CHEMICAL STABILIZATION OF SUB-GRADE SOIL WITH GYPSUM AND NACL

GVLN Murthy, K.B.V. Siva Kavya, A. Venkata Krishna, B Ganesh
[1]Assistant Professor, Department of Civil Engineering,
Sri Vasavi Engineering College, TP Gudem, AP, India

ABSTRACT

The object of this paper is to investigate the effect of adding different Compounds including (NaCl & Gypsum) on the engineering properties of silty clay soil. Gypsum is a source of calcium which is major mechanism that binds soil organic matter to clay in soil which gives stability to the soil aggregates. Gypsum complements or even magnifies the beneficial effects of water soluble polymers used as amendments to improve soil structure. Significantly for alkaline soil gypsum is a suitable chemical for improvement of bearing capacity. In case of silty clay soils the engineering properties are improved by adding chloride salts like Nacl, $Mgcl_2$ and $Cacl_2$. Chloride salts increase the maximum dry density (MDD) by decreasing the optimum moisture content (OMC). In this study an attempt is taken to analyze the properties of soil using gypsum and Nacl. Various amounts of salts (15%, 20%, and 25%) are added to the soil to study the effect of stabilizing agents on the compaction characteristics, consistency limits and compressive strength. The main findings of this study were that the increase in the percentage of each of the chemical compounds increased the maximum dry density and decrease the optimum moisture content. The liquid limit, plastic limit and plasticity index decreases with the increase in additives content. The unconfined compressive strength increases as the chemical content increases and also bearing capacity of soil increases.

KEYWORDS: *sub grade soil, density, bearing capacity, NaCl, Gypsum.*

I. INTRODUCTION

1.0 Chemical Stabilization of Sub-Grade Soil

Large areas of plain terrains consist of soils with high clay contents which have low strengths and bearing capacity. This problem has an influence on construction of road and highway, if adequate support does not exist, the road will rapidly deteriorate. The solution to these construction problems is by soil treatment with chemical additives. Soil stabilization is the alteration of soil properties to improve the engineering performance of soils. The properties most often altered are density, water content, plasticity and strength.

The soil stabilization includes both physical stabilization (such as dynamic compaction) and chemical stabilization (such as mixing with cement, fly ash, lime, and lime by-Products, etc.). Nearly every road construction project utilizes one or both of these stabilization techniques due to improvement in technology which make soil stabilization is most economical method and has been widely used today. Chemical stabilization involves mixing or injecting the soil with chemically active compounds such as Portland cement, lime, fly ash, calcium or sodium chloride or with viscoelastic materials such as bitumen. Chemical stabilizers can be broadly divided into three groups, Traditional stabilizers such as hydrated lime, Portland cement and Fly ash; Non-traditional stabilizers comprised of sulphated oils, ammonium chloride, enzymes, polymers, and potassium compounds; and by- product stabilizers which include cement kiln dust, lime kiln dust etc. Among these, the most widely used chemical

additives are lime, Portland cement and fly ash. Although stabilization with fly ash may be more economical when compared to the other two, the composition of fly ash can be highly variable.
The Engineers often faced the problem of constructing roadbeds on or with soils (especially soft clayey and expansive soils). These problematic soils do not possess enough strength to support the wheel loads upon them either in construction or during the service life of the pavement. These soils must be, therefore, treated to provide a stable sub-grade or a working platform for the construction of the pavement. The high strengths obtained from cement and lime stabilization may not always be required, however, and there is justification for seeking cheaper additives which may be used to alter the soil properties. Many attentions have been also paid to the effect of salt on soil properties. It is reliably learnt from researches that salt treatment generally produces higher maximum dry density at lower moisture content. The potential of sodium chloride as a stabilizer in soil- aggregate mixtures results good outcomes. The conclusions are that CBR values, unconfined compression strength, and indirect tensile strength are greatly improved with the inclusion of sodium chloride as a stabilizing agent.
A difficult problem in civil engineering works exists when the sub-grade is found to be clay soil. Soils having high clay content have the tendency to swell when their moisture content is allowed to increase. Many research have been done on the subject of soil stabilization using various additives, the most common methods of soil stabilization of clay soils in pavement work are cement and lime stabilization. The high strengths obtained from cement and lime stabilization may not always be required, however, and there is justification for seeking cheaper additives which may be used to alter the soil properties.
Gypsum can help stabilize aggregate structure in some soils. Use of gypsum in other soils will not improve soil physical or chemical properties, so it is important to understand the processes that occur when gypsum is added to soil. Water, air, and roots move between soil aggregates, which are clumps of soil particles cemented together. The pores between aggregates are fairly large, whereas the pores within aggregates and between particles are often too small for effective water movement or root penetration. Soil aggregate formation and stability, also called soil structure, is one of the most important manageable soil physical properties. In all but the sandiest soils, good aggregate structure is needed for water infiltration and soil drainage.

This study is aimed to attain the objectives defined below. The methodology used first describes the features of the stabilization of soils followed by need and scope of study and objectives. Further a brief literature review is given to focus the features of the study. The next step of methodology is design and analysis which is made by conducting the experiments and obtaining the results. The results are represented by various tables and graphs. The study comes to an end by giving the conclusions followed by the scope for future research.

1.1 Need and Scope of Study

As the residential growth increases the area of land requires for construction of building is also more. Hence to evaluate the soil strength as where the building constructed some tests are to be conducted. This leads to measures to be taken for improving the bearing capacity of soils. Hence the need of the test is to:

- Evaluate the original strength of soil in terms of CBR.
- To found the strength of soil after treatment with chemicals.

Comparing the results and suggest the measures to be adopted.

1.1.1 Objectives

The objectives of this study are to:

- Evaluate the effectiveness of soil stabilization by using chloride compounds and gypsum for silty clay soil.
- Determine the percentage of strength improvement for silty clay soil obtained for different chlorides compounds used at different concentration.
- To increase the shear strength and bearing capacity of the soil.

- To reduce water content and in-situ conditions.
- Increase of soil properties by indicating CBR test results.

1.1.2 Limitations

- There are chances of save inert material in the soil.
- The area is having the combination of little inert matter.
- Area of sample excavation is subjected to high flooding at the time of test.
- Variation may occur in the material due to humidity in the atmosphere.

II. LITERATURE REVIEW

2.0 Theory

Soil stabilization aims at improving soil strength and increasing resistance to softening by water through bonding the soil particles together, water proofing the particles or combination of the two. Usually, the technology provides an alternative provision structural solution to a practical problem. The simplest stabilization processes are compaction and drainage (if water drains out of wet soil it becomes stronger). The other process is by improving gradation of particle size and further improvements can be achieved by adding binders to the weak soils. Soil stabilization can be accomplished by several methods. All these methods fall into two broad categories, namely,

a) Mechanical stabilization

Under this category, soil stabilization can be achieved through physical process by altering the physical nature of native soil particles by either induced vibration or compaction or by incorporating other physical properties such as barriers and nailing. Mechanical stabilization is not the main subject of this review and will not be further discussed.

b) Chemical stabilization

Under this category, soil stabilization depends mainly on chemical reactions between stabilizer (cemen-titious material) and soil minerals (pozzolanic materials) to achieve the desired effect. A chemical stabilization method is the fundamental of this review and, therefore, throughout the rest of this report, the term soil stabilization will mean chemical stabilization.

Chemical stabilization is achieved by mixing chemicals, such as cement, lime, fly ash, bitumen, or combinations of these materials, with soil to form a stronger composite material. Selection of the type and percentage of additive is a function of the soil classification and the degree of improvement desired. Chemicals and/or emulsions can be used as

Compaction aids to soils as:

- Binders and water repellents.
- A means of modifying the behavior of clay to form a stronger composite material.

Chemical stabilization can aid in:

- Dust control.
- Water-erosion control.
- Fixation and leaching control of both waste and recycled materials.

2.1 COMPONENTS OF STABILIZATION

Soil stabilization involves the use of stabilizing agents (binder materials) in weak soils to improve its geotechnical properties such as compressibility, strength, permeability and durability. The components of stabilization technology include soils and or soil minerals and stabilizing agent or binders (cementitious materials).

a) Soils

Most of stabilization has to be undertaken in soft soils (silty, clayey peat or organic soils) in order to achieve desirable engineering properties. According to Sherwood (1993), fine- grained granular materials are the easiest to stabilize due to their large surface area in relation to their particle diameter. A clay soil compared to others has a large surface area due to flat and elongated particle shapes. Organic soils have high exchange capacity; it can hinder the hydration process by retaining the calcium ions liberated during the hydration of calcium silicate and calcium aluminates in the cement to satisfy the exchange capacity. In such soils, successful stabilization has to depend on the proper selection of binder and amount of binder added

b) Stabilizing Agents:

These are generally traditional and non-traditional stabilizing agents.

Traditional chemical techniques include:

- Cement (generally used as a base-course treatment and not as a surface treatment, but included because it is one of the standard "traditional" stabilizers).
- Gypsum
- Lime.
- Fly ash.
- Bituminous materials.
- Combinations of the above.

Two procedures for selecting types and quantities of these products are provided.

Non-traditional Stabilizers:

In recent years an increasing number of non-traditional additives have been developed for soil stabilization purposes. These stabilizers are becoming popular due to their relatively low cost, ease of application, and short curing time. Since the Chemical formulas of the products are modified often based on market tendency, it is rather difficult to evaluate the performance of a single product.

Non-traditional Stabilizers are:

- Chlorides (chlorides, salts, calcium chloride, magnesium chloride, sodium chloride).
- Clay additives (clay additives, clay, filler, bentonite, montmorillonite).
- Electrolyte emulsions (electrolyte stabilizers, ionic stabilizers, electrochemical stabilizers, acids).
- Enzymatic emulsions (enzymatic emulsions, enzymes).
- Lignosulfonates (lignosulfonates, lignin, lignin sulphate, lignin sulphides).
- Synthetic-polymer emulsions (synthetic-polymer emulsions, polyvinyl acetate, and vinyl acrylic).
- Tree-resin emulsions (tree-resin emulsions, tall-oil emulsions, pine-tar emulsions).

i) Gypsum

Gypsum is a naturally occurring mineral that is made up of calcium sulphate and water ($CaSO_4$+$2H_2O$) that is sometimes called hydrous calcium sulphate. It is the mineral calcium sulphate with two water molecules attached. By weight it is 79% calcium sulphate and 21% water. Gypsum has 23% calcium and 18% sulphur and its solubility is 150 times that of limestone, hence it is a natural source of plant nutrients. Gypsum naturally occurs in sedimentary deposits from ancient sea beds. Gypsum is mined and made into many products like drywall used in construction, agriculture and industry. It is also a by-product of many industrial processes.

- In a soil to which gypsum, calcium carbonate or cement was added, the content of dispersible clay was related to both exchangeable sodium percentage (ESP) and electrical conductivity (EC).
- The electrolyte concentration in the soil which could be maintained by addition of calcium carbonate was such that an ESP of >3 was required to maintain clay coagulation.
- Small amounts of gypsum (0.2% w/w) coagulated most of the clay by lowering the ESP and raising the electrolyte concentration.
- However, the clay gradually dispersed as the soil was subjected to wetting and drying cycles and the electrolyte concentration was decreased. The most efficient use of gypsum would appear to be as small annual additions.
- The addition of cement resulted in the stabilization of particles 250-2000 µm diameter, i.e. cementation as opposed to coagulation. Both processes resulted in changes to various physical properties and mechanical properties of the soil.
- It is suggested that both coagulation and cementation in a soil may be achieved by the addition of gypsum and cement or lime, with significant improvements of soil structure.

ii) Sodium chloride

Soil water salinity can affect soil physical properties by causing fine particles to bind together into aggregates. This process is known as flocculation and is beneficial in terms of modifying the required engineering properties of the soil. Taking into consideration the abundance of salt and economic viability, the use of sodium chloride is preferable. Sodium has the opposite effect of salinity on soils. The forces that bind clay particles together are disrupted when too many large sodium ions come between them. When this separation occurs, the clay particles expand, causing swelling and soil dispersion.

işık yilmaz, , berrin civelekoglu (2009) have studied the performance of the gypsum as an additive for treatment of the expansive clay soils by means of swell potential and strength. optimum water content for the best compaction of the bentonite was first determined by standard compaction tests. different quantities of gypsum such as 2.5%, 5%, 7.5%, and 10% by mass were added to bentonite and compacted in optimum water content obtained. obtained changes in the plasticity, swell percent and strength parameters of treated and untreated samples indicated that gypsum can be used as a stabilizing agent for expansive clay soils, effectively.

Journal of Babylon University (2013) aims to investigate the effect of adding chloride salts including (NaCl, MgCl2, and CaCl2) on the engineering properties of silty clay soil. Three amount percentage of salt (2%, 4%, and 8%) were added to the soil to study the effect of salts on the compaction characteristics, atterberg limits, and unconfined compressive strength. The results showed that the increase in the percentage of each of the chloride salts increased the maximum dry density and decreased the optimum water content. The liquid limit, plastic limit, and plasticity index decreased with increasing salt content. Also the results showed that the unconfined compressive strength increased when the salt content increased too.

Soil dispersion causes clay particles to plug soil pores, resulting in reduced soil permeability. The three main problems caused by sodium-induced dispersion are reduced infiltration, reduced hydraulic conductivity, and surface crusting. When sodium-induced soil dispersion causes loss of soil structure, the hydraulic conductivity is also reduced. Another important aspect of soil texture has to do with surface area. Because of their tiny size, a given volume of clay particles has far more surface area than the same volume of a larger sized particle. Sands have larger particle sizes, resulting in less surface area; correspondingly, they cannot accept as much sodium as clay particles. Experiments are done to determine better bearing stability values using different bearing capacity equations.

III. DESIGN AND ANALYSIS

3.0 Laboratory Requirements

Soil Sampling and Suitability: An approved Geotechnical Engineer should visit the project during the construction and collect a bag sample of each type of soil in sufficient quantity for performing the specified tests. The geotechnical engineer should review the project geotechnical report and other pertinent documents such as soil maps, etc., prior to the field visit. The geotechnical consultant shall submit the test results and recommendations, along with the current material safety data sheet or mineralogy to the engineer for approval. When the geotechnical engineer determines the necessity of chemical-soil stabilization during the design phase, they should design a subgrade treatment utilizing the chemical for the stabilization in the geotechnical report in accordance with guidelines. Following tests should be performed and the soils properties should be checked prior to any modification or stabilization.

- ✓ Atterberg limits
- ✓ Compaction test apparatus
- ✓ CBR testing machine

3.1 Tests Conducted

The amount of Con-Aid stabilizer was as prescribed by the manufacturers. Samples of untreated and treated with Con-Aid soil were prepared and the following tests were carried out according to the required standards: Compaction test for Optimum Limit, Plastic Index) and CBR test.

3.1.1 Atterberg limits:

The water content at which the soil changes from one state to other are known as Consistency limits or Atterberg's limits

a) Liquid limit:

Soil contains high water content in a liquid state. It offers no shearing resistance and can flow like liquids. It has no resistance to shear deformation and, therefore, the shear strength is equal to zero. As the water content is reduced, the soil becomes stiffer and starts developing resistance to shear deformation. At some particular water content, the soil becomes plastic. The water content at which the soil changes from the liquid state to plastic state is known as liquid limit.

b) Plastic limit:

As the water content is reduced the plasticity of the soil decreases. Ultimately the soil passes from the plastic state to the semi-solid state when it stops behaving as a plastic. It cracks when moulded. The water content at which the soil becomes semi-solid is known as plastic limit. In other words the plastic limit is the water content at which the soil just fails to plastically.

3.1.2 Compaction test:

Compaction test is used to determine of the dry density-moisture content relationship of soil. The mould recommended is of 100 mm diameter, 127.3 mm height and 1000ml capacity. The rammer recommended is of 2.6kg mass with a free drop of 310 mm and face diameter of 50 mm. the soil compacted in three layers. The mould is fixed to a detachable base plate. The collar is of 60 mm height. If the percentage of soil retained on 4.75 mm sieve is more than 20%, a larger Mould of internal diameter 150mm, effective height of 127.3 mm and capacity 2250 ml is recommended. Obtain a sufficient quantity.

Procedure:

About 3 kg of air-dried, pulverized soil passing 4.75mm sieve is taken. Water is added to the soil to bring its water content to about 4% if the soil coarse grained and to about 8% if it is fine grained. The water content should be much less than the expected optimum water content. The soil is mixed thoroughly and covered with a wet cloth and for maturing for about 15 to 30 min. the mould is cleaned, dried and greased lightly. The mass of the empty mould with the base plate, but without collar, is taken. The collar is then fitted to the mould. The mould is placed on a solid base and filled with fully matured soil to about one-third its height. The soil is compacted by 25 blows of the rammer, with a free fall of 310mm. the blows are evenly distributed over the surface. The soil surface is scratched with spatula before the second layer is placed. The mould is filled to about two-thirds height with the soil and compacted again by 25 blows. Likewise, the third layer is placed and compacted. The third layer should project above the top of the mould into the collar by not more than 6mm.

The collar is then removed, and the soil is trimmed off flush with the top of the mould. The mass of the mould, base plate and the compacted soil is taken, and thus the mass of the compacted soil is determined. The bulk density of the soil is compacted from the mass of the compacted soil and the volume of the mould. Representative soil samples are taken from the bottom, middle and top of the mould for determining the water content. The dry density is computed from the bulk density and the water content.

Bulk mass density, $P = M/V$ gm/ml

Where, M = mass of compacted soil (gm),

V = volume of the mould (ml)

Dry density, $P_d = p / (1+w)$

Where, 'w' is the water content.

The soil is removed from the mould is broken with hand. More water is added to the soil so as to increase the water content. It is thoroughly is mixed and allowed to mature. The test is repeated and the dry density and the water content determined.

3.1.3 CBR Test:

The CBR test is a type of test developed by the California division of highways in 1929. The test is used for evaluating the suitability of sub grade and the materials used in sub-base and base courses. The test results have been correlated with the thickness of various metals required for flexible pavements. The test may be conducted on a prepared specimen in a mould or on the soil in-situ condition. The laboratory CBR apparatus consists of a mould 150mm diameter and 175mm high, having a separate base plate and collar. The load is applied by a loading frame through a plunger if 50mm diameter. For dial gauges are used for measurement of expansion of the specimen and penetration. It may be noted that with the displacer disk inside the mould, the effective height of the mould is only 125mm.The consists of causing the plunger to penetrate the specimen at the rate of 1.25 mm per minute. The loads required for penetration of 2.5mm and 5.0mm are recorded by a proving ring attached to the plunger. The load is expressed as a percentage of the standard load at the respective deformation level, and is known as the CBR value. The CBR value is determined corresponding to both 2.5mm and 5.0mm penetration, and the greater value is used for the design of flexible pavement.

CBR value = (Test Load / Standard Load) x 100.

Generally, the CBR for 2.5mm penetration is high. However, if the CBR for 5.0mm penetration is greater than 2.5mm penetration. The value of 5.0mm penetration is used for defining CBR value.

Standard loads at specified penetrations:

Penetration depth (mm)	Unit Standard load (kg/ cm^2)	Total Standard load (Kg)
2.5	70	1370
5	105	2055
7.5	134	2630
10	162	3180
12.5	183	3600

Procedure:

1. Sieve the sample through 20mm IS sieve. Take the material passing 20mm IS sieve for the test. However, make allowance for large size material by replacing plus 20mm size material by an equal amount of material which passes 20mm IS sieve, but is retained on 4.75 mm IS sieve.
2. Take about 4.5 to 5.5 kg of the material, as obtained in step (1). Mix it thoroughly with the required quantity of water. If the sample is to be compacted at optimum water content and the corresponding dry density, as found by compaction test (light or heavy compaction), take exact quantity of water and the soil to make sure that the water content is equal to the optimum water content.
3. Fix the extension collar to the top of the mould. Also fix the base plate to the bottom.
4. Insert the spacer disc over the base, with central hole of the disk at the lower face. Place coarse filter paper disc on the top of the displacer disc.
5. Take the soil sample in the mould. Compact it using either the light compaction rammer or the heavy compaction rammer, as desired. For light compaction, the soil is to be compacted in 3 equal layers; each layer is given 56 blows by 2.6 kg rammer with drop of 310mm. For heavy compaction, the soil is compacted in 5 equal layers; each layer is given 56 blows by 4.89 kg rammer with drop of 450mm.
6. Remove the extension collar. Trim even the excess compacted soil carefully with a straight edge with the top of the mould. Any hole that may from on the surface of the compacted soil by the removal of the coarse particles should be patched with small size particles and levelled.
7. Loosen the base plate. Remove the base plate and the spacer disc.
8. Weigh the mould with the compacted soil.

9. Place a filter paper disc on the base plate. Invert the mould with the compacted soil. Clamp the base plate. Place a perforated disc fitted with an extension stem on the specimen top after placing a filter disc.
10. Place annular masses to produce a surcharge equal to the mass of the base material and wearing cost of the pavement expected. Each 2.5 kg annular mass is equivalent to 70mm of construction material. However, a minimum of two annular masses should be placed.
11. Immerse the mould assembly I a tank full of water. Allow free access of water to the top and bottom of the specimen.
12. Mount the tripod of the expansion measuring device on the edge of the mould, and take the initial reading of the dial gauge.
13. Keep the mould in the tank undisturbed for 96 hours. Take the readings of the dial gauge every 24 hours, and note the time of readings. Maintain water level constant in the tank. Take the final reading at the end of 96 hours.
14. Remove the tripod. Take out the mould from the tank. Allow the specimen to drain off for 15 minutes. Remove all the free water on the mould, without disturbing the surface of the specimen.
15. Weigh the mould with the soaked specimen.

IV. RESULTS AND DISCUSSION

4.0 Effect of Salt on Consistency Characteristics

The liquid limit, plastic limit and plasticity index decreased as the salts content increased. They attributed this behavior to the fact that the liquid limit and plastic limit is controlling by shearing resistance and inter particle level as also the thickness of diffused double layer. The shearing resistance in the case of plastic limit is found to be higher than in the case of the liquid limit and the diffuse double layer thickness is much lower. The below values shows the atterberg's limits:

Liquid limit values for Soil Sample are:

Table-1

Test number	I	II	III
No of blows (N)	33	25	22
Can number	1	2	3
Mass of can(gm)	36	36	36
Mass of can+ wet soil(gm)	39	42	41
Mass of can+ dry soil(gm)	37	39	39
Mass of water(gm)	2	1	2
Mass of dry soil(gm)	1	5	3
Water content (%)	0.67	0.5	0.4

Liquid limit values for NaCl sample:

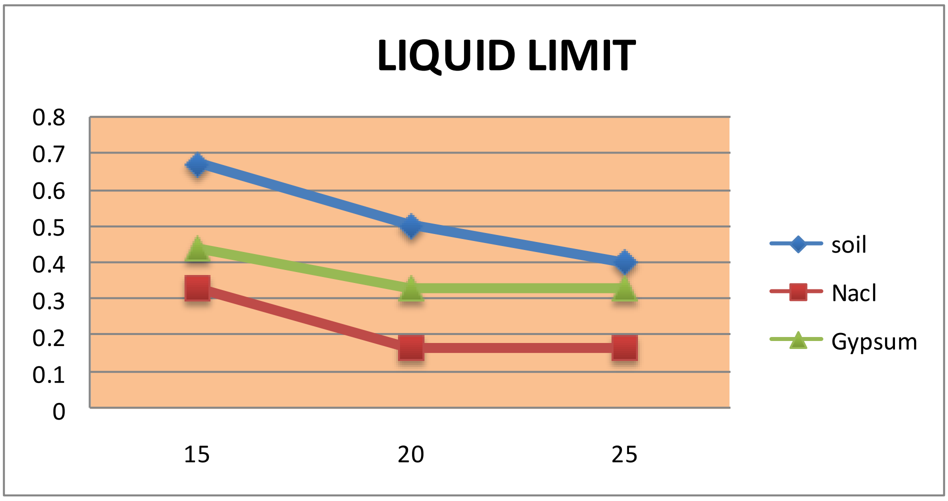
Table-2

Test number	I	II	III
%NaCl	15	20	25
No of blows(N)	28	12	14
Can number	1	2	3
Mass of can(gm)	36	36	36
Mass of can+ wet soil(gm)	42	42	42
Mass of can+ dry soil(gm)	40	41	41
Mass of water(gm)	2	1	1
Mass of dry soil(gm)	4	5	5
Water content (%)	0.33	0.167	0.167

Liquid limit values for Gypsum:

Table-3

Test number	I	II	II
% Gypsum	15	20	25
No of blows(N)	8	15	20
Can number	1	2	3
Mass of can(gm)	36	36	36
Mass of can+ wet soil(gm)	45	42	42
Mass of can+ dry soil(gm)	41	40	40
Mass of water(gm)	4	2	2
Mass of dry soil(gm)	5	4	4
Water content (%)	0.44	0.33	0.33



Graph-1: Percentage of Chemicals vs. Water Content

Plastic limit values for sample soil:

Table-4

Test number	I	II	III
Can number	1	2	3
Mass of can(gm)	36	36	36
Mass of can+ wet soil(gm)	52	53	51
Mass of can+ dry soil(gm)	48	49	48
Mass of water(gm)	4	4	3
Mass of dry soil(gm)	12	13	12
Water content (%)	0.25	0.24	0.2

Plastic limit values for NaCl:

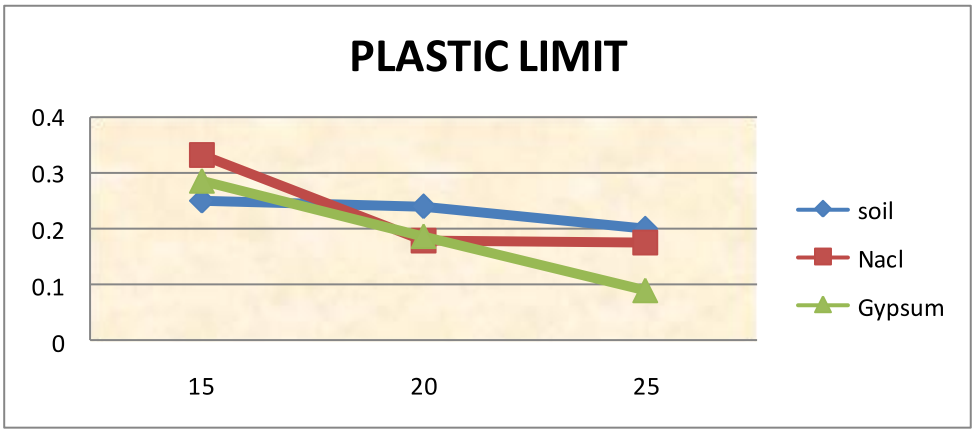
Table-5

Test number	I	II	III
% NaCl	15	20	25
Can number	1	2	1
Mass of can(gm)	36	36	36
Mass of can+ wet soil(gm)	48	47	53
Mass of can+ dry soil(gm)	44	45	50
Mass of water(gm)	4	2	3
Mass of dry soil(gm)	12	11	14
Water content (%)	0.33	0.18	0.176

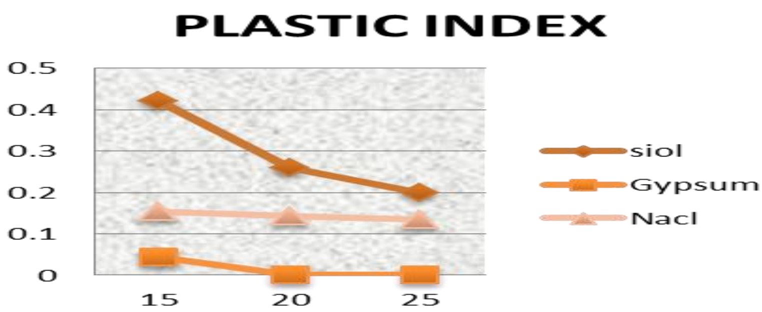
Plastic limit values for Gypsum:

Table-6

Test number	I	II	III
% Gypsum	15	20	25
Can number	1	2	3
Mass of can(gm)	36	36	36
Mass of can+ wet soil(gm)	50	52	47
Mass of can+ dry soil(gm)	46	49	46
Mass of water(gm)	4	3	1
Mass of dry soil(gm)	10	13	10
water content (%)	0.286	0.187	0.09



Graph-2: Percentage of chemicals Vs. Plastic Limit



Graph-3: Percentage of chemicals Vs. Plastic Index Value

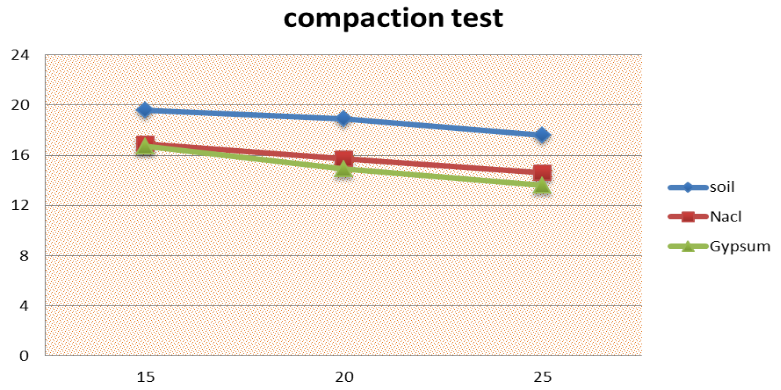
4.1 Effect of Compaction Characteristics

The relation between dry density and water content for stabilization agents used (NaCl and gypsum) and adding different proportions. The addition of salt to the soil increases the dry density on the dry side of optimum moisture content while it causes no significant change in the dry density on the wet side of optimum moisture content.

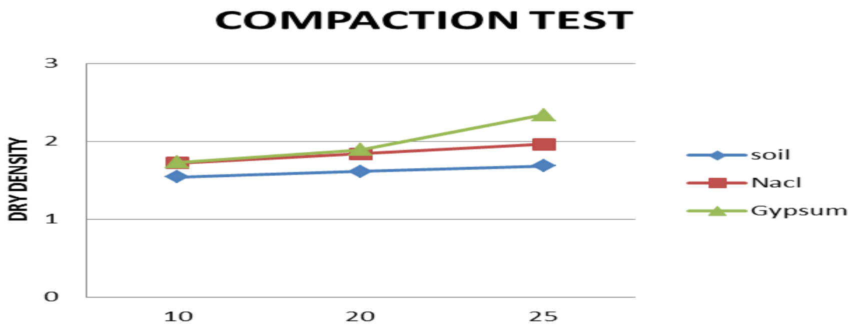
4.2 Effect CBR Values

The relation between penetration and load on the plunger for finding the bearing capacity of the soil in different proportions.The increase of chemicals to the soil the increase in the strength.

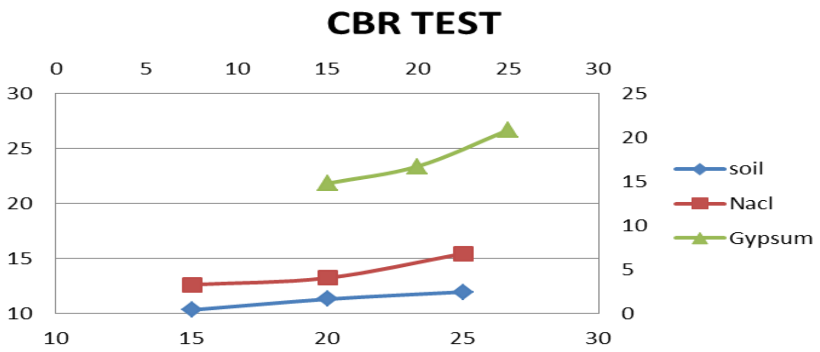
Compaction and CBR test results:



Graph-4: Percentage of chemicals Vs. OMC Value



Graph-5: Percentage of chemicals Vs. Dry density



Graph-6: Percentage of chemicals Vs. CBR Value

V. CONCLUSIONS

Based on the laboratory tests result, the following conclusions can be drawn:

- The liquid limit, plastic limit and plasticity index decreased as the chemicals (NaCl &gypsum) Content increased.
- The additions of chemicals (NaCl & Gypsum) to the soil increase the maximum dry density and reduce the optimum moisture content.
- The addition of sodium chloride and gypsum as stabilizing agents produces a marked increase in CBR value.
- The adding of stabilization agents increases the dry density and decrease of moisture content.
- Finally concluded that the increase in the bearing capacity and decrease in the consistency limits.

VI. SCOPE FOR FUTURE WORK

Gypsum is one of the chemical which is widely available and its application is in different areas other than stabilization of soils by using gypsum it is possible to conduct various experiments by changing the chemical combinations. Not only for stabilization that also for research and efficiency of phospho gypsum for reclamation of poor soils which is connected to the branch of soil sciences. It is also possible to study on applied soil ecology ion a saline soils using gypsum. Because various types of gypsum combinations are available like mined gypsum etc.., it's effect on sodicity induced lands having vast scope for study. Similar effects of Nacl on hydraulic conductivity of soils in saturated condition are also evaluated through studies. Gypsum and lime-calcium sulphate effects are evaluated through various researches by changing the combinations. However this study may helps to some extent for focus some important properties when gypsum and Nacl are used.

REFERENCES

[1]. "Soil mechanics and foundation engineering" by Dr K.R. Arora.
[2]. Ground improvement technics by Dr N. Purushotham Raj.
[3]. BS 1377-4:1990.Method of test for soils for civil engineering purposes.
[4]. Bowles, J. E. (1982). Engineering Properties of Soil. Vol.2. New York: McGraw- Hill.
[5]. Perl off, W. H. (1976). Soil Mechanics, Principals and Applications. New York: John Wiley & Sons.
[6]. Das, Braja M. Principles of Geotechnical Engineering, 3rd edition, PWS Publishing Co., Boston MA, 1994.119.
[7]. Singh, G. and Ali, M. M. "A Comparative Study of the Effectiveness of Sodium Chloride in Soil Stabilization for Pavement Construction", Indian Roads Congress, Highway Research Board Bulletin No.7, 1978.
[8]. Bowles, J.E. "Engineering Properties of Soil", Vol.2. New York: McGraw- Hill, 1982.
[9]. Gypsum is Almost A Universal Soil Amendment", A. Wallace and G. Wallace. Soil Amendments and Amendment Technologies – Volume 1, 1995, A. Wallace - Editor, Wallace Laboratories, ISBN 0-937892-12-2.
[10]. Texas Department of Transportation, "Guidelines for Modification and Stabilization of Soils and Base for Use in Pavement Structures." ftp://ftp.dot.state.tx.us/pub/txdot-info/cmd/tech/stabilization.pdf. (March 2008).
[11]. Işık Yilmaz, Berrin Civelekoglu Gypsum : An additive for stabilization of swelling clay soils Applied Clay Science, Volume 44, Issues 1–2, April 2009, Pages 166–172
[12]. Journal of Babylon University/Engineering Sciences/ No.(5)/ Vol.(21): 2013 "Stabilization of Soft Soils Using Salts of Chloride" Hassnen Mosa Jafer Civil Engineering, Engineering College, Babylon University

AUTHORS BIOGRAPHY

GVLN Murthy was born in Akividu, India, in 1969. He received the Bachelor degree from The Institution of Engineers (India), in 1997 and the Master degree from the Osmania University, Hyderabad in Year 2012. His research interests include stabilization of soil sub grades, pavement material characterization and urban transportation system planning.

K .B.V.SIVA KAVYA was born in Tadepalligudem, India, in 1992. She received the Bachelor in civil engineering degree from the University of JNTUK, Kakinada, in 2013 and the Master in geotechnical engineering degree from the University of JNTUK,kakinada, in 2015. Her research interests include stabilization of soils and foundation engineering.

VENKATA KRISHNA A was born in Nidadavole, India, in 1984. He received the Bachelor degree in civil engineering from the Acharya Nagarjuna University, Guntur, in 2006 and the Master in structural engineering from Andhra University, Visakhapatnam, in 2010. He is currently pursuing the Ph.D. degree with the Department of civil Engineering, Andhra University, Visakhapatnam. His research interests include replacement of materials in concrete, stabilization of soils and earthquake resistant design of buildings.

Ganesh B was born in **Mandapeta**, India, in 1987. He received the Bachelor degree from the Andhra University, Visakhapatnam, in 2009 and the Master degree in Geo-Informatics and Surveying Technology from the JNTUH, Hyderabad, 2014. His research interests include rock mechanics and geology.