ISSN No. 2456-0472
The Engineering Journal of Application & Scopes, Volume 4, Issue 2, Dec 2019

PROPERTIES OF CLAY SOIL AFTER STABILIZATION WITH LIME

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Abstract
People have to use soft and weak soils around for construction activities. The reason behind this is high growth of population, fast urbanization and more construction of structures. The weak soil possesses high swelling and shrinkage. The research deals with improvement of mechanical behavior of such nature of soil by employing stabilization techniques to make it useful for construction activities. The study has scope in solving the significant problems created by unstable soil for pavements or structures. With proper design and construction techniques, lime treatment chemically transforms unstable soil into stable soil. A reaction takes place between hydrated lime and clay particles and results in formation of permanent strong cementation matrix. In this project, an experimental study is carried out with 5%, 10% and 15% lime content. Samples of clayey soil were collected from Kaliyar road, Roorkee (Uttarakhand). The properties of soil, namely Liquid Limit and Plastic Limit were determined. Changes in these soil properties were analyzed with addition of varying percentages of lime.

1. Introduction

Wet, weak, fine grain soil can prove to be a major challenge at many construction sites. Access for construction vehicles becomes difficult. It is difficult to reach the soil moisture and compaction requirements established by the project civil or geotechnical engineer. Wet, poorly compacted soil results in poor pavement support and embankment/fill. At a construction site, lost time means lost money.

The long –term performance of any construction project depends on the soundness of the underlying soils. Unstable soils can create significant problems for pavements or structures. With proper design and construction techniques, lime treatment chemically transforms unstable soils into usable materials. Indeed the structural strength of lime stabilized soils can be used for pavement designs.

Lime can be used to treat soils to varying degrees, depending upon the objective. The least amount of treatment is used to dry and temporarily modify soils. Such treatment produces a working platform for construction or temporary roads. A greater degree of treatment – supported by testing, design and proper construction techniques- gives permanent structural soil stabilization [10].

2. Literature Review

2.1 Clayey Soil

Engineers classify soil into different types based on the grain (particle) size distribution. According to this classification, the main soil types are boulders, gravel, sand, silt, and clay. Different 'soil separate size limits' have developed by different institutions and organizations. However, currently the classification of Unified Soil Classification System is widely used all over the world.

According to unified soil classification system, if particle sizes of soil are less than 0.075mm, they may either be silt or clay. Both clay and silt fall under the category of fine grained soil. The soil in which percentage fines is greater than 50% is classified as clayey soil.

Clay-A soil is classified as clay when it contains clay minerals. Clays are plastic and cohesive. Clay particles can be seen through a powerful microscope only. Kaolinite, montmorillonite, illite are mostly found clay minerals in soil. These are tiny plates or flake like structures. Clay minerals are very active electrochemically. The soil is known as heavy or dense soil when lots of clay minerals are found in it. In dry condition, clay is almost hard like concrete. The spaces between soil particles are very tiny. In soil mechanics, clay plays an important role as it has the ability of changing the behavior of a given soil. Soils with clay minerals are commonly used to make or mould shapes and statues. Movement of air and water through wet clay is very hard [1] [9]

2.2 General Properties of Clayey Soil

There are mainly three types of soil considered by geologists. The quality of soil depends on the amount of sand, loam and clay that it contains, because soils with differing amounts of these particles often have very different characteristics. Soil with a large amount of clay is sometimes hard to work with, due to some of clay's characteristics.

Particle Size-Clay has the smallest particle size of any soil type, with individual particles being so small that they can only be viewed by an electron microscope. This allows a large quantity of clay particles to exist in a relatively small space, without the gaps that would normally be present between larger soil particles. This feature plays a large part in clay's smooth texture, because the individual particles are too small to create a rough surface in the clay.

Structure-Because of the small particle size of clay soils, the structure of clay-heavy soil tends to be very dense. This density is responsible for clay-heavy soil being thicker and heavier than other soil types, and clay soil takes longer to warm up after periods of cold weather. This density also makes clay soils more resistant to erosion than sand or loam-based soils.

Permeability and Water-Holding Capacity-One of the problems with clay soil is its slow permeability resulting in a very large water-holding capacity. Because the soil particles are small and close together, it takes water much longer to move through clay soil than it does with other soil types. Clay particles then absorb this water, expanding as they do so and further slowing the flow of water through the soil. This prevents water from penetrating deep into the soil [9]

2.3 Engineering Properties of Clay Soil

The main engineering properties of soil are permeability, plasticity, compaction, compressibility and shear strength [2] [3] [4]

Permeability: The permeability is defined as the property of a porous material which permits the passage or seepage of water through its interconnecting voids

Plasticity: It is defined as the property of a soil which allows it to be deformed rapidly, without elastic rebound, without volume change.

Compaction: Compaction is a process by which the soil particles artificially rearrange and packed together into a closer state of contact by mechanical means in order to decrease the porosity of the soil and thus increase its dry density.

Compressibility: The property of soil mass pertaining to its susceptibility to decrease in volume under pressure is known as compressibility.

Shear Strength: This is the resistance to deformation by continuous shear displacement of soil particles or on masses upon the action of a shear stress.

2.4 Index Properties of Soil

The properties of soil, which are not of primary interest to the geotechnical engineering, but are indicative of the engineering properties are called index properties.

This includes –

Particle Size Analysis: This is method of separation of soils into different fraction bases on particles present into soils. It can be shown graphically on a particle size distribution curve.

Atterberg's Limit: The water content at which the soil changes from one state to other state are known as consistency limits or Atterberg‟s limit .The Atterberg‟s limit which are useful for engineering purposes are; Liquid limit, plastic limit and shrinkage limit. These limits are expressed as percent water content.

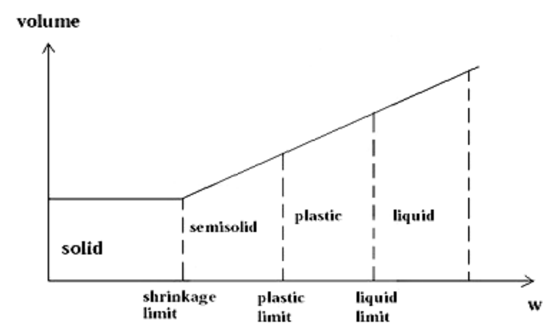

Fig. 1 [11]

Liquid limit: - It is defined as the minimum water content at which the soil is still in liquid state but has a small strength against flowing which can be measured by standard available means.

Plastic limit:- It is defined as minimum water content at which soil will just begin to crumble water rolled into a thread approximately 3mm in diameter, Plasticity index is determined as difference of L.L. and P.L.

Shrinkage limit: - It is defined as the maximum water content at which a reduction in water content will not cause a decrease in the volume of soil mass.

3 Lime Stabilization

3.1 Lime

Lime in the form of quicklime (calcium oxide- CaO), hydrated lime (calcium hydroxide-Ca $[OH]_2$), or lime slurry can be used to treat soils. Quicklime is manufactured by chemically transforming calcium carbonate (limestone-$CaCO_3$) into calcium oxide. Hydrated lime is created when quicklime chemically reacts with water. It is hydrated lime that reacts with clay particles and permanently transforms them into a strong cementitious matrix.

Most lime used for soil treatment is ‘’high calcium’’ lime, which contains no more than 5 percent magnesium oxide or hydroxide. On some occasions, however, ‘’dolomitic’’ lime is used. Dolomitic lime contains 35 to 46 percent magnesium oxide or hydroxide. Dolomitic lime can perform well in soil stabilization, although the magnesium fraction reacts more slowly than the calcium fraction.

3.2 Principle of Lime Stabilization

When soils are treated with lime, either modification in soil properties or binding or both actions may take place. In the case of clayey soils with high plasticity the predominant action is generally modification resulting benefits such as reduction in plasticity and volume changes due to variation in moisture content. Other benefits are, soil lime mixes become friable and easy to be pulverized having less affinity with water; also there could be puzzolanic action resulting in slow rate of increase in strength with curing period. All these modifications are considered desirable in construction of soil stabilized roads. Lime also imparts a little binding action in soils.

The maximum dry density of soil lime mix is decreased by 2 to 3 percent in terms of untreated soils; however this decrease in dry density with the addition of small proportion of lime does not cause reduction in strength.

When clay is treated with lime, the various possible reactions are Base Exchange, coagulation or flocculation, reduction in thickness of water film around clay particles, cementing action and carbonation. The fine clay particles react with lime and get flocculated or aggregated into larger particle groups which are fairly stable even under subsequent soaking. Plastic clay soils tend to agglomerate more than silty and sandy soils. Due to this flocculation the lime treated clays indicate a different grain size distribution, indicating substantial reduction in the proportion of fines. The changes in plasticity, characteristics of soil lime mixture also take place simultaneously; the total time required for the changes depends on several factors including the soil type.

3.3 Applications of Lime Stabilization

Soil lime is quite suitable as sub base course for all types of pavements and base course for pavements with very low traffic. Soil lime cannot be used as a surface course even for light traffic in view of its very poor resistance to abrasion and impact. Soil lime is quite suitable in warm regions; but it is not very suitable under freezing temperatures

Lime quickly improves the soil condition during construction and can add long term improvements to key soil properties. Adding lime can cause three major soil improvements:

- Soil Drying – Reducing the soil moisture content
- Soil Modification – Reducing soil plasticity, aiding compaction and increasing early strength

- Lime Stabilization – Increasing long term strength and reducing swell potential

  Lime can be used to stabilize pavement subgrade soil containing clay. Lime stabilization generates a long term pozzolanic strength-gaining reaction between lime and the silica and alumina minerals solubilized at high pH from the clay, forming calcium silicates and calcium aluminates. If the subgrade soil or aggregate base lacks suitable reactive clay, it is advantageous to add a coal fly ash pozzolanic material along with the lime.

  In addition to the benefits provided by lime modification, the benefits of stabilization include:

- Greater strength improvements than from soil modification.
- Increase in CBR penetration resistance and resilient modulus stiffness.
- Freeze-thaw resistance.
- Long-term retention of strength improvements.

  As a general rule, authorities on soil stabilization recommend that lime be considered for all soils when the plasticity index exceeds 10 and the percent of soil smaller than the #200 mesh sieve exceeds 25%.

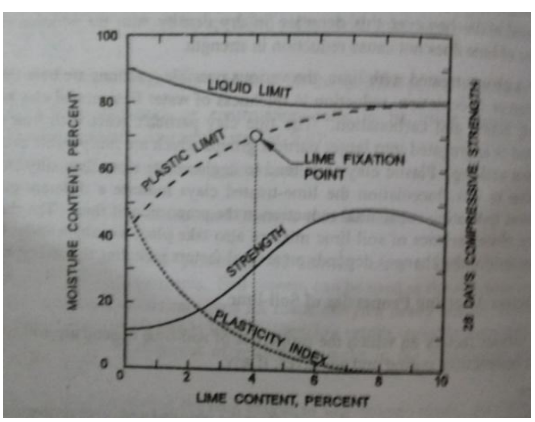

Fig. 2 authorities on soil stabilization [6]

4 Materials and Methods

The samples of clayey soil are taken from Kaliyar Road near Rehmadpur area, Roorkee for study of soil properties namely Liquid Limit and Plastic Limit. The lime is added in soil samples in different proportions (varying to 5%, 10% and 15%) and variation in the properties of stabilized soil is studied.

An oven for maintaining to 105^0 C to 110^0 C is required to dry the clayey soil. The other requirements for carrying out liquid limit and plastic limit test are-(i) Mechanical liquid limit device consists of a cup and arrangement for raising and dropping through a specified height, (ii) Standard grooving tools, (iii) Other apparatus include spatula, evaporating dish, moisture container balance of capacity of 200gm sensitive to 0.01gm, drying crucibles and oven, (iv) Vernier Calipers' device.

5 Experimental Section

5.1 Liquid Limit Test

The liquid limit of a soil is the moisture content expressed as a percentage of the weight of the oven-dried soil at the boundary between the liquid and plastic states of consistency. The moisture content at this boundary is arbitrarily defined as the water content at which two halves of a soil cake will flow together, for a distance of ½ in. (12.7 mm) along the bottom of a groove of standard dimensions separating the two halves, when the cup of a standard liquid limit apparatus is dropped 25 times from a height of 0.3937 in. (10 mm) at the rate of two drops/second [5]

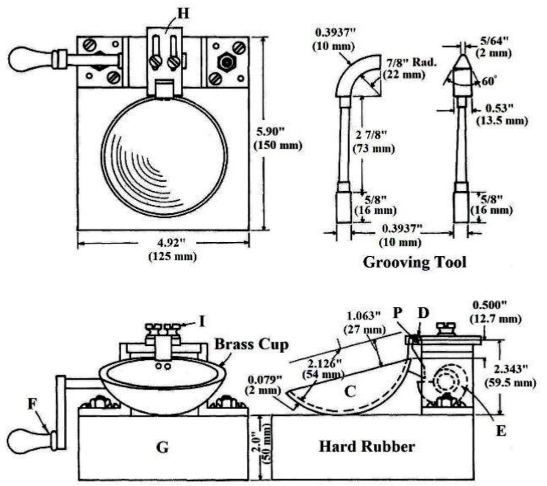

Fig. 3 Mechanical Liquid Limit Device [5].

5.2 Plastic Limit Test

The plastic limit of a soil is the moisture content, expressed as a percentage of the weight of the oven-dry soil, at the boundary between the plastic and semisolid states of consistency. It is the moisture content at which a soil will just begin to crumble when rolled into a thread ⅛ in. (3 mm) in diameter using a ground glass plate or other acceptable surface.

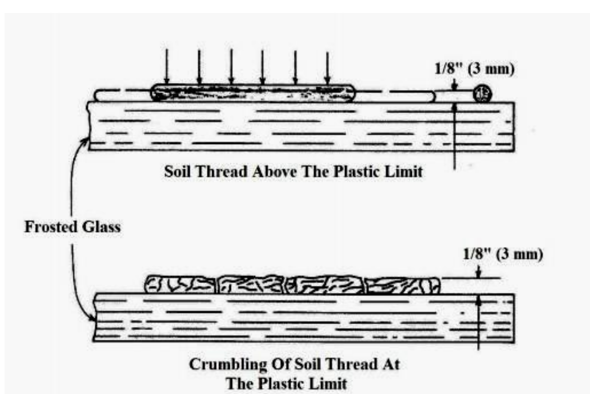

Fig.4 Plastic Limit Test [5]

5.3 Plasticity Index

The plasticity index of a soil is the numerical difference between its liquid limit and its plastic limit and is a dimensionless number. Both the liquid and plastic limits are moisture contents [5].

Calculations:

Plasticity Index=Liquid Limit-Plastic Limit

PI = LL – PL

6 Results of Experimental Investigation

Table 1 shows the liquid limit for clayey soil and stabilized soil with 5%, 10% and 15% lime.

Table 2 shows the plastic limit for clayey soil and stabilized soil with 5%, 10% and 15% lime.

Table 3 shows the plasticity index for clayey soil and stabilized soil with 5%, 10% and 15% lime.

LIQUID LIMIT : For analyzing liquid limit, Plastic limit and plasticity index the sample was taken 120 grams.

Table 1: Liquid limit

S.No.	Clayey soil + 0% lime	
	% of water	No. of blows
1	43.95	28
2	46.01	16
L.L.	**44.47%**	
S.No.	Clayey soil + 5% lime	
	% of water	No. of blows
1	39.99	27
2	40.57	20
L.L.	**40.16%**	
S.No.	Clayey soil + 10% lime	
	% of water	No. of blows
1	33.40	35
2	36.69	21
L.L.	**35.75%**	
S.No.	Clayey soil + 15% lime	
	% of water	No. of blows

1	33.25	35
2	35.07	19
L.L.	**34.38%**	

L.L= Liquid Limit

Table 2: Plastic limit

S.No.	Composition of soil	Plastic Limit
1	Clayey soil+0%lime	27.29%
2	Clayey soil+5%lime	34.89%
3	Clayey soil+10%lime	Non Plastic
4	Clayey soil+15%lime	Non Plastic

Table 3: Plasticity index

S.No.	Composition of soil	Plasticity Index
1	Clayey soil+0%lime	17.18%
2	Clayey soil+5%lime	5.27%
3	Clayey soil+10%lime	-
4	Clayey soil+15%lime	-

7 Conclusions

On the basis of study and experimental investigations, it was observed that the properties of clayey soil effectively improved by use of different percentage of lime contents. In this research varying percentage (5%, 10% and15%) of lime was used to stabilize the clayey soil. Points which were drawn from this study are listed below-

- It was observed that with increase in lime content, liquid limit decreased consequently.
- It was observed that with 5% addition of lime content, plastic limit increased and with increase in lime content to 10% and 15%, the sample became non-plastic.
- The plasticity index decreased with the addition of lime.

Thus it can be concluded that lime stabilizes the clayey soil to a great extent as visible in experimental results of liquid limit test and plastic limit test. The liquid limit decreases and plastic limit increases with the lime addition which makes the soil reliable for construction activities. The stabilized soil can be used for construction of embankment for roads and foundation purposes if clayey soil is present to smaller depths.

References

[1] Arora, Dr. K.R., ``Soil Mechanics and Foundation Engineering", Standard publisher Distribution, Delhi-110006.

[2] Punmia, B.C., ``Soil Mechanics and Foundation Engineering'' Laxmi Publication (P) Ltd., New Delhi.

[3] Ranjan G., ``Basic and Applied Soil Mechanics", New Age International (P) Publishers Ltd. Publishers, New Delhi.

[4] IS 2720 (Part 2)-1973,"Determination of Water Content"

[5] IS 2720(Part 5)-1985,"Determination of Liquid Limit and Plastic Limit"

[6] Khanna S.K., Justo C.E.G. and Veeraragavan A., ``Highway Engineering", Nem Chand & Bros publisher, Roorkee.

[7] Garg S.K., ``Soil Mechanics and Foundation Engineering'', Khannna Publishers, Delhi-110006

[8] http://www.differencebetween.com

[9] http://homeguides.sfgate.com/properties-clay-soil-71840.html

[10] http://www.carmeusena.com/markets/construction/lime-soil-stabilization

[11] https://www.google.co.in/search?q=atterberg+limits&source=lnms&tbm=isch&sa=X&ved=0ahUKEwis06eK7fjSAhVKrI8KHckEDOwQ_AUIBigB&biw=1366&bih=638#imgrc=_u_Vi8iX_LoeSM: