Plate Anchors with Geosynthetics

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ABSTRACT: Small scale laboratory model tests were conducted to investigate the uplift behaviour of plate anchors with geosynthethics, embeddèd at shallow depth in sand. Three different type of geosynthetics, namely, a woven geotextile, a needle punched non woven geotextile and a geocomposite consisting of a non woven geotextile layer sandwiched between two layers of Netlon Geogrid CE-121, were used in this investigation. The variables in the investigation were type of geosynthetics, its location and size and number of layers of geosynthetics . Based on this investigation, it is found that the ultimate uplift capacity of plate anchors can be increased significantly by the use of geosynthetics. Only one layer of geosynthetics just on the top of anchor plate is found to be most effective for enhancing the uplift capacity. However, the displacement required for peak uplift resistance to be mobilised is relatively large in case of anchors with geosynthetics as compared to that required for anchors alone.

1 INTRODUCTION

Increasing use of anchors to resist and sustain uplift forces necessitates the improvement of soil in which these anchors are embedded in order to achieve cost effective solutions. Traditional footings can resist smaller uplift forces (approximately equal to the weight of soil in the failure zone plus the weight of footing) as compared with the large compressive forces they transfer. By improving the fill, anchors and footings can be made to resist larger uplift forces.

A few investigations have been reported on the use of geosynthetics for enhancing the uplift capacity of anchor piles and plate anchors. Subbarao et al. (1988) reported the results of a laboratory investigation on the use of geosynthetic ties for enhancing the uplift capacity of concrete anchor piles embedded in sand at shallow depth. Polypropylene strips were used as geosynthetic ties. Based on their investigation, authors concluded that geotextile ties can be used at the base of shallow anchor piles to enhance its uplift capacity. Uplift capacity increases with the increase in embedment ratio (defined as ratio of depth of embedment with the diameter of anchor pile). Authors also reported that multiple layers of ties are useful but the increase in the number of layers doesn't offer proportional increase in the uplift capacity. Resistance to pull out force will be reduced for multilayers if the higher layers are close to the surface level of fill. Therefore authors suggested that a single layer of ties is satisfactory.

Krishnaswamy and Parashar (1991) studied the uplift behaviour of plate anchors with geosynthetic inclusions in a cohesive soil medium. This investigating showed that geosynthetics can be used to increase the uplift capacity of plate anchors and footings in cohesive soil medium unlike other reinforced earth structures where a well graded granular fill is more or less indispensable. Also the submergence of footings and anchors embedded in a cohesive soil medium results in relatively less reduction in the uplift capacity as compared to the footings embedded in sand as reported by Parashar (1992) and Krishnaswamy and Parashar (1994).

The purpose of this paper is to report briefly the results of an experimental investigation on the uplift behaviour of plate anchors embedded at a shallow depth in a dry cohesionless soil medium.

2 TEST FACILITIES AND SAMPLE PREPARATION

The schematic diagram of the test set up is shown in Figure 1. The tests were conducted in a rigid tank made of wooden planks and mild steel strips with plan dimensions of 700 x 700 mm and a depth of 600 mm.

The model anchor was made of 6.15 mm thick mild steel plate and had a diameter of 60 mm. The uplift load was applied to the anchor plate through a connecting rod by a standard loading frame which was gear driven by an electric motor with a speed range of 0.127 mm/min to 1.27 mm/min. The model anchor was pulled at a constant rate of pull out of 1.27 mm/min. Krishnaswamy and Parashar (1992) reported the effect of strain rate on the uplift resistance of plate anchors with and without geosynthetics. This investigation showed that the reduction of rate of pull out by 10 times from 1.27 mm/min to 0.127 mm/min results in a reduction of ultimate uplift resistance of about 16 to 18%. However, the percentage variation in the uplift capacity of plate anchors with and without geosynthetics remains nearly the same. Uplift resistance of plate anchors was recorded by a load cell at an interval of 0.5 mm vertical displacement till failure while vertical displacement was measured using a dial gauge with a least count of 0.01 mm.

The soil used in these tests was a uniformly graded medium sand with effective size, D_{10} = 0.33 mm, coefficient of uniformity, C_u = 1.69 and coefficient of curvature, C_c = 1.19. The soil was compacted to a density of 15.51 kN/m^3, giving a relative density of 56.9% and the friction angle, as determined by the direct shear box , 39^0.

Two types of geotextiles, one woven and another non woven variety and two types of geogrids, all manufactured in India, were used in this investigation. The properties of geotextiles is shown in Table 1 whereas Table 2 shows the properties of geogrids.

Table 1 Engineering Properties of Geotextiles

Type of Geo-textile	Mass per unit area g/m^2	Avg thick-ness mm	5% secant modu-lus kN/m	Stiff-ness mg.m	Angle of Inter-face friction degree
Woven Geo-textile	209	0.50	140.0	2.50	38^0
Non-Woven Needle punche	460	3.90	50.0	100.0	38.5^0

Table 2 Properties of Geogrids

Geo-grid	Mesh size mm	Mesh thick ness mm	Load at 10% exten sion kN/m	Exten sion at max load %	Exten sion at 1/2 peak load %	Tens ile stre-ngth kN/m
CE-121	8 x 6	3.30	6.80	20.2	3.20	7.68
CE-131	27 x 27	5.20	5.20	16.5	3.70	5.80

To prepare the soil bed - anchor -geosynthetic system, a known quantity of sand was spread in the tank and levelled properly. This sand was compacted by one blow of a 2.6 kg rammer with a free fall of 280 mm, covering a soil area of 165 x 165 mm. The sand was compacted in layers of 50 mm compacted height. A depth of 150 mm of soil was maintained below the anchor plate. The model anchor was connected with the threaded anchor rod and lowered so that it was seated firmly on the prepared bed of sand. A hole equal to the diameter of the connecting rod was punched at the centre of the geosynthetic mat and was placed at the required level. After placing the model anchor and geosynthetic mat in position, subsequent layers of sand were placed and compacted upto the desired height. In case of multilayers with second layer of geosynthetics in the soil below the anchor plate, binding wires at four predetermined points were attached to the bottom layer and these wires were taken to the level of geosynthetic mat on the top of anchor plate, to be connected with it. In case of second layer of geosynthetics on the top of anchor plate, two layers of geosynthetics were not interconnected but only placed at predetermined locations. The anchors were embedded at a depth of 240 mm giving a depth embedment ratio, defined as the ratio of depth of embedment with the diameter of anchor, equal to 4.

3 TEST RESULTS AND DISCUSSIONS

The main purpose of this investigation was to study the effect of geosynthetic inclusion on the uplift capacity of plate anchors and to determine its optimum location. The test results consist of load displacement curves and observation of surface heave. Improvement in the uplift capacity is represented as uplift capacity ratio, which is defined as the ratio of ultimate uplift resistance of plate

Table 3 Ultimate Uplift Resistance of Anchors with Geosynthetics

Anchor	Depth of Embedment mm	Type of Geosynthetics	Size of Geosynthetics mm	Ultimate Uplift Resistance Qult (N)	Uplift Capacity Ratio (UCR)
Circular Anchor 60 mm diameter	240	-	-	129	-
	240	Two layers of Geogrid, one 25 mm below the anchor & another at 50 mm above the anchor plate.	300 x 300	167	1.29
		Two layers of Geogrid one just below the anchor & another on top of anchor.	300 x 300	259	2.00
		Only one layer of Geosynthetics on the top of anchor plate			
		Geogrid CE -131	300 x 300	247	1.91
		Woven Geotextile	180 x 180	193	1.50
			240 x 240	251	1.95
			300 x 300	305	2.36
		Non Woven Geotextile	180 x 180	217	1.68
			240 x 240	236	1.83
			300 x 300	305	2.36
		Geocomposite	180 x 180	329	2.55
			240 x 240	367	2.85
			300 x 300	524	4.06
			360 x 360	540	4.18

Table 3 - continued

Anchor	Depth of Embedment mm	Type of Geosynthetics	Size of Geosynthetics mm	Ultimate Uplift Resistance Qult (N)	Uplift Capacity Ratio (UCR)
		Two layers of Geocomposite, one on the top of anchor plate and another	300 x 300		
		(i) below the anchor at			
		25 mm		524	4.06
		50 mm		508	3.94
		75 mm		521	4.04
		100 mm		562	4.35
		(ii) Above the anchor at			
		25 mm		540	4.19
		50 mm		513	3.98
		100 mm		487	3.78
		150 mm		482	3.74

anchor with geosynthetics to the ultimate uplift resistance of same anchor without geosynthetics, embedded in the same soil at the same depth. The summary of test results is presented in Table 3.

To investigate the best location of geosynthetics for enhancing the uplift capacity of plate anchors, series of tests were conducted using geogrid reinforcement. As a first trial, two layers of geogrid CE-131, one below the anchor at 25 mm from it, and another at 50 mm above the anchor plate, were used. In the next test, both the layers of geosynthetics were placed at the anchor level, one immediately below the anchor plate and other on the top of it. In the next test, only one layer of geogrid just on the top of anchor plate was provided. The load displacement curves for these tests are shown in Figure 2. As can be seen clearly from this figure, only one layer of geosynthetics just on the top of plate anchor is most effective for enhancing its uplift capacity.

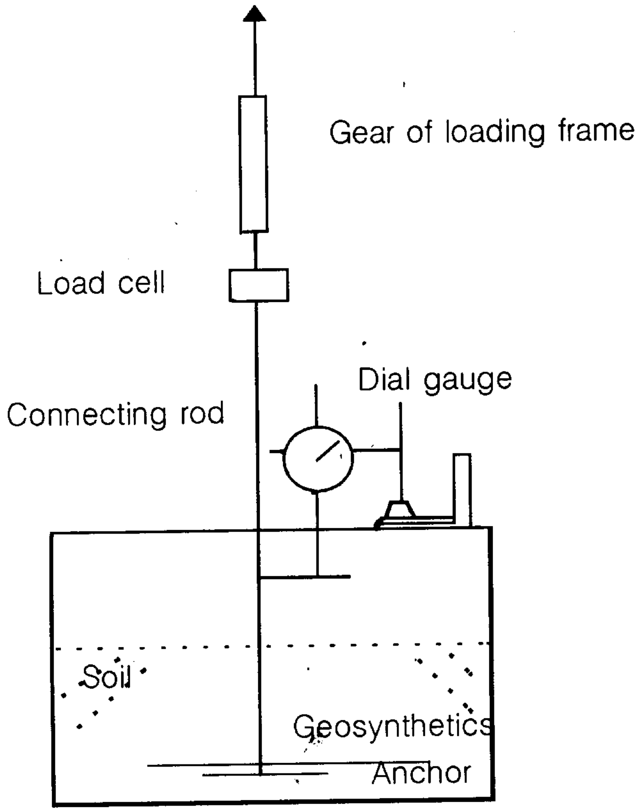

Fig 1. Schematic diagram of test set up

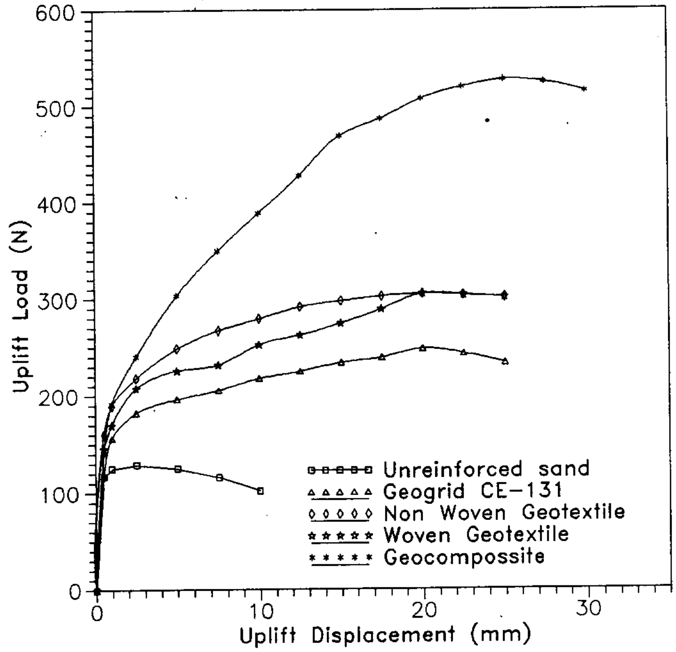

Fig. 3 Load – Displacement curves for various Geosynthetics (300 x 300 mm)

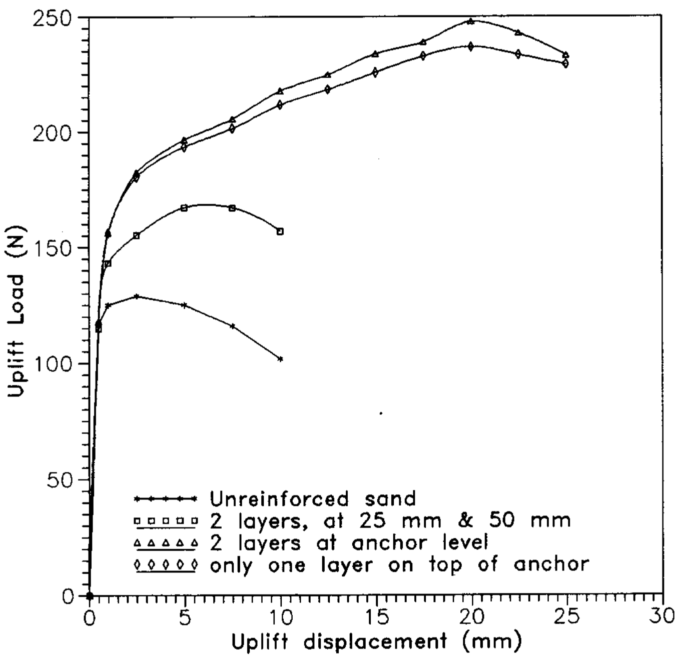

Fig. 2 Load – Displacement curves for various arrangements of geogrid reinforcments.

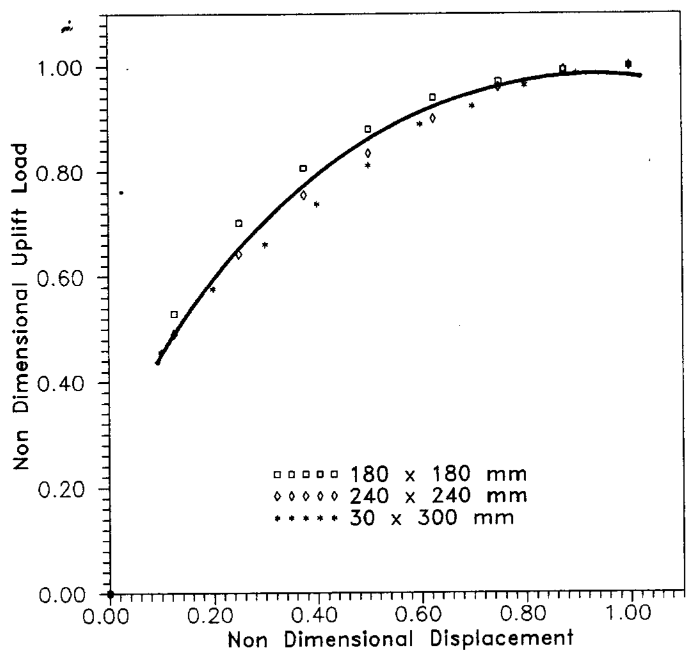

Fig 4 Non Dimensional Load – Displacement curve for various sizes of Geocomposite inclusions.

For investigating the suitability of different type of geosynthetics and their sizes, 4 different type of materials were used. A typical load displacement curve, for various type of geosynthetics tested for a case where only one layer of geosynthetics of 300 x 300 mm size was placed just on the top of anchor plate, is shown in Figure 3. For tests on anchors without geosynthetics, maximum uplift resistance was reached at a displacement ratio, less than 5% where displacement ratio is defined as ratio of vertical displacement to the diameter of anchor. For anchors with geosynthetics, uplift resistance increases with vertical displacement and is mobilised fully at a much higher displacement level. This high value of displacement required for peak uplift resistance to be mobilised indicates that the geosynthetics itself functions as a flexible anchor rather than an internal soil reinforcement. Figure 4 shows a typical non dimensional load displacement curve, for geocomposite inclusions. Non dimensional displacement is obtained by dividing the displacement at any particular stress level by the displacement required for peak resistance to occur. Similarly, non dimensional uplift resistance is obtained by dividing the uplift load at any particular displacement level by the ultimate uplift resistance . As can be seen from this figure, there exists an unique non dimensional load displacement curve which seems to be independent of the size of geosynthetic inclusion in the tested range. Also, approximately 90% value of the ultimate uplift resistance occurs at approximately 60 to 65 % of the ultimate displacement level. Similar results were obtained for other type of geosynthetics used in this investigating.

Ultimate uplift resistance increases with the increase in the size of geosynthetics however it is was found that increasing the size of geosynthetic inclusion beyond five times the size of anchor plate doesn't result in a proportional increase in the uplift capacity.

A single layer of geosynthetics just on the top of anchor plate is found to be most effective for enhancing the uplift capacity of anchors. Introduction of additional geosynthetic layers in the fill either above or below the anchor plate did not result in any increase in uplift capacity over what was achieved with a single layer.

Introduction of geosynthetic inclusions results in an increased surface heave. The extent of the surface heave was found to vary with the type of geosynthetics and its size.

Introduction of geogrids didn't result in any substantial increase in uplift capacity of anchors due to its wider mesh openings and the consequent decrease in area of contact with the soil. Use of geotextiles, (woven as well non woven) resulted in higher uplift capacity ratio as compared to those obtained with the geogrids. However, the displacement required for peak resistance to be mobilised in case of geotextiles was higher as compared to that with geogrids. Geocomposite inclusions, prepared by sandwiching a layer of non woven geotextile between two layers of geogrids CE-121, gave best results as compared with other geosynthetics. Mobilisation of higher interlocking and passive resistance resulted in higher ultimate uplift resistance.

4 CONCLUSIONS

From the present investigation, it can be concluded that uplift capacity of plate anchors can be increased by the use of geosynthetic inclusions. Only one layer of geosynthetics just on the top of anchor plate is most effective for improving the uplift capacity and introduction of additional layers of geosynthetics in the fill either above or below the anchor plate do not contribute to any further increase. Also for anchors with geosynthetic inclusions, a large vertical displacement is needed for peak resistance to be mobilised.

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