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Interaction between Geosynthetics and Granular Soil in Reinforced Foundation Bed

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Abstract: Geosynthetic reinforcement are placed in soil below footings in order to improve the bearing capacity and to improve the properties of weak soil. In general, soils possess a low tensile strength. The main objective of strengthening the soil mass is to increase bearing capacity improve stability and decreased settlements and lateral deformations. One of the approaches is the use of polymeric materials. Geosynthetic is a well-known technique in soil reinforcement. In almost every application, the common trend is to place the reinforcement in horizontal layers. Theoretically, for the reinforcement to be effective, it must pass through the tensile arc. Hence the ideal pattern for reinforcement will be horizontal below the footing and becomes progressively more vertical further away from the footing. This paper presents the results of finite element analyses carried out to evaluate the effect of pattern of reinforcement on the axial forces on geogrid and stress distribution at the interface of geogrid and sand. The results of finite element analyses are validated by carrying out a series of Laboratory Scale Load Tests. It is observed that the pattern of reinforcement significantly influences the axial force on geogrid and stress distribution at the interface between sand and geogrid.

Keywords: Geosynthetic; Tensile Arc; Finite Element Analyses; Foundation Bed; Weak Soil.

I. INTRODUCTION

The use of reinforcement below footing improves the properties of soil possessing low strength. Application of geosynthetics for improving the performance of shallow foundations has been studied by engineers over the past three decades. For marginal ground conditions, geosynthetic reinforcement is proved to be a cost-effective solution and in some cases geosynthetics open up the possibility of constructing shallow foundations in lieu of expensive deep foundation.The use of it, can significantly improve the soil performance and reduce costs in comparison with conventional designs. Among the range of geosynthetics available on the market, geogrids are the most preferred type for reinforcing the foundation beds. The beneficial effect of a geosynthetic inclusion is largely dependent on the form in which it is used as reinforcement. For example, the same geosynthetic material, when used in planar layers or geocells or discrete fibers, comprising exactly the same quantity of material, will give different strength improvements in different forms. This difference in strengths achieved is mainly due to the different mechanisms of failure in soil reinforced with geosynthetics in different forms.

Much research has been carried out to understand the beneficial effects of using planar forms of reinforcement in soil, such as [1], [2], [3], [5], [6], [8], [9], [10], [11], [12], [15], [20], [21].

The relative performances of different forms of reinforcement (i.e. geocell, planar and randomly distributed mesh elements) in sand beds under strip footing were compared by [7]. To compare the performance of geosynthetics materials in different forms, [16] carried out a systematic series of triaxial compression tests on sand reinforced with geosynthetics in three forms (planar, discrete fiber and cellular), using the same quantity of reinforcement.

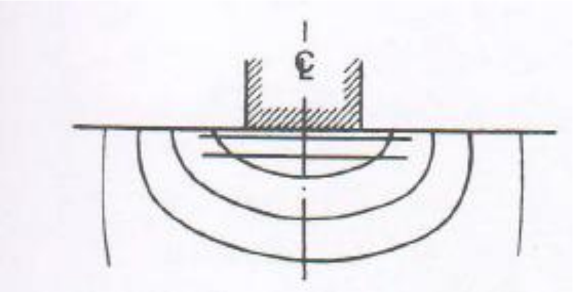


Fig 1. Ideal Pattern of Reinforcement Beneath Footing [14]

The kinematics of failure is usually such that the failure surface intersects the reinforcement obliquely. This oblique pull can be considered as a combination of transverse and axial pulls. The reinforcement is thus subjected to both axial and transverse components of the force by the sliding mass of soil. Most available theories for the analysis and design of reinforced soil structures consider only the axial resistance of the reinforcement to pull-out and not the transverse one [13]. The inclination of the reinforcement force is considered by few researchers ([4], [17], [18], [19] etc.) to vary between the direction of the reinforcement and the tangent to the slip surface.

Conventionally in almost all reinforced soil applications, the geosynthetic is kept horizontally, whereas the ideal pattern would be horizontal below footings and become progressively more vertical further away from the footing [14]. This pattern is presented in figure 1.

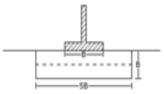
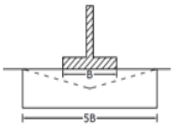
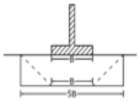
This paper presents the results of a series of finite element analyses carried out to investigate the effect of pattern of reinforcement on the stress distribution at the interface between geogrid and sand and the axial forces on geogrid.The results of finite element analyses are compared with those obtained from laboratory scale load tests for validation.Here triangular, tarapezoidal and horizontal configuration are tried.

II. FINITE ELEMENT ANALYSIS

AnFinite element analyses are carried out using the commercially available finite element software PLAXIS 2D. In the present study Mohr-Coulomb model is used to simulate soil behaviour. This non-linear model is based on the basic soil parameters that can be obtained from direct shear tests; internal friction angle and cohesion intercept. Since strip footing is used, a plain strain model is adopted in the analysis.

The soil is modelled using 1 noded triangular elements. The displacement of the bottom boundary is restricted in all directions, while at the vertical sides; displacement is restricted only in the horizontal direction. The initial geostatic stress states for the analyses are set according to the unit weight of soil. Mesh generation can be done automatically. Medium mesh size is adopted in all the simulations.The size of the strip footing (B) is taken as one metre and the width of soil mass is taken as 5B and depth of soil as 10B in all analyses

TABLE-1 REINFORCEMENT PATTERNS

Pattern	**Figure**	**Description**
1		Horizontal Reinforcement at mid height of RFB
2		Triangular pattern with centre of Geogrid at Mid height of RFB
3		Trapezoidal pattern with bottom width = B, at base of RFB

The reinforcement is modelled using the 5-noded tension element. To simulate the interaction between the reinforcement and surrounding soil, an interface element is provided on both upper and lower surface of reinforcement.

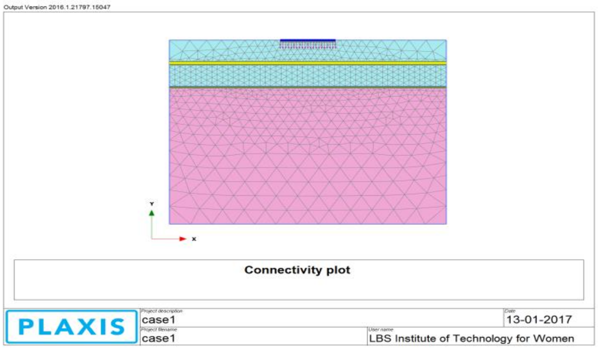
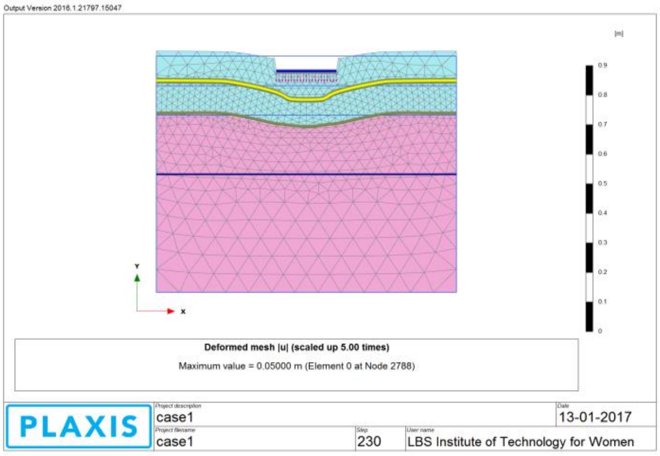


Fig.2.Discretised Model (Horizontal configuration)

The interaction between soil and reinforcement is simulated by choosing an appropriate value for strength reduction factor R_{inter} at the interface. The value of R_{inter} adopted from literature is 0.80. Analyses are carried out for various patterns of reinforcement as detailed in Table 1. A typical descretised model and deformed shape after loading for various patterns are shown in figure 2-7. The soil is modeled using 15-node triangular elements. Poisson's ratio of the soil is assumed to be 0.25 for all cases.



Deformed mesh |u| (scaled up 5.00 times)

Maximum value = 0.05000 m (Element 0 at Node 2788)

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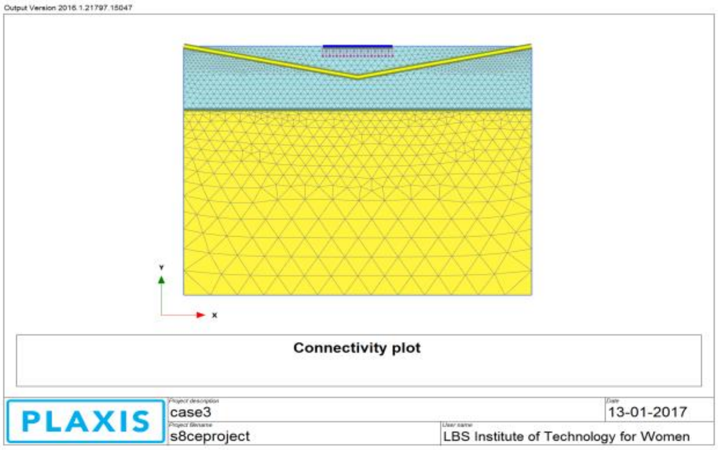
Fig.3. Deformed shape after loading



Connectivity plot

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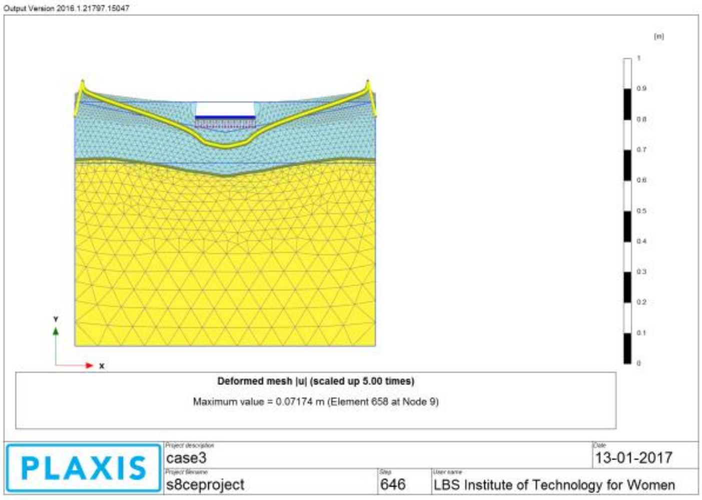
Fig.4.Discretised Model (Triangular configuration)



Deformed mesh |u| (scaled up 5.00 times)

Maximum value = 0.07174 m (Element 658 at Node 9)

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Fig.5.Deformed Mesh

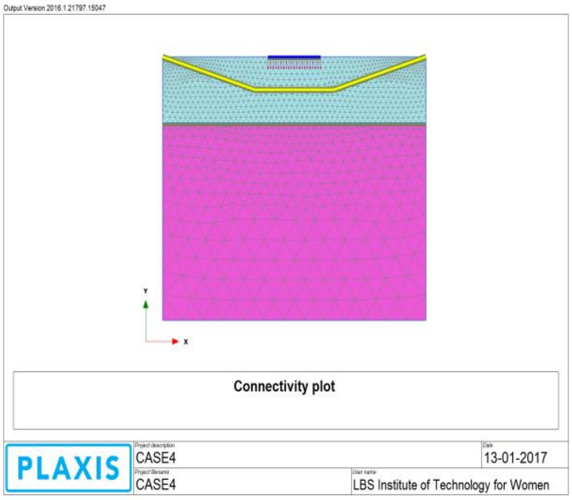

Fig.6.Discretised Model(Trapezoidal Configuration)

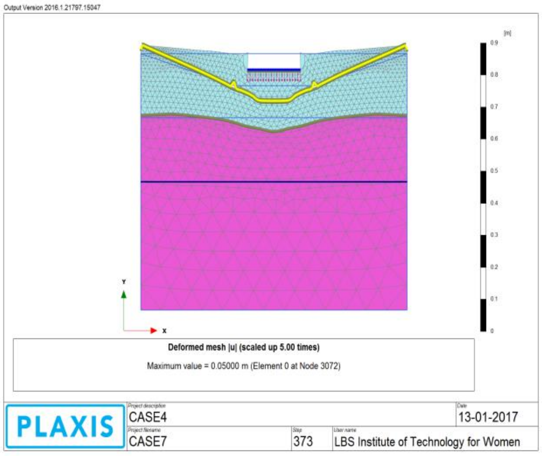

Fig.7. Deformed Mesh

I. RESULTS AND DISCUSSIONS

All The results obtained from Finite Element Analyses and are presented below.

a. Axial force on Geogrid

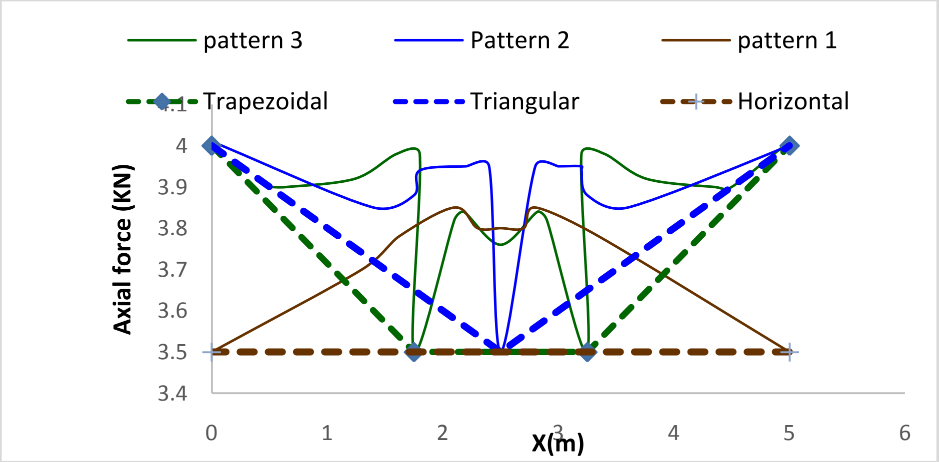

Fig.8.Axial forces on geogrid placed in different configurations

Figure 8 shows the axial force on geogrid placed in various configuration,obtained from finite element analyses. Here the reinforcement is placed in horizontal, triangular and trapezoidal configurations. Among different patterns the axial force reaches the highest value when trapezoidal configuration is used. It is seen that the axial force reaches its lowest value at junctions. This trend is common for all patterns.

b. Effective Normal stress On Geogrid

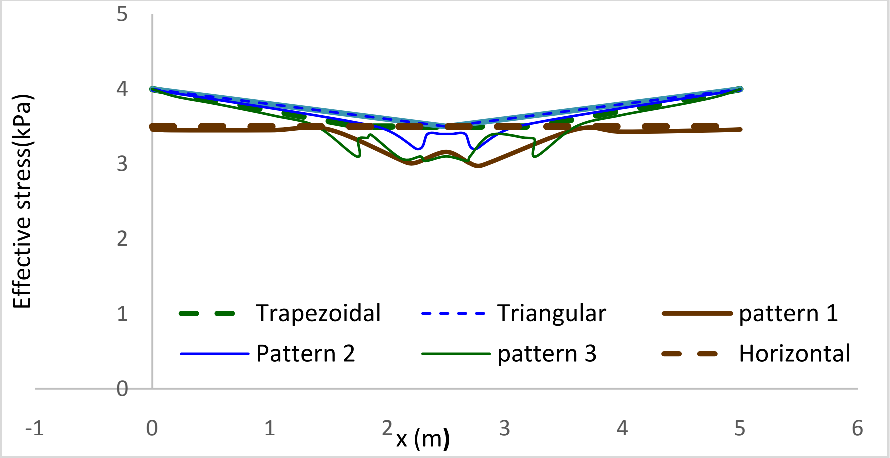

Fig.9. Effective normal stress on geogrid

Effective normal stress distribution on geogrid, obtained from finite element analyses are shown in figure 9. It is seen that normal stress pattern for all configuration are different. The curve for trapezoidal configuration behaves in an irregular manner.

c. Maximum Shear stress On Geogrid

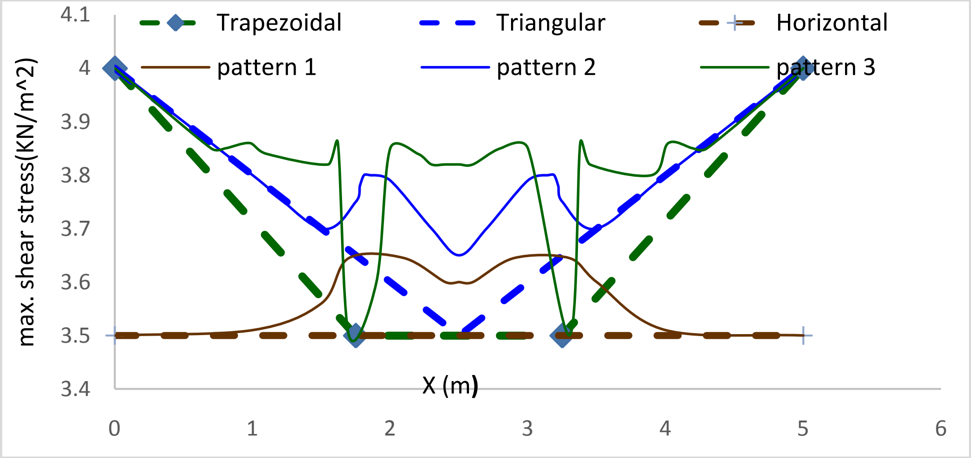

Fig.10.Maximum shear stress on geogrid

Figure 10 shows the maximum shear stress acting on geogrid placed in different configuration. The shear stress is found to be less when horizontal configuration is used. By analyzing the patterns obtained for different configuration it is seen that the shear stress reaches its lowest value at junctions. It is also seen that shear stress is maximum when trapezoidal configuration is used.

III. CONCLUSION

1. The Different configurations of reinforcement influences axial force, maximum shear stress and normal stress.
2. Axial force reaches its lowest value at junctions.
3. Shear stress reaches its lowest value at junctions.
4. Effective normal stress is concentrated more at the junctions.

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