A Study on Engineering Behaviour of Geogrid Reinforced Clay

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Abstract — Construction work done on cohesive soil have low shear strength and load carrying capacity. Thus, causing reduction in the durability of structure and leading to fail in near future. Earlier to stabilize these types of soil for carrying out construction activity many techniques were used like replacing the top most weak cohesive soil with much stronger granular fill, increasing the footing size, incorporating natural fibers in the soil. However, these conventional methods were not reliable and durable for longer time. Hence use of artificial fibers known as geosynthetic material emerged rapidly. The study shows laboratory results of clay reinforced with geogrid, where load is passed in the soil through a surface square footing having dimensions 75mm×75mm. The parameters analysed in the study includes the vertical spacing of first geogrid layer from footing base (u), optimum depth of effective reinforcement (d), number of geogrid layers (N). Testing was done with geogrid in a steel tank of dimension 750 mm × 450 mm × 600 mm with acrylic sheet along one of the longitudinal sides of tank to get the visual observation of the settlement. The experimental results it is observed that clay soil along with geogrid increases the load carrying capacity of clay when compared to unreinforced clay. Optimum spacing between base of footing and first geogrid is between to 0.34B-0.51B. Depth of effective reinforcement(d) was near by 1.36B with optimum geogrid layers (N) as 4.

Keywords—Cohesive soil; Geogrid; Bearing Capacity; Footing

I. INTRODUCTION

Construction of structure on clay is very difficult due to its low load carrying capacity and settlement over the years. It is low in shear strength and compressible having strength less than 40 kPa and can get easily molded with little pressure. To handle this problem different materials that increase the strength of clay and help it to lift the load coming, are incorporated along. Earlier, the top most clay was removed and was replaced with thick granular full layer or the size of the footing was increased to distribute the load to a larger area thus reducing the pressure. But these techniques could not achieve the actual strength required and moreover were not economical. In 20th century much stable material called polymer was introduced that replaced lesser stable techniques. With time the polymeric material like geosynthetic were used in many engineering works as a reinforcement in mechanically stabilized earth wall, slopes, pavements, earth structure, reinforced foundation.

From the past literatures it is noted that geosynthetic material improves the properties of soil. One of the noticeable works in the area was done by [1] who suggested to use Bearing Capacity Ratio (BCR) technique.

Thereafter the focus area was to work on parameters that would influence the BCR. Reference [9] investigated model strip footing placed over soft clay reinforced with heat-bonded nonwoven polypropylene geotextile. Reference [3] examined footing width effect on sand and concluded that BCR was practically constant when the width was equal to or more than 130 mm to 140 mm. Reference [4] studied improvement of clay subgrade reinforced with geogrid. Optimum distance between footing base and first reinforcement was found at 0.175B. Reference [13] investigated bearing capacity of sand reinforced with geogrid. It was observed that optimum embedment depth is at which bearing capacity is maximum with single reinforcement layer. Reference [12]) observed strip footing supported in unreinforced, and sand reinforced with a geotextile bed subjected to static and repeated loads. Rate of settlement decreased as number of loading cycles increased and with increase in amplitude of repeated load regardless of reinforcement. Reference [5] studied foundation behavior on geosynthetic reinforced sandy soil. From the study it was concluded that with two or more reinforcement layers, settlement can be reduced to about 20%. Results also showed that sand reinforced with geogrid and geotextile composite behaved superior than sand reinforced with geogrid or geotextile alone. Reinforcement also distribute load more uniformly hence reducing stress concentration. Reference [2] studied the behavior of foundations on clayey soil reinforced with geogrid. The result showed increased bearing capacity and reduction in settlement. Settlement could be reduced by more than 50% after providing three or more reinforcing layers.

In the present study elaborated laboratory model footing tests on unreinforced and reinforced soil have been done to analysis the effect of all the parameters used in the study for the improvement of bearing capacity and settlement reduction using geogrid reinforcement. The experimental results obtained are presented and discussed in results section.

II. MATERIALS PROPERTIES

A. Clay

In the experimental work, the clay used is collected from Tekanpur town, near Gwalior, Madhya Pradesh, India. It is of intermediate plasticity having plasticity index 24. It is then cleaned to free it from debris, grass roots, other organic matter. And oven dried for 24 hours to remove moisture and passes through 75 mm IS sieve. Average unit weight of undisturbed un-situ clay was 18.7kN/m^3, having cohesion as 83kPa and coefficient of internal friction as 4°. Maximum dry density of clay was noted as 16.1kN/m^3 at an optimum moisture content of 17.2%. Properties of clay is provided in TABLE I.

TABLE I. PROPERTIES OF CLAY

Properties	Value
Specific Gravity	2.7
Percentage passing IS Sieve 75 micron (%)	83
Liquid limit (%)	43
Plastic limit (%)	19
Plasticity index (%)	24
Maximum dry Unit Weight (kN/m^3)	16.1

B. Geogrid

In the study, single type of geogrid is used. It is made from polypropylene. The properties of geogrid are provided by the manufacturer is shown in TABLE II.

TABLE II. PROPERTIES OF GEOGRID

Properties	MD	TD
Tensile Strength (kN/m)	7.8	8.2
Tensile Modulus at 0.5% strain (kN/m)	550	350
Aperture Size (mm)	30×30	
Material	Polypropylene	

III. EXPERIMENTAL SETUP

In this section, experimental procedure is described in different steps.

A. Prepration of testing bed

All the experiments were conducted in a steel tank of dimension 750 mm × 450 mm × 600 mm. Air dried clay was filled in tank in three lifts which were compacted at its maximum dry density of 16.1kN/m^3. Clay is mixed with optimum water which was determined from Standard proctor test. Soil is put in tank and compacted with help of rammer having base of 150 mm falling freely from a height between 25mm to 102mm depending upon reinforcement spacing. In the end of compaction, sprit level was used to check horizontal surface of bed.

B. Placement of Geogrid

Geogrid of required size was cut and placed in the soil at the appropriate location as calculated. After placement of geogrid, soil was again filled in the tank up to top location.

C. Equipment Setup

Test was performed in tank with one longitudinal side of tank made of acrylic sheet to get the visual observation. Square footing of dimension 75mm × 75mm was used as surface footing placed at the center of clay bed. The sides of the tank were fabricated with steel sheet to counter the bulging of the steel tank. Load was applied through Compression Testing Machine and the settlement was recorded with the help of two dial gauges attached having accuracy of 0.001 mm. Load cell of 25kN capacity was placed at center. Fig. 1 shows the schematic view of the soil reinforced with geogrid. Bearing capacity ratio (BCR) is defined as the ratio of bearing capacity of reinforced soil to that of unreinforced soil. Bearing capacity is obtained by double tangent method. Two tangents were drawn, one from the start of the curve and another from the end of the curve. The projection of interception on x-axis is the observed bearing capacity.

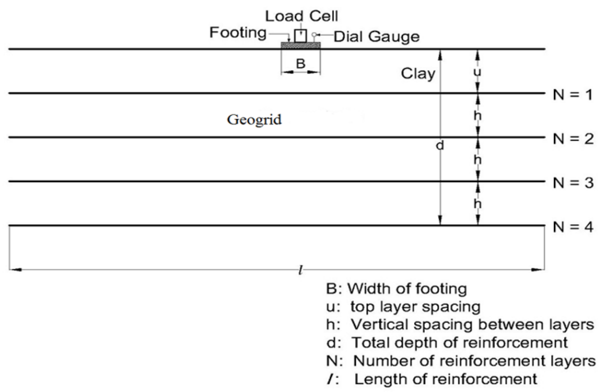

Fig. 3 Geogrid Reinforced Clay foundation

D. Testing Procedure

The objective of the study was to investigate geogrid effect on the bearing capacity of clay. The parameters considered were vertical spacing of first geogrid layer from footing base (u), effective depth of reinforcement (d), number of geogrid layers (N). At first, test on clay was performed at unreinforced condition to compare the result with reinforced condition. Load was applied at the center of the square footing with help of compression testing machine. The resultant settlement of the footing recorded with help of dial gauge. For reinforced condition, optimum vertical spacing between geogrid and footing base, 'u' was found. 'u/B' values were varied form 0.17, 0.34, 0.51, 0.68 and 0.85 respectively. Likewise, number of geogrid layers were varied from N=1 to N=5 by taking the vertical spacing between the layers of geogrid as 'u' optimum.

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IV. RESULTS AND DISSCUSSION

A. Effect of first reinforcement depth (u)

The effect of first reinforcement depth i.e. u was investigated using a single layer of geogrid located below footing base. u/B is defined as the distance of the first geogrid layer from footing base (u) to the width of the footing (B). Fig. 2 shows pressure settlement curve of reinforced clay footing for single geogrid. From the graph it is observed that value of bearing pressure increases with u/B. Fig. 3 shows the relationship between bearing capacity ratio (BCR) and u/B. Fig. 3 shows variation of BCR with u/B at different settlement. From Fig. 3, is noted that BCR increases with the increase in u/B values. However, after a certain point the BCR decreases with increase in u/B. Hence, optimum value of 'u' is approximately found between 0.34B-0.51B.

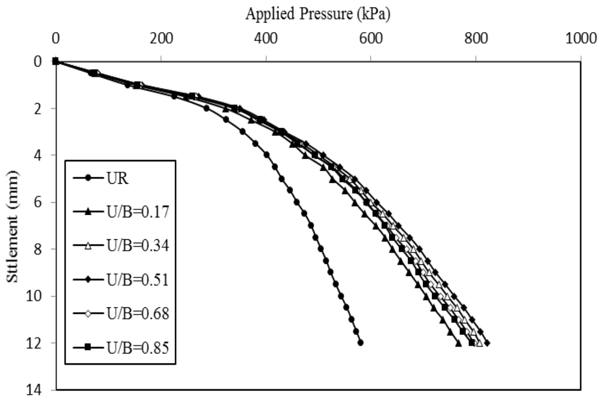

Fig.2 Pressure- settlement curves for Geogrid

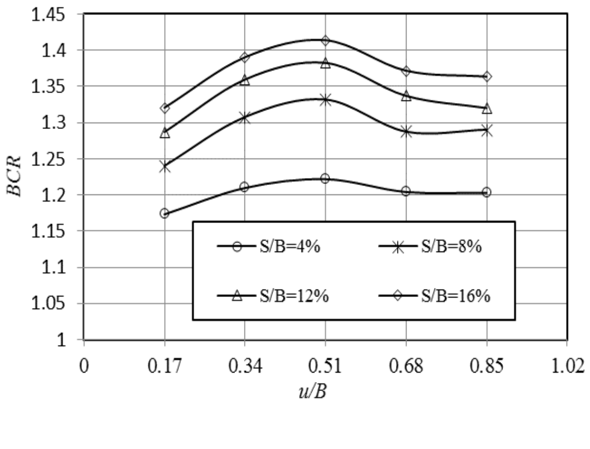

Fig. 3 Bearing capacity ratio (BCR) for geogrid for (u/B)

Reference [2] from their study found that clay when reinforced with geogrid observe maximum bearing pressure at 0.33B for single rinforcement layer. Reference [10] noted that for sand reinforced with geocell, optimum distance between footing base and first reinforcement layer falls between 0.25B-0.40B. Similar results were found by [9]. For clay reinforced with geotextile, optimum vertical spacing is between 0.35B-0.40B.

B. Optimum depth of effective reinforcement (d/B)

Effective depth of reinforcement is the depth beyond which the influence of reinforcement in the improvement of bearing capacity is almost negligible. In the study, effective reinforcement depth is denoted by'd'. From the literatures, it has been noted that'd' is equivalent to number of reinforcement layers. The relation between'd' and 'N' is shown as in (1)

$$d = u+(N-1)\times h \tag{1}$$

Where, h is the vertical spacing between two reinforcing layers, 'u' is the first reinforcement depth and N is the number of reinforcing layers. Fig. 4 shows the variation between BCR and effective reinforcement depth. From the figure it is observed that, the BCR increases with increase in the reinforcement depth is nearly equal to 1.36B. Further increase in d/B value, no significant increment in bearing capacity was observed. Therefore, optimum number of reinforcements was found equal to 4.

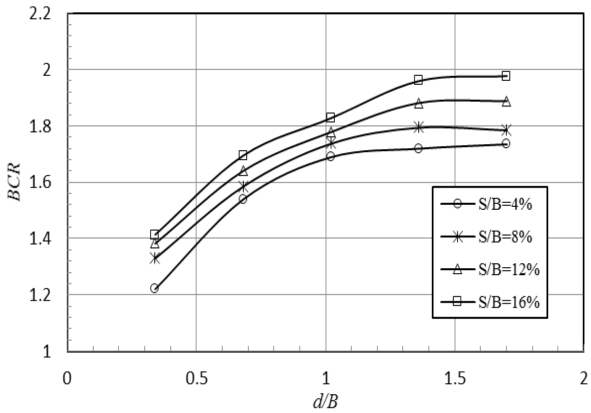

Fig. 4 Bearing capacity ratio (BCR) for geogrid for (d/B)

Reference [11] found influence depth for for strip footing over geogrid reinforced clay is 1.8B. Reference [2] for clay reinforced with geogrid found influence depth at 1.5B depth.

V. CONCLUSION

Based on tests performed, following conclusion were drawn:

- Optimum spacing between footing base and first geogrid was found in between 0.35B-0.51B for surface square footing on clay.

- Load carrying capacity of clay enhances with increase in geogrid numbers up to a certain depth. This depth is called as influence depth or effective reinforcement depth (d).
- Influence depth (d) was found nearly around 1.36B.

The study shows that geogrid can be incorporated in the clay to increase its bearing capacity hence a win-win condition for the clay having properties like that of clay used in the study.

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