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Study on Stabilization of Expansive Soil with Fly-ash

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Abstract – Expansive soils are unsaturated clayed soils that exhibit considerable volume change swelling and shrinking, under moisture content fluctuations. Volume changes of these soils can cause damages on structures resting on them. For transportation and other structures, these kinds of soils cannot be reliable. It is important to stabilize the expansive soil, where they are anticipated and proper preparation of the site before construction begins can significantly reduce the tendency of soil to swell when wet. This paper presents the study of the stabilization of expansive soil by using various percentages of fly-ash. Soil sample is taken from 3ft depth of open pit at Ywezu Village, Patheingyi Township, Mandalay. Fly ash samples are taken from Tiger Head cement factory. Soil sample is classified by Unified Soil Classification System (USCS). For making soil stabilization, the knowledge of the characteristics and engineering properties of soils are essentials. Therefore, the existence of expansive soil at the proposed construction site is to be identified by using laboratory tests such as grain size analysis, Atterberg's limit tests, specific gravity test, and free swell test etc. The strength of the road formation layers is based on California Bearing Ratio (CBR) value. In this study, the CBR test is done by the optimum moisture content gained from the compaction test. After that the CBR tests are frequently done by various fly-ash content and moisture content to get optimum fly-ash and moisture ratio which gives the maximum CBR value. From the test results, 17.8% of water content and 16% of fly-ash give the maximum CBR value. The CBR value of the ordinary soil sample is about 2.05 (poor condition) and that of fly-ash stabilized mixture is 31.5 (good condition) and the stabilized soil can be used as base or sub-base in road construction.

Indexed Terms – expansive soil, USCS, stabilization, fly ash, CBR

I. INTRODUCTION

Transportation is the most important facility in moving men and materials. Transportation plays a vital role for the country's industrial, economic and cultural progress as well as in the defense of the country. The natural earthroads are unable to withstand the effect of load and weather. Every rural area, the natural earthen roads should be improved by using the suitable low-cost stabilizer.Expansive soil is high dry strength and low wet strength. Expansive soil is a term generally applied to any soil or rock material that has a potential for shrinking or swelling under changing moisture conditions.Expansive soil is a well-known group of soils characterized by dark gray to black color, high clay content; neutral to slightly alkaline reaction and deep crack during summer.Fly-ash is the very small particle mineral residue that results from the burning of powdered coal. Fly-ash is a pozzolan, a silica, alumina and calcium based material which in the presence of water, will chemically combine with the free lime contained in the fly-ash and produces a cementitious material with excellent structural properties. In this paper, fly-ash has been used as stabilizer introduced in varying percentage to study engineering property of soil.

II. CLASSIFICATION OF SOIL

Soil sample is classified by Unified Soil Classification System (USCS). TABLE I and Figure1 are used to classified soil sample.

R_{200} = 100-F_{200}

where

R_{200} = the percentage of soil retained on No.200 sieve (coarse fraction)

F_{200} = the percentage of soil passing through the No. 200 sieve (Fine fraction)

R_4 = 100- F_4

TABLE I UNIFIED SOIL CLASSIFICATION SYSTEM-GROUP SYMBOLS FOR SILTY AND CLAYED SOIL ($R200 \leq 50$)[98BRA]

Group Symbol	Criteria
CL	Inorganic, LL<50. Pl>7; Atterberg limits plot on or above A-Line (See CL zone in figure 2.4)
ML	Inorganic, LL<50, Pl<4 or Atterberg limits plot below A-Line (See ML zone in figure 2.4)
OL	Organic (LL-oven-dried) (LL-not dried) <0.75; LL<50 (see OL zone in figure 2.4)
CH	Inorganic, LL ≥ 50, Atterberg limits plot on or above A-line (see CH zone in figure 2.4)
MH	Inorganic LL ≥ 50, Atterberg limits plot below A-line (see MH zone in figure 2.4)
OH	Organic (LL-oven-dried)/(LL-not dried)<0.75; LL ≥ 50 (see OH zone in figure 2.4)

CL-ML	Inorganic, Atterberg limits plot on in the hatched zone in figure 2.4
Pt	Peat, muck, and other slightly organic soils

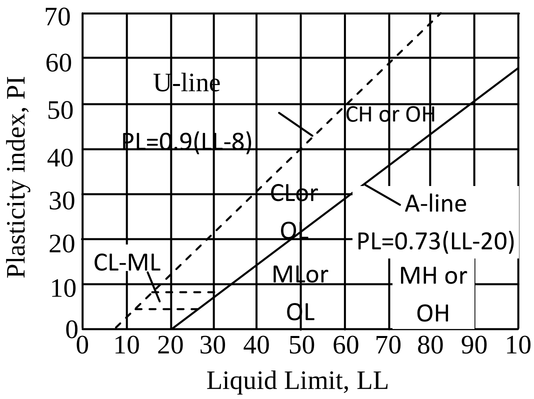

Figure 1. Plasticity Chart

III. INDEX PROPERTIES OF SOIL SAMPLES

The properties of soil, which are not primary interest to the geotechnical engineering, but are indicative of the engineering properties are called index properties.

A. 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. Sieve analysis and hydrometer analysis are generally used to find the particle size distribution of soil.

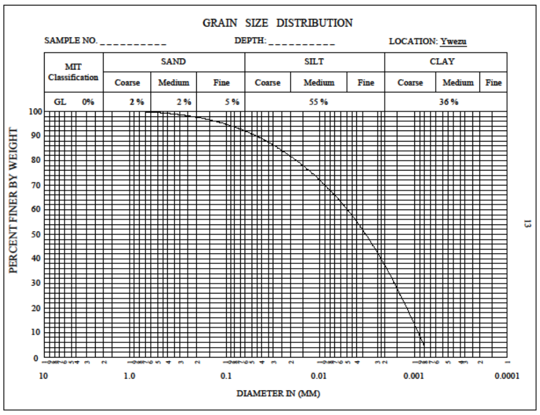

Figure2. Grain Size Analysis

B. Atterberg's Limit Test

The moisture content, in percent, at which the transition from solid to semisolid state takes place is defined as the shrinkage limit. The moisture content at the point of transition from semisolid to plastic state is the plastic limit, and from plastic to liquid state is the liquid limit. These parameters are also known as Atterberg limits.

C. Liquid Limit(LL)

The moisture content, in percent, required to close a distance of 12.7 mm (0.5 in.) along the bottom of the groove after 25 blows is defined as the liquid limit.It is difficult to adjust the moisture content in the soil to meet the required12.7 mm (0.5 in.) closure of the groove in the soil pat at 25 blows.

D. Plastic Limit(PL)

The plastic limitis defined as the moisture content in percent, at which the soilcrumbles, when rolled into threads of 4.2 mm (1/8 in.) in diameter. The plastic limit is the lower limit of the plastic stage of soil.

E. Plasticity Index(PI)

Plasticity index is the difference between the liquid limit and plastic limit.

$$PI = LL - PL$$

where, PI = Plasticity Index
LL = Liquid Limit
PL = Plastic Limit

F. Specific Gravity

Specific gravity is defined as the ratio of the unit weight of a given material to the unit weight of

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

where,
G_s = Specific gravity of soi
G_t= specific gravity of water at t temperatu
W_s= Weight of air-dry soil
W_1= Weight of bottle plus water pluss
W_2=Weight of bottle plus water
Mean specific gravity = 2.70

TABLE II DETERMINATION OF SPRCIFIC GRAVITY

Bottle No.	1	2	3	4
Wt. Bottle + water + Soil, W_1 (g)	693.0	693.3	693.9	694.5
Temperature, t (°C)	41°C	37°C	33°C	29°C
Wt. bottle + water W_2 (g)	631.9	632.6	633.2	633.9
Wt. dish + dry soil (g)	518	518	518	518
Wt. Soil, W_s(g)	96.3	96.3	96.3	96.3
Specific Gravity of water at t, G_t	0.992	0.993	0.995	0.99
Specific Gravity of soil, Gs	2.71	2.702	2.691	2.69

G. Modified Free Swell Index Test

$$\text{Modified Free Swell Index} = \frac{V - V_s}{V_s}$$

Classification of soil is shown in TABLE III by using the following Test Results.

TABLE III GRAIN SIZE ANALYSIS, ATTERBERG LIMITS TEST

Sand			Silt (0.006-0.002 mm)	Clay (less than0.002 mm)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)
Coarse (2-0.6mm)	Medium (0.6-0.2 mm)	Fine (0.2-0.006 mm)					
2%	2%	5%	55%	36%	52.8	25.02	27.78

According to unified soil classification system, the soil is situated in CH group. And percent finer than No. 200 sieve is 91.96 % , therefore it situated in fine grain soil group and liquid limit is greater than 50%, plasticity index is greater than 20%, so it can described as inorganic clay of high plasticity. From the specific gravity table, the specific gravity value of soil sample is 2.7 and it is located in the range (2.6 to 2.9) for clay. The free swell index of the soil sample is 3.86 and the swelling potential of soil sample is moderate.

IV. STABILIZATION

Soil sample is expansive soils which are stabilized with fly-ash. In this paper, fly-ash contents are 4%,8%,12%,16% and 20% by weightof natural soils. Compaction test and California Bearing Ratio tests are carried out forfly-ash stabilized soils compacted at optimum moisture content.

A. Compaction Test (Standard Proctor Test)

The degree of soil compaction of a soil is measured in terms of its dry unit weight. A curve is drawn between the water content and the dry density to obtain the maximum dry density and optimum moisture content.

In the Proctor test, the soil is compacted in a mold that has a volume of 944 cm^3 (1/30ft^3). The diameter of the mold is 101.6 mm (4 in.). During the laboratory test, the mold is attached to a baseplate at the bottom and to an extension at the top. The soil is mixed with varying amounts of water andthen compacted in three equal layers by a hammer that delivers 25 blows to each layer. The hammer has a mass of 2.5 kg (6.5 lb) and has a drop of 30.5 mm (12 in). Figure 2 shows variation of maximum dry density and variation of optimum moisture content.

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

where,

W = weight of the compacted soil in the mold

V=volume of the mold=944cm^3

γ =moist unit weight (lb/ft^3)

With the known moisture content, the dry unit weight γ_d can be calculated as follows:

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

where,

γ_d = dry unit weight of soil

γ = moist unit weight of soil

ω = moisture content (%)

TABLE IV TEST RESULTS FOR A CLAYEY SILT

Sr No	Water content(ω%)	Dry density (lb/ft^3)
1	11.86	75.22
2	17.59	84.95
3	22.48	94.69
4	23.18	93.08
5	26.27	89.37

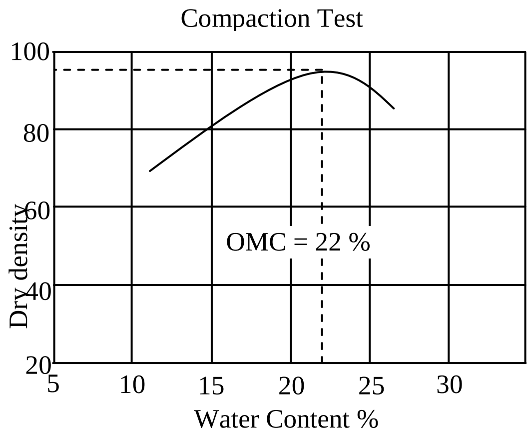

Figure 3.Water Content and Dry Density

Figure 3 shows the relationship of the dry densities and water contents of the studied soil. It can be seen that the maximum dry density of the studied soil is 95 lb/cu-ft and at the optimum moisture content is 22%.

B. California Bearing Ratio(CBR) Test

California Bearing Ratio test is used for evaluating the relative quality of subgrade, sub-base, and base soils for pavements. The CBR number is used to rate the performance of soils primarily for use as bases and subgrades beneath pavements of roads and airfields.The CBR is the ratio of the force per unit area required to penetrate a soil mass with standard circular penetration plunger of 50mm diameter at a uniform rate of 1.25mm/min to the corresponding penetration load of the standard material.[03Mur].The CBR values are usually calculated for penetration of 2.5mm and 5mm .Generally, the CBR value at 2.5mm penetration will be greater than that at 5mm penetration and in such a case the former shall be taken as the CBR value for design purposes.CBR value can be determine

$$CBR = \frac{\text{test unit load}}{\text{standard unit load}} \times 100 \text{ percent}$$

TABLE V CLASSIFICATION SYSTEM ON THE BASIC OF CBR NUMBER

CBR NO.	General rating	Uses
0-3	Very poor	Subgrade
3-7	Poor to fair	Subgrade
7-20	Fair	Subbase
20-50	Good	Base, Subbase
>50	Excellent	Base

The natural soil is mixed with 4%,8%,12%,16% and 20% fly-ash contents at moisture content 18%,22%and 26%. California Bearing Ratio test is undertaken unsoaked tests for soil fly-ash mixtures. CBR values of soil fly-ash mixtures are described in TABLE VI, VI, VIIand Figure 4.

TABLE VI CBR VALUES FOR VARIOUS FLY-ASH CONTENTS AT 18 % WATER CONTENT

Fly-ash (%)	CBR (%)
Natural soil	2.05
4	4.92
8	11.54
12	21.33
16	30.75
20	25.13

TABLE VII CBR VALUES FOR VARIOUS FLY-ASH CONTENTS AT 22 % WATER CONTENT

Fly-ash (%)	CBR (%)
Natural soil	2.05
4	3.84
8	5.20
12	8.27
16	15.71
20	14.21

TABLE VIII CBR VALUES FOR VARIOUS FLY-ASH CONTENTS AT 26 % WATER CONTENT

Fly-ash (%)	CBR (%)
4	0.83
8	2.05
12	2.58
16	5.23
20	3.90

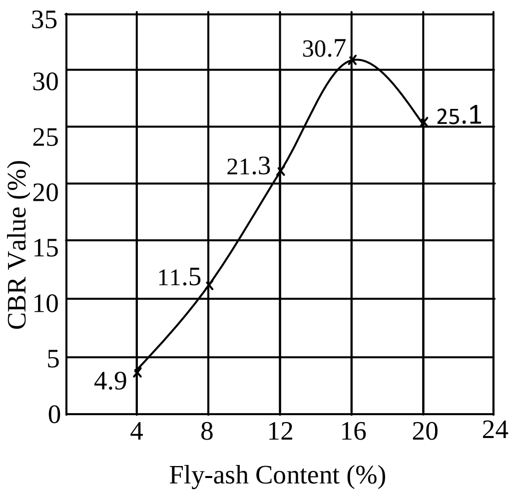

Figure 4. CBR Values and Various Fly-ash Content at 16%

TABLE IX CBR VALUES FOR VARIOUS WATER CONTENT

Water Content (%)	CBR (%)
14	25.62
16	27.94
18	30.75
22	15.71
26	5.23

From the results, 16%offly-ash and 18% of moisture content give the maximum CBR value. Moreover, 16% of Fly-ash andmore and less 18% of moisture contents (14% ,16% , 22% and 22%) are test.CBR values of soil fly-ash mixtures are described in TABLE IX and Figure 5.

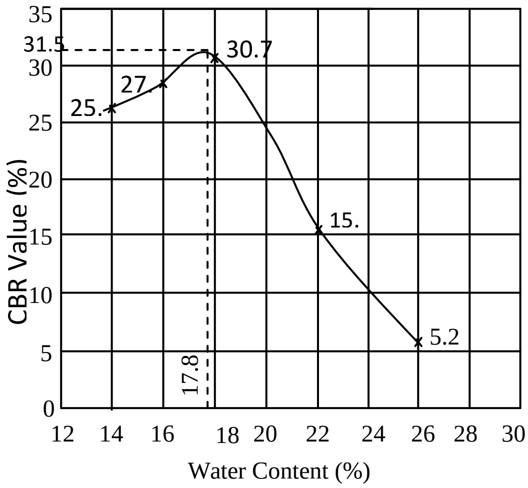

Figure 5. CBR Values and Various Water Content

From this figure, maximum CBR value is 31.5% and OMC is 17.8%.

V. CONCLUSION

In this paper,it has been found that the properties of expansive soil get effectively modified by various properties of fly-ash and water content. In this experimental result, stabilization of soil has been carried out by mixing fly-ash percentages (4%, 8%, 12%, 16% and 20%).

1. The studied soil has 27.78 % of plasticity index. Therefore, the studied soil is suitable with fly-ash stabilization.Therefore, soil stabilization in the studied soil area needs 16% of fly-ash and 17.8% of water for 100% of mixture.
2. The maximum value of CBR (unsoaked) is 30.75% in16% fly-ash content and it can be used as base or sub-base in road formation layers.

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