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"Performance of Geofoam Micropile System for Controlling Heave of Expansive Soil"

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ABSTRACT : *Expansive soils are considered as highly problematic soil because of the volume change behavior. Several mitigating techniques are available to counteract the problems posed by the expansive soils. This paper presents the results of experimental investigations carried out for understanding the effectiveness of geofoam micropile system, as a new technique to control upward movement of lightweight structures over expansive soils. The performance of geofoam layer under footing, micropiles, single micropile with geofoam layer, four micropiles with geofoam layer and geofoam roughened four micropile with geofoam layer were studied on compacted clay bed and their effectiveness were investigated and compared. Laboratory model heave tests were conducted for simulating the various combinations of the geofoam micropile system with respect to varying D/B ratio and L/B ratio of micropiles. Test results showed that there is considerable reduction in heave by using four micropiles at the corners of the footing along with geofoam layer.*

KEYWORDS:*Expansive soil, geofoam micropile system Heave.*

I. INTRODUCTION

Expansive soils as the name implies undergo volume change in presence of water. These soils increase in volume on absorption of water during rainy seasons and decrease in volume on evaporation of water in summer seasons. Because of this behavior, lightly loaded structures founded on these soils get severely distressed. So it becomes necessary to resist the uplift of the foundation caused due to the swelling behavior of the expansive soils. The uplift of the foundations can be minimized either by modifying the properties of the expansive soils or by adopting special foundation techniques. Lime, cement, fly ash and chemicals are used to modify the properties of expansive soils. Belled pier, under-reamed piles and granular pile anchors are some of the special foundation techniques. Anchors are extensively used for structures subjected to both compressive and tensile forces [1].The effectiveness of micropiles as a technique to control upward movement of a lightweight structure over expansive clay can be improved by using rough micropiles. The effect of micropile diameter and number of micropiles in reducing heave are more pronounced in the case of smooth micropiles [2]. The reduction in upward movement of the footing increases as the number of micropiles increases. There can be a 40% maximum heave reduction in case of four micropiles used in soil. Use of single micropile at the center of footing in expansive soil does not make noticeable reduction in heave [3]. Effectiveness of micropile technique to control heave of a soil can be improved by using micropiles surrounded with sand than the micropile without surrounded by sand. Micropiles are more effective in reducing the upward movement of footing over expansive soil [4]. The swelling pressure can be considerably reduced by placing EPS geofoam above the soil sample. Swelling pressures reduces, as the EPS geofoam thicknesses increases. [5], [6], [7]. In the present study attempt has been made to study the effectiveness of micropile along with Geofoam in expansive soils to reduce the heave of the expansive soils.

II. EXPERIMENTAL INVESTIGATIONS

2.1 Experimental Set up

The experimental setup used for present study is as shown in Fig. 1. The assembly for the model test setup consists of a perforated inner tank of size 50 cm x 50 cm x 50 cm placed in outer tank of size 65 cm x 65 cm x 65 cm. The soil bed was prepared in the inner tank. MS model footing plate of size 25cm x 25 cm x 0.5 cm wasthen placed over prepared clay bed. EPS geofoam layer of thickness 25 mm was placed beneath the footing.The micropiles made of M.S. bars were inserted into the compacted clay soil bedpassing through the plate and EPS geofoam layer and fastened to the plate by nut and bolt arrangement. Either four micropiles at the corners of the plate or single micropile at the center of the plate were inserted into the compacted clay soil bed.Dial gauge was placed on footing plate to measure the heave occurred in the soil during test.

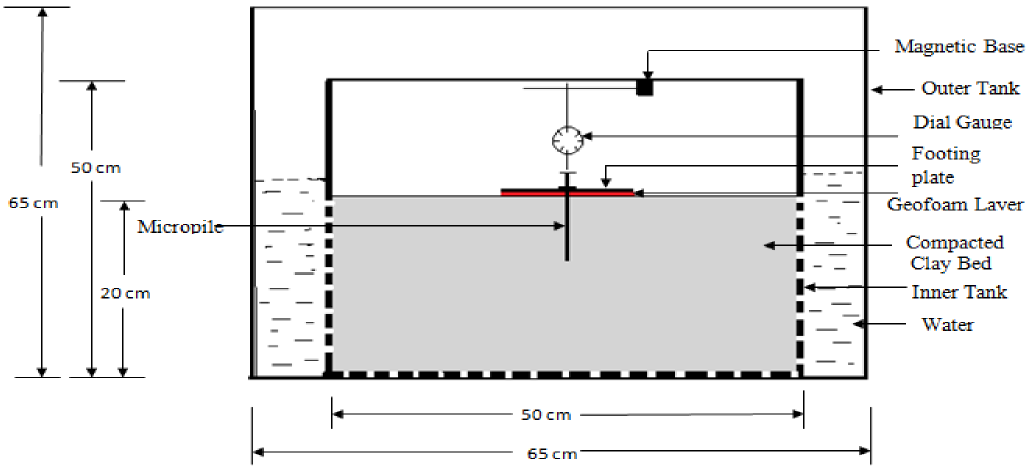

Figure 1: Schematic Representation of Experimental Set Up

2.2 Expansive Soil

The expansive soil used in this investigation was collected from the city Amravati,Maharashtra, India. The various laboratory tests performed for the determination of the index properties of the soils investigated are given in Table I. Based on its liquid limit and plasticity index, the soil was classified as CH according to IS classification.

Table I: Properties of the Soil Used

Sr. No.	**Properties of Clay**	**Value**
1	Plasticity Index (%)	24
2	Optimum Moisture Content (%)	20
3	Maximum Dry Density (kN/m^3)	16.2
4	Free Swell Index (%) (Very high)	80

TestVariables: To study the effectiveness of the various systems viz., micropiles, geofoam layer, single micropile with geofoam layer, four micropiles with geofoam layer and geofoam four roughened micropiles with geofoam layer, the experiments were conducted. The parameters varied during tests were, no. of micropiles, L/B and D/B ration of micropiles, inclusion of geofoam layer and roughness of the micropile surface. 'D' denotes the diameter of the micropile, 'L' denotes the length of the micropile and 'B' denotes the width of the footing plate. The D/B ratio of the micropile was varied from 0.04 to 0.064 viz. 0.04, 0.048, 0.064, 0.1. and the L/B ratio of the micropile was varied from 0.4 to 0.8 viz. 0.4, 0.6, 0.8. Table II show the completeexperimental program.

Table II: Experimental Study Program

Sr. No.	Description	Parameters	No of tests
1	Footing without any swell control arrangement	-	01
2	Footing with Geofoam layer	1 layer of 25 mm thick geofoam of size 25 cm x 25 cm	01
3	Footing with four Micropiles at corners	No of micropile – 04 Diameter – 10 mm Length of micropile – 10 cm	01
4	Footing with micropiles and Geofoam layer	1 layer of geofoam of 25 mm thickness No of micropile- 1 or 4 Diameter – 10 mm, 12 mm, 16 mm, 25 mm Length – 10 cm, 15 cm, 20 cm	24
5	Footing with rough micropiles &Geofoam layer	1 layer of geofoam of 25 mm thickness, No of ribbed micropile – 4.Diameter –25 mm Length –20 cm	01

Test Procedure

Compaction of expansive clay bed: The clay bed of constant density was prepared by compacting the known weight of the soil in the layers of known thicknesses.For the present study, clay beds having a total thickness of 20 cm were prepared. For each experimental set up, the soil was compacted at OMC in four equal layers, each of thickness 5cm to achieve MDD. Each layer was compacted with 163 no. of blows of rammer of weight 11.6 kg and falling through a height of 40 cm, so that the compaction energy is equal to the 6045 kg.cm/1000 cc, which corresponds to the compaction energy in Standard Proctor Test. The blows were uniformly distributed over the layers so as to obtain the uniform thickness of the layers.Sufficient water was added to the outer tank and then dial gauge readings were recorded over a period of time to reach the maximum constant heave. The readings were noted immediately after pouring water into outer tank. Initially, readings were noted at the interval of 5 minutes for first hour. Then readings were noted for after every 30 minutes up to 6 hours and then after every 24 hours. The Complete test assembly is as shown in Fig.2.

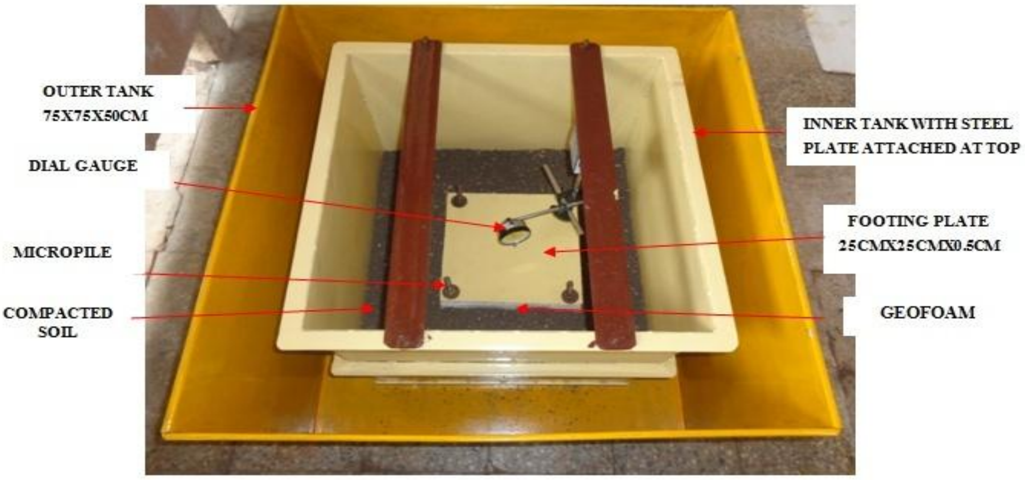

Figure 2: Complete Test Assembly Used in Work

III. RESULTSANDDISCUSSIONS

Fig.3 shows the heave (mm) - log time (minutes) plots for clay bed without any heave control arrangement. Heave steadily increased with increase in time and attained equilibrium. Maximumheave was observed to be 29.2mm.

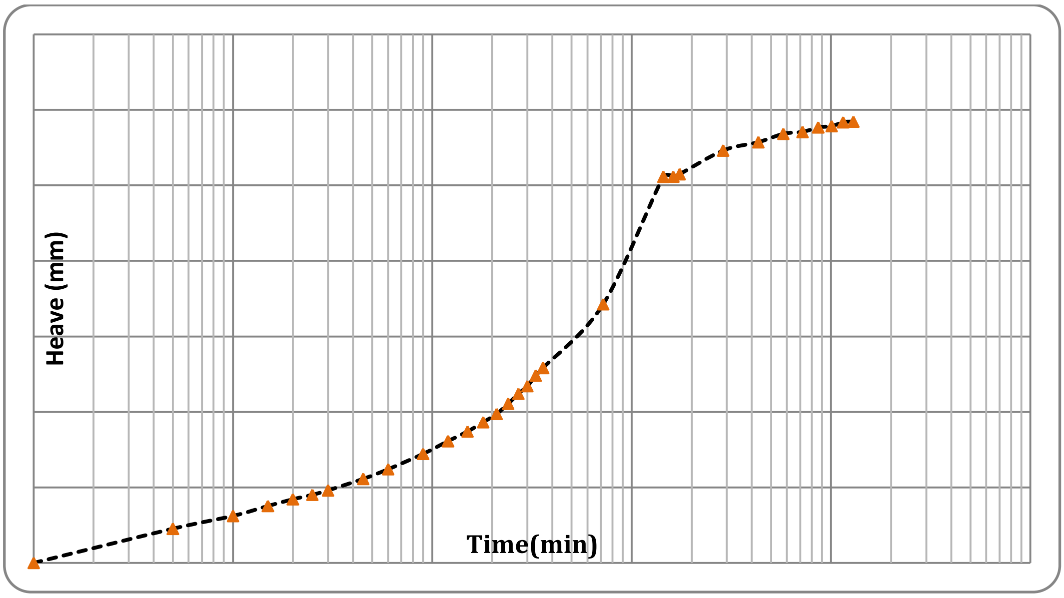

Figure 3: Test Result for Heave Test on Original Soil

Fig.4 shows the comparative result for the heave test performed on the soil using four micropiles.The maximum heave observed was 21.1 mm. Thus the % reduction in the heave due to provision of micropiles was 28 %.

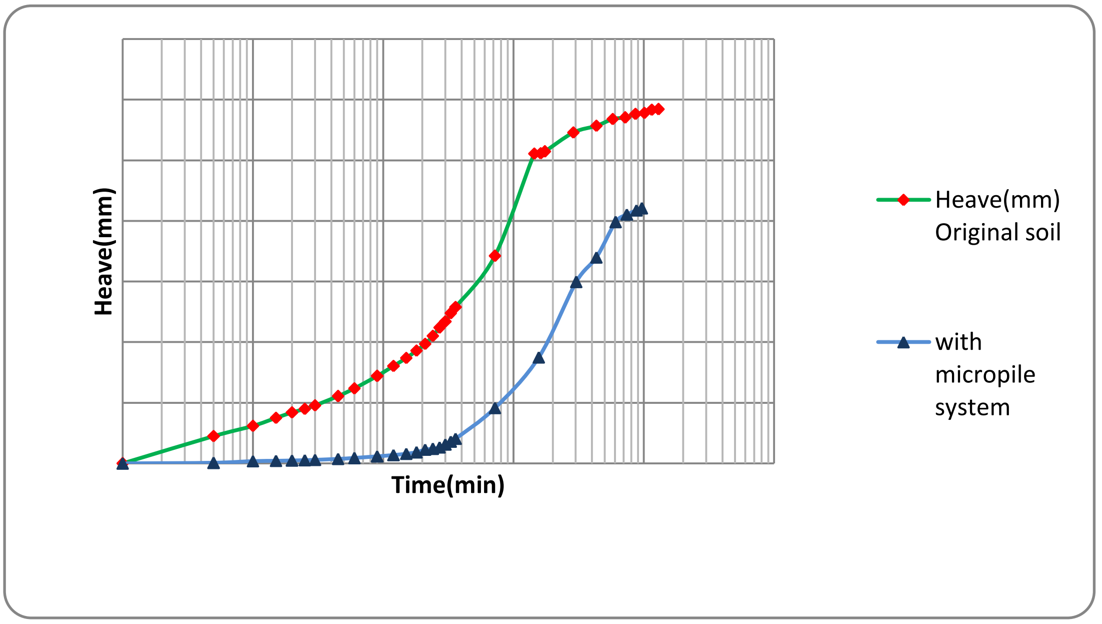

Figure 4: Comparative Results of Heave Test for Soil With and Without Micropiles

Fig. 5 shows the results for the heave test performed on soil using geofoam layer. The maximum heave observed in this case was 19.2 mm. Thus the % reduction in the heave using geofoam layer was 34.29 %.

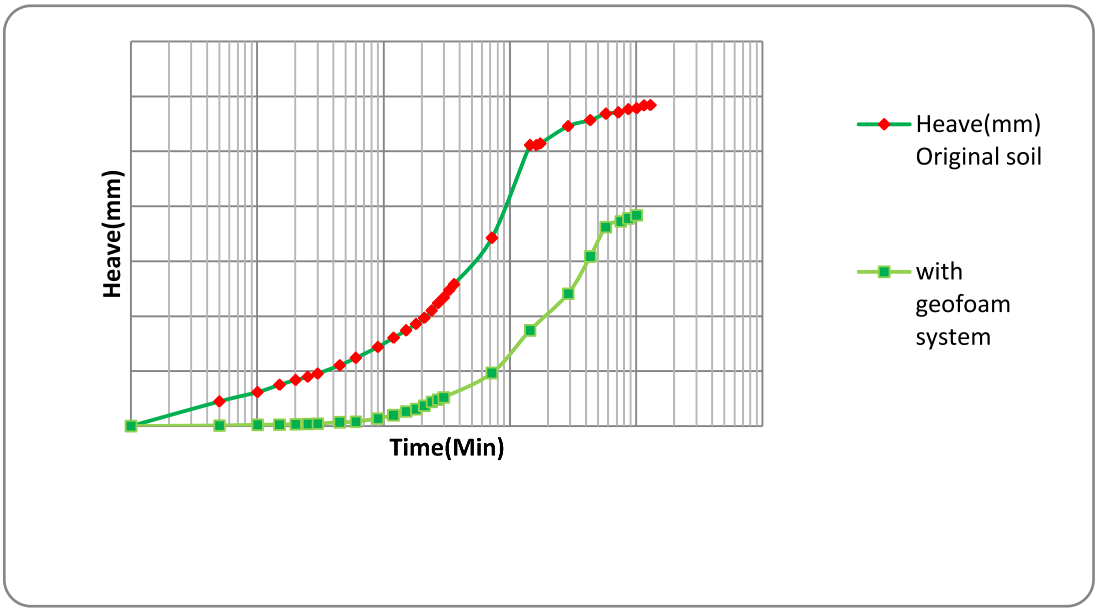

Figure 5: Comparative Results of Heave Test for Soil With and Without Geofoam

Tests were performed on the compacted clay bed for the different combinations of the L/B ratio and D/B ratio of the micropile with a layer of geofoam. Table III shows the results of the tests performed on the soil with single micropile and geofoam.

TABLE III: Test Results for Four Micropilewith Geofoam

Sr. No.	D/B	L/B	Maximum Heave (mm)	% Heave reduction
1	0.04	0.4	25.10	14.10
2	0.048		24.69	15.50
3	0.064		24.11	17.49
4	0.1		18.90	35.9
5	0.04	0.6	22.17	24.13
6	0.064		21.49	26.45
7	0.1		17.86	39.45
8	0.04	0.8	22.61	22.66
9	0.048		20.79	28.85
10	0.064		17.70	39.43
11	0.1		12.72	56.88

Fig.6 shows the variation in % heave reduction due to change in D/B ratio for various L/B ratios of single micropile with geofoam. It is observed that, the micropile with geofoamhaving smaller D/B ratio (D/B ratio < 0.064)is less effective in controlling the heave of the clay soil. Maximum % heave reduction obtained for the D/B ratio of 0.1 and L/B ratio of 0.8 is 57 %. Thus, the single micropile with geofoam with greater D/B ratio (D/B > 0.064) is more effective in controlling the heave of clay soil.

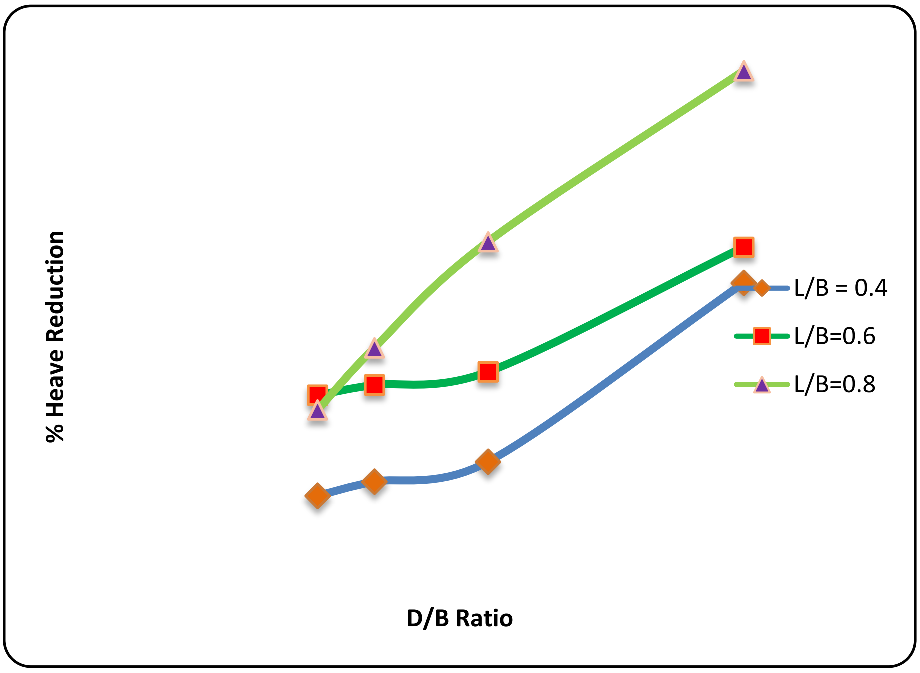

Figure 6:Effect of D/B Ratio of Single Micropile with geofoam on the Heave Reduction

Fig.7 shows the variation in % heave reduction due to change in L/B ratio for various D/B ratio of geofoam single micropile system. It is observed that, for lower D/B ratio (D/B < 0.048) the % heave reduction increases up to a certain L/B ratio, such as L/B equal to 0.6 in the present study, and thereafter there is no further significant increase in the heave reduction with the increase in the L/B ratio. For higher D/B ratio (D/B > 0.048), however, the % heave reduction increases with increase in L/B ratio. In the present study, the maximum heave reduction using single micropile with geofoam is obtained for L/B equal to 0.8 and D/B equal to 0.1.

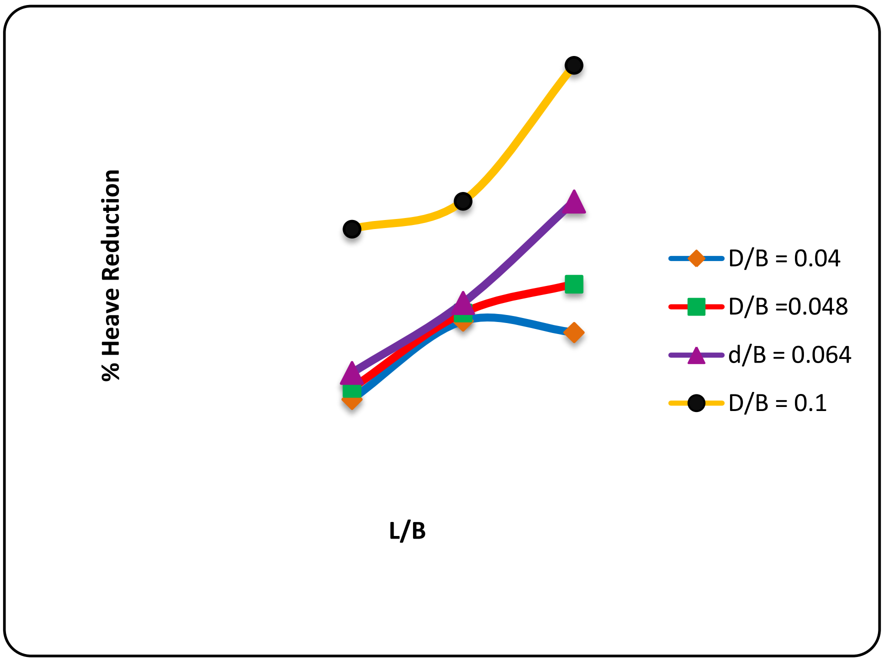

Figure 7:Effect of L/B Ratio of Single Micropile with geofoam on the Heave Reduction

Table IV shows the results for heave observed and % heave reduction for the model heave test performed on expansive soil using four micropiles with geofoam layer.

TableIV**:** Test Results for Geofoam Four Micropile

Sr. No.	**D/B**	**L/B**	**Maximum Heave (mm)**	**% Heave reduction**
1	0.04	0.4	19.35	33.64
2	0.048		17.95	38.36
3	0.064		9.63	67.04
4	0.1		7.88	73.28
5	0.04	0.6	16	45.24
6	0.048		10.60	63.72
7	0.064		7.60	73.99
8	0.1		7.76	73.69
9	0.04	0.8	9.52	67.42
10	0.048		7.80	73.31
11	0.064		6.13	79.12
12	0.1		7.44	74.7

Fig. 8 shows the variation in % heave reduction due to change in D/B ratio for various L/B ratios of four micropiles with Geofoam layer. It is observed that, the effectiveness of the four micropiles with geofoam increases with increase in D/B ratio up to 0.064 and therefore there is no advantage by further increase in D/B ratio.Maximum % heave reduction obtained for the D/B ratio of 0.064 and L/B ratio of 0.8 is 80 %. Hence four micropiles with geofoam having D/B ratio of 0.064 is found to be most effective.

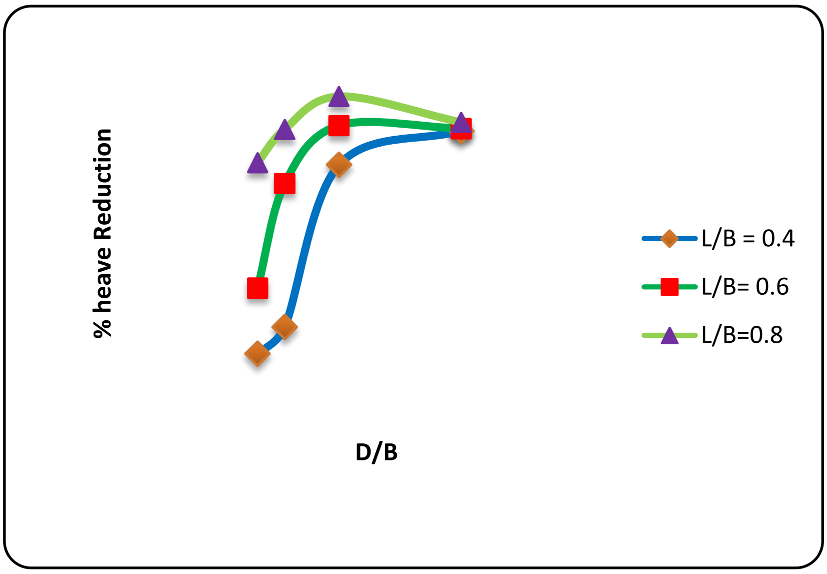

Figure 8: Effect of D/B Ratio of Four Micropileswith geofoam on the Heave Reduction

Fig.9 shows the variation in % heave reduction due to change in L/B ratio for various D/B ratio of four micropiles with geofoam layer. It is observed that, for lower D/B ratio i.e. (D/B<0.048), the effectiveness of the system doesn't increase with increase in L/B ratio. Thus, it may be concluded that a four micropiles with geofoam layer with higher D/B ratio and lower L/B ratio shall be adopted.

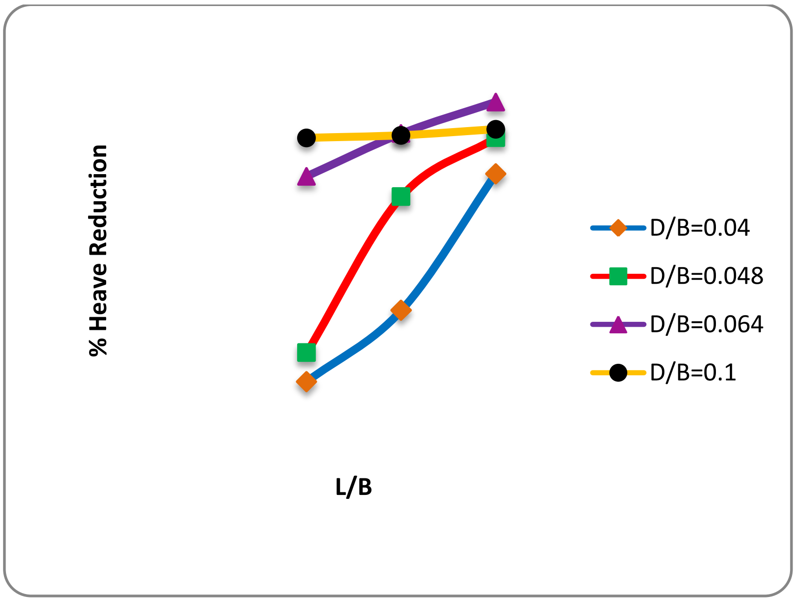

Figure 9:Effect of L/B Ratio of Four Micropiles with Geofoam on the Heave Reduction

One heave test was also performed on clay soil bed provided with four roughened micropiles of L/B ratio 0.8 and D/B ratio 0.1 and geofoam layer. The result of the tests is shown in Fig.10. The maximum heave observed in this case was 5.75 mm, which corresponds to the % heave reduction of 80.32 % as that of original soil.

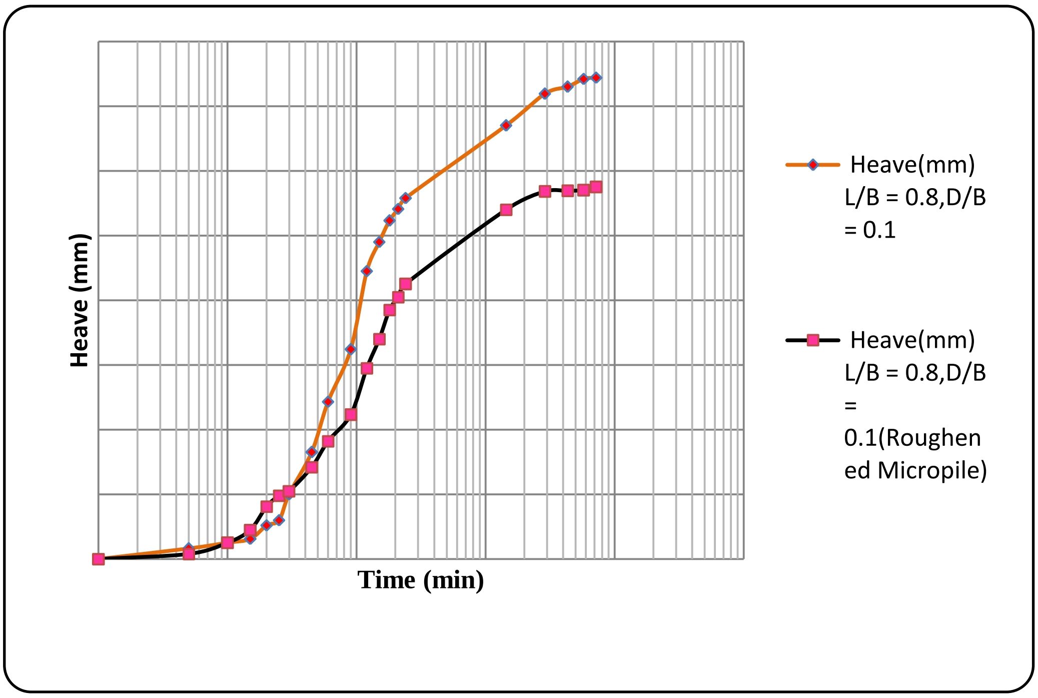

Figure 10: Comparative Results of Heave Test for Soil with Geofoam and Four Micropilesand four Roughened Micropiles

The Fig. 11 shows the heave of the clay soil and the heave of the soil provided with various heave controlling arrangements in the form of bar chart. It is seen that the various heave controlling systems used in the present study are found to be effective in the following order;

[1] Geofoam roughened four micropile system
[2] Geofoam four micropile system
[3] Geofoam single micropile system
[4] Geofoam system
[5] Micropile system

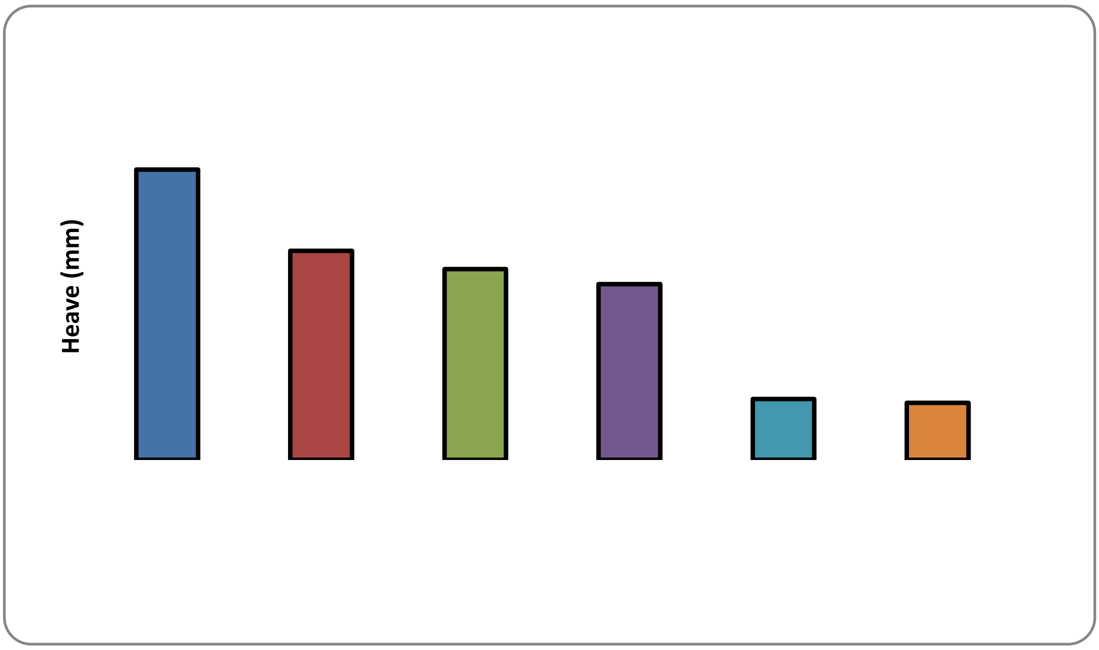

Figure 11: Effectiveness of Various Heave Reduction Systems

IV. CONCLUSIONS

Following conclusionsare drawn from the experimental investigations in the present study.

[1] Provision of Geofoam layer below footing would be much more effective and economical for reducing the heave of expansive soil,as compared to provision of four micropiles.

[2] Provision of single micropile with greater D/B ratio (D/B > 0.064) is more effective in controlling the heave of clay soil.

[3] The maximum heave reduction using combination of geofoam layer and single micropile is obtained for L/B ratio equal to 0.8 and D/B ratio equal to 0.1.Maximum % heave reduction obtained in this case is about 57 %.

[4] The heave reduction system consisting of geofoam layer and four micropiles provided at the corners of footing is effective reducing the heave of the clayey soil bed. Such a system with L/B ratio equal to 0.8 and D/B ratio equal to 0.064 is found to be optimum.

[5] Roughness of the surface of the micropiles further increases the effectiveof the system for heave reduction and is therefore recommended.

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