GEO ENGINEERING PROPERTIES OF LIME TREATED PLASTIC SOILS

NENAVATH SHANKAR, M.Tech (Geotech)
Department of Civil Engineering
Abhinav Hitech College of Engineering
Email id: shankarnaik913@gmail.com

SRINIVAS GANTA
Associate professor
Department of Civil Engineering
Abhinav Hitech College of Engineering
Email id: srinivasganta412@gmail.com

ABSTRACT

For a long time, we are facing problems like failures of small and big structures. The biggest problem behind this is swelling soils. This is very unstable soil. Its property varies from hard to soft and dry to wet. It exhibits swelling and shrinkage with different water content. As a result, many structures usually face excessive settlement and differential movements, which causes damage to foundation systems and other structural elements. We are aware about this situation for a long time, but unable to make improvements due to absence of technologies till now.

Expansive soils are found in many parts of the world like Burma, South Africa, Western USA, Cuba, Spain, Russia and Indonesia, etc. In India it is found in Rajasthan, Tamilnadu, Madhya Pradesh, Maharashtra, Gujarat and Orissa.

Plastic soils undergo swelling and shrinkage causes severe distress and damage to the structure overlaying. Lime has been used as a soil stabilizer from Roman times. Through physico-chemical modifications, lime can control the plasticity, swelling and shrinkage of soil effectively. Also, lime can stabilize soil through cementation which increases strength and stiffness remarkably. This soil modification using lime depends on the type of soil and its mineralogy, lime content and compaction condition with curing period. The stabilizing effect of lime has been studied by a number of researchers. The minerals present in the soil has found to affect the engineering properties of stabilized material and the optimum lime content.

Keywords: *Soils, Lime Stabilization, plastic soils.*

INTRODUCTION

Soil is one of the most commonly encountered materials in civil engineering. All the structures except some, which are founded on solid rock, rest ultimately on soil. Geotechnical engineers all over the world face huge issues, when structures founded on the soil which is expansive in nature. This expansiveness is imparted to such soils when they contain clay minerals like montmorillonite, illite, kaolinite etc. in considerable amount. Due to the clay minerals, the swelling soils expand on wetting and subjected to shrinkage on drying. These soils are commonly unsaturated.

The problem of instability of structures made on such soil is mainly due to lifting up of the structures on heaving of soil mass under the foundation on saturation during rainy season and settlement as a result of shrinkage during summer season. Due to this cavity formed, leading to loss of contact between the soil and structures at some points. This successively results in splitting of structure and failure due to loss of shear strength or unequal settlement.

On the contrary, during rainy season the foundation soil swells on imbibitions of water and it is restrained by the foundation. As a result, an upward swelling pressure is exerted by the soil on the foundation. As this pressure is not uniform everywhere, the net downward pressure becomes uneven. Similarly, during the summer season the soil shrinks and this phenomena is not uniform throughout the soil below the foundation. This additionally results unequal settlement, leading to progressive failure of structures.

Investigation into the properties of lime treated expansive soils would assess the suitability of using lime as stabilizer to reduce swelling of expansive soils. This paper presents the effect of lime stabilization on engineering properties of a lime treated expansive soil.

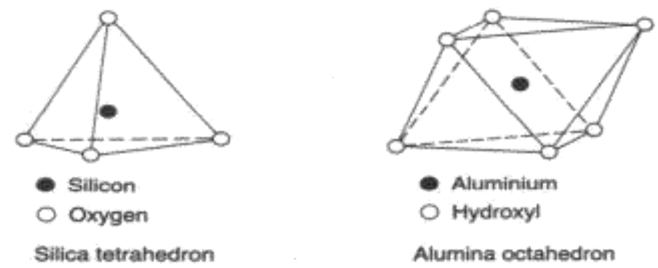
EXPANSIVE SOILS

Expansive soils creates greatest hazard in arid regions. Expansive soils contain clays and fine silts swells and shrinks as their moisture content changes. These expansive soils created problems for the structures, mainly lightweight structures and the structures most commonly damaged are small buildings, roadways, pipelines and irrigation canals.

The moisture in the soils shows variations due to climatic changes, change in water table, watering of gardens and lawn, presence of trees and shrubs and leakage from water and drainage pipes.

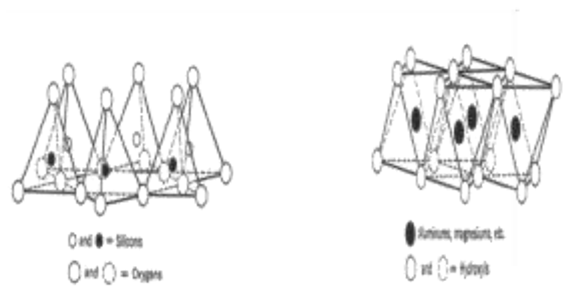
Structure of clay minerals

Clay minerals are primarily the end product produced by chemical weathering of feldspathic rock. Chemically, these minerals are basically hydrous aluminum silicates, although often the aluminum atoms are replaced with atoms of 5other elements, such as magnesium, iron, potassium, or sodium (Duncan, 1992). The atomic structure of a clay mineral is very complex, and consists of a variety of combinations and arrangements of two basic building blocks called the silica tetrahedron and the alumina octahedron as shown inn figure below.

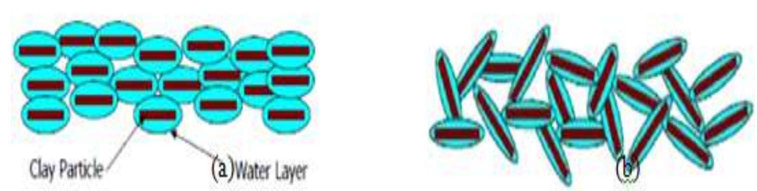


Basic units of clay minerals (Craig, 1993)

The various building blocks those make a clay mineral are arranged in orderly sheets are shown in Figure 1.2 (a) and Figure 2 (b). The particular arrangement and chemical compositions of these building blocks determines the type of clay mineral and its general characteristics.



(a) Silica sheet and (b) Octahedral sheet (Mitchell, 1993)



Molecular structure in (a) untreated clay (b) treated clay

LITERATURE REVIEW

The term expansive soil indicates to soils, which has the tendency to swell when their moisture content is allowed to increase. The water may come from rain, flooding, leakage of water from sewer lines or from a reduction in surface evapotranspiration when an area is covered by a building or pavement. The term cracking soil is also used for these soils as they have the tendency to shrink and crack when the moisture is allowed to decrease. Soils containing the clay mineral montmorillonite generally show these properties **(Komine and Ogata, 1996; Rao and Triphaty, 2003)**.

Expansive soils are mostly found in arid and semi-arid regions of the world. The presence of montmorillonite clay in these soils imparts them swell-shrink potentials (Chen, 1988).

Expansive soils cover nearly 20% of the landmass in India and include almost the entire Deccan plateau, Western Madhya Pradesh, parts of Gujarat, Andhra Pradesh, Uttar Pradesh, Karnataka, and Maharashtra **(Gopal Ranjan and Rao, 1991)**.

Expansive soils have been reported from several parts of the world, mainly in the arid or semi-arid regions of the tropical and temperate zones like Africa, Australia, India, United States and some regions of Canada. This never means that expansive soils do not exist elsewhere, because they can be found almost everywhere. In humid regions, ground water tables are present at shallow depths and moisture changes, which is responsible for changes in volume in soils under extended drought conditions **(Arnold, 1984; Shuai and Fredlund, 1998 and Wayne et al., 1984)**.

In general, expansive soils have high plasticity, and are relatively stiff or dense. The expansive nature of the soil is most obvious near the ground surface where the profile is subjected to seasonal and environmental changes. The pore water pressure is negative initially and the deposit is generally unsaturated. These soils contain some montmorillonite clay mineral. The expansive soil problem is dependent on the amount of monovalent cations absorbed to the clay mineral like sodium **(Fredlund and Rhardjo, 1993).**

The particles of clay have high negatively charged surfaces that attract free positively charged cations and water dipoles. Thus, a diffused water layer is formed around the clay particles and separates the clay particles which make the clay weak and unstable. This phenomenon depends upon the amount of water present, morphology and mineralogy of the clay. **(Little, 1987).**

All types of clay minerals react with lime. The addition of lime has a significant effect on clay soils containing montmorillonite. In fact, expansive soils tend to react rapidly with lime, losing plasticity immediately **(Bell and Coulthard, 1990)**. This is because expansive clay minerals such as montmorillonite exhibit a high cation exchange capacity.

Laboratory testing indicates that lime reacts with medium to fine grained soils to experience decreased plasticity and increased strength and workability **(Little, 1995)**.

When lime is added to a clay soil, it must satisfy the affinity of the soil, i.e. ions are absorbed by clay minerals and are not available for pozzolanic reactions until this affinity is satisfied. This is referred to as lime fixation as the lime is fixed in the soil and is not available for the other reactions **(Hilt and Davidson, 1960)**.

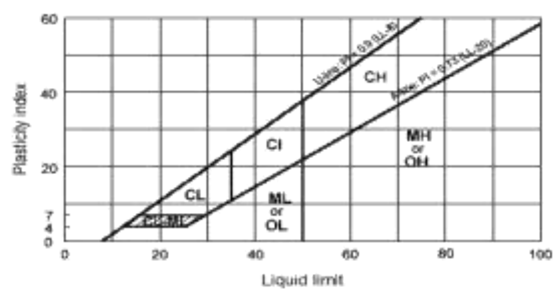
SCOPE OF PRESENT STUDY

Thus, through appraisal of the literature review, it is observed that several attempts have already been made by researchers to study the effect of additive on stabilization of expansive soil. However the researches on the plasticity swell and shrink behavior, strength aspect of soils covering wide ranges of plasticity upon lime stabilization is comparatively less. The experimental program undertaken investigates:

1. Plasticity characteristics of raw soil and lime treated soil
2. Swell and shrinkage properties of virgin soil and lime stabilized soil
3. Effect of lime on the compaction characteristics of soil
4. Effect of lime content on the strength aspect of lime treated soil.
5. The effect of curing period on unconfined compressive strength values of lime treated soil
6. The effect of variation in moisture content on unconfined compressive strength of soil

EXPERIMENTAL WORK AND METHODOLOGY

Lime stabilization of plastic soils reduces the problems associated with constructions faced by the expansiveness of these soils, mostly because of its swell and shrinkage property. So assessment of the behavior of plastic soil at different condition is required before commencing the construction activity. Even through adequate substitute for full scale field tests are not available, tests at laboratory scale provide a measure to control many of the variable encountered in practice. The trends and behavior pattern observed in the laboratory tests can be used in understanding the performance of the structures in the field and may be used in formulating mathematical relationship to predict the behavior of field structures. Details of material used, sample preparation and testing procedure adopted have been outlined in this paper.



Casagrande's plasticity chart for laboratory classification of fine-grained soil

PHYSICAL PROPERTIES OF SOILS

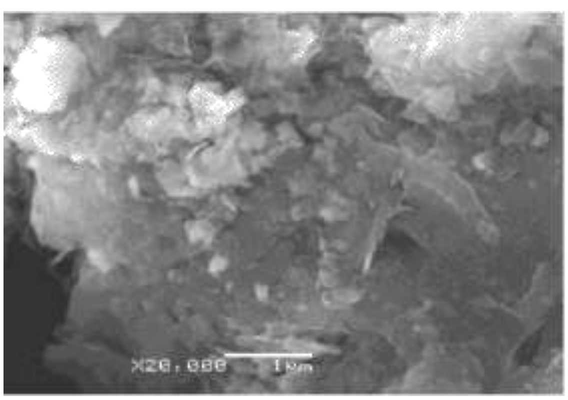
The physical properties of both the soils were determined and are presented in the

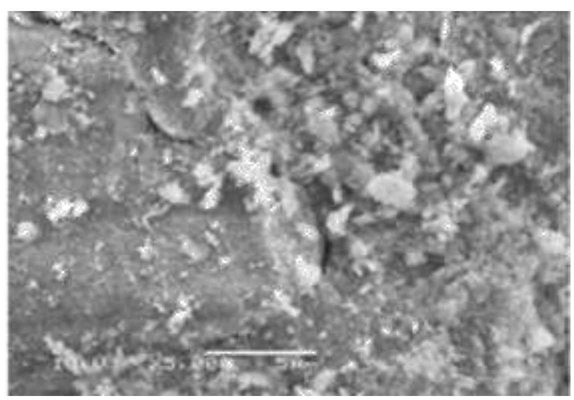
Table Physical properties of soils

Physical Parameters	Value		Physical parameters	Value	
	Bentonite	Residual soil		Bentonite	Residual soil
Color	Grey	Brown	Shape	Platy	Sub-rounded
Silt and Clay (%)	100	86.94	Coefficient of uniformity , C_u	-	7.3
Fine Sand (%)	-	13.06	Coefficient of Curvature , Cc	-	2.2
Medium Sand (%)	-	-	Specific Gravity, G	2.79	2.6
Coarse Sand (%)	-	-	Plasticity index, I_P (%)	272	16

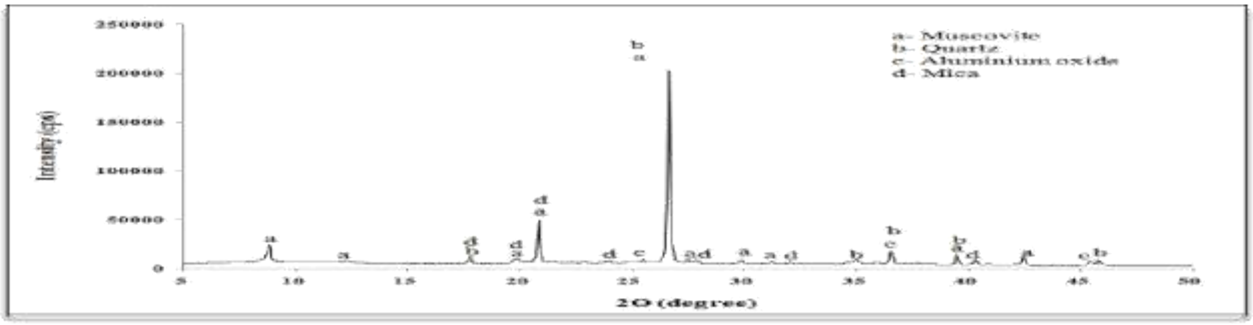
Morphological study of soils

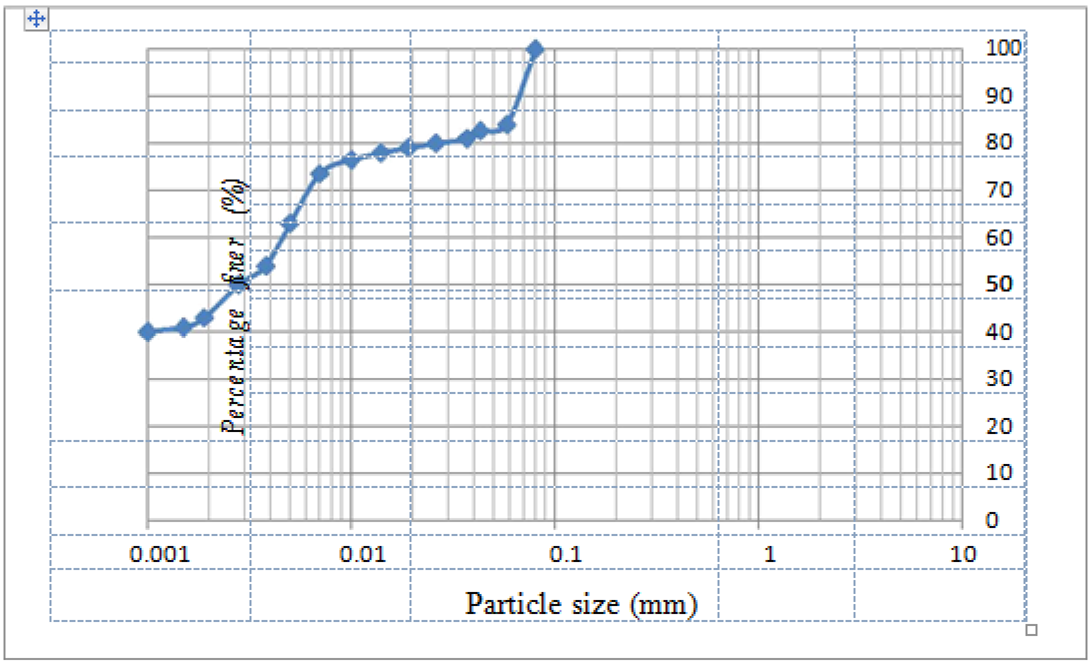
The morphology of soils was studied by Scanning Electron Microscope which produces images of a sample by scanning it with a focused beam of electrons. The electrons interact with atoms in the sample, producing various signals that can be detected and that contain information about the sample's surface topography and composition. The SEM images of bentonite and the residual soil are as shown in figure 3.2. From this analysis, bentonite shows dispersed type fabric arrangement and the residual soil mainly contains individual sub-rounded particles.





(a) (b) Figure 3.2 SEM of (a) Bentonite and (b) Residual soil





Grain size distribution curve for bentonite

The uniformity of the soil can be expressed by uniformity coefficient given by:

$C_u = D_{60}/D_{10}$

The general shape of particle size distribution curve is described by coefficient of curvature or coefficient of gradation given by:

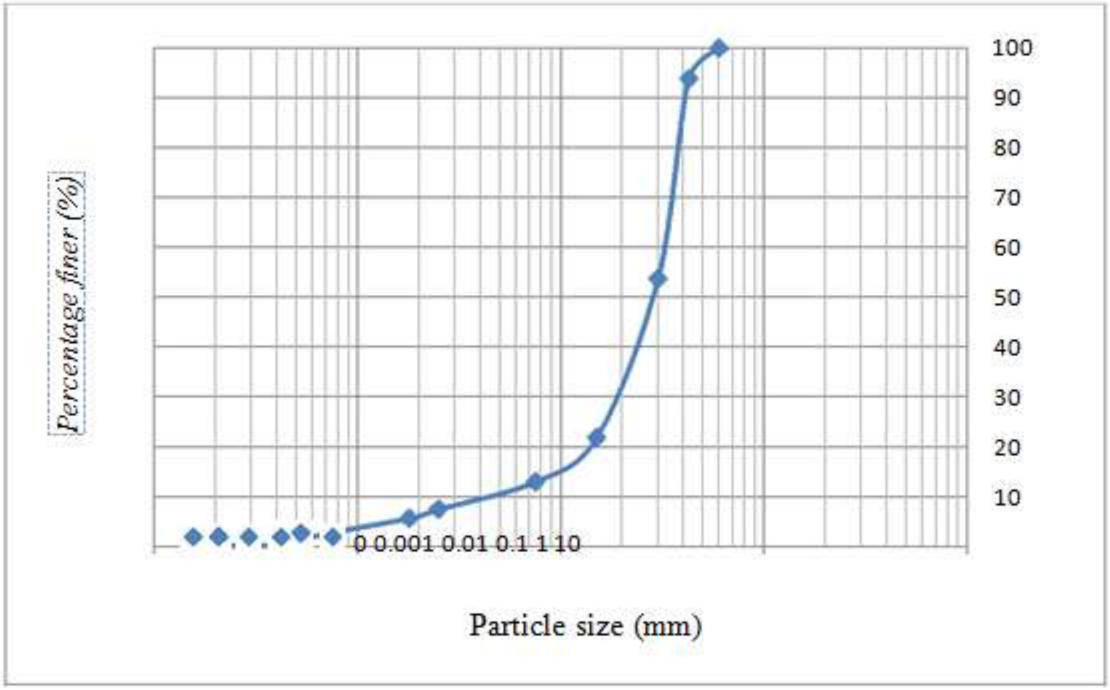
$Cc = (D_{30})^2 / (D_{60} x$

$D_{10})$ Where,

D_{60}= Particle size such that 60% of the soil is finer than this size

D_{30}=Particle size such that 30% of the soil is finer than this size

D_{10}= Particle size corresponding to10% finer



Grain size distribution curve of residual soil

After curing period and before testing, the wax was removed from the end of the specimen. The unconfined compressive strengths of specimens were determined from stress versus strain curves plots and hence the unconfined strength and corresponding failure strain for different raw soils and lime stabilized soils for different days of curing are obtained.

UCS test samples

Lime content (%)	UCS (kPa)				
	0 Days	7 Days	14 Days	28 Days	60 Days
0	438	438	438	438	438
2	400	430	450	472	469
5	620	750	880	1611	1951
9	531	630	690	740	948
13	358	445	450	473	524

Compressive strength of lime stabilized soil (100%RS) for different curing periods

RESULT AND DISCUSSION

Influence of lime on liquid limit of soils is shown in Figure 4.1. There is a significant reduction in liquid limit at 2% of lime content for soils 100%ES and 50%ES+50%RS. Beyond, this lime content the change in liquid limit is comparatively less. It is also observed that there is not much more variation in liquid limits for the soils 10%ES+90%RS and 100%RS with increased lime content. This reduction occur as the lime is added to the soil, Ca+ ions are released into the pore fluid and results increase in electrolyte concentration which reduces the thickness of diffuse double layer held around soil particle leading to a lower liquid limit

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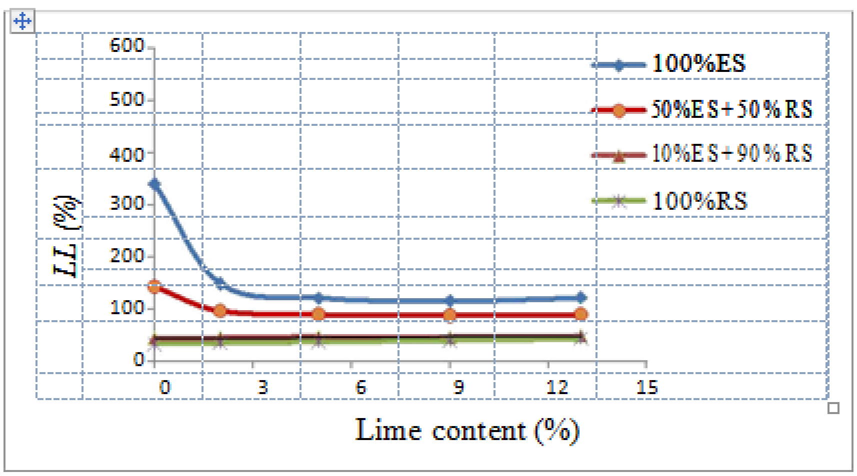

Variations in liquid limit with lime content

Plastic limit

The plastic limit is a measure of cohesion of soil particles against cracking and also it is the water content of soil when it approaches a certain shear resistance. With the addition of lime, the thickness of diffuse double layer decreases which increase charge concentration and thereby viscosity of pore fluid, it results interparticle shear resistance, leading to an increased plastic limit. Figure shown variations in plastic limit with lime content for soils. It is observed that, plastic limit increases with lime content. The influence of lime on plastic limit is more at 2% lime content. Also, it has been seen that beyond 5% lime content liquid limit and plastic limit does not change more

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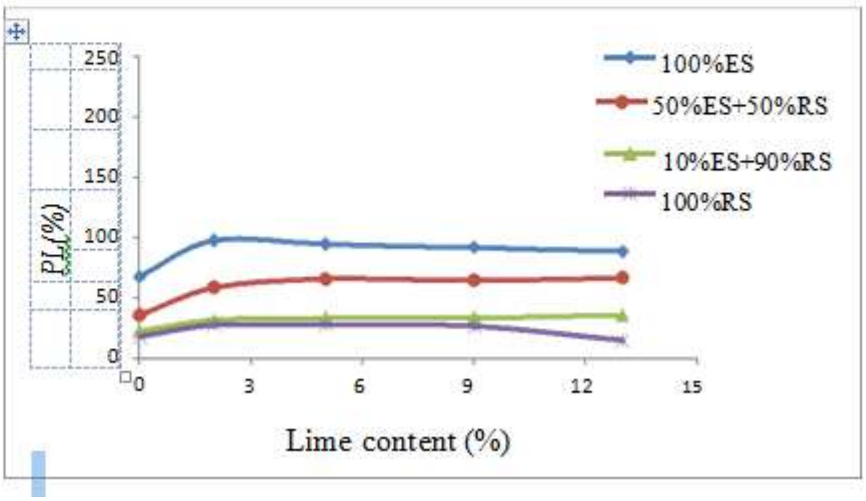

Variations in plastic limit with lime content

Plasticity index

A decrease in plasticity index has been observed as the lime content increases. The variations in plasticity index with lime content for soils are shown in Figure 4.3. This variation is more in case of expansive soil (i.e. 100%ES) at 2% of lime content. Also, it has been seen that, there is comparatively more reduction in plasticity index in case of soil mix 50%ES+50%RS in compare to other two soils (i.e. 10%ES+90%RS and 100%RS)

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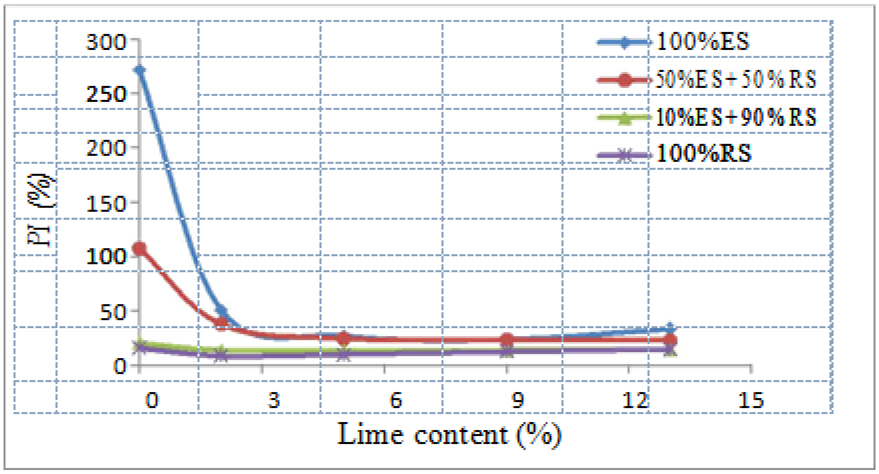
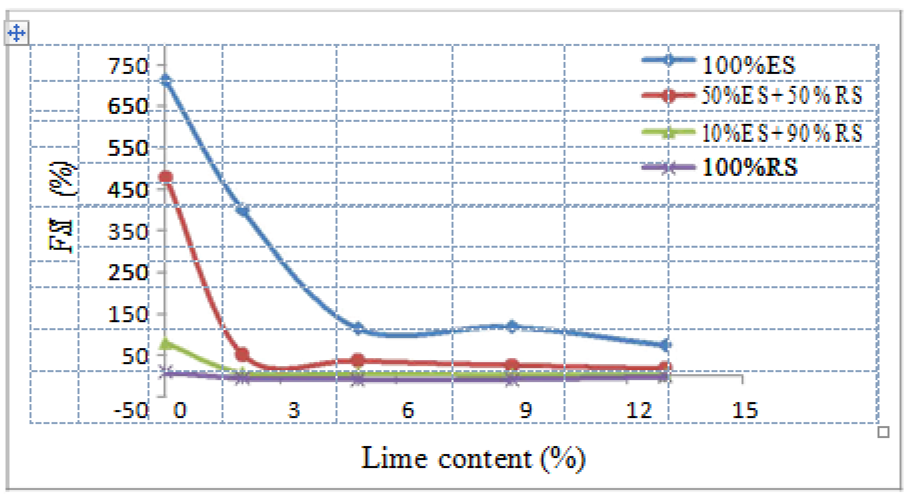


Variations in plasticity index with lime content

Free swell index

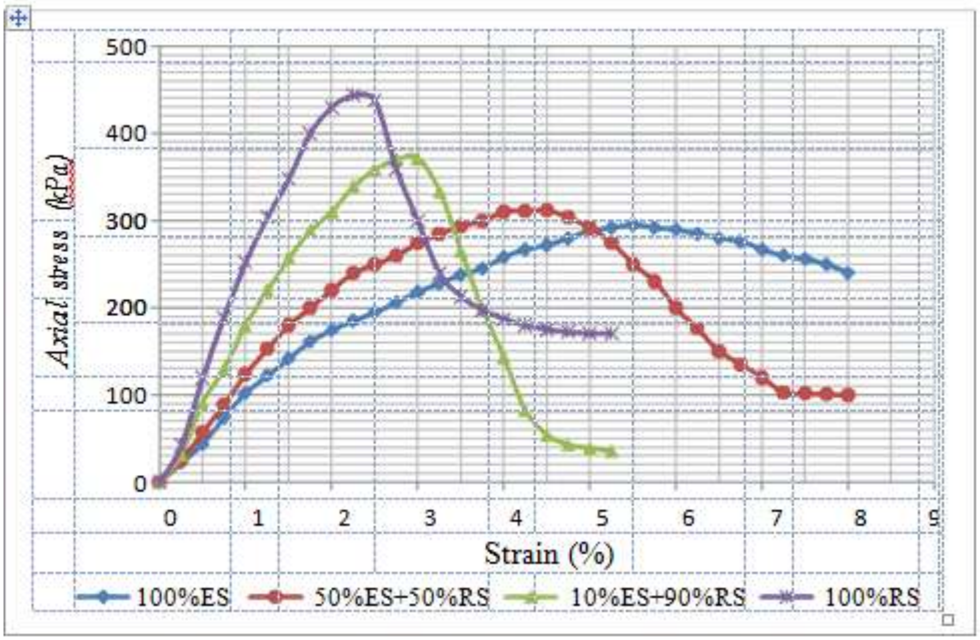
The variation of free swell index with percentage of lime is illustrated in Figure For the soil 100%ES, free swell index reduces largely upto 5% lime content, thereafter the decrease is not substantial. However, for the soil mix 50%ES+50%RS and 10%ES+90%RS a reduction in free swell index value is observed upto 2% lime content beyond which the reduction is not there is not substantial. This indicates that the colloidal reaction in soil of 100%ES continues upto 5% lime content whereas this stops at 2% lime content for soil mix 50%ES+50%RS and 10%ES+90%RS. It has been observed that for the residual soil or residual soil added with lime, the free swell index value is either very close to zero or negative. This observation is in line with the previous researchers who have reported a negative free swell index values for finely powered non cohesive earth material like rock powder



Variation in free swell index with lime content

Unconfined compressive strength

Unconfined compressive strength tests were carried out on untreated soils compacted to their maximum dry density at optimum moisture content. The unconfined compressive strengths are obtained from stress-strain curves for different untreated soils the soils as shown in Figure 4.9. It is observed that for untreated expansive soil (i.e. 100%ES), the compressive strength is less than the Residual soil (i.e. 100%RS). The expansive soil possesses more 11.6% moisture content than residual soil and also the dry density is less. As the expansive soil has high optimum moisture content and lesser maximum dry density, is obvious to show less compressive strength than the residual soil.



Stress-strain curves for untreated soils

the effect of moisture content on strength of untreated soils. The strength of residual soil is more than the expansive soil when compacted at their corresponding optimum moisture contents.

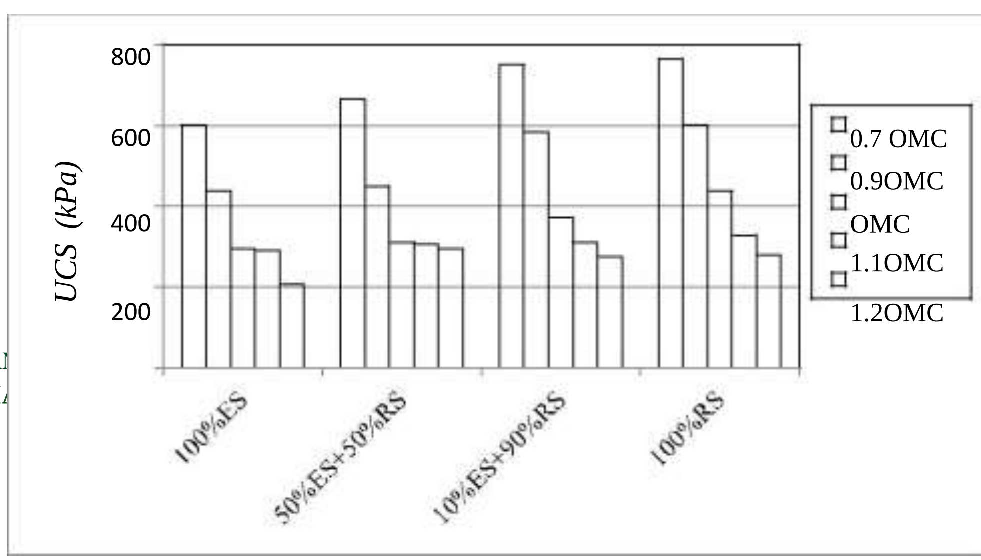


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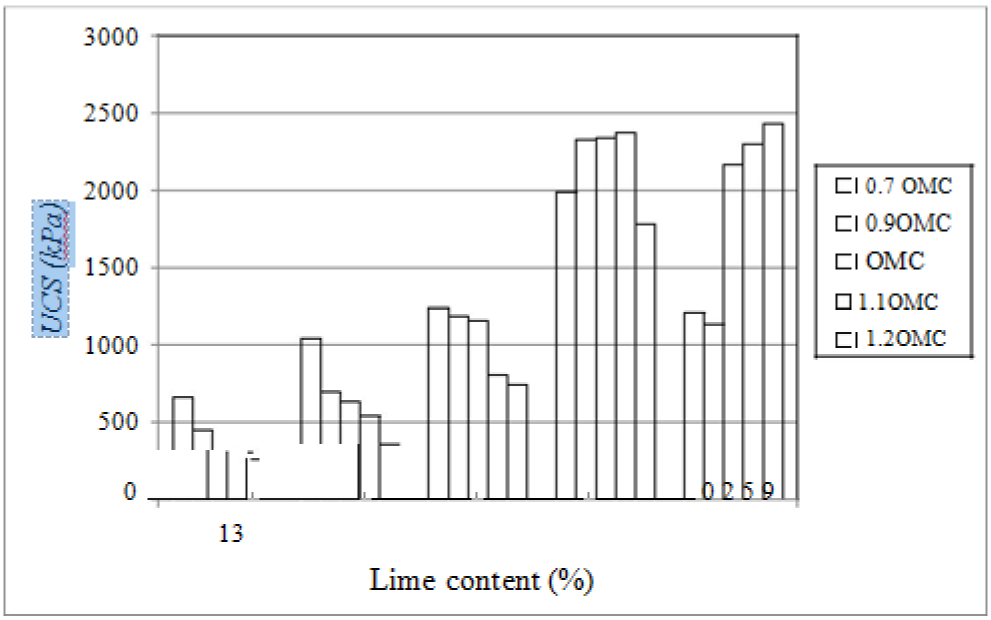
Figure Variation in UCS with moisture content for untreated soils



Variation in UCS with moisture content for lime stabilized soil mix (50%ES+50%RS)

CONCLUSION

The main objectives of this research were identified as follows:

1. To study the plasticity, swell and shrinkage characteristic of soils
2. To study the compaction characteristics of lime treated soils
3. To study the strength development in lime treated soils and hence to find out the optimum percentage of lime required to stabilize the soils

To achieve the above objectives, an overview on lime stabilization of clay soil has been done and also, a review of various studies on geotechnical behaviour (plasticity, swelling, shrinkage and strength) of lime stabilized expansive soils was carried out and the literature review has been summarized in chapter 2. Indian standard (Methods of test for soils) codes are followed to conduct various soil tests.

An extensive experimental program has been undertaken. Four types of soils have been synthesized taking highly expansive montmorillonite clay and a residual silty soil. The artificially prepared soils have a wide range of plasticity. These artificial soils are added with different proportions of lime and a series of tests were conducted to find out their plasticity, swell and shrinkage characteristics, compaction characteristics and the strength properties.

SCOPE OF FUTURE WORK

1. Durability aspects of lime treated soil like drying and wetting, freezing and thawing actions and response to various chemicals like alkalis, chlorides, sulphides are not investigated.
2. Research can be extended to find out the hydration products, morphology and microsture of lime treated soil and co-relations with developed strength.
3. Other geotechnical parameters such as hydraulic conductivity, consolidation parameters can also be performed.
4. The response of lime stabilized clays under repeated loading can be evaluated.

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