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Determination of varriation of soil characteristic due to lime stabilization

Dipanjan Mukherjee

Department of Civil Engineering (Transportation Engineering) National Institute Of Technology, Silchar, Assam, India.

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ABSTRACT

Generally the soil quality improvements through stabilization include better soil gradation, reduction of plasticity index or swelling potential, and increases in durability and in strength. The tensile strength and stiffness of a soil layer can be improved through the use of additives and thereby permit a reduction in the thickness of the stabilized layer and overlying layers within the pavement system. According to Sherwood (1995) and Little (1999), lime stabilization can be used to either modify or stabilize clays. The strength of lime mixture depends to a great extent on the quantity of lime added above lime fixation point. (i.e. it changes the Plasticity Index of soil). In this experiment Indian A-7a type black cotton sol is used. In this paper soil subgrade characteristics are determined by using 0%, 3%, 6%, 9%, 12%, lime (by weight of soil) stabilization techniques & a graphical representation is made % of stabilization Vs PI values. So gradually PI value of soil decreases. But some time in the field plasticity of soil, especially black cotton soil changes very rapidly in this case the advantage of this graph is one can easily get some rough idea about changes soil characteristics due to applications of lime stabilization, when the soil becomes highly plastic to non plastic. Finally a semi empirical formula is made to get an idea about Plastic Index value of A-7a type black cotton soil (As per Highway Research Board of India) due to application of lime stabilization within range of 0 to 12% of lime by weight of soil. This paper also help full to determine how the subgrade strength varies with lime stabilization.

Introduction

Subgrade *Definition*

Subgrade can be defined as a compacted layer, generally of naturally occurring local soil, assumed to be 300 mm in thickness, just beneath the pavement crust, providing suitable foundation for the pavement. The subgrade in embankment is compacted in two layers, usually to a higher standard than the lower part of the embankment. The subgrade, whether in cutting or in embankment, should be well compacted to utilize its full strength and to economize on the overall pavement thickness. The current MORTH Specifications require that the subgrade should be compacted to 100% MDD achieved by the Modified Proctor Test (IS 2720-Part 7). For both major roads and rural roads the material used for subgrade construction should have a dry unit weight of not less than 16.5kN/m3.

Subgrade Soil

Soil is a gathering or deposit of earth material, derived naturally from the breakdown of rocks or decay of undergrowth that can be excavated readily with power equipment in the field or disintegrated by gentle reflex means in the laboratory. The supporting soil below pavement and its special under course is called sub grade. Without interruption soil beneath the pavement is called natural sub grade. Compacted sub grade is the soil compacted by inhibited movement of heavy compactors.

Desirable Property of Subgrade Soil

The advantageous properties of sub grade soil as a highway material are

- Stability
- Incompressibility
- Permanency of strength
- Minimum changes in volume and stability under adverse conditions of weather and ground water
- Superior drainage, and
- Ease of compaction

Soil Stabilization

Pavements are usually designed based on the assumption that specified levels of quality will be achieved for each soil layer in the pavement system. Each layer must resist shearing within the layer, avoid excessive elastic deformations that would result in fatigue cracking within the layer or in overlying layers, and prevent excessive permanent deformation through densification. When the quality of a soil layer is increased its ability to distribute the load over a greater area is generally increased enough to permit a reduction in the required thickness of the soil and surface layers. Generally, the soil quality improvements through stabilization include better soil gradation, reduction of plasticity index or swelling potential, and increases in durability and in strength. The tensile strength and stiffness of a soil layer can be improved through the use of additives and thereby permit a reduction in the thickness of the stabilized layer and overlying layers within the pavement system.

Lime Stabilization:-_ Lime can be used to treat soils to varying degrees, depending upon the objective of the stabilization for a specific project. The least amount of treatment is used to dry and temporarily modify soils (Sherwood, 1995). Such treatment produces a working platform for construction or temporary

Tele:
E-mail addresses: ddiipp90@gmail.com

roads. The highest amount can be used when it is being used to improve the soil strength properties for supporting roads (Sherwood, 1995). Lime stabilization is a widely used means of chemically transforming unstable soils into structurally sound construction foundations. Lime stabilization enhances engineering properties in soils, including improved strength; improved resistance to fracture, fatigue, and permanent deformation; improved resilient properties, reduced swelling, and resistance to the damaging effects of moisture. The most substantial improvements in these properties are seen in moderately to highly plastic clays (Little, 2000).

According to Sherwood (1995) and Little (1999), lime stabilization can be used to either modify or stabilize clays. The strength of lime mixture depends to a great extent on the quantity of lime added above lime fixation point. It is generally found that beyond a certain % of lime the increase in strength ceases & in fact a lowering strength may result due to present of unreacted free lime indicating that there exists optimum lime content for maximum strength grain. So after a certain limit of lime content no development of strength but cost increases. As per Illinois Department of Transportation (2005) for lime modification, the optimum lime content is the percent lime that provides a minimum immediate bearing value (IBV) of 10 percent. For lime stabilization, the optimum lime content is the percent lime that results in a stabilized soil strength gain of 50 psi, so required thickness of granular layer should be reduced by using the optimum quantity of lime stabilizer. But use of optimum quantity of stabilizer is not always economical. The optimum amount of lime for maximum strength gain in stabilizing soil with lime, according to Eades and Grim (1960) is 4 - 6 % for Kaolinite, about 8 % for illite and montmorillonite. Ola (1978) found a linear relationship between the strength of lime – stabilized black Cotton soil and lime content (up to 10 % lime). But in those literatures, authors have not determined the optimum lime requirement to satisfy the cost effectiveness of pavement construction. Generally authors have considered only strength development without considering the cost effectiveness. As per IRC 51-1992 optimum lime content for soil;

Kaolinitic soil	4%
Illitic soil	8%
Montmorillonitic soil	10%

Atterberg Limit : The Atterberg limits are a basic measure of the critical water contents of a fine-grained soil, such as its shrinkage limit, plastic limit, and liquid limit. As a dry, clayey soil takes on increasing amounts of water, it undergoes dramatic and distinct changes in behavior and consistency. Depending on the water content of the soil, it may appear in four states: solid, semi-solid, plastic and liquid. In each state, the consistency and behavior of a soil is different and consequently so are its engineering properties.

Shrinkage limit

The shrinkage limit (SL) is the water content where further loss of moisture will not result in any more volume reduction. The test to determine the shrinkage limit is ASTM International D4943. The shrinkage limit is much less commonly used than the liquid and plastic limits. It is the minimum water content

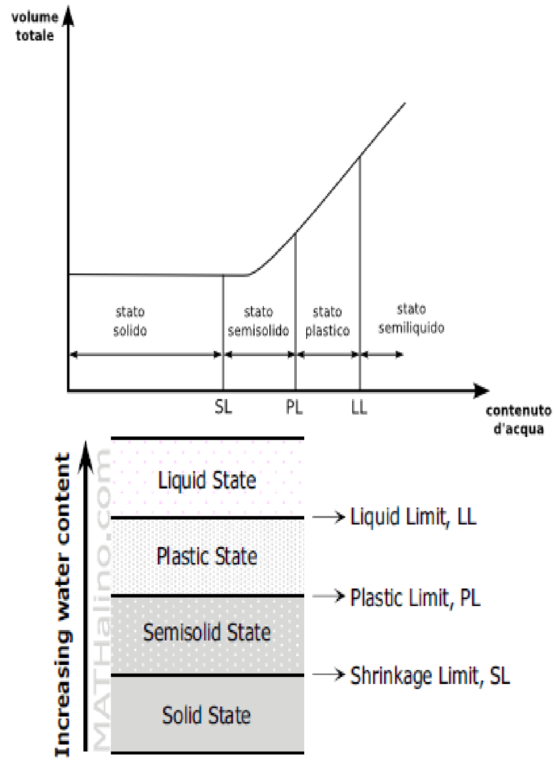


Figure 2 Atterberg Limits

Plastic limit

The plastic limit is determined by rolling out a thread of the fine portion of a soil on a flat, non-porous surface. The procedure is defined in ASTM Standard D 4318. If the soil is plastic, this thread will retain its shape down to a very narrow diameter. The sample can then be remolded and the test repeated.

Liquid limit

The liquid limit (LL) is often conceptually defined as the water content at which the behavior of a clayey soil changes from plastic to liquid. Actually, clayey soil does have a very small shear strength at the liquid limit and the strength decreases as water content increases; the transition from plastic to liquid behavior occurs over a range of water contents. The precise definition of the liquid limit is based on standard test procedures described below

Plasticity index

The plasticity index (PI) is a measure of the plasticity of a soil. The plasticity index is the size of the range of water contents where the soil exhibits plastic properties. The PI is the difference between the liquid limit and the plastic limit (PI = LL-PL). Soils with a high PI tend to be clay, those with a lower PI tend to be silt, and those with a PI of 0 (non-plastic) tend to have little or no silt or clay.

PI and their meanings

- (0-3)- Nonplastic
- (3-15) - Slightly plastic
- (15-30) - Medium plastic
- >30 - Highly plastic

Liquidity index

The liquidity index (LI) is used for scaling the natural water content of a soil sample to the limits. It can be calculated as a ratio of difference between natural water content, plastic limit, and liquid limit: LI=(W-PL)/(LL-PL) where W is the natural water content.

Figure 1 LL & PL Test

Test Result

Basic Properties of soil

1. Specific Gravity	2.66
2. % finer than 4.75mm	100
3. % finer than 75µ	96.83
4. Liquid Limit	63.8%
5. Plastic Limit	34.37%
6. Plasticity Index	29.43%
7. Flow Index	13.3%
8. OMC	31.95 %
9. Maximum Dry Density	14.36 KN/m^3
10. Elastic Modulus	2.706 Mpa
11. Φ value of sample	2.22 deg
12. Cohesion Value	0.452 kg/cm^2
13. Type of black cotton soil (as per HBR)	A-7a
14. General Rating as Sub-Grade 15. (as per HBR)	Poor
16. Suggested Chemical stabilizer	Lime (IRC 51-1992)

Test Result Application of Lime Stabilization

% of Lime Stabilization	Liquid Limit	Plastic Limit	Plasticity Index
0	63.8 %	34.37%	29.43%
3	68%	42.906%	25%
6	70%	45.97%	24.03%
9	71%	47.04%	23.96%
12	72.03%	49.09%	22.94%

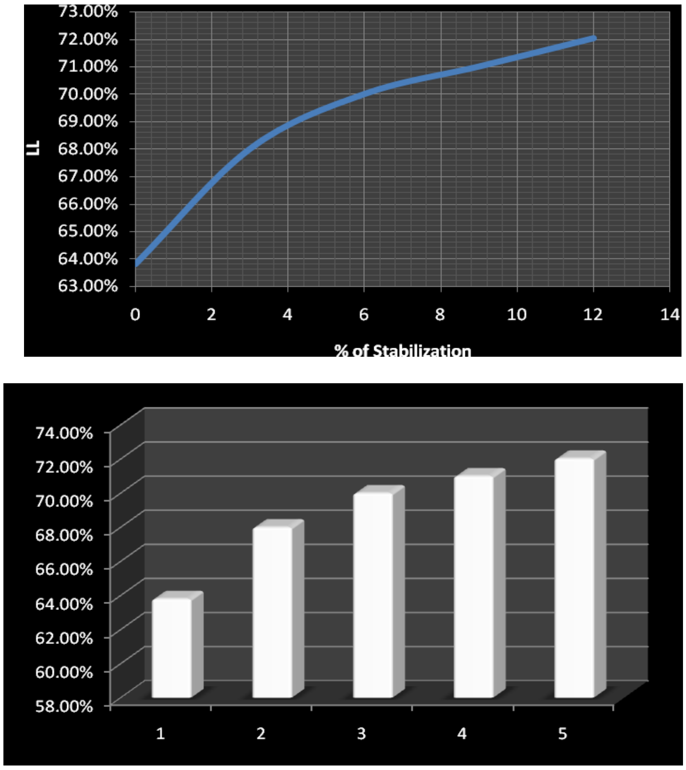


Figure 2 Changes in LL Due to Applications of lime Stabilization

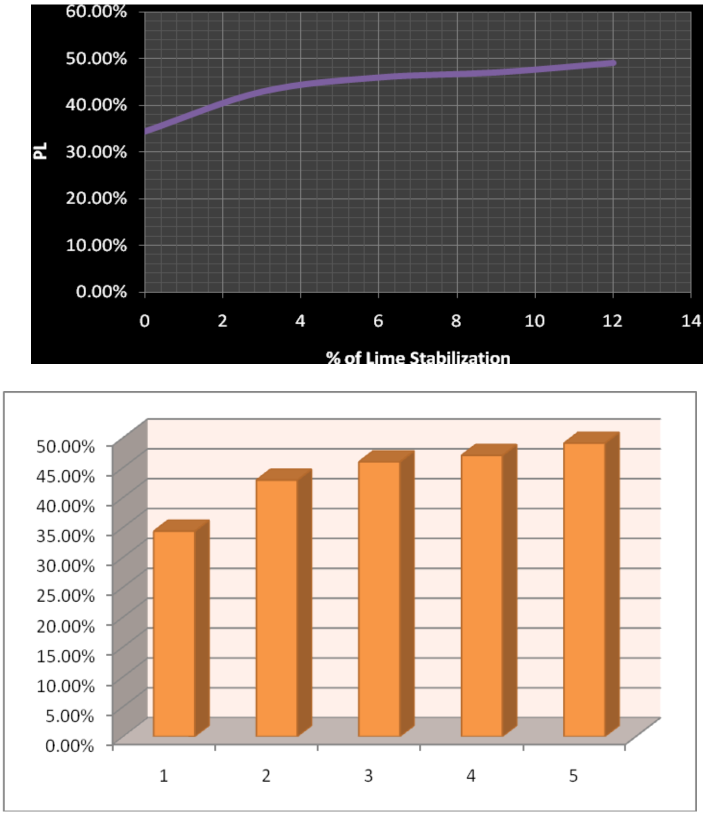


Figure 3 Changes in PL Due to Application of Stabilization

From the Design Chart of % of Stabilization Vs PI value the equation is obtained to determine PI value due to application of Lime Stabilization,

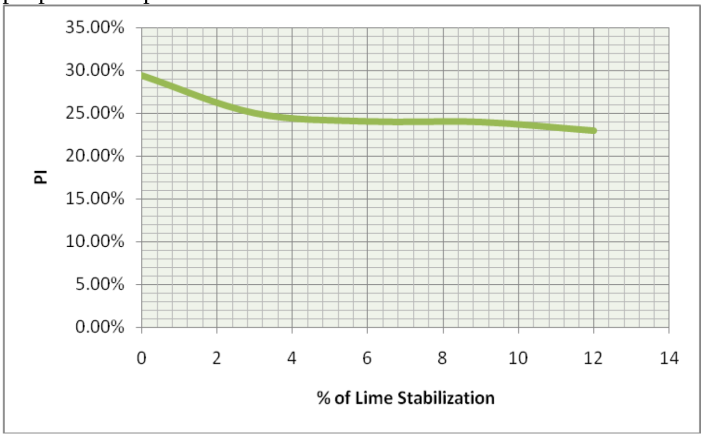
$$y = x - 0.06667a^2 + b$$

Where,

y = PI Value.

a & b are regression constant ants , Values of a & b are obtained from Design Chart given below.

x = initial (0% Application of soil-lime stabilization) PI value for this type of soil only, x value should be determined by proper lab experiment.



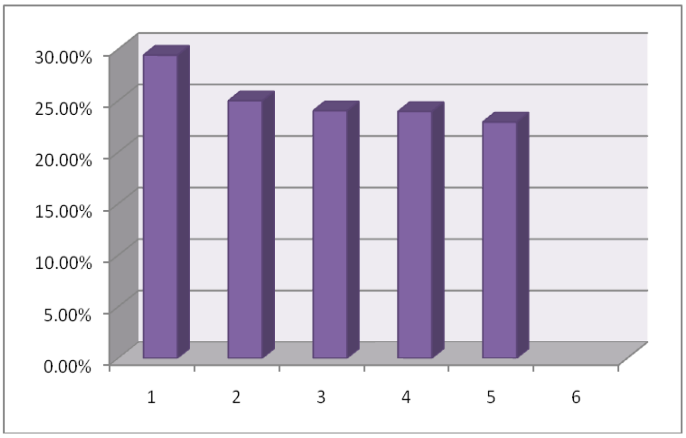
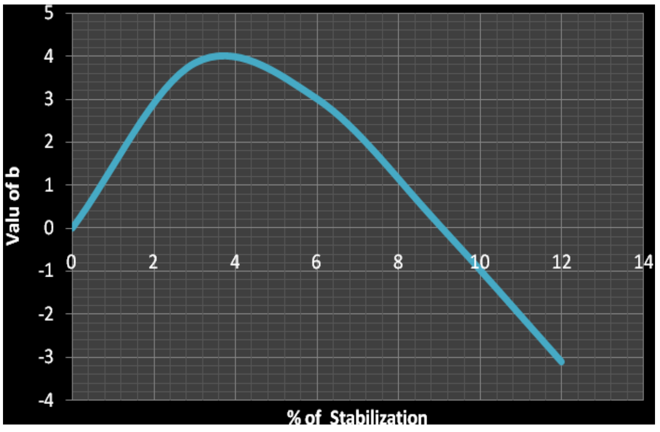


Figure 4 Change in PI Value Due to Application of Lime stabilization



Test result analysis:

As per IRC 51-1992 optimum lime content for soil;

Kaolinitic soil	4%
Illitic soil	8%
Montmorillonitic soil	10%

so, by using the formula & design chart we can get an rough idea about PI value of A-7a type black cotton soil by using 0 to 12% of application of lime stabilization.

Limitations of the Experiment

✓This formula applicable only for specific type of black cotton soil

✓Lime range limited only 0 to 12%

✓ Values of regression constantans may be in negative

✓There may be some positive or negative errors

✓Initial PI value for this type of soil should be determined by proper lab experiment

Conclusion

Although there are many limitations but the formula gives an idea about Plastic Index value of A-7a type black cotton soil (As per Highway Research Board of India) due to application of lime stabilization within range of 0 to 12% of lime by weight of soil. This paper also help full to determine how the subgrade strength varies with lime stabilization.

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