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Control of Heave Action using Micropile with Geotextile Layer in Expansive Soil

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Abstract. Problematic soil needs great care to deal with, due to their swelling and shrinkage characteristics. Due to moisture variation, the volume of the soil vary accordingly and often its leads to differential settlement on superstructure and foundation. Such a nature of expansiveness of soil leads to create negative skin friction on the pile foundation, which further increased the cost of design and construction. To counteract such arisen problem, we made an extensive effort using an application of the geotextile in the foundation soil beside the traditionally available methods of stabilization by different means. A combined system of geotextile and micropile was tested in a series of the experimental plan with and without geotextile. The present study shows the findings of the extensive research which was carried out for understanding the effectiveness of geotextile micropile system. Field condition was constructed in the laboratory by a model tank. Heave action was examined using the dial gauge reading, and comparison was made with a footing base without micropile. Geotextile was used in the single and two-layer, single at 0.33 B and doubled at 0.33 B and 0.67 B from the footing plate. Test results show that it has a 48 % reduction in heave by using the four micropiles. Further with adding the geotextile layers, it has 63 % and 71 % heave reduction for one and two-layer geotextile, respectively.

Keywords: Expansive soil, Geo-textile, Micropile, Footing, Heave control.

1 Introduction

Some of the partially saturated clayey soil is very sensitive to variation in water content and show excessive volume changes; such soil is classified as expansive soil and exists in many parts of the world. Various places of India, Australia, Africa, Israel, and South America are covered with such soil. Geotechnical engineers around the world face problems associated with expansive soils. It is extended nearly one-fifth of our country, mostly in the states of Maharashtra, Gujarat, Madhya Pradesh, Uttar Pradesh, Rajasthan, Karnataka, Andhra Pradesh, and Tamil Nadu. Expansive soil derives their swelling potential mainly from the properties of the minerals which is present in this type of soil. Any structure located on expansive soil may be subjected to large magnitudes of pressures due to development of swelling pressure when the moisture content of clay increases.

On the other hand, due to decrement in the moisture content of such soil lead to shrinking the volume, which would make an uneven settlement called differential settlement of the foundation. Such a differential settlement can put the negative imprints on the structures such as cracks and deformation sometimes may structure lose their stability and got collapsed. We can reduce economic loss by evaluating a swelling characteristic of the soil before constructing any meaningful structure.

Sometimes the minute to medium soil pressure of expansive soil is adjusted by a dead load of the superstructure, but in many cases, such pressure seems too high which could not adjust by dead load only. In such a case, we must reduce the heave by engineering means. Several methods of heave control were well explored and tested by several researchers including pre-wetting [1,2], replacement of the soil [3], stabilization [4,5], drilled pier foundation [6] and many more. Outcomes of these methods show positive results, but it seems expansive to some extent. At the same time, the immerging trend of geotextile has the great advantage of imparting the strength along with heave control.

In the present research, an extensive effort was made to control the heave using the application of the geotextile. Series of the laboratory experiment was performed on a model tank with and without reinforcement layer. Observation for the only footing plate, footing plate with micropile, micropile with one reinforcement layer and micropile with two reinforcement layers was carried out. Micropile used in this study has its geometry as 200 mm of length and 16 mm of the diameter. Piles were used to put into action in the pattern of the triangular. Piles were used to place in such a way so that each pile has a 140 mm distance from the other two. As the soil expands micropile with footing plate has a tendency to rise mainly due to heaving. However, it has observed that micropile reduces the potential of heaving. In the second stage, the non-woven geotextile of 136 GSM is attached to the micropile with nut and bolt arrangement. This geotextile layer with micropile act as reinforcement in the soil and pushes the soil downward, And act as a heave controller. Outcomes of the research show that the geotextile does not control only heave but also imparting the significant strength to the foundation soil.

2 Aim and Objectives of the Research

The ultimate aim of the research is to control the heave action of the expansive soil. The in-depth objective of the current research includes the i) investigation of the expansive soil and their heave action, ii) Investigation of swelling behaviour of the soil under the pile group, iii) Effect of the geotextile layer on the heave control and iv) comparison of the outcomes.

3 Material Procurement and Test Set-up

3.1 Expansive soil

In this research, the soil under investigation is collected from village Rautela, of Dholera City, Gujarat region of India. Fig-1 shows the location of the Google map from where the soil was procured along with site and oven-dried soil sample. To get an unaltered soil sample, we were used to collecting the soil sample from the depth of 1.5 m from the ground level. The obtained soil was air-dried and pulverized manually.

Fig. 1. Location map of procurement site and own dried soil sample

3.2 Non-woven geotextile

Non-woven geotextile used for control of heaving is procured from the manufacturing company. Specifications of the used geotextile in the research are as listed here in the Table-1. The visual images of the non-woven geotextile are as seen in the Fig-2.

Fig.2. Visual Image of Non-Woven Geotextile used in the research

Table 1. Specification of the Non-Woven Geotextile used in the study

Sr. No.	Properties	Unit	Value
1	Mass Per Unit Area	GSM	136
2	Tensile Strength	KN/m	24
3	Elongation on Specified Tensile Strength	%	22
4	Trapezoidal tearing strength	N	250
5	Puncture Strength	N	200
6	Apparent Opening Size	Micron	75
7	Water Flow Rate	$L/m^2/s$	10

3.3 Fabrication of pile

Fabrications of micropile foundation system were done from the steel plate and bars of required diameter and length. Fabricated system of micropile foundation is as shown in Fig-3.


Fig.3. Fabricated micropile system includes a footing plate with micropile (Left) and footing plate with three micropiles (Right)

3.4 Fabrication of Model Tank

The tank of size 75cmX75cmX75cm is fabricated for the purpose of heave control experimental work. Tank with the arrangement of the frame is as shown in fig 4.

Fig.4. Fabricated model tank along with loading frame

4 Methodology

4.1 Experimental set-up

Experimental set-ups of the tank and pile system along with graphical visualization are as shown here in the Fig-5.

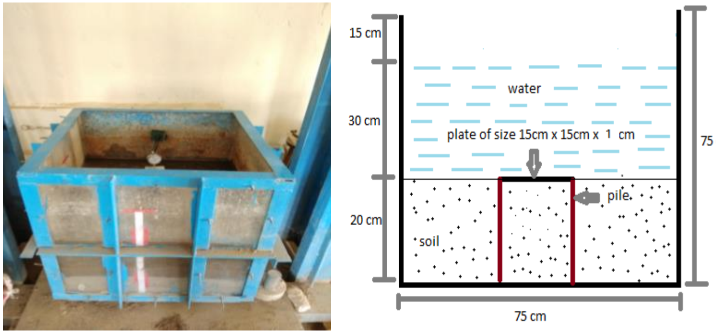

Fig.5. Experimental tank (Left) and Graphical visualization of the tank along with . dimensions (Right)

4.2 Experimental procedure

For experiment purpose, the tank of size 75cm x 75cm x 75cm is used as shown in fig-5, Soil which procured from Dholera region is the first oven-dried for a period of 24hr. Then it is passed through an IS sieve of size 4.75mm, the required amount of water is added to the soil to obtain Optimum Moisture Content and mixed thoroughly, then it is stored in a plastic bag up to a period of 5hr. After this, the soil is placed into the tank to the depth of 20cm in four equal layers of 5cm. Each layer is compacted with the hammer to obtain Maximum Dry Density. Then the group of three micropiles of diameter 16mm with footing plate of size 15cm (L) x 15cm (B) x 1 (H) cm is installed in the soil. Now the remaining 30cm portion of the tank is filled with water. And with the provision of the dial gauge, results are observed at different time interval up to 4 days. Dial gauge arrangement in the model tank during testing and heave action of expansive soil is as well visualized in the Fig-6.

Fig.6. Setup for the heave test with dial gauge arrangement (Left), and Heave action of soil after four days (Right)

4.3 Experimental procedure for micro pile with geotextile

Non-woven geotextile precisely the size of footing is fitted to the micropile with nut and bolt arrangement. First, the experiment is carried out with a single geotextile layer. The layer is fitted to the micropile at 0.33B and in the second stage for double geotextile later it is fitted at a depth of 0.33B and 0.66B, where B is the width of the footing.

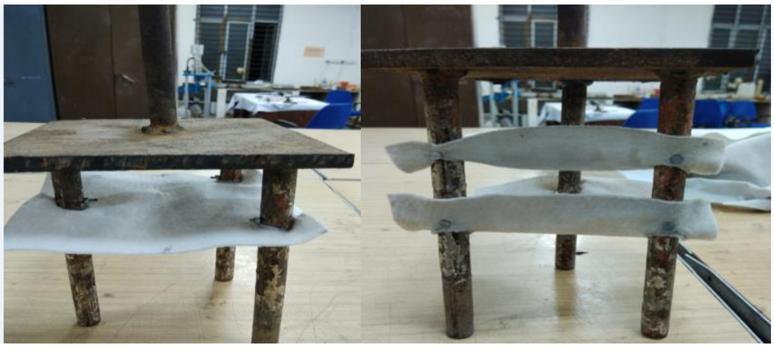

Fig.7. Three Micropile Arrangement with a single and double layer of geotextile

5 Result and Discussion

5.1 Index and Engineering properties of soil

Table 2. Index and engineering properties of expansive virgin soil

Properties	Measured Values	IS Code Referred
Specific Gravity	2.54	IS; 2720(Part-3)-1980
Liquid limit	70 %	IS; 2720(Part 5)-1985
Plastic limit	33 %	IS; 2720(Part 5)-1985
Plasticity index	37 %	IS; 2720(Part 5)-1985
Shrinkage limit	14.57 %	IS; 2720(Part 6)-1978
OMC	26 %	IS; 2720(Part 7)-1980
MDD	14.9 kN/m3	IS; 2720(Part 7)-1980
Free swell index	81 %	IS; 2720(Part 40)-1977
Swell pressure	54.5 KPa	IS; 2720 (Part 41)-1980
Grain size distribution	Clay – 52% &Silt – 48 %	IS; 2720 (Part 4)- 1985

5.2 Results of model test

Test series for heave control was carried out in the laboratory on the model tank, which was fabricated as discussed previously, results for various conditions of a group of micropile and geotextile layer are as described in an upcoming section.

Analysing heaving action on footing plate without any micropile. Here in the first case, only the footing plate is used to know the initial heave action on the footing. Further readings of the experimental work will compare with this initial value of heave. Observation of the test here displayed on heave Vs time plot in Fig-8. Observation shows the 32.4 mm heave on the foundation. The trend of the plot shows that the heave has a tendency to increase gradually and attains its peak at 32.47 mm after 96 hours of time. The reduction in heave can be observed by the formula 1, in percentage reduction in heave.

$$RH(\%) = \frac{\text{Hu} - \text{Hr}}{\text{Hu}} \times 100 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..1$$

Here, Rh (%) stands for percentage reduction in heave; Hu stands for heave of unreinforced soil, and Hr stands for heave of reinforced soil.

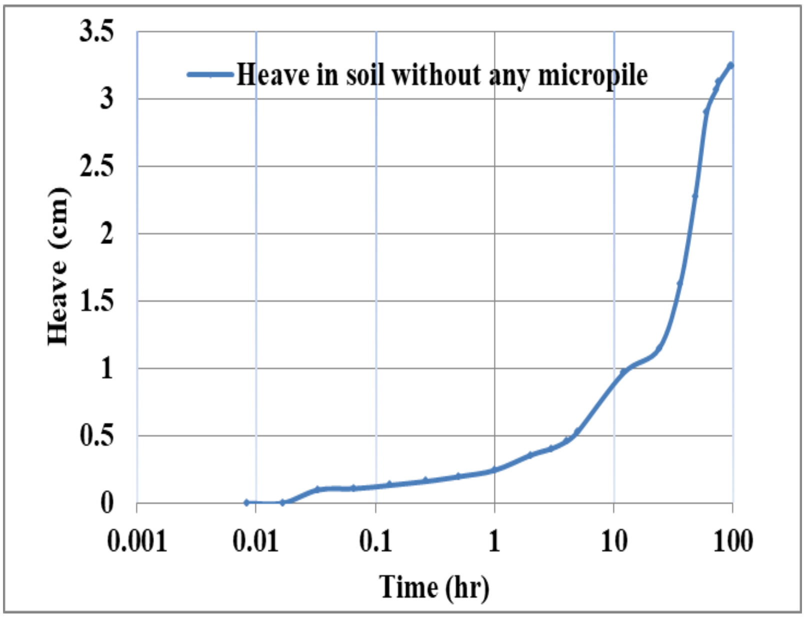

Fig.8. Heave-log time graph for soil without any micropile

Analysing heave action on footing plate with three micropiles in a triangular pattern. Findings of the heave control through micropile in triangulation pattern without attaching any geotextile layer are as shown in the Fig-9. It is observed that there is a 48% reduction in heave by using three micropiles as compared to footing without any micropile.

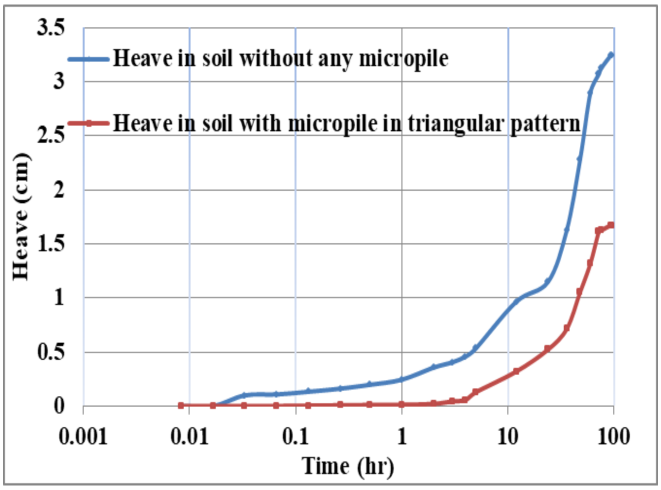

Fig.9. comparison between heave in soil without any micropile and micropile in triangulation pattern

Analysing heave action on footing plate with three micropiles in a triangular pattern and single geotextile layer. Fig. 10 shows the comparison between the heave of soil without any micropile and the single geotextile layer fitted with micropile in a triangular pattern; it is observed that there is a 63% reduction in heave by using Single geotextile layer with micropile.

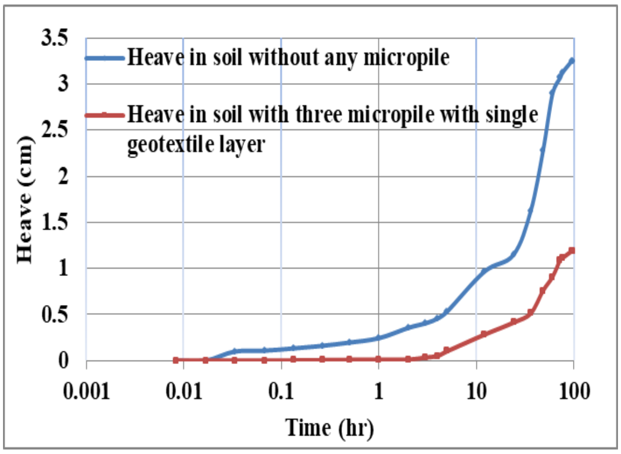

Fig.10. Comparison between heave in soil without any micropile and micropile in triangulation pattern with a single geotextile layer

Analysing heaving action on footing plate with three micropiles in a triangular pattern and double geotextile layer. Fig. 11 shows the comparison between the heaving of soil without any micropile and the double geotextile layer fitted with micropile in a triangular pattern; it is observed that there is a 71% reduction in heave by using double geotextile layer with micropile

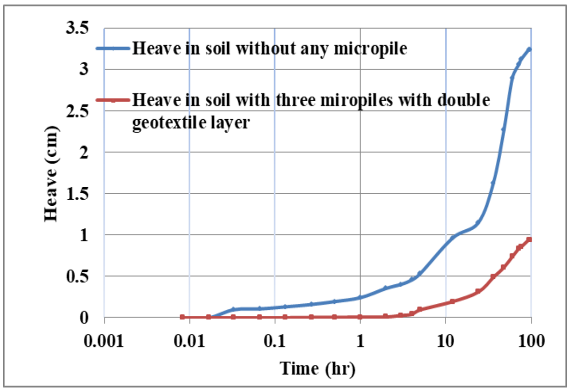

Fig.11. comparison between heave in soil without any micropile and micropile in triangulation pattern with a double geotextile layer

6 Summary of Findings

In this section summary of the complete laboratory experimental series are displayed along with their comparison. Comparisons of the results are as shown in Fig-12. Fig 12 shows that the as micropile inserted in the foundation system it reduces the heave significantly. Besides the micropile, the layer of the geotextiles is also contributing to heave control in an excellent manner.

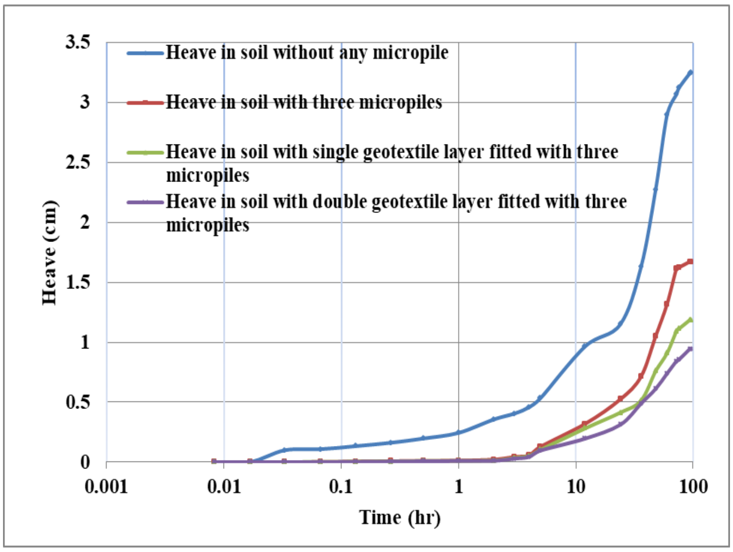

Fig.12. Comparison between all the cases of heave control

Table 3. Summary of the experimental work

Sr No.	Types of Footing	Reduction in heave (%)
1	Soil without micropile	0
2	Soil with three micropile in triangulation pattern	48
3	Soil with three micropile in triangulation pattern and a single layer of geotextile	63
4	Soil with three micropile in triangulation pattern and Double layer of geotextile	71

7 Conclusions

Extensive model-based laboratory test series were conducted to evaluate the effectiveness and performance of micropile and geotextile in reducing the heaving of expansive soil. Based on experimental results, the following conclusions have been drawn.

1. Maximum reduction in heave is observed to be 71% by using three micropile with double geotextile layer.
2. The small increments 8%, is observed in heave control with double geotextile layer as compare to single geotextile layer.
3. Percentage reduction in heave increase with an increase in the number of geotextile layer.

A finding of the research shows that the heave action can be reduced with the help of micropile and geotextile layers. Results of the test series show that the micropile group can reduce 48 % of the heave action on expansive soil; this value has a significant impact for heave control in the expansive soil. Further with adding of the layer of geotextile along with the group of micropile its shows that it gives up to 71% of the heave reduction as compared to only footing without any micropile.

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