Feasibility of minimizing shrink-swell Behavior of black cotton soil

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Abstract - *Adjustment of soils is a compelling strategy for development of soil properties and the asphalt framework execution. Versatility Index is one of the essential properties of soil to decide the conduct of soil in nearness of water. The poorest soil among all is Black Cotton Soil (BC Soil). In Rajkot region this BC Soil is spread over southern piece of District. Rich extent of montmorillonite is found in BC Soil from mineralogical investigation. High level of montmorillonite renders high level of extensiveness. This property comes about splits in soil with no notice. These splits have some of the time degree extreme point of confinement like 1/2 "to 12" profound. Utilization of this sort of land may endure serious harm to the development with the change in environmental conditions. Mini Compaction apparatus is used to determine the compaction properties of the sample soil. Salinity and pH were observed using Salinity meter. X-ray Diffraction and EDX of the sample soil S1, S2, S3 were done. They were also done after the swell-shrink test of the samples.*

Key Words: **Black Cotton Soil (BC Soil), Montmorillonite, Salinity meter, Diffraction, EDX, Swell-shrink**

1. INTRODUCTION

Expansive soils undergo substantial volume change with fluctuations in moisture content. The resulting shrinkage and swelling of the soils inflict damages to structures constructed on them especially if the structures impose light loading on the subgrade. Structures such as small buildings and short-height embankments often suffer irreparable damages because of the shrinks well behavior of soils, upon which they are constructed. Also, the shallow foundations are more susceptible to swelling and shrinkage than deep foundation. Swelling and Shrinkage in the expansive soils arises from change in moisture content occurring in the upper few meters from the ground. The water in the few meters is influenced by cyclic seasonal climatic changes.

This zone is known as active zone. Swelling and shrinkage is attributed to the soil mineralogy which has potential to volume change and water freely moves in the soil. The volume change is dependent on soil type and change in moisture content. Different clay minerals exhibit different swell potentials depending on their structures and chemistry. Montmorillonite exhibits greater swelling potential than illite. Chemically Montmorillonite is hydrated sodium calcium aluminum magnesium silicate hydroxide $(Na, Ca)_{0.33}(Al, Mg)_2(Si_4O_{10})(OH)_2 \cdot nH_2O$. The structural unit of montmorillonite is composed of two silica(tetrahedral)sheets and one alumina (octahedral) sheet as shown in Figure. The interlayer bonding between the top silica sheets is mainly due to van der Waals forces which is weaker as compared to hydrogen bonding or other ion bonding. Partial isomorphic substitution takes place, resulting in a relatively large net negative charge deficiency. Also it has largest specific surface among all clay minerals. This means that a large amount of water can enter layers causing the layer to be separated. So, Montmorillonite swells when a large amount of water enters between the layers and shrinks when water is removed in dry season.

India has a long track of expansive soils known as Black Cotton Soil covering 20% of total land area of India. Black cotton soils have been formed due to solidification of lava in the Deccan plateau during volcanic activity thousand years ago. The volcanic rock (lava) is dark in color. Weathering of this rock causes them to break and this soil is carried by the rivers. This dark clay deposited during floods over millions years and known as Black Cotton Soils. Being very fine, these soils have tendency to retain large amounts of water over long time ensuring its fertility famous for cotton cultivation. It is also valuable for growing diverse crops such as rice, pulses and chillies. This soil is mainly found in Maharashtra, Madhya Pradesh, parts of Karnataka, Andhra Pradesh, Gujarat and Tamil Nadu

1.1 OBJECTIVE

The Objective of the present study was to investigate the effects of the salt on the swell- shrink behavior of the expansive soils.

2. LITERATURE REVIEW

Several studies have been attempted to investigate the swell-shrink behavior of the expansive soils. Various Researchers carried out swell-shrink behavior tests and effects of temperature, lime, ash and aging on it. Also they studied on the change inmicrostructure, clay content of the soils due to swell-shrink test. In this chapter works carried out by different researchers are discussed.

2.1 SWELL-SHRINK BEHAVIOR

Tripathy et al.(2002) showed the swell shrink behavior of compacted expansive soils. The test was conducted on Oedometer with the arrangement of constant temperature during shrinkage process under different surcharge pressures. After swelling, water was removed from Oedometer and shrinkage was commenced under controlled surchargeat constant temperature. Thus it completed one cycle of swell-shrink. The soil reached the equilibrium stage once the vertical deformation during swelling and shrinkage became same. This generally occurred after four cycles. The swelling and shrinkage paths of the specimen subjected to swelling- shrinkage cycles showed a S-shaped curve (two curvilinear portions and one linear portion). The equilibrium swell-shrink behavior was not affected by initial dry density and water content. The equilibrium swell-shrink path changed with the change in surcharge load applied during shrinkage process. About 80% of total volumetric change and 50% of total vertical change occurred in the central linear portion of the S-shaped curve.

Tawfiq and Nalbantoglu (2009) investigated the difference between full swell-full shrinkage and full swell- partial shrinkage. In full swell- partial shrink behavior, soils were dried down to initial moisture content during shrinkage process. A thermocouple was inserted in to the soil to keep the sample at constant temperature throughout the drying process. For one full swell-partial shrinkage was to be completed, a combination of 4 days swelling and 3 days shrinkage were needed. For one full swell-full shrinkage was to be completed, a combination of 4 days swell and 8 days shrinkage were needed. In full swell-full shrinkage process, soils were dried down to the shrinkage limit during shrinkage process. The swelling subjected to full swell-full shrinkage was higher than the full swell- partial shrinkage. It was because more water was absorbed and more micro cracks were developed. The development of the cracks enabled the more water to enter the micro cracks of the soils and increased the swell.

2.2 EFFECT OF AGING ON SWELL-SHRINK BEHAVIOR

Rao and Tripathy (2003) investigated that the swelling potential decreased due to aging. For that, compacted specimen was aged for different predetermined days and kept in glass dessicators containing sulphuric acid of different concentrations representing different relative humidities.Aging effects increased with the increase in the water content for the same dry density.

Aging became more with the increase in degree of saturation at same water content.Initial degree of saturation and water content were thetwo factors that significantly affect the aging process. The effect wasmore pronounced around optimum water content and maximum dry density of the soil.The cyclic swell-shrink test on the aged specimen indicated thatthe effect of aging was eliminated when soils were shrunkmore, but were found to persist for specimens subjected to lower shrinkage magnitudes.

2.3 SUMMARY AND SCOPE OF THE STUDY

It can be observed from the studies that the swell-shrink test of the expansive soils attains equilibrium after 4-5 cycles. On equilibrium, the structures of the soils arealmost disoriented. Swelling potential decreases with the aging. Also the study shows that there is no effect of lime and ash on the swell-shrink behavior of the soils. The effect of the lime and ash lost due to continuous cycles of wetting and drying. The swelling of the expansive soils decreased when the soil was treated with salt.

However, so far rare attention has been given to the effects of salts on the swell shrink behavior of soils.Hence, in the present thesis, effect of salt on the swell-shrink behavior of soils is stidiesusing fixed ring Oedometer. The swell shrink cycles is done until equilibrium is attained when vertical deformation due to swelling or shrinkage is same for consecutively two cycles.To check the prolonged effect of salt, microstructure of the soil can be studied using X-Ray diffraction and Energy-dispersive X-ray spectroscopy.

3. METHODS

3.1 SALINITY AND pH

The Salinity and pH were measured by the Salinity meter.It was found that the salinity of the samples decreased with the increase in the depth of the samples. In the Hadaladistry, the increasing order of salinity was as S1 (0 to 1.5 m) < S1 (3.0 to 4.5 m) < S1 (1.5 to 3.0 m). In the Loliyadistry, the increasing order of salinity was as S2 (3 to 4.5 m) < S2 (1.5 to 3.0 m) < S2 (0 to 1.5 m). In the PipliDistry, the increasing order of salinity was as S3 (3 to 4.5m) < S3 (1.5 to 3.0m) < S3 (0 to 1.5m) as show in Table 4.1. This was due to the fact that as the samples were taken from the area nearby sea, so salts get deposited on the top portion of the soils. The salt content decreases with the increase in the depth. Hence, it can be said that top samples contains more salts than bottom ones. S2 (0 to 1.5 m) have the maximum salinity of all the samples i.e. 6350 ppm and S1 (0 to 1.5m) have the least salinity of all the samples.

pH was also measured with the salinity meter. pH of all the samples varies from 7.5 to 9, making all the samples as alkaline.

TABLE 3.1 SALINITY AND pH

Properties		SALINITY (ppm)	pH
S1 (depth in meters)	0 to 1.5 m	2050	8.45
	1.5 to 3.0 m	330	8.70
	3.0 to 4.5 m	608	8.76
S2 (depth in meters)	0 to 1.5 m	6500	7.73
	1.5 to 3.0 m	6350	7.58
	3.0 to 4.5 m	3650	7.46
S3 (depth in meters)	0 to 1.5 m	5700	7.94
	1.5 to 3.0 m	4650	7.88
	3.0 to 4.5 m	2950	8.06

3.2 X-RAY DIFFRACTION

The presence of Calcium chloride in the soils, make the soil saline. This can be verified by X-ray diffraction analysis. X- Ray diffraction tests were performed for the top soils (0- 1.5m Depth) i.e. S1, S2, S3. It can be observed that in the top soils of S1, S2 and S3, there is presence of Calcium chloride ($CaCl_2$).

3.3 EXPERIMENTAL PROGRAMME

Initially all the samples were tested for the physical properties to get the grain size distribution of the samples. Salinity and pH were determined by salinity meter to get the salt content and alkanity in the samples. Compaction characteristics were determined by using Mini Compaction apparatus. Free Swell Index and Swelling Pressure were also determined using Oedometer apparatus. To study the swell-shrink behavior, the samples were subjected to Oedometer test having high swelling pressure alone. After that the same high swelling soils were treated with the samples having high salinity in different ratio and again swell-shrink behavior was analyzed to get the effect of salt. X-ray Diffraction and Energy-dispersive X-ray spectroscopy (EDX) was used to study the mineralogy of the samples containing high salinityand also it was done after the swell- shrink behavior test to check the prolonged effect of salt.

4 METHODOLOGY

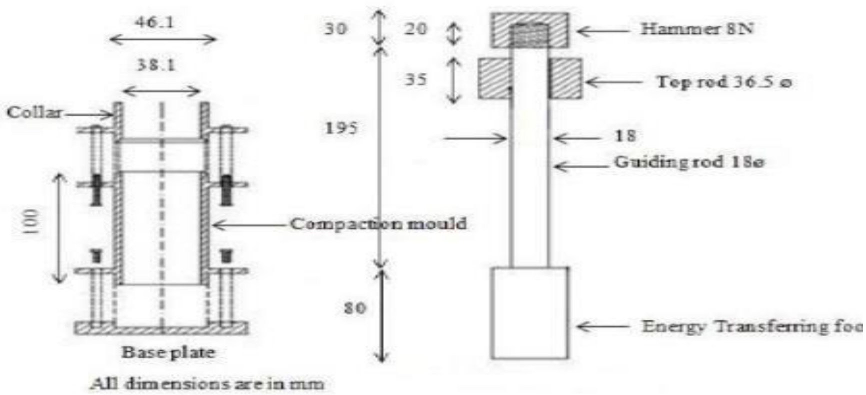

FIG- 4 MINI COMPACTOR

In this study mini compaction apparatus was used to study the compaction characteristics of the soil. Line diagram of the mini compaction apparatus is shown in Fig 3.8. It consists of an iron mold and a steel drop hammer with guide frame. The sample mold is of 3.81 cm internal diameter and 4.61 cm external diameter and 10 cm in height. The sample mold assemble has a detachable base plate and a removable collar 3.50 cm height. The hammer assemble consists of a guiding frame and drop weight. The guiding frame consists of three detachable portions: top, middle and bottom. The guiding frame is such that the dropping weight is a floating weight between the bottom of the top portion and top of the bottom portion. The bottom portion of the guiding rod is 3.0 cm long and 3.65 cm in diameter. The vertical rod in the middle portion acts as bore guide for the hammer. The height of free fall was 16 cm, over the energy tranferring foot. In mini compaction, bulging is avoided with the help of energy transferring foot, higher side wall friction and lesser impact on soil making it denser. For each compaction test about 200 gm of soil was used. Required amount of water was added to the soil and mixed thoroughly. The mixed soil is stored in a polythene bag for moisture equilibrium. After which the sample is remixed thoroughly with help of metal ruler

4.1FREE SWELL TEST

This test determines the free swell index of soil that helps identifying the potential of a soil to swell. It is conducted in accordance with the IS: 2720 (part XL) – 1977. 10 gm of oven dried soil was placed in a graduated glass jar of 100 ml capacity and was filled with water. Similarly, 10 gm of soil was poured to another glass jar and was filled kerosene. Readings were taken at intervals until the volume change of the specimen stabilized. The free swell index was calculated from the following formula.

FSI = (Vw-Vk)/Vk *100

Wherein Vw and Vk are the volume of soil mass in water and kerosene after stabilization reached.

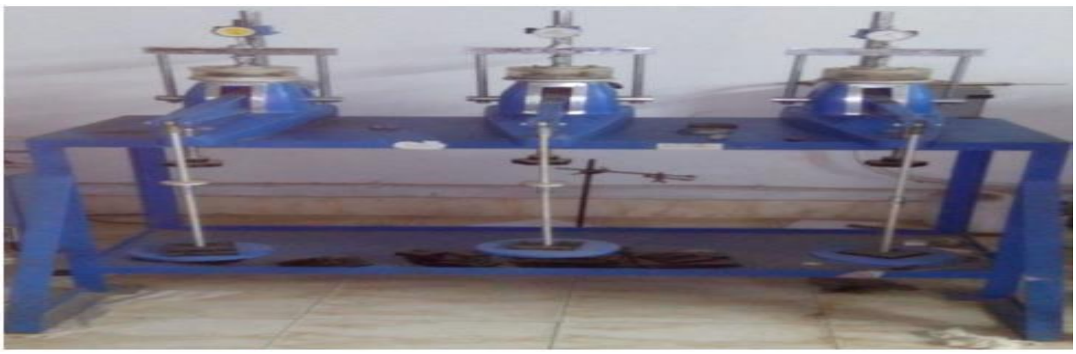

Figure 3.11 Oedometer apparatus

It consists of a ring either floating or fixed with porous stone on both face of the sample. It has a means for providing vertical load, submerging samples and for measuring change in the thickness of the specimen. Suitable provision was made to enable the dial gauge to be fixed in such a way that dial gauge accurately measured the vertical expansion of the soils. The ring has a diameter of 60 mm and height of 20 mm.

4.2 EDX

Energy-dispersive X-ray spectroscopy (EDX) is an analytical technique used for the elemental analysis or chemical characterization of a sample. It is an additional feature of Scanning Electron Microscopy (SEM) which produces the image of the sample by scanning it by beam of electron. Analytically by using X-ray radiation to get the information about the mineralogy of the materials.In this method X-rays are released as a result of the electron beam interactions with the sample

5. RESULT AND DISCUSSION

5.1 SWELL-SHRINK BEHAVIOR

Swell-shrink behavior was performed on S1 (3.0 to 4.5 m), S2 (3 to 4.5 m) and S3 (3 to 4.5m) as these samples have high Swelling pressure. Initially S1 (3 to 4.5 m) was performed with swell shrink behavior and it was found that the swelling of the soil increased slowly as the number of cycles increased and attained equilibrium after two cycle. After first swell shrink cycle, the development of cracks imbibed more water and thus increased the swell. Similarly, the shrinkage decreased after first cycle and then became constant after second cycle. Shrinkage was commenced at the load of $50kN/m^2$. Since all the top soils (0 to 1.5m) of S1, S2 and S3 have high salinity in comparison to their bottom soils (3.0 to 4.5m). So, the top soils were mixed with bottom soil of their respective sample in the different ratio. The swell-shrink behavior was performed on mixture of bottom soils of S1 with top soils of S1 in the ratio of 3:1 and 1:1. It was observed that vertical deformation of mixture of top and bottom soils after attained of equilibrium was less than that of bottom soils alone. Similar trends were observed in with S2 and S3.

There is decrease in the swell-shrink behavior of the samples when the test is performed with the soils having high salinity. As the ratio of top soils increases in bottom soils, vertical deformation decreases. This may be due to the reason that the top soils have high salinity which made the soils to swell and shrink less

5.2 MICROSTRUCTURE ANALYSIS

The bottom soils were treated with the top soils and subjected to 6 cycles of drying and wetting. From the XRD analysis of soils after treatment, it was observed that there was still presence of Calcium chloride ($CaCl_2$) in the treated soils as presented in the figure 4.13 to figure 4.15. Hence it can be assumed that Calcium chloride ($CaCl_2$) as a salt has a prolonged effect on the treated soils. But after the treatment of the top samples with bottom samples at 1:1 and1:3 ratio, Calcium (Ca^{++}) can be observed. So, from the result of XRD and EDX, it can be observed that Calcium chloride was present after the swell-shrink test.

6. SUMMARY AND CONCLUSION

6.1 SUMMARY

The index properties were determined for all the samples. Compaction properties were determined by Mini Compaction apparatus. Salinity and pH were analyzed by Salinity meter. Swelling pressure and Free swell index was also determined for all the samples. Swell-shrink behavior were performed on the bottom soils of S1, S2 and S3 alone and with the treatment of bottom and top soils in the ratio of 1:1 and 3:1 at the surcharge pressure of $50kN/m^2$ during the shrinkage process. X-ray Diffraction and EDX was done on the top samples of S1, S2 and S3. They were also done after the swell-shrink test of the samples.

6.2 CONCLUSIONS

- From the studies it is found that, Free Swell Index Swelling pressure increases with the depth. As the salinity is high in top soils, hence it reduces the double layer thickness and adsorption capacity of the soils. So less amounts of water imbibes into the soils which make it less swell as compared to the bottom soils having less salinity.
- From the swell-shrink behavior study it is observed that S1, S2 and S3 attains equilibrium after four consecutive cycles with a surcharge pressure of 50 kN/m2 . However, after the mixing of bottom soils with top soils in the ratio of 3:1 and 1:1, it is seen that when the ratio of top soils on the bottom soils increases, the vertical deformation during swelling and shrinkage decreases. Hence, the equilibrium attained have also less range.

- XRD and EDX analysis of the top samples shows the presence of the Calcium Chloride. Also after the treatment of bottom samples with the top sample on the swell-shrink behavior, the presence of Calcium Chloride as salt is confirmed by XRD and EDX analysis. This shows the prolonged effects of Calcium Chloride in the soils after 6 cycles of wetting and drying.

6.3 FUTURE SCOPE

- In the present test, swell-shrink behavior was commenced at the constant pressure of 50kN/m^2 during the shrinkage process. This can also be commenced at different surcharge pressure such as 25, 100 and 200kN/m^2 to get the effect of load on the behavior of salt over soil.

- Also the swell-shrink behavior can be done at constant temperature by using thermocouple during the shrinkage process.

7. REFERENCES

1) IS 2720- Part-X -1977 (Reaffirmed 2002) "Determination of Free Swell Index of Soils". Method of test for soils.

2) IS 2720-Part-XLI-1977 (Reaffirmed 2002). "Measurement of Swelling pressure of Soils". Methods of test for soils.

3) IS 2720-Part-XXVII-1977 (Reaffirmed 2006) "Determination of total soluble contents". Method of test for soils.

4) Guneya, Y.,Sarib, D., Cetinc, M. and Mustafa, T (2007)."Impact of cyclic wetting–drying on swelling behavior oflime-stabilized soil", Building and Enviroment, Vol 42, pp 681-688.

5) Rao, K.S.S and Tripathy, S. (2003). "Effect of Aging on Swelling and Swell-Shrink Behavior of a Compacted Expansive Soil",Geotechnical Testing Journal, Vol. 26, No. 1.

6) Rao, S.M., Reddy, B.V.V and Muttharam, M (2001)."The impact of cyclic wetting and drying on the swelling behavior of stabilized expansive soils", Engineering Geology, Vol 60, pp.223-233.

7) Rao, S.M., Reddy, B.V.V and Muttharam, M (2001)."The impact of cyclic wetting and drying on the swelling behavior of stabilized expansive soils", Engineering Geology, Vol 60, pp.223-233.

8) Basma, A.A., Al- Homoud, A.S., Malkawi, A.I.H and Al Bashabsheh, M.A (1996)."Swelling Shrinkage behavior of natural expansive clays".Applied Clay Science 11 211-227.

9) Belabbaci, Z., Mamoune, S.M.I and Bekkouche, A (2013)."Laboratory Study of the Influence of Mineral Salts on Swelling (KCl, MgCl2)", Canadian Center of Science and Education. Earth Science Research,Vol. 2, No. 2.

10) Dif, A.E. and Bluemel, W.F (1991)." Expansive Soils under Cyclic Drying and Wetting," Geotechnical Testing Journal, GTJODJ, Vol 14, No. 1, pp.96-102.

11) Tawfiq, S., and Nalbantoglu, Z (2009). "Swell Shrink behavior of expansive soils" 2nd International Conference on New Developments in Soil Mechanics and Geotechnical Engineering, 28-30 May 2009, Near East University, Nicosia, North Cyprus.

12) Tripathy, S., Rao, K.S.S and Fredlund, D.G (2002)."Water content-void ratio swell shrink path of compacted expansive soils", Canadian Geotechnical Journal.39: 938–959.

13) Jones, D. E., and Holtz, W. G. (1973), Expansive soils – the hidden disaster. Civil Engineering- ASCE, 43(8), 49-51 .

14) Shah, V.A., Shrivastav, M.B., Gandhi, H.M., RAmanuj, P.S and Chudasama, M.K (2015)."Irrigation Strategy in Bhal area (A Casestudy of Bhal Area)", International Journal for Scientific Research & Development, Vol. 3, Issue 01

15) Sridharan, A., Sivapullaiah, P.V (2004). "Mini Compaction Test Apparatus for Fine Grained Soils". Geotechnical testing Journal, Vol. 25, No.2, 199-209.