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The Effect of Initial Moisture Content on the Swelling Characteristics, Compression Index and Swelling Index of Expansive Soils

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ABSTRACT

Expansive soils are prone to swell or shrink with the change of moisture content. They swell or increase in their volume when they imbibe water and shrink or reduce in their volume on evaporation of water. The swell and shrinkage characteristics of the expansive soil causes change in volume of expansive soil which poses many problems before the geotechnical engineers. When a structure is founded on the expansive soils, they swell and put an uplift pressure on the foundation causing damage to the structure. When these expansive soil are used in embankments or water retaining structures, the swell and shrinkage characteristics of the expansive soil causes the cracks in the structures which lead to the failure of structures. The swelling of expansive soil depends upon a lot of factors like type of clay minerals, amount of clay, initial moisture content of soil and density of the soil etc.

In the present study, the effect of initial moisture content on the swelling characteristics, Compression Index and Swelling Index of expansive soil is studied using the Clay-Bentonite mix. The initial moisture content of soil-bentonite mix. is varied as 10%, 20%, 25%, 30%, 35% and 40 % and the Compression Index and Swelling Index of soil-bentonite mix. is determined. The surcharge on the samples was varied as 25 kPa, 50 kPa and 100 kPa. 200 kPa, 400 kPa and 800 Kpa.

I. INTRODUCTION

Expansive soils are prone to swell or shrink with the change of moisture content. They swell or increase in their volume when they imbibe water and shrink or reduce in their volume on evaporation of water (Chen 1988). The swell and shrinkage characteristics of the expansive soil causes change in volume of expansive soil which poses many problems before the geotechnical engineers. When a structure is founded on the expansive soils, they swell and put an uplift pressure on the foundation causing damage to the structure. When the expansive soil are used in embankments or water retaining structures, the swell and shrinkage characteristics of the expansive soil causes the cracks in the structures which lead to the failure of structures. The swelling of expansive soil the depends upon a lot of factors like type of clay minerals, amount of clay and initial moisture content of soil, density of the soil etc. Expansive soil is found in many parts of India which includes Gujarat, Maharashtra, Karnataka and Madhya Pradesh on the Deccan lava plateau and the Malwa Plateau, but their characters are different as per the clay mineralogy. The soil map of India is shown in Figure 1. A vast majority of

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expansive soils are montmorillonite-rich clays, over consolidated clays and shales (Nelson and Miller, 1992, Pillappa, 2005). Generally, the chemical composition of the expansive soil constitutes SiO_2, $Al2O_3$, TiO_2, Fe_2O_3, MnO, CaO, K_2O and Na_2O. The values of these compounds vary according to the type of clay minerals present in soil viz. kaolinite, illite and montmorillonite.

Terzaghi, K (1948) has expressed "mechanical concept of swelling" of soils in the statement that "the flow of water into or out of a soil is exclusively due to the existence of a hydraulic gradient with a purely mechanical origin." It is believed when a soil takes in water, causing swell, the water in the soil is in a state of tension. This tensile stress would explain Terzaghi's idea of the hydraulic gradient.

Dobson, Dale E., (1963), in an approach gave the to the idea energy concept for the swelling of expansive soils. According to this theory, the soil should be to place in a state of equilibrium. In other words, the soil would be in its preferred structure and the demand for water would be satisfied. Soils not placed in a state of equilibrium would have a tendency to reach this condition resulting in a volume change. According to the ideas expressed by this concept, swelling characteristics could be controlled by regulating the density and moisture content during placement.

II. METHODOLOGY OF STUDY

In the present study, 6 nos. samples of clayey soil passing 425 micron IS sieve were mixed with bentonite to study the effect of initial moisture content on the shrink- swell characteristics of expansive soil, Compression Index (Cc) and Swelling Index (Cs) . The engineering properties of soil and bentonoite are given in Table 1. The bentonite was mixed with soil in the proportion of 10%, 20%, 25%, 30%, 35% and 40%. All the soil samples are remolded and tested by one dimensional consolidation test apparatus by varying the initial moisture content of soil samples as 10%, 20%, 25%, 30%, 35% and 40 %. The diameter of each sample was 60 mm and height of soil sample was 20 mm. The density of each set of soil samples was kept constant. The test was conducted as per IS 2720-Part-15. The soil samples were allowed to expand under submerged conditions in consolidation cell.

Figure 1: Soil map of India

III. RESULTS AND DISCUSSIONS

a. Effect on Compression Index, Cc

It was observed that Compression Index (Cc) initially decreases upto a moisture content of 20 % for soil-bentonite mix. of 10 % and 20 % and become maximum at 25 % initial moisture content and after that Compression Index decreases with the increase of initial moisture content. For the soil-bentonite mix. of 25 %, 30 %, 35 % and 40 % , the Compression Index (Cc) initially decreases upto a moisture content of 25 % and increases nearly upto maximum at 30 % initial moisture content and

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after that Compression Index decreases with the increase of initial moisture content. The behavior of soil-bentonite mix. may be attributed to fact that Optimum Moisture Content which is nearly 85% - 90 % of saturation moisture content. The value of Compression Index, Cc initially decreases then nearly become maximum at the OMC. Further addition of the water decreases the value of Cc. The values of the Compression Index (Cc) of different soil-bentonite mix. at different moisture content is given in Table 2 and also presented in Figures 2(a) to 2(f).

b. Effect on Swelling Index, Cs

The behavior of Swelling curve (Cs) was observed same as was observed for the Compression Curve (Cc). The Swelling Index (Cs) initially decreases upto a moisture content of 20 % for soil-bentonite mix. of 10 % and 20 % and become nearly maximum at 25 % initial moisture content and after that Swelling Index decreases with the increase of initial moisture content. For the soil-bentonite mix. of 25 %, 30 %, 35 % and 40 % , the Swelling Index (Cs) initially decreases upto a moisture content of 25 % and increases nearly upto maximum at 30 % initial moisture content and after that Swelling Index decreases with the increase of initial moisture content. The behavior of soil-bentonite mix. may be attributed to the soil structure present in the soil samples. When the soil have the moisture content less than Optimum Moisture Content, the soil have flocculated structure and when the soil have the moisture content more than Optimum Moisture Content, the soil have flocculated structure. The values of the Selling Index (Cs) of different soil-bentonite mix. at different moisture content at different moisture content is given in Table 3 and also presented in Figures 3(a) to 3(f).

It shows that the swelling properties are directly related to the amount of water present in the soil. (Parcher, James, 1965) also confirms this behavior that swell potential is dependent on the initial moisture content. Seed and Chan, (1961) also confirm this conclusions in their investigations and concluded "that soil samples compacted dry of optimum exhibit higher swelling characteristics and swell to higher water contents than do samples of the same density compacted wet of optimum." They indicated that this may be due to the different soil structure present in the soil on the dry of optimum and wet of optimum. It has been found that compacted clayey soil when compacted dry of optimum moisture content are likely to have a flocculated structure while the soils when compacted wet of optimum moisture content tend to have a dispersed structure.

Table 1: Properties of Materials used for the Study

Material	Clay	Silt	Fine sand	Medium Sand	Coarse sand	Liquid Limit	Plastic Limit	Plasticity Index
Soil	53.8	44.1	2.1	0.0	0.0	63.8	28.8	35.0
Bentonite	84.3	14.2	1.2	0.3	0.0	452.0	41.0	411.0

Effect of Initial Moisture Content on Swelling Pressure of Soil

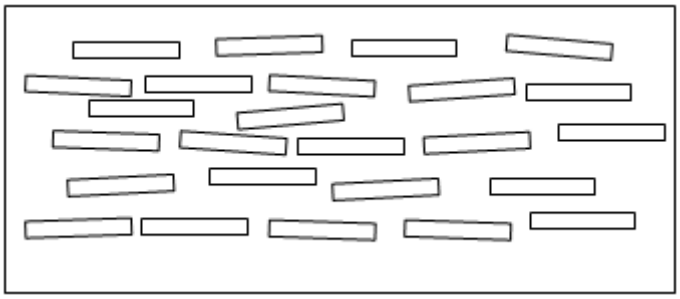

Figure 4: Dispersed Soil Structure

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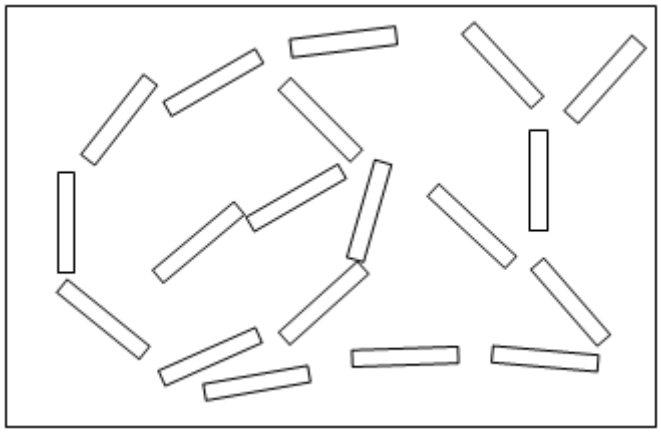

Figure 5: Flocculated Soil Structure

Table-2: Relation between Initial Moisture Content Vs. Compression Index, Cc
Compression Index, Cc

Initial Moisture Content	Soil+10% Bentonite	Soil+20% Bentonite	Soil+25% Bentonite	Soil+30% Bentonite	Soil+35% Bentonite	Soil+40% Bentonite
10%	0.3508	0.4298	0.4890	0.5281	0.5340	0.5978
20%	0.2105	0.2800	0.4136	0.4129	0.4111	0.5412
25%	0.4017	0.4411	0.2977	0.2200	0.2917	0.4093
30%	0.3180	0.3462	0.3449	0.3252	0.4031	0.4490
35&	0.2430	0.2942	0.3067	0.3081	0.3444	0.3228
40%	0.2151	0.2412	0.2568	0.2512	0.2362	0.2312

Table-3: Relation between Initial Moisture Content Vs. Swelling Index, Cs
Swelling Index, Cs

Initial Moisture Content	Soil+10% Bentonite	Soil+20% Bentonite	Soil+25% Bentonite	Soil+30% Bentonite	Soil+35% Bentonite	Soil+40% Bentonite
10%	0.0667	0.0933	0.1864	0.1245	0.1369	0.1587
20%	0.0369	0.0354	0.1488	0.1190	0.0903	0.1217
25%	0.0777	0.1037	0.1126	0.0536	0.0600	0.0896

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30%	0.0616	0.0995	0.1331	0.1029	0.0821	0.1082
35&	0.0456	0.0638	0.1154	0.0873	0.0673	0.0631
40%	0.0375	0.0419	0.0894	0.0572	0.0425	0.0326

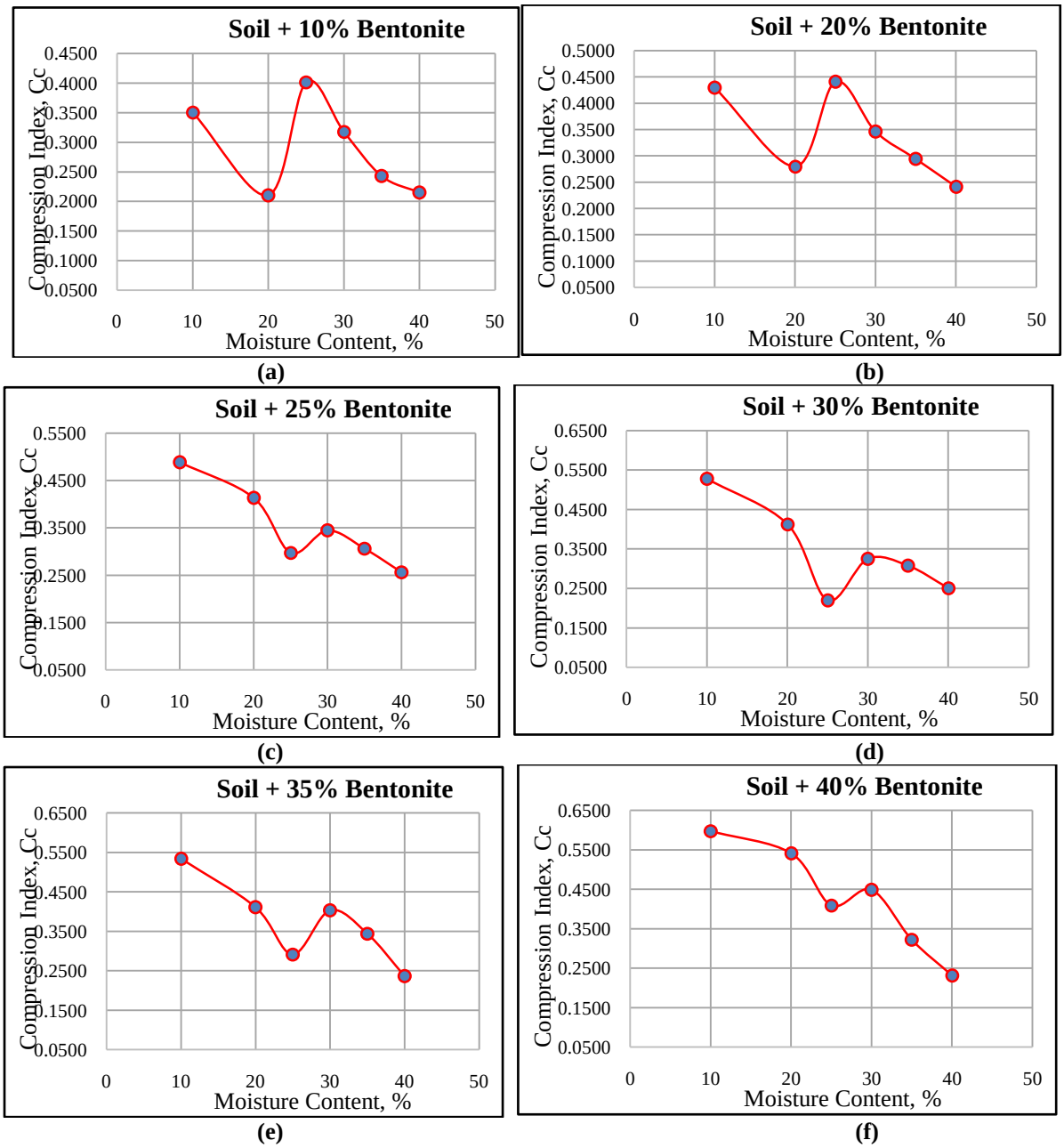

Figure 2: Effect of Initial Moisture Content on Compression Index, Cc

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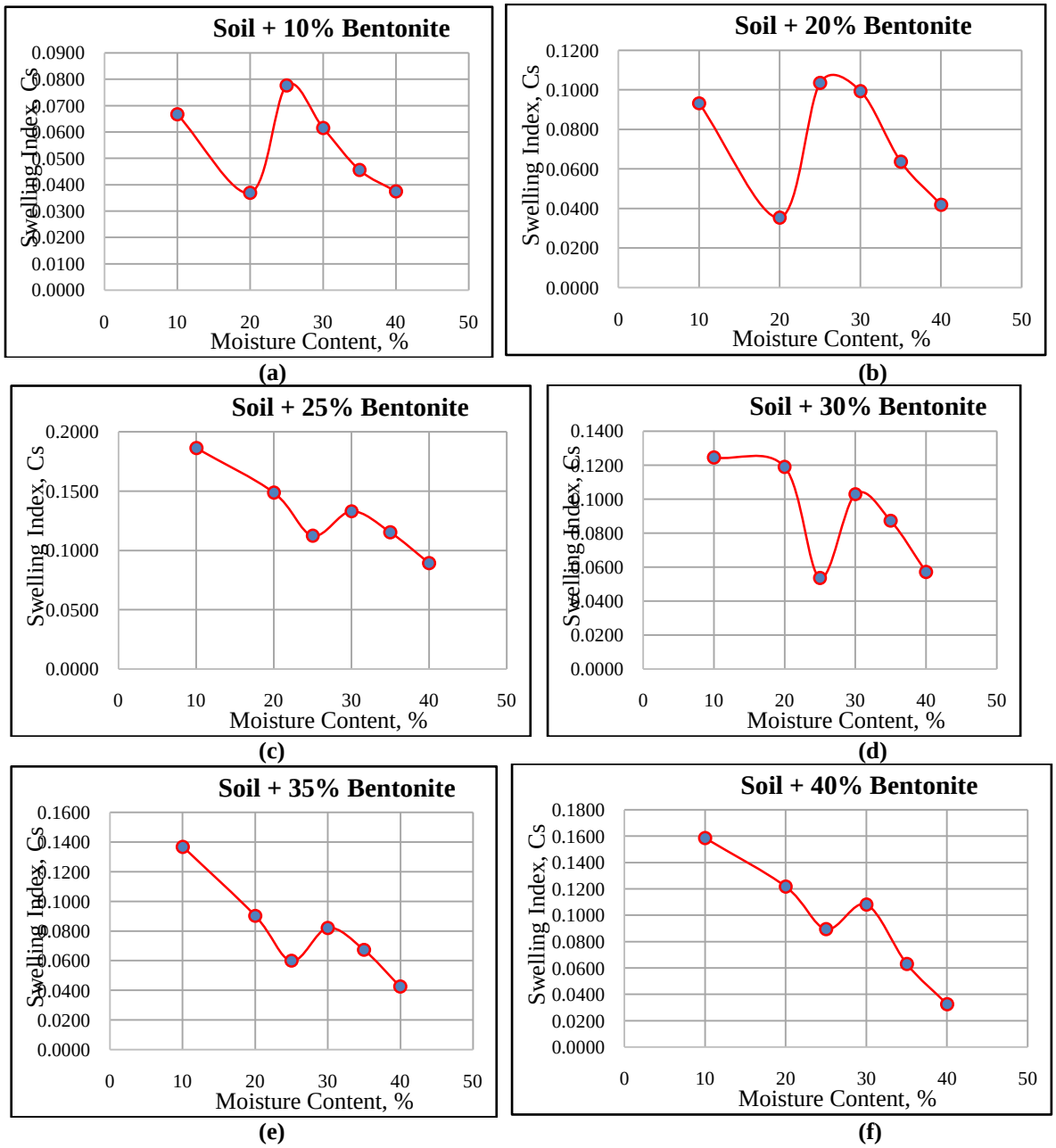

Figure 3: Effect of Initial Moisture Content on Swelling Index, Cs

IV. CONCLUSIONS

Based upon the study carried out on the effect of initial moisture content on the swelling Characteristics, Compression Index (Cc) and Swelling Index (Cs) of the Clay-Bentonite mix., it is concluded that the Compression Index (Cc) and Swelling Index (Cs) in general decreases with the increase of initial moisture content. A constant value of Cc was expected for each set of soil because the dry density for each set of soil samples was nearly a constant. The behavior observed may be explained be considering the variation in initial degree of saturation. As the initial moisture content increased in each sample, the degree of saturation was also increased, as a result, the wetter samples more closely conformed to the assumptions made by Terzaghi that the samples are saturated at the beginning of the consolidation.

The compression index and swelling index has different behavior before the saturation and after the saturation. When the water quantity is very low, the Compression Index (Cc) and Swelling Index (Cs) decreases sharply but after a certain level of saturation, the Compression Index

and Swelling Index increases and become maximum nearly at the saturation. After the saturation, the Compression Index (Cc) decreases with the increase moisture content. This behavior of expansive soil is also confirmed by the study carried by the William Howell Branum (1966) on the Putnam soil (a type of soil found in northern Missouri, exhibits the characteristics of an expansive soil). It appears that at lower initial moisture contents the soil has flocculated structure and after saturation, it has dispersed structure which has different energy state which also indicate the different behavior of soil before and after the saturation.

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