BEHAVIOUR OF SHALLOW ANCHORS EMBEDDED IN A REINFORCED COHESIONLESS SOIL

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ABSTRACT

Pull-out tests on model anchors embedded in sand, reinforced with rough strip papers placed in two directions forming a grid, showed beneficial effects of this type of reinforcement on the pull-out resistance of shallow anchors. The test results showed that the pull-out resistance of shallow anchors is affected critically with the depth of the reinforcing grid, length of strip reinforcing elements, and number of reinforcing layers.

INTRODUCTION

Earth reinforcement is now in popular use for dealing with the problem of increasing strength and stability of soils. The utilizing of earth reinforcement for the improvement of bearing capacity of subgrade is reported by Binquet and Lee [1], Giround and Noriray [2], Verma and char [3], Mahmoud [4], Mahmoud and Abdrabbo [5], Collois et al [6] and Tumay et al [7]. MacGown el al [8] reported that low modulus fabric and extensible inclusion reinforcement are the best type of reinforcement fabric in sense of modifying stress-strain behaviour of sandy soil and showed relatively small losses post peak strength. And thus it is benefit of using this sort of reinforcement in increasing the strength and stability of cohesionless soil.

The practical method of executing a shallow anchor, embedded in an uncompacted cohesionless soil extending down to a large depth is to dig the soil down to the required depth and then the anchor is executed, cohesionless backfilling is compacted in layers. It is benefit to place reinforcements within the backfilling in order to increase the pull-out resistance of the embedded anchors. And thus in the present study, pull-out load tests were performed on shallow anchors embedded in dense sand, reinforcement with rough paper forming a grid reinforcing layers. The effects of reinforcing layer location, length, anchor relative depth and number of reinforcing layers on the pull-out resistance of shallow anchors were investigated.

MODEL TEST

The pull-out tests were conducted in a circular rigid steel tank of 0.75 m diameter. The tank comprised from two circular parts, 0.3 m high each having top and bottom flanges. The two parts were tight firmly with 13 mm bolts via holes drilled in the flange. The anchor plates were made from mild steel having 50, 75, 100 mm in diameter whereas the anchor tie rod was fabricated from mild steel with 6 mm diameter. The pull-out force was applied via a lever system designed by Abdelmonsef [9]. The test apparatus is shown in figure (1). The pull-out force was applied continousely via a triaxial machine of 50 kN with a rate of 0.025 mm/min. The steel lever was provided with two knife edges, ball bearings, and two guide plates and counter weights to direct the direction of the vertical pulling force and eliminate the effects of friction stresses may be developed, Abdel-Monsef [9]. The anchor vertical movement was recorded via two dial gauges of 0.001 mm sensitivity whereas the pull-out load was recorded via a proving ring of 2 kN capacity with 1.52 N sensitivity.

The sand bed was formed using silicious sand having effective diameter and uniformity coefficient of 0.215 mm and 2.513 respectively. Direct shear tests were conducted at unit weight of 17 kN/m^3 (relative density and angle of internal friction were found to be 92% and 42^o respectively). The reinforcing strips were cut from a rough paper. The strips were 20 mm wide and 1.00 mm thick. The angle of friction between the strips and the soil was measured using the shear box apparatus and was found to be 40^o. The strips were placed to form a grid having spacing ratio S/B=2.0, Mahmoud [4]. The sand beds were formed by placing the sand bed in layers of 50 mm thickness. Each layer was compacted manually using a hammer weighing 35 N. The sand density was measured using four special wooden boxs of 90 cm^3 placed at different depths in the sand bed. The measured densities enabled a check of homogeneity of the formed bed.

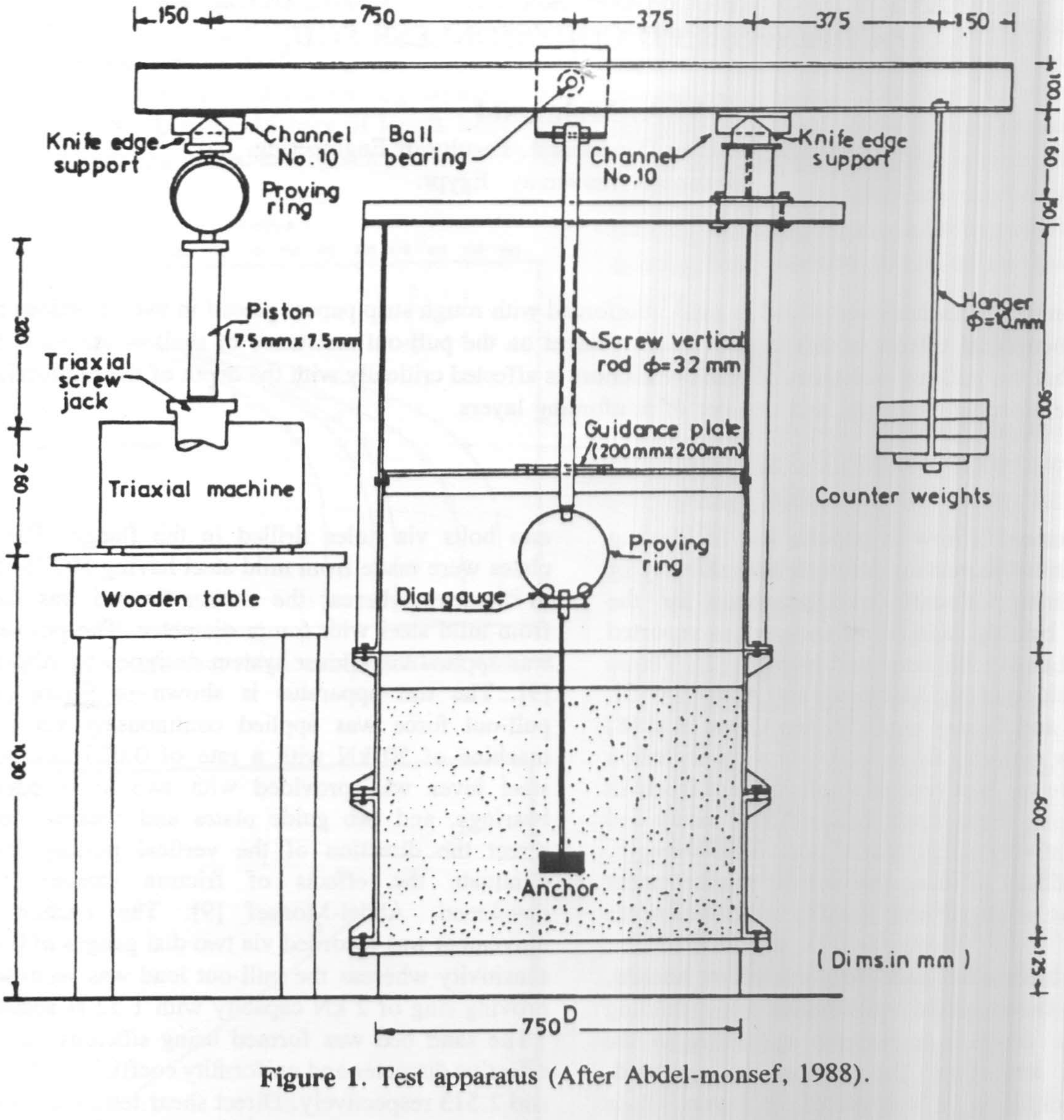

Figure 1. Test apparatus (After Abdel-monsef, 1988).

TEST RESULTS AND DISCUSSION

A non-dimensional pull-out load ratio PLR is used to help in analysing the test data and is defined as,

$$PLR = T/T_o \quad (1)$$

Where,

T and T_o are the peak of the pull-out loads of an anchor embedded in reinforced and unreinforced soil respectively.

Optimum depth of the reinforcing layer

The loading test program was designed and conducted to define the best location of a single reinforcing gr layer. A typical load displacement curve is shown figure (2). The reinforcing layer was placed at depth h/H (h = the depth of the reinforcing grid measured fro ground surface, H = anchor depth) ratios of o, 0.1 0.33, 0.5, 0.66, 0.83. The tests were carried out wi three anchor diameters of 50, 75, 100 mm. It can be se from Figure (2) that the reinforcement had little effect the pull-out load of the anchor until a displacement of 3 of anchor diameter. This means that up to this level anchor displacement the strains developed around t anchor are insignificant to moblize the skin friction alo the reinforcing element-soil interface.

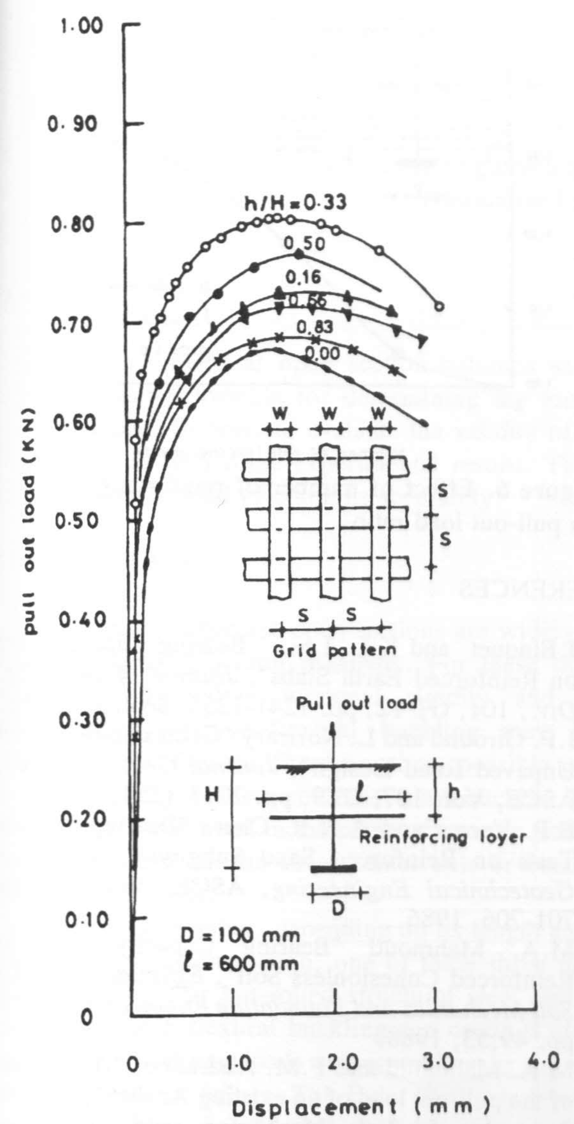

Figure 2. Pull-out load VS displacement.

Figure (3) demonstrates the variation of PLR against the relative depth ratio h/H. Figure (3) shows that the pull-out ratio PLR increases as the relative depth ratio h/H increases up to a certain value, depends upon the anchor-height/diameter ratio, after which the PLR gradually decreases. The magnitude of PLR attained values of 1.19, 1.125 and 1.14 when H/D are 3.0, 4.0 and 6.0 respectively. This implies that the failure plane in the soil mass around the anchor would be intersected with the reinforcing grid layer, resulting an increase in the pull-out resistance of anchors. Figure (3) also demonstrates that as H/D ratio increases PLR decreases and the optimum location of the reinforcing layer measured from ground surface increases. A series of pull-out tests were carried out on an anchor having diameter of 100 mm with the variation anchor depth ratios H/D of 3.0, 2.0 and 1.5. The results are shown in figure (4). Figure (4) demonstrates that the optimum reinforcing grid depth is independent on H/D ratio and found to be 0.35 . The PLR attained values of 1.19, 1.12 and 1.10 for H/D of 3.0, 2.0 and 1.0 respectively.

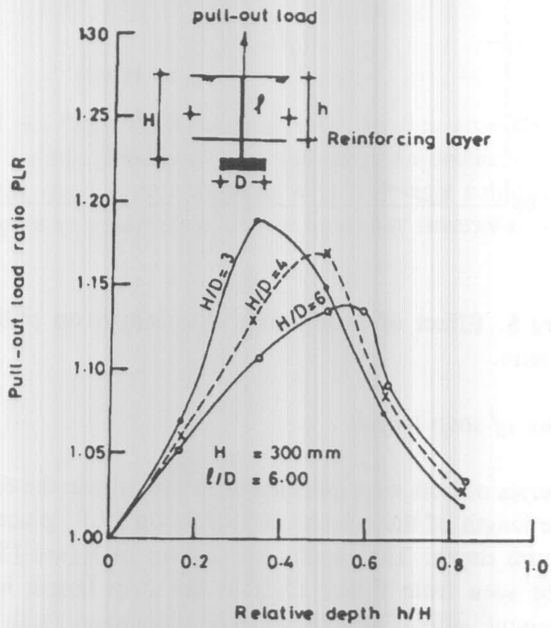

Figure 3. Effect of anchor diameter on pul-out load ratio.

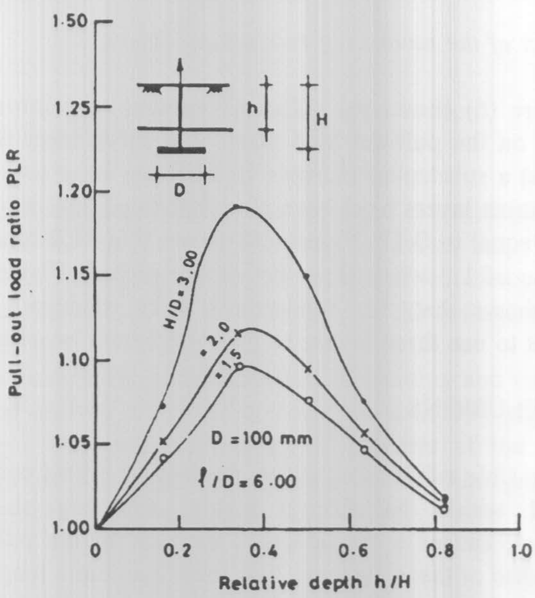

Figure 4. Effect of anchor relative depth on pull-out load ratio.

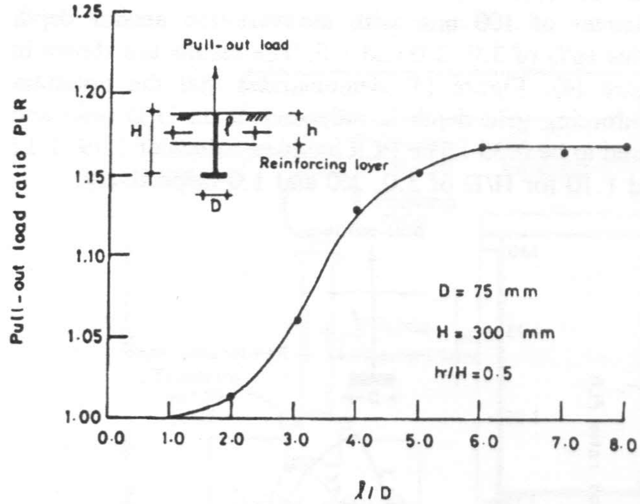

Figure 5. Effect of reinforcing strip length on pull-out load ratio.

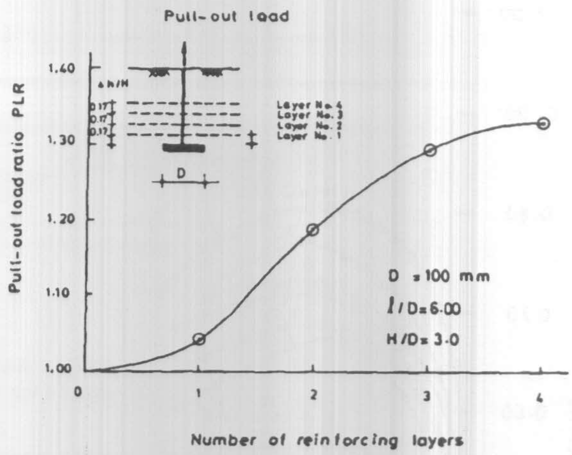

Figure 6. Effect of number of reinforcing layers on pull-out load ratio.

Effect of strip length

A series of tests were performed to investigate the effect of the length of the reinforcing strips on PLR, placed at optimum depth. The results are shown in figure (5). It can be seen from figure (5) that the strip length has a paramount effect and PLR ratio increases with the increase of ℓ/D ratio up to ℓ/d ratio equal to 6. Beyond that limit the reinforcing element strips has negligible effect.

Effect of the number of reinforcing layers

Figure (6) shows the effect of number of reinforcing layers on the pull-out load ratio. It is clear from figure (6) that a substential increase in PLR has been achieved when three layers have been placed at equal spacing ratio $\Delta h/D$ equal to 0.17. Figure (6) shows that PLR attained a value of 1.3 when three layers are placed. Figure (6) also shows that, for economical point of view, it is benefit to use three layers to gain maximum benefits.

CONCLUSIONS

Extensible reinforcing strips, formed as a grid pattern, placed within backfilling during executing shallow anchors, causes a considerable increase in the pull-out resistance of these anchors. The most economic length of the reinforcement is equal to six times the anchor diameter. No more than three sequence reinforcing layers with spacing ratio $\Delta h/H$ equal to 0.17 are recommended.

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