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Technical Note

Uplift Behaviour of Horizontal Plate Anchors with Geosynthetics

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Introduction

There are many examples in civil engineering design such as tall transmission towers, radio and television towers, retaining walls, suspension bridges and offshore structures, whose foundations are subjected to large uplift forces. In such cases an economical design solution may be achieved by the use of tension members known as anchors, so that they can resist the pull out forces with adequate safety. Plate anchors are one of the most commonly used types of anchor.

To improve the uplift capacity of plate anchors, a well-established technique for achieving cost effective solution is use of geosynthetics in the form of reinforcement. The increase of uplift capacity is due to frictional characteristics of soil geosynthetic system.

Very few investigations have paid attention to study the behaviour of plate anchors with geosynthetics.

Subbarao et al. (1988) conducted model tests on two types of reinforced concrete anchors. One is a cylindrical pile of 0.1 m diameter and other is a belled anchor of 0.075 m stem diameter and 0.19 m base diameter with geotextile ties of 0.65 m and 0.35 m length for cylindrical and belled anchors in sandy medium. He observed that geotextile ties provide much greater uplift resistance than the anchors without ties. They also observed that multiple layers of tie are useful but the increase in

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number of layers does not offer proportional increase in the uplift resistance.

Krishnaswamy and Parashar (1994), and Parashar and Krishnaswamy (1994) have studied the uplift behaviour of plate anchors embedded in cohesive and cohesionless soil medium, with and without geosynthetics with the help of small scale model tests. Many factors, such as the type of geosynthetics, the ratio of the area of geosynthetic inclusion to the area of plate anchor, the depth of embedment, the type of soil, the strain rate and the position of water table have been found to significantly influence the uplift behaviour of plate anchors. It was found that the inclusion of geosynthetic in both cohesive and cohesionless soils enhances the uplift capacity of plate anchors.

Garg (1997) studied the behaviour of shallow horizontal plate anchors in reinforced cohesive and cohesionless soils. The plate anchors of strip, circular and square with width of 50 mm and 100 mm and depth to width ratio 1, 2, 3 and 4 depending upon the sizes have been tested in laboratory. Geosynthetics of size 3 times the width of anchor was kept at placement ratio 0.25. They developed an analytical solution to predict ultimate uplift capacity of reinforced shallow horizontal anchors subjected to vertical loads. The analysis is done for the above anchors using non-woven, woven and geogrid types of geosynthetics. They concluded that there is a definite increase in uplift capacity due to reinforcement and this increase is due to frictional properties of geotextile and type of geotextile. They also observed that geogrid type of reinforcement is found to be best as compared to woven and non-woven geotextiles. They found the increase of uplift capacity is 30 to 50% in case of cohesive soils and for any uplift load, the deformation of reinforced anchor is less than non reinforced anchors. Experimental results were compared with the values predicted by proposed analysis. A good agreement was reported.

The aim of this investigation is to study the behaviour of horizontal plate anchors in cohesionless soil with and without geosynthetics experimentally.

Test Program

This study has been restricted to horizontal plate anchors only. The model anchors were made from mild steel plates of 6 mm thickness. Tests were performed on horizontal plate anchors of two shapes (i) Square (100 mm × 100 mm) and (ii) Circular (100 mm diameter).

The soil used in this study was Ranipur sand (SP, C_u = 1.63,

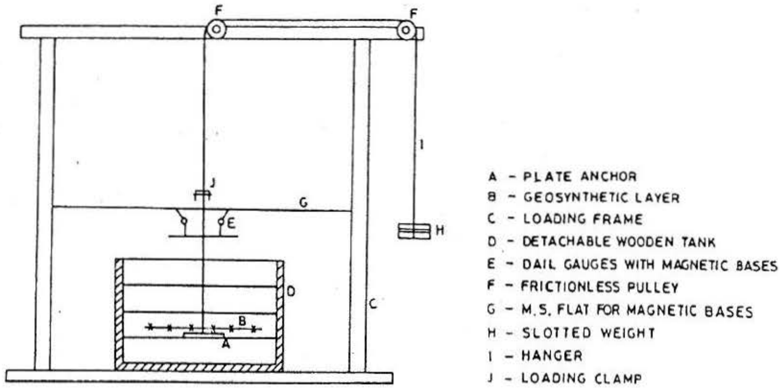

FIGURE 1 : Test Set-Up

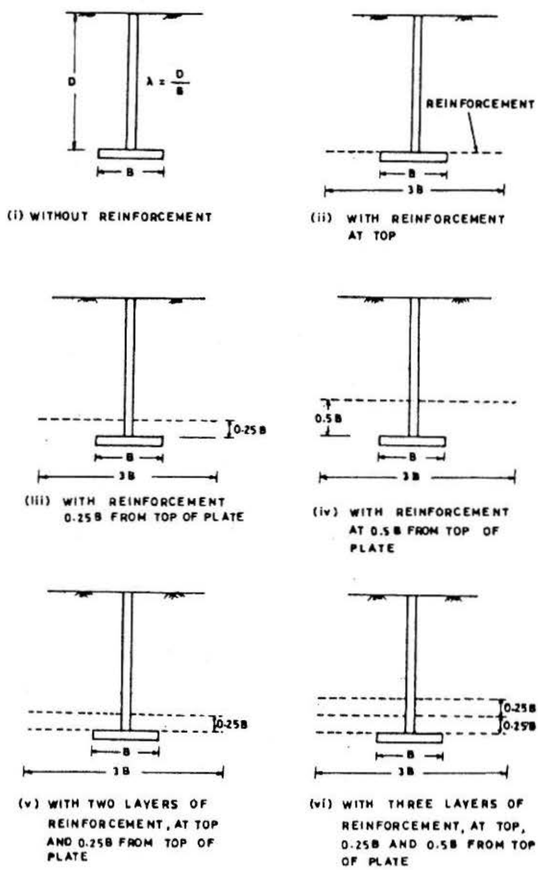

FIGURE 2 : Placement of Reinforcement during Testing

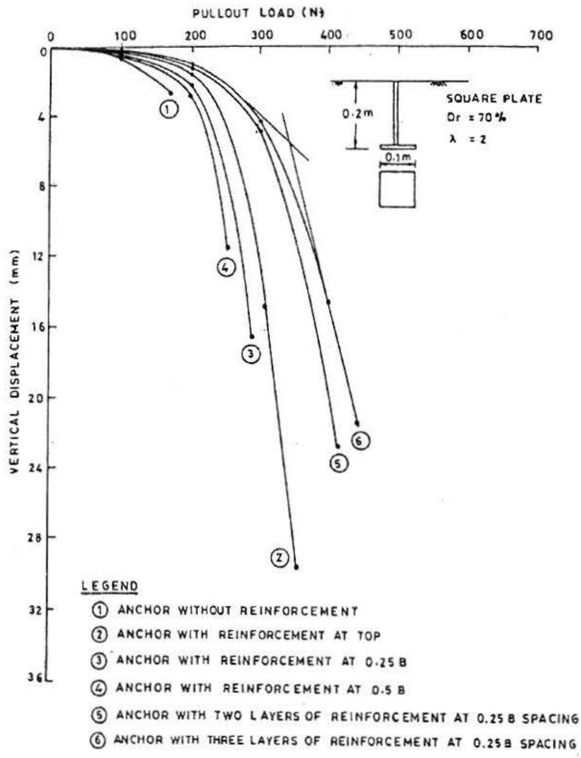

FIGURE 3 : Load Displacement Curve

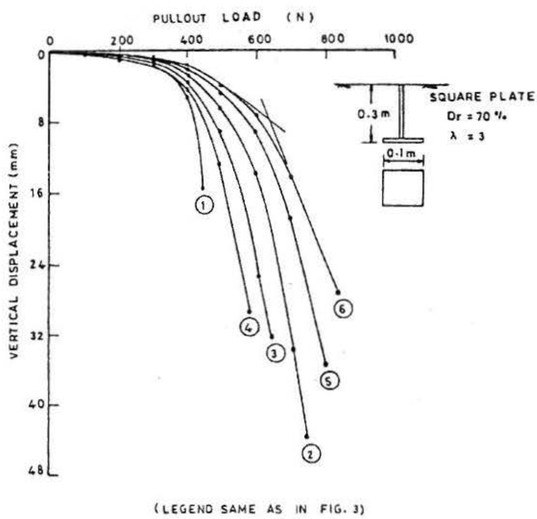

FIGURE 4 : Load Displacement Curve

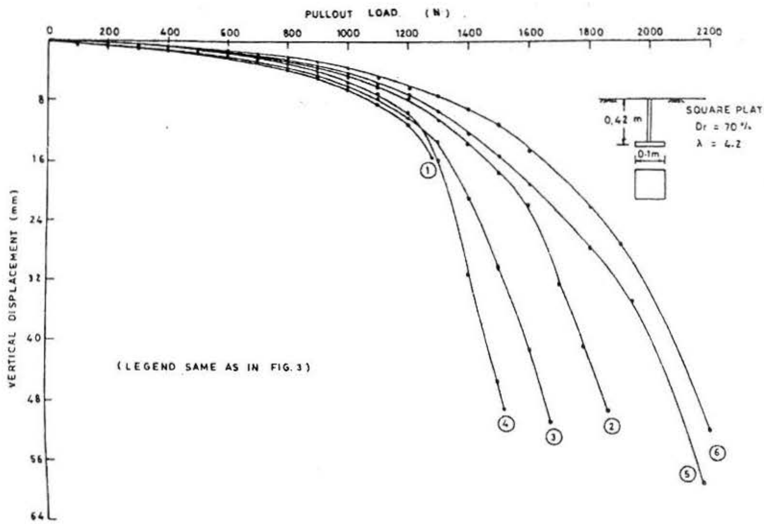

FIGURE 5 : Load Displacement Curve

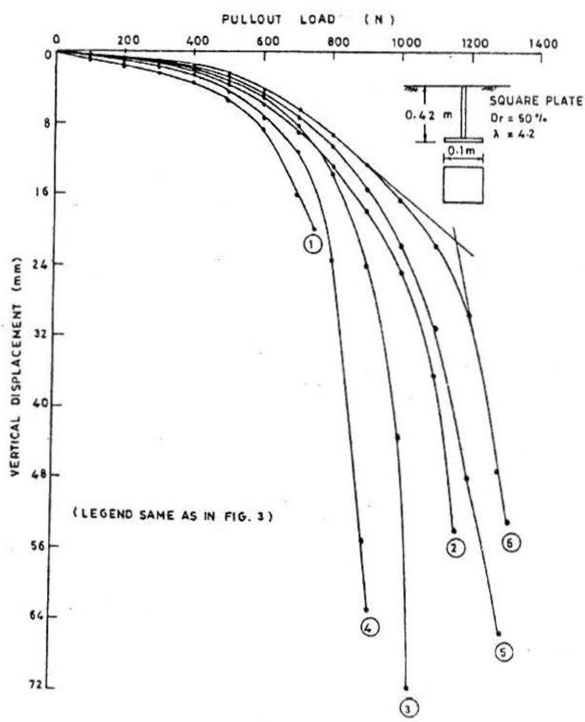

FIGURE 6 : Load Displacement Curve

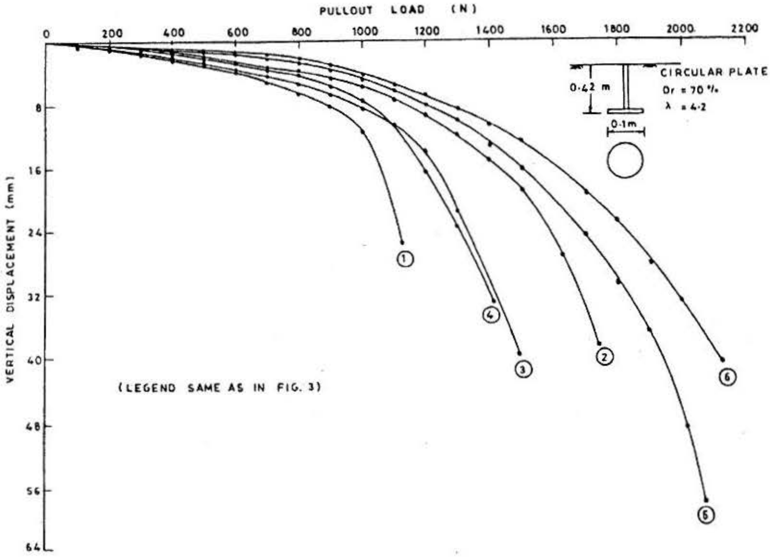

FIGURE 7 : Load Displacement Curve

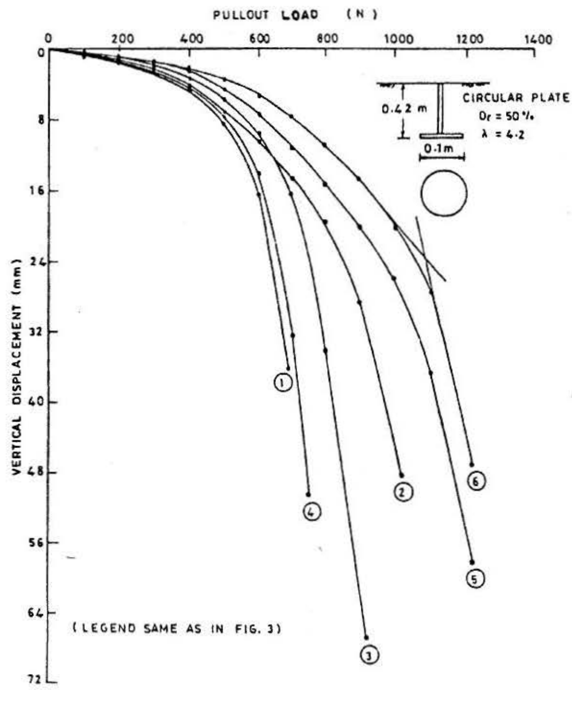

FIGURE 8 : Load Displacement Curve

D_{10} = 0.24 mm). The tests were conducted by placing sand at relative densities (D_r) of 70% (ϕ = 38°) and 50% (ϕ = 36°).

The reinforcement used was geogrid (CE-121 HDPE). The tensile strength of the reinforcement was found as 7.7 kN/m. The size of the geogrid mesh was kept as 3 times of the size of anchor plate (i.e. 300 mm × 300 mm).

Tests were performed in a tank of size 500 mm × 500 mm × 600 mm high. The sand was placed firstly upto anchor plate level only. The anchor plate was then positioned and tank filling was then continued. In between the filling of sand, the geogrid layers were placed at desired positions. The sand was placed by rainfall technique in which the sand was rained from the required height to attain the desired relative density. The loads on the anchor plate were applied through pulley-hanger arrangement, and the corresponding displacements were noted with dial gauges. The complete set up is shown in Fig.1.

The depth ratio (λ) is defined as ratio of depth of anchor plate below surface of sand to the size of anchor plate. Tests were performed on depth ratios of 2, 3 and 4.2.

In all 36 tests were performed in six series. In each series six tests were performed as per the arrangement of reinforcing layers shown in Fig.2. The six series are detailed as below:

Series I Square plate (100 mm × 100 mm), D_r = 70%, λ = 2

Series II Square plate (100 mm × 100 mm), D_r = 70%, λ = 3

Series III Square plate (100 mm × 100 mm), D_r = 70%, λ = 4.2

Series IV Square plate (100 mm × 100 mm), D_r = 50%, λ = 4.2

Series V Circular plate (100 mm dia.), D_r = 70%, λ = 4.2

Series VI Circular plate (100 mm dia.), D_r = 50%, λ = 4.2

The pullout load versus vertical displacement curves are shown in Figs.3 to 8.

Interpretation

The pullout capacities of the anchor plates were obtained from pull out load versus vertical displacement curves using intersection-tangent method (Fig.4). The values of pull out capacities are listed in Table 1.

TABLE 1 : Values of Pull-Out Capacities

S.No.	Description	Pull Out Capacity, kN					
		No Reinf. Fig.3(i)	With Reinf. at Top Fig.3(ii)	With Reinf. at 0.25D Fig.3(iii)	With Reinf. at 0.5D Fig.3(iv)	With 2 Layers of Reinf. Fig.3(v)	With 3 Layers of Reinf. Fig.3(vi)
1.	Square D_r = 70%, λ = 2	0.150	0.280	0.230	0.200	0.300	0.350
2.	Square D_r = 70%, λ = 3	0.420	0.620	0.530	0.470	0.630	0.640
3.	Circle D_r = 70%, λ = 4.2	1.000	1.460	1.280	1.160	1.890	1.930
4.	Circle D_r = 50%, λ = 4.2	0.580	0.870	0.710	0.640	1.040	1.100
5.	Square D_r = 70%, λ = 4.2	1.210	1.560	1.450	1.280	1.960	2.010
6.	Square D_r = 50%, λ = 4.2	0.590	1.060	0.900	0.780	1.090	1.160

It is evident from this table that the pullout capacity increases from unreinforced anchor to reinforced anchor. In the case of single layer reinforcement, the maximum pullout capacity is obtained when the reinforcement is kept at top of the plate and decreases when the reinforcement position is shifted away from the plate. The justification for the above statement is that in this case the contribution of frictional force from the reinforcement is more because of large vertical overburden pressure and also the contact area of reinforcement with soil, beyond the failure zone is more. The deformation at any stage is less in reinforced anchor compared with unreinforced anchor. It was also observed that in all cases the deformation is less when single reinforcement is placed at top of the plate. Therefore this shall be the best location for enhancing the maximum pullout capacity with less deformation.

The pullout capacity increases when second layer of reinforcement is placed, but only marginal increase is observed with three layers of reinforcement. The deformations at any stage of loading in double reinforcement is less than the same in single reinforcement and this can be observed from load-displacement test result. When the third layer is placed the deformation at the initial stage of loading are almost very near to the deformation in double reinforcement and shows small deformations at further stage of loading.

The pullout capacity is more in square plate when compare with circular plate because the area contribution to resist the uplift is more in square plate.

The pullout capacity increases with the increase in the depth of embedment of plate anchor as the weight of the soil, shearing resistance along the failure surface and frictional force contribution due to reinforcement is large.

The increase in soil density results in higher pullout capacity of anchors both with and without reinforcement. It is further observed that the deformations are less at higher density as compared with lower density.

Conclusions

The following conclusions are drawn from the present investigation.

1. The ultimate uplift capacity of anchors can be increased significantly by the use of geosynthetics.

2. The pullout capacity in square shaped plate anchor is more than circular anchor.

3. The deformation at any stage in reinforced anchor is less than the deformation in unreinforced anchor.

4. The pullout capacity of anchor is maximum when the reinforcement is kept at top of the plate anchor in single reinforcement and decreases as the distance of the reinforcement position from the top of the plate increases.

5. The pullout capacity increases from single layer of reinforcement to double layer of reinforcement, while the pullout capacity increases only marginally with third layer of reinforcement.

6. The pullout capacity of anchor placed in dense sand is more than the capacity of anchor placed in loose sand.

7. The pullout capacity is observed to increase with the increase in depth ratio.

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