An experimental investigation on bearing capacity behavior of rectangular footing over reinforced soil slope

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Abstract. Various Geotechnical engineering works demand the construction of foundation over cohesive soil slope. The construction of foundation over these soils may cause higher settlement which can obliterate the overlying structure. On the other hand, the use of reinforcement techniques in the soil stability is also increasing rapidly. Amongst them, the use of geosynthetics to reinforce the foundation soil is one of the cost-effective options. In the present study, a number of model footing tests were performed in laboratory to check the effect of geosynthetics in the development of bearing capacity on shallow foundation resting over cohesive soil slope. For this purpose, a bi-oriented geo-grid was chosen as a reinforcement material. Parametric studies such as effective depth of reinforcement, number of reinforcement layers, were considered in the present study. A number of laboratory tests were conducted, and their results were analyzed. From the analysis it was observed that soil reinforced with geosynthetics overlain by rectangular footing showed substantial increase in ultimate bearing capacity of the reinforced soil, thus signifying the potential benefits of reinforcements in soil.

Keywords: Soil slope; geogrid reinforcement; bearing capacity.

1 Introduction

The construction of shallow foundation over clayey soil slope is very difficult due to its poor load carrying capacity and excessive settlement. The conventional method to increase the bearing capacity of soil is replacement of existing cohesive soil with strong granular fill. This replacement of cohesive soil layer by granular fill requires more laborious works and uneconomical from the construction point of view. Several laboratory model footing tests, numerical studies and large-scale tests have been conducted to analyse the behaviour of reinforced soil shallow foundation. [1-6]. [2] studied the bearing capacity of geogrid and geotextile reinforced earth slab. They investigated that bearing capacity improvement is not significant when reinforcement provided after the optimum number of reinforcement layers. [3] conducted the laboratory model footing tests on strip foundation over clayey slope reinforced with geosynthetics. The soil slope was varied from 35º to 50º. Geosynthetic was placed at a different location to find out the optimums in layout. Based on the laboratory tests results they suggested that the first depth of reinforcement should be located at 0.4B from the footing base

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to achieve the maximum bearing capacity. The major emphasis of the research is towards the estimating the improved bearing capacity of foundation being construction over slopes, with the application of geogrid under different working conditions. For this purpose, small scale model footing tests have been conducted to analyze the performance of geogrid in bolstering the bearing capacity of shallow foundation constructed over cohesive soil slopes and reducing the percentage settlement induced due to weak soil strength.

2 Material used

2.1 Soil and geosynthetic

In the present study, A silty clay was used to prepare the foundation bed. Soil sample has been collected from Gwalior, India. The geotechnical properties of soil are presented in Table 1. Based on the unified soil classification system (USCS), the soil is classified as low compressible soil. On the other hand, A bi-oriented geogrid was chosen as a reinforcement material. The Mechanical properties of geosynthetics in both directions i.e. machine direction (MD) and cross direction (CD) are presented in Table 2.

Table 1. Geotechnical properties of soil

Properties	Values
Specific Gravity	2.62
Liquid limit (%)	34.0
Plasticity index	15
Plastic limit (%)	19
Maximum dry unit weight (kN/m^3)	17.1
Optimum Moisture Content (%)	15

Table 2. Mechanical properties of geosynthetics (Source: Supplier's data)

Parameters	Polypropylene Geogrid	
Tensile Strength (kN/m^2)	115 MD	115 CD
Stiffness at 0.5% Strain (kN/m^2)	550 MD	350 CD
Aperture Size (mm)	30×30	

3 Methodology

3.1 Slope preparation

The test bed was prepared in a steel box of size length = 750 mm, width = 450 mm and height = 600 mm. The soil was compacted at its maximum dry density, so a predetermined water content was added into the soil. The slope was constructed in three lifts in case of unreinforced soil slope whereas for reinforced soil slope the thickness of each lift was dependent on the number of reinforcement layers. After the compaction of each layer, the top surface of the layer was levelled horizontally with the help of spirit level so that uniformity of layer could be maintained.

3.2 Testing procedure

The aim of the study was to check the influence of slope angle, edge distance (D) and the optimum depth of first reinforcement (u) to achieve the maximum possible benefit from the reinforcements. The tests for u/B were conducted for corresponding values at 0.2, 0.4, 0.6, 0.8 and 1 respectively to find out the optimum of first reinforcement depth. The tests for u/B and N were conducting by fixing the slope angles at 45º and at D/B = 1. The effect of slope geometry and edge distance were analyzed for geogrid reinforced soil, by varying the slope angles by 35º, 40º and 45º respectively and fixing the value of D/B = 1.

3.3 Experimental testing setup

A number of small-scale model footing tests were carried out on the geogrid reinforced soil bed in the laboratory. A square footing of dimension of 75 mm × 75 mm was used as the model footing. A geometric diagram of slope model is shown in Fig.1. The foundation of clayey slope was used with a dimension of 750 mm × 450 mm ×200 mm and a slope of height 300 mm was prepared over the foundation at different slope angles. The sides of the steel box were made of steel sheet and an acrylic sheet was used at front side of the box for the visualization of failure pattern of soil slope. The tank was tested in loading frame consisted of a platen attached to the cross head of the loading frame. A load cell was used to measure the load values and two dial gauges were used to measure the footing settlement in the experimental study.

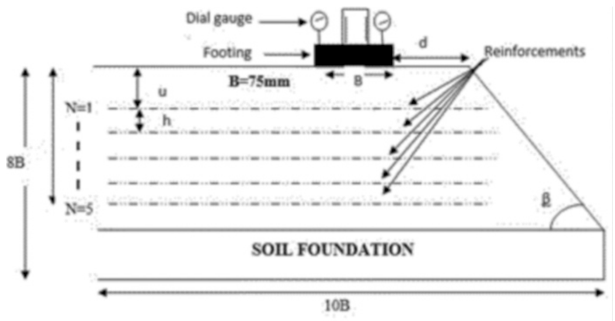
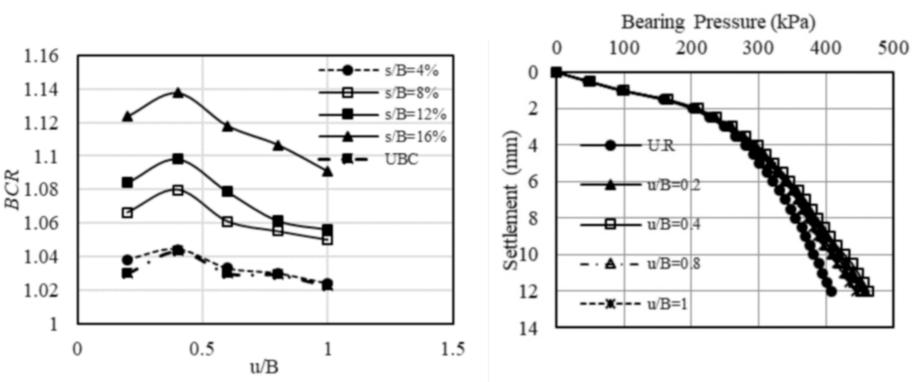


Fig. 1. Geometric view of reinforced soil slope

4 Results and discussion

4.1 Effect of topmost reinforcement depth (*u*)

To find the value of optimum depth of top layer of geogrid, a series of number of tests were conducted. Bearing capacity ratio (BCR) was determined for each settlement ratio which is defined as the ratio of the bearing pressure of a reinforced soil to that of an unreinforced soil, when evaluated at the same settlement ratio (Sr = 4%, 8%, 12%, 16% and ultimate bearing capacity UBC). Fig. 2 (a-b) show the BCR and pressure settlement graphs of soil slope reinforced with geogrid. It is clearly seen from the graph that maximum value of bearing pressure obtained at u/B= 0.40 and beyond this depth a decrease in bearing capacity was found as reinforcement depth increases. The probable reason behind this is that any further increment in reinforcement depth would deteriorate the possible benefits of reinforcement.



(a) (b)

Fig. 2. (a) Bearing capacity ratio versus u/B for Geogrid (b) Pressure Settlement Curve for Geogrid at different u/B ratios

4.2 Effect of number of reinforcement layers (*N*)

To check the effect of number of layers of geogrid, the first layer of reinforcement was fixed at u/B then number of reinforcement layers were varied with a spacing of 0.4B (optimum depth of top layer) up to those layers where significant improvement in bearing capacity improvement become insignificant. Fig. 3. Shows the relation between the number of reinforcement layers and BCR for different settlement ratios. From the Fig 3. It can be seen that beyond the number of reinforcement layers equal to 4 the improvement in bearing capacity is almost constant. The reason for this can be attributed that at N=4, reinforce depth located beyond the pressure bulb of footing.

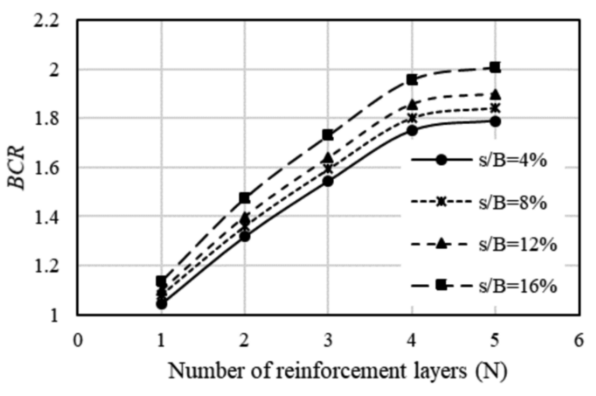
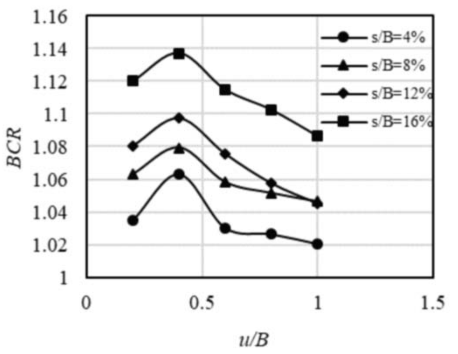


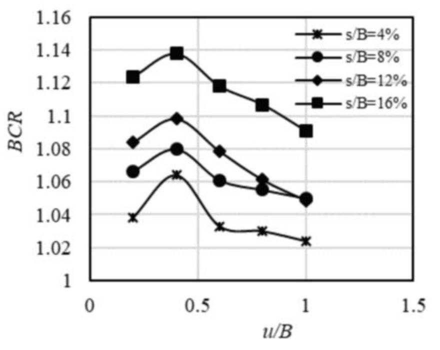
Fig. 3. Bearing capacity ratio versus Number of reinforcement layers (N) for Geogrid

4.3 Influence of slope angle (β) on unreinforced slope

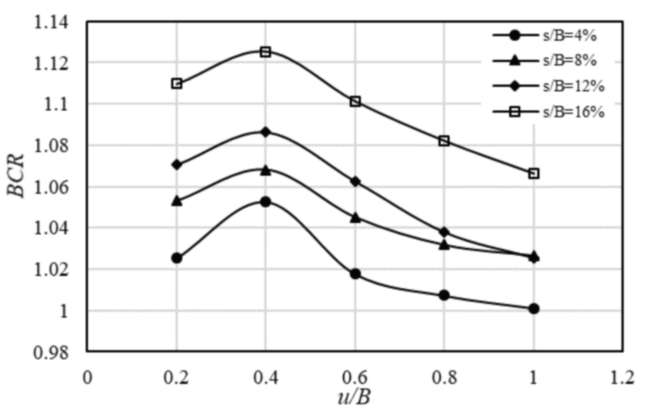
In the laboratory, different soil slope models were made and then tested to check the effect of slope angles on the bearing capacity of soil slope. Fig 4. (a-c) Show the BCR vs u/B curves for different slope angles and s/B ratios at D/B=1. From the graph it is observed that with increasing the slope angles the bearing capacity decreases and the maximum improvement in bearing capacity was found when at β=35°. The probable reason can be explained that as slope angle decreases the stability of slope increases thus more improvement in bearing capacity can be expected.



(a)



(b)



(c)

Fig. 4. Bearing capacity ratio curves for (a) β=35° (b) 40° (c) 45°

5 Conclusion

Based on the experimental work following conclusions were drawn from the study.

(1) The optimum depth of top layer reinforcement for geogrid was obtained at u/B = 0.4 and maximum number of reinforcement layers were observed at N = 4.

(2) Maximum bearing capacity was achieved at β=35°, with respect to β=40° and 45°.

(3) Geogrid performance is very significant at lower settlement (e.g. s/B=4%) which is very useful reinforcement in shallow foundation work.

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