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Behaviour of Strip Footing Supported on Stressed Encapsulated Granular Trenches

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ABSTRACT: Rapid and urban growth demands more land for further development. Construction is often required to be carried out in land of poor geotechnical quality. Techniques to improve the performance of footings in such weak soils is presented. Granular Trench(GT) is a replacement technique where the poor soil immediately below a footing is replaced with a good quality high frictional granular material. In Encapsulated Granular Trench(EGT), sand is confined by encapsulating the same in a geosynthetic wrap. Attempt has been made to pretension the geosynthetic and induce stresses within the encapsulating geosynthetic, which when loaded with footing will oppose the induced stresses. Laboratory model plate load tests were conducted on strip footings resting on stressed encapsulated granular trench or SEGT. Tests were conducted by varying the density of the granular trench material and also different prestressing force were used to investigate the influence of the same. It was found that SEGT performs better than EGT and GT Enhancement of ultimate bearing capacity up to 8 times was noticed in the configurations tested. Comparison between experimental and analytical results were done.

KEYWORDS: Stressed Encapsulated Granular Trench, Pre stress, Bearing capacity ratio

I. INTRODUCTION

The availability of good quality land for construction is decreasing day by day. The soil at the construction site is not always totally suitable for supporting structures such as buildings, bridges etc. This has forced Geotechnical Engineers to adopt ground improvement techniques to improve the weak soils. The various methods of ground improvement include stabilization, dynamic compaction, grouting, provision of soil reinforcement, etc. The main objective of ground improvement is to reduce the settlement of structures, improve the shear strength and bearing capacity of shallow foundations and to reduce the shrinkage and swelling of the soil. The concept of soil reinforcement is extensively used in many geotechnical structures including retaining walls, embankments, foundations, highways, airport payments and railway tracks. The use of geosynthetics to improve the bearing capacity and settlement performance of foundation has proven to be a cost effective solution in certain situations. In marginal ground conditions geosynthetics enhance the ability to use shallow foundation in the place of more expensive deep foundation

Over the past three decades, the beneficial use of reinforcement materials like metal strips and geosynthetics to increase the bearing capacity of sand has been clearly established. [1]-[11]. The supporting capacity of soft compressible ground may be increased and the settlement may be reduced through the use of tensile reinforcement. Strip footings are often supported on granular trenches below the footing level in weak soils. Granular Trench is a replacement technique whereby the weak soil below the footing is replaced with a good quality compacted frictional fill. The improved strength and deformation properties of the replacement material improves the overall performance of the footing resting over it.

It has been reported that provision of a geosynthetic wrap around a granular trench improves the response of a strip footing over it. Such a granular trench is called as Encapsulated Granular Trench[18]. In the investigation reported herein, attempt has been made to stress the granular material in the EGT by means of pre-tensioning the



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geosynthetic[19]. The term Stressed Encapsulated Granular Trench (SEGT) is introduced. Laboratory model tests were conducted on strip footings in loose sand resting on Encapsulated Granular Trenches and Stressed Encapsulated Granular Trenches. Parameters such as density of the trench material and Prestressing force were investigated.

II. STRESSED ENCAPSULATED GRANULAR TRENCHES (SEGT)

Granular trench is a two dimensional extension of a stone column Encapsulated granular trench is formed by wrapping geosynthetic around the granular trench. The geosythetics are pre-tensioned to induce stress within the granular material. In practice, such pre-stress can be induced using the principle of screw jack after anchoring to a post driven into the soil. In the laboratory environment, pre-stress was provided through suspended weights. Use of geosynthetic encapsulation is expected to provide additional confinement to the granular fill material. Installation of the stressed encapsulated trench is easy and it does not require special equipment or manpower.

The installation procedure is as follows. The trench is excavated to the desired level. The geosynthetic is spread over the surface of the trench with its edges unfolded over the surface of the bulk soil. The trench is filled with granular fill to the desired relative density. The granular trench is wrapped with the geotextile by bringing both ends together. The prestressing force is applied prior to loading by suspending weights by means of strings. One end of the string is anchored to the geotextile and weights are allowed to hang from the other end. This induces a pre-stressing force in the geosynthetic.

III. EXPERIMENTAL INVESTIGATIONS

Based on the review of literature, it was found that provision of granular trench below strip footing increases the load carrying capacity [18]. Experimental investigations were carried out to examine the improvement in performance of strip footing supported on Encapsulated Granular Trench (EGT) and Stressed Encapsulated Granular Trenches (SEGT)

A. MATERIALS AND TEST FACILITIES

Soil used in the entire testing program was dry sand. Weak soil in the form of sea sand of low relative density was utilized. Sea sand was used to form bulk soil and river sand was used to form the replacement soil. The sand used to form the bulk soil and the replacement soil was classified as poorly graded sand (SP) by unified soil classification system The other properties of sand as determined in the laboratory are shown in the Table 1. Particle size distribution is shown in the Fig. 1. The maximum and minimum dry densities of sand were found and the corresponding values of maximum and minimum voids ratio were found out.

To maintain the same relative density for all the tests, the rainfall technique is adopted for the deposition of sand. But this method is suitable for obtaining low relative densities only. For obtaining higher densities a tamping system was adopted. Constant energy of compaction was maintained between experiments. For all the tests the density of bulk soil is (sea sand) is maintained as 13.9%(very loose condition). The replacement soil is filled in four different densities. The relative density values for replacement soil are shown in Table 2

Properties	Value	
	Sea sand	River sand
Specific gravity	2.67	2.65
Effective particle size(D10) mm	0.19	0.50
Mean particle size(D50) mm	0.42	1.70
Maximum density (g/cc)	1.9	2.04
Minimum density (g/cc)	1.50	1.68
Uniformity coefficient	2.31	3.7
Coefficient of curvature	1.55	1.82
Maximum voids ratio	0.77	0.64
Minimum voids ratio	0.34	0.29

Table 1. Properties of sea sand and river sand



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Table 2. Relative density values for replacement son		
Denseness	ID%	
Loose	22.4	
Medium dense	56	
Dense	66	
Very dense	87	

Table 2. Relative density values for replacement soil

Two different types of geosynthetics were used in the present study. These are designated as Grid 1 and Grid 2. Grid 1 is a geogrid used for actual reinforcement applications having a relatively larger opening size and higher stiffness. Grid 1 has a low stiffness value and a small opening size and is commercially used as insect screen.

Table 3. Properties of Geosynthetics			
Properties	Grid 1	Grid 2	
Mass per unit area(g/m2)	270	240	
Thickness	5	1	
Opening size	Square 3.8mm×3.8mm	Diamond 2mm×2mm	
Tensile Strength(kN/m)	11.35	1.2	



Fig.1. Particle size distribution of sea sand and river sand



Fig .2. Geogrids used in the study



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B. FORMATION OF GRANULAR TRENCH

To begin with, the sand bed is placed to the desired thickness at the desired relative density by sand raining technique. The triangular trench of the required size is formed. Geosynthetic is then laid with the ends spread over the sand bed. Well graded river sand used for the granular trench is placed at the desired relative density. The geosynthetic is folded over the filled trench and is overlapped. In the case of SEGT, the prestressing force is applied by means of suspended weights prior to loading. The footing is placed over the completed trench and loaded



Fig 3. Trench

C. TESTING PROGRAMME

Laboratory model strip footings with and without EGT support and SEGT support were loaded to failure. Tests were conducted on strip footings resting on unreinforced sand in very loose condition, Encapsulated Granular Trenches and Stressed Encapsulated Granular trenches. Relative density of replacement soil and prestressing force in the geosynthetic were varied.



Fig. 4. Schematic diagram of load testing setup.

Based on the previous studies [19], triangular trench of width 30cm and depth 10cm was found to be most efficient. Hence this trench size was adopted for further investigations. Laboratory model plate load test were conducted as per IS 1888-1982. Tests were conducted in different series, i.e., unreinforced sand, EGT with loose, medium dense, dense and very dense in fill. For each combination of EGT, prestressing forces of 0.20kN/m, 0.33kN/m, 0.44kN/m and 0.60kN/m were applied. In all the tests Grid 1 and Grid 2 is used in combination. Grid 2 is primarily used as a separator.

For forming the encapsulation, it is necessary to bring both ends of the geotextile and join it. In the case of



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overlapped joint, one end of the geotextile is spread over the trench for the full width. The geosynthetic will be in contact with the soil on one face. On the top exposed face, a layer of well graded sand was provided for ensuring sufficient friction. The other end of the geosynthetic is then laid over this and another layer of well graded sand is spread over the exposed face of the geosynthetic. The footing was placed over this layer of sand. When overlapped in this manner, the friction between the soil and geosynthetic provides necessary anchorage and the encapsulation become effective. The prestressing force is applied by suspending weights by means of strings. One end of the string is anchored to the geosynthetic and at the other end the weights are suspended.

Laboratory model plate load tests were conducted on strip footings resting on, EGT and SEGT. The arrangement for the testing programme is shown in Fig. 5. The dimensions of the tank were fixed as 0.75m long, 0.75m wide and 0.75m deep. The model footing was 0.75m long, 0.13m wide and 0.07m thick and was made of steel. Vertical load was applied to the model footing by means of a hydraulic jack. Magnitudes of the applied load were recorded with the help of a sensitive proving ring of 100kN capacity. To record the vertical settlement of footing for each increment of load applied, two sensitive dial gauges of least count of 0.01mm were used. The average of the readings was reported as the settlement. The dial gauges were mounted on a rigid beam by means of magnetic bases.



Fig.5. Experimental Setup

IV. ANALYTICAL STUDY

Finite element analysis were performed to simulate the response of footings on EGT and SEGT. Analysis were carried out using commercially available software PLAXIS 2D Version 8. Plaxis is capable of modelling a wide variety of nonlinear geotechnical situations. Soil is modelled using Hardening-Soil model. Footing was modelled as linearly elastic material made of steel. Geogrid was modelled using geogrid element. Comparison of the experimental and analytical results were made

V. RESULTS AND DISCUSSIONS

Fig.6. show bearing pressure versus settlement behaviour of footings on Encapsulated Granular Trench (EGT) where the trench material is of varying densities. Grid 1 and Grid 2 were used in combination in EGT. The load settlement response of footings without granular trench (on homogenous sea sand bed) is also shown for comparison. The figure clearly shows that by providing Encapsulated granular trench below the strip footing, the load carrying capacity is increased. It is also seen that by increasing the density of the trench material, the load carrying capacity is further enhanced.

Fig.7, Fig.8, Fig.9 and Fig.10 shows the bearing pressure versus settlement behaviour of footings on EGT and SEGT, SEGT for prestressing force of 0.20, 0.30, 0.44, 0.60kN/m. From the graph it is clear that by increasing the prestressing force, the load carrying capacity of the strip footing is increased and the settlement reduced.



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Fig.6. Bearing Pressure versus settlement for EGT for varying densities





and SEGT



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Fig.10.Bearing Pressure versus settlement for EGT (very dense) and SEGT

Fig.11. shows the variation of prestressing force vs ultimate load taken by the strip footing. From the graph it is seen that the ultimate load taken by the strip footing increases with increase in the prestressing force and thus increases the load carrying capacity of the strip footing. A near linear pattern of variation is observed. It is necessary to conduct experiments with higher pre-stress forces to establish the trends at such levels.

Fig.12. shows the variation of bearing pressure versus Relative density .From the graph it is clear that as the relative density of the trench material increases the load carrying capacity of strip footing increases. From the graph it is also clear that for a particular density as the prestressing force increases the load carrying capacity is increased.



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For the purpose of comparison of the performance of various configurations, a non-dimensional factor called Bearing Capacity Ratio (BCR) is being used. In the present investigation, BCR is defined as the ratio of the ultimate load taken by the granular-trench supported footing (q_g) and that of the footing without granular-trench (q).

$$BCR = \frac{q_g}{q}$$

Fig 13,Fig 14,Fig 15, and Fig 16 shows variation of bearing capacity ratio with settlement for encapsulated granular trenches and stressed encapsulated granular trenches for a settlement of 5mm, 10mm, 15mm, 20mm and 25mm The settlements (s) are normalised with the footing width (B). From the graph it is seen that for a given settlement, the bearing capacity ratio increases with increase in prestressing force and also with increase in relative density.







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Fig. 15. Variation of BCR with normalized settlement for EGT and SEGT supported strip footings



Fig. 16. Variation of BCR with normalized settlement for EGT and SEGT supported strip footings



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Fig.17 Comparison of Experimental and Finite element Results for Encapsulated Granular Trench (EGT)



Fig 18 Comparison of Experimental and Finite element Results for Stressed Encapsulated Granular Trench (SEGT)

Fig 17, 18 shows the comparison of experimental and analytical results for EGT and SEGT. Both the experimental and finite element results show compareable behaviour regarding the load carrying capacity.

V. CONCLUSIONS

The study was aimed at exploring the possibility of improving the load carrying capacity of strip footing in loose sand with the help of encapsulated granular trenches and stressed encapsulated granular trenches (SEGT). Load tests were carried out on strip footing supported encapsulated granular trenches. Relative density of trench fill material was varied over a range. Also various prestressing forces were applied. Provision of geosynthetic encapsulation increased the load carrying capacity of the footings. The results also showed that by increasing the relative density of the trench material, the load carrying capacity increased. Stressing the granular trench by means of pre-stressing the geosynthetic further improved the load carrying capacity. By increasing the prestressing force, the load carrying capacity of the strip footing can be increased. Maximum BCR improvement up to 8 times was observed for the configurations tested. Analytical and experimental results showed comparable behavior.



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