"PRODUCTIVITY OF DIFFERENT CHEMICAL STABILIZERS ON EXPANSIVE SOIL"

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UNDER THE GUIDANCE OF

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CANDIDATE'S DECLARATION

I, MOIN KHAN(2K19/GTE/08),Student of MTech. (Geo-Technical Geotechnical), hereby declare that the minor project I titled "**PRODUCTIVITY OF DIFFERENT CHEMICALS STABILIZERS ON EXPANSIVE SOIL"** which is submitted by me to the Department of Civil Geotechnical, Delhi Technological University, Delhi in partial fulfillment of the requirement of the award of the degree of Master of technology, is original and is not copied from any source without proper citation. This work has not previously formed the basis of the award of any degree, diploma associateship, fellowship, or any similar title of recognition.

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CERTIFICATE

I hereby certify that the minor project I titled "**PRODUCTIVITY OF DIFFERENT CHEMICALS STABILIZERS ON EXPANSIVE SOIL**" by MOIN KHAN, belonging to Master of technology, Geo-Technical geotechnical, Civil Geotechnical Department, Delhi Technological University, Delhi in partial fulfillment of the requirement for the award of the degree of Master of Technology, is a record of the project work carried out by the students under my supervision. To the best of my knowledge, This work has not been submitted in part or full for any Degree or Diploma of this University or elsewhere.

Place– Delhi
Date: 21/July/2021

Prof. Kongan Aryan
SUPERVISOR

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ABSTRACT

Expansive soil is assessed as volatile soil. Soils stabilization of expansive clay may be performed through replacement, chemical, and bodily methods. I try to cause them to greater viable for production purposes, several substances and strategies were used to stabilize the soil. In this study, the additive sand strategies carried out for stabilizing expansive soils can be centered on, with admire in their performance in enhancing the geotechnical residences of the soils. This study researches the stabilization of expansive clay through the usage of chemical methods, via way of combining soil with Phosphogypsum, Copper residue, Rice husk. Specimens had been subjected to Atterberg limits (LL/PI) plastic limit, free swell index, unconfined compressive energy. The following chemical compounds with soil had been delivered with at a few chances particularly around 10%, 20%, 30% and had been hardened for 7 days, 14 days, and 28 days, and after that, the boom in energy became calculated and graph had been plotted. All the substances used had been the ones giving excessive energy to soil and the height factor became additionally shown.

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LIST OF ABBREVIATIONS AND SYMBOLS

BC	-	Black Cotton
BIS	-	Bureau of Indian Standards
CBR	-	California Bearing Ratio
C_c	-	Coefficient of Curvature
FSI	-	Free Swell Index
g/cc	-	gram / centimeter cubic
MH	-	Silt(M) with High plasticity
IS	-	Indian Standards
kN/m^2	-	Kilo Newton / meter square
LL	-	Liquid Limit
MDD	-	Maximum Dry Density
µm	-	Micrometer
OMC	-	Optimum Moisture Content
PG	-	Phosphogypsum
PL	-	Plastic Limit
RHA	-	Rice Husk Ash
SL	-	Shrinkage Limit
G_s	-	Specific Gravity
UCC	-	Unconfined Compression
UCS	-	Unconfined Compressive Strength

CHAPTER 1

INTRODUCTION

1.1 GENERAL

There is a vast boom in industrialization and civilization in progressing nations like India, manual to a growing shortage of land which drives us to utilize the beneficial land extraordinarily it is probably interesting. Hard soils are hose having low bearing capacity, excessive compressibility, and excessive swelling /shrinkage and as they may be now no longer in shape for any geotechnical exercises, in maximum geotechnical projects, it is now no longer possible to acquire a site that will meet the layout condition, that is the soil ought to be proficient of withstanding the weight from the superstructure transferred as stress via the foundation, without going via shear failure in addition to the intense settlement, so our current process is to evolve geotechnical residences of the authentic difficult soils to cover the layout specifications. Expansive soil is likewise recognized as complex soil.

Those soils are remaining deposits fashioned after basal or else rap rocks, incorporates required clay mineral montmorillonite, that is the maximum unpredictable clay mineral, thus the soils have shrinkage and swelling characters upon distinction in water proportion. The climatical occasions undergo in dry and semiarid regions in which evaporation passes precipitation and further in which negative leaching and drainage may be unreliable for the development of expansive soils. Soil stabilization's main cognizance is on growing strength of soil and reduces in settlement and extent alternate of soil. compaction and drainage are straightforward stabilization strategies, similarly, soil up-gradation may be finished via way of means of alternate in gradation of particle length and destiny up-gradation may be finished via way of means of an extension of blinders to susceptible soils. Soil stabilization strategies are received via way of means diverse strategies.

1.2Mechanical Stabilization

The procedure that is gained through enhancing the nature of herbal soil debris through both vibration or compaction with the assist of limitations and nailing, this kind of technique is mechanical stabilization. This procedure attempts to tackle geotechnical characteristics in parts of the soil combination. It is designed in shrinking void ratio through satisfying space among large coarse soil values with better soil. The mixture of soils owning changed rough proportions observed over compaction, so referred to as the technique of soil stabilization is referred as coarse equilibrium. The compaction procedure makes sure the void ratio is compacted which refines the soil strength variables along with cohesion (C) and perspective of inner friction.

1.3 Chemical Stabilization

Chemical stabilization is the system that specifically relies upon chemical response among stabilizers and minerals present in the soil. The chemical is known as cementitious material and the mineral is known as pozzolanic material. By soil stabilization, unbound substances may be stabilized with cementitious combos like lime, bitumen, fly ash, lime, etc. The stabilized soils are better strength, better permeability, and decrease compressibility as compared to unstabilized soil. The factors which might be looking at the problem are compressibility, permeability, quantity stability, durability. Various techniques are there to progress the duty of poor-pleasant soils, the system wall of a selected technique relies specifically on the sort of soil to be improved, location of improvement required for a selected usage. Chemical stabilizers are one of the most lower-priced techniques for development in the geotechnical behavior of expansive soil. Applications for those techniques are (highway, railway, runway) to enhance sub-bases and subgrades aimed at ridges by way of soil change in nonstable grades, for example, backfill for bridge and Retaining walls.

1.4 Stabilizing Agents Used for Stabilization

Stabilizing agents could be primary binders or secondary binders causing which after comes into connection by water or by occurrence of pozzolanic materials reactions with water towards cemented merged material. The cast-off folders in these projects stand as Phosphogypsum, copper residue.

1. Phosphogypsum- Phosphogypsum (PG) is a by-product of phosphate fertilizer production. It is extracted from phosphate rock and phosphoric acid. Its distribution varies depending on the type of ore and processing technology. The larger the material covered is based on environmental characteristics, mainly due to the presence of bedrock Radioactive material.Phosphogypsum is wet, gray, medium-fine, silty, or silty sandy. The maximum number of particles (50 to 75%) is less than 0.075 mm. The density of the phosphogypsum group ranges from 2.3 to 2.6, and the maximum dry bulk density is approximately 1470 to 1670 kg/m3.

2. Copper residue – A waste product which is obtained from copper industries after the process of smelting having irregular shape and specific gravity from 3 to 4 with a bulk density of 2.08 g/cc. The copper residue is a dark glazed particle, granular in the atmosphere with an identical particle magnitude choice similar to sand. The rest of the copper is black, and its rough form contains less than 1% moisture. The residue has a fine density of 3.2 and a particle size range of 2.36 mm to 1.18 mm, which corresponds to the condition of sand. Mainly made of copper. The residue contains oxides of copper, iron, and silicon dioxide.

1.5 STABILIZATION MECHANISM

The attachment of chemicals to excellent grained soil including dense clay in occupancy if water can also additionally have numerous reactions. cation alternate and flocculation create unexpected step in soil plasticity and workability and additionally, there may be a few developments at the strength. Apart from this strength is going up due to outside changes. The compounds are made through calcium and the alumina and silica oxides dissolved from clay shape an excessive PH.

The strength advanced is primarily based totally on the amount of cemented gel formed and consequently on the amount of chemical devour (expended), besides the circumstance that the total of chemical computed has to be in relation with clay inorganic contented in soil.

1.6 FACTOR FOR STABILIZATION

1.Organic matter –

In most cases, the topsoil, the surface layer, contains more organic matter, and the soil is well-drained, and the organic matter can diffuse to the depth of 1.5 m to 2 leads to a lower PH.

2.Compaction-

After completion, the final result of the mixer and the strength of the soil is decisive. The stable mixer has the driest density, unstable soil below the specified compaction level. The lower moisture content of the material increases as the binder grows. In stable soil, hydration entrainment occurs immediately after cement and water move together. This method requires the soil mixture to harden, so it is very important to compact and bind the soil as quickly as possible. In addition, it causes stable soil to harden, so additional compaction work may be required to achieve an accurate impact. It can also cause serious damage to the connection and cause power outages. Change the material by plasticity from clay instead of soil. Compared with cement, it takes longer to compact lime. Stable soil has several advantages. Lime-stabilized soil takes a long time to spread on the ground, so it makes most of the result plastic. After this process, the lime-stabilized soil can be mixed again and compacted to the maximum, which generates extraordinary strength than usual.

3.Moisture Content-

In soothed soil, sufficient water content material may be very powerful now no longer easy for hydration system but additionally for properly organized compaction. Fully hydrated cement takes as much as approximately 20% of its very own weight. Further, Quicklime (CaO)sales approximately 32% of the very own weight of water as of nearby. Inadequate water content material may be the motive for binders to take part with soils in command to increase a few portions of moisture.

For soils top having soil water attraction (inclusive of clay and natural loams), the hydration system could be retarded due to inadequate water content material, so in the end it affects the strength at some point .

4. Temperature-

The volcanic ash reaction is very sensitive to temperature changes. The temperature of the soil around the clay fluctuates constantly. The volcanic ash reaction between the binder and the soil particles slows down the very low temperature and leads to a decrease in the strength of the stable quality. In cold regions, stabilizing the soil in the hot season may be beneficial.

5. Geo-Polymerization –

An alkaline fluid can be put to use in reaction counter with silicon and aluminum in source material of geological cause or in after impact constituents like as residue or fly ash to produce binders. Because these reactions represent an inorganic polymerization process, hence the word came out to be known as Geopolymer. The polymerization progression comprises considerably a speedy Natural response beneath basic process on SiAl minerals which outcomes in three-dimensional polymeric cable and ring construction consists of Si-O-Al-O bonds. No water is present in the geopolymeric matrix. Water takes no role in natural reactions; it entirely affords workability to composition through pick up. The category and measure of stabilized supplementary are based primarily on strength and presentation which desires to be accomplished.

1.7 NEED FOR THE STUDY-

For the Great presentation of constructions made on expansive soils, geotechnical behavior of alike soil wishes to change positively. It is surely proved from the literature that the addition of chemicals brings an optimistic variation in the index and geotechnical properties of expansive soil. Though several researchers worked on stabilization of expansive soils, many studies are being carried out using a regular type of stabilizer like lime, cement, fly ash, etc., differing with its percentage. Since a handful of chemicals are coming up for the benefits of the construction industry, there is a required study whether such chemicals could come into practice for refining geotechnical properties of expansive soils.

Hence, it is crucially important that a detailed investigation of the behavior of soil reacted with different chemicals needs to expand. Accordingly,area of the preferable investigation is argued to have an understanding of the soil stabilized with various chemicals for eg. Phosphogypsum and Copper Residue. To attain the same, the objectives of presents study are framed and presented below.

1.8 OBJECTIVE OF PRESENT STUDY -

The objective of current research is

1. Analyze the result of Phosphogypsum on the index properties and unconfined compressive strength of expansive soil, by ranging different percentage of Phosphogypsum and period of curing.

2. To estimate the index and geotechnical belongings of expansive soil mixed through copper residue by ranging different percentages of copper residue.

1.9 SCOPE OF WORK-

The scope of the work is to carry out comprehensive laboratory investigations on soil stabilized with different stabilizers such as Phosphogypsum as well as Copper residue described below.

1. Characterization of soil.

2. Performing liquid limit, plastic limit, and shrinkage limit tests on soil – chemical mixture by varying the amount of chemical and duration of curing.
3. Performing standard proctor compaction tests on soil -chemical mixture to get compaction-like characteristics.

Performing Unconfined Compressive Strength test on soil chemical mixture to get unconfined Compressive strength by varying amount appropriate for chemical and curing period.

1.10 THESIS COMPOSITION

The present thesis consists of five chapters as follows:

(i) Introductory chapter presents an outline of difficulties related to expansive soils, the dominant mineral present in the expansive soil and highlights, the structure and chemical composition of chemical stabilization of expansive soils, different stabilizers used for stabilization and their beneficiary outcomes stabilization mechanism and factors influencing the actions of stabilized expansive soils. Requirement for the extra learning on stabilization of expansive soil using quite a few chemicals is also shown along with the objective of the present study.

(ii) Some of the related works arranged in soil stabilization by Phosphogypsum, Copper residue described by literature which is talk about shortly in Chapter 2. The stabilization mechanism of chemically reacted soil is shown. Factors affecting elasticity as well as the strength of chemical-soil combinations are discussed. Influence by chemical stabilization on physicochemical properties, index properties ,strength, and well shrink characteristics are revealed.

(iii) Chapter 3 gives us points about several chemicals used in present study for stabilization. The belongings in expansive soil revealed in current learning are also offered in chapter 3. In addition details of percentage of chemicals used, the curing period adopted and details of experiments conducted are also given in chapter 3.Chapter 3 also includes the influence of construction chemicals on index values like plastic limit, liquid limit, plasticity index, and shrinkage limit is presented in chapter 4.

(iv) The variation of UCS was examined concerning chemical cast-off along with hardening phase. The influence of each parameter on UCS by chemical soothed soil stays discussed. Chapter 4 also presents the index values with unconfined compressive strength in Phosphogypsum reacted models reacted by changed proportion in Phosphogypsum with changed hardening phase offered in chapter 4.Further impact of Copper residue proceeding various index properties with unconfined compressive strength stays deliberated in chapter 4.

(v) Chapter 5 summarizes the investigation and shows conclusions arrived in a proper format.

Chapter II

Review of literature and scope of the investigation

2.1 GENERAL

This section offers a comprehensive literature review on the chemical stabilization of soil.The disparity of index properties and geotechnical properties of soil due to stabilization with several chemical stabilizers as seen in the literature were studied. The research works reviewed have conversed in the following order.

Studies on Impact of soil with Phosphogypsum.

Studies on Impact of soil with Copper Residue.

2.2 STUDIES ON IMPACT OF SOIL WITH PHOSPHOGYPSUM

James discovered the productivity of Phosphogypsum on so-called strong point along with index values in expansive soil. The Phosphogypsum cast-off got attained from the fertilizer plan of Coromandel Fertilizers, situated in Ennore, north of Chennai, India. Soil cast-off in the study was attained from Thamanji Village, Thiruvallur District, Tamil Nadu, India. The belongings of soil and Phosphogypsum when mixed soil with were gained from laboratories. The quantity of Phosphogypsum used in soil was 40%, 50% and 60%. The Tests were carried on the samples, included consistency limits, free swell index and unconfined compression tests.

Mishra and Mathur (2004) had aligned (stabilized) expansive soil with phosphogypsum and observed the optimum percentage as 40%. Degirmenci (2007) also appealed that the research of phosphogypsum on various properties like liquid limit (wL), plastic limit (wP), OMC, MDD, UCS of expansive soil.

By stabilization with phosphogypsum, the MDD improved, OMC declined, and UCS improved. Yilmaz and Civelekoglu (2009) had calculated that the conclusion of phosphogypsum on Atterberg's limits, UCS concluded that up to 5% addition of gypsum and the properties of expansive clay enhanced suggestively.

The Tests results specify the following,

(i) Accumulation of PG on expansive soil has resulted in the downfall of liquid limit and progress of plastic limit, which showed better plasticity characteristics of the soil.

(ii) There was a growth in shrinkage limit of soil specifying an enhancement in swell-shrink characteristics.

(iii) Expansive soil its arrangement from CH to ML.

(iv) Soil give better rise in UCC strength as compared to some of the extra industrial waste materials, thereby improving the strength features of soil.

Divya explored outcome on Phosphogypsum along with fly ash for stabilizing soil. This paragraph deals in learning which was agreed obtainable for checking progress assets of soil by Phosphogypsum with different proportions (i.e.,5,10,15%) through a set fly ash (5%). Sieve analysis, Atterberg limits, specific gravity, Proctor compaction, free swell index, and unconfined compressive strength tests are among the experimental research run on virgin soils to get geotechnical properties in compliance with Indian standards (BIS).

Tests results were as follows,

1. Strength of stabilized soils was enlarged with a rise in the total of Phosphogypsum with fly ash at an ease of 5%.

2. Hardening duration of mixing plays role leading restriction as chemically stabilized reactions are highly dependent on the situation. As a response, the strength will strengthen as the hardening phase enlarges.

3. Unconfined compressive strengths of reacted soils were higher than that of untreated soils. The lowest increase is 1.72 and 2.25 times for the Soil S1 and S2 on adding 5% fly ash and 2% Phosphogypsum at a curing time of 7 days.

2.3 STUDIES ON IMPACT OF SOIL WITH COPPER RESIDUE

Gupta displayed a trial study of clayey soil by copper residue. The compaction and shear strength structures of clayey soil were studied with several mixed proportions of copper residue from 10, 20,30, 40 up to 100% additional with clayey soil. Copper Residue had an extreme amount of silica (71.52%) and an actual fewer amount of CaO (0.16%). The value of silica, alumina and iron oxide in copper Residue was found to be around 92.12%. So, it has good potential to make high-quality pozzolanas. The following outcomes were detected in these studies the absolute maximum dry density was found to be 1.937 g/cc for the grouping of 50% Clay and 50% Copper residue. The maximum dry density was also higher than 1.87 g/cc for a shared outcome of 70% Clay with 30% Copper residue to 30% clay with 70% copper residue.

Ravi made out the study on the Clay Soil Features by using Copper Residue Stabilizations. The experimental study contained sequences of trials with clay soil diverse(mixed) with 10%, 20% and 30% of copper residue, therefore outcomes of Maximum Dry Density (MDD), Optimum Moisture Content (OMC) and California Bearing Ratio (CBR) were linked alongside ASM in addition to Indian standards aimed at planned necessities in subgrade for the plastic roadway. They have concluded with the following observations.

i. The rise in the percentage of copper residue helps in the rise of the maximum dry density of the Stabilized clay soil which in return decreases the plasticity.

ii. The CBR value was also continuously increasing in attraction towards copper residue with accumulation in Stabilized operation.

iii. The greater the CBR value inside 30% addition of copper residue, the better the conventionality for the case of flexible pavement, particularly in the minimization of subgrade course thickness.

iv. The grouping of 70% clay soil and 30% copper residue is well-matched equilibrium ratio which increases all the desirable characteristics of sub-grade requirements.

2.5 SUMMARY OF LITERATURE REVIEW

1. Addition of chemical stabilizers improves the properties of problematic soil.

2. Addition of the stabilizers declines liquid limit plastic limit rises, reduction in the plasticity index value.

3. Stabilization process decreases the activity and swelling potential of virgin soil.

4. Dry density declines and OMC upsurges for increasing percentage of stabilizers.

5. Improvement in unconfined compressive strength of the stabilized soil rest mainly on the proportion of stabilizers adopted, hardening date granted.

6. Change in expansive soil takes place due to the function of cation exchange with the addition of stabilizers.

2.6 SCOPE OF THE STUDY

Though several researchers worked on improving the geotechnical behavior of the soil by using various stabilizers, collective information regarding the efficiency of different stabilizer on enlightening geotechnical behavior of a particular soil is no well documented. Such studies would help the practicing engineers to choose a specific stabilizer for improvement based on their requirements. Hence, contemporary learning focuses to carry available impact in Phosphogypsm and Copper Residue on index and engg. assets of expansive loam by varying the amount of stabilizer and curing period, through detailed laboratory research.

CHAPTER 3

MATERIALS AND METHODS

3.1 GENERAL

Facts in the location from which soil samples have been obtained, method of preparation of soil samples for several Testing, the chemical composition of Phosphogypsum and Copper residue designated for this study are discussed in this chapter. The properties determined are liquid limit, plastic limit, shrinkage limit, basic Proctor compaction characteristics, confined compressive strength. The material chosen properties and for future use. By Performing some strength test we could get to know whether the material is fit for the soil or not and if it fits we can use it for future development.

The material mixed with some proportions with soil to get better results and it was noticed at what point their strength goes down and after the Graphs were developed on those readings. for each material we will be taking 3 readings each excluding virgin soil and strength is noticed for 7 14 28 days.

The several testing procedures adopted for both virgin soil and cured samples to fix the above properties are presented in the following sections. Though it was very difficult to deal with expansive soil therefore , there can be Enhancement in assets of an expansive or challenging soil meant rise in compressive strength and absorptivity, decreases plasticity and compressibility, and up-gradation in the resilience of soils.

3.2 METHODOLOGY

The stabilizers selected for this study are Phosphogypsum, Copper residue. The Soil chosen for this study is plastic clay. Variables measured are in percentage of stabilizer and period of curing. Various tests are conducted to estimate the index and geotechnical Belongings of stabilized soil. The methodology is exposed in a flow determining the stabilizers, the chemical, the percentage and the curing days, and the test performed.

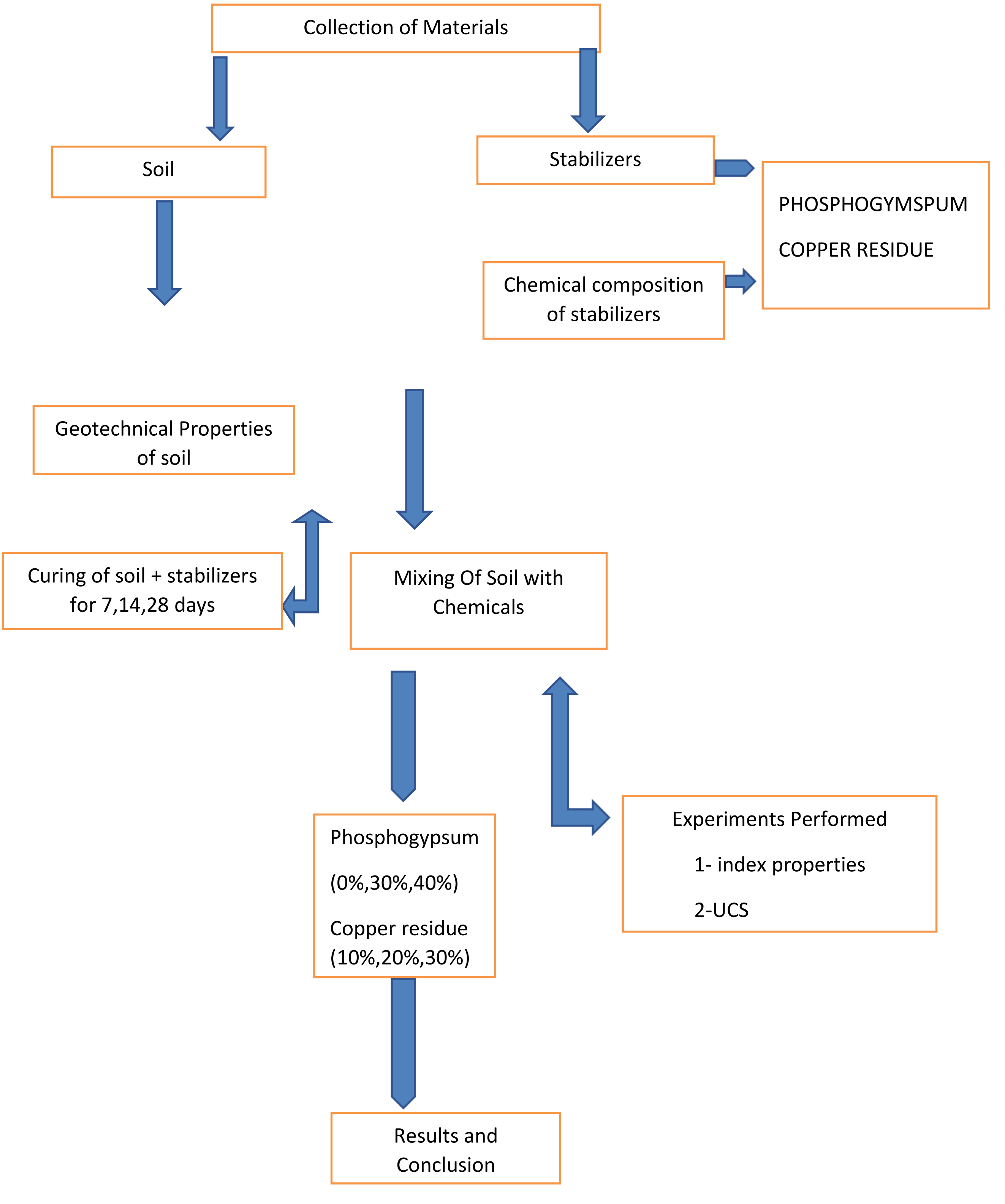

Table -Flow Chart of Methodology

3.3 MATERIALS

The properties of soil samples and chemicals used currently are discussed in the following sections.

3.3.1 Soil

Chemical stability is a process that stabilizes clayey soil mainly fat clays like expansive clay impassively. Hence, the soil which falls in the group of clay of higher strength selected materials. The soil cast-off in current learning remained different. The soil was collected from Gurgaon ,Manesar from a specific store, the compulsory volume of soil sample stayed as one kg and was administered and stored in stell trays for conducting experiments. Since the expansive soil is identified for its poor geotechnical response, the situation is decided to learn the outcome by Phosphogypsum, Copper residue on numerous properties like, liquid limit, plastic limit, shrinkage limit, Unconfined compressive strength.

One factor which consumes a strong impact response of chemical stability of soil is the method adopted for the preparation of model samples for various experiments. To avoid variation in the results of the identical tests, a uniform procedure was implemented.

The clayey soils collected from New Delhi, are dried out in mid air and crushed and permitted over 425 μm sieve preceding practice for Atterberg limits, initial consumption of lime, differential free swell index. For Proctor compaction and Unconfined Compressive Strength, the crushed soil was conceded over a 4.75 mm sieve. Laboratory trials are shown on representative soil samples and chemical stabilized soil to evaluate index and strength properties. Grain size distribution, specific gravity, Atterberg limits, differential free swell index, standard Proctor compaction characteristics, unconfined compressive strength, test trials were made as per IS ideals recommendations.

3.3.2 Index property Test

The tests comprised of the index properties of virgin soil and assorted with admixtures as follows

1. Specific gravity (IS 2720 Part III -1980)22

2. Grain extent distribution (IS 2720 Part IV - 1985)23

3. Liquid limit (IS 2720 Par V - 1985)25

4. Elastic limit (IS 2720 Par V - 1985)26

5. Shrinkage limit (IS 2720 Par VI - 1972)27

6. Differential free swell index (IS 2720 Part XL -1977)24. Procedures to conduct the above tests are briefed in the following subsections.

3.3.3 Specific Gravity

Specific gravity is the fraction of a material's thickness to the thickness of reference material; correspondingly, it is also the proportion of a substance's volume to the number of primary sources for the same given volume. The perceived specific gravity is the weight of a volume of the substance final weight of an equal quantity of the given volume. It is calculated by using the formula;

$$\text{SPECIFIC GRAVITY} = \frac{(W2-W1)}{(W2-W1)-(W3W4)}$$

where,

W1=Unfilled mass of pycnometer

W2=Mass of pycnometer + oven-dry soil

W3=Mass of pycnometer + oven-dry soil + water

W4=Mass of pycnometer + water full

3.3.4 Grain Size Distribution

The specified scope of soil is obtained by directing dry sieve analysis and hydrometer analysis. Sieve analysis is conducted for coarser fractions whose size is greater than 75μ. For fractions finer than 75μ hydrometer analysis is conducted. The essential amount of sample of about one kg is saturated for 2 days and it is sieved through a 75μ sieve to isolate the finer and coarser fraction. The sample reserved about 75μ sieve is separated, dried out used for sieve analysis. The sample passed through a 75μ sieve kept in soaked condition to settle down the particles, after that the sample is dried out and about 50 grams of sample is taken for hydrometer analysis.

The dry filter analysis is done through a set of filters from 4.75 mm to 75μ sieve and for the finer fraction; grain size circulation is done by hydrometer analysis. The pictorial illustration of various fractions of the soil sample is obtained from dry filter analysis.

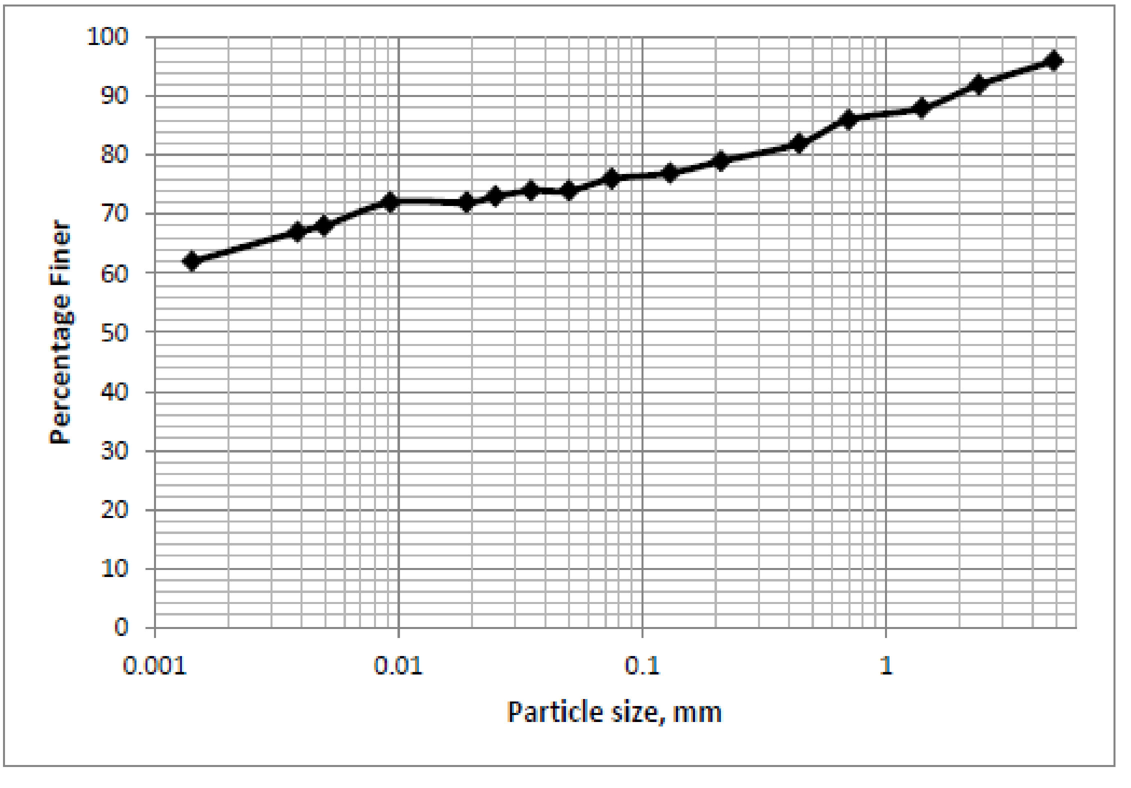

Figure 3.1- Grain Size Distribution Curve of Soil

3.3.5 Liquid Limit

A liquid limit is a fluid concentration estimated as a proportion of the volume of oven-dried soil where the soil turns from liquid to plastic. The water content of a soil where only two portions of a soil segment are divided by a gap of having significant (1 cm deep) would link to an extent of 1/2 inch underneath the impact of 25 blows utilizing the Casagrande equipment (Figure 3.2).

Fig 3.2 Liquid Limit Apparatus

3.3.6 Plastic Limit

The plastic limit shows both the proportion of moistness wherein the soil transitions from a plastic to a semisolid state whenever dampness is minimized or by a semisolid to a plastic condition while wetness is maintained. It is also the plastic state's ultimate limit. It is the proportion of wetness where a string of soil can be stretched before flouting, until it is only 3 mm in diameter, just starting to disintegrate with applying load. That little increase in wetness over PL could trigger the soil's cohesive and tensile strengths to fail. The plasticity index is defined as the difference between the soil.

Figure 3.3- Plastic limit

3.3.7 Shrinkage Limit

The moisture content in soil once the moisture is indeed suitable to occupy all the spaces of the soil. Soil-soaked seems to be the shrinkage limit. When the water content gets lowered just under the shrinkage limit, the volume of the soil doesn't diminish. The correlation may be used to calculate the shrinkage limit.

$$Ws = \frac{(M1-Ms)-(V1-V2)pw\times 100}{Ms}$$

Somewhere,

M1= Original wet mass

V1= Original volume

Ms = Dry mass

V2 = Volume after drying

Pw= density of water (1g/cc)

Figure3.4 Shrinkage Limit Test

3.3.8 Differential Free Swell

The rise in the volume of soil without any external building when subjected to submergence in water, also known as free swell or differential free swell. The formula is used to compute it.

$$\text{Free swell index} = (Vd-Vk)*100/ Vk$$

Where,

Vd = volume of a soil specimen containing distilled water was measured.

Vk = kerosene-containing soil specimen volume measured

3.3.9 Physical and Geotechnical Properties

Several Tests were directed on virgin soil and stabilized soil to estimate

physical and geotechnical assets stand below.

1. Standard Proctor compaction Test (IS 2720 Part VII - 1980)
2. Unconfined compressive strength Test (IS 2720 Part X - 1970)

3.3.10 Standard Proctor Compaction Test

The Test comprises compacting the soil with dissimilar water contents in the mould, in three equal layers, each layer being given 25 blows using a hammer weighing 2.5kg released from an altitude of 30 cm. The dry density for each Test is determined by knowing the build of the compacted soil and its water content.

The program consisted of grinding soil with varying amounts of water levels in moulds having three equal layers, with every surface experiencing 25 blows from a sled carrying 2.5kg emitted from a depth of 30 cm. The dry density by each Test gets established by identifying the structure of the soil sample including its water content.

A curve is drawn between diverse water content and the dry density which is known as the compaction curve. The dry density goes on growing with the increase in water content till extreme density is reached.The water content equivalent to the maximum density is called the ideal moisture content. Beyond that, an upsurge in water content leads to a reduction in dry density.

Figure3.5 The photograph of accessories used for the compaction Test

3.3.11 Unconfined Compressive Strength

The main goal of the Unconfined Compression test is to quickly assess the degree of unconfined compressive strength of rocks or fine-grained soils that are resilient enough even to withstand testing in the unconfined condition. Uniaxial compressive stress is applied to a specimen with 38 cm length and 76 mm elevation planned at a certain density and water content, and the stress at failure is expressed as load-carrying capacity (UCS).

3.4 Properties of Soil Sample

Table no 3.1- Soil Properties

Properties	Values
Specific Gravity	2.72
Granular (%)	2
Sand (%)	19
Silt (%)	8
Clay (%)	71
Liquid limit (%)	68
Plastic limit (%)	27
Plasticity index (%)	41
Shrinkage limit (%)	10
Differential Free swell index (%)	60
IS Soil classification group symbol CH	CH
Optimal Moistness Contented (%)	19.22
Maximum Dry unit weight (kN/m^3)	16.1
Swell classification High	High

The grain scope distribution arch of soil cast-off in the proposed investigation is presented in Figure 3.2. The colour of the soil is grey in the dry state and black in the wet state. The properties of soil are specified in table 3.1.

The gravity of natural soil is 2.72. The soil is composed of 2% gravel fractions, 19% sand fractions, 8% sludge fraction and 71% sand fraction. The soil exhibited liquid limit and plastic limit as 68% and 27% respectively. The elasticity index is 41% and its shrinkage limit is 10%. Grounded on IS soil arrangement scheme. The soil specified as Clay of High elasticity (CH).The soil displayed a differential swell of 60%. According to IS 2911 part III 1980 for   swell index of 60%, the soil remains classified as high bulge soil. Further, the plasticity index and shrinkage limit values of soil also, confirm its high swelling quality.

Figure 3.5 displays the standard Proctor compaction arch for soil. The soil showed a supreme dry element mass of 16.1 kN/m3 at optimal water contented as 19.22% for Standard Proctor energy. The permeability of CH group soil when compacted is known as impervious. The shear strength once compressed and soaked is poor. The compressibility after being compressed and soaked is poor. Since the CH group soil is not exhibiting suitable geotechnical properties, there is a necessity to improve its behavior and chemical stabilization is one of the famous practices.

3.5.1 Phosphogypsum

Phosphogypsum is the by-product of the fertilizer industry, especially the production of phosphoric acid from phosphate rock. Phosphogypsum primarily consists of calcium sulphate and contains some impurities.

Figure 3.6- Phosphogypsum

The Phosphogypsum was collected from HPM fertilizers Ltd. located at Manesar,Haryana .The chemical composition of Phosphogypsum is shown in Table 3.2.

3.7 Chemical composition of Phosphogypsum

Sample components	**Percentages**
$CaSO_4.2H_2O$	90-94
Fe2O3 + A12O3	0.3 max
CaO	30-31
MgO	0.1 max
Chloride as C1	0.3-0.5
pH of 10% solution	3-5

3.5.2 Copper Residue

The copper residue is a by product removed the smelting process goes on. Impurities from residue and drifted on the upper layer of such molten iron to be frozen in water, forming uneven grains, which become carried as trash, its copper deposit is dark and coarse. Its copper deposit is dark and coarse, a smaller amount like 1% moisture. The specific gravity of the residual extends around 3 to 5, as well as the grain sample size is usually about 2.36 mm and 1.18 mm, which is quite close to the sand attribute. Copper residual is often comprised of copper, iron, and silicate oxides.

Table 3.3 Properties of copper residue

Content	Values
Specific gravity	3.45
Density	2.31 g/cc
Proportion of granular	1 %
The proportion of rough gravel	16 %
Percentage of standard gravel	79 %
The proportion of fine gravel	4 %
Percentage of finer fraction (<75µ)	Nil
Uniformity Coefficient, Cu	2.83
Coefficient of Curvature, Cc	1.08
IS soil arrangement group symbol	SP

Figure-3.7 Copper Residue

The grain size distribution curve shows that majority of copper residue comprises medium-sized sand fractions. The properties of copper residue are offered in table 3.7.The specific gravity of copper residue stands at 3.45. It is composed of 1% granular, 16% coarse gravel, 79% of average sand, 4% of acceptable sand. The uniformity coefficient in addition to coefficient of curvature for copper residue 2.83 and 1.08. According to Indian standard soil organization scheme, copper residue stands as off-color grouped sand (SP).

3.6 SAMPLE PREPARATION

The following process is approved for the preparation of soil samples with numerous chemicals to study the behavior of uncured and chemically cured soil samples.

1. Soil was mixed with numerous required percentages of chemicals like Phosphogypsum (30%, 40% & 50%), Copper residue (10%, 20% & 30%), a consistency closer to the liquid limit.

2. Soon after the soil was mixed with chemicals and an essential quantity of water, it is placed in an airtight container and kept in a humidity chamber to prevent loss of dampness during curing. After the lapse of the required curing period (7, 14 and 28 days) the samples were tested for index properties.

3. For conducting a compaction test, the soil was mixed with the required amount of chemical in the dry condition, and sufficient liquid was poured into the soil– chemical fusion, to attain undeviating soil–chemical mix, this mixture is then subjected to a standard proctor tests.

4. For the UCS tests, After the requisite curing times, the soil specimens were sorted according to their mix proportion and dry unit weight and examined. The details of the soils and chemicals used and the procedure adopted to attain objectives of the study have been discussed in detail in this chapter. The procedure implemented for preparation of samples to carry out, different viz. Specific gravity, liquid, plastic, shrinkage limit, differential free swell index, Proctor compaction and unconfined compressive strength trials were also briefly discussed in this chapter.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 GENERAL

The segment hand over outcomes and analysis of experimental work executed to conduct the impact of numerous chemical stabilizers on index and strong point properties of high elastic sand soil. Trials stood accepted on natural soil, with increasing percentage of chemicals Phosphogypsum (30%, 40%) and Copper Residue (10%, 20%,30%).

The soils were merged with different chemicals were restored for required curing period preceding to testing. The possessions for instance liquid limit, plastic limit, shrinkage limit and unconfined compressive strength were acquired for natural soil and preserved soil are exposed and talk over in the following sections.

4.2 IMPACT OF CHEMICALS ON THE PROPERTIES OF SOIL

The index lines, which include the liquid limit, plastic limit, and shrinkage limit, conduct comprehensive identifying position by average view factor of comforting soil geotechnical behaviour. Regardless of the soil conditions, numerous real-world link ups have been developed to anticipate geotechnical behaviour of pleasant granular soil, which is primarily designed for index lines. Because both the Atterberg limits and geotechnical homes are influenced by similar components such as clay minerals, ions in pore water, and pressure records of soil deposit, the Atterberg limits are decided to shape up by geotechnical behaviour of soils.

Take a look at tiny sand and clay, whereby energy gets influenced by same factor called unconfined compressive strength. The unconfined compressive energy examination was created to be carried out on samples containing a wide range of chemical compounds.

4.3 IMPACT OF PHOSPHOGYPSUM ON INDEX PROPERTIES AND STRENGTH

Tables 4.1 to 4.3 recaps the experimental outcomes acquired for soil mixed by dissimilar proportions of Phosphogypsum , cured for 7 days, 14 days and 28 days respectively with percentages of virgin soil and 30% and then 40% and therefore after that, graphs related to each point liquid limit , plastic limit , plasticity index are plotted to get a overview of increase or decrease in strength.

Table 4.1 Effect of Phosphogypsum by elasticity characteristics and UCC strength for 7 days curing

Percentage of Phosphogypsum	0%	30%	40%
Liquid limit (%)	67	66.5	64
Plastic limit (%)	28	22	23
Plasticity index(%)	42	45	40
Shrinkage limit(%)	11	19	20.7
UCS(KN/m^2)	194	250	390

Table 4.2 Effect of Phosphogypsum by elasticity characteristics and UCC strength for 14 days curing

Percentage by Phosphogypsum	0%	30%	40%
Liquid limit (%)	67	64	60
Plastic limit(%)	28	21	20.8
Plasticity index(%)	42	41.5	40
Shrinkage limit(%)	11	15	16.5
UCS(KN/m^2)	194	330	395

Table 4.3 Effect of Phosphogypsum by elasticity characteristics and UCC strength for 28 days curing

Percentage by Phosphogypsum	0%	30%	40%
Liquid limit (%)	67	61	57.5
Plastic limit(%)	28	20.8	23.5
Plasticity index(%)	42	39.5	35.5
Shrinkage limit(%)	11	16	17.5
UCS (KN/m^2)	194	350	450

4.4 Impact of Phosphogypsum on index properties

The consequences of the soil are attempted out through differing the quantity of Phosphogypsum through 30%, 40% through dry weight of soil after curing them for 7, 14 and 28 days. The version in liquid restrict with curing duration is demonstrated in Figure 4.4 By this Figure it may be visible, liquid limit decreases with growth in curing duration and percent of phosphogypsum as well. The liquid limit reduced from 67% to 57 five% for 28 days curing duration.The drop in liquid restrict fee is most for 40% of Phosphogypsum that's observed from Figure 4.10 .Figures 4.5and 4.6 display the version of plastic restrict and plasticity index for any percent of Phosphogypsum and curing duration. The assessment in plastic restrict values is seems to be minimum. The end result of Phosphogypsum at the plastic restrict isn't always as splendid as liquid restrict.

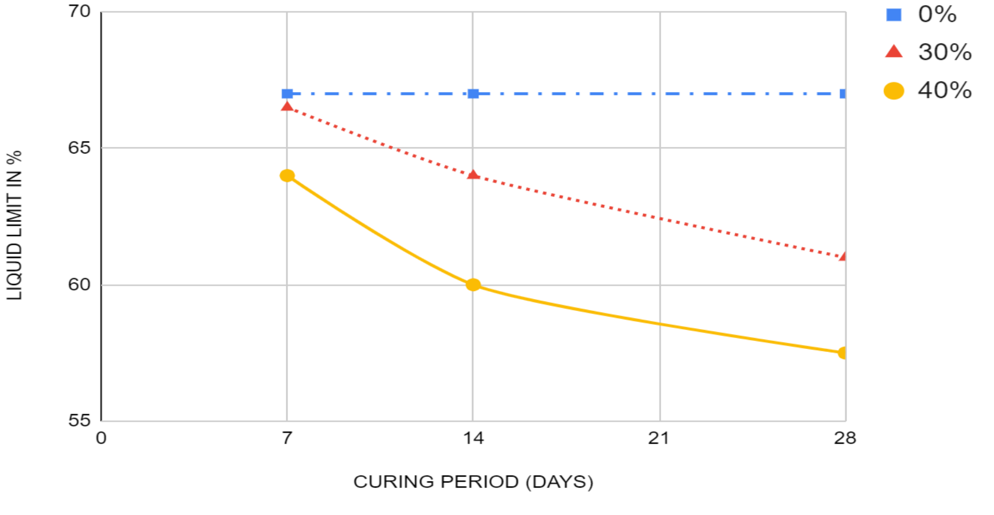

Figure 4.1 Liquid Limit Vs curing period for Numerous Proportions of Phosphogypsum

It doesn’t display variant with curing duration and percent of Phosphogypsum. Reduction in plasticity index may be visible from Figure 4.6. As the version of plastic limit could be very minimum the drop in plasticity index is likewise less. 4.6 display the version of shrinkage restrict of phosphogypsum stabilized soil with curing duration. The shrinkage restrict fee is discovered to be better for 7 days curing for any percent of Phosphogypsum. The growth in shrinkage restrict, coupled with discount in liquid restrict, reduces the variety over which the soil can go through alternate in quantity upon alternate in water content.

This switch in behaviour is observed due to reactions occurred between water and Phosphogypsum. Phosphogypsum (calcium sulpate-$CaSO_4$) on reaction with water makes Calcium Silicate Hydrate (C-S-H) a cementations gel. The calcium sulphate then gets reacted with water present as the adsorbed layer on the clay surface which is the cause of diffuse double layer, produces C-S-H gel .

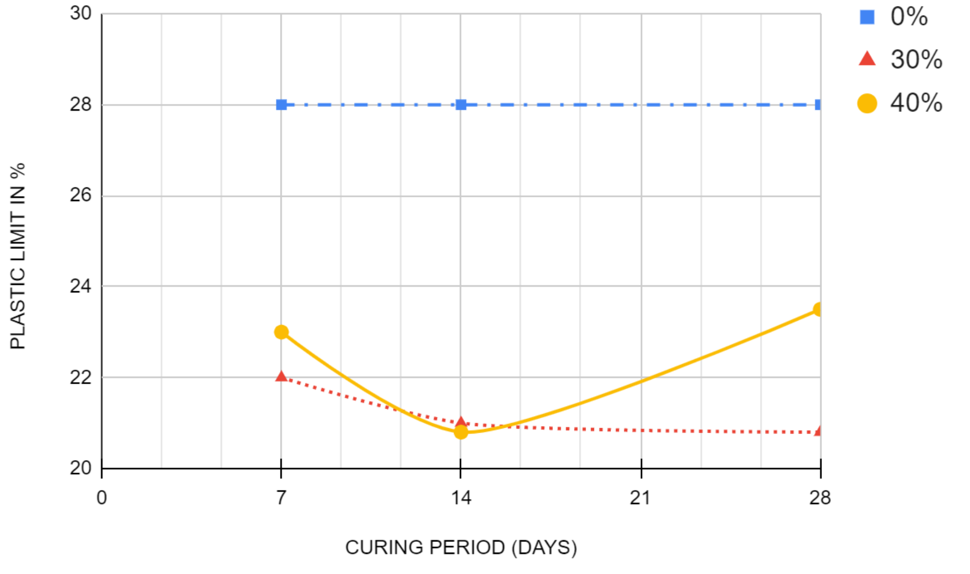

Figure 4.2 Plastic Limit Vs curing period for Numerous Proportions of Phosphogypsum

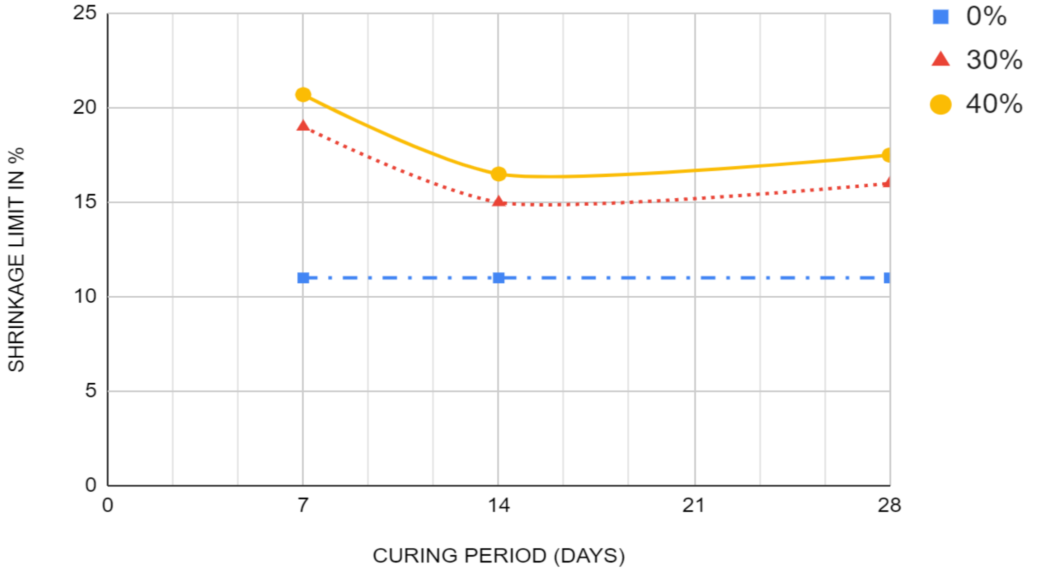

Figure 4.3 Shrinkage Limit Vs curing period for numerous proportions of Phosphogypsum.

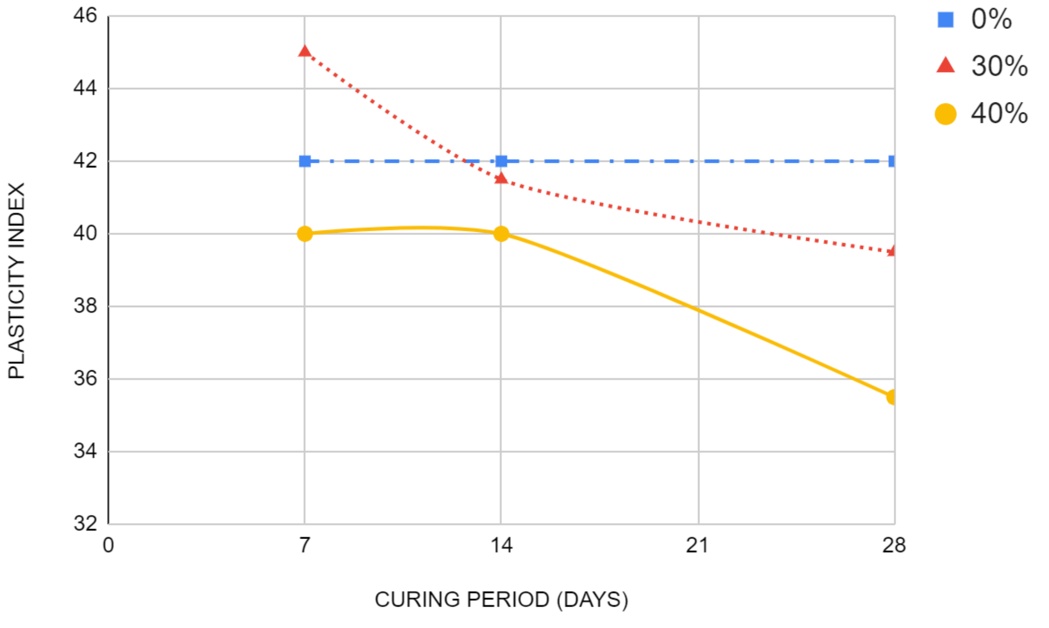

Figure 4.4 Plasticity index Vs curing period for numerous proportions of Phosphogypsum.

4.5 Impact of Phosphogypsum upon unconfined compressive strength

The unconfined compressive strength check is carried on quantity of samples handled with 30%, 40% of Phosphogypsum. Figure 4.5 display the strain-stress characteristics of Phosphogypsum admixed soil for the curing duration of seven days. The pattern fails on the most strain of 250 kPa for 30% of Phosphogypsum. The most failure strain decreases for 30% Phophogypsum .The complete pattern fails at extra or much less same stress. From Table 4.3 it's far determined that the most strain at failure for 30% Phosphogypsum is 330 kPa for 14 days curing however the pattern fails at better stress. Table 4.3 indicates the strain-stress version for 28 days curing duration. It is determined that failure of pattern happens on the strain of 450 kPa for 40% Phosphogypsum at 28 days curing duration.

Table 4.1 to Table 4.3 display the unconfined compressive strength of handled by quantity in phosphogypsum curing for 7, 14 and 28 days with hardening duration. Strength will increase with growing curing duration. The UCS price is better for 40% of Phosphogypsum at 7 and 14 days curing duration.

At 28 days curing duration the UCS price is determined to be better for 40% of Phosphogypsum. The strength changed into determined to boom from 194 kN/m^2 to 450 kN/m^2 for 40% of Phosphogypsum for the curing duration of 28 days. It indicates that the strength will increase for better percent of Phosphogypsum at better curing duration. The boom in strength is because of formation of growth in C-S-H gel. The establishment by C-S-H gel, act as permanent agent among the soil particle thereby growing the strength of soil. The growth in strength with curing duration is because of presence of pozzolanic compound (CAO). This pozzolanic fabric might react with soil with time. Pozzolanic response is time established response that's the supply for later boom in strength of soil.

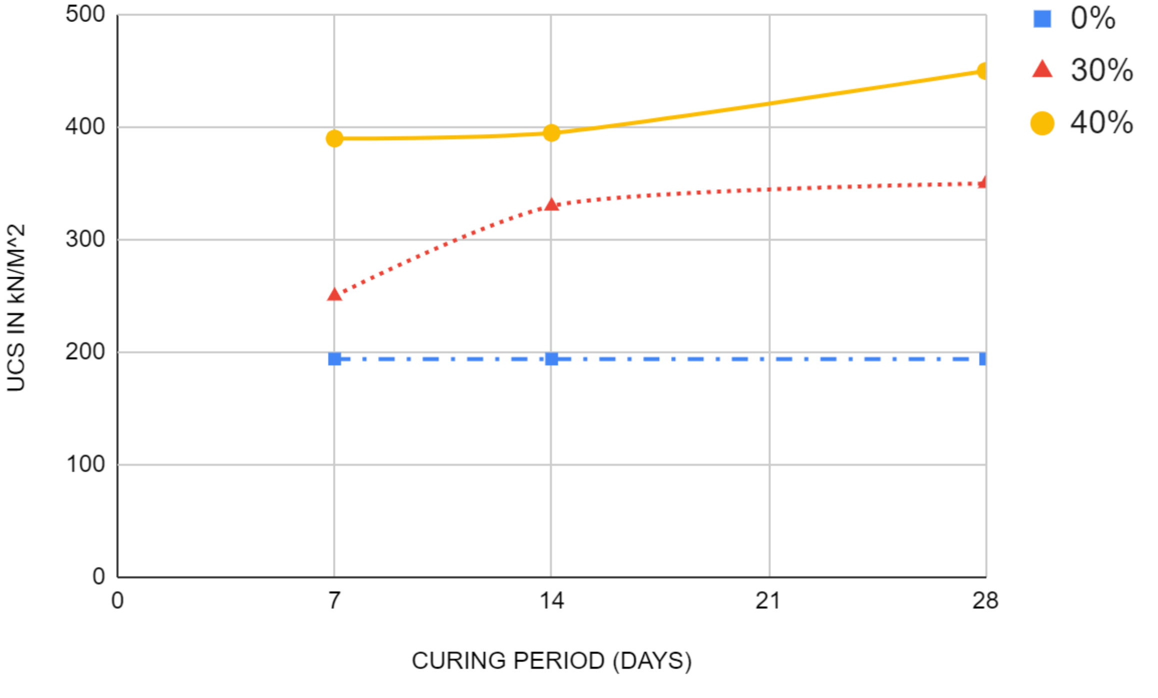

Figure 4.5 Compressive Strength vs Hardening Phase for various percentage of Phospogypsum.

4.6 IMPACT OF COPPER RESIDUE ON INDEX PROPERTIES

Index characteristics such as the liquid, plastic, shrinkage limit, and variable free swell index are critical in influencing the action of fine-grained soil. Prescribed tests are conducted for soil with the addition of copper residue from 10 to 30 % with 10 % increment. The soil samples are varied with copper residue in dry state by its suggested weight of soil and tested. The results achieved after above trials presented (Table 4.4). Figure 4.6 plots the variation of Atterberg limits (liquid, plastic shrinkage limit and Plasticity index) in loam merged with copper residue.

The liquid limit slips down from 65.50 to 34 % upon addition of copper residue. The flexible limit of the loam shows a decrease by 34.10 to 18.74 % on copper residue increment. The plasticity index also goes down by 31.70 to 23.85 % whereas the shrinkage limit goes up by 12.91 to 18.90 % on copper residue addition. Figure 4.7 plots the variation in swell index of the loam mixed by dissimilar proportions in copper residue and it varies from 100 to 30% with copper residue addition of 0 to 30 %.

MIX PROPORTIONS	**LL(%)**	**PL(%)**	**PI(%)**	**SI(%)**	**FSI(%)**
VIRGIN SOIL	65.50	34.10	31.70	12.91	95
SOIL +10%CS	57.44	30.72	26.32	15.68	70
SOIL +20%CS	48.32	23.98	24.53	16.68	55
SOIL + 30%CS	43.39	18.74	23.85	18.90	45

Table 4.4 Index property test results for soil mixed with various copper residue content

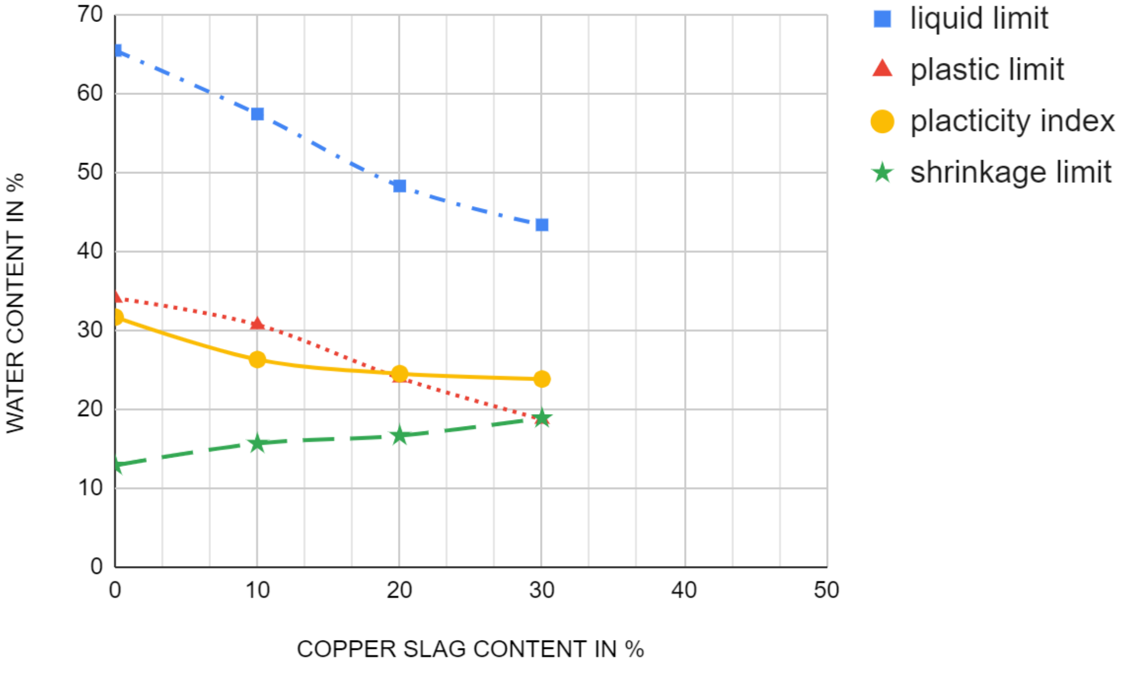

Figure 4.6 Deviation of Atterberg limit with copper residue**.**

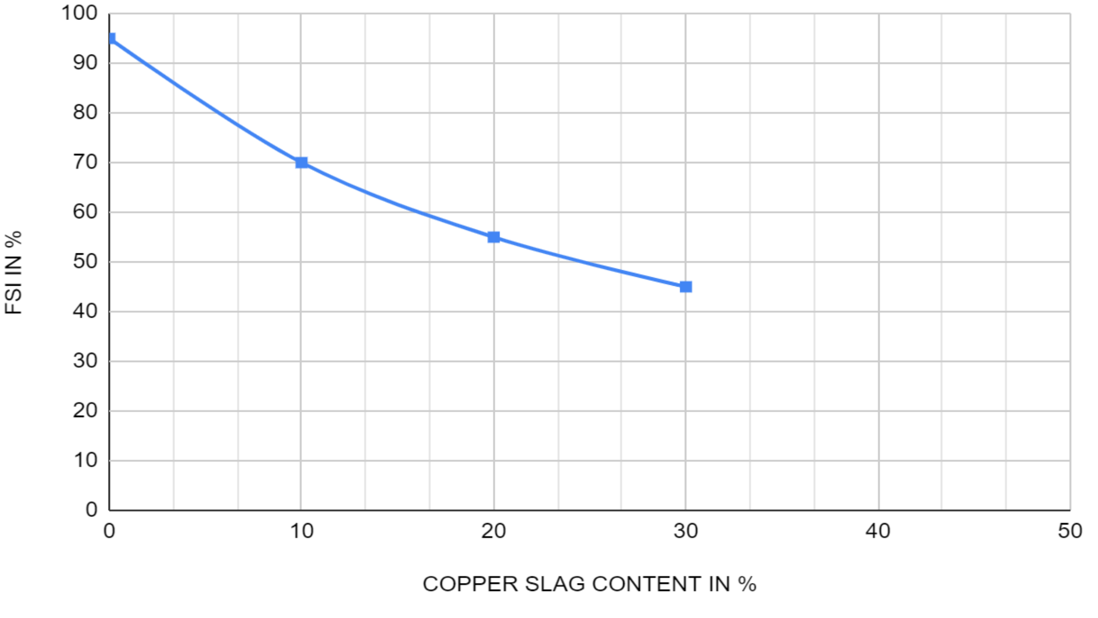

Figure 4.7 Free swell index Deviation for unlike proportions of copper residue

4.7 Impact of copper residue with compaction characteristics, unconfined compressive strength.

In sequence to understand the adaptation in the compactness and optimal moistness contented in soil stabilized for different proportions of copper residue as 10%,20% and 30%. Standard proctor compaction test was conducted Compaction curve acquired for different mix proportions were compared with the virgin soil. The values of determined dry thickness and optimal moistness contented were reported in table 4.5. The adjustment to maximum dry density and optimum moisture content in various proportions of copper slab to be depicted graphically.

Mix Proportions	**MDD (KN/m^3)**	**OMC(%)**
Virgin soil	15.50	20.9
Soil +10% CS	16.10	18.61
Soil +20%CS	17.02	16.13
Soil +30%CS	18.50	14.44

Table 4.5 Deviation in MDD and OMC by changed proportions of copper residue

From the above figure it is recognized that with the addition of copper residue, the value of dry density goes up from 15.50Kn/m^3 to 18.50kn/m^3 from the estimate of virgin soil to 30% addition of copper residue and on the same line the optimum moisture content goes down from 20.9 to 14.44, after that worth addition of copper residue, the OMC value increases but value of dry density shows smaller increment. Now to look into the outcome of copper residue on unconfined compressive strength of soil. Copper residue is varied with proportions of 10,20,30% replacement with the weight of soil. The samples are made ready to similar density and moistness contented and tested.

Mix Proportions	**γ_d (KN/m3)**	**OMC (%)**	**UCS (KN/m2)**
Virgin Soil	15.50	20.9	172.66
Soil+10% Copper Residue	16.10	18.61	181.54
Soil+20% Copper Residue	17.02	16.13	184.78
Soil+30% Copper Residue	18.50	14.44	230.12

Table 4.6 Deviation of UCS for changed copper residue contented

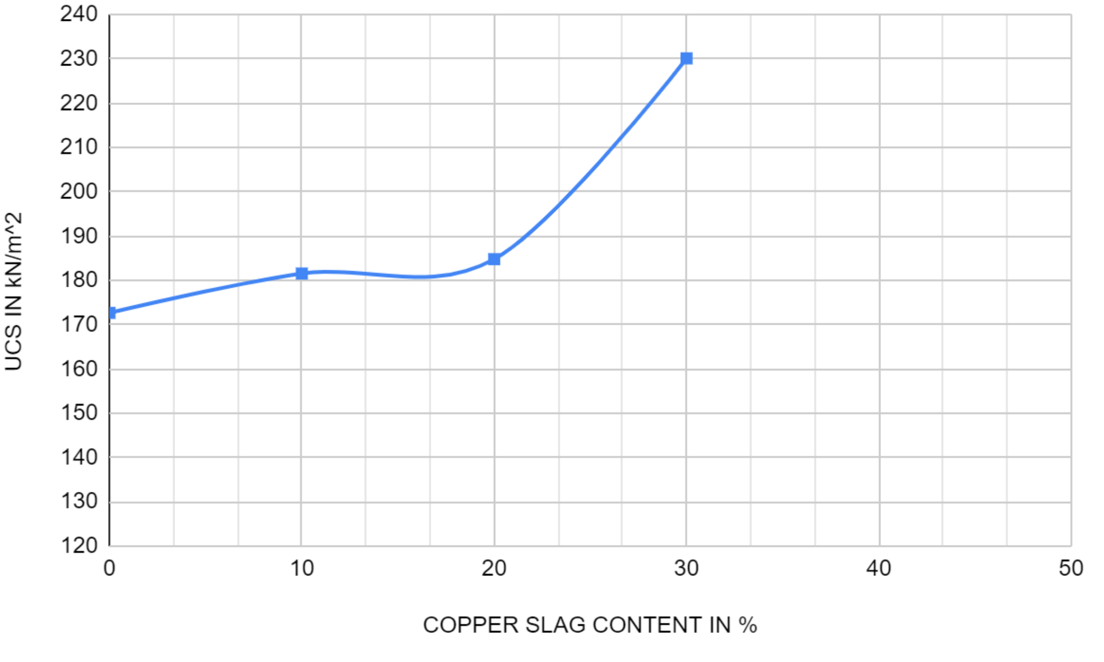

Figure 4.8 Deviation of UCS with copper residue .

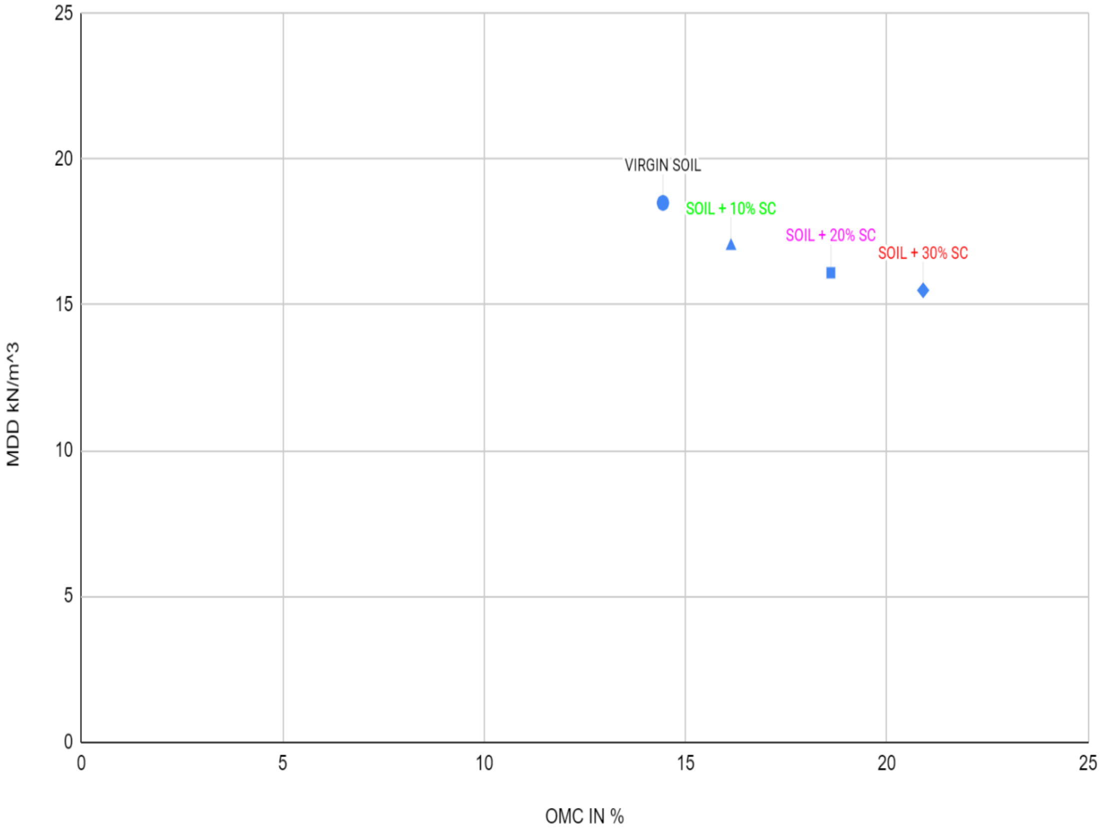

Figure 4.9 Deviation of MDD with OMC.

Maximum axial strain of virgin soil crushed at the compactness of 15.50 KN/m^3 and Optimum water content of 20.9% is comes out to be 172.66 KN/m^2 which is at its top strength. The strength goes up with addition of copper residue with almost same value of 20% and goes up again for 30%.

From the above figure, it is noted that addition of copper residue gives an acceptable result in UCS value. With standby 10% of copper residue, it had rose to 5% and for 20% there is a rise of 17% and for 30% of copper residue there is a rise of 21%.

Chapter V

Summary and Conclusion

5.1 GENERAL

In arrangement to understand the carry out of distinct chemicals of index as well as strength features in extensive soil. Tests were handled with soil models having distinct percentages of chemicals and period of curing period. The different chemicals handed down in the this study are Phosphogypsum ,Copper residue. The over-all assumptions pinched by survey of trial outcomes to be presented in this chapter.

5.2 SUMMARY

1.Addition of Phosphogypsum, Copper residue declines the liquid limit and will increase elastic limit and in return declines plasticity index standards in soil. Addition of Phosphogymspsum and copper residue does now no longer display a whole lot version in liquid restrict and plastic restrict with boom in percent and curing period. However, Phosphogypsum indicates full-size version. The reduction in elasticity traits has been linked to the limitation of dual bulk density owing to mass transfer in excessive valence elements, whereas elasticity traits of lime-treated soil increased significantly at a longer curing period.

2. For optimum percentage, the ability of chemical to diminish the flexibility of soil with the command of Phosphogypsum<Copper residue. The drop in plasticity behaviour diminishes the enlargement character of mud.

3. Shrinkage restriction in soil handled in case of Phosphogypsum and copper residue chemical compounds has enlarged reasonably with boom in percent of chemical and curing length while for lime handled soil, the boom of shrinkage index is 3% to 4%instances better than that of crude soil. The better the shrinkage restriction the better will be the decrease in behaviour of soil.

4. The unrestricted compressive power increased for whichever percentage among all compounds. In case of Phosphogypsum, two to three instances the power is expanded for 40% and for copper residue dealt with soil the growth in power excellent in comparison to different chemicals.

5. The liquid limit declines upon accumulation of Copper residue by 33%, Plastic limit decreases by 41%, Plasticity index reduces by 24% and variation free swell index diminishes by 46% .

6. The optimum moisture content declines by 31% when 30% replacement of copper residue. Further increment in copper residue content shows growth in optimum moisture content.

7. In UCC test, with the replacement of 10% of copper residue, it displays a growth of 9% with 30% replacement, it shows 50% increase in UCC value.

5.3 CONCLUSIONS

Due to the special advantages of these chemicals, this learning was reviewed to find the best of employing substituted chemicals for the upgradation of problematic soil as a substitute for standard chemicals such as phosphogypsum, copper residue.

Phosphogypsum, Copper Residue of distinct percentage varied with soils bring down the plasticity characteristics and increases the strength. As this work documents the cumulative information on the impact of two distinct chemicals on the Breaking characteristics and endurance of high plastic sand. Above mentioned chemicals can also be used to focus on improving the behaviour of granular soils depending on the extent of enhancing mandated as well as the availability of convinced chemical.

5.4 SCOPE FOR FUTURE STUDY

Existing study mainly focused on refining the plasticity features and strength of high plastic clay. There is a possibility to cover this study by focus on the result of changed chemicals due to the brilliant features, consolidation features, permeability features in expansive mud.

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