Effect of Geogrid Configuration on The Behaviour of Foundation Bed Underlying The Embankment

A.S. Aiswarya
M Tech student,
Department of Civil Engineering,
Marian Engineering College, Kazhakuttom-695582

J. Jayamohan
Professor,
Department of Civil Engineering,
LBS Institute of Technology for Women,
Thiruvananthapuram- 695012

Neema Therese
Research scholar,
Department of Civil Engineering,
LBS Institute of Technology for Women,
Thiruvananthapuram- 695012

V. Rani
Associate Professor,
Department of Civil Engineering,
Marian Engineering College, Kazhakuttom-695582

ABSTRACT—Reinforced soil is a composite construction material formed by combining soil and reinforcement to improve the bearing capacity and decreased settlements and lateral deformations. In most of the current civil engineering applications, the reinforcement generally consists of geosynthetic sheets or strips, arranged horizontally or in the directions in which the soil is subject to the undesirable tensile strains. Geosynthetic is a well-known technique in soil reinforcement, where the common trend is to place the reinforcement in horizontal layers. Theoretically, for an effective reinforcement, it must pass through the tensile arc. This paper presents the results of laboratory model tests carried out to evaluate the effect of different pattern of reinforcement of an embankment resting on reinforced foundation bed overlying weak soil. It is observed that the pattern of reinforcement significantly influences the stability of embankment.

Keywords*— *Embankment, Geosynthetic, Load-settlement behaviour, Finite element analyses

I. INTRODUCTION:

Application of geosynthetics for improvement of shallow foundations has been studied by engineers over the past decades. Nowadays, the extensive use of geosynthetics to improve the bearing capacity and settlement performance of shallow foundations has proven to be a cost-effective foundation system. This is done by either reinforcing the weak cohesive soil directly or replacing the poor soils with stronger granular fill in combination with geosynthetic reinforcement. Among the range of geosynthetics available, geogrids are the most preferred type. reinforcing the foundation beds. The optimum effect of a geosynthetic inclusion is largely dependent on the various patterns of reinforcement provided. In low lying areas with poor foundation soils, the geosynthetic reinforced foundation bed can be placed over the weak soil which results in a composite ground called Reinforced Foundation Bed (RFB). Thus RFB will improve the load carrying capacity of the embankment and provide better pressure distribution on top of the underlying weak soils, hence reducing the associated settlements. Conventionally in most of the 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 (Jones C. J. F. P., 1996) and the pattern is shown in Fig 1.

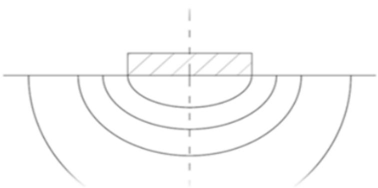

Fig 1. Ideal Pattern of Reinforcement beneath Footing (Jones 1996)

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. Here horizontal, inclined, trough-shaped and parabolic configuration of geogrid in RFB is compared.

II. MATERIALS USED:

Locally available weak clay and sand are used in this study. Biaxial Geogrid is used as reinforcement. The material used for the embankment is Lateritic Soil collected, which is well graded sand. The properties of clay, sand, lateritic soil and geogrid are presented in tables 1,2,3 and 4 respectively.

Table 1. Properties of Clay used as embankment foundation

Properties	Clay
Specific gravity	2.63
Optimum moisture content (%)	18
Dry Unit Weight (kN/m^3)	15.61
Liquid limit (%)	58
Plastic limit (%)	22
Plasticity index	36
Permeability (m/s)	3.03x10^{-6}
Percentage of clay (%)	68
Percentage of silt (%)	30
IS Classification	CH
Friction angle (ϕ °)	5
Cohesion (KPa)	25

Table 2. Properties of Manufactured sand used as granular soil

Properties	Sand
Specific gravity	2.65
Dry Unit Weight (kN/m^3)	17.33
Permeability (m/s)	1.07 x10^{-4}
Friction angle (ϕ °)	31.2
Cohesion (KPa)	0
Bulk density (kN/m^3)	18.436
Void ratio	0.5
IS Classification	SW

Table 3. Properties of Lateritic Soil used as Embankment soil

Properties	Lateritic Soil
Specific Gravity	2.6
Optimum Moisture Content (%)	15.5
Dry Unit Weight (kN/m^3)	18.835
Liquid Limit (%)	49
Plastic Limit (%)	36
Plasticity Index	12.5
Friction angle (ϕ °)	32
Cohesion (kPa)	13
D60 (mm)	1
D30 (mm)	0.425
Uniformity Coefficient (Cu)	6.67
Coefficient of Curvature (Cc)	1.204
IS Classification	SW

Table 4. Properties of Geogrid (Source: Manufacturer)

Properties	Values
Colour	Black
Coating Type	PVC
Textile Type	High Tenacity Low Shrinkage Polyester Yarn
Tensile Strength (kN/m)	13
Aperture Size (mm)	26 x 20
Mass per Unit Area (g/m^2)	225
Roll size (m x m)	100 x 2.40

III. LABORATORY MODEL TESTS

The laboratory scale load tests reported in this paper are carried out in the Geotechnical Research lab of LBS Institute of Technology for Women, Thiruvananthapuram.

A. Test Setup

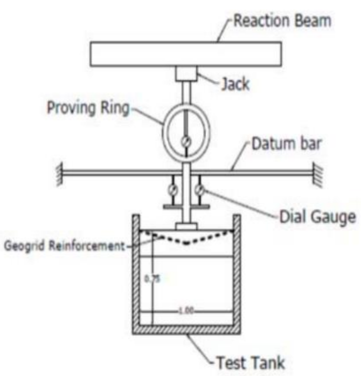

Fig 2. Test setup

Fig 3. Arrangement for measuring Load and Settlement

The load tests are conducted in a combined test bed and loading frame assembly. The test beds are prepared in a tank which is designed keeping in mind the size of the model embankment to be tested and the zone of influence. The dimensions of the test tank are 1000 mm length × 750 mm width × 750 mm depth. An inverted Tee Beam of flange width 100 mm is used over the model embankment to distribute the line load uniformly. The web of the Tee Beam is stiffened using MS angle sections. The loading tests are carried out in a loading frame fabricated with ISMB 300. The load is applied using a hand operated- mechanical jack of capacity 50kN. The applied load is measured using a proving ring of capacity 10kN. The settlement of the model embankment is measured using two dial gauges kept diametrically opposite to each other. The model embankment is placed exactly beneath the centre of loading jack to avoid eccentric loading. The width of foundation bed is taken as 55cm and thickness equal to 10cm for all the tests; where the top and base width of the model embankment is 15cm and 45cm respectively. At first the weak soil is filled in the test tank to the required level with compaction done in layers, to achieve the pre-determined density. Then sand bed is filled with reinforcement as per the pattern and compacted. The reinforcement is then placed with its centre exactly beneath the jack. Then sand above the reinforcement is placed and compacted to the predetermined density. The densities to which the soils are compacted are indicated in Table 1 and 2. The compaction effort required to achieve the required density of both the soils is determined by trial and error. Preparation of underlying soil in all the tests involved compaction of soil using a rammer. In the preparation of foundation bed, the sand is compacted using a small plate vibrator. The embankment is prepared over the sand bed with laterite soil and well compacted. The details of test setup are shown in Figure 3 and photograph in Figure 4.

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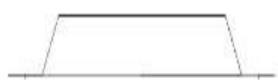
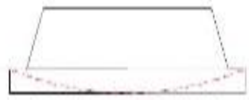
Table 5. Reinforcement Patterns

Pattern	Figure	Description
1		Embankment over weak Clayey soil
2		Embankment over granular bed with no reinforcement
3		Horizontal Reinforcement at mid height of RFB
4		Triangular pattern with centre of Geogrid at Base of RFB
5		Triangular pattern with centre of Geogrid at Mid height of RFB
6		Parabola pattern with centre of geogrid at base of RFB
7		Parabola pattern with centre of geogrid at mid height of RFB
8		Trapezoidal pattern with bottom width = B, at base of RFB
9		Trapezoidal pattern with bottom width = B, at mid height of RFB

IV. RESULTS AND DISCUSSIONS:

The load-displacement curves of unreinforced foundation bed and various patterns of reinforcement provided in the Foundation Bed obtained from model laboratory tests on loading are presented below.

Figure 4 presents the vertical stress vs normalized settlement curves for various configurations of reinforcement obtained from laboratory model tests. It is observed that horizontal reinforcement gives the lowest bearing capacity. Similar behaviour was observed from finite element analyses also. Pattern with Triangular Pattern with apex at mid height of RFB gives the best load-settlement behaviour. In general triangular pattern shows better results than trapezoidal pattern. In trapezoidal pattern the performance increases with the length of horizontal portion of reinforcement. In trapezoidal pattern, for the same length of reinforcement, performance is better when the horizontal portion is at the bottom of RFB. Parabola at mid depth of RFB shows better performance when compared to inclined pattern.

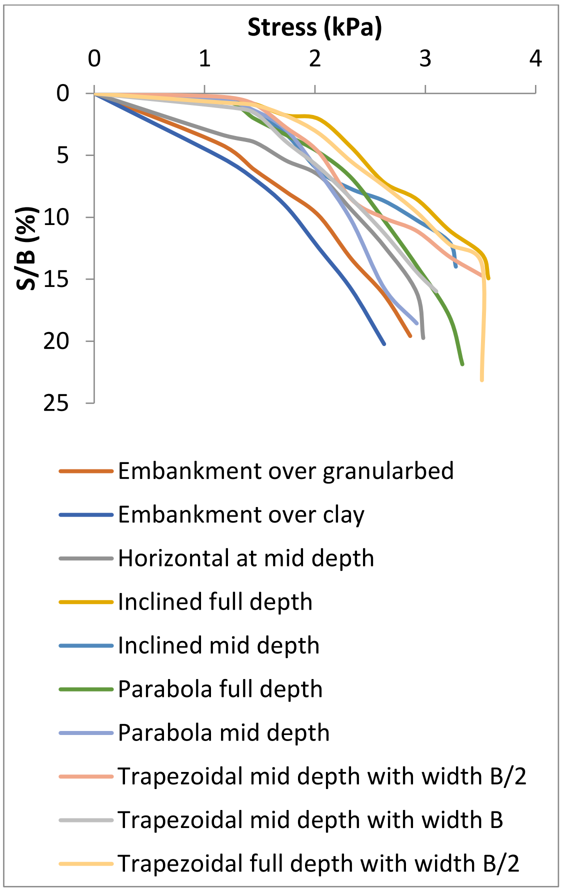


Fig 4. Stress vs Normalized settlement curves of various patterns of geogrid reinforcement.

Figure 4 shows the Stress vs Normalized settlement curves acting on geogrid placed in different configuration. The shear stress is found to be less when horizontal configuration is used. By analysing the patterns obtained for different configuration it is seen that the shear stress reaches its lowest value at junctions. It is seen that bearing capacity is optimum when trapezoidal full depth with base width equals half width of embankment configuration in RFB is used.

V. CONCLUSION

- The influence of inclination of geosynthetic on the Reinforced Foundation Bed is significantly influenced by the configuration of reinforcement.
- Horizontal Pattern of reinforcement gives the least load-settlement behaviour.
- Stress vs Normalized settlement curves for various configurations of reinforcement obtained from

laboratory model tests where shear stress reaches its lowest value at junctions.

- Performance is better of trapezoidal- shaped and parabolic configuration of reinforcement than inclined configuration in RFB.

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