A STUDY ON EFFECT OF SOIL SUCTION ON SHEAR STRENGTH OF FINE GRAINED SOIL

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ABSTRACT

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 unsaturated soil zone refers to the geologic media which lie below ground surface but above the water table. 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, also termed as the negative pore water 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. Shear strength is an important parameter in geotechnical engineering which is significantly affected by variation in suction. The relationship between suction and shear strength of soil is important to address various geotechnical issues related to construction of embankment, fill etc. The engineering behaviour as well as stability of unsaturated soil is difficult to understand and is strongly affected by the state of soil with variation in suction.

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 unconfined compressive strength 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 unconfined compressive strength tests were conducted on samples with the above water contents and suction measurements were made.

The study brings out the observation that the soil suction decrease with increase in initial compaction water content. Suction is found to be higher on the dry side of optimum water content and it goes on decreasing towards the wet side of optimum. The unconfined compressive strength of soil increases with increase in suction value. The soil possesses high unconfined compressive strength at 10% of OMC on dry side of optimum with a suction value of 5300kPa and it goes on decreasing as the suction decreases towards the wet side. The trend was found to be similar for all the three compaction efforts.

Keywords: Filter paper method, Initial compaction water content, Suction, Unconfined compressive strength, Unsaturated soil
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ABSTRACT: The relationship between suction and shear strength 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 unconfined compressive strength of soil. Suction measurement was done by Filter paper method. A series of unconfined compressive strength tests were conducted on samples with various water contents. The study brings out the observation that soil possesses high unconfined compressive strength at 10% of OMC on dry side of optimum and decreases as suction decreases towards wet side. The trend was similar for all compaction efforts.

INTRODUCTION

Behaviour of unsaturated soil is not consistent with the concepts of classical saturated soil mechanics and is greatly influenced by the change in soil suction which is the difference between the pore water pressure and pore air pressure. Compaction conditions such as compaction water content and compaction effort are important factors that affect soil suction. Due to variation in these factors the suction gets changed which significantly influence the properties of soil and thus the soil suction is of primary interest in many engineering problems.

A number of suction measurement techniques are there in the field of engineering. Most of the 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.

Thus in the present study, 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 unconfined compressive strength of the selected soil was examined. 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 unconfined compressive strength tests were conducted on samples with the above water contents and suction measurements were made.

A locally available fine gained soil was selected in this study. 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. The results of effect of suction on unconfined
compressive strength of soil indicate that the unconfined compressive strength increases with increase in suction value. This is because the increase in negative pore water pressure act as a confining pressure for soil and it hold the soil particle together which inturn increases the strength of soil.

EXPERIMENTAL STUDY

Materials Used

Soil used for the study was sandy silt collected from Coimbatore, Tamil Nadu at an average depth of 1 m from the ground level. The soil was initially air dried in open atmosphere before the commencement of experiments. The soil was characterized for its specific gravity, grain size distribution, liquid limit and plastic limit and is listed in Table 1.

<table>
<thead>
<tr>
<th>Properties</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific gravity</td>
<td>2.56</td>
</tr>
<tr>
<td>Liquid limit(%)</td>
<td>68</td>
</tr>
<tr>
<td>Plastic limit(%)</td>
<td>34</td>
</tr>
<tr>
<td>Plasticity index(%)</td>
<td>34</td>
</tr>
<tr>
<td>Shrinkage limit(%)</td>
<td>15</td>
</tr>
<tr>
<td>Clay(%)</td>
<td>44</td>
</tr>
<tr>
<td>Silt(%)</td>
<td>22</td>
</tr>
<tr>
<td>Sand(%)</td>
<td>34</td>
</tr>
<tr>
<td>Maximum dry density(g/cc)</td>
<td>17.2</td>
</tr>
<tr>
<td>Optimum moisture content (%)</td>
<td>19.54</td>
</tr>
</tbody>
</table>

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.

EXPERIMENTAL PROGRAMME

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.
Unconfined Compression Test

Unconfined compression tests were conducted as per IS 2720 (Part-10)-1973. Unconfined compression test were done on soil samples prepared at various water contents corresponding to dry side and wet side of optimum of reduced compaction test, standard Proctor test and modified Proctor test. Unconfined compressive strength (UCS) tests were conducted with the main intention of determining the variation in shear strength of soil due to variation in suction. The soil samples were prepared at constant dry density of 17kN/m$^3$ for both reduced and standard Proctor test with varying water content corresponding to dry side and wet side of optimum. The dry density of modified Proctor test was kept fixed as 19kN/m$^3$. The soil samples were prepared using a UCC test mould of 7.6cm height and 3.8cm diameter. UCC tests were conducted and the readings were noted. The unconfined compressive strength of samples was then obtained from the stress-strain curve.

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. For example, in case of embankment such as rock embankment, embankment on hill side and slope, embankment over existing roads etc the moisture content is controlled within -2% and 1% of optimum moisture content. In the construction of earth fill dams, the material forming the embankment should be placed with sufficient moisture and the moisture content should be in the range of -1% to 3% of optimum moisture content. 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 compactive efforts. Variation of unconfined compressive strength with suction

Depending upon type of soil and nature of construction work, different compactive efforts were used in the field of civil engineering. The suction of a soil gets changed with variation in compactive efforts. So, there is a need of investigation which reveals the effect of variation in compactive effort on soil suction which will help to identify the suction effect on different structures at particular as compactive efforts.

![Fig. 1 Variation of suction with initial compaction water content](image1)

![Fig. 2 Unconfined compressive strength Curve at dry side for reduced compaction](image2)
Fig. 3 Unconfined compressive strength Curve at dry side for reduced compaction

Fig. 4 Unconfined compressive strength at dry side of optimum for light compaction

Fig. 5 Unconfined compressive strength at wet side of optimum for light compaction

Fig. 6 Unconfined compressive strength at dry side of optimum for heavy compaction

Fig. 7 Unconfined compressive strength at dry side of optimum for heavy compaction

Fig. 8 Effect of suction on unconfined compressive strength of soil under reduced compaction
The results of effect of suction on unconfined compressive strength of soil indicate that the unconfined compressive strength increases with increase in suction value. This is because the increase in negative pore water pressure act as a confining pressure for soil and it hold the soil particle together which intern increases the strength of soil. On moving from dry side to wet side of optimum moisture content, the water content increases, which reduce the ability of soil to attract more water and the suction, get reduced. The reduction in suction value causes a reduction in the strength of the soil. After a particular value, with increase in the suction value, the unconfined compressive strength of soil becomes almost constant. This may be attributed to the fact that after a particular water content or suction the soil has less ability to attract and hold water. This may be due to almost all voids in the soil may be filled with water and addition of more water didn’t cause any considerable variation in strength of soil.

CONCLUSION
- Soil suction increases with decrease in initial compaction water content.
- Suction was higher in the dry side of optimum water content and it goes on decreasing towards the wet side.
- The unconfined compressive strength of soil increases with increase in suction value.
- The soil possesses high unconfined compressive strength of 104.97kN/m$^2$ at 10% of OMC on dry side of optimum with a suction value of 8100kPa for reduced compaction and unconfined compressive strength decreases to 63.16kN/m$^2$ at 10% of OMC on wet side of optimum with a suction value of 3500kPa
- The soil possesses high unconfined compressive strength of 127.43kN/m$^2$ at 10% of OMC on dry side of optimum with a suction value of 9000kPa for light compaction and unconfined compressive strength of soil decreases to 64.75kN/m$^2$ at 10% of OMC on wet side of optimum with a suction value of 4100kPa
- Under heavy compaction condition, the soil possesses unconfined compressive strength of 243.48kN/m$^2$ at 10% of OMC on dry side of optimum with a suction value of 9400kPa and unconfined compressive strength of soil decreases to 169.91kN/m$^2$ at 10% of OMC on wet side of optimum with a suction value of 4500kPa

This study demonstrates the usefulness of Whatman No.42 filter paper for measuring the suction of a fine grained soil. The behaviour of soil under varying suction is an important aspect to predict the strength and stability of a soil. The tests
presented here can be used to identify the range of compaction water contents that can be adopted, so that the selected soil shows better strength.

REFERENCES


