Effect of Moulding Water Contents on Collapsible Potential of Coastal Region soils

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Abstract- Soils are unconsolidated materials that are result of weathering and erosion process of rocks. Many soils can prove problematic in Geotechnical engineering applications, because they expand, collapse, disperse and undergo excessive settlement. Although wind-blown soils have more collapse behavior but collapsibility behavior are seen in other type soils such as clay and silt. In Andhra Pradesh coastal region soils are most probably behave like Expansive nature. These Expansive soils in India are popularly known as Black cotton soils is one such that which undergo volume changes when change of water content that occur independently of loading and are attributed to swelling and shrinkage. These volume changes can give rise to ground movement which can cause damage to low raise buildings that they don't have sufficient weight to resist. These soils also represent a problem when they are encountered in road construction, and shrinkage settlement of embankments composed of such clays can lead to cracking and breakup of the roads they support. In this paper a detailed study on the volume change and collapsibility characteristics of Black cotton soil were carried out which was collected from the coastal regions of Andhra Pradesh and also examines the effect of placement water contents on collapsibility and volume change characteristics of Black cotton soil. The collected soil samples were subjected to one dimensional compression at various placement moisture contents like OMC, Dry of optimum, wet of optimum, plastic limit and liquid limit. At these placement water contents Consistency, Heave, swell potential, swell pressure and collapse potential characteristics were studied. In this regard, it was done a series of laboratory tests to evaluate the volume change and collapsibility rate.

KEYWORDS: Embankments, shrinkage, compression, collapsibility

I. INTRODUCTION

Expansive and collapsible soils are some of the most widely distributed and costly of geologic hazards. These soils are subject to changes in volume and settlement in response to wetting and drying, often resulting in severe damage to structures. Expansive soils are encountered in arid and semi-arid regions of the world, where annual evaporation exceeds annual precipitation. In India, expansive soils cover about 20% of the total land area. These soils increase in volume on absorbing water during rainy seasons and decrease in volume when the water evaporates from them. The volume increase (swell) if resisted by any structure resting on it; then vertical swelling pressure is exerted by the soil on the structure. Collapsible soils consist of loose, dry, low-density materials that collapse and compact under the addition of water or excessive loading. These soils are distributed specifically in areas of young alluvial fans, debris flow sediments, and loess (wind-blown sediment) deposits. Soil collapse occurs when the land surface is saturated at depths greater than those reached by typical rain events. This saturation eliminates the clay bonds holding the soil grains together. Similar to expansive soils, collapsible soils result in structural damage such as cracking of the foundation, floors, and walls in response to settlement.

Some investigators studied the swelling characteristics of expansive soils after repeatedly wetting-drying cycles. Chen et al (1985), Chen and Ma (1987), Subba Rao and Satyadas (1987), Dif and Bluemel (1991) concluded that when soils were subjected to full swell and allowed to shrink to their initial water content, they showed less expansion due to the fatigue of clay.

II. MATERIALS

To study the effect of placement water contents on volume change and collapsible characteristics of high expansive clay soil, which is obtained from delta areas of Godavari River in Bhimavaram, Andhra Pradesh, India.

1.1 Black cotton soil

Expansive soils in India are popularly known as Black cotton soils, the collected soil was dried and pulverized into the required sizes and tested for properties like gradation ,compaction, strength as per IS2720 and the results are shown in Table 1 and Fig. 1

Table 1-Geotechnical properties of Black cotton soil

Property	Values
Gravel (%)	0
Sand (%)	4
Fines (%)	96
a Silt(%)	50
b Clay(%)	46
Liquid Limit (%)	74
Plastic Limit (%)	29
Plasticity Index (I_p)	45
Type	Brown Clay
I.S Classification	CH
Specific gravity	2.69
Optimum moisture content (OMC) (%)	26
Maximum dry density (MDD) (g/cc)	1.52
California bearing ratio (CBR) (%) (Soaked condition)	1.0
Unconfined compression strength (t/m^2)	16
Cohesion - C (t/m^2)	6.0
Angle of Internal Friction (Ø)-deg	12

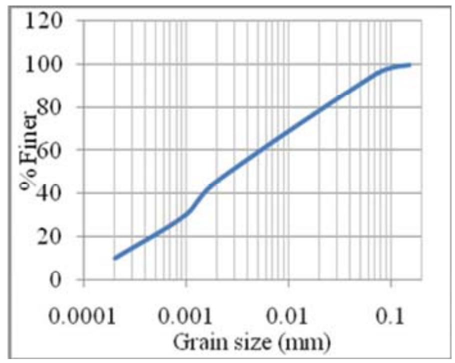


Fig .1 Gradation distribution curve of Expansive soil

III. RESULTS AND DISCUSSIONS

3.1 Compressibility characteristics:

Soil is compacted at different placement moisture contents and dry densities in a container of dimension 6mm dia and 2mm height. These samples was soaked in water for a period of 3-4 days under surcharge of 5 kPa and the increase in thickness is known as heave (ÄH) and decrease in thickness were noted down after completion of the soaking period and the results are listed in Table -2 and 4 Fig -3 and 4.

Table- 2 Compressibility characteristics of black cotton soil Table.3 densities and void ratio values for water contents

Water content	20%	26%	30%	35%
pressure(p) KPa	void ratio(e)	void ratio(e)	void ratio(e)	void ratio(e)
5	1	1.04	1.04	0.93
10	0.98	1	0.96	0.88
20	0.95	0.94	0.9	0.83
40	0.9	0.9	0.82	0.77
80	0.86	0.79	0.75	0.7
160	0.83	0.77	0.66	0.63
320	0.72	0.68	0.57	0.55
640	0.6	0.58	0.45	0.46
1000	0.45	0.42	0.38	0.42
1280	0.3	0.32	0.36	0.4

water content(%)	Dry density $_d$(g/cc)	Initial void ratio(e_s)	Change in void ratio(Äe)	Final void ratio(e)
20	1.45	1	0.148	0.866
26	1.51	1.04	0.27	0.77
30	1.48	0.98	0.155	0.82
35	1.43	0.93	0.047	0.88
40	1.38	---------	---------	0.95

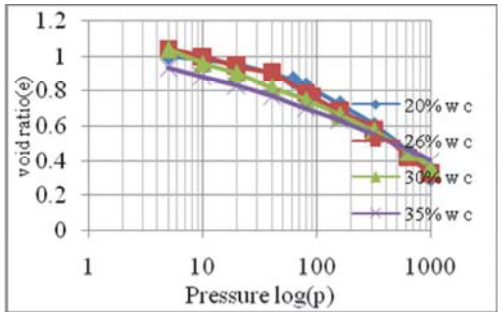


Fig.2 void ratio Vs pressure

From the swell pressure test (IS 2720-part 41:1977), it is observed that as the placement water content increases swell pressure values are increasing up to OMC and then decreasing. For an OMC of 26% the maximum swell pressure of 90KPa were observed. The initial void ratio i. e swell void ratio (1.04) is maximum at OMC and change in void ratio (0.27) is maximum at OMC.

Table 4 Compressibility and swell characteristics of black cotton soil

water content(%)	$I_c=(W_L-W_n)/Ip$	$I_L=(W_n-W_P)/I_p$	Heave(ÄH)mm	Swell potential Sp=(ÄH/H)100	Swell pressure Ps(KPa)
20	1.2	-0.2	1.6	8	62
26	1.07	-0.07	3	15	90
30	0.98	0.022	1.7	8.5	40
35	0.87	0.133	0.5	2.5	10
40	0.76	0.245	0.2	1	0

3.2 Relationship between Consistency and volume change characteristics of Black cotton soil:

The main purpose of studying these two consistency index along plastic index is to know the volume change behavior of expansive soil mass with respect to swell pressure, heave and swell potential etc. From the test results as the consistency index values decreases heave values are increasing up to OMC and then decreasing.

Maximum heave (3mm) at OMC is due to availability of more solids (clay particles) due to high dry density and at these water contents the soil is still active in absorbing moisture, resulting increasing the repulsive forces which increases the disturbance between particles, and as the placement water content nearing to the plasticity index the amount of heave is decreasing and further it becomes to zero. This is due to the soil is already in the swollen state which does not allow further water to imbibe into it. And as the Liquidity index values increases heave values are increasing up to OMC and then decreasing. As the placement water content nearing to the plasticity index the amount of heave is decreasing and further it becomes to zero.

From the test results as the consistency index values decreases Swell potential values are increasing up to OMC and then decreasing. Maximum Swell potential (15%) at OMC is due to availability of more solids (clay particles) due to high dry density and at these water contents the soil is still active in absorbing moisture, resulting increasing the repulsive forces which increases the disturbance between particles, and as the placement water content nearing to the plasticity index the amount of swell potential is decreasing and further it becomes to zero. This is due to the soil is already in the swollen state which does not allow further water to imbibe into it. And as the Liquidity index values increases swell potential values are increasing up to OMC and then decreasing. At moisture contents nearing plasticity index the soil has less dry density, availability of sufficient moisture, less solids in a given volume space which reduces the soil-water interaction and availability of less electron-negativity and the net repulsive forces are decreasing and the amount of swell potential is less.

From the test results as the consistency index values decreases swell pressure values are increasing up to OMC and then decreasing. Maximum swell pressure (90KPa) at OMC is due to generation of repulsive forces between clay particles and also high dry densities, and less water contents are responsible for soil water system to generate more thrust between soil particles which are in the form of volume increase. Hence more thrust is to be generated at high dry densities and less water contents. And as the Liquidity index values increases swell pressure values are increasing up to OMC and then decreasing. As the placement water content nearing to the plasticity index the amount of swell pressure is decreasing and further it becomes to zero. This is due to the soil is already in the swollen state which does not allow further water to imbibe into it.

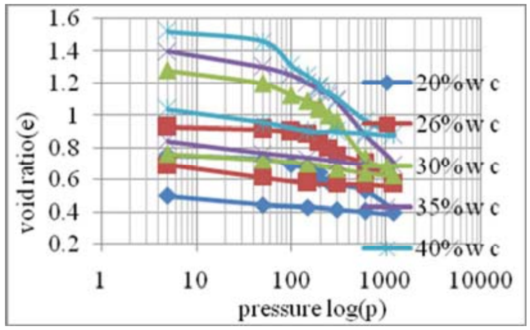
3.2 Collapsibility characteristics:

Soil is compacted at different placement moisture contents like 20%, 26%, 30%, 35% and 40% and dry densities in a consolidation ring of dimensions 6mm dia and 2mm height. The sample is placed in the odometer. A small seating load is applied to the specimen. The soil is gradually loaded to the anticipated field loading conditions i. e 200KPa. At this stress level, the sample is then inundated with water and allowed to saturate. The resulting hydro collapse is then observed. Loading of the specimen is then continued with consolidation permitted. And the results are shown in table -5

Table 5 Collapsibility characteristics of black cotton soil at different placement water contents

Water Content	20%	26%	30%	35%	40%
Pressure (p) Kpa	void ratio (e)	void ratio (e)	Void ratio (e)	Void ratio (e)	Void ratio (e)
5	0.754	0.93	1.28	1.4	1.52
50	0.728	0.915	1.199	1.301	1.46
100	0.694	0.9	1.127	1.25	1.31
150	0.672	0.89	1.09	1.2	1.244
200	0.649	0.86	1.065	1.172	1.189
200	0.603	0.833	1.04	1.151	1.17
250	0.581	0.802	1	1.13	1.142
300	0.57	0.758	0.965	1.09	1.11
600	0.531	0.704	0.739	0.88	0.97
1200	0.396	0.569	0.626	0.69	0.88
600	0.401	0.569	0.64	0.696	0.892
300	0.415	0.57	0.668	0.712	0.9
150	0.429	0.578	0.7	0.735	0.902
50	0.443	0.613	0.724	0.764	0.956
5	0.499	0.691	0.761	0.841	1.04

From the collapsibility test data it is observed that at the low placement water contents the initial compression is very low due to the availability of less water content and the soil particles are densely packed which require little high water to deform significantly. As the placement water contents increasing and reaching to plasticity index the initial compression values are increasing this is due to the swollen soil particles which will deform easily at even low pressures. All the soil samples were subjected to a constant inundation pressure i.e 200KPa and here the collapse characteristics were studied. The collapse potential is expressed by the change in height after wetting and an applied load. The following equation shows a typical engineering definition of collapse potential in terms of change in void ratio which is associated with the difference in height.



Cp = Äe/1+e_0
where:
e= decrease in void ratio due to wetting, and e_0= is the initial void ratio.

Fig.3 Collapsibility characteristics of black cotton soil at different placement water contents

From the collapsibility test data the soil sample compacted at 20, 26 and 30% water content shows maximum collapse potential values are 2.62, 1.9 and 1.09% which comes under moderate severity. But soil sample compacted at 35 and 40%water content shows a collapse potential value of 0.875 and 0.753% which comes under no severity. Since the soil particles are compacted at high densities and less parental water is held in between the soil particles allows more water and break the bond between the soil particles. At the low placement water contents the initial compression is very low due to the availability of less water content and the soil particles are densely packed which require little high water to deform significantly. This is due to the availability of sufficient water content and the soil particles are slightly with loose packed structure which requires little low water to deform significantly.

From the test results it is observed that as the placement water content increases the collapse potential values are decreasing. The variation of collapse potential are varying in between 0.7-2.62 which shows that the severity of the problem of soil belongs to no problem to moderate problem.

Table 6 Variation of collapse potential w. r. t water content

water content (%)	Initial void ratio (eo)	Change in void ratio (e)	Collapse potential(%) =(e)/(1+eo)
20	0.754	0.046	2.62
26	0.93	0.027	1.39
30	1.28	0.025	1.09
35	1.4	0.021	0.875
40	1.52	0.019	0.753

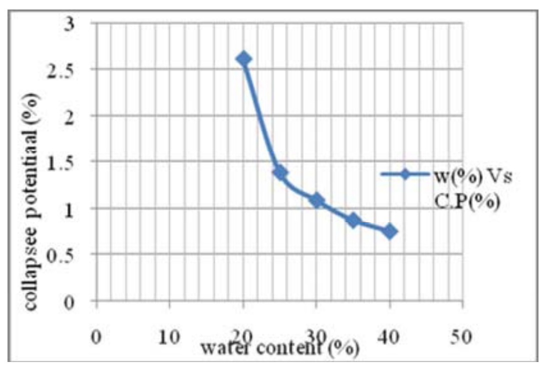


Fig.4 Variation of collapse potential w. r. t water content

At low placement water content (20%) the collapse potential is maximum of 2.62% and at high placement water content (40%) the collapse potential is minimum of 0.753%. This is due to the soil particles are compacted at high densities and less residual water is held in between the soil particles allows more water and break the bond between the soil particles.

IV. CONCLUSIONS

1. It is identified that the soil contains fines(less than 75µm) of 95.% shows it is of alluvial origin and contains 55% of silt and 46% as clay particles. The presence of fines contributed for high liquid limit (WL) of 74% and plasticity index of 45% and classified as CH.

2. It is also identified that as the placement water content increases the collapse potential values are decreasing. The collapse potential values are varying in between 0.7-2.62 which shows that the severity of the problem of soil belongs to no problem to moderate problem
3. At low water content the compression of the specimen is low but the collapse potential value is high and at higher water contents the compression is more but the collapse potential value is less.

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