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Effect of Dual Geotextile Reinforcements on Shallow Anchor Uplift Capacity

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Abstract. Small scale laboratory pullout model tests were performed on sand beds having a relative density (R_d) of 70% in the present study. For the tests, a mild steel test tank of 1000 mm (length) x 1000 mm (width) x 1000 mm (height) and circular-shaped anchor size (D) of 100 mm were used. The embedment depth (L) to diameter (D) ratio (L/D) of the anchor plate during the model tests was maintained constantly at 4. For the anchor uplift capacity improvement, the model tests were performed using polypropylene geotextile (PPGT) as a reinforcement material. Furthermore, a series of laboratory model tests were performed to see the effect of number of reinforcements on anchor uplift capacity using single and double number of reinforcements having a size of each 2D and maintained 0.1D and 0.5D vertical spacing (h) for the case of double number of reinforcements. For all the model tests, the first reinforcement was placed directly above the anchor plate. The test results showed that the improvement is higher with double reinforcements at lower uplift displacements compared tothe single number of reinforcements. However, irrespective of number of reinforcements, the test results revealed that the amount of improvement of the anchor ultimate capacity is same.

Keywords: Anchors, Geosynthetic reinforcements, Sands, Pull-out Capacity.

1 Introduction

The Plate anchors are used to improve the uplift capacity of tall tower kinds of structures such as transmission towers, television towers, etc., (Zhuang et al. 2021). However, the percentage of improvement using plate anchors is not sufficient to resist the uplift forces of the structures that occurred in the real field (Kishor Kumar and Ilamparuthi 2020). Hence, the geosynthetics have been used to improve the anchor(s) uplift capacity (Krishnaswamy and Parashar 1994; Ilamparuthi and Dickin 2001b;

Kishor Kumar and Ilamparuthi 2020). Several researchers used different types of geosynthetics to improve the pullout capacity of the anchors such as geotextiles, geogrids, geo-composites, and geocell reinforcements (Krishnaswamy and Parashar 1994; Kishor kumar and Ilamparuthi 2020). Krishnaswamy and Parashar (1994) per- formed pullout tests by maintaining different spacing of double number of reinforce- ments using the plate anchor size (D) of 60 mm. The tests were performed using dou- ble number of geo-composite reinforcements by varying the spacing of the reinforce- ments of 0.4D to 2.5D. The test results showed that the spacing of reinforcement of 0.4D exhibit higher improvement compared to the other spacings of reinforcements. However, the amount of improvement is almost same as of single number of reinforcements. Similar study was performed by numerical analysis simulating the geotextile reinforcement by varying the spacing of reinforcement from the anchor plate surface using single number only (Banerjee and Mahadevuni 2017). Kishor Kumar and Ilamparuthi (2020) performed the model tests to see the effect of planar form of reinforcements compared with the reinforcement of geocell (3D) configuration. During the model tests, the researchers were used double number of geogrid reinforcements and maintained the same quantity in the geocell form also.

As per the literature, the laboratory model pullout tests using geosynthetics were limited to geo-composite i.e., placing non-woven geotextile between two geogrid reinforcements (Krishnaswamy and Parashar 1994), and geogrid as well as geonet reinforcements (Makarchian et al. 2012; Kishor Kumar and Ilamparuthi 2020). However, hardly very few studies have been performed to understand the effect of quantity of geotextile reinforcements on the anchor uplift capacity. Hence, the following research study focus on the effect of geotextile reinforcements amount on anchors' pullout capacity.

2 Materials

2.1 Sand

A poorly graded sand collected nearer to the institute was used for the present model tests and performed the sieve analysis as per IS 2720- 4 (1985). As per the sieve analysis, the sand consists uniformity co-efficient (C_u) and coefficient of curvature (C_c) is 3.03 and 1.36, respectively. The shear strength properties (i.e., cohesion and angle of internal friction) were measured as per IS 2720-13 using small-size direct shear box of 60 mm x 60 mm x 30 mm and the following results of cohesion and angle of inter- nal friction were 0 kPa and 40.2^0, respectively. Table 1 describe the properties of sandused in the research.

Table 1. Properties of sand

Sand			
Property	Values	Property	Values
Specific Gravity, G_s	2.69	Coefficient of Uniformity, C_u	3.03
D_{10} (mm)	0.33	Coefficient of Curvature, C_c	1.36
D_{60} (mm)	0.86	IS Classification	SP

2.2 Reinforcement Material

The model tests were performed using woven polypropylene geotextile reinforcement (PPGT) which was collected from Techno Fabrics Geosynthetic (P) Ltd., Gujarat, India. The physical properties known as thickness and mass per unit area were meas- ured as per ASTM D 5199-12 and ASTM D 5261-18, respectively and the mechanical properties known as tensile strength was determined as per ASTM D4595-17. Table 2 presents the properties of the geotextile material used in the present study.

Table 2**.** Properties reinforcement material of PPGT.

PPGT	
Property	Values
Thickness (mm)	0.4
Mass per unit area (g/m^2)	130
Ultimate tensile strength - MD x CMD (kN/m)	29.6 x 23.5
Tensile stiffness at 5% strain (kN/m)	101
Failure strain - MD x CMD (%)	30.2 x 21.4

MD: Machine direction; CMD: Cross-machine direction

3 Experimental test setup

A small thickness (6 mm) of plate anchor made with mild steel having a size (D) of 100 mm was used for the model tests. The tests were performed in a mild steel test tank having dimensions of 1000 mm (length) x 1000 mm (width) x 1000 mm (depth). To eliminate the test tank boundaries during pullout, the size and depth of test tank is maintained as 10 times of the size of the anchor, D (Rahimi et al. 2018). The depth (L) of the anchor plate during the model tests was maintained as shallow i.e., L/D = 4 (Ilamparuthi et al. 2002). It means that the embedment depth (L) of the anchor was maintained in all the model tests as a 400 mm. During the model tests, the sand bed was prepared in the test tank at a relative density (R_d) of 70%, by maintaining the tamping technique method as procedure followed by Ilamparuthi and Dickin (2001a). A long tie wire was inserted through a circular plate anchor and to restrict the moving out of the plate, the tie wire was fixed at bottom of the plate anchor with nut and bolt arrangement. While performing the model tests, the applied load would be transferred to the tie wire through pulley system, as a result the anchor would be pulled out.Fig.1a show the complete view of test setup used in the present research study. As perthe literature, the single number of reinforcement layer which is placed directly above the anchor gives the higher uplift capacity in comparison to the other placementdepths and also compared with the multi-layered reinforcement conditions (Krish- naswamy and Parashar 1994). Hence, the model pullout tests for single and double number of reinforcement sand beds were performed by placing the first reinforcementimmediately above the anchor plate as depicted in Fig. 1b. The size of the reinforce- ment is maintained as 2 times of the size of the anchor, D (Kishor Kumar and Ilampa- ruthi 2020). During the pullout, the anchor movement or displacement was measured using two dial gauges which were placed on the small thickness of circular plate laid on the surface level of the sand bed as shown in Fig. 1a.

Fig. 1a A Photographic view of complete laboratory test setup.

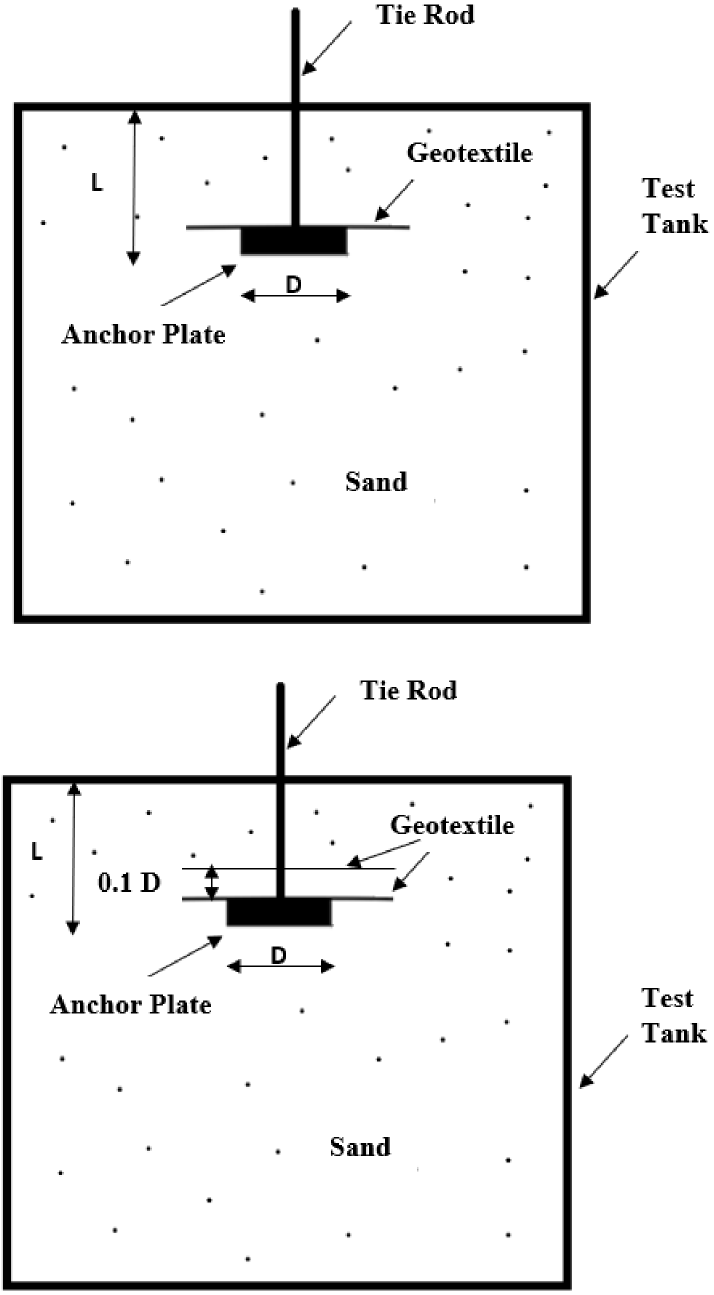

Fig. 1b A line diagram representing different position of reinforcements above the anchor plate.

4 Results and Discussion

Fig. 2 shows the load-displacement behavior of the plate anchor of both unreinforced sand and reinforced sands. The test results revealed that the unreinforced sand was failed at a pullout load of 1200 N or 1.20 kN (peak pullout load) and the following test result is consistent with the theoretical findings (i.e., 1.05 kN) of Ilamparuthi et al. (2002). The test results of single number of PPGT reinforced sand show the peak failure of 1.40 kN and it proves that the anchor pullout capacity with PPGT rein- forcement increased a factor of about 1.17 times higher than the unreinforced sand. The photographic view of failure reinforced sand bed is depicted in Fig. 3. For the case of unreinforced sands, the bulging rupture surface with the anchor plate surface makes 22.2^0 angle (i.e., $\phi/2$) as shown in Fig. 4. The following test result is identical with the findings of literature (Ilamparuthi et al. 2002).

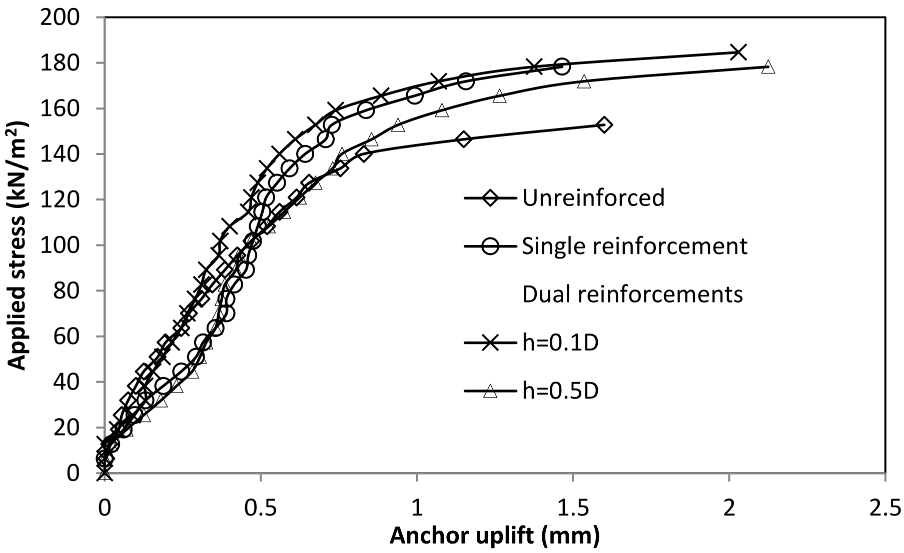

Fig. 2 Variation of applied stress with anchor uplift for unreinforced soil and soil with single and double reinforcements

Fig. 3 A Photographic view of reinforced sand bed after failure.

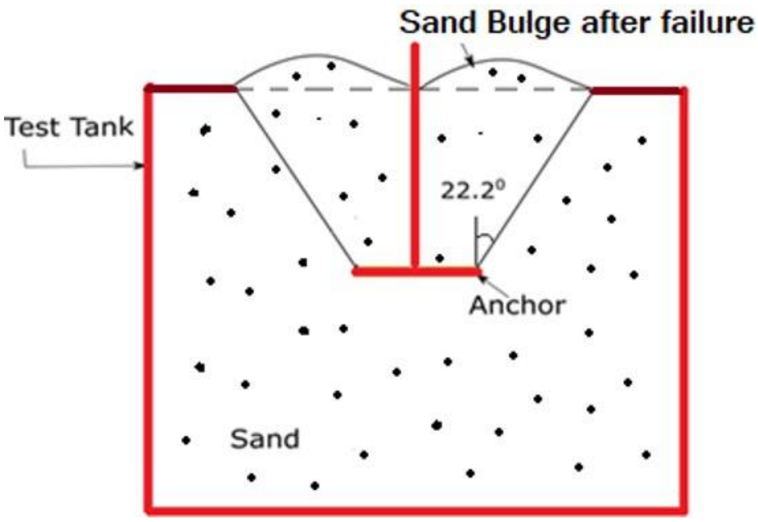

Fig. 4. A detailed view of unreinforced sand bed after failure.

Fig. 2 also show the effect of load-displacement curves of anchor in presence of double number of PPGT placed at a spacings (h) of 0.1D and 0.5D. Interestingly, the test results revealed that the anchor pullout capacity with double number of reinforcements having 0.1D show higher compared to the single number of reinforcements during the initial uplifts. It could be happened due to the less interaction between the sand-geotextile reinforcement during the initial uplift for the case of single number of PPGT. Furthermore, the overall stiffness of reinforced sand bed is more for the case of multi-layer (double number) reinforced sand beds compared to single number reinforced sands, and as a result shows the higher im- provement during initial uplifts itself. Contrastingly, the reinforcement placed at a spacing (h) of 0.5D show lesser improvement even though at initial uplifts as compared to the results double number of reinforcements having spacing (h) of 0.1D. The following behavior consistent with the test results of Krishnaswamy and Parashar (1994). However, irrespective of number of reinforcements, the ultimate uplift capacity is same for both single and multiple number of reinforcements. It could be understood that the multiple number of reinforcements not improves the anchor uplift capacity as compared to the unreinforced sand improvement which occurred in the presence of single number of reinforcement (Krishnaswamy and Parashar 1994).

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5 Conclusion

The anchor pullout capacity with single and double numbers of PPGT reinforcement increased about a factor of 1.17 times higher compared to unreinforced sand. Finally, the test results elucidate that the placement of single number of reinforcements enhances the anchor uplift capacity more as compared with the introducing another reinforcement i.e., multiple reinforcements.

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