$ |
| AT 12% (CEMENT+LIME+ KOH) | : | 1.57g/cm$^3$ |

There is a mixed effect on maximum dry density & optimum moisture content for the various combinations of the additives.

## 5.7 CALIFORNIA BEARING RATIO

1. CBR % at 2.5mmpentation

| | | |
|---|---|---|
| CAMPUS SOIL | : | 0.846% |
| AT 4% CEMENT | : | 0.535% |
| AT 8% CEMENT | : | 0.910% |
| AT 12% CEMENT | : | 0.490% |
| AT 4% (CEMENT+LIME) | : | 0.610% |
| AT 8% (CEMENT+LIME) | : | 0.840% |
| AT 12% (CEMENT+LIME) | : | 0.569% |
| AT 4% (CEMENT+LIME+ KOH) | : | 0.590% |
| AT 8% (CEMENT+LIME+ KOH) | : | 0.450% |
| AT 12% (CEMENT+LIME+ KOH) | : | 0.610% |

2.CBR % at 5 mm penetration

| | | |
|---|---|---|
| CAMPUS SOIL | : | 1.012% |
| AT 4% CEMENT | : | 0.710% |
| AT 8% CEMENT | : | 1.630% |
| AT 12% CEMENT | : | 0.660% |
| AT 4% (CEMENT+LIME) | : | 0.764% |
| AT 8% (CEMENT+LIME) | : | 1.121% |
| AT 12% (CEMENT+LIME) | : | 0.720% |
| AT 4% (CEMENT+LIME+ KOH) | : | 0.770% |
| AT 8% (CEMENT+LIME+ KOH) | : | 0.530% |
| AT 12% (CEMENT+LIME+ KOH) | : | 0.720% |

The highest CBR value is reported at 8% cement for 2.5 mm penetration. For 5 mm penetration also, the highest CBR value is at 8% cement. However, the CBR value is always reported at 2.5 mm penetration.

# 5.8UNCONFINED COMPRESSION TEST

COMPRESSIVE STRESS

| | | |
|---|---|---|
| CAMPUS SOIL | : | 0.72kg/cm$^2$ |
| AT 4% CEMENT | : | 0.77kg/cm$^2$ |
| AT 8% CEMENT | : | 1.35kg/cm$^2$ |
| AT 12% CEMENT | : | 0.67kg/cm$^2$ |
| AT 4% (CEMENT+LIME) | : | 1.84kg/cm$^2$ |
| AT 8% (CEMENT+LIME) | : | 2.09kg/cm$^2$ |
| AT 12% (CEMENT+LIME) | : | 0.73kg/cm$^2$ |
| AT 4% (CEMENT+LIME+ KOH) | : | 1.38kg/cm$^2$ |
| AT 8% (CEMENT+LIME+ KOH) | : | 2.00kg/cm$^2$ |
| AT 12% (CEMENT+LIME+ KOH) | : | 1.39kg/cm$^2$ |

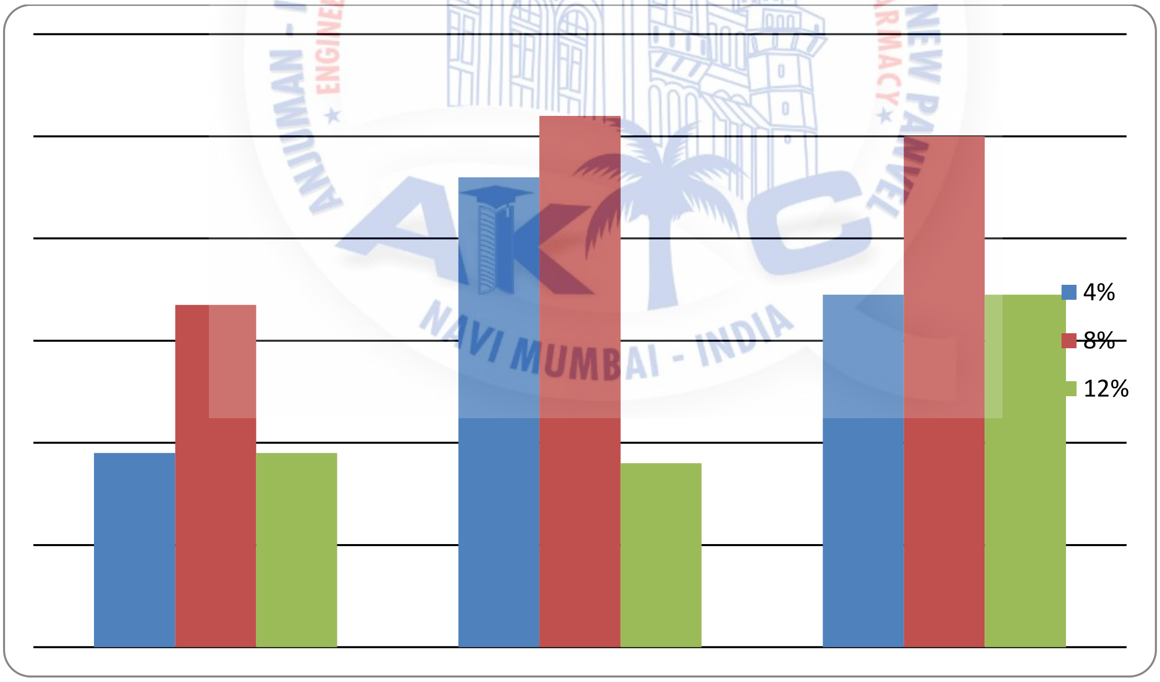
Unconfined compression strength is most significant parameter in soil engineering. At 8% (cement+lime) & at 8% (cement + lime + KOH), the unconfined compression strength is seen to be highest (around 2 kg/cm$^2$).

# 5.9 SHEAR STRENGTH

Shear strength test had not been performed but from unconfined compressive strength test (qu), the shear strength of the soil will be qu/2

COMPRESSIVE STRESS

| | | |
|---|---|---|
| CAMPUS SOIL | : | 0.36 kg/cm$^2$ |
| AT 4% CEMENT | : | 0.38 kg/cm$^2$ |
| AT 8% CEMENT | : | 0.67 kg/cm$^2$ |
| AT 12% CEMENT | : | 0.38 kg/cm$^2$ |
| AT 4% (CEMENT+LIME) | : | 0.92 kg/cm$^2$ |
| AT 8% (CEMENT+LIME) | : | 1.04kg/cm$^2$ |
| AT 12% (CEMENT+LIME) | : | 0.36kg/cm$^2$ |
| AT 4% (CEMENT+LIME+ KOH) | : | 0.69 kg/cm$^2$ |
| AT 8% (CEMENT+LIME+ KOH) | : | 1.00kg/cm$^2$ |
| AT 12% (CEMENT+LIME+ KOH) | : | 0.69 kg/cm$^2$ |




GRAPH 33 SHEAR STRENGTH OF SOIL

By addition of cement, lime and KOH in soil the shear strength of soil has increased and it gives better result at8% combination.

# CHAPTER 6

# CONCLUSION

- Owing to the non-plastic nature of cement particles, the liquid limit of soil was observed to be decreasing as the cement percentage was made to increase. The soils to be used for various civil engineering applications, especially in highway constructions, require controlled liquid limit, as per the relevant code values. Stabilization of soil using cement would be one of the alternatives for the same.

- Plastic limit was also seen to be decreasing as the cement percentage was increased. The soil becomes plastic &loses its plasticity characteristics partially due to the addition of non-plastic cement.

- By controlling the liquid limit & plastic limit of soil, the required plasticity index can be maintained for the various large civil engineering projects.

- The effect of addition of cement & (cement + lime) was seen on shrinkage limit of soil. Shrinkage limit got reduced as the additive percentages were increased. As shrinkage limit is connected with the volume change of soil, cement & lime can be advantageously utilized to achieve the required shrinkage limit for the soil.

- The value of specific gravity can be increased considerably by the combined dosage of (cement + lime + KOH). Increased specific gravity of the soil has enormous advantages in soil engineering.

- The various combinations of the additives are seen to be having significant effect on optimum moisture content & maximum dry density of soil.

- CBR value, which forms the basis for the highway design, was seen to be highest at the 8% dosage of cement.

- The dosages of (cement + lime) & (cement + lime + KOH)were seen to be increasing the unconfined compression strength of the soil. As the shear strength, which is one of the deciding parameters in soil engineering, depends upon the unconfined compression strength as per one of the approximate rules, the shear strength also obviously increases with the help of the required dosage of the additives.

- The three additives viz. cement, lime & potassium hydroxide have considerable roles in modifying the properties of the soil.

- These additives can be used to enhance the engineering properties of the soil, as per the need of the project.

- The existing soil can be improved with the different dosages of these additives, so that the soil serves its intended purpose.

# CHAPTER 7

# REFRENCES

1. SatyendraMittal, 2013, “An Introduction to Ground improvement engineering",scientificinternational Private limited.

2.Olaniyan OS, Olaoye RA, Okeyinka OM,Olaniyan DB, December 2011 , “Soil stabilization using sodium hydroxide additives” International Journal of Civil & Environmental Engineering.

3. J Nyamangara, S Munotengwa, P Nyamugafata, G Nyamadzawo, 2007, “The effect of hydroxide solutions on the structural stability and saturated hydraulic conductivity of four tropical soils”

4. B.C Punmia B. C., “Soil mechanics and foundation engineering”.

5. Asma Muhmed, Dariusz Wanatowski ,May-June 2013, “Effect of lime stabilization on the strength of microstructure of clay” IOSR-Journal of Mechanical and Civil Engineering(IOSR-JMCE).

6.Basit Riyaz, Munib Hilal, Mujtaba Mir, Munib Bashir, March 2015, “Study of Soil Cement Stabilization for Pavement Base Course and Sub grade” International Journal of Engineering Research and Management Technology.