International Journal of Trend in Scientific Research and Development (IJTSRD)
International Open Access Journal
ISSN No: 2456 - 6470 | www.ijtsrd.com | Volume - 2 | Issue – 5

Effect of Lime on Engineering Properties of Cohesive Soil

Nyein Nyein Thant
Lecturer, Department of Civil Engineering, Technological University,
Mandalay, Myanmar

ABSTRACT

Soil is a unique natural material and the properties of soils can be altered by adding stabilizing agents such as lime. Lime is the oldest traditional stabilizer used for soil stabilization. Lime is one of the several products that can be used in the improvement of the engineering characteristics of soils. This research presents the effect of lime on engineering properties of cohesive soil. In order to identify and classify this soil, at first physical properties of soil are determined. And then, mechanical property tests are conducted. Next, lime is added to natural soils. Lime contents are selected as 4%, 6% and 8% by weight of natural soils. The plasticity index decrease with increasing the percentage of lime content. Soil is mixed with selected lime contents at their maximum dry density. In cohesive soil, the more the lime content, the more the cohesion. The lowest value of cohesion is 0.59 kg/cm2 at lime 4% and it increases according to lime content. The percentage of lime increased, CBR value is also increased.

KEYWORD: *Cohesive Soil, Stabilization, Lime*

I. INTRODUCTION

Cohesive soils are those possessing cohesion. They have a higher water content and a natural tenancy to "ball" together when squeezed. Under pressure from loads these type of soils settle and consolidate over a number of years. These soils contain sufficient quantities of clay to render soil mass virtually impermeable when properly compacted. Such soils are all verities of clay or clayey soils. Cohesive soil is available everywhere in Myanmar and this is not suitable for engineering construction works. Addition of lime to clayey soils to improve their engineering properties is a well-established practice. Lime used in stabilization is the product of calcining limestone. Lime is most commonly used as a modifier of cohesive soils. The quantity of lime used for stabilization of most soils usually is in the range of 2% - 10%. The main benefit from lime stabilzation is the reduction of the soil's plasticity, and the soil becomes more rigid. It also increases the strength and workability of the soil, and reduces the soil's ability to swell. Soil lime stabilization is more suitable in warm region than in cold region. Soil-lime can be used as base course for low traffic roads. It cannot be used as surface course as it has little resistance to abrasion and impact.

II. TESTING OF SOIL METHODS

The following tests are performed to determine the engineering properties of cohesive soils.

1. Water Content Determination
2. Specific Gravity Test
3. Grain-size Analysis Test
4. Atterberg Limits Test
5. Free Swell Test
6. Standard Proctor Compaction Test
7. Triaxial Shear Test
8. California Bearing Ratio (CBR) Test

A. *Water Content Determination*

Water content is defined as the ratio of the weight of water to the weight of solids in the soil. Table 1 shows the specific gravity for various types of soil.

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

Where,

ω = water content (%)

W1 = Weight of container plus wet soil

W2 = Weight of container plus dry soil
WC = 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.

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

Where,
Gs = Specific gravity of soil
K = Specific gravity of water at temperature (t)
WS = Weight of air-dry soil
W1 = Weight of bottle plus water plus soil
W2 = 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 test includes;

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.

Shrinkage Limit (SL) – The moisture content, in percent, at which the volume of the soil mass ceases to change, is defined as the shrinkage limit.

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

$$PI = LL – PL$$

E. *Free swell Test*

Free swell test is performed to determine the increase volume of the soil. Table2. Shows soil classification based on free swell ratio.

$$FSR = \frac{V_w}{V_s}$$

Where,
FSR = Free swell ratio
V_w = Sediment volume of soil in distilled water (cm^3)
V_s = Sediment volume of soil in kerosene (cm^3)

Table2. Soil Classification Based on Free Swell Ratio

Free swell ratio	Clay type	Degree of expansion
≤ 1.0	Non-swelling	Negligible
1.0-1.5	Mixture of swelling and non-swelling	Low
1.5-2.0	Swelling	Moderate
2.0-4.0	Swelling	High
> 4.0	Swelling	Very High

F. *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
γ = moist unit weight of soil
W = weight of the compacted soil
V = volume of the compacted soil
ω = water content of the compacted soils

G. *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)

H. *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 Table.3.

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

Where,

P_T = total test load

P_s = standard test load

Table3. 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 results of cohesion soil are as follows.

Table4. Result of Water Content Determination

Determination no.	1	2	3
Container no.	33	43	60
Wt. of container + wet soil, W_1 (gm)	23.30	26.30	22.50
Wt. of container + dry soil, W_2 (gm)	18.90	21.30	18.40
Wt. of container, W_c (gm)	8.20	9.20	8.50
Wt. of water, W_1 - W_2 (gm)	4.40	5.00	4.10
Wt. of dry soil, W_2 - W_c (gm)	10.70	12.10	9.90
Water content, ω (%)	41.12	41.32	41.41
Mean water content, ω (%)	41.28		

Table5. Result of Specific Gravity

Bottle no.	1	1	1
Wt. of bottle + water + soil, W_1 (gm)	685.3	684.9	684.8
Temperature, t (^{o}C)	40^{o}	42^{o}	44^{o}
Wt. of bottle + water, W_2 (gm)	626.3	626.1	625.6
Wt. of dish + dry soil	374.1	374.1	374.1
Wt. of dish	281.1	281.1	281.1
Wt. of dry soil, W_s	93	93	93
Specific gravity of water at t, G_t	0.9922	0.9915	0.9907
Specific gravity, G_s	2.71	2.70	2.73
Mean specific gravity, G_s	2.71		

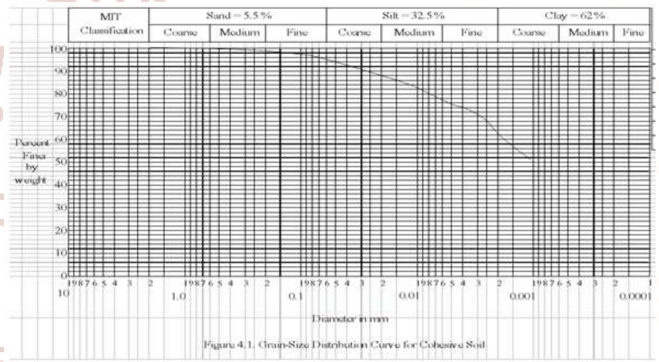

Fig1. Particle Size Distribution Curve

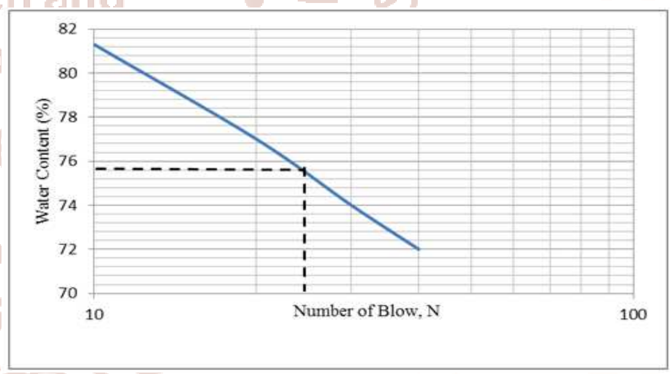

Fig2. Flow Curve for Liquid Limit Determination of Cohesive Soil

Table.6 Results of Atterberg Limit Test

LL	PL	PI	SL
74.3	28.81	45.49	6.71

Table.7 Results of Free Swell Test

Soil	V_w	V_k	FSR = $\frac{V_w}{V_k}$
Cohesive	22	12	1.83

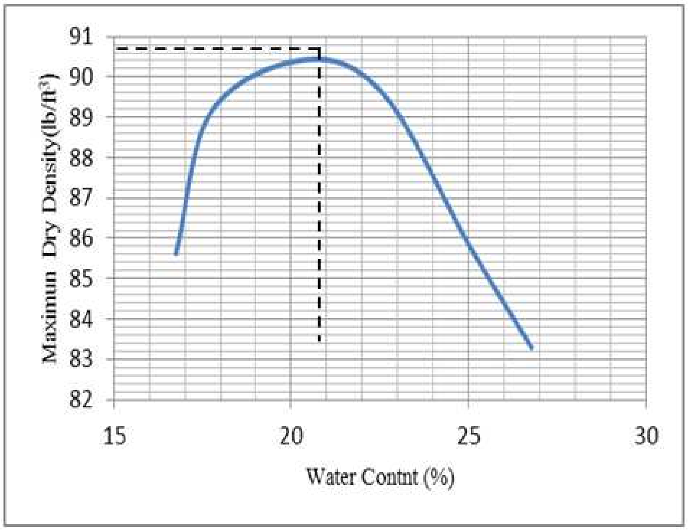

Fig 3. Compaction Curve for Cohesive Soil

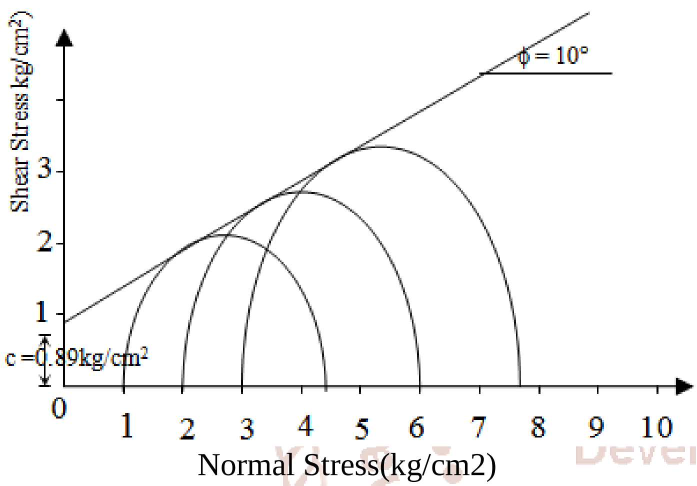

Fig 4. Result for Triaxial Curve

Table 8. Results of CBR Test for Cohesive Soil at OMC

Penetration (in)	Standard load (psi)	Dial gauge reading		Load (psi)		CBR (%)
		Top	Bottom	Top	Bottom	
0.025		24	14			
0.050		34	16			
0.075		42	22			
0.100	1000	49	26	196	104	15
0.150		56	30			
0.200	1500	60	34	240	136	12.54
0.300		65	39			
0.400		68	43			
0.500		71	46			

Engineering properties of natural soils are Summarized in Table9.

Table9. Physical and Mechanical Properties of Studied Soil

Sr No.	Property	Values
1	Grain size distribution	
	(a) Gravel (%)	-
	(b) Sand (%)	5.5
	(c) Clay (%)	62
	(d) Silt (%)	32.5
2	Specific gravity	2.71
3	Consistency limits	
	Liquid limit (%)	74.3
	Plastic limit (%)	28.81
	Plasticity index (%)	45.49
	Shrinkage limit (%)	6.71
4	Free swell	
	Free swell ratio	1.83
5	Standard proctor compaction test	
	OMC (%)	20.8
	Max dry density (lb/ft^3)	90.5
6	Triaxial Test	
	c (kg/cm^2)	0.89
	ϕ (degree)	10°
7	CBR value (%)	15

IV. EXPERIMENTAL INVESTIGATION ON EFFECT OF LIME

The consistency limits, compaction characteristics, triaxial test and CBR values of the lime treated cohesive soil are determined. 4%, 6% and 8% of lime is considered for investigation.

A. *Consistency Limit*

Fig. 5 shows the variation of consistency limits with lime content. It decreases the liquid limit and increases the plastic limit of cohesive soil resulting in a decrease in plasticity index. The plasticity index decreases from about 45% to 8% for lime contents varying from 0 to 8%. The consistency limits with various lime percent are shown in Table.10.

Table.10 Consistency Limits

Type	0% Lime	4% Lime	6% Lime	8% Lime
LL	74.3	68.18	59.4	52.08
PL	28.81	39.42	42.73	44
PI	45.49	28.76	16.67	8.08

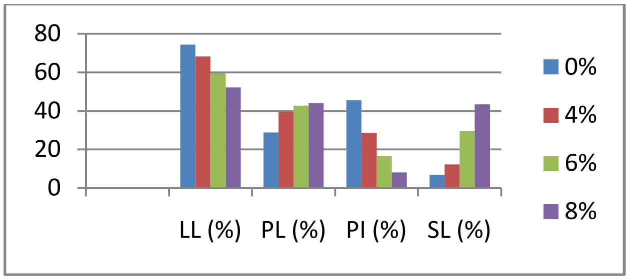

Fig5. Consistency Limits

B. Compaction Characteristics

Fig. 6 and 7 show the comparison of compaction characteristic untreated and lime treated cohesive soil. It can be observed that, the maximum dry density is increases when the lime is added. But the increase in percentage of lime, maximum dry density goes on decreasing. The more the percent dosage of lime, the higher the OMC, the maximum OMC is found at 6% of lime, and at 8%, the OMC is decreased.

Table.11 Results of Compaction Test Comparison

Type	0% Lime	4% Lime	6% Lime	8% Lime
Optimum moisture content (%)	20.8	22.2	24.5	23
Maximum dry density(lb/ft^3)	90.5	93.6	93.2	92.5

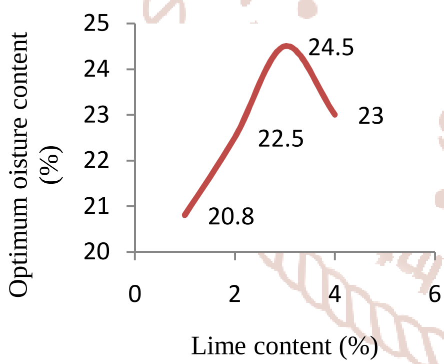

Fig6. Variation in Optimum Moisture Content Treated with Lime

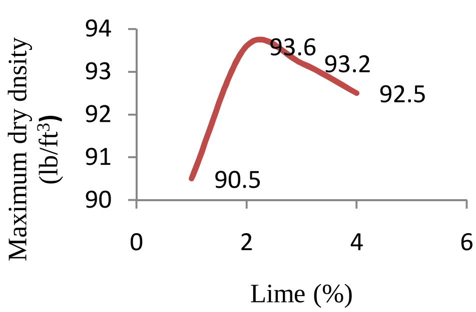

Fig7. Variation in Maximum Dry Density Treated with Lime

C. Triaxial Test

Table.12 shows the value of cohesion and angle of internal friction of cohesive soil with and without lime. The percentage of lime from 4 to 6%, the value of cohesion is decreased. It is increased nearly about the value of natural soil at 8% of lime content. The maximum value of angle of internal friction, ϕ is found at 4% of lime, after that its value decrease with increasing percent dosage of lime.

Table.12 Results of Triaxial Test Comparison

c(kg/cm^2)	0% Lime	0.89
	4% Lime	0.59
	6% Lime	0.62
	8% Lime	0.83
ϕ(degree)	0% Lime	10°
	4% Lime	21°
	6% Lime	20°
	8% Lime	13°

D. California Bearing Ratio (C. B. R.)

Fig. 8 shows the variation of CBR values with and without lime. CBR test results comparisons are also shown in Table.13. The CBR samples are treated with 4, 6 and 8% of lime are tested under unsoaked condition. The value of CBR increase, the lime content increase. According to Table.3, CBR samples are treated with 4% of lime, the general rating is changed fair to good condition. At 8% of lime, the general rating is very good.

Table.13 CBR Test Results Comparison

Samples	CBR value	General rating
0% Lime	15.00	Fair
4% Lime	37.60	Good
6% Lime	44.00	Good
8% Lime	58.80	Very Good

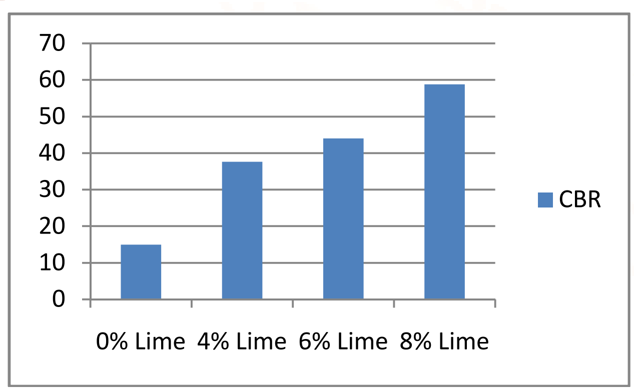

Fig8. CBR values

V. CONCLUSIONS

This research deals with the effect of lime on engineering properties of cohesive soil. In this study, to identify and classify the studied soil, physical property tests are firstly carried out. Soil sample is taken from the depth of 3ft. It is used for the water content determination, specific gravity, grain size analysis, Atterberg limits; free swell test, compaction characteristics, triaxial and CBR test. According to the test results, the natural soil can be concluded that; it has 62% of clay, 32.5% of silt, 5.5% of sand and 0% of gravel. And then, the studied soil has specific gravity of 2.71, free swell ratio of 1.83, liquid limit of 74.3%, plastic limit of 28.81%, plasticity index of 45.49%, Shrinkage limit of 6.71%, cohesion of 0.89 kg/cm^2, angle of internal friction of 10° and CBR of 15. According to Table.1 and 2, the studied soil is inorganic soil and the degree of expansion is moderate. The general rating of studied soil is fair such as shown in Table.3. To know the effect of lime on engineering properties of cohesive soil, consistency limit, compaction characteristics, triaxial and CBR test are performed. Lime contents are selected as 4%, 6% and 8% of lime by weight of natural soil. From the result of consistency limit, it can be observed that decrease in liquid limit and plasticity index with an increase of lime contents. When the lime contents are increased, the optimum moisture content and maximum dry density is slightly increased. From the triaxial test results, the more percentage of lime, the cohesion is increased but the angle of internal friction is decreased. Not only the CBR value but also the general rating is increased when the dosage of lime increased.

REFERENCES

1. [78 Jos] Joseph E. Bowels. *Engineering Properties of Soils and Their Measurement*. Second Edition.USA. MC Graw-Hill, Inc(1978)
2. [05 Thu] Thu Zar Win. Ma. *Study on Engineering Properties of Clay treated with Lime*. ME Thesis. Department of Civil Engineering MTU (2005)
3. Braja M. Das,: *Advanced Soil Mechanics*, Third Edition. (2008)
4. Braja M. Das,: *Principal of Geotechnical Engineering*, Seventh Edition. California State University, Sacramento, PWS Publishing Company (2010).