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Study on the Properties of Natural Soil Stabilized with Various Percentages of Lime Contents

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ABSTRACT

This paper presents study of the stabilization of natural soil with lime. Firstly, Soil samples from Madaya Township are collected and several laboratory tests are carried out to determine the characteristics and engineering properties of the studied soil. Then experimental tests have been conducted for the determination of Atterberg limits and California Bearing Ratio (CBR) values. The studied soil contains more than 50% of silt-clay fraction. So, the studied soil is stabilized with lime contents selected as 5% and 10% by weight of natural soil at maximum dry density. When soil samples are mixed with lime, the values of liquid limit, plasticity index and CBR values are changed. These changes are decreased in swelling and shrinking potential of the soil, decreased in the settlement of the pavements, increase in workability and increase in the bearing capacity of the soils. In this study, the CBR values of soil-lime mixtures are 71.4% and 64.4% higher than that of studied soil. It can be seen that the CBR value of lime 5% is greater than lime 10% and natural soil. So, soil-lime mixture with lime 5% content is suitable for soil stabilization of the street, road and highway.

KEYWORDS: *soil stabilization, lime, soil-lime mixture*

I. Introduction

Soil is very important for the stability of buildings, dams, road construction and any other structures depend on the properties of underlying soils. UnsTablesoil can create significant problems for the structures. Sub-grade soil is an integral part of pavement hence must give adequate support and stability under adverse loading conditions.

Since the nature and properties of natural soil vary widely, a suitable stabilization technique has to be adopted for a particular situation after considering the soil properties. Soil stabilization is the repeated rotation of soils to enhance their physical properties. Stabilization can increase the shear strength of a soil and control the shrink-swell properties of a soil, thus improving the load bearing capacity of a sub-grade to support pavements and foundations. Soil stabilization can be utilized on roadways, parking areas, site development projects, airports and many other situations where sub-soils are not suiTablefor constructions.

II. Testing of Soil

The following tests are performed to know the characteristics and engineering properties of the studied soil. They are water content determination test, specific gravity test, grain size analysis, Atterberg limit tests, standard proctor compaction test, triaxial shear test and the California Bearing Ratio (CBR) test.

A. Water Content Determination for Natural soil

Water content is defined as the ratio of the weight of water to the weight of solids in the soil.

$$\omega = \frac{w_1 - w_2}{w_2 - w_c} \text{ x } 100\%$$

Where,
ω = water content (%)
W_1 = Weight of container plus wet soil
W_2 = Weight of container plus dry soil
W_c= Weight of container

B. Specific Gravity Test

Specific gravity is defined as the ratio of the unit weight of a given material to the unit weight of water. Table.1 displays the specific gravity for various types of soil.

$$G_s = \frac{K \times W_s}{W_s - W_1 + W_2}$$

Where,
G_s = Specific gravity of soil
K = Specific gravity of water at temperature (t)
W_S = Weight of air-dry soil
W_1 = Weight of bottle plus water plus soil
W_2 = Weight of bottle plus water

Table1 Specific Gravity For Various Types Of Soil

Type of soil	Gs
Sand	2.65-2.67
Silty sand	2.67-2.70
Inorganic soil	2.7-2.80
Soils with micas of iron	2.75-3.00
Organic soil	Variably but may be under 2

C. Grain Size Analysis

Grain size analysis is the determination of the size range of particles present in a soil, expressed as a percentage of the total dry weight. Two methods are used to find the particle size distribution of soil.

1. Sieve Analysis is used for particle sizes larger than 0.075 mm in diameter, and
2. Hydrometer Analysis is used for particle sizes smaller than 0.075 mm in diameter.

D. Atterberg Limit Test

The Atterberg limit tests provide measurements of the water content of clayey soils. Atterberg limit tests include:

1. Liquid Limit (LL)
2. Plastic Limit (PL)
3. Shrinkage Limit (SL)

Liquid Limit (LL) – Liquid limit is defined as the moisture content, in percent, at which the soil changes from a liquid state to a plastic state.

Plastic Limit (PL) – Plastic limit is defined as the moisture content, in percent, at which the soil changes from a plastic stage to a semi-solid state.

Plasticity index (PI) - Plasticity index is the difference between the liquid limit and plastic limit.

PI = LL – PL

E. Standard Proctor Compaction Test

Use to obtain the maximum dry density of the soil sample and the optimum moisture content. Compaction reduces in soil void ratio by expulsion of air from the voids or by expulsion of water from the voids.

$$\gamma_d = \frac{\gamma}{1+\omega}$$

$$\gamma = \frac{W}{V}$$

Where,

γ_d = dry unit weight of soil

0 = moist unit weight of soil

W = weight of the compacted soil

V = volume of the compacted soil

ω = water content of the compacted soils

F. Triaxial Shear Test

Triaxial shear test is one of the most reliable methods for determining the shear strength parameter.

$$\sigma_1 = \sigma_3 + \Delta\sigma_f$$

Where,

σ_1 = major principal stress

σ_3 = minor principal stress (confined pressure)

$\Delta\sigma_f$ = deviator stress at failure (piston stress)

G. California Bearing Ratio (CBR) Test

The determination of the potential strength of sub-grade, sub-base, and base course material, including recycle materials for use in road and airfield pavement. Classification system on the basic of CBR number is shown in Table2.

$$CBR = \frac{P_T}{P_s} \times 100$$

Where,

P_T = total test load

Ps = standard test load

Table2 Classification System on the Basic of CBR Number

CBR number	General rating	Uses
0-3	Very poor	Sub-grade
3-7	Poor to fair	Grade
7-20	fair	Sub-base
20-50	good	Sub-base, base
>50	Very good	Base

III. Test Results of Studied Soil

The test results of studied soil are described in the following Tables.

Table3 Water Content Determination of the Studied Soil

Container No.	A	B	C
Wt. of Container + Wet Soil, W_1 (g)	123.7	103.9	102.6
Wt. of Container + Dry Soil, W_2 (g)	111.6	95.6	93.2
Wt. of Container, W_c (g)	55.2	53.2	50
Wt. of Water, $W_1 - W_2$ (g)	12.1	8.3	9.4
Wt. of dry soil, $W_2 - W_c$ (g)	56.4	42.4	43.2
Water Content (%)	21.45	19.58	21.76
Mean Water Content (%)	20.93		

Table4 Specific Gravity Test Result for the Studied Soil

Location		Madaya Township	
Bottle No.		1	2
Wt. of Bottle	((g)	52.32	52.84
Wt. of Bottle + Water + Soil, W_1	(g)	156.92	161.77
Temperature, t	(℃)	25	25
Wt. of Bottle + Water, W_2	(g)	150.64	155.49
Wt. of Bottle + Dry Soil	(g)	62.33	62.84
Wt. of Dry Soil, W_s	(g)	10.01	10
Specific Gravity of Water at t, G_t		0.997	0.997
Specific Gravity of Soil, G_s		2.675	2.68
Mean Specific Gravity of Soil, G_s		2.68	

The calculated mean specific gravity of the studied soil is 2.68 according to test result. So, it is arranged within 2.67-2.7 which is silty sand.

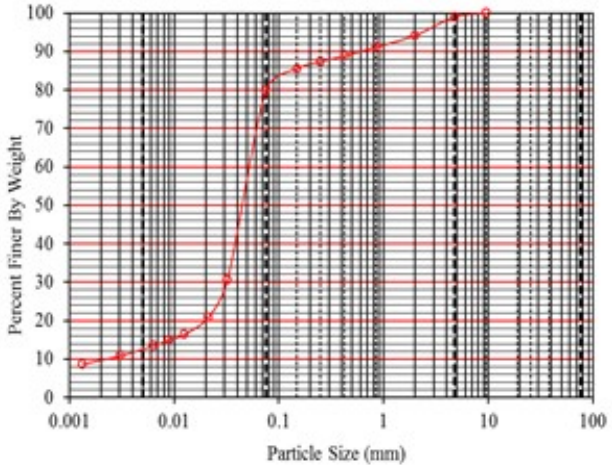

Figure 1. Grain-Size Distribution Chart for Studied Soil

Clay=12.5%	Silt=67.2%	Sand=19.3%	Gravel=1.0%

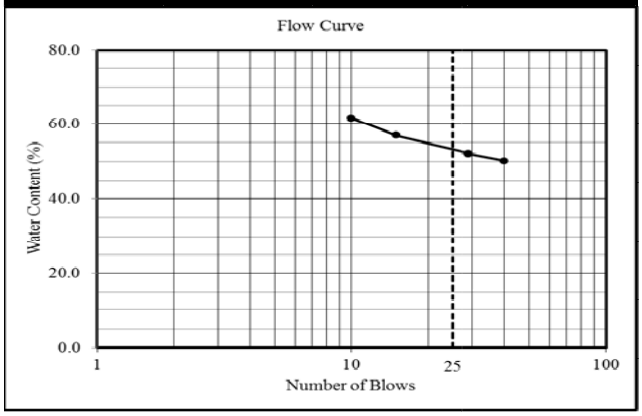

Figure 2. Flow Curve of Liquid Limit Determination for Studied Soil

Plastic limit, liquid limit and plasticity index are determined by Atterberg limit tests. PL=21.2%, LL=54.7%, PI=33.5% is high plasticity soil within the PI range of 20 to 40.

The liquid limit of the studied soil is 54.7% which is greater than 50% and PI value is greater than 23. Therefore the studied soil is in CH group which is inorganic clay of high plasticity. Percent retained of No.200 sieve is 15.4 which is between 15 and 29, and the ratio of sand friction to gravel friction is 14.4 which is greater than 1, so the group name of the studied soil is fat clay with sand.

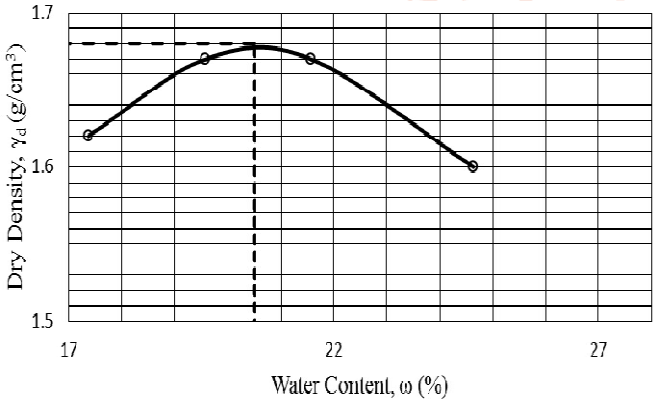

Figure 3. Water Content and Dry Density Relationship for Studied Soil

It can be seen that the maximum dry density (MDD) is 1.68 g/cm^3 at the optimum moisture content (OMC) of 20.5%.

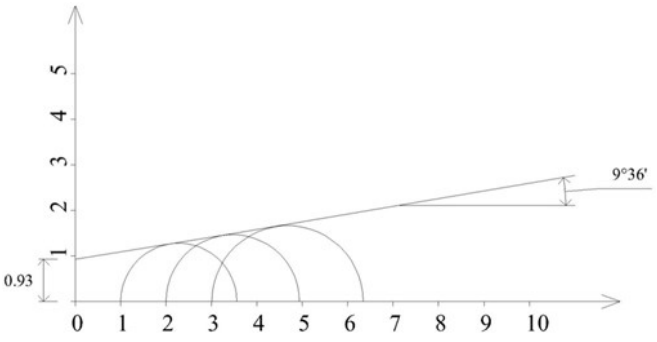

Figure 4. Results for Triaxial Test

The cohesion of the studied soil is 0.93 kg/cm^2 and the angle of internal friction is 9°36'.

Table5. Results on CBR Test at OMC

Penetration (mm)	Load (kg)	CBR (%)
0	0	
0.5	112	
1	172	
1.5	200	
2	212	
2.5	219	16
3	224	
4	230	
5	237	11.5
7.5	247	9.4
10	256	8
12.5	262	7.3

According to the test results, the percentages of CBR value at standard penetration are 16.0%, 11.5%, 9.4%, 8.0% and 7.3%. The CBR value for 2.5 mm penetration of natural soil is greater than 5 mm penetration. Therefore, 2.5 mm penetration of CBR values, 16.0% is taken as CBR values of this studied soil. So, this soil is suitable for sub-base.

IV. Test Results for Natural Soil with Various Percentages of Lime Contents

The studied soil is inorganic clay of high plasticity and suitable for sub-base. To improve the performance of natural soil, it is required to stabilize. As silt-clay fraction is more than 50%, the amount of lime is considered 5% to 10% by weight of natural soil for stabilization. So, the studied soil is mixed with selected lime contents such as 5% and 10% by weight of the natural clayey soil in this study. Atterberg limit tests, compaction test, and California Bearing Ratio (CBR) test are carried out for lime stabilized soil compacted at optimum moisture content.

A. Atterberg Limit Tests for the Studied Soil with Lime 5% and 10%

In this study, the clayey soil with lime 5% and 10% are tested with Atterberg limit tests to know the water content levels at which the soil change from one state to other.

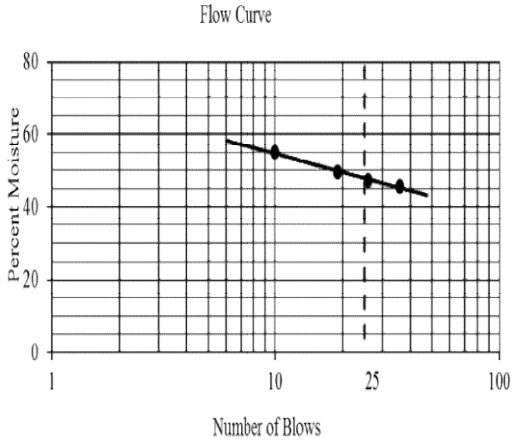

Figure 5 Liquid Limit of Studied Soil with Lime 5%

From the test results, PL and LL of studied soil with lime (5%) are 19.3% and 48.4% respectively. So, the PI value is 29.1%.

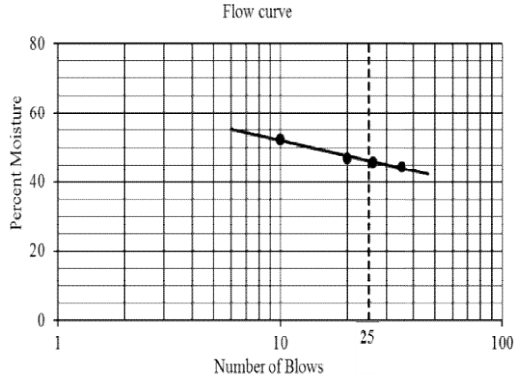

Figure 6 Liquid Limit of Studied Soil with Lime 10%

The results of PL and LL of studied soil with lime (10%) are 21.5% and 46.8% respectively. The PI value is 25.3%.

Table6 Comparison of Atterberg Limits between Natural Soil and Various Mixture of Soil-lime

Atterberg Limits	LL(%)	PL(%)	PI
Natural Soil	54.7	21.2	33.5
Natural Soil with Lime 5(%)	48.4	19.3	29.1
Natural Soil with Lime 10(%)	46.8	21.5	25.3

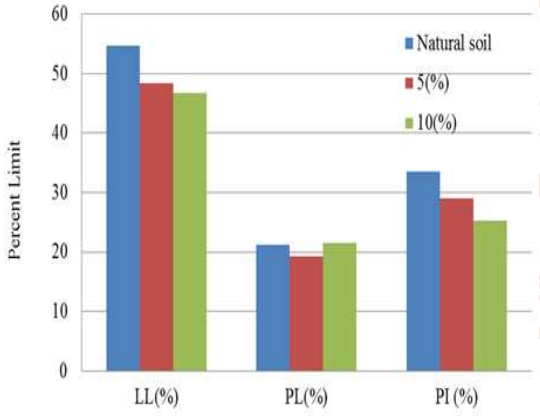

Figure 7 Comparison Results of Atterberg Limit Tests

B. Compaction Tests for Studied Soil with Lime 5% and 10%

In this study, the clayey soil with lime 5% and 10% are identified by compaction test to increase its strength.

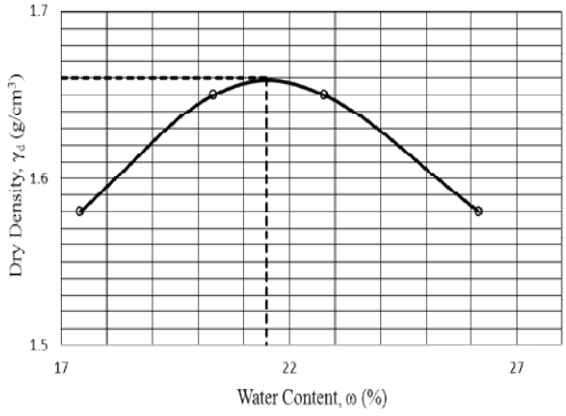

Figure 8. Determination of Water Content and Dry Density of Studied Soil with Lime 5%

From the above Figure, the maximum dry density is 1.66 g/cm³ the optimum moisture content of 21.5%.

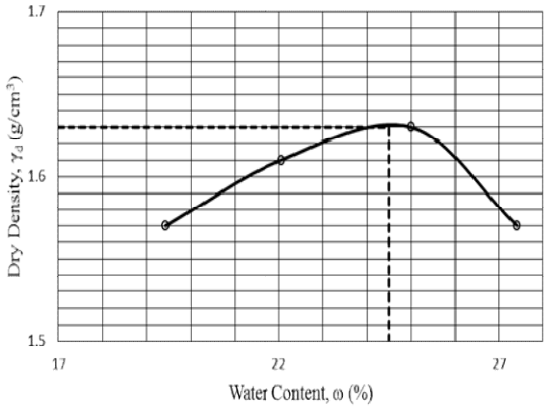

Figure 9 Determination of Water Content and Dry Density of Studied Soil with Lime (10%)

According to Figure 9, the maximum dry density is 1.63 g/cm³ at the optimum moisture content of 24.5%.

Table7 Comparison results of Compaction Tests between Natural Soil and Various Mixture of Soil-Lime

soil lime %	Natural soil	lime5%	lime10%
OMC	20.50%	21.50%	24.50%
MDD (g/cm^3)	1.68	1.66	1.63

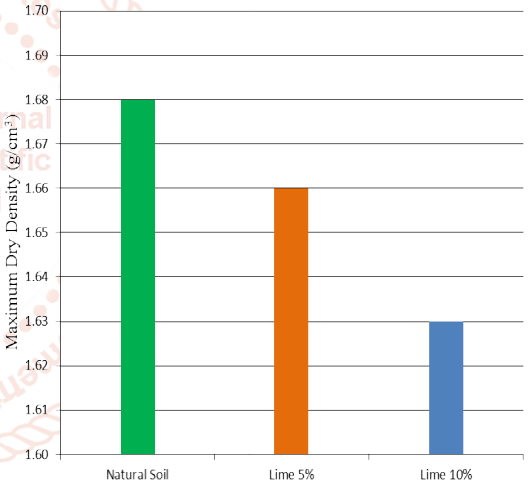

Figure 10 Comparison Results of Maximum Dry Density

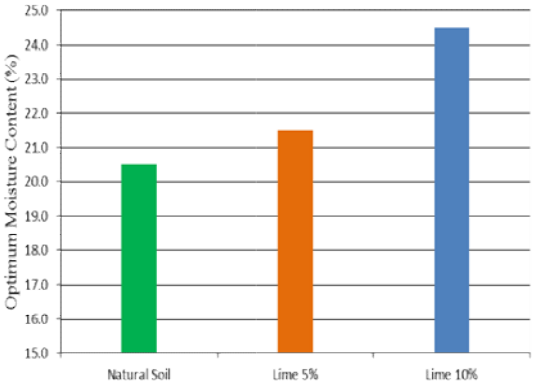

Figure 11 Comparison Results of Optimum Moisture Content

C. California Bearing Ratio (CBR) Test for Studied Soil with Lime 5% and 10%

In this study, the clayey soil with lime 5% and 10% are evaluated with California Bearing Ratio (CBR) Test to classify the quality of soil for pavement of the fields.

Table8. CBR Results of 5% Lime at OMC

Penetration (mm)	Load (kg)	CBR%
0	0	
0.5	244	
1	457	
1.5	600	
2	695	
2.5	766	55.9
3	823	
4	919	
5	987	48
7.5	1114	42.4
10	1214	38.2
12.5	1303	36.2

According to the test, the value of CBR test for soil-lime (5%) mixtures is 55.9% as shown in Table8. So, it is excellent used for base course.

Table9. CBR Results of 10% Lime at OMC

Penetrations (mm)	Load (kg)	CBR%
0	0	
0.5	130	
1	299	
1.5	436	
2	539	
2.5	615	44.9
3	676	
4	784	
5	877	42.7
7.5	1069	40.6
10	1227	38.6
12.5	1263	35.1

The result of CBR test is 44.9% for soil- lime 10% mixture in Table9. Therefore, this is good for both base and sub-base course of road.

Table10 Comparison results of CBR Test between Natural Soil and Various Mixture of Soil-Lime

Soil-Lime (%)	Natural Soil	Lime 5%	Lime 10%
CBR (%)	16.0	55.9	44.9

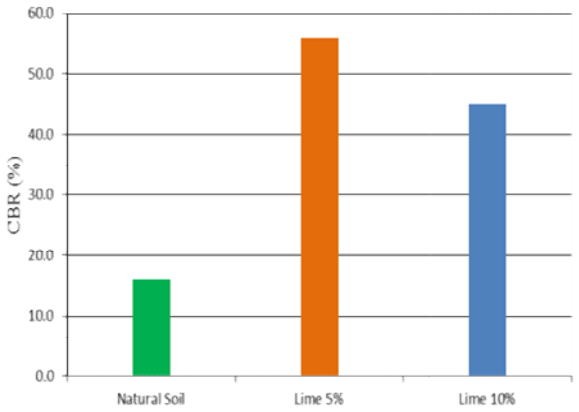

Figure 12 Comparison Results of CBR Test

Conclusion

In this study, soil sample is taken from Madaya Township. Soil classification is firstly made to know the physical properties of soil. By performing the tests, it can be seen that the studied soil is a type of clay. In this study, the studied soil is clayey soil so it improves their engineering properties greatly upon addition of lime which are arranged from 5% to 10% for stabilization. Atterberg limit test is performed to know physical properties of soil-lime mixtures. Compaction test and CBR test are performed to obtain mechanical properties of soil-lime mixtures.

From the test results, liquid limit of soil-lime mixtures of lime contents 5% and 10% are 48.4% and 46.8% respectively. Thus, liquid limits of mixtures are generally 12% and 14% lower than that of natural soil. The plasticity index of lime content 5% and 10% of mixtures are 29.1% and 25.3% respectively. Therefore, plasticity index of mixtures are generally 13% and 25% lower than that of natural soil. The maximum dry density is 1.66 g/cm^3 at lime 5% mixture and 1.63 g/cm^3 at lime 10% mixture. Maximum dry density of lime 10% treated clayey soils is lower than that of soil-lime mixture with lime 5%. The optimum moisture contents of soil-lime mixtures with lime 5% and 10% are 21.5% and 24.5% respectively. Optimum moisture contents of lime 10% treated clayey soils is higher than that of soil-lime mixture with lime 5%. When lime content 5% and 10% are added to clayey soils, CBR value of soil- lime 5% mixture is 55.9% rated as good for base course and that of soil-lime 10% mixture is 44.9% which is good for base and sub-base course. So, the CBR values of soil-lime mixtures are 71.4% and 64.4% higher than that of studied soil. Among them, maximum CBR value is found at soil-lime mixtures with lime 5% in this study. So, it should be selected for the street, road and highway in economical point of view.

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