UPLIFT CAPACITY OF STAR ANCHOR PLATE MODIFIED FROM CIRCULAR SHAPE EMBEDDED IN COHESIVE COMPACTED SOIL

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ABSTRACT***:*** This study aims to investigate various types of anchors with 5, 4, and 3 plates star in which its section area reduced and equivalent diameter constant. We performed experimental test by modeling anchor with 5 mm thick and 30 mm width and 100 mm diameter. Pull test was subjected on the anchor in the compacted soil where the anchor was placed in the various depths, 300 mm, 600 mm, and 900 mm. The test results indicated that anchor plate with reduced area to star shape whit 5, 4 and 3 plate decrease in pullout capacity. But percentage in dcrease pull capacity under decrease reduced of area. The depth of anchoring is also significant factor to pullout capacity.

Keywords: Pull Capacity, Star Plate Anchor, cohesive Soil.

I. Introduction

Indonesia is one of the countries with vast coastal areas. Recently, infrastructure developments have been undergoing, either in onshore or offshore. Those including floating deck, mooring dolphin, traditional floating deck called as "bagang". The structures necessitate such anchor to stabilize against the movement of currents, waves, and winds which affect their stability horizontally and vertically. Anchors with drag, helical, and circle/rectangular plate are widely used depending on structure loads, and soil condition. Mechanical behavior of anchor is indicated by its failure mechanism. The type of circle or rectangle plate anchor is mostly used with dimension, depth and material type varying.

Laboratory test on plate anchor subjected to clayey soil with various consistency was undertaken by Mayerhoff and Adams (1968). They suggested that slip failure cannot be predicted. Vesic (1971) assumed that pull capacity is such combination between effective weight of anchor and effective weight of soil, and vertical shear strength along slip failure. He suggested that the deeper the anchor penetrating, the larger pull capacity it had. Das (1978,1980) developed laboratory model test to estimate pull capacity of circle plate anchor in soft cohesive soil.

The development of anchor with sufficient pull capacity is necessary. In particular, anchor in cohesive soil at deep enable the use of stars anchor. Therefore, we undertook a number of experimental tests on star shape anchors in which circle plate anchors were modified to be star plates with various number of element consist of 5, 4 and 5 element. The performance of the anchors were observed including its pull capacity and failure mechanism.

II. Method

II.1. Model of Anchor

Typical anchor used in this study is star plates anchor with various number of plates. The anchor was made from steel plate attached to a steel rod. The length of the rod depends on the depth of anchoring plus 10 cm from the surface. The type of anchor can be seen in Figure 1. Circle plate anchor is 5 mm thick with the section area of 78.5 cm2 and equivalent diameter of 10 cm. Star plate anchor with 3, 4, 5 plates were also used. Their section areas are reduced from the circle shape plate but their equivalent diameters are constant.

II.2. Soil Preparation

The characteristic of soil used in this study was examined by performing a number of tests including water content, specific gravity, soil particle distribution, direct shear test, compaction, and Atterberg Limit. The soil was obtain from a field, the particles was crushed until they can pass the sieve no. 4. A box with the size of 280 ×210×100 cm^3 were prepared. Then, plate anchor were placed into the box connected to steel rod with diameter of 8 mm. The box was filled with the soil in which every 10 cm layer of the fill was compacted by using modified compacter. Every layer was colored to signage failure pattern during the test. Hydraulic pump was attached to the anchor rod. Dial gauges were placed in order to record deformation and loading. The equipments and material arrangements are illustrated in Figure 2.

III. Result and Discussion

The characteristic of the soil can be explained with several parameters:

- Water content : 21.14 %.
- Specific gravity : 2.72.
- Liquid Limit (LL) : 65.78 %.
- Plastic Limit (PL) : 33.33 %.
- Plasticity index : 32.45 %.
- Shringkage Limit (SL) : 22.71 %.
- Sieve Analysis : 84.3% passing No. 200.

Based on Unified Soil Classification System, the soil can be classified as organic clay (OH) while AASHTO classified it as A-7-5 clay soil. By conducting Standard Proctor Test, optimum water content was found at 33.12 % and dry density γdry maks at 1.26 gr/cm^3. Relative density was accounted for 85.1%. Relation between water content and dry density is shown at Figrue 3. Unconfined test was also undertaken and it was found that unconfined pressure (qu) is 1.1 Kg/cm^2. This indicated that the soil consistency is at medium level. It was found also shear strength of the soil is 0.54 Kg/cm^2.

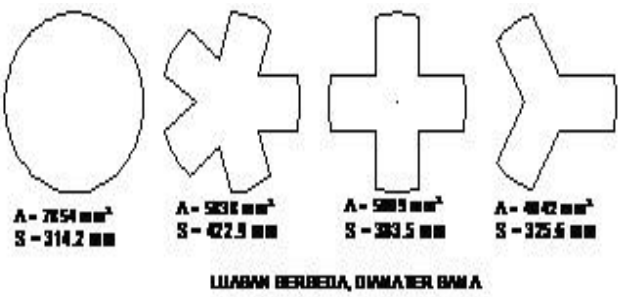

Figure 1. Anchor Model

Pullout Capacity of the anchor

Pullout capacity on various plates of star plates anchor with constant area was investigated at the anchoring depth of 30 cm, 60 cm, and 90 cm. Figure 4 shows pullout capacity with the uplift displacement at every depth. At the depth of 30 cm, the test was carry out until failure ground surface was obtained. On the other hand, at the depth of 60 and 90 cm, the test was done until the large deformation with constant load was obtained. The results show that the performance of anchors is different. The pullout capacity of the anchor model A1 (Circle), A3 (3 plates), A4 (4 plates), A5 (5 plates) at the depth of 90 cm is larger than those at the depth of 60 cm and 30 cm. Pullout capacity was determined from the graph at the condition of constant load with incrasing displacement (Figure 5). It can be seen that the performance of the anchors depending on the model of anchors (Table 1)

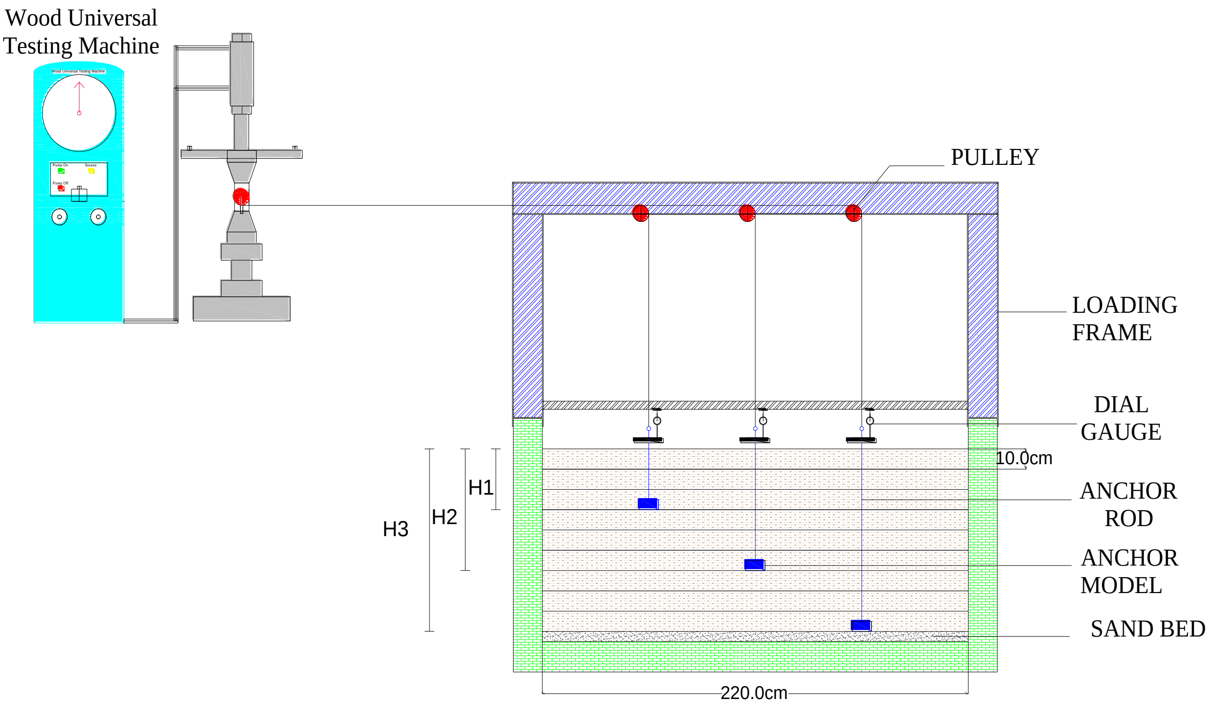

Figure 2. Laboratory Model

Relationship between Reduced Area and Pullout Capacity

The change of area in relation to the decrease of pullout capacity is illustrated in Table 2. The reduced of area yields the decrease of pullout capacity. It is very clear that the anchor model A1 to A5, the pullout capacity decrease by 8.74%, while the anchor model A1 to A4 was found at 16,34%, and A1 to A3 is 24,6 %. At the depth of 60 cm the decrease of pullout capacity of the A1 to A5 was found at 16 %, A1 to A4 is 20 % and A1 to A3 is 26.72%. At the depth of 90 cm , pullout capacity decrease by 8,9% for A1 to A5, 19.23% from A1 to A4, and 23.07%, For A1 to A3. Its clearly that percentage of decrease in pullout capacity still smaller than percentage ini reduced area of anchor. Its A1 to A5 is 25.67%, A4 is 36.22% and A3 is 48.54%.

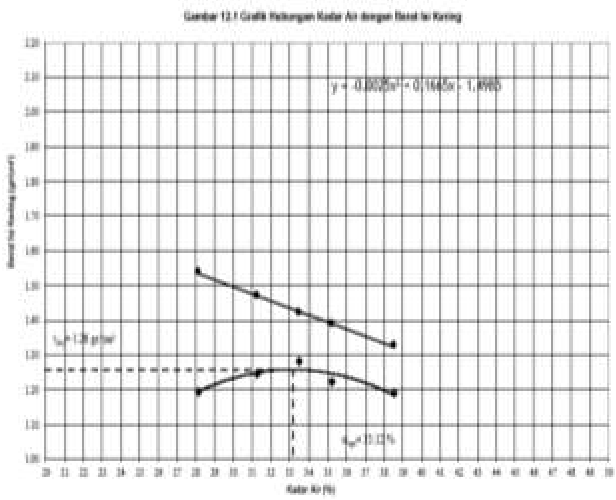

Figure 3. Optimum water content and density of soil sample

Slip Failure in the Soil due to Pulling of Anchor

The results also show failure mechanism of the soil as impact of pullout stress increasing (figure 6). At the depth of 30 cm, slip of the soil is imminent at the surface. Compared to that, at the depth of 60 cm, the slip failure was seen from the anchor plate to the surface (shallow anchor). Its form looks like cone with the area increasing as it approaching to the surface. In constrast, the depth of 90 cm did not show any slip failure clearly in the surface except it just located at around the anchor plate. We suggested that this can classified as deep anchor.

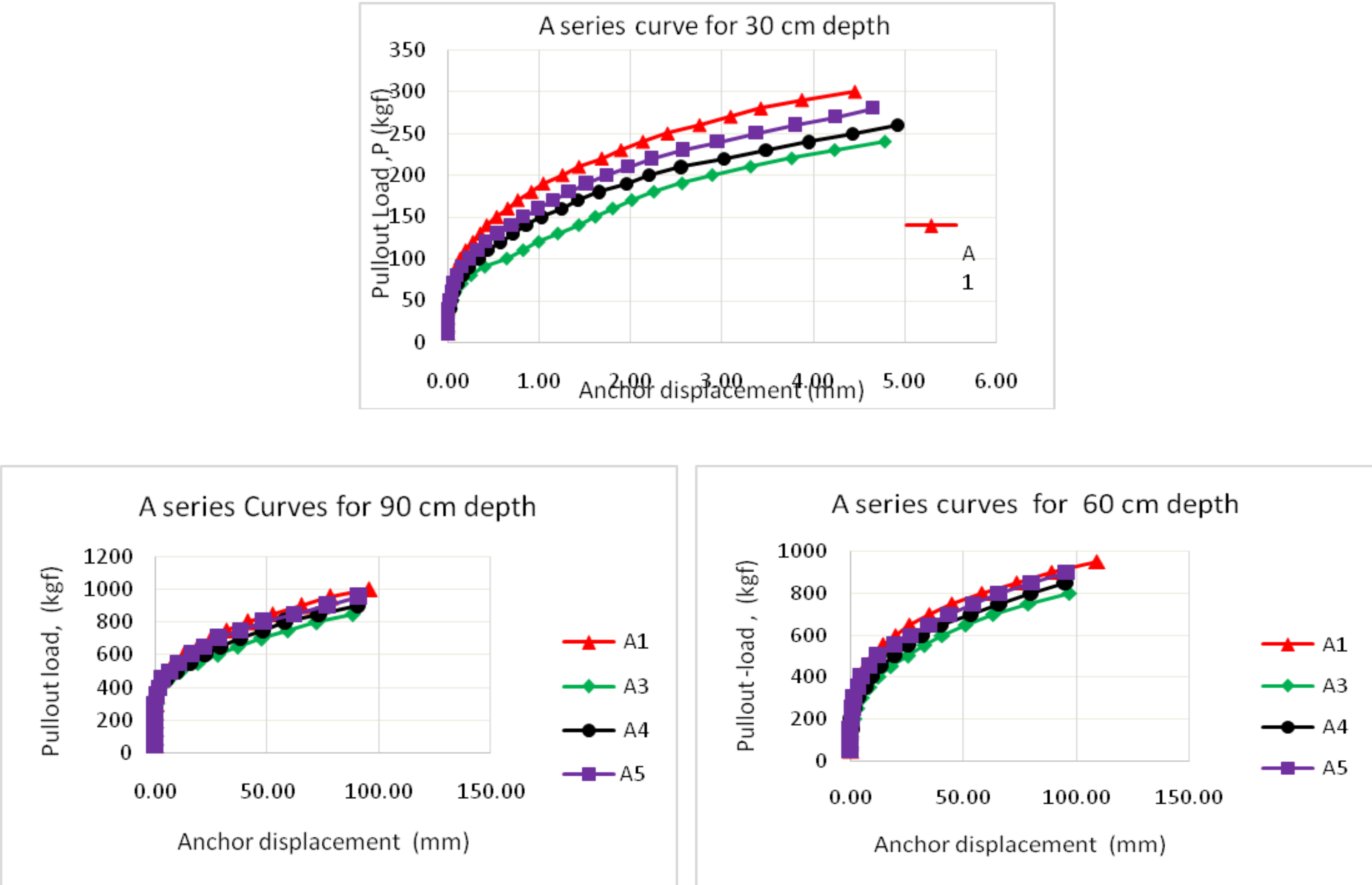

Figure 4. Load vs Displacement of anchor models

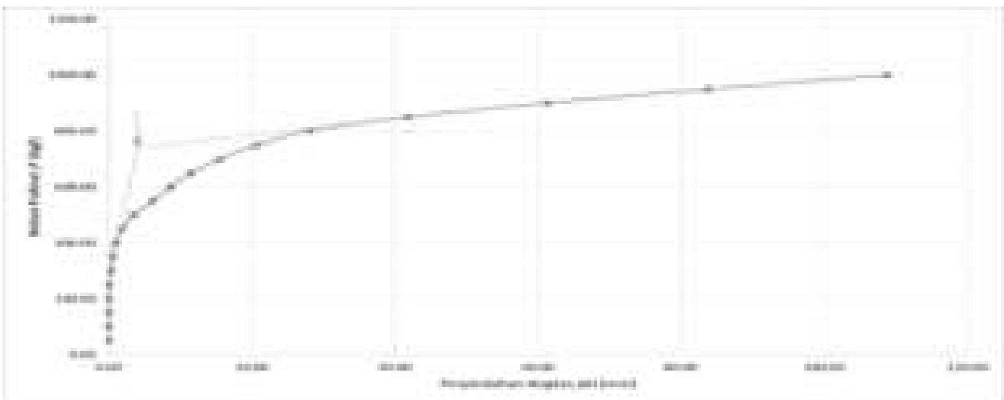

Figure 5, Determination of Pullout Capacity of the anchors

Table 1. Pullout Capacity of the Anchor Models.

No	Anchor Shape	Pu (kgf)		
		30 cm	60 cm	90 cm
1	A1 (circle)	183	625	650
2	A5 (tree plates)	167	525	592
3	A4 (four plates)	158	500	525
4	A3 (fife plates)	138	458	500

Table 2. Relationship between Reduced Area and Pullout Capacity.

Anchor Plate		A1	A5	A5	A3
Area (mm2)		7854	5838	5009	4042
Decrease of Area (%)		-	25.67	36.22	48.54
Decrease Pullout Capacity (%)	30 cm deep	-	8.74	16.34	24.6
	60 cm deep	-	16.0	20.0	26.72
	90 cm deep	-	8.90	19.23	23.07

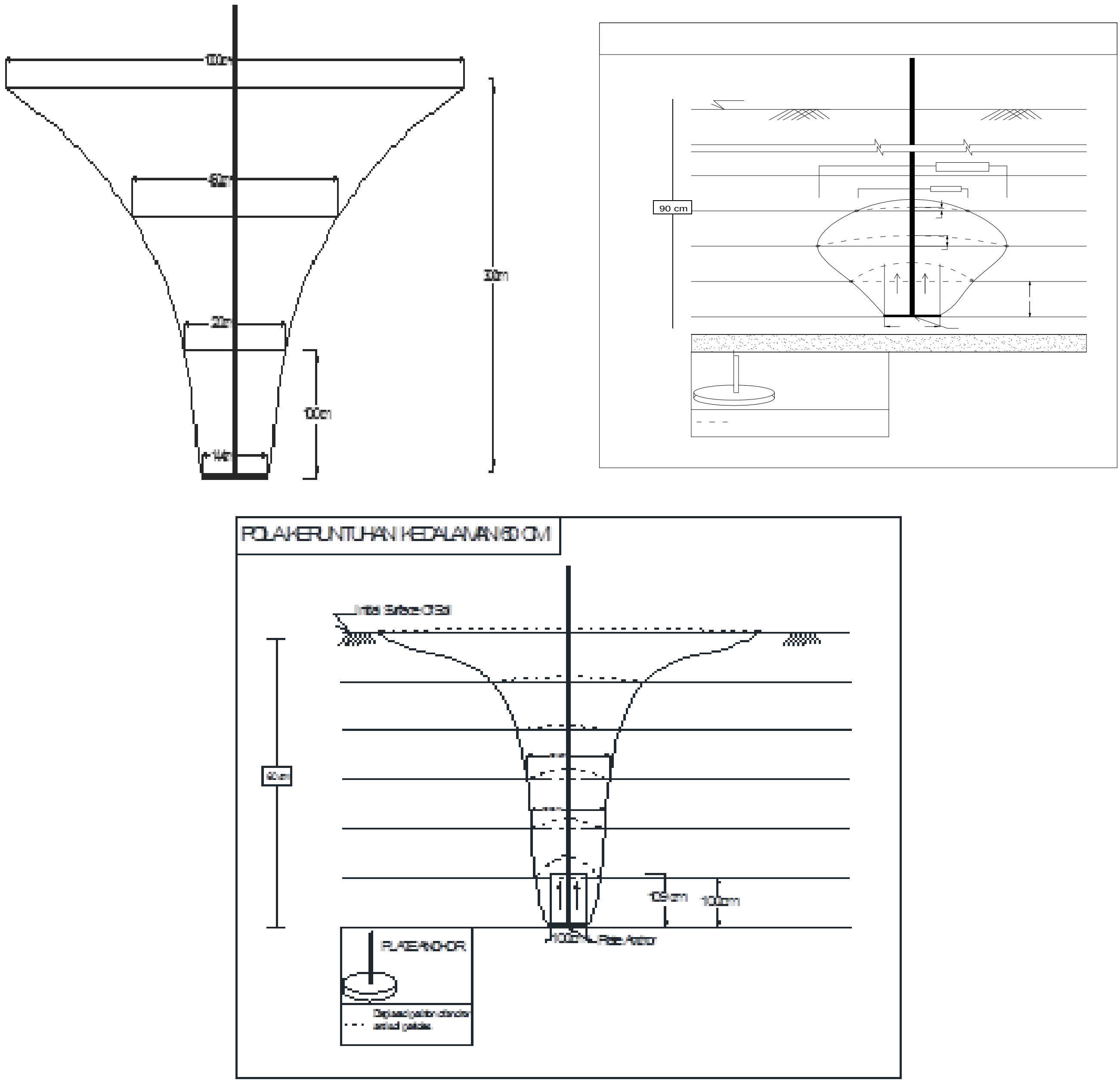

Figure 6. Slip Failure of soil due to Pulling Anchor (a) 30 cm, (b) 60 cm, and (c) 90 cm.

V. Conclusion

1. The results of the analysis of the pullout capacity with the star shape anchor plates has been discusse. The modification of the circular anchor plate into the star shape indicates a fairly good performance. For this model with a circular area reduced to the stars shape model, the percentage reduction in capacity is smaller than the decrease in the extent modified.

2. The depth of anchoring also effect on pullout capacity. The deeper anchoring, the larger pullout capacity will be.

3. The magnitude of increase pullout capacity is large from the depth of 30 cm to 60 cm compared the depth of 60 cm to 90 cm.

4. Slip failure of the soil due to pulling anchor differentiate shallow and deep anchor.

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