Pull Out Resistance of a Plate Anchor Embedded in a Three Layered Sand

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Summary In this paper model tests investigating the pull out resistance of circular plate anchors embedded in a three layered sand are reported . It is observed that the peak pull out load decreases with the thickness of the weak (loose) upper layer and increases with the thickness of the strong (dense) bottom layer. It is also observed that the ultimate pull out load is similar to that obtained in a homogeneous uniform loose sand.

1. INTRODUCTION

A great deal of laboratory and field work on uplift resistance of plate anchors embedded in homogeneous sands has been carried out during the last decade (Murray & Geddes, 1987, Dickin, 1988, Bouazza & Finlay, 1989, Ghaly et al, 1991, etc ...). Several important aspects of the behaviour of these types of foundation have been investigated e.g. anchor geometry & cyclic loading (Andreadis et al, 1981, Stewart, 1988), disturbance during placement (Zakaria, 1986), eccentric loading (Das & Seeley, 1976, Bouazza & Finlay, 1990a). However, very few studies on the pull out capacity of a plate anchor embedded in a multilayered system have been carried out. Literature review with direct relevance to the present problem is very scarce. Nevertheless, it is worth noting the work performed by Stewart (1985) on a related problem in which a model anchor study was carried out in a clay overlain by sand. In an earlier paper (Bouazza & Finlay, 1990b), the author presented the results of an investigation on the uplift capacity of a plate anchor embedded in a two layered sand. The test results of the cases of a medium sand layer overlying a dense sand layer and a loose sand layer overlying a dense deposit of sand were reported.

The purpose of the present paper is to present the experimental results of model scale tests of shallow plate anchors embedded in a three layered sand (dense, medium, loose).

2. MODEL TESTS AND RESULTS

The three layered soil for this test series consisted of a loose upper layer overlying a medium middle layer resting on a dense layer of sand (Figure 1). The sand used was a coarse Leighton Buzzard sand with the following properties: uniformity coefficient = 1.8, specific gravity = 2.65, grain shape = subrounded, porosity limits: minimum = 33.2%, maximum = 44.2%.

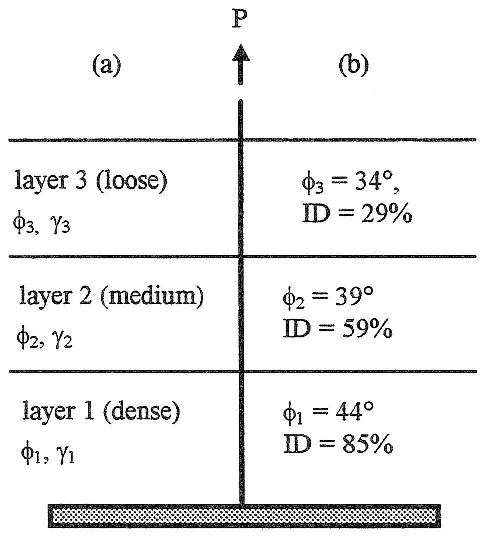

Figure 1: Plate anchor under vertical uplift load in three layered sand: a) general case, b) test series.

The model anchor pull out tests were performed in a steel tank 500 mm diameter and 700 mm deep, large enough for tests to be carried out without any side effects. The model anchor was made from brass, 37.5 mm diameter and 3 mm thick, and an anchor shaft 6 mm diameter screwed into the brass disc to make the anchor unit. At the start of each test a 75 mm thick layer of sand was compacted into the bottom of the tank. The anchor plate was then placed in position on top of this layer, and the sand rained in layers through a raining device which could be adjusted to give a range of densities for the sand as placed. To form a depth of sand with uniform density, two factors are of prime importance: a) the height of fall of the sand and b) the intensity of deposition, (i,e. the weight deposited per unit area per unit time). Variation of either parameter controls the density of the sand as placed. In the present investigation the test beds had relative densities (ID) of 29%, 59% and 85%. At those densities, triaxial tests yielded peak values of ϕ =34°, 39° and 44° respectively. These values were interpolated from tests done over a wide range of relative densities.

The anchor unit was attached to a load cell which was connected to a pneumatic loading device to apply a static loading under load control. As the applied load approached the failure (ultimate) value, the load increment was reduced to give a more clearly defined load value. The peak load was taken as that measured at the last increment before total failure occured (Fadl, 1981, Bouazza, 1990). A linear variable displacement transducer recorded the displacement of the anchor throughout the tests and this information together with the load cell reading, was logged at intervals throughout each test.

The pull out tests were carried out on an anchor embedded at a depth D in a combination of layers of sand. The thickness of each layer was increased to a certain proportion of the anchor diameter. In the present work it was increased from 0.5 to 3.5 anchor diameters for the loose and the dense layers whereas the increase for the middle layer varied from 1 to 3 anchor diameters. The tests were carried out in the shallow range with D/B varying from 3 to 5 with D being the anchor embedment depth and B the anchor diameter. Tests have been carried out, firstly, in a homogeneous sand bed (dense and loose) to establish the upper and lower limits of the load-displacement curve and then on a three layered sytem. Each test has been duplicated and a total of 58 tests have been performed.

3. DISCUSSION

Dimensionless parameters based on the layer thickness ratio are introduced. These are the bottom layer thickness ratio λ_1 (dense layer), the middle layer thickness ratio λ_2 (medium layer) and the upper layer thickness ratio λ_3 (loose layer). They correspond to the ratio of a given thickness of layer H to anchor diameter B. Figure 2 shows a typical load displacement relationship for a plate anchor embedded at D/B= 4.0 and for various layer thickness ratios. It can be seen that the load displacement curves for a plate anchor embedded in

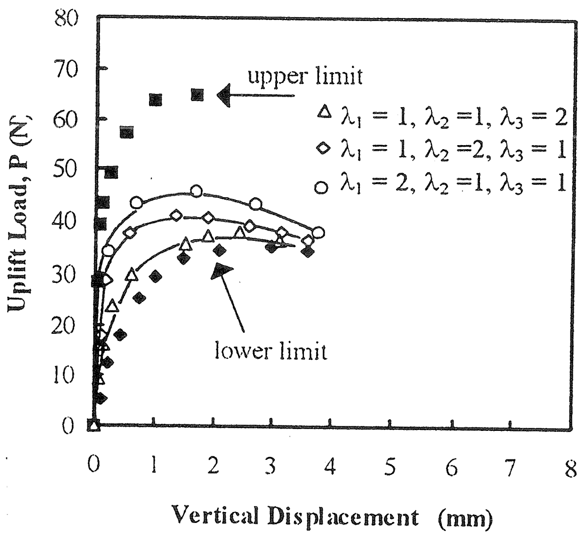

Figure 2 Typical load displacement relationship for plate anchor embedded in a three layered sand; D/B = 4

a three layered sand lay between the upper and lower limits of the anchor pull out load displacement curves in the homogeneous dense and loose sand states available in the test series. It can also be observed that the load capacity falls as the proportion of loose material above the plate anchor increases and that the load displacement relationship is dependant of the layer thickness ratios. Figure 2 shows also that the load falls towards an ultimate value corresponding to a final displacement of about 3.8 mm. This ultimate value appears always to be similar to that obtained in a pull out test in a uniform homogeneous loose sand. In this case, it seems that the load transferred from the anchor to the sand started at the beginning to break out the dense layers and attained the peak values, once the weaker layers had been reached, less force was required to break out the soil and, consequently, a drop in the pull out load occured and reached an ultimate value close to that seen in a homogeneous loose sand. A similar behaviour has been observed in a two layered sand (Bouazza & Finlay, 1990b).

Typical test results of the peak pull out load of a plate anchor embedded in a three layered sand at a depth/diameter ratio of 5 (D/B=5.0) are shown in Figure 3. This figure indicates that, for a given middle layer thickness ratio, the peak uplift load decreases with the increase of the upper layer thickness ratio and the decrease of the bottom layer thickness ratio.

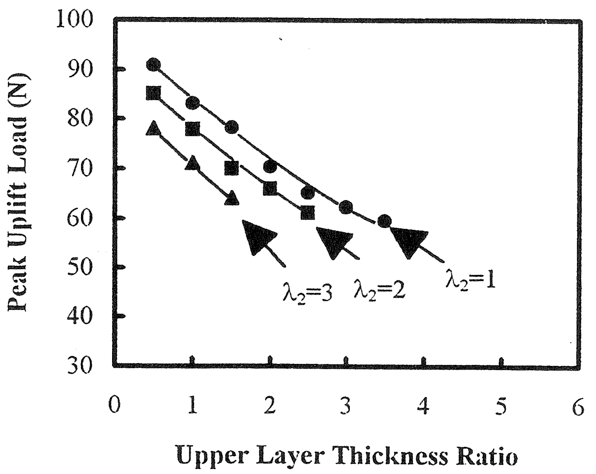

Figure 3: Typical variation of peak uplift load against upper layer thickness ratio; D/B = 5

4. CONCLUSIONS

The results of model tests on circular plate anchors embedded in a three layered sand show that the peak pull out load decreases with the thickness of the weak upper layer and increases with the thickness of the strong bottom layer. The ultimate value seems to be similar to that obtained in a uniform homogeneous loose sand.

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