Experimental Study on Behaviour of Plate Anchors in Cohesionless Soil
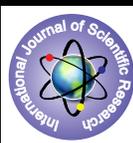
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ABSTRACT *Soil anchors are commonly adopted as foundation system for structures that require uplift or lateral resistance. For different civil engineering structures like retaining wall, transmission towers etc. anchors are extensively used. Different types of anchors are being employed in the field depending on the magnitude and type of loading, type of structure, importance of the structure and subsoil condition. Horizontal plate anchors are widely used in civil engineering constructions to resist vertical pulling loads. In this paper the uplift behavior of plate anchors with and without geogrid reinforcement has been investigated with the help of laboratory model tests. From the test results it is observed that the geogrid reinforcement system enhances the uplift response substantially in loose, medium and dense sand conditions.*

INTRODUCTION

The design of many engineering structures requires that foundation systems resist vertical uplift or horizontal pullout forces. In such cases, an attractive and economic design solution may be achieved through the use of tension members. These members, which are referred to as soil anchors, are typically fixed to the structure and embedded in the ground to sufficient depth so that they can resist pullout forces with safety.

Different types of anchors are being employed in the field depending on the magnitude and type of loading, type of structure to be supported, importance of the structures and subsoil conditions. Ultimate resistance of such plate anchors depend on the shape and size of anchor, depth of embedment, characteristics of the embedding soil and inclination of the pulling loads.

But if the pulling load to be resisted is large, then either the size of the anchor plate or the depth of embedment or both need to be increased resulting increase in the size of excavation area and depth of excavation. This not only leads to increase in size of the foundation and cost of excavation, but also

problem of excavation below water table. Presence of compacting fill material below water table at great depths, can not be ruled out.

Without changing the depth of embedment and size of the anchor plate the pullout capacity of such anchors may be increased by introducing circular geogrid over the anchor plate and then compacting the fill above the layer. The increase in the capacity to resist pulling load of such combination will be dependent on the relative size of the geogrid compared to that of the anchor plate, depth of embedment, characteristics of the geogrid and properties of the fill materials.

UPLIFT CAPACITY OF ANCHOR

Uplift capacity of an embedded anchors made by several components such as effective anchor weight, effective surcharge of the soil involved in the failure and shear resistance along failure lines as shown in Figure 1
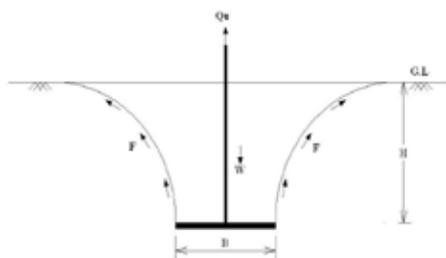

Figure 1. Typical failure surface of plate anchor

The uplift capacity of the plate anchor embedded in cohesion less soil can be given by the following equation

$$Q_u = W + T \qquad (1)$$

Where

Q_u	= Uplift capacity of anchor
W	= Weight of the soil involved in the Failure including anchor weight
T	= sum of vertical component of shear resistance (F) along failure surface

EXPERIMENTAL SETUP

Model breakout test were conducted on horizontal circular plate anchors of diameters D (10cm and 15cm) for varying depth, H resulting embedment ratios ranging from (0.5 to 3). All these tests were conducted in model tank in which the model anchor plates were placed in horizontal position at chosen depth. For this purpose model tank with inner dimensions of 1m x 1m x 0.8m was used to conduct test on model anchors.

These embedded circular plates were attached to steel wire for pulling it axially in vertical direction. For this purpose the wire was taken over a pulley fixed on above and attached at the top on a horizontal frame fixed to the tank as shown in Fig. 2. The wire was then taken horizontally over another pulley fixed over the same horizontal frame and taken down and attached to a loading pan for applying loads to apply the necessary pull. The vertical movement of

the anchoring system was measured with the help of dial gauge, attached on a fixed horizontal stand as shown in Fig. 2.
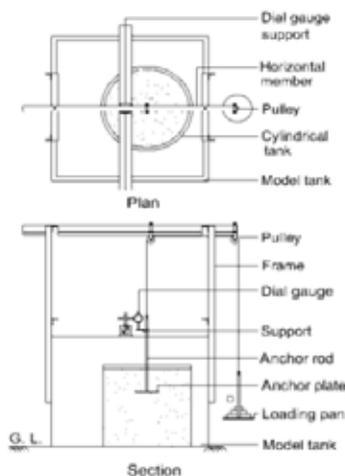
Figure 2: Plan and section of the model tank with accessories

EXPERIMENTAL PROCEDURE

The controlled pouring and tamping technique is adopted to achieve uniform sand bed of required density for medium and dense sand conditions. In the case of loose sand, sand raining technique is adopted. The sand bed of specific thickness is prepared from the bottom of the tank and is levelled.

The plate anchors were subjected to increasing pulling loads till failure, accompanied with measurement of vertical movement. Applied load vs. vertical movement of the pull was plotted and pullout

load was obtained from such load-displacement diagram. The load-displacement graph is shown in fig 3.
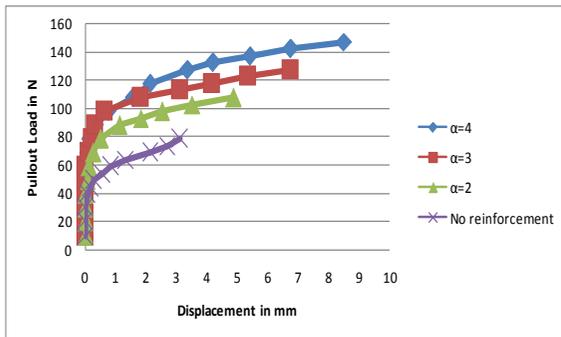
Figure 3. Pullout response of 10 cm diameter plate anchor in dense sand

The similar tests were further repeated for same diameter, D and embedded depth, H, but with varying geogrid diameter D_G.

The breakout resistances of 10 cm and 15 cm diameter plate anchor are presented in table 1 to 6.

Embedment depth in 'cm'	$\alpha = D_G/D$	Breakout pulling load in 'N'	% increase in Pullout load
10	1	39	
	2	49	25
	3	68	75
	4	79	100
20	1	59	
	2	68	17
	3	88	49
	4	108	83
30	1	79	
	2	98	25
	3	117	50
	4	127	63

Table 1: Experimental result of 10 cm. diameter anchor in loose sand

Embedment depth in 'cm'	$\alpha = D_G/D$	Breakout pulling load in 'N'	% increase in Pullout load
10	1	49	
	2	64	30
	3	78	60
	4	88	80
20	1	69	
	2	78	14
	3	98	43
	4	128	86
30	1	88	
	2	108	23
	3	127	44
	4	147	56

Table 2: Experimental result of 10 cm. diameter anchor in medium sand

Embedment depth in 'cm'	$\alpha = D_G/D$	Breakout pulling load in 'N'	% increase in Pullout load
10	1	59	
	2	78	33
	3	98	67
	4	108	83
20	1	79	
	2	98	25
	3	127	63
	4	147	88
30	1	108	
	2	128	19
	3	157	45
	4	177	64

Table 3: Experimental result of 10 cm. diameter anchor in dense sand

Embedment depth in 'cm'	$\alpha = D_G/D$	Breakout pulling load in 'N'	% increase in Pullout load
7.5	1	49	
	1.5	78	60
	2	98	100
15	1	59	
	1.5	88	50
	2	108	83
22.5	1	69	
	1.5	98	43
	2	127	86

Table 4: Experimental result of 15 cm. diameter anchor in loose sand

Embedment depth in 'cm'	$\alpha = D_G/D$	Breakout pulling load in 'N'	% increase in Pullout load
7.5	1	64	
	1.5	98	54
	2	108	69
15	1	69	
	1.5	98	43
	2	118	71
22.5	1	88	
	1.5	127	44
	2	147	67

Table 5: Experimental result of 15 cm. diameter anchor in medium sand

Embedment depth in 'cm'	α =D_G/D	Breakout pulling load in 'N'	% increase in Pullout load
7.5	1	69	
	1.5	107	57
	2	128	86
15	1	74	
	1.5	118	60
	2	137	87
22.5	1	98	
	1.5	137	40
	2	157	61

Table 6: Experimental result of 15 cm. diameter anchor in dense sand

CONCLUSION

From the experimental study presented in this paper following conclusions are made.

- The breakout capacity of shallow anchors can be increased many folds by adopting geogrid of suitable diameter depending on the requirement of increase.
- The pullout capacity increases with increase in diameter of geogrid.
- It also increases with increase in embedment ratio and relative density of sand.

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