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Study on Physical and Mechanical Properties of Dispersive Soil

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ABSTRACT

This paper deals with determination of physical and mechanical properties of dispersive soil. Soil is the foundation material which supports loads from the overlaying structure. Soil dispersivity is mainly due to the presence of exchangeable sodium present in the structure. Dispersive soils are identified by an unstable structure, easily flocculated in water, and very erodible. Using dispersive clay soils in hydraulic structures, embankment dams, or other structures such as roadway embankments can cause serious engineering problems if these soils are not identified and used appropriately. Some important parameters of dispersive soil obtained from laboratory testing are investigated in this paper. Soil sample is taken from Mandalay at about 3ft depth. To determine physical properties of soil, water content determination, specific gravity test, grain-size analysis, Atterberg limits test, crumb test. Standard Proctor compaction test, Unconfined Compression Strength (UCS) test are carried out to determine mechanical properties of soil. According to Unified Soil Classification System, the studied soil is in CH group and group name is lean clay with sand. From crumb test, sample has grade-4. Therefore, the studied soil is highly dispersive.

KEYWORDS: *Dispersive Soil, Sodium, Crumb*

I. INTRODUCTION

Dispersion occurs in soils when the repulsive forces between clay particles exceed the attractive forces, thus bringing about deflocculation, so that in the presence of relatively pure water the particles repel each other to form colloidal suspensions. In non-dispersive soil, there is a definite threshold velocity below which flowing water causes no erosion. The individual particles cling to each other and are only removed by water flowing with a certain erosive energy. By contrast, there is no threshold velocity for dispersive soil; the colloidal clay particles go into suspension even in quiet water and therefore are highly susceptible to erosion and piping. In the presence of dispersive soil, piping is due to a deflocculation process where water travels through a concentrated leakage channel, such as a crack (even a very small crack), from its source. The erosion of the walls of the leakage channel then occurs along the entire length at the same time.

II. TESTS FOR PHYSICAL PROPERTIES OF SOIL

The following tests are performed to determine the physical properties of soil.

1. Water Content Determination
2. Specific Gravity Test
3. Grain-size Analysis Test
4. Atterberg Limits Test
5. Crumb 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.

$$\omega = \frac{W_1 - W_2}{W_2 - W_C} \text{ x } 100\% \quad (1)$$

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 shows the values of specific gravity for various types of soil.

Table1. Specific Gravity for Various Types of Soil

Type of Soil	G_s
Sand	2.65-2.67
Silty Sand	2.67-2.7
Inorganic Clay	2.70-2.8
Soils with Micas of Iron	2.75-3.00
Organic Soil	Variably but may be under 2.00

$$G_s = \frac{kW_s}{(W_s + W_2) - W_1}$$

Where,
K = Specific gravity of water at temperature (t)
WS = Weight of oven dry soil
W1 = Weight of bottle plus water plus soil
W2 = Weight of bottle plus water

C. Grain-Size Analysis

Soils are generally characterized as gravel, sand, silt or clay depending upon the predominant sizes of particles within the soil. In determination of grain-size distribution of the soil, sieve analysis is carried out for particles greater than 0.075 mm and hydrometer analysis is used for particles smaller than 0.075 mm.

D. Atterberg Limit Tests

The state of the soil depends on the amount of water present in the soil. The water content levels at which the soil change from one state to the other are the Atterberg limits. They are the liquid limit (LL), plastic limit (PL).

Liquid Limit (LL)

During the drying process, the initially liquid state reaches a consistency at which the soil ceases to behave as a liquid and begins to exhibit the behaviour of plastic. The water content at this state is called the liquid limit (LL).

Plastic Limit (PL)

As the drying process continues, the plastic state reaches a consistency at which the soil ceases to behave as a plastic and begins to break apart and crumbed when rolled by hand into cylinders 3.22 mm in diameter. The water content at this state is called the plastic limit (PL).

Plasticity Index

The plasticity index of a soil is the numerical difference between its liquid limit and its plastic limit, and is a dimensionless number. Both the liquid and plastic limits are moisture contents.

Plasticity Index = Liquid Limit – Plastic Limit
PI = LL – PL

E. The Crumb Test

The crumb test is the simplest of the tests used for detecting dispersive clays. Crumb tests are often performed during an investigation to supplement laboratory information on samples collected. To perform the crumb test in the lab, a cubical specimen of sides of approximately 15 mm is placed in 250 millilitres (ml) of distilled water. Once placed in water, the soil is monitored after two minutes, one hour, and six hours and classified based on the tendency of the colloidal particles to deflocculate and go into suspension. Observations are made at each time interval and the soil is classified into four grades;

Grade 1 – No colloidal cloud develops. Even though the crumb may slake and particles spread away from the original clod because of this slaking activity, no trace of a colloidal cloud is observed in the water is called Non-dispersive.
Grade 2 – A colloidal cloud is observable, but only immediately surrounding the original clod. The cloud has not spread any appreciable distance from the crumb is called Intermediate.
Grade 3 – A colloidal cloud emanates an appreciable distance from the crumb. However, the cloud does not cover the bottom of the glass, and it does not meet on the opposite side of the glass bottom from the crumb is called Dispersive.
Grade 4 – The colloidal cloud spreads completely around the circumference of the glass. The cloud may not completely obscure the bottom of the glass, but the cloud does completely cover the circumference of the glass. In extreme cases, the entire bottom of the glass is covered by the colloidal cloud is called Highly Dispersive (Bureau of Reclamation, 1991). A dispersive soil may sometimes give a nondispersive reaction in the crumb test. However, if the crumb test indicates dispersion, the soil is probably dispersive.

III. TESTS FOR MECHANICAL PROPERTIES OF SOIL

In mechanical properties of soil, compaction test, unconfined compressive strength (UCS) test are performed.

A. Compaction Test

Compaction is one kind of densification that is realized by rearrangement of soil particles without outflow of water. It is realized by application of mechanic energy. It does not involve fluid flow, but with moisture changing altering.

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

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

where,
γd = 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

Unconfined Compressive Strength Test

The unconfined compression test is a special case of the unconsolidated undrained triaxial test. In this case no confining pressure to the specimen is applied (i.e., = 0).

$$\sigma = \sigma + \Delta\sigma = \Delta\sigma = \theta_\upsilon$$

where,
σ_1 = major principal stress
σ_3 = minor principal stress (confined pressure)
$\Delta\sigma_f$= deviator stress at failure (piston stress)
q_u = unconfined compression strength

TEST RESULTS OF STUDIED SOIL

The physical and mechanical properties of studied soil are shown in the following tables.

Table2. Water Content Determination Of Studied Soil

Container No.	A	B
Wt. of Container + Wet soil, W_1 (gm)	118.1	108.2
Wt. of Container + Dry soil , W_2 (gm)	105	97.1
Wt. of Container, W_c (gm)	51.4	53.3
Wt. of Water, W_1–W_2 , (gm)	13.1	11.1
Wt. of Dry soil, (gm)	53.6	43.8
Moisture Content, ω (%)	24.4	25.3
Mean moisture Content, ω (%)	24.9	

Table3. Specific Gravity of Studied Soil

Location	Studied Soil	
Bottle No.	1	2
Wt. of Pycnometer, (gm)	47.17	55.62
Wt. of Dry Soil + Pycnometer, (gm)	57.17	65.61
Wt. of Soil + Water + Bottle, W_1 (gm)	153.72	161.87
Wt. of Water + Bottle, W_2 (gm)	147.43	155.60
Wt. of Dry Soil, W_s (gm)	10.0	9.99
Temperature, t (˚C)	23	23
Specific Gravity of Water at t, G_t	0.9976	0.9976
Specific Gravity of Soil, G_s	2.69	2.68
Mean Specific Gravity of Soil, G_s	2.69	

Particle-size distribution curve for natural soil is shown in Figure 1.

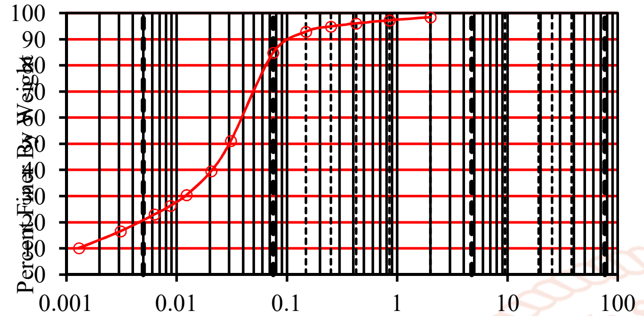

Fig1. Particle Size Distribution Curve

Table4. Grain size analysis test result of studied soil

Property	Value
Gravel (%)	0.5
Sand (%)	14.7
Silt (%)	64.2
Clay (%)	20.6
F_{200}	84.8
R_{200}	15.2
F_4	99.5
R_4 (GF)	0.5
SF=R_{200} - R_4	14.7
SF/GF	>1

Table5. Liquid limit determination of studied soil

Dish No.	1	2	3	4
No. of Blows	45	30	20	12
Wt. of Dish + Wet Soil (gm)	64.7	63.0	72.6	75.2
Wt. of Dish + Dry Soil (gm)	52.3	50.1	59.1	61.3
Wt. of Dish (gm)	25.3	23.8	32.8	35.2
Wt. of Dry Soil (gm)	27.0	26.3	26.3	26.1
Wt. of Water (gm)	12.4	12.9	13.5	13.9
Moisture Content (%)	45.9	49.0	51.3	53.3

Flow curve for liquid limit determination is shown in Figure 2.

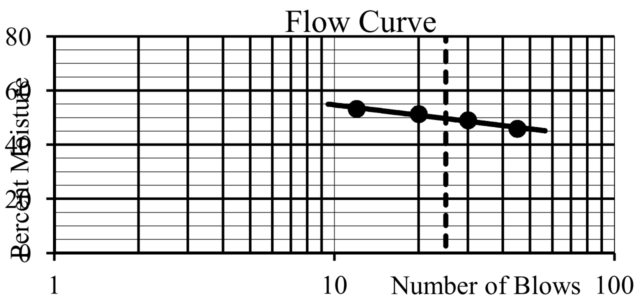

Fig2. Flow Curve for Liquid Limit Determination

Table6. Plastic limit determination of studied soil

Location	Sample Soil	
Dish No.	G	H
Wt. of Dish + Wet Soil (gm)	81.8	82.6
Wt. of Dish + Dry Soil (gm)	79.3	80.0
Wt. of Dish (gm)	66.5	66.9
Wt. of Dry Soil (gm)	12.8	13.1
Wt. of Water (gm)	2.5	2.6
Moisture Content (%)	19.5	19.8
Avg: Moisture Content (%)	19.7	

Table7. Results obtained for crumb test

Medium	Crumb Condition	Time	Grade
Distilled Water	Remolded	2 minutes	1
		1 hour	4
		6 hours	4

From above Table, sample has grade-4. Therefore, the studied soil is highly dispersive.

Moisture content and dry density relation curve for natural soil is shown in Fig 4.

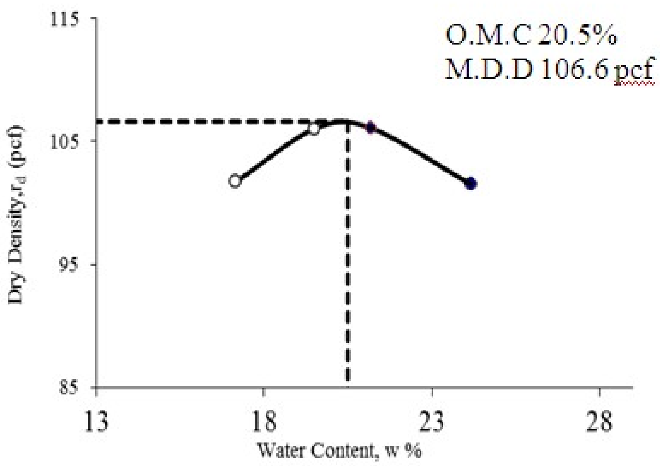

Fig3. Compaction Curve

The curve shown in Fig 3 represents the relationship of moisture content and dry unit weight. The optimum moisture content is 20.5% and the maximum dry unit weight is 106.6 lb/ft³

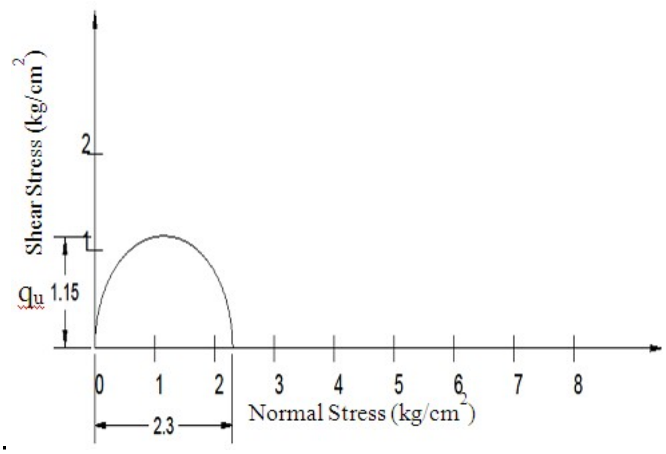

Fig4. Unconfined Compression Strength at OMC

From fig 4, unconfined compression strength of natural soil at OMC is 2.3 kg/cm². Undrained shear strength of natural soil is 1.15 kg/cm².

The Engineering properties of natural soil are summarized in following

Table8. Physical and mechanical properties of studied soil

Sr No.	Property	Values
1	Grain size distribution	
	A. Gravel (%)	0.5
	B. Sand (%)	14.7
	C. Clay (%)	64.2
	D. Silt (%)	20.6
2	Specific gravity	2.69
3	Consistency limits	
	Liquid limit (%)	50.3
	Plastic limit (%)	19.7
	Plasticity index (%)	30.6
5	Standard proctor compaction test	
	OMC (%)	20.5
	Max dry density (lb/ft³)	106.6
6	Unconfined compression strength, qu(kg/cm²)	.2.3

IV. DISCUSSION AND CONCLUSIONS

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 3 ft. Soil sample is used for Atterberg limit test, grain-size analysis test, specific gravity test, compaction, UCS test and crumb test. For the studied soil, the value of specific gravity is 2.69 and so the soil sample is silty sand. According to grain size distribution and Atterberg limit results the group sample is CH and soil type is lean clay with sand. From crumb test, soil sample has grade-4. Therefore, the studied soil is highly dispersive. The studied soil has 64.2% of clay, 20.6% of silt, 14.7% of sand and 0.5% of gravel. And then, this soil has LL of 50.3%, PL of 19.7% and PI of 30.6%.The optimum moisture content and maximum dry density of studied soil are 20.5% and 106.6 pcf. The unconfined compressive strength of studied soil is 2.3 kg/cm² and consistency is medium.

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