STUDY OF SWELLING CHARACTERISTICS OF THE SOIL-BENTONITE MIXTURE

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Abstract : In past, limited research has been done for the expansive soil in the case of large scale model close to the field condition. In present study the model footing test were carried out to check the swelling pressure of soil-bentonite mixture compacted at dry side. The main aim of this study is to determine the swelling pressure of mixture of soil with 5 varying proportion of bentonite using model footing test and compare it with the swelling pressure obtain by oedometer test. Also basic index properties of soil-bentonite mixture namely liquid limit, plastic limit, free swell index, Compaction test data, Unconfined compression strength are determined and effect of bentonite on each properties is checked.

Key words **- Black cotton soil, Bentonite, Swelling pressure, Oedometer test, Model footing test**

I. INTRODUCTION

Major part of India is covered with Expansive soil which is mainly known as 'Black cotton soil'. These black cotton soil exhibit high Swelling and Shrinkage on wetting and drying respectively. The swelling of soil is very important factor which affect the performance of foundation resting on it. Also the shrinkage behavior of soil affect the foundation. By understanding the swelling behavior of soil will help in designing of shallow foundation constructed on them and also proper soil treatment can be apply to the soil strata before commencement of any structure.

Many research has been done on the expansive soil in accordence with its swelling properties, atterbergs limits,CBR strength, Unconfined compression strength, consolidation test. By checking these physical and strength properties they gave corelatipn between atterbergs limits value and selling pressure .Also many empirical formula has been developed by researchers. Jennings (1963) gives three method for determination of Swelling pressure in laboratory namely method of different surcharge,constant volume method and method of free swell. Of these ,the free swell method has been found to give the largest value of swell(Shanker et all. 1982; Sridharan et al. 1986). Sullivan and Mc Clelland (1969) and Uppal and Palit (1969) recomended the use of the constant volume method as it simulates the stress path followed in the field. Peck(1974), Mohan (1977), Murthy and Raman (1977) gave relationship between swelling pressure and soil basic properties like liquid limit; plasticity index, Shrinkage index and colloidal content; free swell index respectively. El-Sohby and Mazen(1983) study the influence of the minerological composition as a governing factor for sweliing behavior of expansive clayey soil. Sivapullaiah et al. (1996) studied thet swelling behavior of a mixture of the clay and coarse fraction with increasing percentage of clay in the composition. Subba Rao et al. (2000) studied the compaction control in cyclic swelling of expansive soils. A.R. Estabragh , A.A javadi (2014) studied the effect of the different wetting fluid on cyclic wetting and drying behavior of expansive soil. A Forouzan (2016) studied on prediction of swelling behavior of expansive soil i.e. Kaolinite mixed with Bentonite soil using Free swell index, Methylene Blue and Swell Oedometer tests. Mohammed Y. Fattah, Aysar H.S. Al-Lami (2016) studied the behavior and characteristics of the compacted expansive unsaturated Bentonit-Sand mixture in laboratory as well as large scale model test. Many researchers like Seed(1962), Komornik and David(1969), Chen(1975), Nayak and Christensen (1974) gave the empiracal formulae to determine the swelling pressure of expansive clayey soil.

Swelling characteristics of the expansive soil has been study in laboratory testing till date. Very few researchers have done study on large scale model resemble to field conditions. So in present study the swelling pressure of soil-bentonite mixture were determine using Swell Oedometer test. Also the Model Footing test close to field condition were carried out to check the swelling pressure of each combination of soil-bentonite mixture. Swelling Pressure obtain by both test were analyzed to get an idea about how swelling pressure differ in Model footing test from Oedometer test data. Meanwhile laboratory test were carried out to determine the Free swell index, Maximum dry density and optimum moisture content, Unconfined compression strength, Atterberg's limits. Effect of Bentonite addition in black cotton soil is analyzed based on data obtain by laboratory test.

II. MATERIALS USED FOR INVESTIGATION

2.1 Expansive Soil

The black cotton soil was collected from Dethan village, Vadodara, Gujarat at a depth about 0.5-meter depth. An Index and Engineering properties of procured black cotton soil are listed in **Table1**.Minerological composition of black cotton soil is listed in **Table 2** By the sieve analysis and atterberg's limits procured black cotton soil is classified as CH soil. The free swell index value for black cotton soil is measured as 85% by differential volume method as per IS 2720 (Part 40).

2.2 Bentonite clay

A bentonite clay in powdered form was collected from the construction site of Vadodara. This bentonite is supplied by STAR bentonite exports. It has cream color. By performing Free swell test as per IS 2720 (part 40) free swell index of bentonite clay is

520%. Energy dispersive spectrum test is carried out on bentonite clay to determine its mineralogical property. **Table 3** shows the weight percentage of the element present in bentonite clay and its atomic percentage.

Table 1 Index and Engineering Properties of Black cotton soil

Sr. No	Index and Engineering Properties	Value
1	Specific gravity	2.68
2	Atterberg's limits ▪ Liquid limit (%) ▪ Plastic limit (%) ▪ Plasticity index ▪ Shrinkage limit (%)	 65.3 30.6 34.7 9.77
3	Grain size distribution ▪ Sand (%) ▪ Silt and clay (%)	 5% 95%
4	IS Soil Classification	CH
5	Free swell index (%)	85
6	Engineering Properties Light Compaction ▪ Maximum Dry Density, (gm/cc) ▪ Optimum Moisture Content (%)	 1.486 27.66
7	Swelling pressure (kg/cm^2) ▪ Dry Compacted at Y_d = 1.3 gm/cc	 0.518
8	Unconfined compression strength(kg/cm^2)	2.23

Table 2 Mineralogical components of Black cotton soil

Element	Weight(%)	Atomic (%)
O K	54.98	71.02
Na K	0.56	0.50
Mg K	1.50	1.27
Al K	6.88	5.27
Si K	22.01	16.19
Cl K	0.18	0.11

Table 3 Mineralogical Components of Bentonite clay

Element	Weight(%)	Atomic (%)
O K	50.62	67.30
Na K	2.11	1.95
Mg K	1.63	1.43
Al K	8.17	6.44
Si K	22.08	16.72
Cl K	0.31	0.19

III. EXPERIMENTAL METHODOLOGY

Following tests were conducted during laboratory hours as per IS code to determine the properties of soil and soil-bentonite mixture. Soil Sample preparation, readings and calculation were done as per respective IS code for particular test.

- Free swell(IS 2720 P-XL)
- Swelling pressure(IS 2720 P-XLI)
- Standard Proctor test(IS 2720 P-VII)
- Liquid limit test - cone penetration(IS 2720 P-V)
- Plastic limit test(IS 2720 P-V)
- Specific gravity(IS 2720 P-III)
- Particle size distribution (IS 2720 P-IV)

IV. MODEL FOOTING TEST

To check the effect of bentonite addition on swelling pressure a model footing test were carried out which is a large scale model to measure swelling pressure with time .Also Upheaval of footing plate caused by swelling of soil were noted. The procedure of Model footing test include following steps.

- Tank is filled with the oven dry soil in four layers , 3 each of 10 cm and one of 5 cm by hammer compaction keeping dry density 1.3 gm/cc.
- Footing plate of 30 cm dia and 2 cm thickness is placed on the compacted soil by proper centring and levelling using plum-bob and spirit level.
- Proving ring and two deformation dial gauge placed diametrically and 80% - 85% saturation is achieved by adding water in the tank as per requirement.
- PDGR is taken on addition of water and simultaneously DDGR1 and DDGR2 is taken until it shows the constant value.
- Once the constant values are achieved the counter pressure is applied to bring the DDGR to its initial position and PDGR is noted.
- Soil sample is taken from different layers to draw a moisture profile.

Table 4 Model Footing Parameters

Tank Diameter (cm)	57
Tank Height (cm)	50
Footing plate diameter (cm)	30
Footing plate thickness (cm)	2
Loading frame size (cm x cm)	93 x 93

Figure 1 shows the schematic diagram of Model footing test. Arrangements of Proving ring to measure pressure , Deformation Dial gauge to measure upheaval of footing plate and all fitting arrangements were done as shown in **Figure 1**.

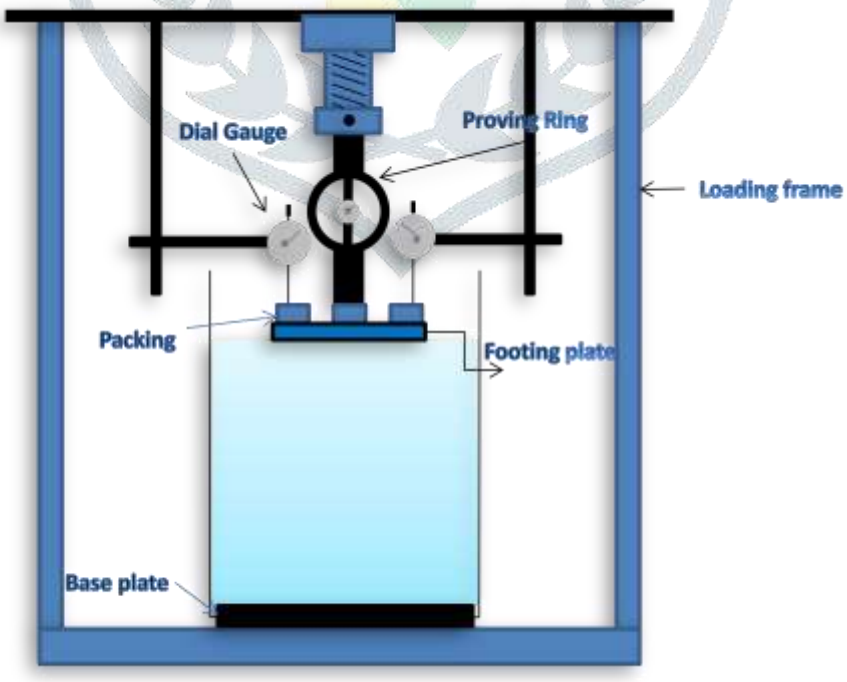

Figure 1 Schematic diagram of Model footing test

Figure 2 Dry compaction of the layer using a dry standard hammer

Figure 3 Placing of footing plate on compacted soil

Figure 4 Placing of Proving ring and dial gauge

Figure 5 Flooding of water

Figure 2 to **Figure 5** shows stepwise procedure of Model footing test. As shown in Figure 3 Paint was applied on footing plate and packers to prevent corrosion due to water flooding as shown in Figure 5. Oven dry soil passing through 4.75 mm IS sieve was used for all model footing test. Bentonite clay is added in black cotton soil in five different percentage i.e. 0%, 10%, 20%, 30%, and 40%.

V. RESULT AND DISCUSSION

5.1 Effect of bentonite addition on Engineering Properties of Black cotton soil

With addition of bentonite clay in black cotton soil value of, Liquid limit, Plastic limit, Plasticity index, Free swell index is increases as shown in **Figure 6** and **Figure 8** respectively. Value of Liquid limit ,Plastic limit and Plasticity index are increases from 65.3%, 34.7%, 30.6% for natural soil to 120%, 67.5%, 52.2% for 40% bentonite clay percentage.Whereas Specific gravity of black cotton soil does not differ more from natural soil with the addition of bentonite clay as shown in **Figure 7.** When compaction test were carried out on all five combination of soil-bentonite mixture , Maximum dry density decreases from 1.486 gm/cc to 1.325 gm/cc for 0% to 40% addition of bentonite clay in black cotton soil. While data for Optimum moisture content shows that the value of OMC is increases from 27.22% to 33.33% as shown in **Figure 10.** Unconfined compressive strength of soil is decreases from219.66 kPa for natural soil to 114.16 kPa for 40% bentonite clay in black cotton soil as shown in **Figure 9.**

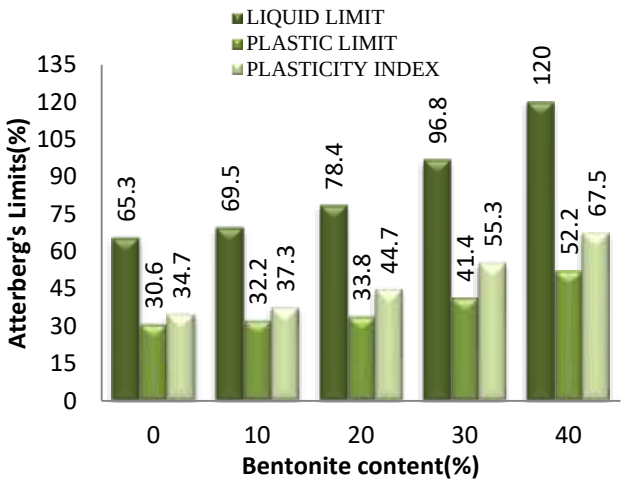

Figure 6 **Effect of Bentonite content on Atterberg's limits**

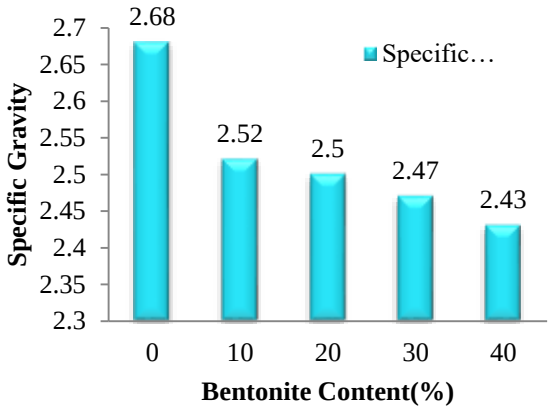

Figure 7 **Effect of bentonite content on Specific gravity**

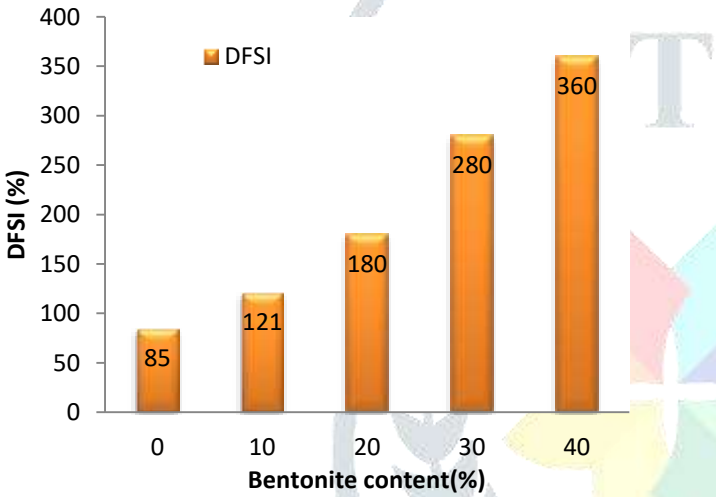

Figure 8 **Effect of Bentonite on Differential FSI**

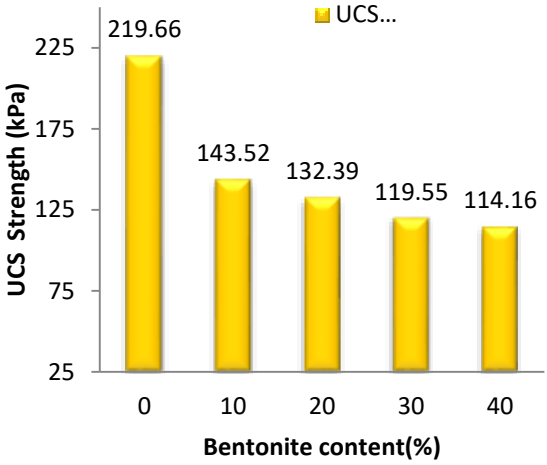

Figure 9 Effect of Bentonite on UCS value

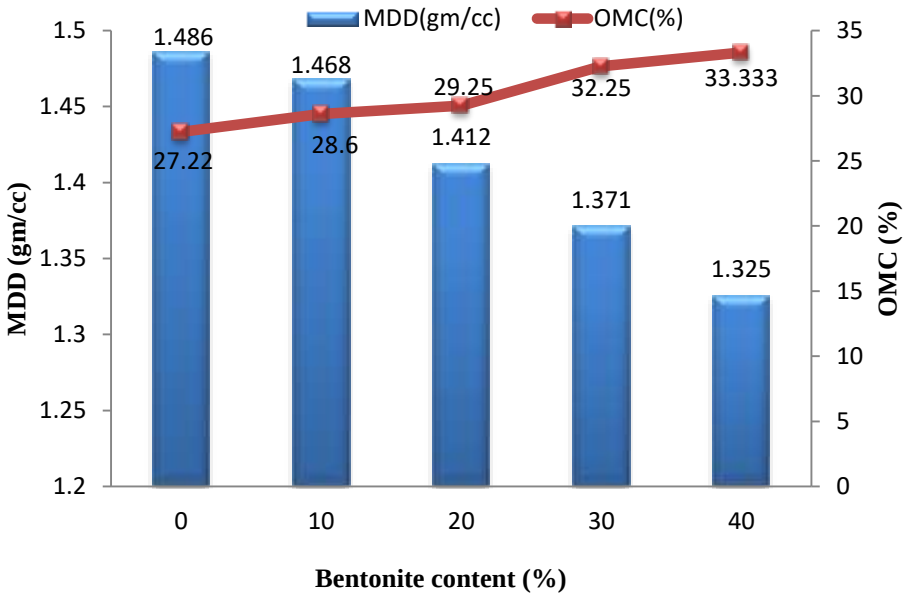

Figure 10 Effect of bentonite on MDD and OMC

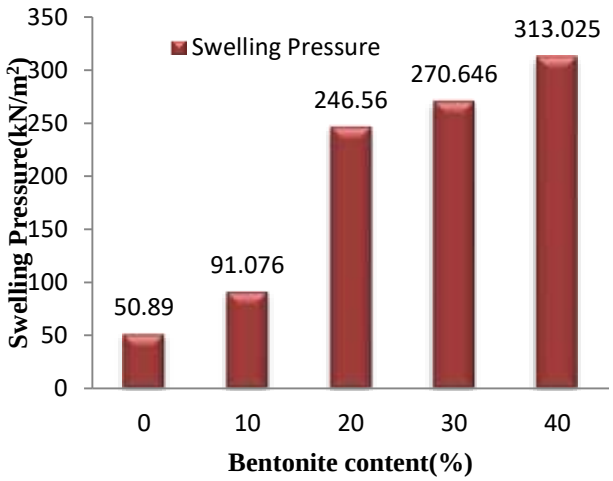

Figure 11 Effect of bentonite on swelling pressure obtain by oedometer

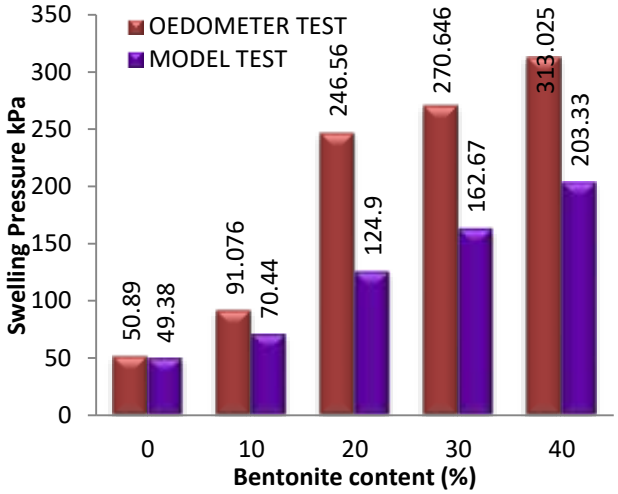

Figure 12 Comparison of Swelling Pressure

Figure 11 shows the swelling pressure value obtain by swell oedometer test by free swell method in laboratory. Which shows that the addition of bentonite clay increases Swelling pressure of natural black cotton soil. As bentonite clay contains montmorrilonite clay mineral which exhibit High Swell and Shrinkage behavior with wetting and drying cycles. Due to these property of bentonite clay ,its addition in black cotton soil makes it more expansive and value of swelling pressure is increases. **Figure 12** shows the comparision of swelling pressure value obtain by oedometer test and model footing . Model footing test on the soil-bentonite mixture with different proportion also shows that an increase in bentonite content ultimately increases in montmorillonite mineral, soil swells more and exert more swelling pressure on footing plate. The swelling pressure value is less in model footing test than the swelling pressure value obtain from oedometer test for the same proportion of soil-bentonite mixture. The swelling pressure obtains by oedometer test is under ideal condition. The soil sample is confined from all sides. So swelling pressure of soil is totally exerted on loading plate and recorded swelling pressure is maximum. Also, saturation of the soil sample is from both sides, top as well as the bottom of the sample. Whereas in the case of model footing test, loading plate diameter is less than the soil sample. Due to which there is a side upheaval of soil and swelling pressure exerted on loading plate was not maximum. Also, water is applied through the top, which causes slow as well as partial saturation.

VI. CONCLUSION

The following are the main conclusion drawn from the Laboratory and model footing test carried out on a Soil-Bentonite mixture of different proportion during this dissertation:

With the addition of bentonite clay in the black cotton soil, its liquid limit, plastic limit, and plasticity index are increased. Also, free swell value obtains by differential volume method is increases.The Maximum dry density is decreases and optimum moisture content is increases as bentonite content increases from 0% to 40%. Unconfined compression strength also decreases with bentonite addition. Value of specific gravity also decreases.

The Swelling pressure value obtain in oedometer test is under ideal condition whereas Model footing test is large scale model close to field conditions. In actual field, soil arround the footing is not confined from all sieds and they are free to expand in all direction.SO when soil swell it exert pressure on footing but on other side it will also move outside the footing edges. Due to this reason swelling pressure develope on actual field is lesser then the swelling pressure obatin by laboratory test.

VII. REFERENCES

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