

## Influence of Lime on Low Plastic Clay Soil Used as Subgrade

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### Abstract

*Weak clayey soil can cause premature failure in subgrade so their removal or proper treatment is necessary for the efficiency of structure. Soil stabilization is an excellent choice and economical in many circumstances for treatment and proper behavior of weak subgrade soil as recommended by many researchers. Lime is the oldest and well known additive for stabilization of many type of soils. This paper presents geotechnical investigation of low plastic clay soil being used as subgrade stabilized with lime. The low plastic clayey subgrade soil was stabilized with different percentages of lime and results show that soil can be satisfactorily stabilized with the addition of 6% lime. The Atterberg's limit, compaction characteristics and strength tests including unconfined compressive strength (UCS) and California bearing ratio (CBR) tests were performed. Results indicate that addition of lime reduce plasticity index. An increase in OMC was observed with the decrease in maximum dry density (MDD). CBR and unconfined compressive strength of soil ( $q_u$ ) values improved significantly with the addition of lime.*

**Keywords :** Soil Stabilization, Lime, Subgrade Stabilization, Low Plastic Clay

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### I. Introduction

Subgrade is the native material underneath a constructed road pavement or railway track. The subgrade is the foundation of the pavement structure, on which the sub-base is laid. Poor subgrade soil conditions can result in inadequate pavement support and reduce pavement life. Removal of

poor subgrade and placing of new material is sometime not economical in many areas so poor subgrade is improved or stabilized by adding different type of chemical additives like lime, cement, bitumen or any waste material like rice husk ash, fly ash, slag etc. depending on type of soil or type of additive. Soil stabilization applications are used not only in roads but in construction of other civil engineering structures also. Soil stabilization is an emerging, economical and efficient way of improving weak subgrade soils. Clayey soils are problematic due to their expansive nature and less strength so their proper treatment is necessary either by replacement with the new material or by other mechanical methods of stabilization. Among soil stabilization lime and cement has gained much importance relative to other conventional stabilizers.

Clay and lime in presence of water react and form new compound through the process of cationic exchange, flocculation, carbonation and pozzolanic reaction (Al-Rawas et al, 2005) [I]. Reaction between  $\text{Ca}^{++}$  ions (due to hydration of lime) react with silica and alumina of clay and formation of cementitious products like Calcium-Silicate-Hydrates (CSH) and Calcium Aluminate Hydrates (CAH) occur. (Eisazadeh et al., 2012a) [II]. These reactions are responsible for long strength of soil clay mix. Typical soil lime reaction is explained in figure 1. Optimum lime content to stabilize clayey soil ranges from 3 to 8% (Murthy, 2002) [VII]. Lime increases strength of soil upto 100psi (Little et al, 1987). CBR of soil using lime increases by 3-4% and swell of soil reduces to less than 0.01% (Dallas, 1987) [IV].

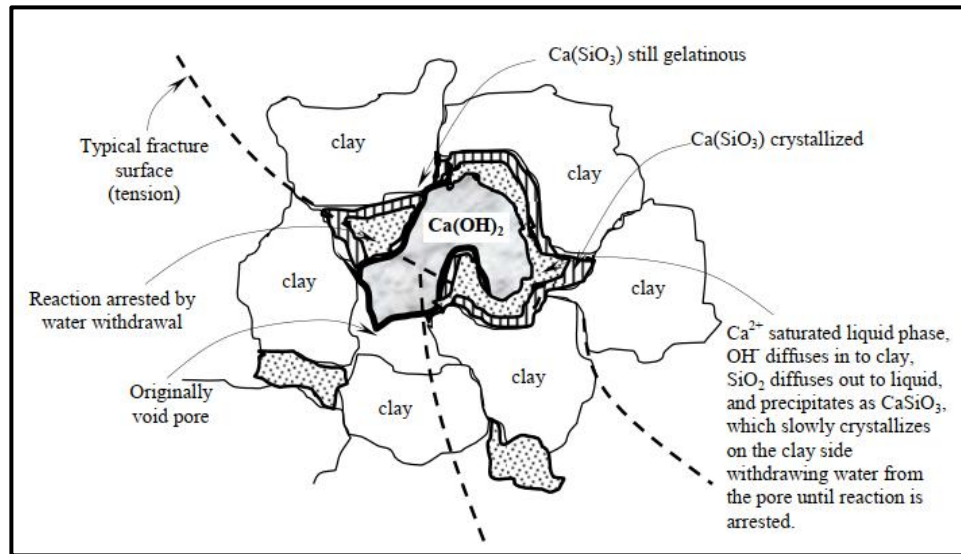


Figure 1: Reaction Mechanism of Stabilization Clay (Ingles, 1972) [V]

Despite of a lot of research in field of soil stabilization a single particular stabilizer cannot be used for all types of soils. Evaluation of different geotechnical properties in laboratory needs to be

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done before using that stabilizer in field. So objective of this study to assess influence of lime on geotechnical properties of low plastic clay being used as subgrade in a rural road project in Islamabad, Pakistan.

## II. Related Work

Due to economic, environmental, sustainable development and engineering properties enhancement point of view many researchers have worked on different type of materials and their effect on different type of subgrade soils. Literature work by few authors and their findings are summarized here.

An extensive study was carried out by Basma and Tuncer, 1991[XI] to find out that how lime effect the different properties of an expansive clay. It was concluded that grain size distribution was greatly altered by addition of lime and coarser grained fraction increased while clay fraction decreased with increasing lime and curing time. They further concluded that plasticity index decreased with increasing lime content. It was reported that classification of treated soil changed from MH-CH at 3% and 6% lime for both soils respectively.

Rogers and Roff, 1997 [X] performed modification of clay soils with lime and concluded that liquid limit is altered at low lime content while plastic limit requires greater lime addition. They also presented that different clay need different curing periods for modification however large changes occur with small addition of lime about 1% and within 6 hours.

Osinubi et al., 2009 [IX] performed stabilization of expansive soil lime mix with the addition of bagasse ash studied the effect of bagasse ash and reported improvement in strength of soil. He obtained highest CBR values by using combination of 8% lime and 4% bagasse ash.

Ghobadi et al., 2014 [III] stabilized clay soils by adding lime and observed change in shear strength parameters due to pH variations. He concluded that clay soil can be satisfactorily stabilized with about 7% addition of lime. He mentioned that MDD decreased with addition of lime and unconfined compression strength increased by nearly five times at 7% lime and 30 days curing.

Muhmed and Wanatowski, 2013 [VIII] observed effect of lime stabilization on strength and microstructural properties of clay and reported that plastic and liquid limit both decrease while plastic index decreases. It was also mentioned that OMC increase and MDD decrease with addition of lime. Increase in UCS was reported with increase in curing period but decrease in UCS was observed with increase in OMC. They performed SEM test of lime stabilized clay and it was presented cementitious products were formed due to pozzolanic reaction due to which soil strength increase.

KhelifaHarichane, 2011 [IV] carried out stabilization of high plastic and low plastic soils using lime and natural pozzolana and concluded that lime and natural pozzolana both reduce plastic index of soil. Soil type changes from CH and CL to ML for both type of soils. It was also reported increase in shear strength of soil-lime-natural pozzolana mix and highest cohesion was reported at 20% natural pozzolana and 8% lime.

Numerous other studies on soil and subgrade stabilization has been conducted by using lime and different stabilizers on different type of soils that proved beneficial. Studies on fly-ash, rice husk ash, lime, cement, gypsum, coal waste etc. (Eads and Grim 1960; Thompson 1966; Lazaro and Moh, 1970; Mitchell 1981; Nelson and Miller 1992; George et al 1992; Bell 1996; Petry and Little 2002; Jung et al 2008; Dalla Rosa 2009; Seco et al 2011; Consoli et al 2011; Negawo et al 2017).

### III. Materials and Methodology

#### Clay:

Soil used to carry out stabilization in this research was obtained from a road construction site in Islamabad, Pakistan. Soil was collected 2 feet below top surface level to avoid any impurity, grass and debris etc. Geotechnical properties of soil were determined including sieve analysis, consistency limits and strength tests as per ASTM. Main Geotechnical properties of soil are shown in Table 2.

#### Lime:

Locally available quick lime was used in this study. Chemical analysis of lime was done using X-Ray Fluorescence. Chemical constitution of lime used are as shown in Table 2:

Table 1: Chemical Constitution of Lime

Parameter	SiO <sub>2</sub>	CaO	Fe <sub>2</sub> O <sub>3</sub>	SrO
Percentage	4.32	88.92	3.32	3.42

#### Methods:

This research was carried out in three phases. The first phase was the classification and determination of different geotechnical properties of natural soil. The second phase was optimization of lime content using Eads and Grim pH test and unconfined compressive strength test. Lime content obtained from UCS testing was used as optimum. However, Eads and Grim test was performed to get the limiting value for UCS testing of lime so that UCS testing can be performed within the range of lime content obtained from pH test. The last step in this research was to find outcome of optimum lime content on different geotechnical properties of treated soil.

Material was collected and transported to plastic bag in air tight plastic bags. Different tests were performed on the clayey soil to discover fundamental properties. Soil collected consisted of 80% clay and was classified as CL based on Atterberg's limit and percent passing sieve #200 as per ASTM. A number of soil samples were prepared and mixed with quick lime. Optimum quantity of lime is usually 3% to 8 % for stabilization of soil (Basma Tuncer). Behavior of geotechnical properties of CL soil with addition of 2, 4, 6 and 8% lime. Soil and lime were thoroughly mixed. Compaction test was performed for effect of lime on optimum moisture content and maximum dry density. Soil lime mix samples of UCS were prepared at OMC and

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 cured for 7 and 28 days. Samples were wrapped in air tight plastic bags and cured at 40°C temperature in oven. Soaked CBR was performed for natural and treated soil. The samples were soaked for 96 hours and swell reading was noted. The geotechnical tests carried out in the present study are GSD i.e. percent passing sieve#200, Atterberg's limit test, modified proctor test, CBR and UCS. All tests were performed in a manner conforming to the ASTM (1990–2000).

#### IV. Results/Discussion

The results obtained from laboratory tests were evaluated and behavior of low plastic clay soil was assessed. Suitability of lime for stabilization of CL soil was derived using following results.

##### Natural Soil Properties:

The fundamental geotechnical properties of CL soil are summarized in Table 2. Natural soil has a liquid limit of 33.33 a plastic limit of 17 and percent passing sieve#200 is 80.85%. Both of these parameters show that soil fulfills the criteria for soil to be suitable for lime stabilization i.e. clay content > 25% and PI > 10. These parameters also show that the soil is low plastic clay soil. Soil In soaked condition soil loses upto 90% UCS strength and has high shrinkage and swelling characteristics, which can be problematic for road pavements and other structures.

Table 2: Natural Soil Properties

Properties	Values
% Passing Sieve#200	80.85
Liquid Limit	33.33
Plastic Limit	17
Plasticity Index	16.33
Soil Type USCS	CL
Moisture Content	11.11 %
Maximum Dry Density	1.96 g/cm <sup>3</sup>
Specific Gravity	2.67
UCS Un-soaked	46.08 psi
UCS Soaked	4.62 psi
CBR Soaked	5.00 %
Swell Potential	2.7 %

##### Eads and Grim pH Test:

Eads and Grim test was conducted to find the approximate quantity of lime to stabilize the soil. pH test was performed on lime soil mix with lime content of 2, 4, 6 and 8%. Below figure 1 shows results of the test.

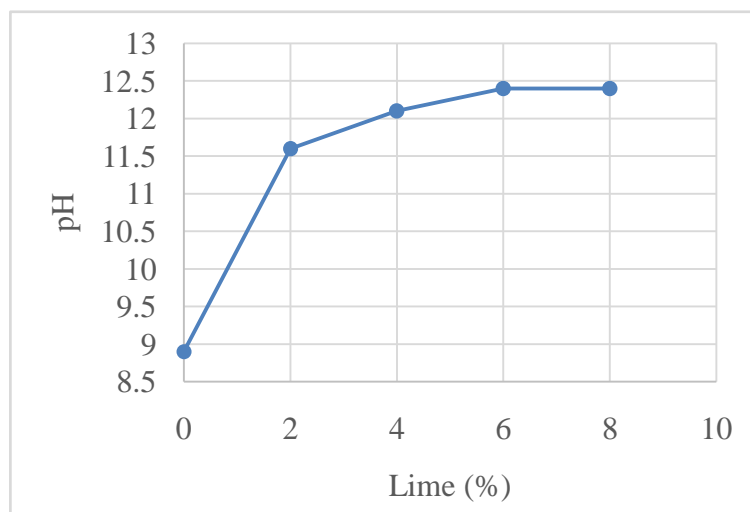


Figure 2: Lime vs pH

### Effect on Compaction Characteristics :

The modified proctor test was conducted to find optimum moisture content and maximum dry density at various lime content. Results obtained indicate increasing trend in OMC and reduction in MDD with increase in lime content. The increase in OMC can be related to hydration reaction of water with soil due to pozzolanic activity of lime while decrease in MDD was due to flocculation and agglomeration reaction of soil lime. Below figure 2 shows effect of lime on MDD and OMC.

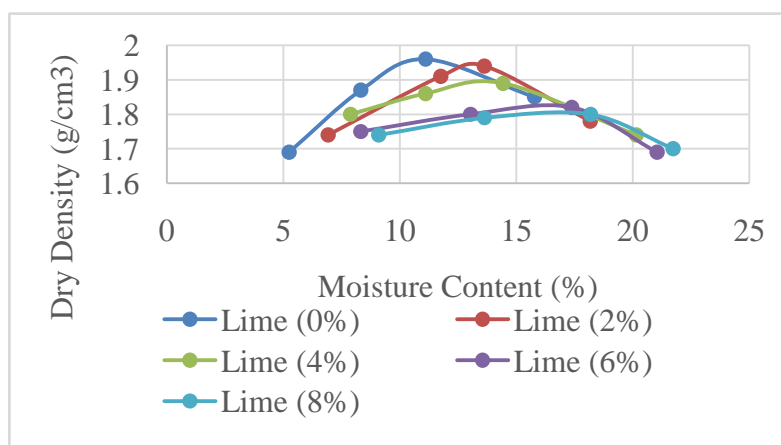


Figure 3: OMC vs MDD

### Effect on UCS

The UCS samples of CL clayey soil were prepared at OMC as obtained from

compaction test. Samples were cured for 7 and 28 days and its results are presented below in figure 3 and 4. Increasing trend of UCS was observed up to addition of optimum quantity of lime. The UCS of treated CL soil with 6% lime increased by 211%. In addition, the UCS increased by 275% when the samples were cured for 28 days. Increase in UCS can be associated with the hydration and pozzolanic reaction between soil and lime and water forming Calcium Silicate Hydrate and Calcium Aluminate Hydrates and fill the void space, and flocculate particles together improving the strength of the whole mix. Overall, lime in road construction can result in reduction of the cost of due to reduction in pavement layer thickness. And it can also save the economy of replacing the weak subgrade soil with high strength material.

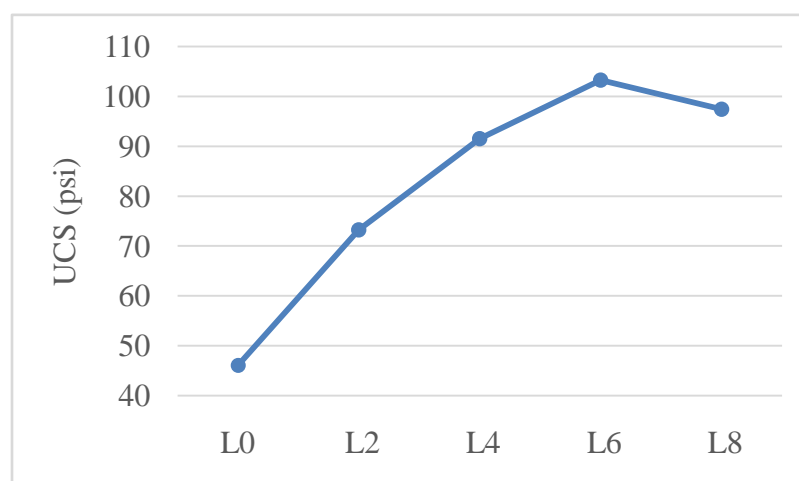


Figure 4: Effect of Lime on  $q_u$

### Treated Soil Properties :

Based on UCS of soil lime mix the percent of lime giving highest improvement in UCS of soil was selected as optimum lime content and other testing was performed on soil treated with optimum lime content. Based on properties of treated soil as shown in Table 3. The soil type changed from CL to ML (silt clay). CBR of treated soil also increased almost 3 times as that of natural soil and swell almost became zero.

Increase in UCS, CBR and OMC was observed while decrease in liquid limit, MDD, plasticity index and swelling was observed.

Table 3: Treated Soil Properties

Properties	Values
% Passing Sieve#200	70.43
Liquid Limit	25.02
Plasticity Index	4.88%
Soil Type USCS	ML
Soil Type AASHTO	A-4
Moisture Content	17.39 %
Maximum Dry Density	1.82 g/cm <sup>3</sup>
UCS Unsoaked (7-days)	103.27 psi
UCS Unsoaked (28-days)	143.65 psi
UCS Soaked (7-days)	64.35 psi
UCS Soaked (28-days)	75.11 psi
CBR Soaked	12.5 %
Swell	0.01 %

## V. Conclusion

The most important conclusion drawn from the research are summarized below:

Behavior of the low plasticity clay with the lime results in an increase in the optimum water content and a decrease in maximum dry density.

It was observed from  $q_u$  test that as the lime percentage rise from 0 to 6% the value of  $q_u$  increase from 46.08 psi to 103.27 psi. However, this value decreases when lime percentages rise beyond the optimum content of 6%. The fundamental contribution in increase of  $q_u$  strength is due to development of flocculated particles in the CL soil lime mix.

Improvement in other properties of lime-soil mix with optimum lime content percentage was observed. Plasticity index of soil decreased and type of soil changed from low plastic to silt soil.

Reduction in swell show that lime treated CL soil became unexpansive and increase in soaked CBR was observed. Increase in CBR can reduce pavement layer thickness so use of lime will be economical.

## VI. Acknowledgement

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