EFFECT OF LIME ON SOME GEO-ENGINEERING PROPERTIES OF SOIL

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Abstract: **For the construction and establishment of any engineering structure like bridges, dams, roads, residential houses etc a stable substratum is required which is soil in most of the cases. The structure is so constructed that the loads are fully transmitted to the soil beneath and the soil supports the overlying structure without causing any damage. When the structure is founded on a very weak soil, the risks are very high as there are enormous chances of differential settlements owing to low shear capacity and high compressibility. Therefore as civil engineers it is our utmost concern to observe and test the geoengineering properties of soil before the commencement of the construction. The present research work aims on improving the geoengineering properties (especially the shear strength) of the soil which is considered the most reliable property from the construction point of view by adding lime. Thus the present study points out the use of lime to the soil as an additive to achieve the desired results of strength. In addition to its application to the soil, the lime can also be successfully employed to the roads and runways with specific standards. Thus the current investigation describes the behavioral aspect of soils blended with 1 percent, 2 percent, 5 percent, 9 percent and 13 percent lime to elevate the load resisting capacity of soil.**

Index terms: Lime, Specific gravity, Atterberg's limits (liquid limit, plastic limit) Shear strength, Water content, MDD, OMC

Introduction

The stabilization of soil refers to the process by which the soil that was initially insufficient to bear the required loads, now acquires all the engineering properties as a result of which the soil is safe in shear and has better shear strength now. The main aim of the soil stabilization is usually to improve the strength and bearing capacity and to combat dust formation and soil erosion. Its main objective is to create a soil material or system better enough that can sustain any type and extent of loading for the safe design and planned life of the engineering project. Every project location do not have the same soil properties as these vary greatly from place to place even at the same location and in such cases the effectiveness of soil stabilization is greatly dependent on the soil testing. There are innumerous modes by which soil can be stabilized and it is important to verify the mode of stabilization in soil material laboratory prior to its actual application in the field. The main focus of the stabilization is to enhance the compressive strength to a great extent which is achieved at 9 percent lime content in this research. This research also focuses on other key goals of stabilization in strengthening the soil to establish a strong and stable foundation for the overlying structure. This land stabilization is being used all over the world especially in both developing as well as developed countries. By observing the properties of lime treated expansive soils, it would assess the suitability of using lime as stabilizer to reduce swelling of expansive soils. This paper mainly focuses on the effect of lime stabilization on engineering properties of a lime treated expansive soil. In this research work soil engineering tests like Atterberg limits, differential free swell test, shrinkage test, and strength test has been conducted on virgin soil and also on mixture of soil and lime. Earlier, the soil stabilization was solely accomplished by the utilization of the binding properties of clay soils, cement-based products such as soil cement and use of soil compaction techniques. In addition to this, the green technologies were also used which include biopolymers, surfactants, enzymes, tree resins, ionic stabilizers, fibre reinforcement, sodium chloride, magnesium chloride and much more. Latest research, however has increased the number of conventional additives used for soil stabilization purposes. These untraditional stabilizers include: calcium chloride, fibre reinforcement, sodium chloride, polymer-based products. Lime was used as an effective mode of stabilization.

1.1 Stabilization techniques

i. Soil Bitumen Stabilization
ii. Mechanical Stabilization
iii. Soil Cement Stabilization
iv. Soil Lime Stabilization

I. Soil Bitumen Stabilization

Bitumen is non-aqueous system of hydrocarbons soluble in carbon disulphide. Bitumen stabilizes the soil through water proofing and bonding. The former inherits the strength properties and retains the other properties of the soil but in case of cohesionless soils, bitumen provides both bonding as well as water proofing. The coarse grained soils may be individually coated and adhered by a thin film of bituminous material but in case of fine grained soils, the bitumen fills up the voids between soil particles thus making the compacted soil-bitumen water proofing surface. The commonly used materials are cutback bitumen and bitumen emulsions. A suitable grade of cutback must be chosen (depending upon the weather conditions and mixing problems of soil and bitumen) as the heating of large quantities of soil and bitumen is not possible. But the emulsions can be used during the scarcity of water.

II. Mechanical Stabilization
This technique involves the change of gradation of soil(correctly proportioned materials-aggregates and soil). Mixing of two or more types of soils is done which results in the formation of a composite material that has the superior quality than its individuals. These soils are then properly compacted by mechanical means which is referred as mechanical stabilization. It involves proportioning and compaction.

III. Soil Cement Stabilization
This is done by mixing soil and ordinary Portland cement with water and then compacting the resulting mixture which is known as soil cement. This cement imparts strength to the soil and modifies the properties of the soil. The strength developed is due to the bond formed by the hydrated cement and compacted soil particles (that are in contact) in granular soils but in case of fine grained soils the strength developed is due to reduction in plasticity and formation of structure enclosing small clay lumps.

IV. Soil Lime Stabilization
It involves addition of lime to the soil. It is usually employed for clayey soils. When the lime is added to the soil, exchange of cations in the adsorbed water layer occurs and plasticity decreases. Lime also imparts binding actions in granular soils. The maximum dry density of soil lime is decreased by 2-3 percent than the original soils however this decrease does not result in overall strength. The lime stabilized soil is suitable in warm regions for constructional purposes.

2. Literature Survey

The term expansive soil refers to the soils which has the affinity to swell when their moisture content is increased. The moisture may be in the form of rain, flood or any leakage. These soils may also be referred as cracking soils as they have the tendency to shrink and crack when the moisture content is decreased. These properties are observed due to the presence of montmorillonite **(Komine and Ogata, 1996; Rao and Triphaty, 2003)**.

The swell-shrink potentials in expansive soils are due to montmorillonite **(Chen, 1988; Sabtan, 2005).** These soils have been known from Western Madhya Pradesh, parts of Gujarat, Andhra Pradesh, Uttar Pradesh, Karnataka, and Maharashtra **(Gopal Ranjan and Rao, 1991)**.

The problem of expansiveness depends on the amount of monovalent cations absorbed to the clay mineral like sodium **(Fredlund and Rahardjo, 1993).**

When the lime is added to the soil, colloidal reaction occurs quickly which reduces the plasticity and swelling properties hence workability is increased **(Thompson, 1968)**.

While as during pozzolanic reaction, pH value increases (even up to 12). Due to higher pH minerals like silica and alumina from clay are dissolved and react with the calcium from lime, forming cementitious compounds thus improving the strength **(Ingles, 1964; Yoder and Witczak, 1975).**

As the lime content is increased, consistency limit decreases initially but beyond 5% lime content there seems no change. Lime improves the strength of the soil, but beyond certain limit, strength is reduced due to excess formation of silica gel which is a highly porous material **(Dash and Hussain, 2012)**.

During the addition of lime, plasticity and liquid limit are reduced. It has been seen that the clays containing montmorillonite are more susceptible to lime stabilization, and therefore depict earlier strength gain **(Bell, 1996)**.

Due to the presence of montmorillonite, the expansive soils exhibit swelling characteristics. On the addition of lime or hydrated lime [Ca (OH)2 swelling & swelling pressure are reduced but the strength gets improved.**(Kate, 2009)**.

If the lime is added to highly plastic clays shrinkage is reduced with increasing additive percentages and the linear shrinkage is decreased (from approximately 4 to 7 %) at 5% lime **(Russell *et al.*, 2007)**.

The maximum dry density is decreased as the lime content increases but the OMC (optimum moisture content) gets enhanced and at the lower percentages of lime this drop in density is more prominent. Upto 4% lime no enough strength is achieved by the time of curing. **(Kumar *et al.*, 2007)**.

The gain in strength is mostly dependent on the amount of silica and alumina and it has been seen that lime stabilization for montmorillonite soils is more effective than for kaolinite soils **(Lees *et al.*, 1982)**.

3. Methodology

The experimental work in the present research provides the details of laboratory investigation program to observe the properties of untreated soil sample and stabilized soil sample with lime. The soil was stabilized with different lime contents by weight of dry soil. The tests performed are:

1. Liquid limit test by Casagrande's apparatus
2. Plastic limit test by thread test
3. Plasticity Index
4. Free swell Index
5. Linear shrinkage index
6. Unconfined Compressive Strength by Stress-Strain Curve

4. RESULT AND DISCUSSION

4.1 Liquid limit by Casagrande's method

Result: The lime stabilized soil showed a reduced liquid limit, especially at 2% lime content. But as the lime content is increased, the liquid limit does not depict a sharp reduction. Therefore, the soils with 2% lime content have a greater strength.

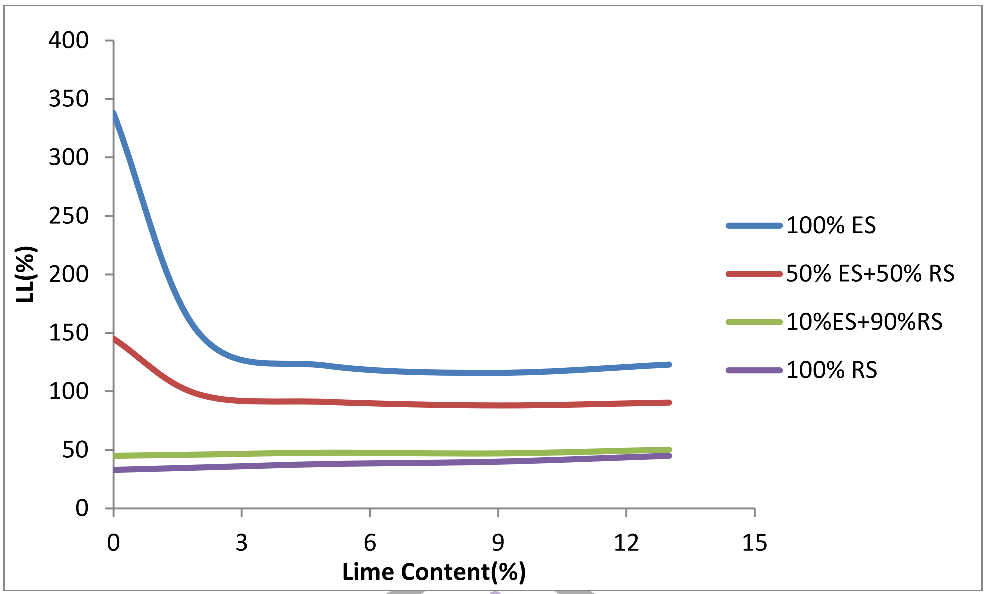

Fig 1 Variation of liquid limit with lime content

4.2 Plastic limit

On the addition of lime, the plastic limit is increased due to which shear resistance is developed and the soil behaves better enough compared to previous one(i.e, without lime). However the increase in plastic limit is more significant only upto the lime content of 2%.

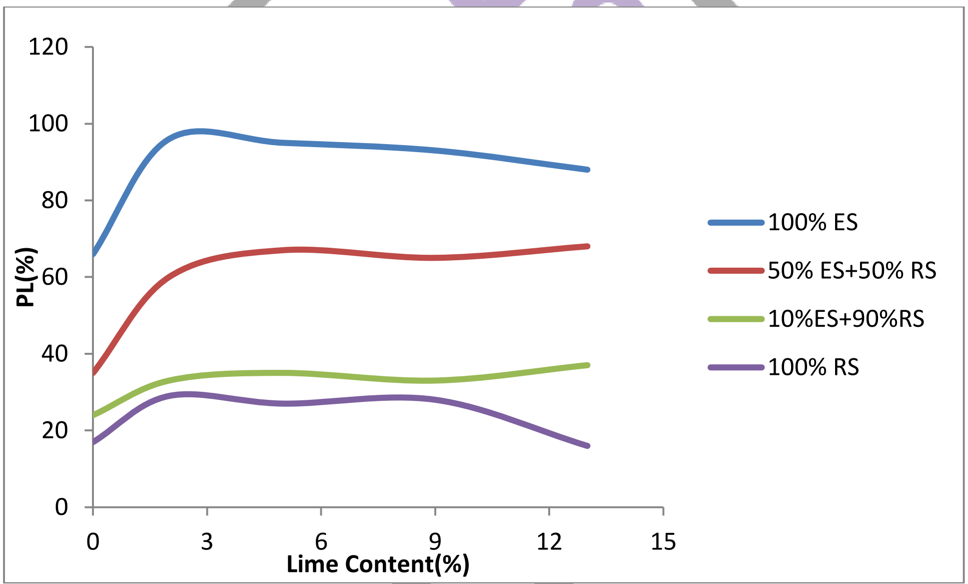

Fig 2 Variation of Plastic limit with lime content

4.3 Plasticity index

The Plasticity index decreases on increasing the lime content. This decrease in plasticity index is more for 100% ES soils at 2% lime content.

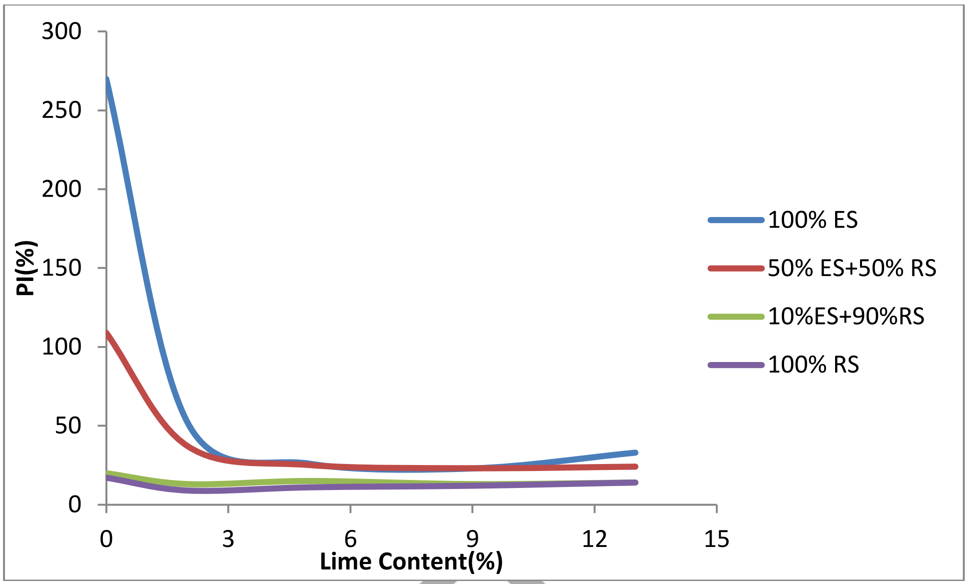

Fig 3 Variation of Plasticity index with lime content

4.4 Free swell index

The lime reduces the free swell index of soils (especially 100% ES-reduction is large) upto 5% lime content. While as for 50% ES+50% RS, the free swell index is reduced only upto 2% lime content. This clearly indicates that in the soils of 100% ES, colloidal reaction (key of reduction of free swell index) continues upto 5% lime content but for 50% ES+ 50% RS, the reaction stops only at 2% lime content.

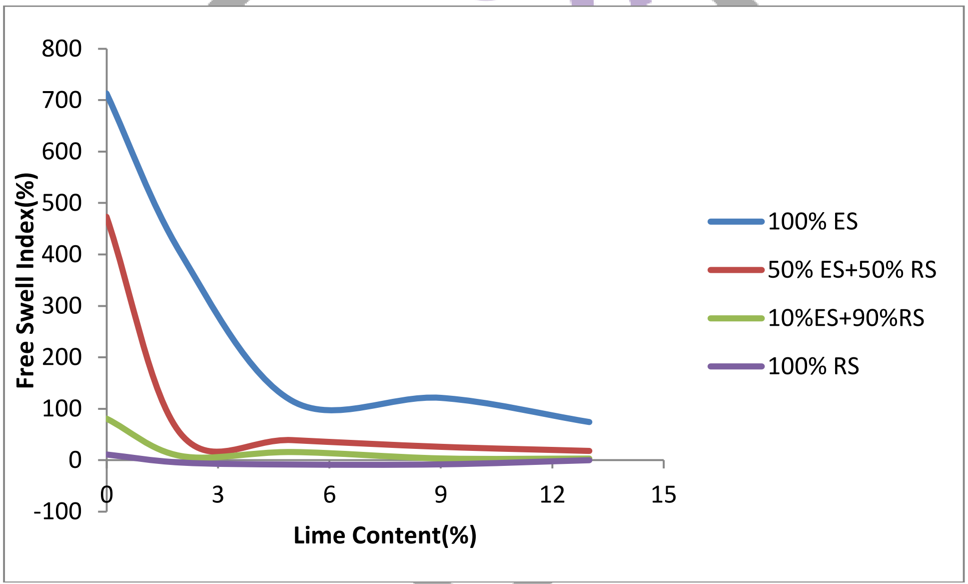

Fig 4 Variation of FSI with lime content

4.5 Linear Shrinkage Index

It was observed from the research that the shrinkage reduced for highly plastic clays with increasing lime content. Actually due to the addition of lime, the aggregation and flocculation of particles occurs due to which these soils become less plastic.

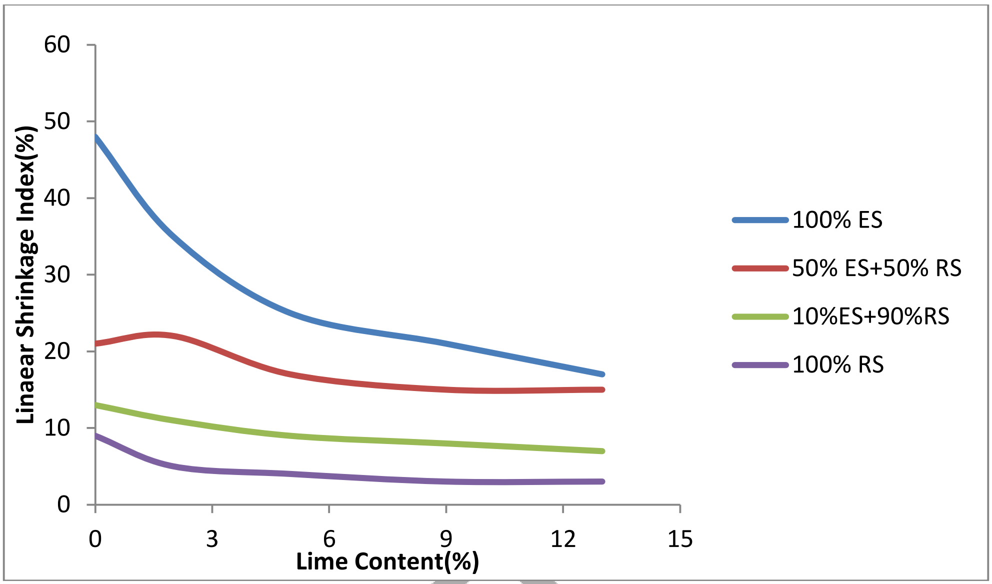

Fig 5 Variation of LSI with lime content

4.6 Unconfined Compressive Strength

This was calculated from the stress-strain curves for various soils. It has been evaluated that for residual soil (100%RS), the compressive strength is more than the untreated expansive soil (100% ES). The moisture content of residual soil being less than the expansive soil, hence the compressive strength of residual soil is more than the expansive soil.

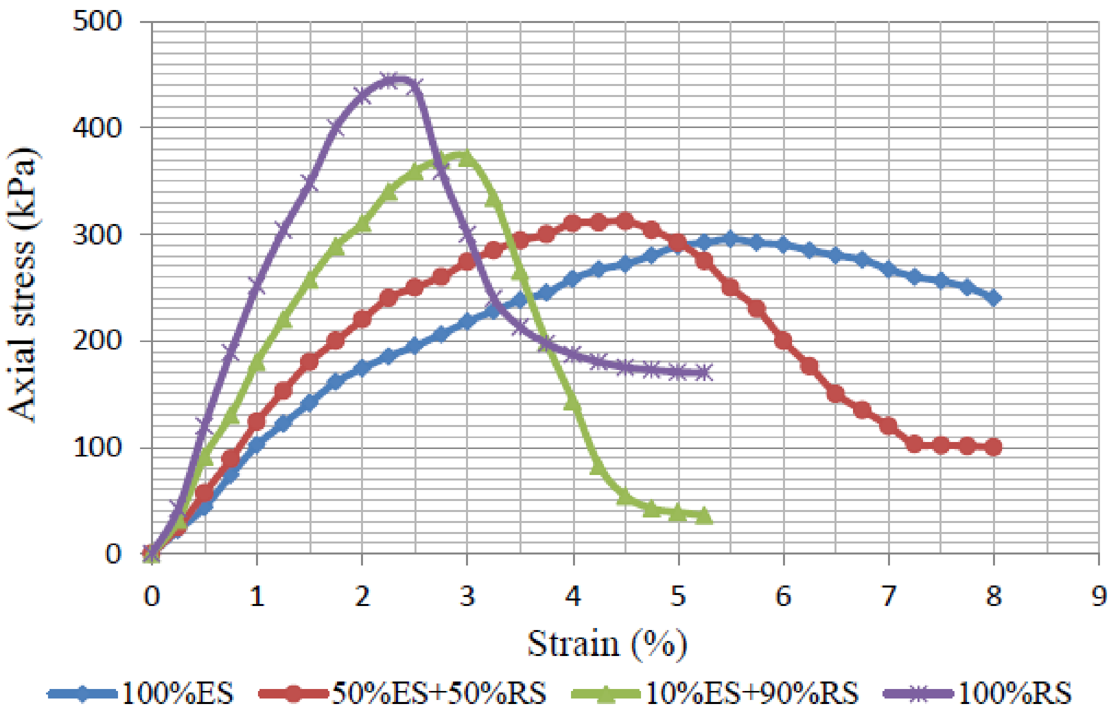

Fig 6 Stress-Strain curves

Conclusion

1. In the present research it was found that the liquid limit of soil decreases with an increase in lime content. This result is obtained due to reduction in thickness of double layer as the electrolyte concentration increases in the pore fluid.
2. The plastic limit of soil was also found to increase with lime contents as the charge concentration of pore water increases, the viscosity increases and offers high resistance against interparticle movement.
3. It was also observed that the plasticity of soil got reduced with increased lime content.
4. There was a significant reduction in free swell index of high plastic clay at low lime content in comparison to other low and medium plastic clays.
5. In addition to this, the amount of shrinkage arrest caused by addition of lime correlated with raw soils specific surface area and was found that more shrinkage occurred for high plastic clays.
6. Also the compaction characteristics of soils were found to vary significantly at low lime content.

7. The strength of lime treated soil depends on type of soil, lime content, curing period and moisture content. For high plastic clays maximum strength was achieved at 60 days cured sample with 9% lime content whereas, for low plastic clay occurred with 5% lime.

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