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COMPARATIVE STUDY OF VARIOUS CHARACTERISTICS OF DIFFERENT KINDS OF EXPANSIVE SOIL

Subrata Mondal[1], Joyanta Maity[2] and B.C.Chattopadhyay[3]

[1] PG student, CE Dept., MSIT, Kolkata-150,
[2] Assistant Professor, CE Dept., MSIT, Kolkata-150,
[3] Professor, MSIT, CE Dept., Kolkata-150,

Abstract - *Expansive soil causes serious problems on civil engineering structures in arid and semi-arid climate regions of the world. Such soils swell during rainy season and shrink in summer season. In India, expansive soil includes almost the entire Deccan plateau, Western Madhya Pradesh, parts of Gujarat, Andhra Pradesh, Uttar Pradesh, Karnataka, and Maharashtra and causes in damage to houses, other buildings, roads, pipelines, and other structures each year. The swelling soils are commonly known as Black Cotton Soils.*
In the present study, an attempt has been made to study the behavior of both natural expansive soils as well as bentonite mixed ordinary soils. Different engineering properties like, specific gravity, grain size analysis, Atterberg's limit test, compaction properties, California bearing ratio (CBR), Free swell index (FSI) and Unconfined compressive strength (UCS) have been studied for both natural expansive soils as well as bentonite mixed ordinary soils.

Key Words: Expansive soils[1], Black Cotton Soil[2], Swelling soils[3], Bentonite[4] California bearing ratio[5] and Free swell index[6].

1. INTRODUCTION

Expansive soils are mostly found in the arid and semi-arid regions and it covers large area of the world. Such soils swell when given an access to water and shrink when they dry out. For swelling to occur, these soils must be initially unsaturated at some water content. If the unsaturated soil gains water content, it swells. On the other hand, if a decrease in water content occurs the soil shrinks. Expansive soils causes in damage to houses, other buildings, roads, pipelines, and other structures. Engineering problems due to expansive soils have been reported in many countries all around the world. They cause huge economical loss due to their severe damages on structures. The lightly loaded structures and pavement are more sustainable to the damage by the differential movement caused by the expansive soil. Various types of distress in buildings are occurs, which are provided with conventional open foundation, raft foundation or latest under reamed pile foundations. Similarly in the pavements large cracks occur due to the non-consideration of the expansive behaviour of subgrade. In this experimental study, specific gravity test, grain size analysis, Atterberg's limit test, compaction test, California bearing ratio (CBR), Free swell index (FSI) test and Unconfined compressive strength (UCS) have been done to find out different engineering properties of both natural expansive soil and bentonite mixed ordinary soil.

2. REVIEW OF PAST WORKS

In the recent years several experimental studies have been conducted to investigate the behaviour of expansive soils. Most of the studies have been done on behavior, stabilization and characteristics and engineering properties of expansive soil. Expansive soil cause serious problems in the engineering practice due to swell and shrinkage upon wetting and drying. Pal et al (2013) conducted an experimental study on montmorillonite clay sample to determine the various properties of clay such as specific gravity, grain size, liquid limit and plastic limit, pH value, standard proctor compaction, modified proctor compaction, hydraulic conductivity, consolidation and free swell index. From the experimental results, it was observed that the value of MDD of the montmorillonite clay sample increases as compactive effort increases, whereas OMC decreases. Rimsheena et al (2013) studied on the effect of organic and inorganic leachate components on geotechnical properties of bentonite and bentonite-sand mixture. Due to high swelling and adsorption capability, bentonite is commonly used material for liners. Sand is the basic material used with bentonite to improve its properties. Based on the experimental study, it was observed that as the percentage of acetic acid increases, the liquid limit of bentonite and bentonite-sand mixture decreases. On the other hand with addition of NaCl the liquid limit increases whereas for $Al(OH)_3$ and formamide has insignificant changes in liquid limit. Addition of leachate components with bentonite, the OMC value increases whereas MDD value decreases. As the concentration of leachate components increases, the OMC value decreases and MDD increases for bentonite-sand mixture.

3. OBJECTIVES AND SCOPE

The main objective of the present study is to investigate the behavior of both natural expansive soils as well as bentonite mixed ordinary soils. Different engineering properties like, specific gravity, grain size analysis, Atterberg's limits, compaction properties, California bearing ratio (CBR), free swell index (FSI) and unconfined compressive strength (UCS) have been studied in this experimental study for both natural expansive soils as well as bentonite mixed ordinary soils.

3. MATERIALS USED AND TEST PROGRAMME:

3.1 MATERIALS USED

A. Natural expansive soil: Black cotton soil was taken from Hebbal of Mudhol in the district of Bagalkot of Andhra Pradesh, India.

B. Artificially prepared expansive soil: Locally available ordinary cohesive soil was collected from Garia, Kolkata. As per I.S. Classification (IS 1498, 1970), the soil is classified as "CI". Artificially expansive soil was prepared by adding different percentage of Bentonite with ordinary cohesive soil. Bentonite was procured from the local market of Kolkata, West Bengal.

3.2 TEST PROGRAMME:

In this experimental study, different physical properties, like Compaction properties (MDD and OMC), Plastic properties (Liquid limit and Plasticity index), California Bearing Ratio (CBR) and Free swell index (FSI) have been investigated for both natural and artificially prepared expansive soils. Artificially expansive soil was prepared by adding different percentage of Bentonite with ordinary cohesive soil in different proportion of 5, 10, & 15% by dry weight of soil sample. All the tests were conducted as per relevant I.S. codal provision.

Following laboratory tests have been conducted in the laboratory as per IS codal provision to determine the physical properties of both natural expansive soils as well as bentonite mixed ordinary soils.

a) Specific gravity and grain size analysis test.

b) Atterberg`s Limit test to determine Liquid limit and Plasticity index.

c) Proctor Compaction test to determine MDD and OMC.

d) California Bearing Ratio (CBR) test.

e) Free swell index (FSI) test.

f) Unconfined compressive strength (UCS)

4. RESULT AND DISCUSSION

To investigate the variation of different physical properties of both natural expansive soils as well as bentonite mixed ordinary soils, a series of Specific gravity and Grain size analysis test, Atterberg`s Limit test, Proctor Compaction test, test, California Bearing Ratio (CBR) test, Free swell index (FSI) test and Unconfined compressive strength (UCS) have been conducted in the Geo-technical laboratory of Meghnad Saha Institute of Technology as per I.S. codal provision.

a) Specific Gravity test:

Specific gravity of soil has been done by density bottle method. The results of specific gravity of different types of soil are tabulated in table 1.

Table 1 Results specific gravity of soil

Types of soil	Specific Gravity
Expansive Soil	2.264
Normal Clayey Soil	2.242
95% Normal Clayey Soil + 5% Bentonite	2.149
90% Normal Clayey Soil + 10% Bentonite	2.118
85% Normal Clayey Soil + 15% Bentonite	2.013
Bentonite	2.63

From the above table, it is observed that the value of specific gravity of normal clayey soil decreases as the percentage of Bentonite increases.

b) Grain size analysis test:

Sieve analysis and hydrometer test are generally performed to separate the soil into different size fraction like sans silt and clay particles. The results of grain size analysis of different types of soil are tabulated in table 2.

Table 2 Results grain size analysis of Soil

Type of soil	Sand	Silt	Clay Content
Expansive Soil	13.85	40.97	43.55
Normal Clay Soil	5.02	24.13	70.85
Clay soil (95%) + Bentonite (5%)	4.78	22.92	72.3
Clay soil (90%) +Bentonite (10%)	4.52	21.72	73.77
Clay soil (85%) +Bentonite (15%)	4.27	20.51	75.22
Bentonite	3.88	0	96.12

From the above table, it is observed that as the percentage of Bentonite increases, the clay content of that sample increases.

c) Atterberg's limit test:

Atterberg's limit test has been done to determine the plasticity properties of soils. The test results of Liquid and Plastic Limits of different types of Soil are given in table 3.

Table 3 Results of Liquid and Plastic Limits of different types of Soil

Type of soil	LL	PL	PI
Expansive Soil	60.90	36.21	24.71
Normal Clay Soil	33.33	17.31	16.02
Clay Soil (95%) + Bentonite (5%)	45	28.29	16.71
Clay Soil (90%) +Bentonite (10%)	47	29.1	17.90
Clay Soil (85%) +Bentonite (15%)	49.9	31.06	18.89
Bentonite	115.95	30.60	85.35

From the above table, it is observed that as 5%, 10% and 15% bentonite have been mixed with normal clay, the value of liquid limit of normal clay increases from 33.33 to 45, 47, and 49.95 respectively, whereas plastic limit also increases from 17.31 to 28.29, 29.1, and 31.06 as 5%, 10% and 15% bentonite mixed to normal clay. Similarly, increase in PI value has been observed from 16.02 to 16.71, 17.9, and 18.89.

d) Standard Proctor test:

Standard Proctor test has been conducted on soil to determine the Optimum Moisture Content (OMC) and maximum dry density (MDD). The test results of Light compaction test of different types of Soil are given in table 4.

Table 4 Results of Light compaction test of Soil

Type of soil	MDD (gm/cc)	OMC (%)
Expansive Soil	1.515	22.85
Normal Clay Soil	1.745	15.17
Clay Soil (95%) + Bentonite (5%)	1.668	17.32
Clay Soil (90%) +Bentonite (10%)	1.631	18.5
Clay Soil (85%) +Bentonite (15%)	1.612	19.75
Bentonite	1.31	30.17

From the table it is observed that the MDD value of normal soil decreases from 1.745 to 1.668, 1.631 and 1.612 for 5%, 10% and 15% bentonite mixed soil. On the other hand, an increasing tendency of OMC is observed as 5%, 10% and 15% bentonite have been mixed with clayey soil.

e) California bearing ratio (CBR) test:

Both Unsoaked and Soaked CBR test has been conducted on soil to determine the CBR value. The test results of both unsoaked and soaked CBR of different types of soil are given in table 5.

Table 5 Results of Unsoaked and Soaked CBR of Soil

Type of soil	Unsoaked CBR (%)	Soaked CBR (%)
Expansive Soil	4.42	3.3
Normal Clayey Soil	5.94	4.51
Clay Soil (95%) + Bentonite (5%)	4.58	3.65
Clay Soil (90%) +Bentonite (10%)	4.16	3.32
Clay Soil (85%) +Bentonite (15%)	3.74	3.07

From the above table, it is observed that there is a tendency in decrease of unsoaked CBR value from 5.94 to 3.74 as 5%, 10% and 15% bentonite have been mixed with clay. Similarly, soaked CBR value has been decrease from 4.51 to 3.32, when 5%, 10% and 15% bentonite have been mixed with clay.

f) Unconfined Compressive Strength Test:

Unconfined Compressive Strength test has been conducted on different types of soil to determine the shear strength of soil. The UCS test results of different types of soil are given in table 6.

Table 6 Results of Unconfined Compressive Strength Test of different types of Soil

Type of soil	UCS (kg/mm2)
Expansive Soil	1.18
Normal Clay Soil	2.47
Normal Clay Soil (95%) + Bentonite (5%)	1.82
Normal Clay Soil (90%) +Bentonite (10%)	1.64
Normal Clay Soil (85%) +Bentonite (15%)	1.51

From the above table, it is observed that the mixing of bentonite decreases the UCS value of clayey soil.

g) Free swell index (FSI) test:

The Free Swell Index test is the ratio of the difference between the final and initial dry volume of poured soil and the initial dry volume of poured soil in percent. Free Swell Index test has been conducted on different types of soil. The test results of Free Swell Index test of different types of Soil are given in table 7.

Table 7 Results of Free Swell Index test of Soil

Type of soil	Free Swell Index (%)
Expansive Soil	41.67
Normal Clay Soil	2.50
Clay Soil (95%) + Bentonite (5%)	7.69
Clay Soil (90%) +Bentonite (10%)	18.18
Clay Soil (85%) +Bentonite (15%)	23.96

From the above table, it is observed that Expansive soil has an Free swell index of 41.67%, whereas free swell index of Normal clay soil is 2.5%. After mixing bentonite in the percentage of 5, 10, and 15 with the normal clay the free swell index becomes 7.69%, 18.18% and 23.96% respectively which shows that the free swelling of clayey soil increases with the increase in percentage of bentonite.

h) Determination of Activity no.:

Activity no. of soil is the ratio of plasticity index and the ercent of clay content in the soil. The test results of Free Swell Index test of different types of soil are given in table 8.

Table 8 Activity no. of different types of Soil

Type of soil	Clay content	Activity no
Expansive Soil	43.55	0.57
Normal Clay Soil	70.85	0.23
Clay Soil (95%) + Bentonite (5%)	72.3	0.23

Clay Soil (90%) +Bentonite (10%)	73.77	0.24
Clay Soil (85%) +Bentonite (15%)	75.22	0.25
Bentonite	96.12	0.89

From the above table, it is observed that the activity no of clayey soil increases with the increase in percentage of bentonite.

CONCLUSIONS

Based on the experimental study, following conclusions can be drawn:

[1] The Specific Gravity of normal clayey soil decreases as the percentage of Bentonite increases.
[2] Both the value of Liquid Limit and Plastic Limit of normal clay increases as the percentage of Bentonite increases. Similarly there is an increase in Plasticity Index value for normal soil when mixed with increase percentage of Bentonite.
[3] MDD value of normal soil decreases as the percentage of bentonite increases. Whereas an increasing tendency in the value of OMC of normal clayey soil has been observed as 5%, 10% and 15% bentonite is mixed with normal soil.
[4] Tendency in decrease of both unsoaked and soaked CBR value have been observed when bentonite of 5%, 10% and 15% are mixed with clay.
[5] The free swelling of clayey soil increases with the increase in percentage of bentonite.
[6] The decrease in UCS value has been obtained with increase in mixing of bentonite to the clay soil.
[7] Normal soil changes its behavior towards expansive in nature due to increase percentage of bentonite.

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