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S.J.C INSTITUTE OF TECHNOLOGY

DEPARTMENT OFCIVIL ENIGINEERING

Chickballapur-562101

CERTIFICATE

This is to certify that the Project work entitled **"IMPROVEMENT OF MECHANICAL PROPERTIES OF LATERITESOIL TREATED WITH ADMIXITURES"** carried out by **ANITHA B R (1SJ16CV401), ANUSHREE R S (1SJ16CV402), SINDHU P M (1SJ16CV432), KUSUMA M (1SJ14CV039)** students of **S J C Institute of Technology** in partial fulfillment for the award of Bachelor of Engineering in Civil Engineering of the **Visvesvaraya Technological University, Belgaum** during the year **2018-19.** It is certificated that all corrections / suggestions indicated for internal assessment have been incorporated in the report deposited in departmental library.

The Project report has been approved as it satisfies the academic requirements in respect of project work prescribed for the said Degree.

17/6/19	17/6/19	17/6/19
Signature of the Guide	**Signature of the Project co-ordinator**	**Signature of HOD**
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VISVESVARAYA TECHNOLOGICAL UNIVERSITY

Jnana Sangama, Belgaum, Karnataka, India -590 014

A PROJECT REPORT

On

"IMPROVEMENT OF MECHANICALPROPERTIES OF LATERITE SOIL TREATED WITH ADMIXITURES"

Submitted in partial fulfilment of the requirements for the continuation of Degree of Bachelor of Engineering

in

CIVIL ENGINEERING

Submitted by

ANITHA B R

(1SJ16CV401)

Under the Guidance of

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2018-2019

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ANITHA B R

(1SJ16CV401)

CHAPTER-1

INTRODUCTION

1.1 GENERAL

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

From the beginning of construction work, the necessity of enhancing soil properties has come to the light. Ancient civilizations of the Chinese, Romans and Incas utilized various methods to improve soil strength.

In India, the modern era of soil stabilization began in early 1970's, with a general shortage of petroleum and aggregates, it became necessary for the engineers to look at means to improve soil other than replacing the poor soil at the building site. With the availability of better research, materials and equipment, it is emerging as a popular and cost-effective method for soil improvement.

Here in this project laterite soil stabilization has been done with the help of building materials such as steel slag and saw dust. Laterite soil is known as rock type soil with high organic. It has low capacity and high compressibility many kind of soil improvement method has been adopted to improve its behavior. Those methods are not environmentally friendly. Because of that stabilization method using steel slag and saw dust had been develop to improve the behavior of laterite soil.

Soil is the mixture of minerals, organic matter and gases, liquid that can support plant life.It is aexists a part of exosphere and it performs four important functions:

1. Medium for plant growth
2. Means of water storage supply and purification Modifier the atmosphere
3. Habitat for organism that take part in decomposition and creation of habitat for that organisms.

4. Soil is considered by the engineer as a Complex material produced by the weathering of the solid rock. Soil classification I the arrangement of soils into different groups such that the soil in a particular group have similar behavior.
5. Soils is generally May be classified as cohesion less and cohesive or as course grained and fine grained. These terms however are too general and include a wide range of engineering properties. Hence, additional means of categorization are necessary to make the terms more meaningful in engineering practice.

1.2 SOIL CLASSIFICATION

Natural soil deposits are never homogeneous in character, wide variations in properties and behavior are commonly observed. Deposits that exhibit similar average properties, in general, may be grouped together as a class. Though classification of soil can obtain an appropriate, but fairly accurate idea of the average properties of the soil group.

From engineering point of view, classification be made based on the suitability of a soil for use as a foundation of soils, all the engineering properties are determined after conducting a large no of tests. However, an appropriate assessment of the engineering properties can be obtained from index properties after conducting classification tests. A soil is classified according to the index properties such as particle size and plasticity characteristics.

A classification system that provides a common language between engineers dealing with soils. It is useful in exchange of information and experience between the geotechnical engineers. For final design of large structure, the engineering properties should be determined by conducting elaborate tests on samples. Requirements for a soil classification system.

For a soil classification system to be useful to the geotechnical engineers, it should have the following basic requirements:

1. It should have a limited number of groups.
2. It should be based on the engineering properties, which are most relevant for the purpose for which the classification has been made.

3. It should be simple and should use the terms, which are easily understood. Any soil classification must provide off with information about the probable engineering behavior of a soil. Most of the classification system developed satisfy the above requirements.

1.3 SOIL CLASSIFICATION SYSTEMS

Several classification systems were evolved by different organizations having a specific purpose as the object. A. Casagrande (1948) describes the systems developed and used in highway engineering, airfield construction etc. The two classification systems, which are adopted by the US engineering agencies and the State Departments, are the Unified Soil Classification (UCCS) and the American Association of State Highway and Transportation Officials (AASHTO) system.

For general engineering purposes, soils may be classified by the following systems

1. Particle size classification
2. Textural classification
3. Highway Research Board (HRB) classification
4. Unified Soil Classification
5. Indian Soil Classification

1.3.1 PARTICLE SIZE CLASSIFICATION

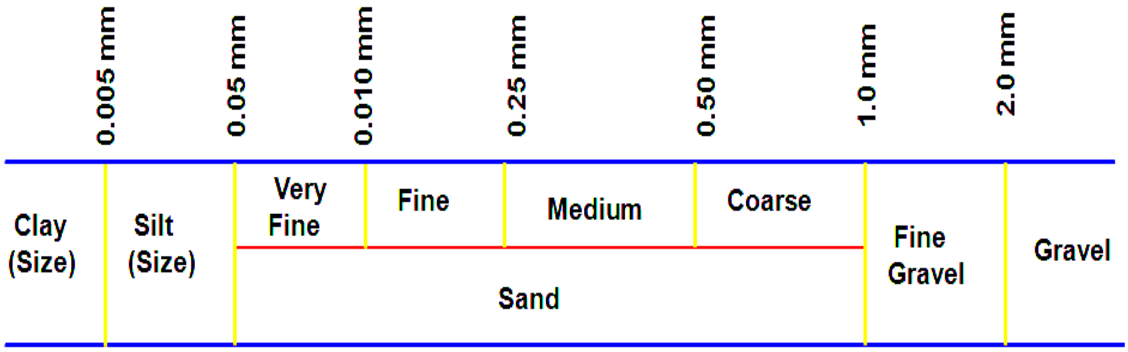
The size of individual particles has an important influence on the behavior of soils. It is a general practice to classify the soils into four broad groups, namely, gravel, sand, silt size and clay size.

Classification based on particle size is of immense value in the case of coarse-grainedsoils rather than fine-grained soils because the behavior of such soils depends mainly onthe particle size, whereas fine-grained soils depend on the plasticity characteristics. Someof the classification systems based on particle size alone are:

i) U.S. Bureau of Soil and Public Road Administration (PRA) System Classification
ii) International soil classification
iii) M.I.T System
iv) Indian Standard Classification

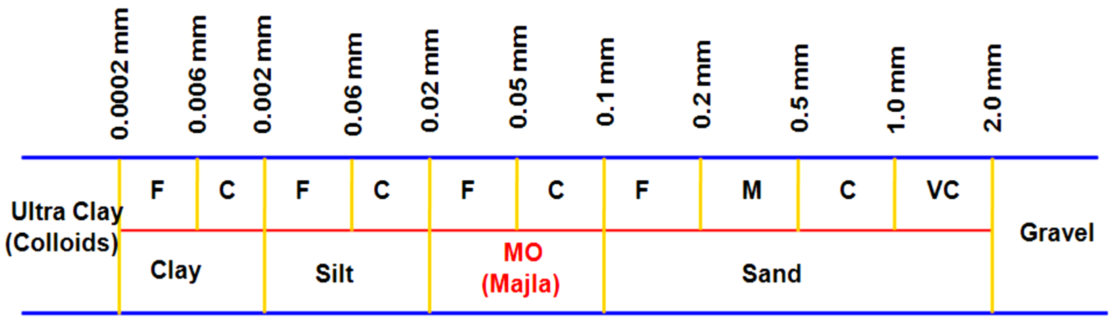
(i) U.S. Bureau of Soils Classification

This is one of the earliest classification systems developed in 1895 by the U.S. Bureau of soils.



(ii) International Classification System

This system was proposed for general use at the international Soils Congress held at Washington in 1927. This was known as the Swedish Classification system before it was adopted as International system. In this system, an additional term Mo (Majla) has been used for soil particles in the size range between sand and silt.



(iii) MIT System

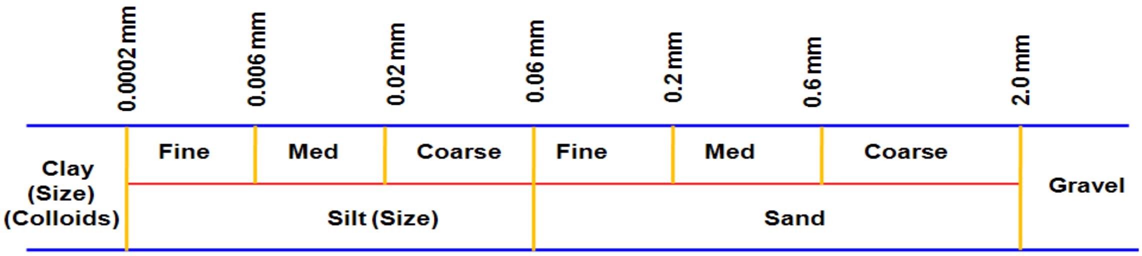
Prof. G. Gilory at Massachusetts Institute of Technology in U.S.A developed MIT system of classification of soils. In this system, the soil is divided into four groups:

(a) Gravel, particle size greater than 2 mm

(b) Sand, particle size between 0.06 mm to 2 mm

(c) Silt size, particle size between 0.002 mm to 0.06 mm

(d) Clay size, particle size smaller than 0.002 mm (2 μm)



iv) Indian Standard Classification

As per I.S. Classification (IS: 1498-1970) the soil is divided into six groups:

(a) Boulders, particle size greater than 300 mm

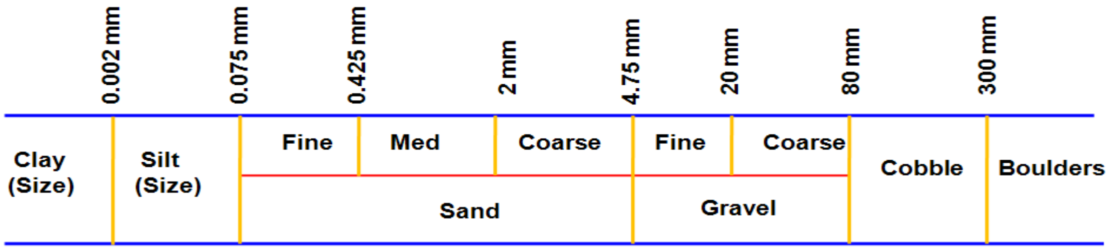
(b) Cobble, particle size between 80 mm to 300 mm

(c) Gravel, particle size between 4.75 mm to 80 mm

(d) Sand, particle size between 0.075 mm to 4.75 mm

(e) Silt (size), particle size between 0.002 mm to 0.075 mm

(f) Clay (size), particle size smaller than 0.002 mm (2 µm)



1.3.2 TEXTURAL CLASSIFICATION

The visual appearance of a soil is called its texture. The texture depends upon the particle size, shape of particles and gradation of particles and gradation of particles. The textural classification incorporates only the particle size. Here, the term texture is used to express the percentage of the three constituents of soils, namely, sand, silt and clay.

According to the textural classification system, the percentages of sand (size 0.05 to 2.0 mm), silt (size 0.005 to 0.05 mm) and clay (size less tan 0.005 mm) are plotted along the three sides of an equilateral triangle. The equilateral triangle is divided into 10 zones, each zone gives a type of soil. The soil can be classified by determining the zone in which it lies. A key is given that indicates the directions in which the lines are to be drawn to locate the point.

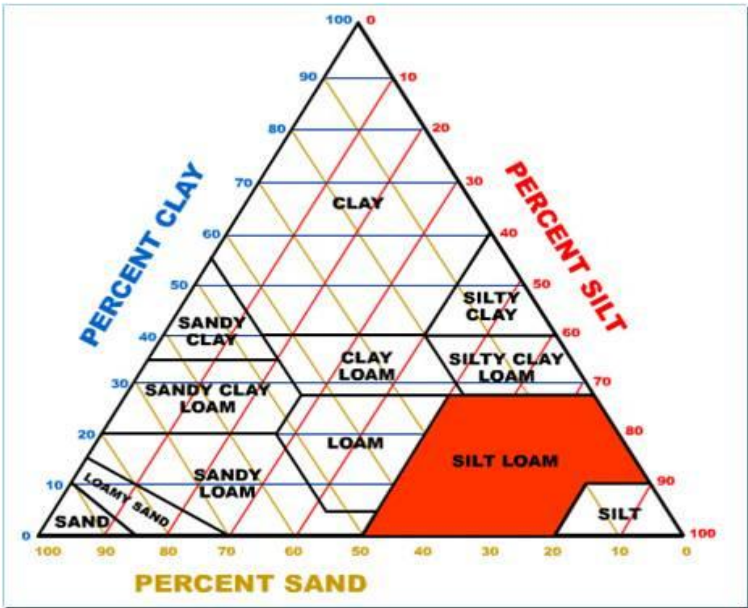


Fig.1.1 Textural Classification of soil

The textural classification system is useful for classifying soils consisting of different constituents. The system assumes that the soil does not contain particles larger than 2-mm size. However, if the soil contains a certain percentage of soil particles larger than 2 mm, a correction is required in which the sum of the percentages of sand, silt and clay is increased to 100 %. For e.g. if a soil contains 20 % particles of size larger than 2-mm size, the actual sum of the percentages of sand, silt and clay particles is 80 %. Let these be respectively 12, 24, and 44 %. The corrected percentages would be obtained by multiplying with a factor of 100/80. Therefore, the corrected percentages are 15, 30 and 55 %. The textural classification of the soil would be done based on these corrected percentages.

1.3.3 INDIAN STANDARD SOIL CLASSIFICATION SYSTEM

Indian Standard Soil Classification system is in many respects similar to the Unified system. However, there is one basic difference in the classification of fine-grained soils. The fine-grained soils in this system are sub-dived into three categories of low, medium and high compressibility instead of two categories of low and high compressibility in Unified soil classification system.

Soils are divided into three broad divisions:

1) Coarse-grained soils, when 50 % or more of the total material by weight retained on 75 μm IS sieve.

2) Fine-grained soils, when more than 50 % of the total material passes 75 µm IS sieve.
3) If the soil is highly organic and contains a large percentage of organic matter and particles of decomposed vegetation.

COARSE GRAINED SOIL

The classification of coarse grained soil is done on the basis of their grained and graduation characteristics as illustrate in table, when the fines present in them less than 5% by weight. Coarse grained soils are sub divided into gravel and sand. The soil is termed gravel when more than 50% of coarse fracture is retained in 4.75mm IS sieve, and termed if more than 50% of coarse fraction is smaller than 4.75mm IS sieve.

FINE GRAINED SOIL

The fine grained soils are classified on the basis of their plasticity characteristics using the IS plasticity chart shown in fig. the fine grained soil further divided into three some divisions depending upon the values of the liquid limit.

- Silts and clays of low compressibility- these soils a liquid limit less than 35%
- Silts and clays of medium compressibility- these soils have a limit > 35% but < 50%.
- Silts and clays have high compressibility- these soils have a liquid limit > 35%.

1.4 NEED FOR STABILIZATION

- Soil stabilization the cost effective, long term physical and chemical alteration of soils to enhance the physical properties.
- Can improve shear and unconfined compressive strength, and permanently lower the soils permeability to water.
- Soil stabilization improves the strength of the existing soils improve its capacity for load bearing and allows increase and evenly to the structure.
- Soil stabilization improves the bearing capacity of foundation and its strength and water tightness resistance to without.

Soil is one of the nature most abundant construction materials. Almost all construction is built with or upon soil.

When unsuitable construction conditions are uncounted, contractor has four options.

1) Find a new construction site.
2) Re-design the structure so it can be constructed in the poor soil.
3) Remove the poor soil and replace it with good soil.
4) Improve the engineering properties of site soil.

In general options 1 and 2 tend to be impractical today, while in the past option 3 has been the most commonly used method. However, due to the improvement technology coupled with increased transportation cost. Option 4 is being used more often today and is expected to dramatically increase in the future. Stabilization means that the engineering properties of the soil have been changed enough to allow filed construction to take place.

There are two primary method of soil stabilization used today.

- Mechanical soil stabilization
- Chemical soil stabilization.

1.4.1 MECHANICAL SOIL STABILIZATION

Mechanical soil stabilization refers to either compaction or the introduction of fibers and other nonbio-degradable reinforcement to the soil. This practice does not requirechemical change of soil, although it is common to use both mechanical and chemical means to achieve specified stabilization.

COMPACTION

Compaction typically consists of a heavy weight soil density by applying pressure from above. Machines are often used for this purpose the large soil increasing density to meet engineering requirements.

Operators of the machines must be careful not to over compact on the soil, for too much pressure can result in crushed aggregates that loss their engineering properties.

SOIL REINFORCEMENT

Soil problems are sometimes remedied by utilizing engineer or non engineer mechanical solution. Geo textile plastic mesh are assigned to trap soil and help control erosion moisture condition and soil permeability. Larger aggregates, such as gravel, stones and boulders are often employed where additional mass and rigidity can prevent unwanted soil migration are improved load bearing properties.

1.4.2 CHEMICAL SOIL STABILIZATION

One method of improving the engineering properties of soil by adding chemicals or other materials to improve the existing soil. This technique is generally cost effective for example the cost, transportation on processing of stabilization of agent such as soil cement of lime to treat an in place of soil material will probably more economical than importing aggregate for the same thickness of base course.

Additives will me mechanical, meaning that upon addition to the parent soil their own bearing properties bolster characteristics of the parent soil. Additives can also be chemical meaning that the additives react with or change the chemical properties of soil their by upgrading its engineering properties. Placing the wrong kind to long amount of additives or improperly incorporating the additive into the soil can have devastating results on the success of the project.

Combining the additives with the soil is typically done with various machines. The method used in based on the factors; what machines are available, the location and the additives that have been used. The mixing should be as uniform as possible.

The most economic and time efficient method is used to rotary mixture the large machine that incorporates additives with the soil by tumbling than in large missing chamber equipped with a rotary designed to breakup and mix the materials. It is capable of uniform with introducing additives and water.

For some application that require more precisions, and plug in is used. The pugmill is essentially a large mixing chamber that similar to cement mixer measure a pre graded aggregates, additives and usually water are produce high quality stabilization.

Blade mixing is done with the use of the motor grade. Blade mixing is not nearly as efficient as the previously described the system. But it is far less complex. Essentially the additives is place in flat windows and blade of the grader mixer the additives with the soil in a series of turning and tumbling action.

1.5 MACHINERY USED FOR SOIL STABILIZATION

- Compact jet slurry mixer is used for slurry production.
- Motor grade with scarified is used to scarified the subgrade to the specified dept and width and then partially pulverized.
- It is desirable to remove non soil materials larger than three inches. Mechanical spreader is used for dry lime application.
- Rotary mixer should be employed to ensure through missing of the lime, soil and water.
- Compaction can be accomplished in one lift using in heavy pad foot roller or combination of the sheep foot and light pad foot.

Fig.1.2 Sheep foot roller

Fig.1.2 Mechanical Spreader

1.5 ADVANTAGES OF SOIL STABILIZATION

- **Substantial Savings**

Stabilizing the existing subgrade, the costs associated with excavating the existing soil, removing it from the site, and replacing it with suitable materials are eliminated. This can result in substantial savings to the owner.

- **Reduces Weather Related Delays**

In areas where the climate and weather conditions prevent site work during certain times of the year, soil stabilization may be utilized to treat unstable soils in order to continue site work. This can impact construction schedules in a positive way and translate in a cost savings for an owner who does not have to wait for good weather to continue work on the project.

- **Eliminates Supply Problems**

In areas where replacement of existing material is problematic mainly if the site is located in a remote area where aggregate supply is cost prohibitive to import, soil stabilization becomes a cost effective alternative.

❖ **Additional Material Reduction**

In roadway sections or parking areas, the sections of base material and asphalt paving may be reduced if the existing subgrade is stabilized in order to create sufficient strengths. This reduction in the sections of base material and asphalt paving can also create cost savings to the owner.

1.7 APPLICATIONS OF SOIL STABILIZATION

- Soil stabilization is used in many sectors of the construction industry. Roads, parking lots, airport runways, building sites, landfills and soil remediation all use some form of soil stabilization.
- The use of soil stabilization for slope protection, levee and dam cores, impervious liners and maintenance accessibility are feasible based on both economical and service life considerations.
- Other applications include waterway management, mining and agriculture.
- Pavements, especially flexible pavements, are constantly under changing conditions, thus they are inherently unstable. Water infiltration weakens the underlying soil condition and variable loading moves those conditions throughout the pavement structure. The use of chemical stabilization in roadway design speaks directly to these issues of long-term life-cycle stability.

CHAPTER-2

LITERATURE REVIEW

2.1 INTRODUCTION

For any structure, the foundation is very important and it has to be strong to support the entire structure. In order for the foundation to be strong, the soil around it plays a very critical role. To work on soil we need to have proper knowledge about their properties and factors which affect their behavior. Laterite soils always create a problem more for lightly loaded structures than moderately loaded structures. In these papers the experimental results obtained in the laboratory on laterite soils treated with different materials are presented.

MECHANICAL IMPROVEMENT OF A FINE-GRAINED LATERITIC SOIL TREATED WITH CEMENT FOR USE IN ROAD

According to, Emmanuel Mengue; Hussein Mroueh; Laurent Lancelot; and Robert Medjo Eko4

Emmanuel Mengue have measured the mechanical strength of a fine-grained lateritic soil treated with CEMII/BM 32.5 N cement up to 9% by weight of dry soil and prepared at three different moulding water contents was investigated by means of California bearing ratio (CBR), unconfined compressive strength (UCS), indirect tensile strength (TS), and triaxial shear tests. The effect of cement treatment on the microstructure of the lateritic soil was investigated by scanning electron microscopy (SEM) and Raman spectroscopy. The results indicated that cement improved the performance of lateritic soil, particularly at the optimum moisture content (OMC) and dry side of optimum (ωDRY), thus offering the possibility of using the tested lateritic soil in road pavement layers. Furthermore, soils with 6 and 9% cement addition satisfied the strength requirements so that lateritic soil can be used as a base course in rigid pavements.

They concluded the results of triaxial shear tests revealed the existence of two types of behaviour, namely, a ductile behaviour for untreated soil and brittle behaviour for cement-treated soil. These positive impacts are mainly related to the fact that cement addition gives way to the formation of ettringite, calcite, portlandite, and calcium silicate hydrates (afwillite and tobermorite), which derive principally from cement hydration.

MECHANICAL-CEMENT STABILIZATION OF LATERITE FOR USE AS FLEXIBLE PAVEMENT MATERIAL

According to, Manassjoel and Issac O.Agbede

Manassjoel and IssacO.agbede have to improve the physical strength properties of reddish brown lateritic soil. 15-60% sand by weight of laterite was used as a modifier in the stabilization of laterite with 3-12% by dry weight of Cement. Classification, compaction CBR and unconfined `17% for untreated laterite to 2.5% when treated with a combination of 60% sand+6 cement for the to energy levels of compaction, optimum moisture content(OMC) was found to increase with an increase in cement content but decrease as decreased as the sand content increased.

They have concluded that sand enhanced the effective stabilization of Ikpayongo laterite with cement within the maximum cement content specified by the Nigerian code.

EFFECTS OF KILN ASH ON THE COMPRESSIBILITY OF RESIDUAL LATERITIC SOILS

According to, T. C. de Brito Galva ˜o; A. A. de Mendonc¸a; and G. F. Simo ˜es

The potential for the use of kiln ash as an additive to Lateritic soils to improve their engineering characteristics as road construction material was experimentally investigated.

The results of laboratory tests indicate that no significant improvement of the soil properties occurred until after several weeks of curing time. In general, as the content of kiln ash in the soil was increased, the soil pH increased from 5.5 to 11.8, the maximum unconfined shear strength increased from 340 to 423 kPa for corresponding to 0–8% kiln ash content, the soil liquid limit reduced from 59 to 49% for corresponding to 0–20% kiln ash as content.

No significant change in the plasticity limits of the lateritic soil was observed, in the range of 0 to 8% kiln ash content. Relative to the compressibility of the natural soil measured in terms of the total strain, a decrease of about 3% occurred for kiln ash contents of 5, 10, and 20% within 1 to 7 days and that this decrease reached about 19% for 20% kiln ash content as time progressed to more than 177 days.

EVALUATION OF ADMIXTURE STABILIZATION FOR PROBLEM LATERITE

According to, By Douglas O. A. Osula

To evolve suitable evaluation criteria for admixture stabilization for problem laterite where Portland cement is used as the stabilizer and hydrated lime as the admixture.

The results presented that there are promises of increased strength gain with time. In addition, high durability is recorded for the range of mixes tested. Accordingly, unconfined compressive strength (UCS) and California bearing ratio (CBR) values of 1.38 N/mm2 and 90%, respectively, are recommended as evaluation criteria for this form of stabilization for problem laterite. This high value of UCS compared with the conventional value of 1.08 N/mm2 for lime stabilization is justified by the superior pozzolanic nature of the cementitious reaction in this admixture stabilization.

EFFECTIVNESS OF CEMENT KLIN DUST IN STABILIZING RECYCLED BASE MATERIALS

According to, Ali Ebrahimi,M.ASCE1;Tuncer B. Edil,F.ASCE2; and Young-Hivan Son3

They have determined the effectiveness of Cement kiln dust (CKD) in improving the stiffness of recycled base course materials was studied using both seismic modulus and bench-scale resilient modulus tests. Recycled materials included road surface gravel (RSG) and recycled pavement material (RPM). The modulus of RPM and RSG specimens mixed with CKD increased 5–30 times compared with untreated materials; however, the improvement was not as high as cement stabilization. Modulus generally increased with curing time with more hydration; however, `swelling potential of the CKD. Lower rate of increase in modulus of CKD mixtures compared with cement mixtures with curing timewas attributable to the chemical composition of CKDi.e., high free lime and sulfate contents. Freeze-thaw durability tests resulted in modulus reduction on the order of 0.5 to 0.8 for CKD mixtures and 0.5 for cement mixtures. Attributable to the combined effects of stiffness gain with continuing hydration and stiffness reduction with freeze-thaw cycles, the final modulus of the recycled materials mixed with CKD is 2 to 5 times higher than that of untreated RPM and RSG materials. This study also showed that modulus change of stabilized granular materials can be estimated from seismicYoung's modulus.

PREMIALBILITY OF LIME-TREATED LATERATIC SOIL

According to, Kolawole J. Osinubi,Member, ASCE

They have carried out Laboratory investigations on a residual lateritic soil treated with quick lime (up to 8% by weight of dry soil) in order to evaluate the effect of lime content, curing period and compactive effort on the permeability of lateritic soil-lime mixtures prepared at various maximum dry density settles and corresponding optimum moisture contents. The permeability of uncured specimens (standard Proctor) increased to a maximum at 4% lime content and decreased with increasing lime content. Specimens compacted at the energy of the West African Standard had coefficients of permeability that decreased with increasing lime content.

They have concluded that the permeability of all the lime-treated specimens compacted at the two energy levels increased with curing age up to 14 days and decreased with curing age beyond 14 days.

CHAPTER-3

MATERIALS

3.1 LATERITE SOIL

Laterite is a soil and rock type rich in iron and aluminum, and is commonly considered to have formed in hot and wet tropical areas. Nearly all laterites are of rusty-red coloration, because of high iron oxide content. They develop by intensive and long-lasting weathering of the underlying parent rock. Tropical wreathing (cauterization)is a prolonged process of chemical weathering which produces a wide variety in the thickness, grade, chemistry and ore mineralogy of the resulting soils. The majority of the land area containing laterites is between the tropics of Cancer and Capricorn.

Fig.3.1 Laterite soil

Laterite has commonly been referred to as a soil type as well as being a rock type. This and further variation in the modes of conceptualizing about laterite (e.g., also as a complete weathering profile or theory about weathering) has led to calls from the term to be abandoned altogether. At least a few researchers specializing in regolith development have considered that hopeless confusion has evolved around the name. There is no likelihood, however, that the name will ever be abandoned; material that reasonable to call such material laterite.

Laterites are a source of aluminum ore; the ore exists largely in clay minerals and the hydroxides, gibbsite, boehmite, and diaspora, which resembles the composition of bauxite. In Northern Ireland they once provided a major source of iron and aluminum ores. Laterite ores also were the early major source of nickel.

Laterite covers are thick in the stable areas of the western Ethiopian shield, on cartons of the South America Plate, and on the America Shield. In Madhya Pradesh, India, the laterite which caps the plateau is 30 m(100 ft) thick. Laterites can be either soft or easily broken into smaller pieces, or firm and physically resistant. Basement rocks are buried under the thick weathered layer and rarely exposed. Lateritic soils form the uppermost part of the laterite cover.

3.1.1 PROPERTIES OF LATERITE SOIL

If you are trying to grow a garden with laterite soil, then you have got your work cut out for you. The properties of laterite soil are distinctive, and even a child can learn how the laterite soil is different from compost, humus or other type of soil.

Laterite soil is often referred to as rock type soil. Gardening in laterite soil can pose a major challenge primarily due to the poor drainage in the soil. The inherent wet quality of laterite soil requires the addition of large amounts of organic matter.

1. Texture

Laterite soil has a distinctive texture. When dry, it holds its shape, and does not crumble like sand. When it is wet it can be sculpted and modeled into different shapes. To test the amount of laterite in your soil, roll a moist chunk into different shapes.

2. Soil Structure

In perfect garden soil, there is a moisture of sandy particles, with clay particles, with decomposed organic matter. In clay rich soil, there is little organic matter. It is the organic matter that supplies nutrients and allows the roots of the plant to climb through the soil with little resistance.

3. Physical Characteristics

Contrary to sandy soil, laterite soil has very small particles with tiny pores or micro pores. Since there are more pores spaces, lateritic soil has an overall total pore space than stand by soil due to the soil observes and retains more water. This makes the soil poorly aerated and poorly drained.

4. Temperature Variation

- Given the poor drainage in laterite soil, the soil remains saturated well after the spring thaws and heavy rain. When this happens plants, roots are developed of oxygen, which directly affects the health of plants. Since the soil is slow to warm, it delays the planting of plants, seeds or vegetables at the right time during spring.
- Since laterite soil have a high-water retentive capacity they are prone to alternating and expansion in winters when the ground freeze and thaws. This is particularly a problem in northern gardens.
- This expansion the growing season and is especially troublesome in the colder areas with already short growing seasons.

5. Water Holding Capacity

Laterite soil can hold lot of water. Some of the mineral particles swell up when they get wet. This can choke tender roots. It also results in a very compacted soil when teeny particles are pressed into one another and then swell up again.

6. Acidity and Alkalinity

Laterite soil tends to be very alkaline. Some plants and insects thrive in an alkaline environment. Others prefer an acidic environment most creatures, however, prefer neutrality. The ideal garden soil is fairly neutral at 3-8 on the pH value scale. Adding part moss, composed oak leaves, elemental suffer watering with vinegar, cotton seed meal, ammonium phosphate and gypsum can all acidify the soil.

3.1.2 ADVANTAGES OF LATERITE SOIL

- ✓ Free trade.
- ✓ Cheap rates on goods.
- ✓ Laterite soil improvement can be done by stabilization.
- ✓ The advantages of small scale industries in India can include closer supervision, better employ relationships and simple management procedures.
- ✓ Laterite soil is very weak soil. They require stabilization for construction purpose.

3.2 ADMIXTURES3.2.1. M – SAND

Fig.3.2.1 M - Sand

Manufactured sand is a substitute of a River sand for concrete construction. M-Sand is produced from hard granite stone by crushing. The crushed sand is of cubical shape with grounded edges, washed and graded to as a construction material. The size of M-sand is less than 4.75mm.

The properties of M – Sand

- ➢ **Durability of concrete:** Since manufactured sand (M-Sand) is processed from selected quality of granite, it has the balanced physical and chemical properties for construction of concrete structures.This property of M-Sand helps the concrete structures withstand extreme environmental conditions and prevents the corrosion of reinforcement steel by reducing permeability, moisture ingress, freeze-thaw effect increasing the durability of concrete structures.

- **Workability of concrete:** Size, shape, texture play an important role in workability of concrete. With more surface area of sand, the demand for cement and water increases to bond the sand with coarse aggregates.The control over these physical properties of manufacturing sand make the concrete require less amount of water and provide higher workable concrete. The less use of water also helps in increasing the strength of concrete, less effort for mixing and placement of concrete, and thus increases productivity of construction activities at site.
- **Less Construction Defects:** Construction defects during placement and post-concreting such as segregation, bleeding, honeycombing, voids and capillarity in concrete gets reduced by the use of M-Sand as it has optimum initial and final setting time as well as excellent fineness.
- **Economy:** As discussed above, since usage of M-Sand has increased durability, higher strength, reduction in segregation, permeability, increased workability, decreased post-concrete defects, it proves to be economical as a construction material replacing river sand.
- **Eco-Friendly:** Usage of manufactured sand prevents dredging of river beds to get river sand which may lead to environmental disaster like ground water depletion, water scarcity, threat to the safety of bridges, dams etc. to make M-Sands more eco-friendly than river sand.

Advantages of Manufactured Sand (M-Sand)

- It is well graded in the required proportion.
- It does not contain organic and soluble compound that affects the setting time and properties of cement, thus the required strength of concrete can be maintained.
- It does not have the presence of impurities such as clay, dust and silt coatings, increase water requirement as in the case of river sand which impair bond between cement paste and aggregate. Thus, increased quality and durability of concrete.
- M-Sand is obtained from specific hard rock (granite) using the state-of-the-art International technology, thus the required property of sand is obtained.
- M-Sand is cubical in shape and is manufactured using technology like High Carbon steel hit rock and then ROCK ON ROCK process which is synonymous to that of natural process undergoing in river sand information.

Disadvantages of Manufactured Sand (M-Sand)

- **Workability issues:** Manufactured sand can be of a coarser and angular texture than natural sand, which is smooth and rounded due to natural gradation. This can lead to more water and cement requirement to achieve the expected workability, leading to increased costs.
- **Larger proportion of micro fines:** Manufactured sand can contain larger amounts of micro fine particles than natural sand, owing to its production process. This again can affect the strength and workability of the screed or concrete.

3.2.2 CEMENT

Fig.3.2.2. CEMENT

Cement is a binder, a substance used for construction that sets, hardens, adheres to other material to bind them together. Cement is a seldom used on its own, but rather to bind sand and gravel together. Cement is the most widely used material in existence and is only behind water as the planet's most-consumed resource.

The Physical Properties of Cement

Different blends of cement used in construction are characterized by their physical properties. Some key parameters control the quality of cement. The physical properties of good cement are based on:

- Fineness of cement

- Soundness
- Consistency
- Strength
- Setting time
- Heat of hydration
- Loss of ignition
- Bulk density
- Specific gravity (Relative density)

These physical properties are discussed in details in the following segment. Also, you will find the test names associated with these physical properties.

- **Fineness of Cement:** The size of the particles of the cement is its fineness. The required fineness of good cement is achieved through grinding the clinker in the last step of cement production process. As hydration rate of cement is directly related to the cement particle size, fineness of cement is very important.
- **Soundness of Cement:** Soundness refers to the ability of cement to not shrink upon hardening. Good quality cement retains its volume after setting without delayed expansion, which is caused by excessive free lime and magnesia.
- **Consistency of Cement:** The ability of cement paste to flow is consistency. It is measured by Vicat Test. In Vicat Test Cement paste of normal consistency is taken in the Vicat Apparatus. The plunger of the apparatus is brought down to touch the top surface of the cement. The plunger will penetrate the cement up to a certain depth depending on the consistency. A cement is said to have a normal consistency when the plunger penetrates 10±1 mm.
- **Strength of Cement:** Three types of strength of cement are measured – compressive, tensile and flexural. Various factors affect the strength, such as water-cement ratio, cement-fine aggregate ratio, curing conditions, size and shape of a specimen, the manner of molding and mixing, loading conditions and age. While testing the strength, the following should be considered:

- **Compressive Strength:** It is the most common strength test. A test specimen (50mm) is taken and subjected to a compressive load until failure. The loading sequence must be within 20 seconds and 80 seconds.

- **Tensile strength:** Though this test used to be common during the early years of cement production, now it does not offer any useful information about the properties of cement.

- **Flexural strength:** This is actually a measure of tensile strength in bending. The test is performed in a 40 x40 x 160 mm cement mortar beam, which is loaded at its center point until failure.

- **Setting Time of Cement:** Cement sets and hardens when water is added. This setting time can vary depending on multiple factors, such as fineness of cement, cement-water ratio, chemical content, and admixtures. Cement used in construction should have an initial setting time that is not too low and a final setting time not too high. Hence, two setting times are measured:

  - Initial set: When the paste begins to stiffen noticeably (typically occurs within 30-45 minutes)
  - Final set: When the cement hardens, being able to sustain some load (occurs below 10 hours)Again, setting time can also be an indicator of hydration rate.

- **Heat of Hydration:** When water is added to cement, the reaction that takes place is called hydration. Hydration generates heat, which can affect the quality of the cement and also be beneficial in maintaining curing temperature during cold weather. On the other hand, when heat generation is high, especially in large structures, it may cause undesired stress. The heat of hydration is affected most by C_3S and C_3A present in cement, and also by water-cement ratio, fineness and curing temperature. The heat of hydration of Portland cement is calculated by determining the difference between the dry and the partially hydrated cement (obtained by comparing these at 7th and 28th days).

- **Bulk density:** When cement is mixed with water, the water replaces areas where there would normally be air. Because of that, the bulk density of cement is not very important. Cement has a varying range of density depending on the cement composition percentage. The density of cement may be anywhere from 62 to 78 pounds per cubic foot.

- **Specific Gravity (Relative Density):** Specific gravity is generally used in mixture proportioning calculations. Portland cement has a specific gravity of 3.15, but other types of cement (for example, Portland-blast-furnace-slag and Portland-pozzolan cement) may have specific gravities of about 2.90.

The Chemical Properties of Cement

The raw materials for cement production are limestone (calcium), sand or clay (silicon), bauxite (aluminum) and iron ore, and may include shells, chalk, marl, shale, clay, blast furnace slag, slate. Chemical analysis of cement raw materials provides insight into the chemical properties of cement.

1. **Tricalcium aluminate(C3A)**: Low content of C3A makes the cement sulfate-resistant. Gypsum reduces the hydration of C_3A, which liberates a lot of heat in the early stages of hydration. C3A does not provide any more than a little amount ofstrength.
   Type I cement: contains up to 3.5% SO_3 (in cement having more than 8% C_3A)
   Type II cement: contains up to 3% SO_3 (in cement having less than 8% C_3A)
2. **Tricalcium silicate (C_3S)**: C3S causes rapid hydration as well as hardening and is responsible for the cement's early strength gain an initial setting.
3. **Dicalcium silicate (C_2S)**: As opposed to tricalcium silicate, which helps early strength gain, dicalcium silicate in cement helps the strength gain after one week.
4. **Ferrite (C_4AF)**: Ferrite is a fluxing agent. It reduces the melting temperature of the raw materials in the kiln from 3,000°F to 2,600°F. Though it hydrates rapidly, it does not contribute much to the strength of the cement.
5. **Magnesia (MgO)**: The manufacturing process of Portland cement uses magnesia as a raw material in dry process plants. An excess amount of magnesia may make the cement unsound and expansive, but a little amount of it can add strength to the

cement. Production of MgO-based cement also causes less CO2 emission. All cement is limited to a content of 6% MgO.

6. **Sulphur trioxide**:Sulfur trioxide in excess amount can make cement unsound.
7. **Iron oxide/ Ferric oxide**: Aside from adding strength and hardness, iron oxide or ferric oxide is mainly responsible for the color of the cement.
8. **Alkalis**: The amounts of potassium oxide (K_2O) and sodium oxide (Na_2O) determine the alkali content of the cement. Cement containing large amounts of alkali can cause some difficulty in regulating the setting time of cement. Low alkali cement, when used with calcium chloride in concrete, can cause discoloration. In slag-lime cement, ground granulated blast furnace slag is not hydraulic on its own but is "activated" by addition of alkalis. There is an optional limit in total alkali content of 0.60%, calculated by the equation $Na_2O + 0.658\ K_2O$.
9. **Free lime**: Free lime, which is sometimes present in cement, may cause expansion.
10. **Silica fumes**: Silica fume is added to cement concrete in order to improve a variety of properties, especially compressive strength, abrasion resistance and bond strength. Though setting time is prolonged by the addition of silica fume, it can grant exceptionally high strength. Hence, Portland cement containing 5-20% silica fume is usually produced for Portland cement projects that require high strength.
11. **Alumina**: Cement containing high alumina has the ability to withstand frigid temperatures since alumina is chemical-resistant. It also quickens the setting but weakens the cement.

Advantages of Cement

- Ingredients of concrete are easily available in most of the places.
- Unlike natural stones, Concrete is free from defects and flaws.
- Concrete can be manufactured to desired strength with an economy.
- The durability of concrete is very high.
- It can be cast to any desired shape.
- The casting of concrete can be done in the working site which makes it economical.

- Maintenance cost of concrete is almost negligible.
- The deterioration of concrete is not appreciable with age.
- Concrete makes a building fire-safe due to its non-combustible nature.
- Concrete can withstand high temperatures.
- Concrete is resistant to wind and water. Therefore, it is a very useful in storm shelters.
- As a sound proofing material cinder concrete could be used.

Disadvantages of Concrete

- Compared to other binding materials, the tensile strength of concrete is relatively low.
- Concrete is less ductile.
- The weight of compared is high compared to its strength.
- Concrete may contain soluble salts. Soluble salts cause efflorescence.

3.2.3 CALCIUM CHLORIDE

Fig.3.2.3 Calcium Chloride

Calcium chloride is an inorganic compound, a salt with the chemical formula $CaCl_2$. It is a colorless crystalline solid at room temperature, highly soluble in water.

Calcium chloride is commonly encountered as a hydrated solid with generic formula $CaCl_2(H_2O)_x$, where x = 0, 1, 2, 4, and 6. These compounds are mainly used for de-icing and dust control. Because the anhydrous salt is hygroscopic,

The properties of Calcium Chloride

- **Physical properties**: Calcium chloride is found as an odorless white powder, granules or flakes. It has a density of 2.15 g/mL, melting point of 782 °C and a high boiling point over 1600 °C.
- **Chemical properties:** $CaCl_2$ is highly water soluble, hygroscopic (absorbs moisture from air) and deliquescent (absorbs enough water to turn into liquid). Calcium chloride dissolves in water in a very exothermic manner (releasing a large amount of heat). Calcium chloride fully dissociates in water to give calcium cations and chloride anions. In aqueous solutions, the calcium ions can displace other ions in exchange reactions, such as the conversion of potassium phosphate into calcium phosphate:

$$CaCl_2 + 2\ K_3PO_4 \rightarrow Ca_3(PO_4)_2 + 6\ KCl$$

USES OF CALCIUM CHLORIDE

Road surfacing

The largest application of calcium chloride exploits hygroscopic properties and the tackiness of its hydrates. A concentrated solution keeps a liquid layer on the surface of dirt roads, which suppresses formation of dust. It keeps the finer dust particles on the road, providing a cushioning layer. If these are allowed to blow away, the large aggregate begins to shift around and the road breaks down.Using calcium chloride reduces the need for grading by as much as 50% and the need for fill-in materials as much as 80%.

ADVANTAGES OF CALCIUM CHLORIDE

- ✓ Prewetting
- ✓ Anti-icing
- ✓ Dry blending
- ✓ Spot use of solid deicer

DISADVANTAGES OF CALCIUM CHLORIDE

- ✓ Dangerous for the skin
- ✓ Dangerous for the environment
- ✓ Damages some concrete and plants

3.2.4 SODIUM SULPHATE

Fig. 3.2.4 Sodium sulphate

Sodium sulfate (also known as sodium sulphate or sulfate of soda) is the inorganic compound with formula Na_2SO_4 as well as several related hydrates. All forms are white solids that are highly soluble in water.

FORMS OF SODIUM SULPHATE

- Anhydrous sodium sulfate, known as the rare mineral thernadite, used as a drying agent in organic synthesis.
- Heptahydrate sodium sulfate, a very rare form.
- Decahydrate sodium sulfate, known as the mineral mirabilite, widely used by chemical industry. It is also known as Glauber's salt.

PROPERTIES OF SODIUM SULPHATE

Molecular formula	Na_2SO_4
Molecular weight	142.04gm/mole (anhydrous), 322.20gm /mole (decahydrate)
Appearance	White crystalline solid
Odor	Odorless
Boiling point	14290C(anhydrous)
Flashpoint	8000c
Melting point	8840 c (anhydrous), 32.40C (decahydrate)
Density	2.664gm/ml (anhydrous), 1.464gm/ml (decahydrate)
Refractive index	1.468 (anhydrous), 1.394 (decahydrate)
Solubility	Solubleinwater, glycerol andhydrogeniodide and insoluble inethanol

Uses of Sodium Sulphate

- Sodium sulfate is used to dry organic liquids.
- As a filler in powdered home laundry detergents.
- As a fining agent which removes small air bubbles from molten glass.
- Defrosting windows, in carpet fresheners, starch manufacture, as an additive to cattle feed.

CHAPTER-4

METHODOLOGY

The following are the tests have been carried out in the laboratory as per IS: 2720 specifications.

- Moisture content test
- Specific gravity test
- Particle size distribution
- Liquid limit test
- Plastic limit test
- Shrinkage limit test
- Compaction test
- Unconfined compression test

4.1 MOISTURE CONTENT TEST

Moisture content or the water content is the ratio of the weight of water to the weight of solids in a given mass of soil. The water content is expressed in percentage.

Procedure

1. The number of the container is recorded, cleaned, dried and weighed.(W_1)
2. About 15-30 g of soil is placed in the container and the weight of soil with the sample is recorded.(W_2)
3. The can with the soil is placed in oven for 24 hours maintained at a temperature 105^0 to 110^0C.
4. After drying the container is removed from the oven and allowed to cool at room temperature.
5. After cooling the soil with container is weighed.(W_3)

Calculation:

Water content (%) = $\frac{(W2-W3)}{(W3-W1)}$ x 100

W_1=Mass of container, g

W_2=Mass of container and wet soil, g

W_3=Mass of container and dry soil, g

4.2 SPECIFIC GRAVITY TEST

Specific gravity is the ratio of the equivalent weight of soil solidsto the equivalent weight of waterat constant temperature.

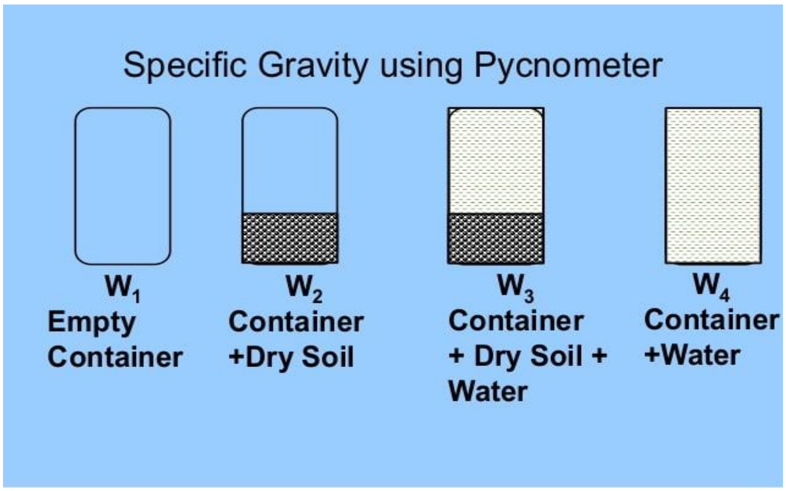


Fig.4.1 Specific gravity determination

Procedure:

1. Clean and dry the pycnometer bottle.
2. Weigh the empty bottle with its cone tightly screwed on (W_1).
3. Take oven dried soil sample of about one third to the volume of pycnometer bottle which is cooled in a desiccator. Transfer it to the bottle. Find the weight of the pycnometer bottle and soil (W_2).
4. Fill the bottle completely with distilled water, place the cone and screw it and keep the bottle under constant temperature water baths.
5. Take the pycnometer bottle and wipe it clean and dry note. Now determine the weight of the bottle and the contents (W_3).
6. Now empty the pycnometer bottle and thoroughly clean it. Fill the bottle with only distilled water and weigh it. Let the weight be W_4.

Calculation:

$$\text{Specific gravity} = \frac{(W2 - W1)}{[(W2 - W1) - (W3 - W4)]}$$

W_1 = Empty weight of pycnometer

W_2 = Weight of pycnometer + soil

W_3 = Weight of pycnometer + soil + full water

W_4 = Weight of pycnometer + full water

4.3 PARTICLE SIZE DISTRIBUTION

A sieve analysis (or gradation test) is a practice or procedure used to assess the particle size distribution (also called gradation) of a granular material. The size distribution is often of critical importance to the way the material performs in use. A sieve analysis can be performed on any type of non-organic or organic granular materials including sands, crushed rock, clays, granite, feldspars, coal, soil, a wide range of manufactured powders, grain and seeds, down to a minimum size depending on the exact method. Being such a simple technique of particle sizing, it is probably the most common.

4.4 LIQUID LIMIT

The liquid limit of a soil is the water content at which the soil behaves practically like a liquid, but has small shear strength. It is defined as the minimum water content at which the soil is still in the liquid state, but has small shearing strength against flowing. The Liquid Limit of Soil is determined as per IS: 2720 (Part-V). It flows to close the groove in just 25 blows in Casagrande’s liquid limit device. As it is difficult to get exactly 25 blows in a test, 3 to 4 tests are conducted and the number of blows (N) required in each test is determined. A semi-log plot is then drawn between log N and the water content (w). The liquid limit is the water content corresponding to N=25, as obtained from the plot.

4.5 PLASTIC LIMIT

The plastic limit is defined as the moisture content at which soil begins to behave as a plastic material. A plastic material can be molded into a shape and the material will retain that shape. If the moisture content is below the plastic limit, it is considered to behave as a solid, or a non-plastic material. As the moisture content increases past the plastic limit, the liquid limit will be approached. The Plastic limit of soil is determined as per IS: 2720 (part V), Specification. It is the water content below which the soil mass stops behaving like a plastic material. It begins to crumbled, when rolled into a thread of 3mm in diameter. At this water content, the soil loses its plasticity and passes to a semi solid state. A small increase in moisture above the plastic limit will destroy the cohesion of the soil.

4.6 SHRINKAGE LIMIT

As the soil loses moisture, the volume is also reduced by the decrease in water content. But, at a particular limit the moisture reduction causes no further volume change. A shrinkage limit test gives a quantitative indication of how much moisture can change before any significant volume change and also indication of change in volume. The shrinkage limit is useful in areas where soils undergo large volume changes when going through wet and dry cycles. The shrinkage limit of soil is determined as per IS: 2720. It is the water content where further loss of moisture will not result in any more volume reduction. The shrinkage limit is much less commonly used than the liquid and plastic limits. It is the minimum water content at which a soil is still in saturated condition.

4.7 COMPACTION TEST

Indian standard light compaction tests should be performed as per provisions in IS:2720 part-6 (1974). The tests have been conducted for various mix proportions of soil and rice husk ash and lime sludge as admixtures in different proportions. Dry density v/s moisture content graphs are plotted and the maximum dry density and optimum moisture content were determined for each mix.

Fig.4.2 Compaction mould and rammer

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

4.8 UNCONFINED COMPRESSION TEST

The unconfined compressive strength is definedas the compressive stress at which an unconfined cylindrical specimen of soil will fail in a simplecompression test.The unconfined compressive strength tests should be conducted on soil, soil-RHA, soil-lime sludge, soil-RHA-lime sludge proportions, as per IS 2720 part X (1973). All the samples are prepared by static compaction at optimum moisture content and maximum dry density to maintain same initial dry density and water content. The test was conducted under a constant strain rate of 1.5mm/min.

The purpose of this test is to determine the shear strength parameters i.e., Angle of shearing resistance and cohesion of a given soil sample.

Preparation of test Specimen

- Sample may be prepared by compacting the soil at the desired water content and dry density in a compaction mould and then cut by the sampling tube.
- Alternatively remolded specimen may be prepared directly in the split mould.

Testing procedure

- Measure the initial length and diameter of the specimen.
- Place the specimen on the bottom plate of the loading device.
- Adjust the upper plate to make contact with the specimen.
- Set the load dial gauge (proving ring) and strain dial gauge to zero.
- Compress the specimen until cracks have definitely developed on the surface of the specimen.

CHAPTER-5

RESULTS AND DISSCUSIONS

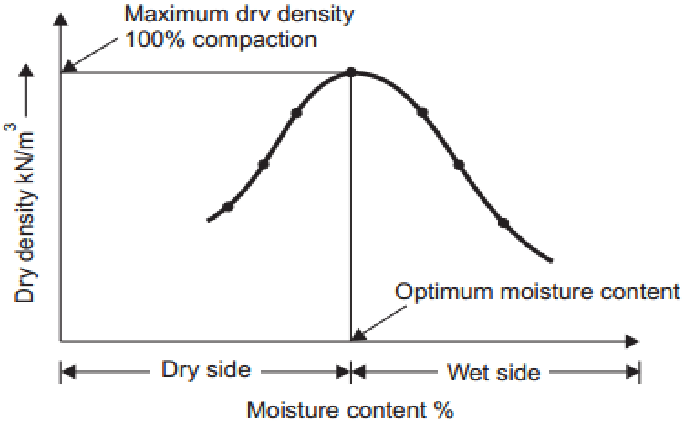
5.1 COMPACTION TEST

The compaction curve is plotted between moisture content and dry density. The peak value of the density is called maximum dry density and corresponding to this, the moisture content is called optimum moisture content. The tests are carried out by mixing soil with different percentages of Cement, M-Sand, Sodium sulphate and Calcium chloride and taking each of them as 4%, 8%, 12%, 16% and 20% in combination with soil sample.

Compaction process helps in increasing the bulk density by driving out the air from the voids. The theory used in the experiment is that for any compactive effort, dry density depends upon the moisture content in the soil. The maximum dry density (MDD) is achieved when the soil is compacted at relatively high moisture content and almost all the air is driven out, this moisture content is called optimum moisture content (OMC). After plotting the data from the experiment with water content as abscissa and dry density as the ordinate, we can obtain the OMC and MDD and some of the equations to calculate the wet density, moisture content and dry density are given below:

- Wet density = $\frac{\text{weight of wet soil in mould}}{\text{volume of mould}}$ in (g/cm^3)
- Moisture content (%) = $\frac{\text{weight of water}}{\text{weight of dry soil}} \text{ x } 100$
- Dry density = $\frac{\text{wet density}}{1+\%\text{ moisture content}}$ in (g/cm^3)

Sl. No	Description	Optimum Moisture Content (%)	Maximum dry Density (g/cm^3)
1	Laterite soil	15.15	1.89



5.1 Compaction curve

5.1.1 COMPACTION TEST RESULT FOR LATERITE SOIL ALONE

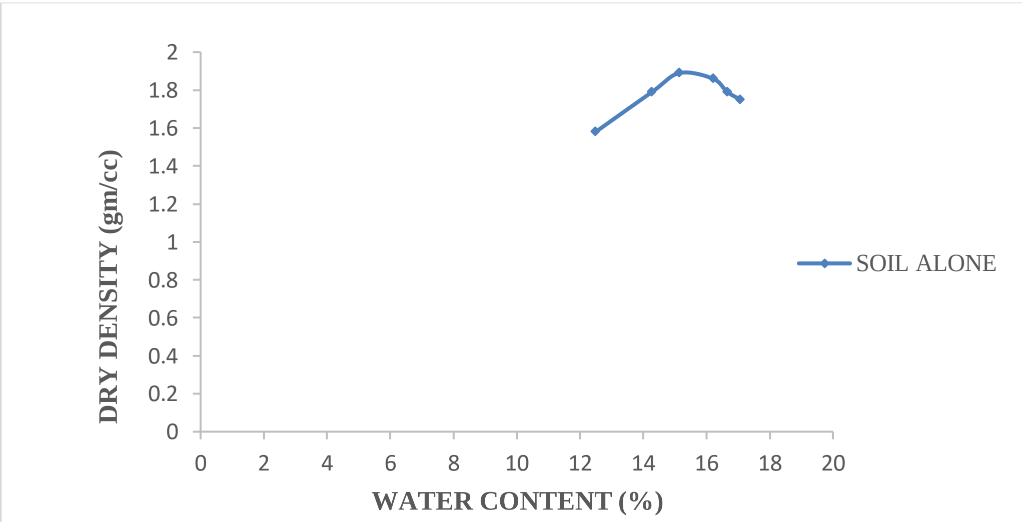


Fig.5.1.1 Dry Density V/S Water Content for Soil alone

Figure 5.1.1 shows that the x-axis represents the water content in percentage(%) and y-axis represents the dry density in (g/cm^3). The compaction test is conducted for laterite soil alone, from the graph it indicates that for corresponding15.15% optimum moisture content obtained maximum dry density value is 1.89g/cm^3.

5.1.2 COMPACTION TEST RESULT FOR LATERITE SOIL WITH VARYING PERCENTAGES OF CEMENT

Sl. No.	Description	Optimum moisture content (%)	Maximum Dry Density (g/cm^3)
1	Laterite soil alone	15.15	1.89
2	Laterite soil + 2% Cement	13.79	1.86
3	Laterite soil + 4% Cement	15.38	1.88
4	Laterite soil + 6% Cement	17.64	1.87
5	Laterite soil + 8% Cement	14.7	1.79
6	Laterite soil + 10%Cement	15.38	1.86

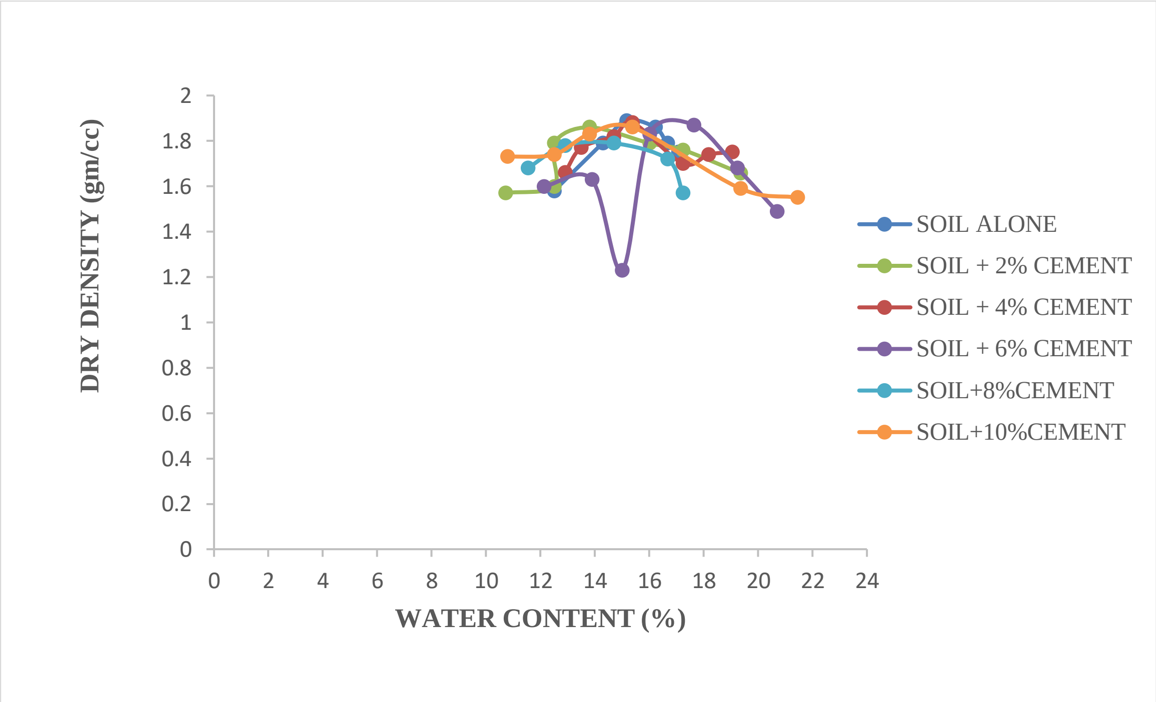


Fig.5.1.2 Dry Density V/S Water Content for Soil Alone +Varying percentages of cement

Figure 5.1.2 shows that the x-axis represents the water content in percentage (%) and y-axis represents the dry density in (g/cm^3). The compaction test is conducted for laterite soil with varying percentages of Cement. By addition of varying percentages of Cement (2%, 4%, 6%, 8%, 10%) to the laterite soil, the 4% of Cement for corresponding 15.38 % Optimum moisture content obtained maximum dry density value is 1.88 g/cm^3.

5.1.3 COMPACTION TEST RESULT FOR SOIL ALONE AND SOIL WITH OPTIMUM PERCENTAGE OF CEMENT

Sl. No.	Description	Optimum moisture content (%)	Maximum Dry Density (g/cm^3)
1	Laterite soil alone	15.15	1.89
2	Laterite soil + 4 % Cement	15.38	1.88

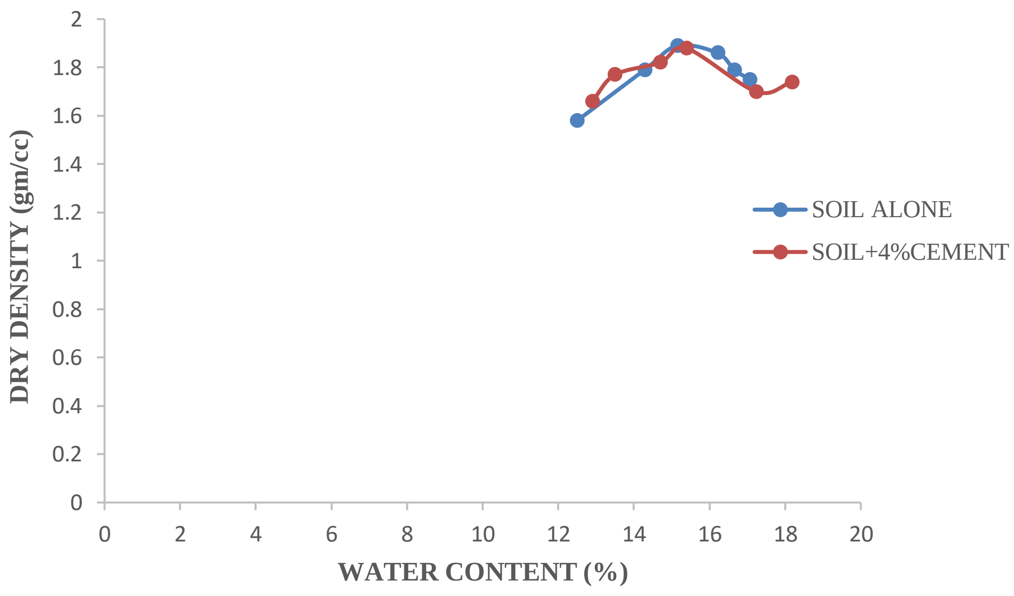


Fig.5.1.3 Dry Density V/S Water Content for Soil Alone + 4% of cement.

Figure 5.1.3 shows that the x-axis represents the water content in percentage(%) and y-axis represents the dry density in (g/cm^3).The graph indicates that lateritesoil alone for corresponding 15.15% optimum moisture content obtained maximum dry density value is 1.89 g/cm^3, by addition of 4% Cement to the laterite soil corresponding 15.38 % optimum moisture content obtained maximum dry density value is 1.88g/cm^3.

5.1.4 COMPACTION TEST RESULT FOR LATERITE SOIL WITH VARYING PERCENTAGES OF M- SAND

Sl No.	Description	Optimum moisture content (%)	Maximum Dry Density (g/cm^3)
1	Laterite soil alone	15.15	1.89
2	Laterite soil + 4% MS	13.79	1.77
3	Laterite soil + 8% MS	15.78	1.74
4	Laterite soil + 12% MS	17.64	1.87
5	Laterite soil + 16% MS	14.7	1.79
6	Laterite soil + 20% MS	15.38	1.86

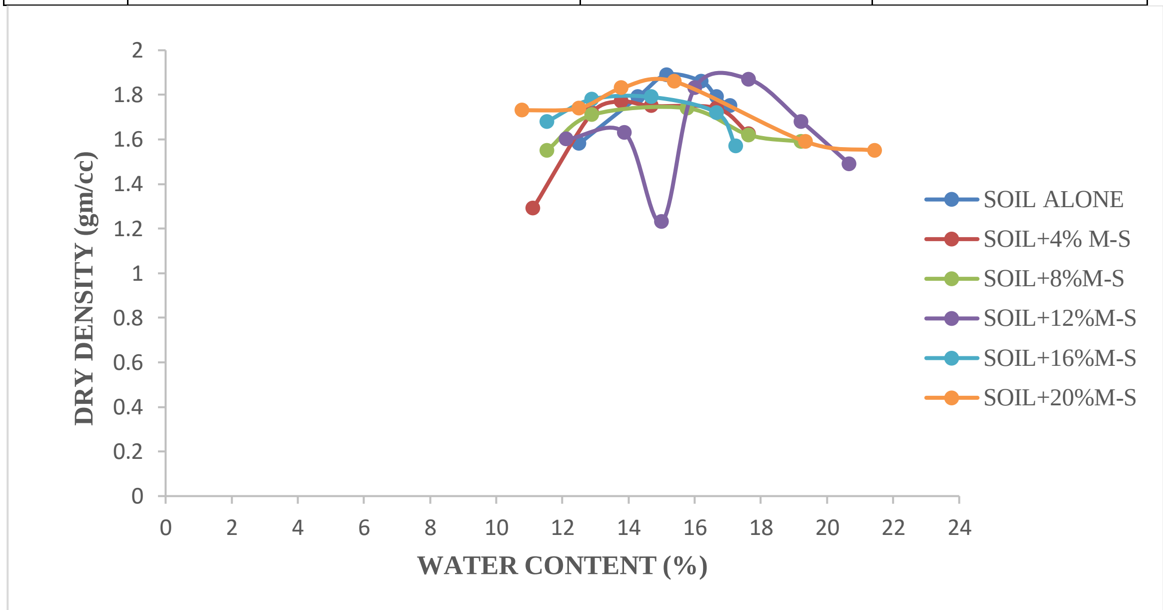


Fig.5.1.4 Dry Density V/S Water Content for Soil Alone +Varying percentages of M-Sand.

Figure 5.1.4 shows that the x-axis represents the water content in percentage (%) and y-axis represents the dry density in (g/cm^3). The compaction test is conducted for laterite soil with varying percentages of M-Sand. By addition of varying percentages of M-Sand (4%, 8%, 12%, 16%, 20%) to the Laterite soil, the 12% of M-Sand for corresponding 17.64% optimum moisture content obtained maximum dry density value is 1.87 g/cm^3.

5.1.5 COMPACTION TEST RESULT FOR SOIL ALONE AND SOIL WITH OPTIMUM PERCENTAGE OF M-SAND

Sl. No.	Description	Optimum moisture content (%)	Maximum Dry Density (g/cm^3)
1	Laterite soil alone	15.15	1.89
2	Laterite soil + 12% MS	17.64	1.87

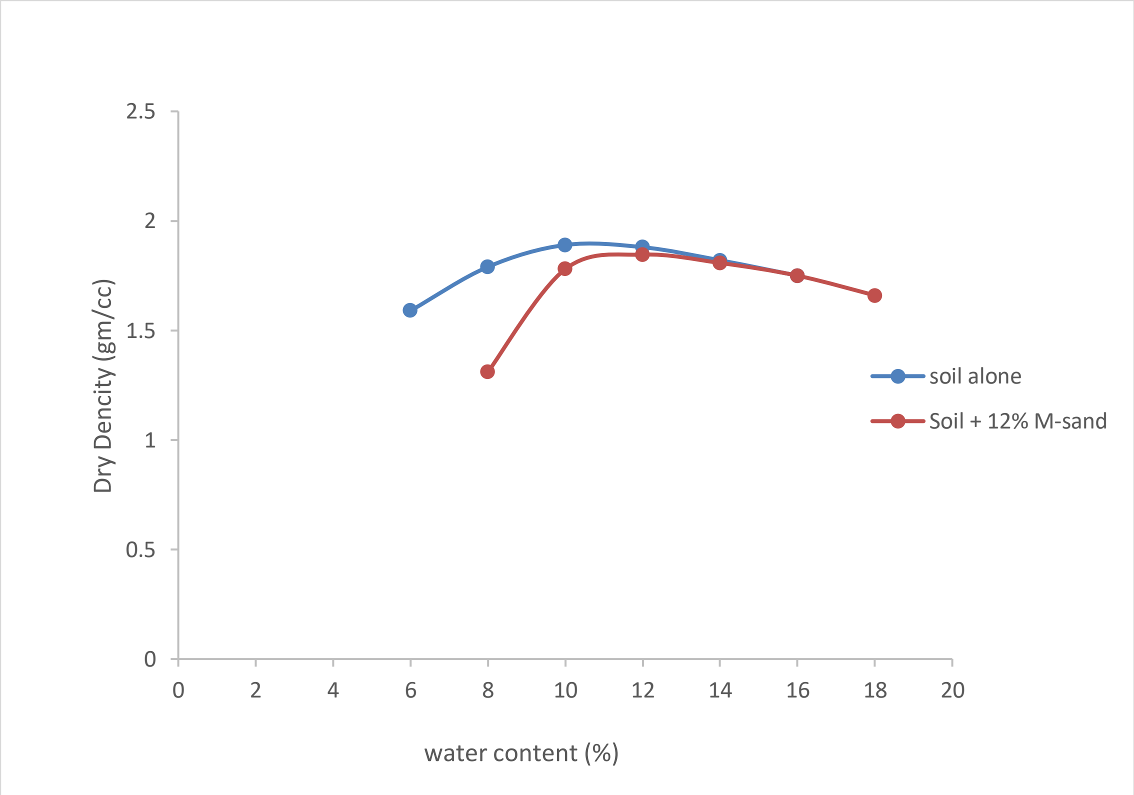


Fig.5.1.5 Dry Density V/S Water Content for Soil Alone +12% of M Sand.

Figure 5.1.5 shows that the x-axis represents the water content in percentage (%) and y-axis represents the dry density in (g/cm^3). The graph indicates that laterite soil alone for corresponding 15.15% optimum moisture content obtained maximum dry density value is 1.89 g/cm^3, by addition of 12% M-Sand to the laterite soil corresponding 17.64% optimum moisture content obtained maximum dry density value is1.87g/cm^3.

5.1.6 COMPACTION TEST RESULT FOR SOIL ALONE AND SOIL WITH OPTIMUM VARYING PERCENTAGE OF SODIUM SULPHATE

SL.NO	Description	Optimum moisture content (%)	Maximum Dry Density (g/cm^3)
1	Soil alone	15.15	1.89
2	Soil+3% of SS	14.6	1.91
3	Soil+6% of SS	17.89	1.87
4	Soil+9% of SS	16	1.89
5	Soil+12% of SS	15.38	1.98

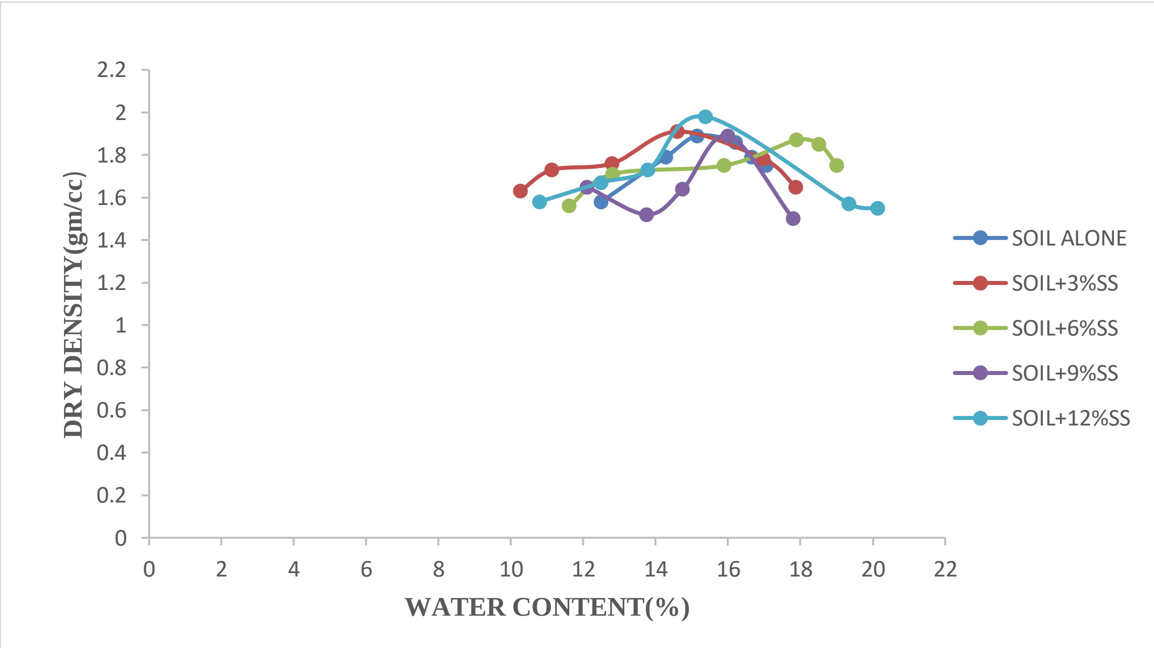


Fig.5.1.6 Dry Density V/S Water Content for Soil Alone +Varying % of Sodium Sulphate.

Figure 5.1.6 shows that the x-axis represents the water content in percentage (%) and y-axis represents the dry density in (g/cm^3).The compaction test is conducted for laterite soil with varying percentages of Sodium sulphate(3%, 6%, 9%, 12%) to the laterite soil, from these varying percentages of Sodium Sulphate for corresponding12% optimum moisture content of 15.38% obtained maximum dry density value is 1.98 (g/cm^3).

5.1.7 COMPACTION TEST RESULT FOR SOIL ALONE AND SOIL WITH OPTIMUM PERCENTAGE OF SODIUM SULPHATE

Sl. No.	Description	Optimum moisture content (%)	Maximum Dry Density (g/cm^3)
1	Laterite soil alone	14.7	1.9
2	Laterite soil + 12% SS	15.38	1.98

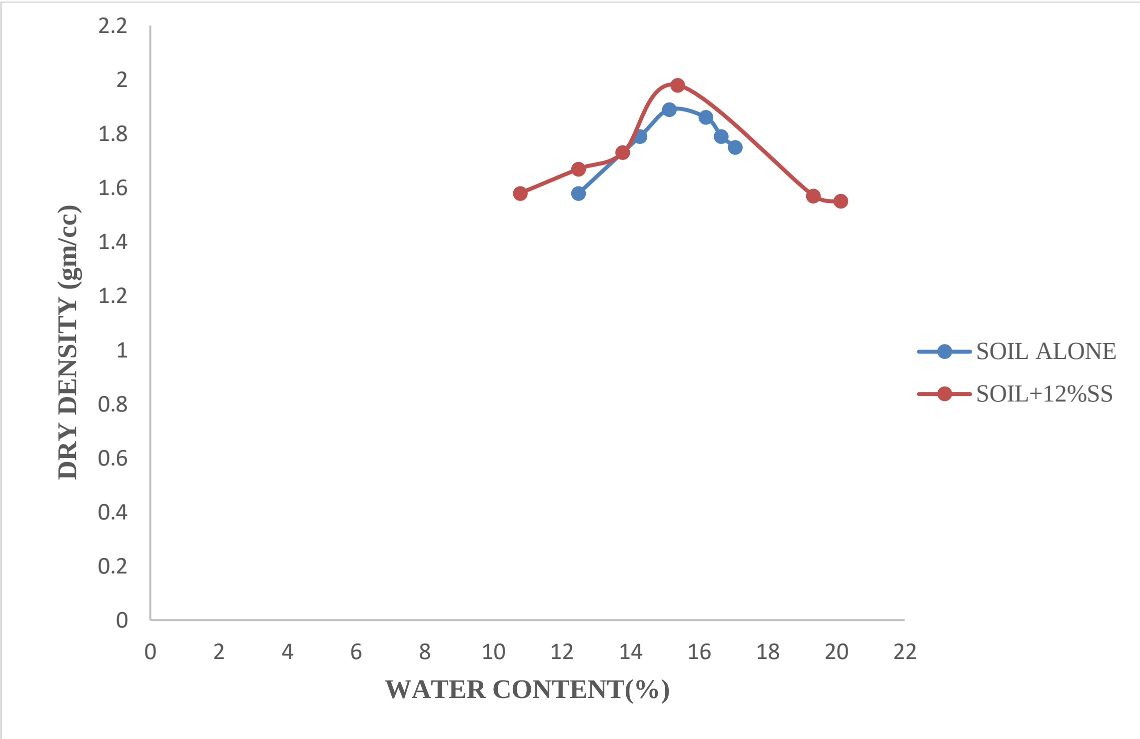


Fig.5.1.7 Dry Density V/S Water Content for Soil Alone +12% of Sodium Sulphate.

Figure 5.1.7 shows that the x-axis represents the water content in percentage (%) and y-axis represents the dry density in (g/cm^3).The graph indicates that laterite soil alone for corresponding 15.15% Optimum moisture content, Maximum dry density (g/cm^3). By addition of 1.89 % Sodium sulphate to the laterite soil corresponding 15.38 % OMC obtained and MDD 1.98 (g/cm^3).

5.1.8 COMPACTION TEST RESULT FOR SOIL ALONE AND SOIL WITH VARYING PERCENTAGE OF CALCIUM CHLORIDE

SL.NO	Description	Optimum moisture content (%)	Maximum Dry Density (g/cm^3)
1	Soil alone	15.15	1.89
2	Soil+3% of CC	16.98	1.84
3	Soil+6% of CC	12.81	1.73
4	Soil+9% of CC	16	1.81
5	Soil+12% of CC	15.38	1.95

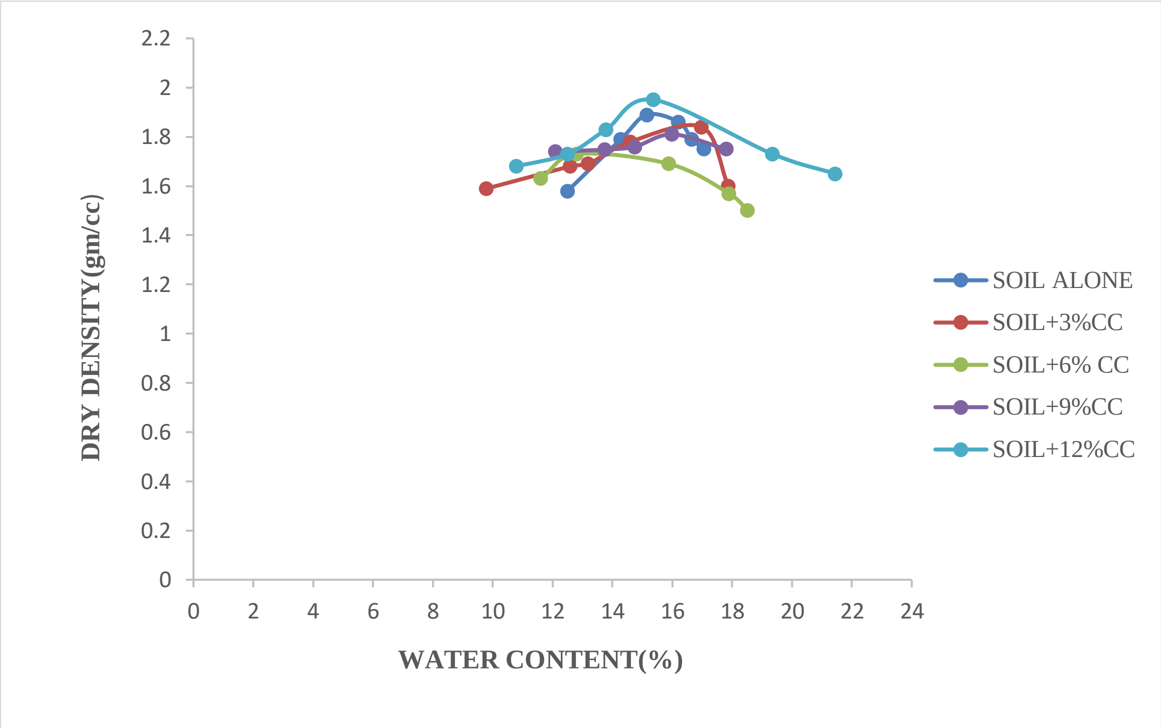


Fig.5.1.8 Dry Density V/S Water Content for Soil Alone + Varying Percentages of Calcium Chloride.

Figure 5.1.8 shows that the x-axis represents the water content in percentage (%) and y-axis represents the dry density in (g/cm^3).The compaction test is conducted for laterite soil with varying percentages of Calcium chloride (3%, 6%, 9%, 12%) to the laterite soil, from these varying percentages ofCalcium chloride for corresponding 12% optimum moisture content of 15.38% obtained maximum dry density value is 1.95 (g/cm^3).

5.1.9 COMPACTION TEST RESULT FOR SOIL ALONE AND SOIL WITH OPTIMUM PERCENTAGE OF CALCIUM CHLORIDE

SL.NO	Description	Optimum moisture content (%)	Maximum Dry Density (g/cm^3)
1	Laterite soil alone	15.15	1.89
2	Laterite soil + 12% CC	15.38	1.95

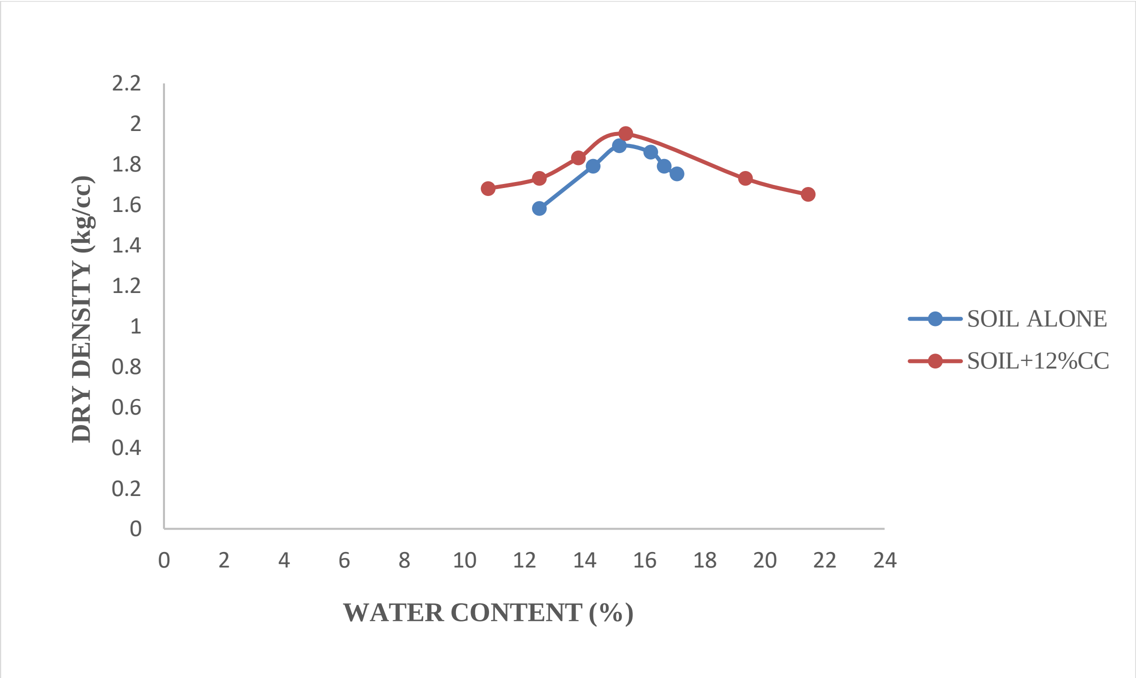


Fig.5.1.9 Dry Density V/S Water Content for Soil Alone +12% of Calcium Chloride.

Figure 5.1.9 shows that the x-axis represents the water content in percentage (%) and y-axis represents the dry density in (g/cm^3).The graph indicates that laterite soil alone for corresponding 15.15% Optimum moisture content, Maximum dry density1.89 (g/cm^3). By addition of 12% Calcium chloride to the laterite soil corresponding 15.38% OMC obtained and MDD 1.95 (g/cm^3).

5.1.9 COMPACTION TEST RESULT FOR SOIL ALONE +4% CEMENT +12% M-SAND

SL.NO	Description	Optimum moisture content (%)	Maximum Dry Density (g/cm^3)
1	Soil alone	15.15	1.89
2	Soil +4% of C	15.38	1.88
3	Soil+12% of MS	17.64	1.87
4	Soil+4% C+12% MS	16	1.93

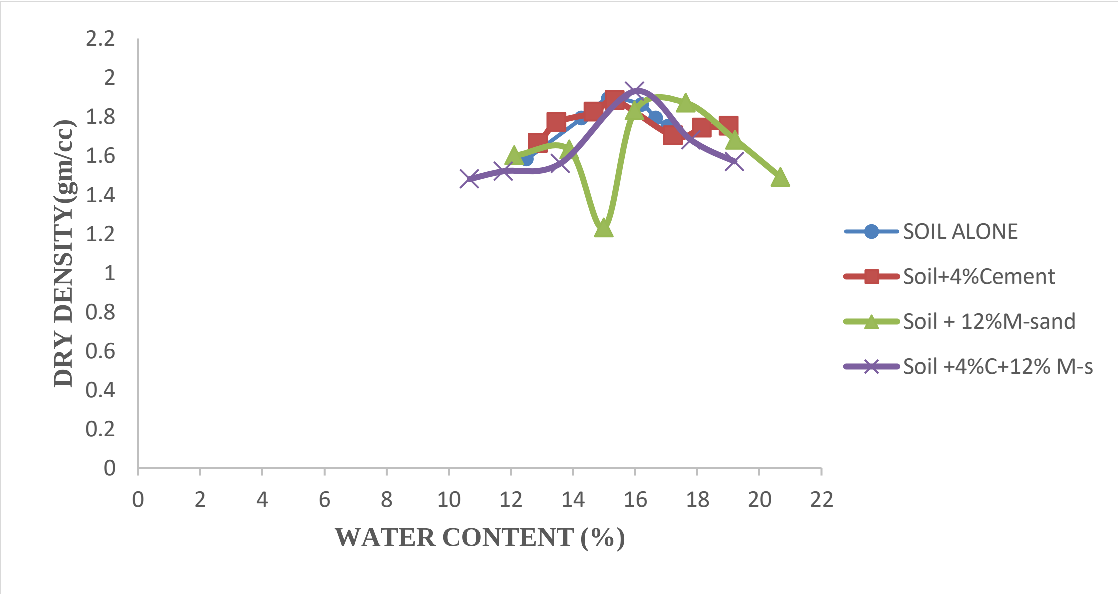


Fig.5.1.9 Dry Density V/S Water Content for Soil Alone +4% Cement and 12% of M Sand

Figure 5.1.9 shows that the x-axis represents the water content in percentage (%) and y-axis represents the dry density in (g/cm^3).The graph indicates the laterite soil alone for corresponding14.7% optimum moisture content the maximum dry density value is 1.9 (g/cm^3).by the addition of both admixtures (i.e., cement and m sand) 4% cement and 12% M- sand to the laterite soil,for corresponding 16% of optimum moisture content obtained maximum dry density value is 1.93 (g/cm^3).

5.1.10 COMPACTION TEST RESULT FOR SOIL ALONE +4% CEMENT + 12% M-SAND + 12% OF SODIUM SULPHATE

SL.NO	Description	Optimum moisture content (%)	Maximum Dry Density (g/cm^3)
1	Soil alone	15.15	1.89
2	Soil +4% of C	15.38	1.88
3	Soil+12% of MS	17.64	1.87
4	Soil+12% of SS	15.38	1.98
5	SOIL+4%C+12%MS+12%SS	16.2	1.9

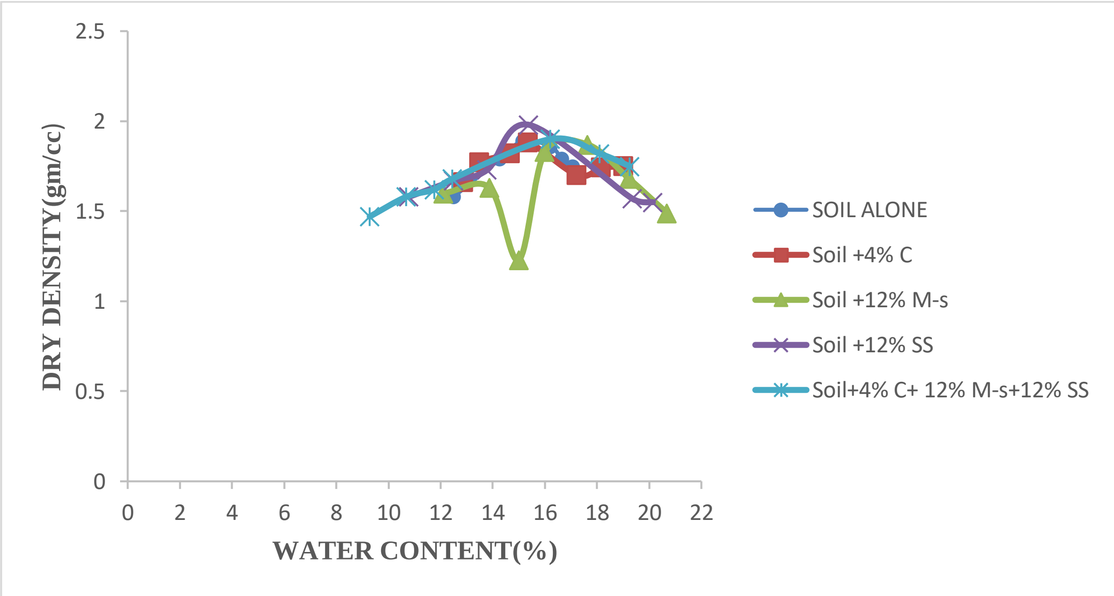


Fig.5.1.10 Dry Density V/S Moisture Content for Soil Alone +4% Cement + 12% of M-Sand+ 12% of Sodium Sulphate

Figure 5.1.10 shows that the x-axis represents the water content in percentage (%) and y-axis represents the dry density in (g/cm^3).The graph indicates the laterite soil alone for corresponding15.15% optimum moisture content the maximum dry density value is 1.89 (g/cm^3).by the addition of admixtures (i.e.,cement, m-sand and sodium sulphate) 4% cement and 12%M-sand and 12% sodium sulphate to the laterite soil,for corresponding 16.2% of optimum moisture content obtained maximum dry density value is 1.9(g/cm^3).

5.1.11 COMPACTION TEST RESULT FOR SOIL ALONE + 4% CEMENT + 12% M-SAND + 12% SODIUM SULPHATE + 12% CALCIUM CHLORIDE

SL.NO	Description	Optimum moisture content (%)	Maximum Dry Density (g/cm^3)
1	Soil alone	15.15	1.89
2	Soil +4% of C	15.38	1.88
3	Soil+12% of MS	17.64	1.87
4	Soil+12% of SS	15.38	1.98
5	Soil+12%of CC	15.38	1.95
6	S+4%C+4%MS+12%SS+12%CC	15.98	1.96

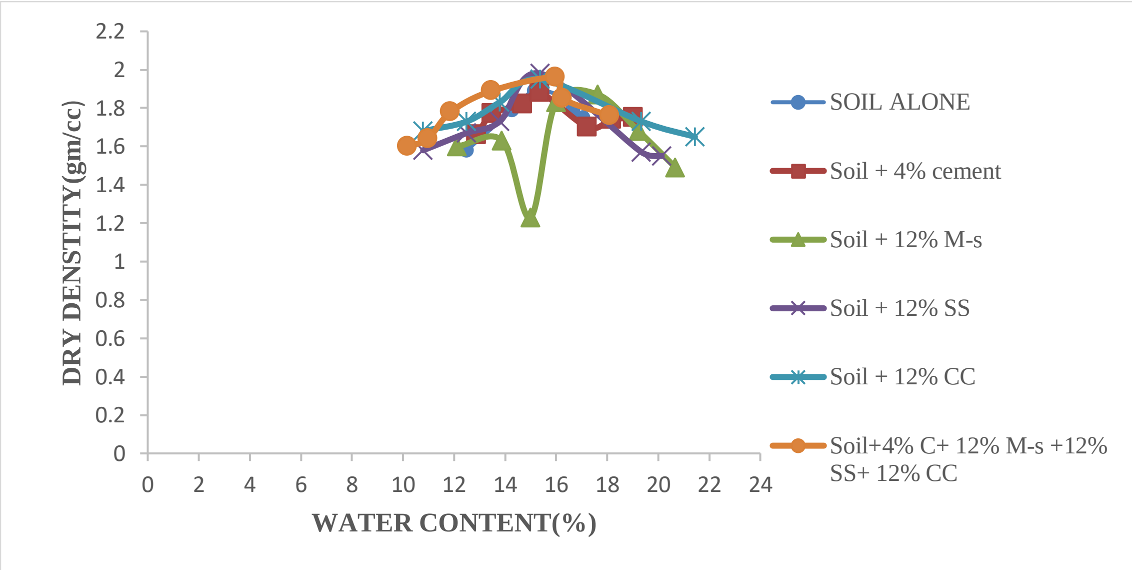


Fig.5.1.11 Dry Density V/S Moisture content for Soil Alone +4% Cement + 12% of M-Sand+ 12% of Sodium Sulphate +12% of sCalcium Chloride

Figure 5.1.11 shows that the x-axis represents the water content in percentage (%) and y-axis represents the dry density in (g/cm^3).The graph indicates the laterite soil alone for corresponding15.15% optimum moisture content the maximum dry density value is 1.89 (g/cm^3). by the addition of admixtures(i.e., cement, m sand, sodium sulphate and calcium chloride) 4% cement and 12% M- sand and 12% sodium sulphate and 12% calcium chloride to the laterite soil, for corresponding 15.98 % of optimum moisture content obtained maximum dry density value is 1.96 (g/cm^3).

5.2 UNCONFINED COMPRESSION TEST

The strength properties of soil can be determined by experimental investigation. In the present study Unconfined Compression test is conducted. The clayey soil has been stabilized with different percentages of Rubber tyre powder, Eggshell powder and tested for unconfined compression strength.

Unconfined compressive strength tests were conducted to investigate the effects of Rubber tyre powder and Eggshell powder on the strength and mechanical behavior of clayey soil and clayey soil treated with these admixtures separately and for the combinations too. Clayey soil with and without reinforcement, additives were prepared at maximum dry unit weight and optimum moisture content determined from compaction test. Specimens were prepared at each compression test with the selected content and additives. Extreme care was taken in preparing the specimens, curing the specimen and conducting the test so as to keep the specimens intact. So the specimens used were 38mm diameter and 87mm height. Observation of failed unreinforced clayey soil specimen revealed shear failure plane and with the addition of reinforcing additives the specimen bulged in compression. These failure modes were observed in all specimens. This unconfined compressive strength is repeated for curing days of immediate, after 7 days, 14 days and 21 days at the loading rate of 1.25mm/min until the samples failed in test.

Fig.5.2.0 Unconfined Compression Strength Test

Fig.5.2.1 Unconfined compression test specimen before test.

Fig.5.2.2 Unconfined compression test specimen after test.

5.3 UNCONFINED COMPRESSION TEST RESULTS ON LATERITE SOIL ALONE

The experimental results of laterite soil on the unconfined compression strength of laterite soil are shown in the table and the graphs for shear stress v/s displacement are shown.

Sl. No.	Description	Days	Shear stress (kg/cm^2)
1	Laterite soil alone	Immediate	1.46
2	Laterite soil alone	7	4.61
3	Laterite soil alone	14	8.19
4	Laterite soil alone	21	9.71

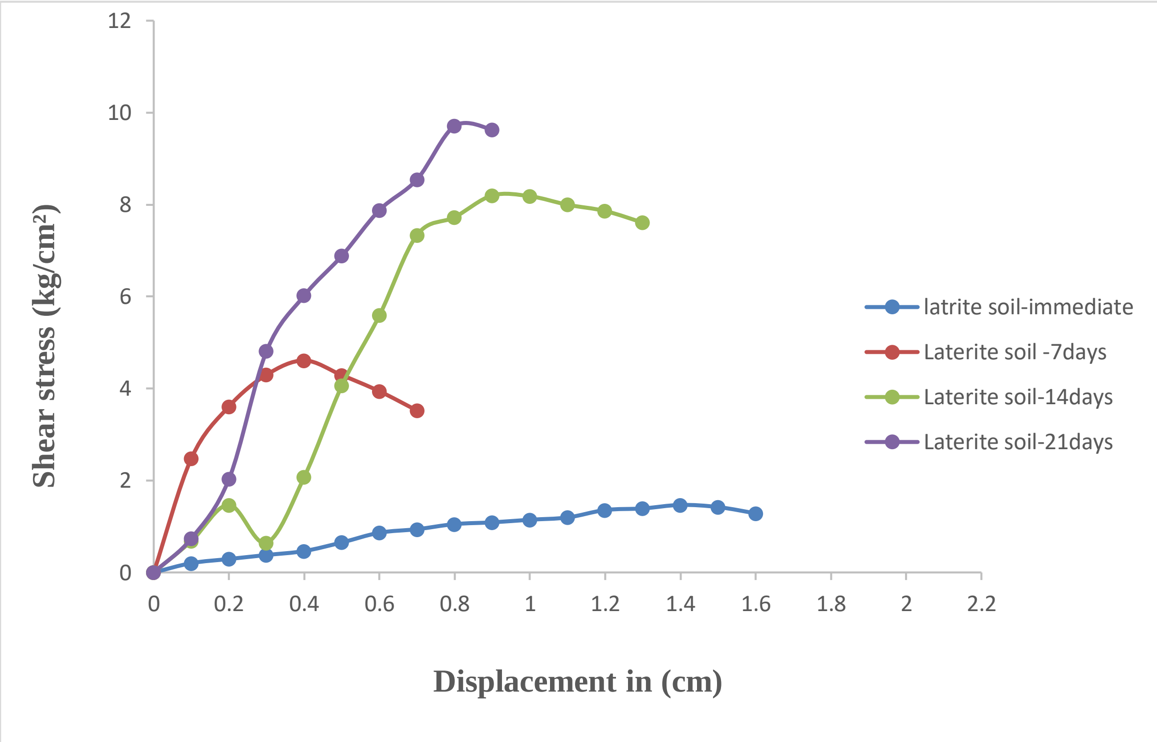


Fig.5.3.1 Shear Stress V/S Displacement for Soil alone

Figure shows that the x-axis represents the displacement in (cm) and y-axis represents the shear stress in (kg/cm^2). The unconfined compression test is conducted for laterite soil at Various curing periods of immediate, 7 days, 14 days and 21 days. The shear stress increases with increase in curing period, compare to immediate, 7 and 14 days for 21 days curing period the maximum shear stress value is 9.71 kg/cm^2.

5.4 UNCONFINED COMPRESSION TEST RESULTS ON LATERITE SOIL WITH 4% OF CEMENT

Sl. No.	Description	Days	Shear stress (kg/cm^2)
1	Laterite soil + 4% Cement	Immediate	1.16
2	Laterite soil + 4% Cement	7	8.34
3	Laterite soil + 4% Cement	14	12.83
4	Laterite soil + 4% Cement	21	12.43

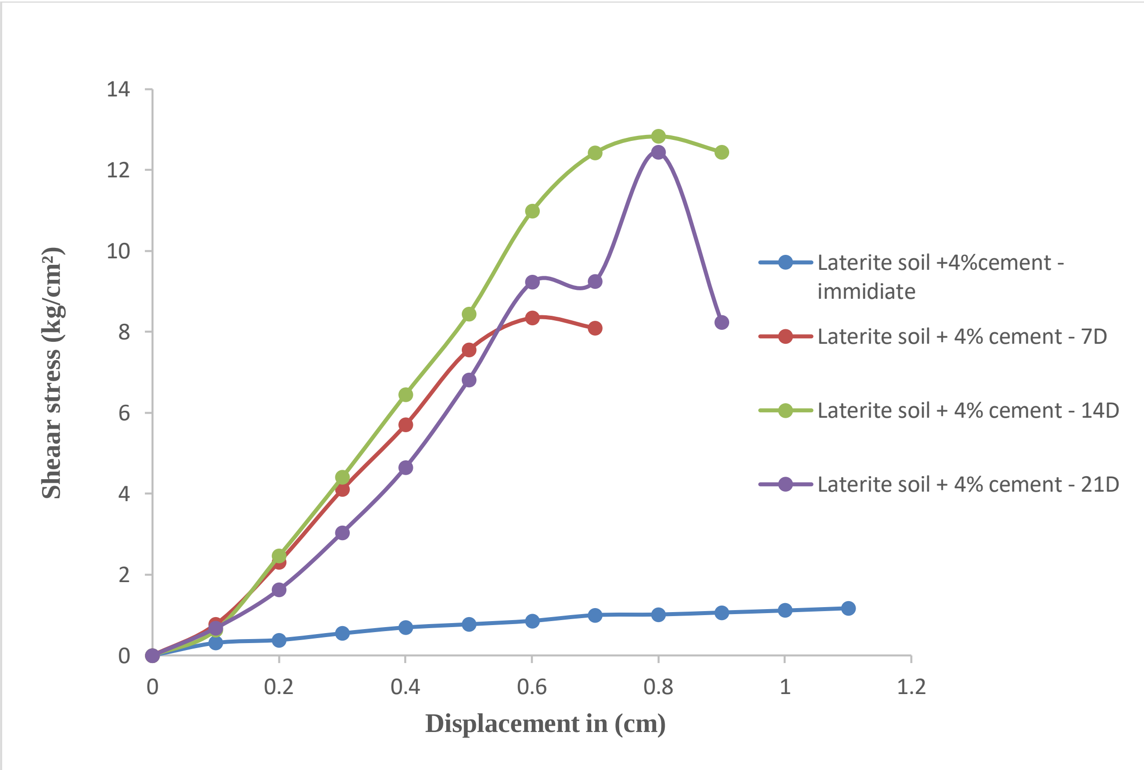


Fig.5.4.1 Shear stress V/S Displacement for Soil with 4% of cement.

Figure shows that the x-axis represents the displacement in (cm) and y-axis represents the shear stress in (kg/cm^2). The unconfined compression test is conducted for laterite soil with 4% of Cement at curing period of immediate, 7 days, 14 days and 21 days. The shear stress increases with increase in curing period, compare to immediate, 7 and 14 days for 21 days curing period the maximum shear stress value is 12.43 kg/cm^2.

5.5 UNCONFINED COMPRESSION TEST RESULTS ON LATERITE SOIL WITH 12% of M – SAND

Sl. No.	Description	Days	Shear stress (kg/cm^2)
1	Laterite soil + 12% M-Sand	Immediate	2.85
2	Laterite soil + 12% M-Sand	7	5.05
3	Laterite soil + 12% M-Sand	14	6.87
4	Laterite soil + 12% M-Sand	21	7.46

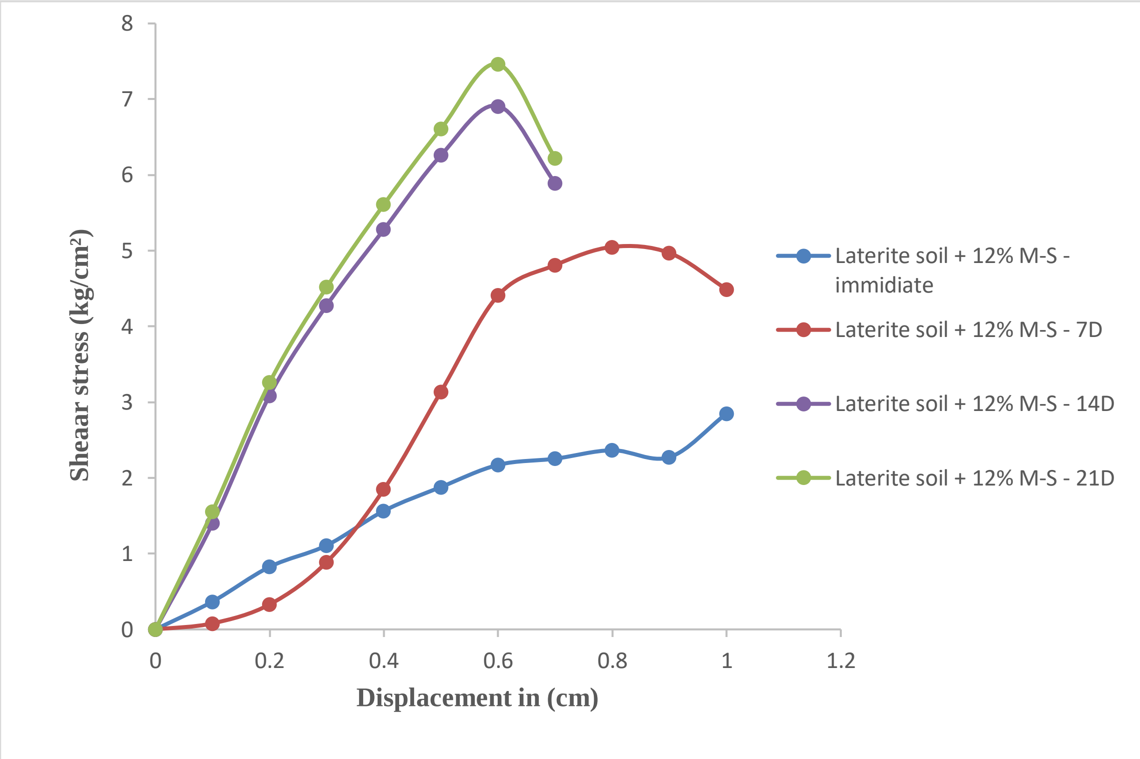


Fig.5.5.1 Shear stress V/S Displacement for Soil with 12% of M-sand.

Figure shows that the x-axis represents the displacement in (cm) and y-axis represents the shear stress in (kg/cm^2). The unconfined compression test is conducted for laterite soil with 12% of M-Sand at curing period of immediate, 7 days, 14 days and 21 days. The shear stress increases with increase in curing period, compare to immediate, 7 and 14 days for 21 days curing period the maximum shear stress value is 7.46 kg/cm^2.

5.6 UNCONFINED COMPRESSION TEST RESULTS ON LATERITE SOIL WITH 12% OF SODIUM SULPHATE

Sl. No.	Description	Days	Shear stress (kg/cm^2)
1	Laterite soil + 12% SS	Immediate	2.34
2	Laterite soil + 12% SS	7	11.64
3	Laterite soil + 12% SS	14	18.43
4	Laterite soil + 12% SS	21	17.78

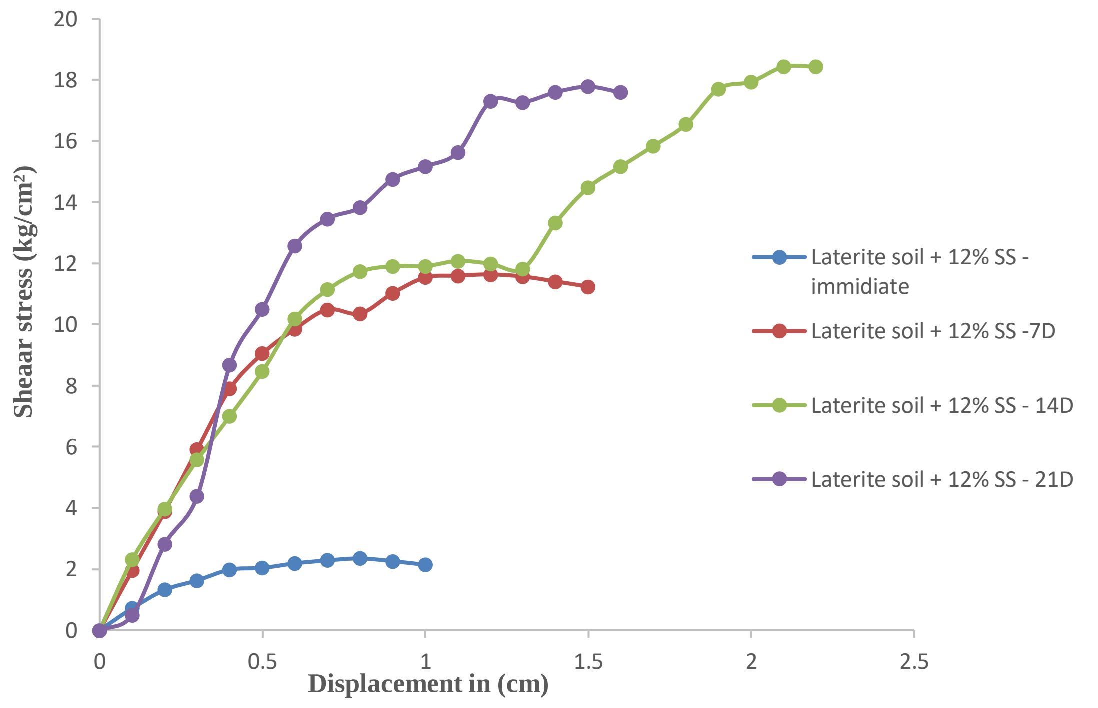


Fig.5.6.1 Shear stress V/S Displacement for Soil with 12% of Sodium sulphate.

Figure shows that the x-axis represents the displacement in (cm) and y-axis represents the shear stress in (kg/cm^2). The unconfined compression test is conducted for Laterite soil with 12% Sodium sulphate at curing period of immediate, 7 days, 14 days and 21 days. The shear stress increases with increase in curing period, compare to immediate, 7 and 14 days for 21 days curing period the maximum shear stress value is 18.43 kg/cm^2.

5.7 UNCONFINED COMPRESSION TEST RESULTS ON LATERITE SOIL WITH 12% OF CALCIUM CHLORIDE

Sl. No.	Description	Days	Shear stress (kg/cm^2)
1	Laterite soil + 12% CC	Immediate	1.22
2	Laterite soil + 12% CC	7	1.79
3	Laterite soil + 12% CC	14	1.01
4	Laterite soil + 12% CC	21	0.95

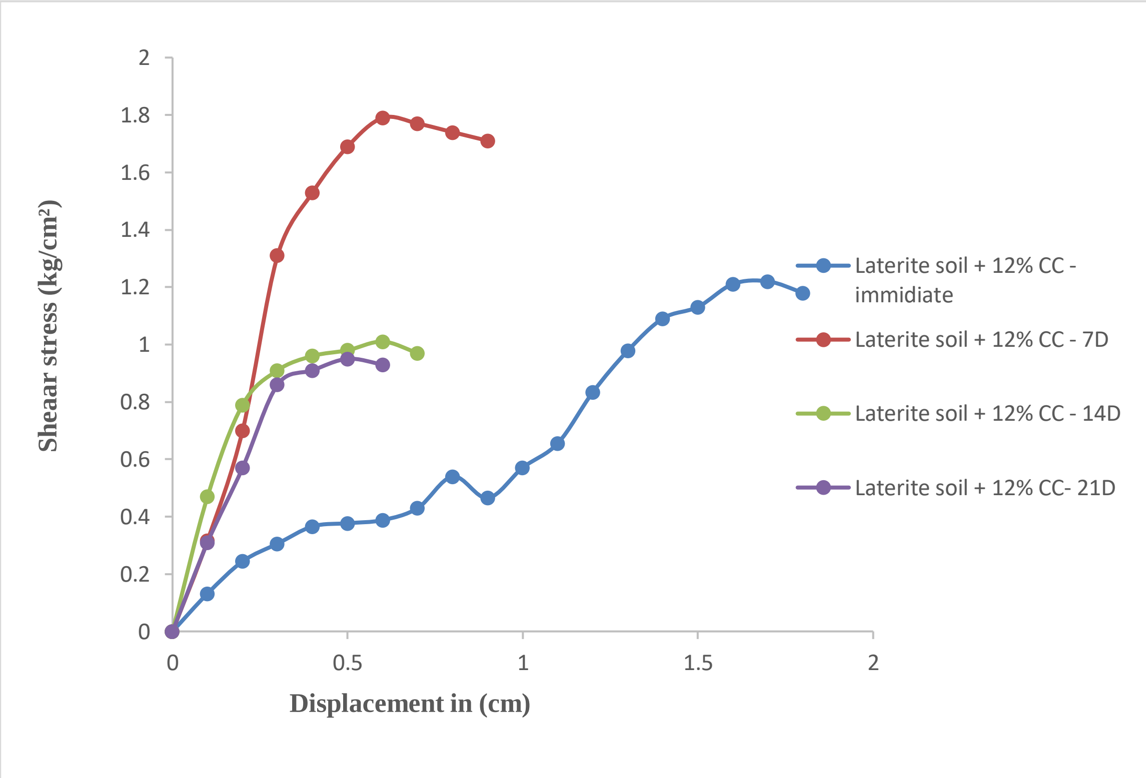


Fig.5.7.1 Shear stress V/S Displacement for Soil with 12% of Calcium chloride

Figure shows that the x-axis represents the displacement in (cm) and y-axis represents the shear stress in (kg/cm^2). The unconfined compression test is conducted for Laterite soil with 12% Calcium chloride at curing period of immediate, 7 days, 14 days and 21 days. The shear stress increases with increase in curing period, compare to immediate, 7 and 14 days for 21 days curing period the maximum shear stress value is 1.79 kg/cm^2.

5.8 UNCONFINED COMPRESSION TEST RESULTS ON LATERITE SOIL WITH 4% OF CEMENT AND 12% OF M - SAND

Sl. No.	Description	Days	Shear stress (kg/cm^2)
1	Laterite soil +4% Cement+4% M-S	Immediate	2.69
2	Laterite soil +4% Cement+4% M-S	7	11.88
3	Laterite soil +4% Cement+4% M-S	14	18.56
4	Laterite soil +4% Cement+4% M-S	21	8.52

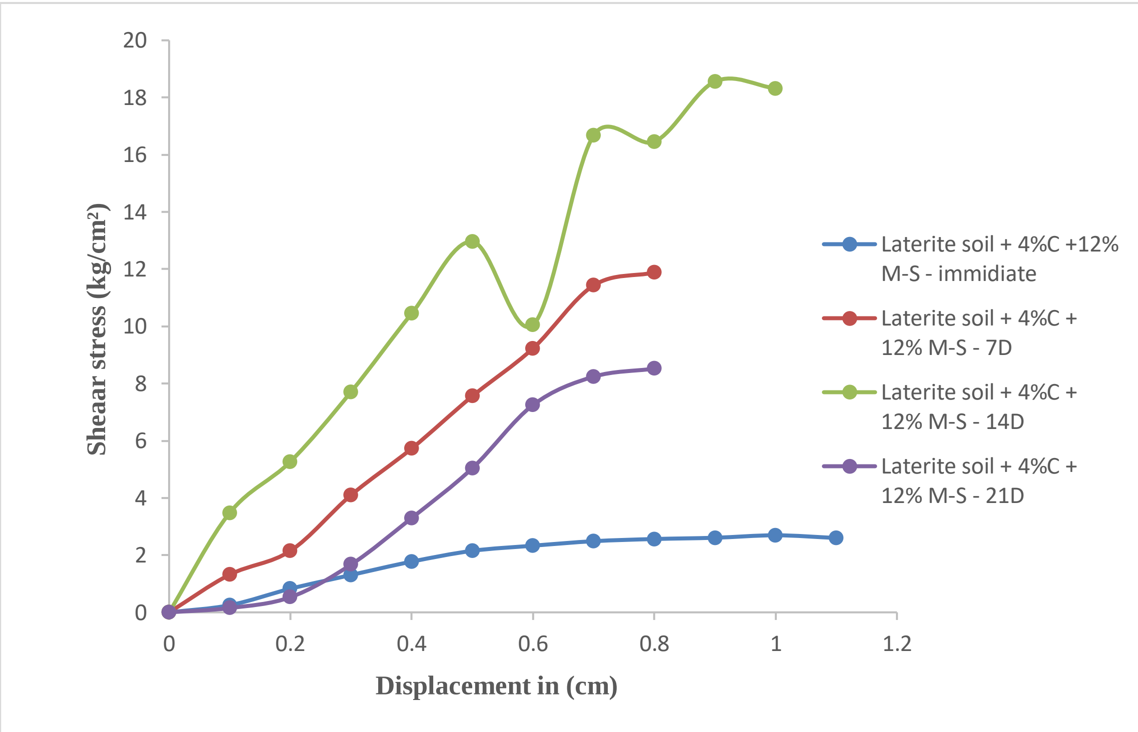


Fig.5.8.1 Shear stress V/S Displacement for Soil with 4% of Cement And 12% of M – Sand

Figure shows that the x-axis represents the displacement in (cm) and y-axis represents the shear stress in (kg/cm^2). The unconfined compression test is conducted for Laterite soil with 4% cement and 12% M-sandat curing period of immediate, 7 days, 14 days and 21 days. The shear stress increases with increase in curing period, compare to immediate, 7 and 14 days for 21 days curing period the maximum shear stress value is 18.56 kg/cm^2.

5.9 UNCONFINED COMPRESSION TEST RESULTS ON LATERITE SOIL WITH 4% OF CEMENT, 12% OF M – SAND AND 12% OF SODIUM SULPHATE

Sl. No.	Description	Days	Shear stress (kg/cm^2)
1	Laterite soil +4% Cement+4% M-S+12% SS	Immediate	4.13
2	Laterite soil +4% Cement+4% M-S+12% SS	7	10.11
3	Laterite soil +4% Cement+4% M-S+12% SS	14	16.52
4	Laterite soil +4% Cement+4% M-S+12% SS	21	10.86

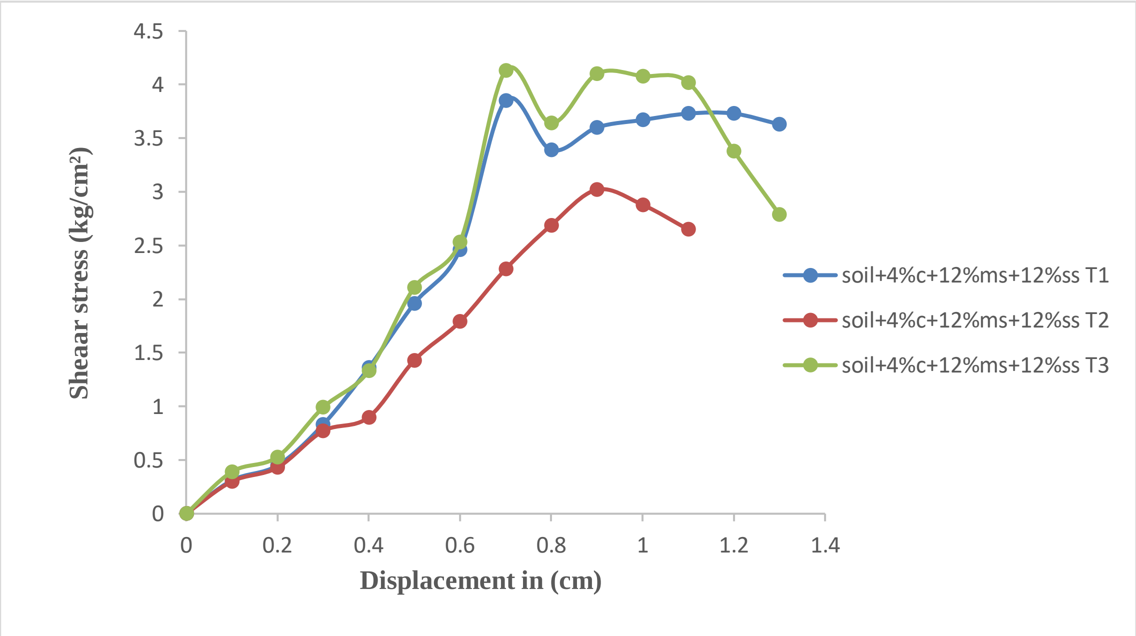


Fig.5.9.1 Shear Stress V/S Displacement For Soil With With 4% Of Cement, 12% Of M – Sand And 12% Of Sodium Sulphate

Figure shows that the x-axis represents the displacement in (cm) and y-axis represents the shear stress in (kg/cm^2). The unconfined compression test is conducted for Laterite soil with 4% cement, 12% M-sandand 12% Sodium sulphateat curing period of immediate, 7 days, 14 days and 21 days. The shear stress increases with increase in curing period, compare to immediate, 7 and 14 days for 21 days curing period the maximum shear stress value is 16.52 kg/cm^2.

5.10 UNCONFINED COMPRESSION TEST RESULTS ON LATERITE SOIL WITH 4% OF CEMENT, 12% OF M – SAND, 12% OF SODIUM SULPHATE AND 12% OF CALCIUM CHLORIDE

Sl. No.	Description	Days	Shear stress (kg/cm^2)
1	Laterite soil +4% Cement+4% M-S+12% SS+12% CC	Immediate	2.54
2	Laterite soil +4% Cement+4% M-S+12% SS+12% CC	7	6.57
3	Laterite soil +4% Cement+4% M-S+12% SS+12% CC	14	13.63
4	Laterite soil +4% Cement+4% M-S+12% SS+12% CC	21	5.17

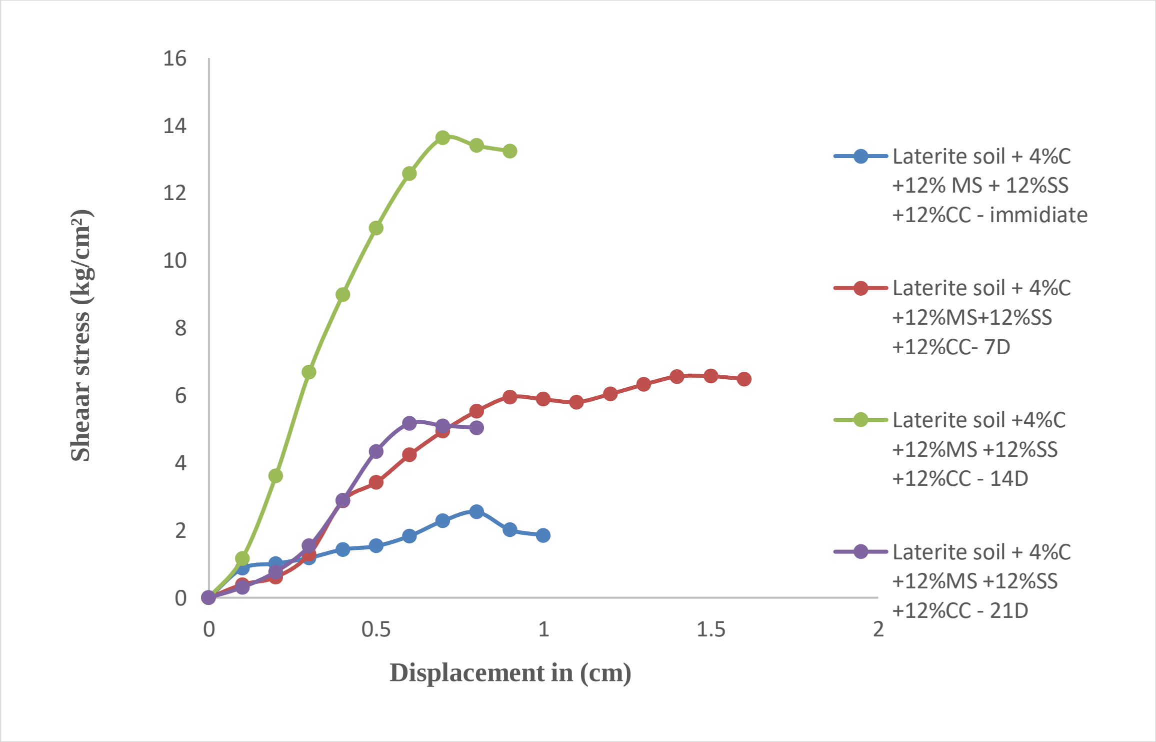


Fig.5.10.1 Shear Stress V/S Displacement For Soil With 4% Of Cement, 12% Of M – Sand, 12% Of Sodium Sulphate And 12% Of Calcium Chloride

Figure shows that the x-axis represents the displacement in (cm) and y-axis represents the shear stress in (kg/cm^2). The unconfined compression test is conducted for Laterite soil with 4% cement, 12% M-sand, 12% Sodium sulphate and 12% Calcium chloride at curing period of immediate, 7 days, 14 days and 21 days. The shear stress increases with increase in curing period, compare to immediate, 7 and 14 days for 21 days curing period the maximum shear stress value is 13.63 kg/cm^2.

5.11 UNCONFINED COMPRESSION TEST RESULTS ON LATERITE SOIL AND LATERITE SOIL WITH 4% OF CEMENT, 12% OF M-SAND,12% OF SODIUM SULPHATE AND 12% OF CALCIUM CHLORIDE AT IMMEDIATE

Sl. No.	Description	Days	Shear stress (kg/cm^2)
1	Laterite soil alone	Immediate	1.46
2	Laterite soil + 4% Cement	Immediate	1.16
3	Laterite soil + 12% M-sand	Immediate	2.85
4	Laterite soil + 12% Sodium Sulphate	Immediate	2.34
5	Laterite soil + 12% Calcium chloride	Immediate	1.22
6	Laterite soil + 4% C + 12% MS	Immediate	2.69
7	Laterite soil + 4% C + 12% MS+12% SS	Immediate	4.13
8	Laterite soil + 4% C + 12% MS+12% SS+12% CC	Immediate	2.54

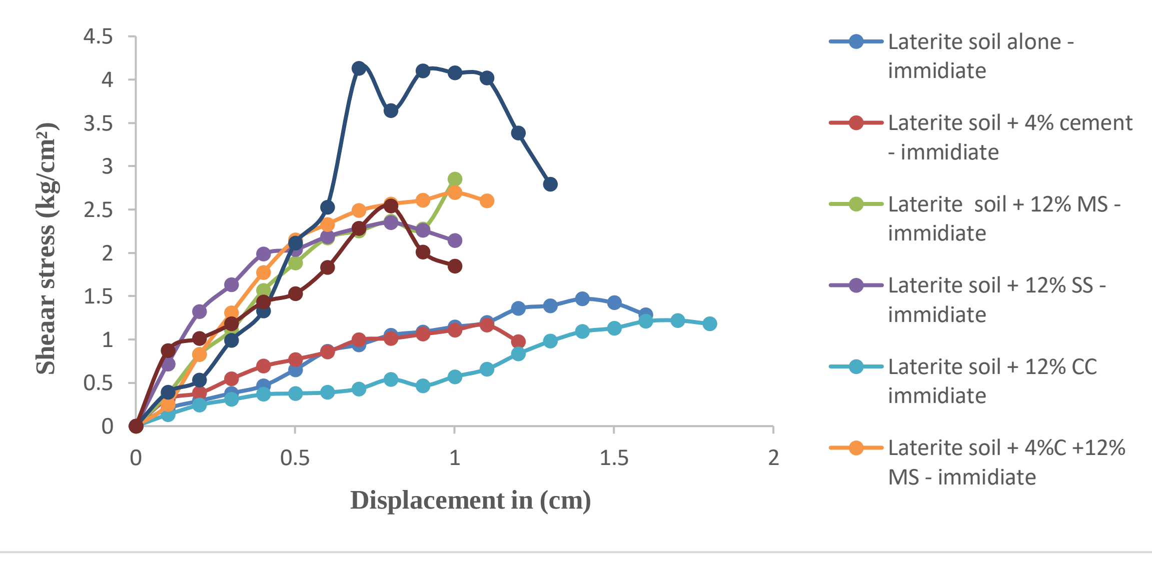


Fig.5.11.1 Shear Stress V/S Displacement For Soil With 4% Of Cement, 12% Of M-Sand,12% Of Sodium Sulphate And 12% Of Calcium Chloride At Immediate.

Figure shows that the x-axis represents the displacement in (cm) and y-axis represents the shear stress in (kg/cm^2). The unconfined compression test is conducted for laterite soil alone and laterite soil with cement, m-sand, sodium sulphate and calcium chloride at immediateperiod. Compare to laterite soil alone, laterite soil + 4% Cement, laterite soil + 12% M-sand, laterite soil + 12% Sodium sulphate and 12% Calcium chloride will gives less shear stress value and Laterite soil with the combinationof obtained shear stress value is 2.85 kg/cm^2.

5.12 UNCONFINED COMPRESSION TEST RESULTS ON LATERITE SOIL AND LATERITE SOIL WITH 4% OF CEMENT, 12% OF M-SAND, 12% OF SODIUM SULPHATE AND 12% OF CALCIUM CHLORIDE AT 7 DAYS CURING

Sl. No.	Description	Days	Shear stress (kg/cm^2)
1	Laterite soil alone	7	4.61
2	Laterite soil + 4% Cement	7	1.16
3	Laterite soil + 12% M-sand	7	2.85
4	Laterite soil + 12% Sodium Sulphate	7	2.34
5	Laterite soil + 12% Calcium chloride	7	1.22
6	Laterite soil + 4% C + 12% MS	7	2.69
7	Laterite soil + 4% C + 12% MS+12% SS	7	4.13
8	Laterite soil + 4% C + 12% MS+12% SS+12% CC	7	2.54

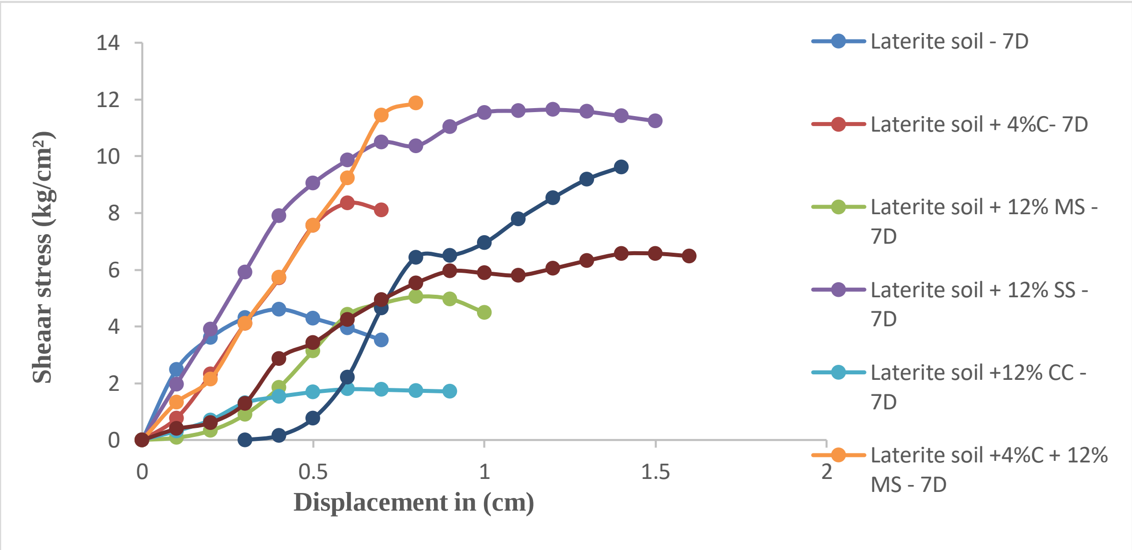


Fig.5.12.1 Shear Stress V/S Displacement For Soil With 4% Of Cement, 12% Of M-Sand, 12% Of Sodium Sulphate And 12% Of Calcium Chloride At 7 Days Curing

Figure shows that the x-axis represents the displacement in (cm) and y-axis represents the shear stress in (kg/cm^2). The unconfined compression test is conducted for laterite soil alone and laterite soil with cement, m-sand, sodium sulphate and calcium chloride at 7 days curingperiod. Compare to laterite soil alone, laterite soil + 4% Cement, laterite soil + 12% M-sand, laterite soil + 12% Sodium sulphate and 12% Calcium chloride will gives less shear stress value and Laterite soil with the combination of obtained shear stress value is 4.13 kg/cm^2.

5.2.11 UNCONFINED COMPRESSION TEST RESULTS ON LATERITE SOIL AND LATERITE SOIL WITH 4% OF CEMENT, 12% OF M-SAND, 12% OF SODIUM SULPHATE AND 12% OF CALCIUM CHLORIDE AT 14 DAYS CURING

Sl. No.	Description	Days	Shear stress (kg/cm^2)
1	Laterite soil alone	14	8.19
2	Laterite soil + 4% Cement	14	12.83
3	Laterite soil + 12% M-sand	14	6.87
4	Laterite soil + 12% Sodium Sulphate	14	18.43
5	Laterite soil + 12% Calcium chloride	14	1.01
6	Laterite soil + 4% C + 12% MS	14	18.56
7	Laterite soil + 4% C + 12% MS+12% SS	14	16.52
8	Laterite soil + 4% C + 12% MS+12% SS+12% CC	14	13.63

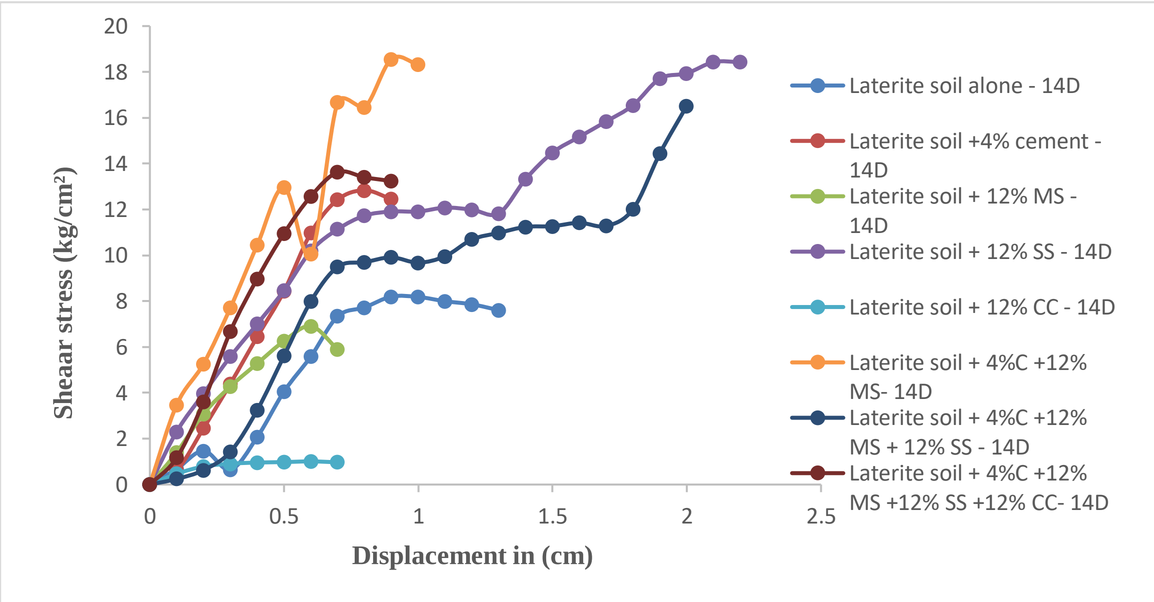


Fig.5.2.11 Shear Stress V/S Displacement For Soil With 4% Of Cement, 12% Of M-Sand, 12% Of Sodium Sulphate And 12% Of Calcium Chloride At 14 Days Curing

Figure shows that the x-axis represents the displacement in (cm) and y-axis represents the shear stress in (kg/cm^2). The unconfined compression test is conducted for laterite soil alone and laterite soil with cement, m-sand, sodium sulphate and calcium chloride at 14 days curingperiod. Compare to laterite soil alone, laterite soil + 4% Cement, laterite soil + 12% M-sand, laterite soil + 12% Sodium sulphate and 12% Calcium chloride will gives less shear stress value and Laterite soil with the combination of obtained shear stress value is 18.56 kg/cm^2.

5.2.12 UNCONFINED COMPRESSIVE TEST RESULTS ON LATERITE SOIL AND LATERITE SOIL WITH 4% OF CEMENT, 12% OF M-SAND, 12% OF SODIUM SULPHATE AND 12% OF CALCIUM CHLORIDE AT 21 DAYS CURING

Sl. No.	Description	Days	Shear stress (kg/cm^2)
1	Laterite soil alone	21	9.71
2	Laterite soil + 4% Cement	21	12.43
3	Laterite soil + 12% M-sand	21	7.46
4	Laterite soil + 12% Sodium Sulphate	21	17.78
5	Laterite soil + 12% Calcium chloride	21	0.95
6	Laterite soil + 4% C + 12% MS	21	8.52
7	Laterite soil + 4% C + 12% MS+12% SS	21	10.86
8	Laterite soil + 4% C + 12% MS+12% SS+12% CC	21	5.17

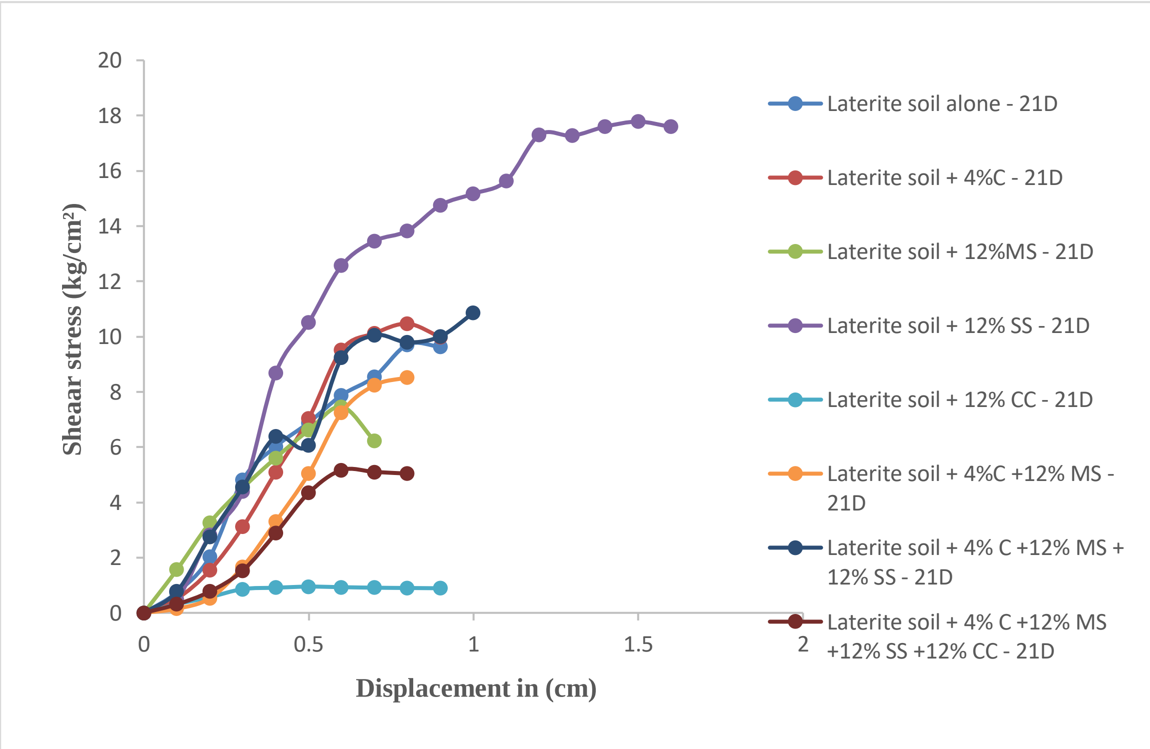


Fig.5.2.11 Shear Stress V/S Displacement For Soil With 4% Of Cement, 12% Of M-Sand, 12% Of Sodium Sulphate And 12% Of Calcium Chloride At 21 Days Curing

Figure shows that the x-axis represents the displacement in (cm) and y-axis represents the shear stress in (kg/cm^2). The unconfined compression test is conducted for laterite soil alone and laterite soil with cement, m-sand, sodium sulphate and calcium chloride at 21 days curingperiod. Compare to laterite soil alone, laterite soil + 4% Cement, laterite soil + 12% M-sand, laterite soil + 12% Sodium sulphate and 12% Calcium chloride will gives less shear stress value and Laterite soil with the combination of obtained shear stress value is 17.78 kg/cm^2.

DETERMINATION OF FREE SWELL INDEX OF SOILS

SWELL INDEX: -Free swell index is the increase in volume of soil, without any external constraints, on submergence in water or kerosene.It may refer to the following material parameters that qualify volume change:

- Crucible swelling test also known as Free swelling index, in soil assay.
- Shrink-swell capacity in soil mechanics
- Unload-reload constant (K) in critical state soil mechanics.

STANDARD

- IS: 2720 (Part 40) 1977.

APPARATUS

- 425 micron IS sieve.
- Graduated glass cylinders 100 ml capacity 2Nos (IS: 878 -1956). Glass rod for stirring.
- Balance of capacity 500 grams and sensitivity 0.01 gram.

PROCEDURE

- Take two representative oven dried soil samples each of 10 grams passing through 425 micron sieve.
- Pour each soil sample in to each of the two glass graduated cylinders of 100ml capacity.
- Fill one cylinder with kerosene and the other with the distilled water up to the100ml mark.
- Remove the entrapped air in the cylinder by gentle shaking and stirring with a glass rod.
- Allow the samples to settle in both the cylinders.
- Sufficient time, not less than 24 hours shall be allowed for soil sample to attain equilibrium state of volume without any further change in the volume of the soils.
- Record the final volume of the soils in each of the cylinders.

CALCULATIONS

Free swell index = **((Vd-Vk)/Vk)*100**

Vd = Volume of the soil specimen read from the graduated cylinder containing distilled water.

Vk = Volume of the soil specimen read from the graduated cylinder containing kerosene.

Determination No.	Mass of dry soil passing 425μ sieve	Volume in water after 24hrs swell(Vd)	Volume in kerosene after 24hrs swell (Vk)	Free swell index((Vd-Vk)/Vk)*100
Soil alone	20 gm	20	20	0
Soil + 4% cement	20 gm	20	20	0
Soil + 12% M-S	20 gm	20	20	0
Soil + 12% SS	20 gm	20	21	4.76
Soil + 12% CC	20 gm	18	19	5.26
Soil + 4% Cement + 12% M-S	20 gm	21	19	10.52
Soil + 4% cement + 12% M-S + 12% SS	20 gm	23	19	21.05
Soil + 4% Cement + 12% M-S + 12% SS +12% CC	20 gm	24	22	9.09

REPORT

- ❖ Read the level of the soil in the kerosene graduated cylinder as the original volume of the soil samples, kerosene being non polar liquid does not cause swelling of the soil.
- ❖ Read the level of the soil in the distilled water cylinders as free swell level. Record the individual and the mean results to the nearest second decimal.

PRECAUTION

- ❖ In the case of highly expansive soils such as Sodium Betonites. the sample size may be 5 grams or alternatively a cylinder of 250ml capacity for 10 grams of sample may be used.

CONCLUSIONS

The following conclusions can be drawn from the experimental results on improvement of mechanical properties of laterite soil treated with admixtures of Cement, M-Sand, Sodium sulphate and Calcium chloride with varying percentages.

1. The compaction test results obtained that the maximum dry density of laterite soil increases with addition of 12% of Sodium Sulphate for corresponding 15.38 percent optimum moisture content the maximum dry density value is 1.98 gm/cm^3.
2. The optimum moisture content of Laterite soil decreases from 15.15% to 13.4% by the addition of 4% of Cement and there is no increment in the MDD values.
3. The compaction test results obtained that the maximum dry density of laterite soil increases with addition of 12% of Calcium chloride for corresponding 15.38 % optimum moisture content the maximum dry density value is 1.95 gm/cm^3.
4. The compaction effect leads to increase in strength of soil by addition of admixtures to the Laterite soil, increase in unconfined compressive strength (UCS) value because of the gradual formation of cementitious compounds due to the reaction between the Cement and Sodium sulphate.
5. The unconfined compression strength of Laterite soil increases with addition of 12% of Sodium sulphate. From the results of unconfined compression test it is observed that the maximum unconfined compression strength is obtained by addition of 12% of Sodium sulphate is 18.43 kg/cm^2 for 14 days curing.
6. The unconfined compression strength of the soil increases with increase in the curing period of 14 days after that there is no increment in 21 days curing.
7. From the Free Swell Index test it is found that, without addition of admixtures free swell index is 0 and with the addition of admixtures of Soil + 4% cement + 12% M-S + 12% SS is 21.05%.
8. It can be concluded that the laterite soil treated with admixtures as a soil stabilizer increases the Shear stress value and which minimize the settlement problems.

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