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AN EXPERIMENTAL STUDY ON PULLOUT BEHAVIOUR OF ANCHORS IN REINFORCED CLAY

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ABSTRACT

Foundation of some structures e.g. jetty structures, transmission towers, mooring systems etc. experience uplift as a consequence of moments due to horizontal forces and wave actions. To resist uplift plate or pile anchors are adopted as foundations of such structures. If the shear strength of surrounding soil is too low to resist uplift, the required shear stress in soil may be mobilised by using reinforcement e.g. geotextiles or geogrids. In the present investigation pullout tests have been done on model square anchors of steel in a brass tank of 380 mm diameter and 500 mm height. Tests were carried out both in reinforced and unreinforced soils. The paper highlights the effect of position of geogrid reinforcements on ultimate uplift capacity and axial movement of anchors at failure and the extent of failure zone at the soil surface as it developed around the anchors.

1. INTRODUCTION

Geotechnical engineers often use anchors or anchor piles as foundations of structures which resist uplift. Transmission towers, mooring systems, offshore structures and the like are typical examples of structures subjected to uplift . As pull is applied to an anchor, it tends to separate itself from the soil with development of a surface of failure formed around the anchor. The shape and extent of failure surface for an anchor of a given size and depth of embedment eviedently depends on the shear strength of the soil. If the shear strength of the surrounding soil is too low to help resist uplift, some improvement of the shear strength may be required. In that case the improvement may be done with the help of some reinforcements, e.g, geotextiles or geogrids. In the research area of anchors and anchor piles investigations have been done by several investigators. Meyerhof and Adams [1], Vesic [2], Hanna [3], Meyerhof [4], Das and Seeley [5], Chattopadhyay and Pise [6], Sarac [7], Nene and Garg [8]. Sharma and Pise [9] presented works on anchors subjected to vertical, inclined and lateral pulling loads under both cohesive and noncohesive types of soil. Nene and Garg [8], however, studied behaviour of shallow plate anchors in reinforced cohesive soil. No proper design procedure for such anchors has yet been established and no detailed study on anchors in reinforced soil has been made till date. But sometimes, in practice, shallow anchor foundation may be required to be adopted where clayey soil of poor strength is encountered. The present investigation has, therefore, been carried out with the object of studying the influence of geogrid reinforcements on behaviour of shallow square anchors embeddedin reinforced cohesive soil.

2. EXPERIMENTAL INVESTIGATION

2.1. Test Programme

Pull out tests were performed on model anchor plates in both unreinforced and reinforced clay. Commercially available Kaolin and geogrid reinforcements were used to prepare foundation bed. Rountine tests were done to determine the engineering properties of Kaolin used.

2.1.1. Pull out tests on model anchors

A total number of 36 tests (9 tests in unreinforced soil and 27 tests in reinforced soil) were performed. The parameters varied were as follows:

(a) Height of geogrid above anchor plate
- (i) 25mm (Single layer)
- (ii) 50mm (Single layer)
- (iii) 25mm and 50mm (double layers)

(b) Embedded depth
- (i) 100 mm
- (ii) 125 mm
- (iii) 150 mm

(c) Anchor size (Square plates)
- (i) 38 mm x 38 mm
- (ii) 50 mm x 50 mm
- (iii) 75 mm x 75 mm

(d) Soil type
- (i) Unreinforced
- (ii) Reinforced

2.2. Equipment and Test Procedure

2.2.1. Properties of Kaolin (obtained from routine tests)

(i) Atterberg Limits:
LL=53%, PL=35%

(ii) Grain Size distribution:
Sand;2%, Silt:33%, Clay:65%

(iii) Undrained shear strength (Cu): 2.5 t/sq.m.

2.2.2. Specification and Properties of Geogrid

A. Specification data : CE III
- (i) Mesh aparture size: 8mmx6mm (+/- 0.2mm)
- (ii) Mesh theckness : 2.8mm (+/- 0.2 mm)

(iii) Structural weight :425 g/sq.m (+/- 5%)
(iv) Polymer :LD polythelene

B. Mechanical Properties:
(i) Tensile strength :2.00 KN/m
(ii) Extension at maximum load :41%
(iii) Load at 10% extension :1.32 KN/m

2.2.3. Test Procedure

The test setup is shown in fig.1. The foundation tank consisting of main cylinder, extension piece and base plate was placed on a wooden platform. Oven dried kaolin was mixed with water (28% by weight) The soil cushion, on which the anchor was placed, was then prepared by compacting the soil by applying 50 blows of hammer used for Proctor test. The soil bed was parepared in three layers and each layer was compacted with 50 blows of a hammer used for proctor test. The model anchor plate fixed with 6mm, diameter anchor shaft was then placed on the soil cushion. The embedment depth of soil above the anchor plate was achieved by compacting the (kaolin mixed with water) in three layers. Geogrid reinforcement layers were placed at the desired positions in each test with the reinforced soil. After the required depth of embedment was achieved, the surface was made levelled. A dial gauge (1 div=0.01mm) was then placed on a plate fixed with the anchor shaft. One end of a nylon rope was then fixed with the achor shaft as shown in fig. 1. The rope was then allowed to pass over two pulleys. The other end of the rope was fixed with a hangar for applica-tion of the required incremental pull by dead weights and the corresponding upward movment was recorded by the dial gauge. The test was continued till failure. The failure lines appeared on the surface and the diameter of failure zone around the anchor shaft was measured by a scale on the soil surface. All the tests were performed in similar manner under identical soil conditions. Pilot tests were performed previously to arrive at the required water content and degree of compaction for achieving a shear strength of kaolin of 2.5 t/sq.m. Water content was recorded for each test and it was observed that the variation of water content was within +/- 2%.

3. RESULTS AND DISCUSSION

3.1. Uplift load vs. axial movement

A typical curve showing variation of uplift load with axial movement is shown in fig.2. The curve is nonlinear upto failure and ultimately becomes asymptotic. The last part of the curve tends to become linear. This might be due to coming out of anchor after failure without application of any uplift load. Therefore, the ultimate pullout loads have been obtained by single tangent method in all the cases.

Comparing all the curves it appears that the anchor in soil reinforced with two layers possesses maximum pullout capacity and highest axial movement at failure. It also appears that for same embedment depth and plate size, the pullout capacity of the plate and load at any movement level and axial movement at failure decreases when geogrid layer is placed at 25 mm above the plate than when it is placed at 50mm above the plate. It might be due to the fact that the greater portion of embedment

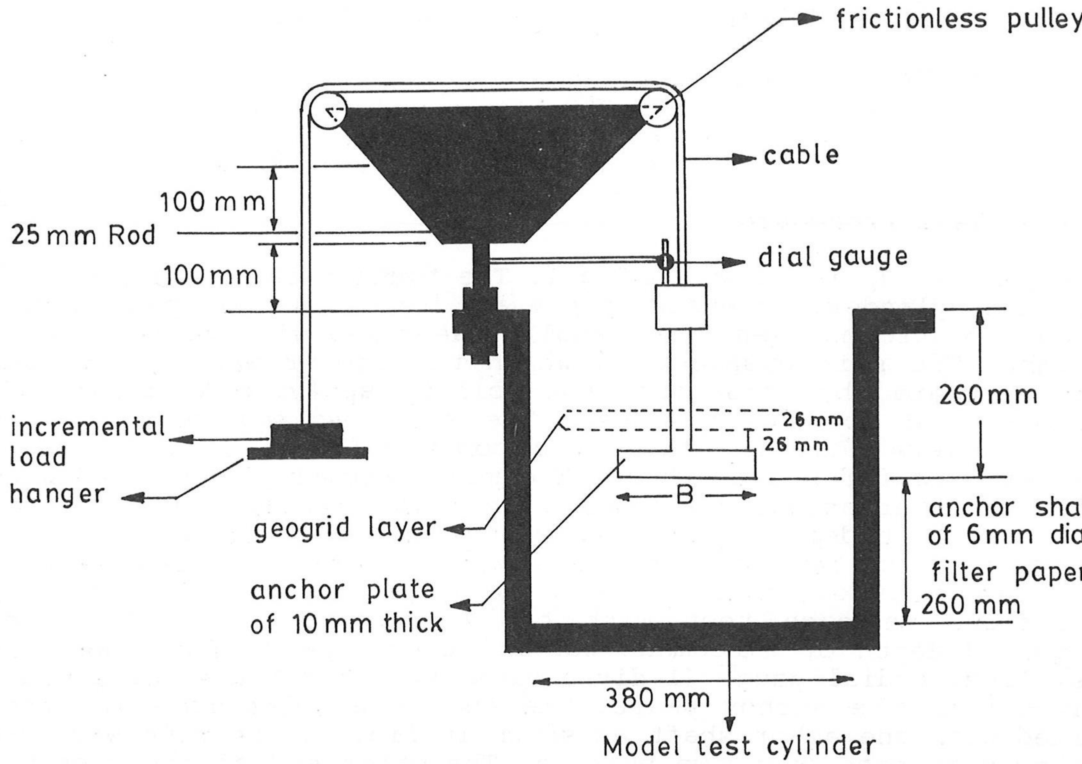

FIG. 1 Test Set up

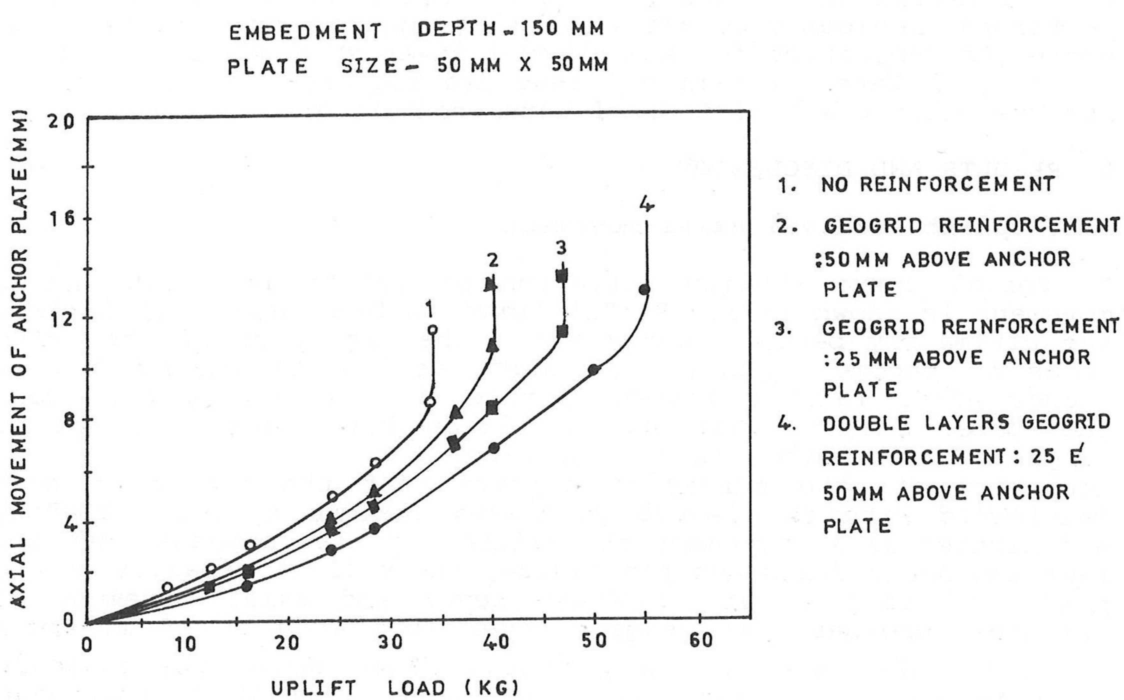

FIG. 2 Axial Movement of Anchor Vs Uplift Load

depth of soil medium is influenced by the reinforcing layer during pullout, when reinforecement is nearer to the anchor plate.

3.2. Influence of plate size and embedment depth on ultimate pullout capacity

Typical curves showing variation of ultimate pullout loads and corresponding axial movement at failure with plate size have been shown in fig 3 (a) and 3 (b) respectively, comparing all the curves it appears that both ultimate pullout capacity and corresponding axial movement at failure increase with plate size under identical test conditions. It also appears that under identical conditions ultimate pullout capacity as well as upward movement at failure increase with increase of embededment depth. This may be due to involvement of more soilmass with increase of plate size and embedment depth.

3.3 Failure zone at surface

Diameters of failure zone as measured at the soil surface for all the tests are presented in Table.1. It may be noted that for same embedment depth and same plate, the diameter of failure zone at surface reduces with increase of height of geogrid layer above the anchor plate. It may, therefore, be inferred that the influence of a single reinforcing layer is more when it is placed nearer to the plate. This may be due to the fact that as the reinforcing layer is more close to the plate, more is the part of the embedment depth affected by the reinforcing layer during pullout.

Table 1. Diameter(mm) of Failure Zone at Surface

Plate Size sq.mm	Embedment Depth (mm)	No Geogrid layer	Providing Single layer at 25 mm. above the anchor plate	Providing Single layer at 50 mm. above the anchor plate	Providing double layers at 25 & 50 mm. above the anchor plate
38x38	100	68	90	73	98
	125	76	97	81	108
	150	80	101	89	117
50x50	100	113	149	128	168
	125	125	168	146	182
	150	130	180	158	190
75x75	100	160	220	183	240
	125	180	240	194	260
	150	192	262	210	280

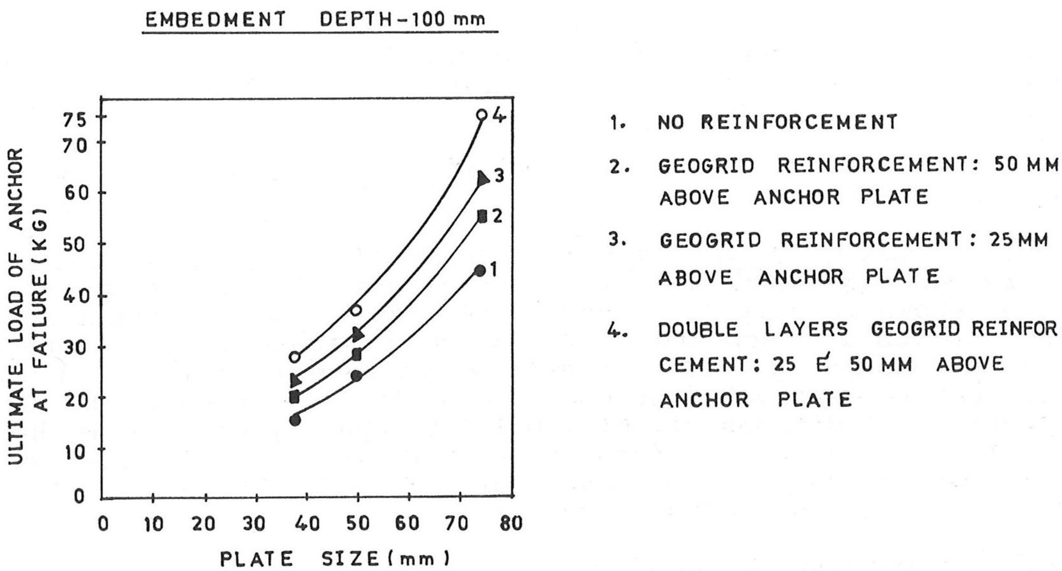

FIG . 3(a) Ultimate Pullout Load Vs. Plate Size

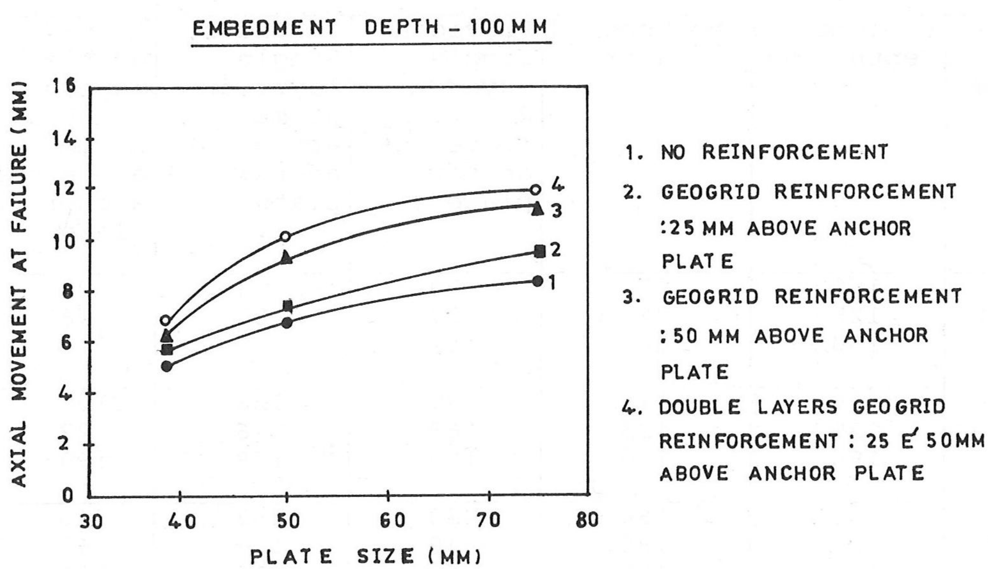

FIG. 3(b) Axial Movement at Failure Vs. Plate Size

4. CONCLUSIONS

1. The uplift load vs axial movement response is nonlinear for both reinforced and unreinforced soils.
2. For same embedment depth of soil pullout capacity as well as axial movement at failure of plate anchor increase as reinforcing layers become nearer to the plate
3. Ultimate pullout load and axial movement at failure increase with plate size under identical condition.
4. Ultimate pull out load and axial movement at failure increase with increase of embedment depth under identical conditions.
5. Diameter of failure zone at surface reduces with increase of height of geogrid layer above the anchor plate.

REFERENCES

1. Meyerhof,G.G., and Adams,J.I.(1968). The ultimate uplift Capacity of Foundations. Canadian Geotechnical Journal Vol. V, No.4.

2. Vesic, A.S.(1971). Breakout resistanceof objects embedded in ocean bottom. Journal of Soil Mechanics and Foundation Engineering Division, ASCE, Vol. 97, No. SM9.

3. Hanna, T.H.(1972). Anchor behaviour in sand. Journal of Soil Mechanics and Foundation Engineering Division, ASCE, Vol. 98, No. SM11.

4. Meyerhof,G.G.(1973).Uplift resistance of inclined anchors and piles. 8th ICSMFE, Moscow, USSR, 2(1):167-172.

5. Das,B.M., and Seeley,G.R.(1976). Uplift Capacity of Group Piles in Sand. Journal of Geotechnical Engineering Divn. Proc. ASCE, Vol.102, No. GT3.

6. Chattopadhyay,B.C., and Pise, P.J.(1986). Uplift Capacity of Piles in Sand. Journal of Geotechnical Engineering Divn. Proc. ASCE, Vol.122, No.9.

7. Sarac,D.Z.(1989). The Uplift Capacity of Shallow Buried Anchor Slabs" - 12th ICSMFE, 1989 : 1213-1216.

8. Nene, A.S. and Garg, S.(1991). Behaviour of shallow plate anchors in reinforced cohesieve soil. Indian Geotechnical Joural Vol. 21, No.4.

9. Sharma, B.V.R. and Pise, P.J. (1994). Uplift capacity of anchor piles in sand under axial pulling loads. Indian Geotechnical Journal, Vol.24, No.3.