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INFLUENCE OF SOIL SUCTION ON SWELL-SHRINK BEHAVIOUR OF EXPANSIVE SOIL

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ABSTRACT: The relationship between suction and swell-shrink behaviour of soil is important in various geotechnical issues. This paper describes the effect of initial compaction water content on soil suction and influence of suction variation on volumetric behaviour of soil. Suction measurement was done by Filter paper method. A series of volumetric shrinkage tests and swell tests were conducted on samples with various water contents. The study brings out the observation that the volumetric shrinkage possesses higher magnitudes at lower suction which means largest magnitudes of volumetric shrinkage were obtained at wet of optimum water content than dry side of optimum. Swelling of soil gets increased with increase in suction value.

INTRODUCTION

Most of the construction works are carried out in soil located above ground water table which is generally unsaturated in nature, possess negative pore water pressure. Behaviour of such soil is not consistent with the concepts of classical saturated soil mechanics. The behaviour of unsaturated soil is greatly influenced by the change in soil suction which is the difference between the pore water pressure and pore air pressure. Suction is a function of many factors such as degree of saturation, compaction conditions such as compaction water content, compaction effort, dry density etc. Due to variation in these factors the suction gets changed and thus the soil suction is of primary interest in many engineering problems. Expansive soil is highly problematic due to their high volume changes and the detrimental volume change is an important parameter in geotechnical engineering which is significantly affected by variation in suction. The relationship between suction and swell – shrink behaviour of soil is thus important to address various geotechnical issues related to construction of pavement, foundation etc.

A number of suction measurement techniques are there in the field of engineering including Tensiometers, Relative Humidity sensors, Filter paper method etc. Most of these instruments have limitation with respect to range of measurement, time required for equilibration and cost. So a method which overcomes the above disadvantages has to be selected. Filter paper method is one of the laboratory suction measurement technique which cover full range of suction in a routine basis and is inexpensive and relatively simple. Both total and matric suction can be measured using this method.

This paper describes the study on the effect of initial compaction water content on both dry side and wet side of optimum on soil suction and the influence of variation in soil suction on the swell and shrink behaviour of the selected soil. For this the samples was prepared at nine initial compaction water content ranging from 2% to 10% of OMC on dry side and wet side of optimum. The influence of initial compaction water content on soil suction was also studied at different compaction efforts. For this reduced compaction, Standard proctor test and Modified proctor test were carried out in laboratory. The suction measurement was done by the Filter paper method using Whatman no.42 filter paper. The calibration curve was developed using NaCl salt solution at different concentration. A series of volumetric shrinkage and swell tests were conducted on samples with the above water contents and suction measurements were made.

EXPERIMENTAL STUDY

Materials Used

The soil used for this study was sandy silt collected from Coimbatore, Tamil Nadu at an average depth of 1 m from the ground level and it was blackish in colour. In order to study the swelling characteristics of soil, it was made expansive by the addition of 10% of Bentonite. Original soil was identified as inorganic clays of high plasticity (CH) from particle size analysis and Atterberg limits. Laboratory tests were performed on both natural soil and natural soil mixed with 10% bentonite (SB10) inorder to determine their properties. The properties of the soil were determined and are listed in Table 1.

Table 1 Properties of soil

Properties	Values
Specific gravity	2.56
Liquid limit(%)	68
Plastic limit(%)	34
Plasticity index(%)	34
Shrinkage limit(%)	15
Clay(%)	44

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Silt(%)	22
Sand(%)	34
Maximum dry density(g/cc)	17.2
Optimum moisture content(%)	19.54

According to ASTM D 5298 ash-free, quantitative type 2 filter paper must be used for suction measurement. Whatman No.42 Filter Paper is such a filter paper which is purchased from Chemind chemicals, Thrissur. Each filter paper has a diameter of 11cm. Sodium Chloride was used for the Calibration of filter paper and it was in powdered form and of laboratory quality. It was purchased from Chemind chemicals, Thrissur. Weighing balance of 0.0001g sensitivity was used for the measurement of filter paper water content

Suction Measurement

A thermodynamic relationship exists between total suction and relative humidity results from a specific concentration of salt in solution. Different salts such as NaCl, KCl etc., can be used for total suction calibration. In this study Sodium Chloride was used for the Calibration of filter paper.

Calibration of Filter Paper by Relative Humidity Method

Initially NaCl solutions were prepared from 0 to 2.7 molality. A 250 ml plastic jar was filled with 150 ml of a solution of known molality of NaCl. A small wire loop was then inserted into the plastic jar to function as a support for filter paper and filter paper was put on the wire loop. The plastic jar lid was sealed tightly with plastic tapes to ensure air tightness.Same procedure was repeated for each different NaCl concentration. After two weeks of equilibrating time weight of filter paper was noted. Weight of dry filter paper was also noted.From the estimated filter paper water content, total suction can be calculated and calibration curve was plotted

Non Contact Filter Paper Method for Total Suction Measurement

Initially 75% by volume of a plastic jar is filled up with the soil. The soil sample was extruded from the compacted specimen by means of a PVC pipe. The sample was 5cm in diameter and 8cm in height so as to occupy the plastic jar of 10cm diameter and 13cm height. A ring type support, which has a diameter smaller than filter paper diameter and about 1 cm in height, is put on top of the soil to provide a non-contact system between the filter paper and the soil. Filter paper was inserted on the ring using tweezers. Plastic jar lid is sealed very tightly with plastic tape. After minimum equilibrating period of one week weights of wet filter paper taken very quickly. From the estimated filter paper water content, total suction is obtained from the calibration curve.

Volumetric Shrinkage Test

When a soil dries, its volume gets decreased which is known as the shrinkage. Due to internal stress on dried and shrunken soil mass, dessication cracks will be developed in the preexisting planes of weakness within the soil mass. As a result of shrinkage, the soil reduces its strength and stability. So, there is a need of investigating the effect of soil suction on volumetric shrinkage of soil at different initial compaction water content varied from dry side to wet side of optimum. The soil samples (SB10) were prepared at constant dry density of 17kN/m3 for both reduced and standard proctor test. The dry density of modified proctor test was kept fixed as 19kN/m3. The samples were prepared in standard proctor mould of 10cm diameter and 12.7cm height. For volumetric shrinkage test under reduced and standard proctor test the mould was filled with sample at particular water content in three layers. Each layer being compacted with 15 numbers of blows for reduced compaction and 25 numbers of blows for standard proctor test. For volumetric shrinkage test under modified standard proctor test the mould was filled with sample at particular water contents in three layers. Each layer being compacted with 56 numbers of blows. The volumetric shrinkage tests were carried out as per IS standards. After compacting the samples were extruded as such with the help of sample extruder and allow air drying. The change in height and diameter of the samples were then measured until they become constant. Volumetric shrinkage of samples was then calculated.

Swelling Test

The soil samples (SB10) were prepared at constant dry density of 17kN/m3 for both reduced and standard Proctor test. The dry density of modified Proctor test was kept fixed as 19kN/m3. The samples were prepared in standard Proctor mould of 10cm diameter and 12.7cm height. Two porous stones were provided at the top and bottom of mould in order to make the water assess. The mould was then inserted into the soaking tank of swell pressure test apparatus and then the tank was filled with water. Pressure was not applied during the test. Dial gauge was inserted to the top of the mould. Dial guage reading was then taken at various time intervals. The effect of suction on swelling characteristics of soil were studied under three compactive efforts such as reduced compaction, standard Proctor test and modified Proctor test.

RESULTS AND DISCUSSIONS

Effect of Initial Water Content on Soil Suction

For many civil engineering structures, the initial compaction water content controlled at particular value. This variation in initial compaction water content has strong impact on soil suction. So, there is a need of investigation which reveals the effect of variation in initial compaction water content on soil suction which will help to identify the suction effect on different structures at particular as compacted water content. Variation of suction with initial water content was shown below.

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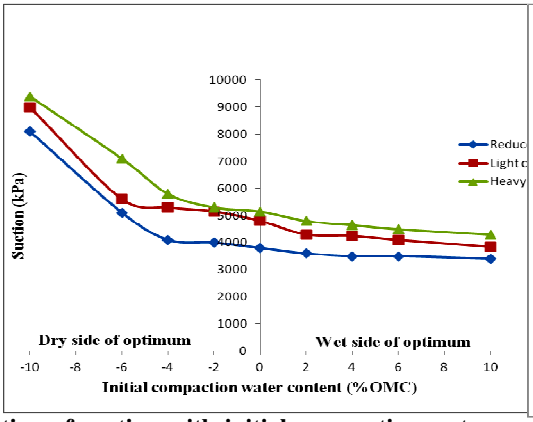

Fig. 1 Variation of suction with initial compaction water content

The relationship between initial compaction water content and soil suction indicates that the suction get reduced as the initial compaction water content increases from dry side of optimum to wet side of optimum. This trend was similar for all the three compactive efforts. This trend is attributed to the soil structure that present in dry side of optimum and wet side of optimum.

Variation of Volumetric Shrinkage of Soil with Suction

After compacting the samples were extruded as such with the help of sample extruder and allow air drying. The change in height and diameter of the samples were then measured until they become constant. Volumetric shrinkage of samples was then calculated. The results of effect of suction on volumetric shrinkage of samples under different compactive efforts were as shown below.

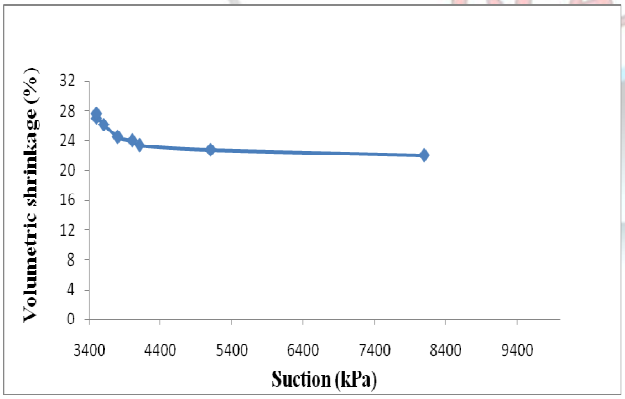

Fig. 2 Effect of suction on volumetric shrinkage under reduced compaction

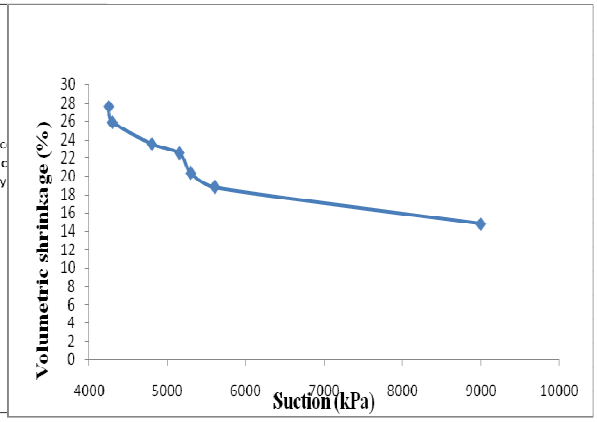

Fig. 3 Effect of suction on volumetric shrinkage under light compaction

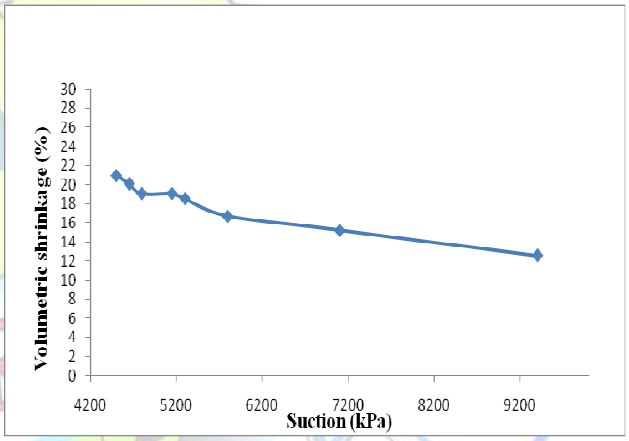

Fig. 4 Effect of suction on volumetric shrinkage under heavy compaction

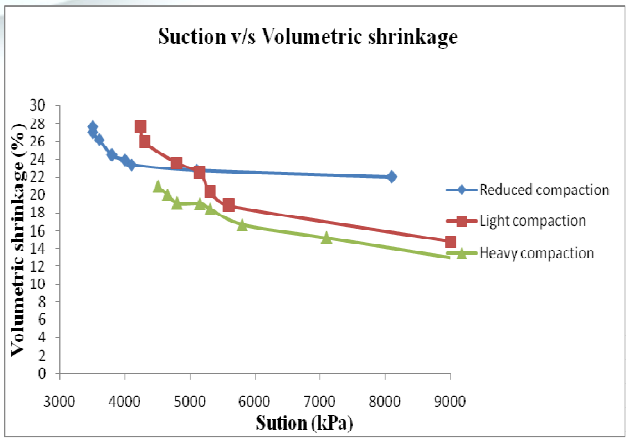

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Fig. 5 Effect of suction on volumetric shrinkage under different compaction efforts

The results indicate that with increase in suction value, the volumetric shrinkage gets reduced. Because an increase in suction value indicates that the water is held with high force of attraction within the soil and the chance of loss of water from the soil is less when the soils possess a high suction. So, the structural damages due to volumetric shrinkage found to be less on dry side of optimum water content since dry side of optimum water content has high suction value. The trend was similar for all the three compactive efforts under varying suction.

Variation of Swelling Characteristics of Soil with Suction

The effect of suction on swelling characteristics of soil were studied under three compactive efforts such as reduced compaction, standard Proctor test and modified Proctor test. The results of effect of suction on swelling characteristics of samples under different compactive efforts were as shown below.

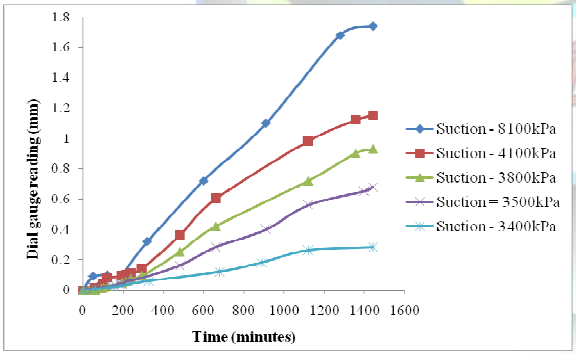

Fig. 6 Effect of suction on swelling of soil under reduced compaction

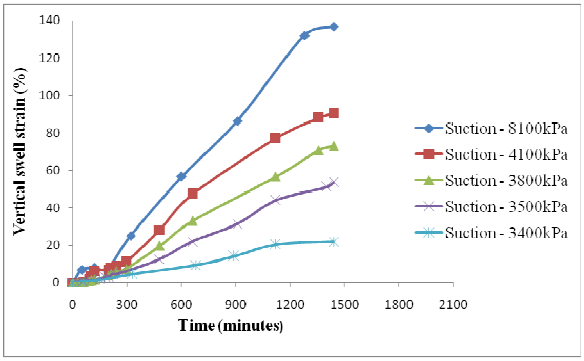

Fig. 7 Variation of vertical swell strain with suction under reduced compaction

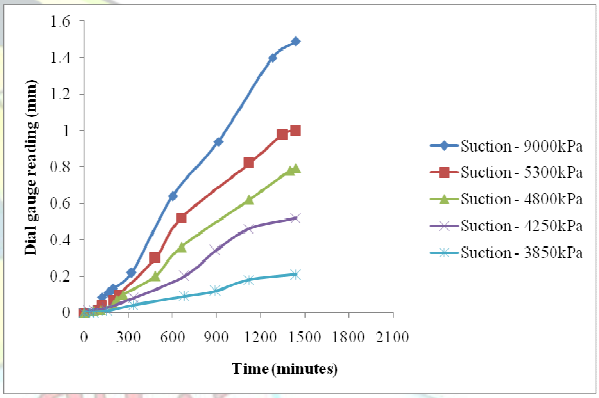

Fig. 8 Effect of suction on swelling of soil under light compaction

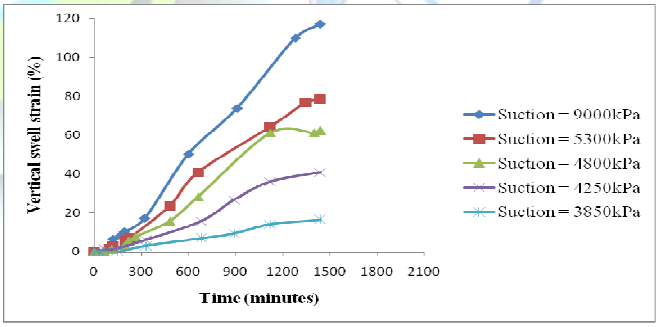

Fig. 9 Variation of vertical swell strain with suction under light compaction

The results indicate that with increase in suction value, the swelling of soil gets increased. Because at high suction the available water is held with high force of attraction within the soil and the ability of soil to attract more water is also high. So, the swelling characteristics of soil is high in dry side of

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optimum water content than wet side of optimum water content since dry side of optimum water content has high suction value and more ability to attract water. The trend was similar for all the three compactive efforts under varying suction.

CONCLUSIONS

- The volumetric shrinkage possess higher magnitudes at lower suction which means largest magnitudes of volumetric shrinkage were obtained at wet of optimum water content than dry side of optimum water content.
- The soil has a volumetric shrinkage of 28.14% at 10% of OMC at wet side of optimum having a suction of 3400kPa and the volumetric shrinkage get reduced to 22% at 10% of OMC at dry side which possess a suction of 8100kPa under reduced compaction.
- In case of light compaction, the soil has a volumetric shrinkage of 27.98% at 10% of OMC at wet side of optimum having a suction of 3850kPa and the volumetric shrinkage get reduced to 14.79% at 10% of OMC at dry side which possess a suction of 9000kPa.
- The soil has a volumetric shrinkage of 22.31% at 10% of OMC at wet side of optimum having a suction of 4300kPa and the volumetric shrinkage get reduced to 12.57% at 10% of OMC at dry side which possess a suction of 9400kPa under heavy compaction.
- Swelling of soil gets increased with increase in suction value.
- Swelling characteristics of soil is high in dry side of optimum water content than wet side of optimum water content since dry side of optimum water content has high suction value and more ability to attract water. The trend was similar for all the three compactive efforts under varying suction.

REFERENCES

1. Agus, T.S., Kabul, B.S., Ahmad,R., and Indrasurya, B.M. (2011).“The Effect of Water Content Change and Variation Suction in Behavior Swelling of Expansive Soil.” International Journal of Civil & Environmental Engineering. Vol.11(3), pp.11-17.
2. Agus, T. S., Sudjianto, M., Cakrawala. (2012). “The Effects of Water Contents on Free Swelling of Expansive Soil .” International Journal of Civil & Environmental Engineering IJCEE-IJENS, Vol.12(6), pp :13-17.
3. Anand, J., Puppala, P.E., and Koonnamas Punthutaecha. (2006). Soil-Water Characteristic Curves of Stabilized Expansive soil.” Journal of Geotechnical and Geoenvironmental Engineering, 132(6), 736-751.
4. ASTM D5298-03, 2007, “Standard Test Methods for Measurement of Soil Potential (Suction) Using Filter Paper,” Annual Book of ASTM Standards, Vol. 04.08, ASTM International, West Conshohocken, PA, 6p.
5. ASTM E104-02, 2007, “Standard Practice for Maintaining Constant Relative Humidity by Means of Aqueous Solutions,” Annual Book of ASTM Standards, Vol. 11.07, ASTM International, West Conshohocken, PA, 5p.
6. M Estabragh, A., Javadi, A. (2012). “Effect of Suction on Volume Change and Shear Behaviour of an Overconsolidated Unsaturated Silty Soil.” Journal of Geomechanics and Engineering, Vol. 4(1), 55-65.
7. Sreedeep, S., Malaya, C. (2011), “Evaluation of Estimated Suction-water Content Relationship for a Locally Available Soil.” Proceedings of Indian Geotechnical Conference, Kochi (Paper No. L-001).
8. Sreedeep, S., and Malaya, C. (2013). “Comparison of Suction Measurements Using Two Low Cost Measuring Methodologies.” Proceedings of Indian Geotechnical Conference, Roorkee.
9. Sreedeep, S., and Malaya, C. (2013). “A Laboratory Procedure for Measuring High Soil Suction.” Geotechnical Testing Journal, Vol.34(5).
10. Sreedeep, S., and Singh, D.N. (2005). “A Study to Investigate the Influence of Soil Properties on Suction.” Journal of Testing and Evaluation., Vol.33, pp1-6.
11. Sreedeep, S., and Singh, D.N. (2011). “Critical Review of the Methodologies Employed for Soil Suction Measurement.” International Journal of Geomechanics, Vol.11, pp.99-104