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Potential of Lime for Stabilization of Subgrade Soil of Gujranwala Region

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Abstract— Clayey soils have degraded properties like low shear strength, low bearing capacity, high shrink and swell potential, low CBR and compressive strength value and high compressibility. These degraded properties are the common reason for most of the foundation failures. With the interaction of water clayey soils undergo volumetric change. With the increase in population density and increased demand of infrastructural development avoiding clayey soils for future construction is not possible. Soil improvement techniques should be applied on such soils before construction. Engineering properties of the site should be improved by some economical mean. The study has been carried out to investigate the stabilization potential of the subgrade soil of said section of N-5. In this research we also check the suitability of Lime a for the improvement in the engineering properties of subgrade soil of gjranwala region. After treatment of soil with lime, soil exhibit a decrease in Plasticity Index and liquid limit, increase in Optimum Moisture Content and decrease in Maximum Dry Density, Unconfined Compressive Strength was increased. The CBR increased and significant reduction in swell potential was noted.

Index Terms— Lime stabilization, Soil stabilization, ground improvement, Gujranwala soil, stabilization techniques, soil improvement, site improvement

1 INTRODUCTION

Transport and communication infrastructure serve as a backbone to support the economic and industrial growth of the country. An efficient transport and communication network enhances productivity, improves efficiency and minimizes the cost of doing business. It has been recognized that poor condition of the road network adversely affect the transportation cost, travel time, and vehicle wear and tear. Resultantly, the economic and industrial growth is impaired. In Pakistan, roads are the most frequent mode of transportation both for passenger as well as goods transportation. According to Ministry of Industries and Production (2003), roads carry 92% of the passenger and freight traffic. Out of a total of 250000kms of paved roads, National Highway Authority (NHA) manages about 10,000kms (3.5%). However, these 3.5% roads carry 75 to 85% of the total commercial traffic.

The pavement subgrade (natural parent material/improved) acts as foundation for a pavement structure. The life and performance of a pavement structure is greatly dependent on the strength properties of subgrade layer. The subgrade soils of Gujranwala–Lahore section of National Highway-5 (N-5) are mostly low plastic clayey soils. The clayey soils with poor drainage properties coupled with non-provision of proper drainage structures results in collection of surface runoff along the road alignment, particularly during rainy season.

Soil stabilization gives technically feasible and one of the most economical solutions to many geotechnical engineering problems related to expansive soils. Most of the solutions in geotechnical engineering are specific for a given site, thus a recommended treatment for a particular site may not be applicable at a different location. It is therefore necessary that detailed field and laboratory investigations must be carried out before recommending a specific stabilization technique. The aim of this study is to find out a economical and permanently feasible solution for the problems of soil by improving the durability and strength characteristics of medium plastic clay to required level.

Over a period of time, this particular pavement section has been rehabilitated several times to repair the ruts developing as a result of poor subgrade strength. Frequent repair and maintenance of this section of road is resulting in lots of financial costs to the concerned agency and is also a source of increased user's cost and passenger discomfort. Improving the in-situ engineering properties of existing subgrade soils of this section by using additives is an economical method to enhance the structural strength of the pavement structure, control distresses and reduce the maintenance costs.

Lime is the oldest and most common chemical stabilizer being used. For fine graded soil lime is a very useful stabilizing agent. Anhydrous quick lime have more draying effect than hydrated lime, therefore it can be proved effective on construction site for draying of wet draying sites.

2 LITERATURE REVIEW

According to NLA (2006), if a soil is having a plasticity index of 10 or more and at least 25% of it is passing Sieve No. 200, then it is considered suitable for stabilizing with lime.

Lime is the oldest and most common chemical stabilizer being used. For medium and high plastic clays or for fine graded soil lime is a very useful stabilizing agent. Anhydrous quick lime have more draying effect than hydrated lime, therefore it can be proved effective on construction site for draying of wet draying sites. The pH of soil increases by adding the lime to the soil which also increases the cation exchange capacity. The texture of soil also changes due to the addition of lime.

Use of lime to increase the subgrade CBR from 8% to 15% yielded a saving of 20% of overall project cost while constructing an interstate highway in Pennsylvania (CARMEUSE 2002). The increased CBR resulted in a reduction of layer thicknesses, thereby, reducing construction cost.

The increase in the soil workability and the drying of wet soil participated to the immediate treatment, whereas the in-

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crease in the shear strength, compressive strength and durability of the soil are associated with the long-term treatment (Locat et al., 1990; Wild et al., 1996; Mallela et al., 2004; Geiman, 2005). When lime is used as an additive for the soil treatment, soil particles became large-sized clusters, resulting in texture change of soil (Terrei et al., 1984). This enlargement of soil particles increase the void ratio and due to increase in void ratio maximum dry density (MDD) of soil decreases. Optimum moisture content of soil-lime mixture increases. Thus, for a broad range of water content the required density can be easily achieved, thereby energy, time and efforts are conserved (Thompson, 1965; Tabatabi, 1997; Mallela et al., 2004).

According to NLA (2006), if a soil is having a plasticity index of 10 or more and at least 25% of it is passing Sieve No. 200, then it is considered suitable for stabilizing with lime. Soil-Lime reactions are best carried out in a pH environment of upto 12.4. The optimum lime required for stabilization purpose of soil is the lowest percentage of lime in soil that produces a laboratory pH of 12.4 (NLA 2006).

Because of increase in plastic limit decrease in plasticity index of lime treated soil occurs, however, depending upon the soil type the liquid limit may increase or decrease (Hausmann 1990). The treated soil becomes non-plastic as Plasticity index reduces to an extent (Little et al. 1987).

Lime increases the optimum moisture content (OMC) while at the same time it decreases the maximum dry density (MDD) of the soil. The reduction in maximum dry density is because of the flocculation and cementation which makes the compaction difficult. Usually maximum dry density reduces by 3 to 5 pcf while the optimum moisture content increases by 2 to 4% (Hausmann 1990).

Due to agglomeration, fraction passing Sieve No. 40 decreases substantially thus the treated soil becomes coarser than the original soil (Winterkorn et al. 1991). So workability of soil improves due to this change in texture.

UCS of soil treated with lime increases significantly. Due to numbers of variables involved the strength gain may vary in different soils, however, the UCS increases with curing period. For many soils for a curing period of 28 days at 73o F an increase of more than 100 psi has been achieved (Little et al. 1987).

Swell potential of the soil is significantly reduced by the lime treatment. CBR swell values at 96 hours soak indicates less than 0.1% swell for most soils (Little et al. 1987).

3 Methodology

Material testing was carried out in three phases:-

Phase I: Properties of untreated soil
Phase II: Optimization of Lime content
Phase III : Properties of treated soil

3.1 Phase I: Properties of untreated soil

The first step in this research was to determine the properties of untreated soil and to establish the potential of soil for stabilization. The clay from the site was used in my research and properties were determined in untreated condition.

Soil characterization was done to determine basic properties of untreated soil sample. The soil sample was oven dried. All tests performed in this research were according to ASTM standards.

Wash sieve method was performed by following ASTM D 422-63. In this test a 350 gm of oven dried sample was pulverized and then washed over sieve no 200. The sample remained on the sieve was again dried in oven for 24 hours.

For gradation of fine particles passing through sieve no 200 hydrometer analysis was performed in accordance with ASTM D 7928-16.

To obtain the liquid limit and plastic limit of soil Atterberg's limits test was performed by following ASTM D 4318. To perform this test the oven dried sample of passing through sieve no 40 was used.

Modified Proctor test was performed in accordance with ASTM D 1557-12 standards. The soil was compacted in 5 layers in 4 inch diameter mold and 25 blows were given to each layer by a 10 pound hammer and an 18 inch fall. The test was started by adding 4% of water by weight of dry soil sample and then increment of 3% was added in each trial.

To determine the compressive strength of untreated soil sample ASTM D 2166 was followed. According to this standard the height to diameter ratio of the sample should be 2:1. So mold with 8 cm height and 4 cm diameter was used. This test was performed in both unsoaked and soaked conditions and relative loses in strength due soaking were noted. The OMC and MDD obtained from modified efforts was used in the prepration of samples.

ASTM D 1883-99 was followed to perform one point CBR test. The mold with diameter of 6 inches and height of 7 inches was used for sample preparation. The sample was prepared at OMC in five layers and 65 blows were given to each layer. A spacer disk of 2 inch height was placed at the bottom of the mold.

CBR test was performed at both soaked and unsoaked condition. Soaking was done for 96 hours in a water tank. One dimensional swell of the soil was determined by following ASTM 4546-96. Both swell potential and CBR of medium plastic clay were determined in this test.

3.2 Phase II: Optimization of Lime content

Modified proctor test was performed in accordance with ASTM D 1557-12 for the optimization of lime content. Eades and Grims test gives the approximate value of lime so to counter check the lime demand for stabilization this test was performed. Four tests were performed by adding 2, 4, 6 and 8 percent of lime by weight. The soil-lime mix was compacted in 5 layers in 4 inch diameter mold and 25 blows were given to each layer by a 10 pound hammer and an 18 inch fall. The test was started by adding 4 percent of water by weight of dry soil sample and then increment of 3 percent was added in each trial.

The samples were made at 2, 4, 6 and 8 percent of lime in accordance with ASTM D 2166. According to this standard the height to diameter ratio of the sample should be 2:1. So mold with 8 cm height and 4 cm diameter was used. The samples were prepared at MDD and OMC obtained from modified proctor test. Two samples were prepared for each percentage and were kept in air tight plastic bags for 7 days at 30ºC. After 7 days samples were tested and the sample giving the highest strength value contains the optimum lime content for stabilization.

3.3 Phase III : Properties of treated soil

All the tests of Phase I were repeated to check the properties of treated soil and to compare properties with untreated soil.

4 Results and Discussions

4.1 Phase I: Properties of untreated soil

Summary of soil characterization results obtained from different experiments is given in table 1.

Table 1: Summary of soil characterization results

Liquid Limit (%)	48
Plastic Limit (%)	24
Plasticity Index	24
% age Passing #200	91
Clay (%)	34
Silt (%)	55
Soil Type (USCS)	CL
Soil Type (AASHTO)	A-6-7
MDD (g/cm3)	1.94
OMC (%)	13.08
Unsoaked UCS (psi)	131.29
Soaked UCS (psi)	24.96
California Bearing Ratio (%)	3.1
Swell Potential (%)	6.3

4.2 Phase II: Optimization of Lime Content

Moisture density relation was established for various lime contents. Four tests were performed by adding 4, 8, 12 and 16 percent of lime by weight of soil. Modified proctor test was used to determine the OMC and MDD for each sample.

The OMC increases with the addition of lime and became maximum at 12 percent of lime. And MDD decreases with the addition of lime and is minimum at 12 percent lime. The decrease in MDD is due to the flocculation of soil particles. As flocculation process occurs soil particles become coarser and due to which MDD decreases.

The following figures show the moisture density relationship for different lime contents. From the figures it is clear that OMC is 18.79% at 12 % lime content and MDD is minimum at 12 % lime and is 1.71 g/cm3.

The relationship between OMC and different contents of lime are shown in figure 1 and relationship between MDD and different contents of lime are shown in figure 2.

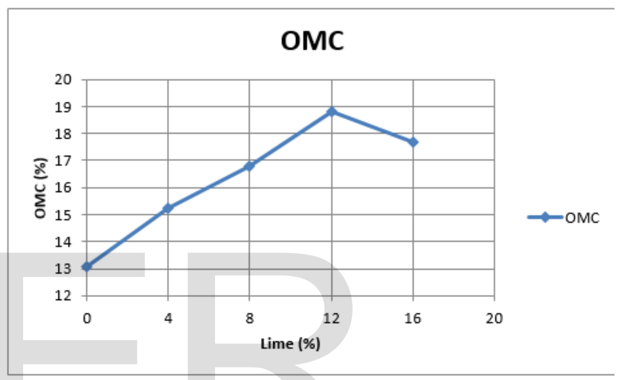

Fig. 1. Relation between OMC and Lime content

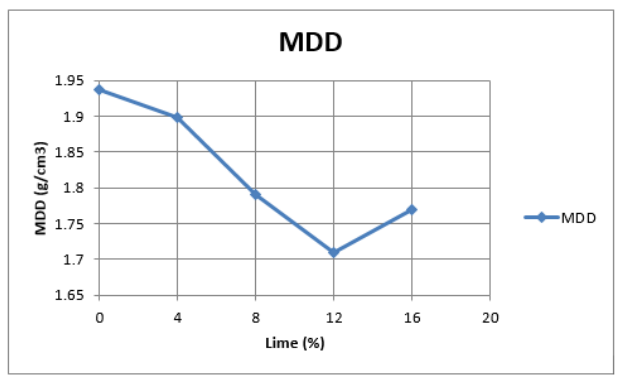

Fig. 2. Relation between MDD and Lime content

The samples were fabricated at 4, 8, 12 and 16 percent of lime at MDD and OMC obtained from modified proctor test. Two samples were prepared for each percentage and were kept in air tight plastic bags for 7 days at 30ºC and after 7 days samples were tested.

At 12 % lime UCS value is maximum and is 539.88 psi. Unconfined compressive strength values at different lime contents are shown in figure 3.

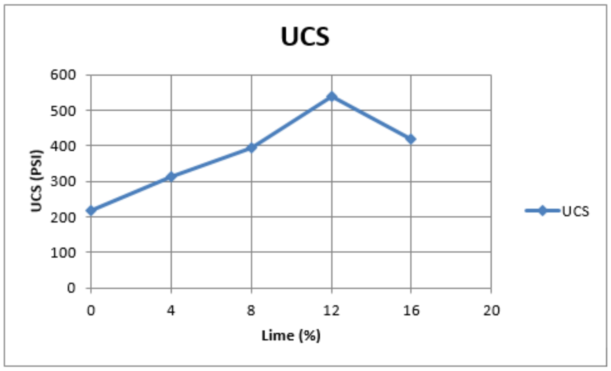

Fig. 3. UCS at Different Lime content

4.3 Phase III : Properties of treated soil

In this stage of this test 12 % of lime was added to the dry sample of soil and Atterberg's limit test was performed. The value of liquid limit reduce to 40 % , whereas value of Plastic Limit was 23 % and value of plasticity index obtained was 17 %.

Details are given in Table 2.

Table 2: Atterberg's Limits at 12% lime content

Atterberg Limit	Untreated Soil	12% Lime
Liquid Limit	48%	40%
Plastic Limit	24%	23%
Plasticity Index	24%	17%

In this step saples for unconfined compressive strength test were fabricated by adding 12 percent of lime and samples were cured for different curing periods of 2, 7, 14, 21 and 28 days.

A continuous increase in strength was noted as curing period increses. Maximum strength was obtainedat curing of 24 days and strength value of UCS was 536.38 psi.

UCS at different curing periods is shown in figure 4.

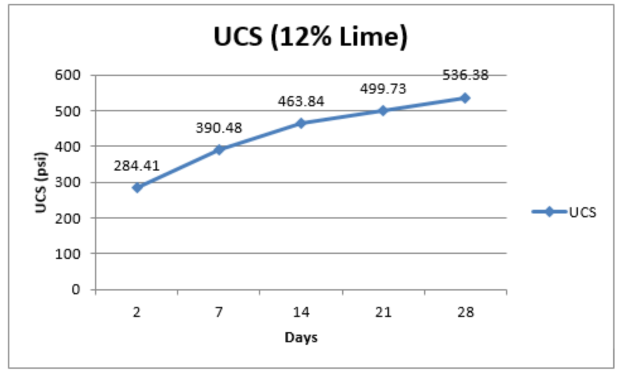

Fig. 4. UCS at Different Curing Periods

California Bearing Ratio and one dimensional swell potential of treated and untreated soil was determined by adding 12 percent of lime in soil.

Test results indicate that significant improvement is observed in CBR and one-dimensional swell. Figure 5 and 6 shows the graphical representation of CBR and Swell Potential at 12 percent of lime content.

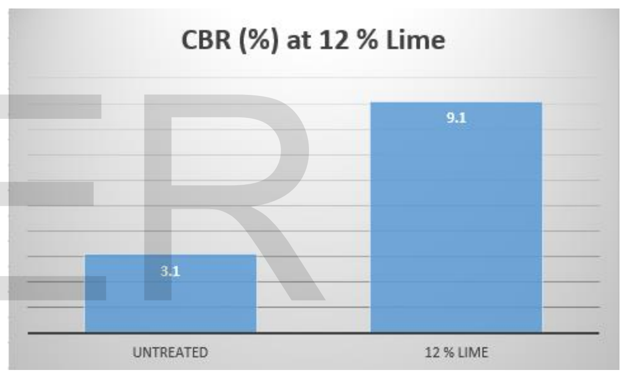

Fig. 4. CBR value of untreated and treated sample

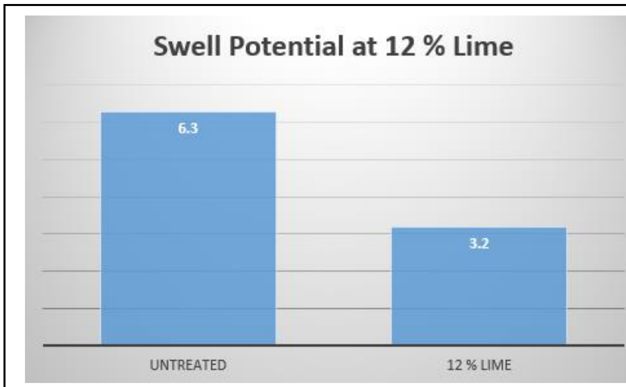

Fig. 4. Swell Potential of untreated and treated sample

5 CONCLUSIONS

Based on experimental work performed during this research following conclusions were made for subgrade soil of Gujranwala region.

- Subgrade soil of Gujranwala–Lahore section of N-5 is low plastic clay (CL). The soil is highly susceptible to loss of strength under wet conditions.
- Due to extremely low compressive strength and a very low CBR under moist conditions, the soil in present condition is not suitable to be used as a pavement subgrade layer.
- The months of May and June are the hottest and dry months in the area providing sufficient temperature for accelerated curing in the field. Any stabilization effort carried out in these months will not only provide ideal temperature for curing but will also restrict soaking of subgrade at an initial stage.
- Liquid Limit and Plasticity Index were decreased significantly when Lime was added to soil sample.
- It was noted that by addition of lime MDD of soil decreases. The decrease in MDD was due to the flocculation of soil particles. Due to flocculation process soil particles become coarser and due to increase in size of particles MDD decreases. OMC of medium plastic clay increased significantly because of reaction between soil and admixtures. When lime is added to soil and water is added exothermic reaction occurs and due to this more water is required for the stabilization process.
- Unconfined compressive strength test was performed to both treated and untreated soil sample. A significant improvement in unconfined compressive strength was noted. In unsoaked condition the improvement in soil compressive strength was almost 7.5 times
- The California Bearing Ratio was improved in treated form than in untreated form. One dimensional swell potential was reduced to 0.85%. The nature of soil was converted from high to low swelling soil in treated form. A sufficient improvement in California bearing ratio and one-dimensional swell potential was observed with the addition of lime.

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