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EXPERIMENTAL STUDY OF PULLOUT CAPACITY OF STARD PLATE ANCHOR

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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 and equivalent diameter constant. We performed experimental test by modeling anchor with 5 mm thick and 30 mm width. 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 longer equivalent diameter yield larger pull stress. The depth of anchoring is also significant factor to pullout capacity.

Keywords: Pull Capacity, Star Plate Anchor, Coastal.

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 anchors in which circle plate anchors were modified to be star plates with various equivalent diameters ranging

from three to five plates. The performance of the anchors were observed including its pull capacity and failure mechanism.

METHOD

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 cm and equivalent diameter of 10 cm. Star plate anchor with 3, 4, 5 plates were also used. Their section areas are the same but their equivalent diameters are different.

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. 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 cm³ 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.

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Dial gauges were placed in order to record deformation and loading. The equipments and material arrangements are illustrated in Figure 2.

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 %.
- Shrinkage 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 γ_{dry} maks at 1.26 gr/cm³. Relative density was accounted for 85.1%. Relation between water content and dry density is shown at Figure 3. Unconfined test was also undertaken and it was found that unconfined pressure (qu) is 1.1 Kg/cm². This indicated that the soil consistency is at medium level. It was found also shear strength of the soil is 0.54 Kg/cm².





Tipe Jangkar	Luas (mm ²)	Keilling (mm)	Lebar daun (mm)	Diameter Equivalent (mm)
	7850	314,2	-	100
	7850	579,8	30	182,6
	7850	573,1	30	145,92
	7850	557,4	30	125,92

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), B3 (3 plates), B4 (4 plates), B5 (5 plates) at the depth of 90 cm is larger than those at the depth of 60 cm and 30 cm.

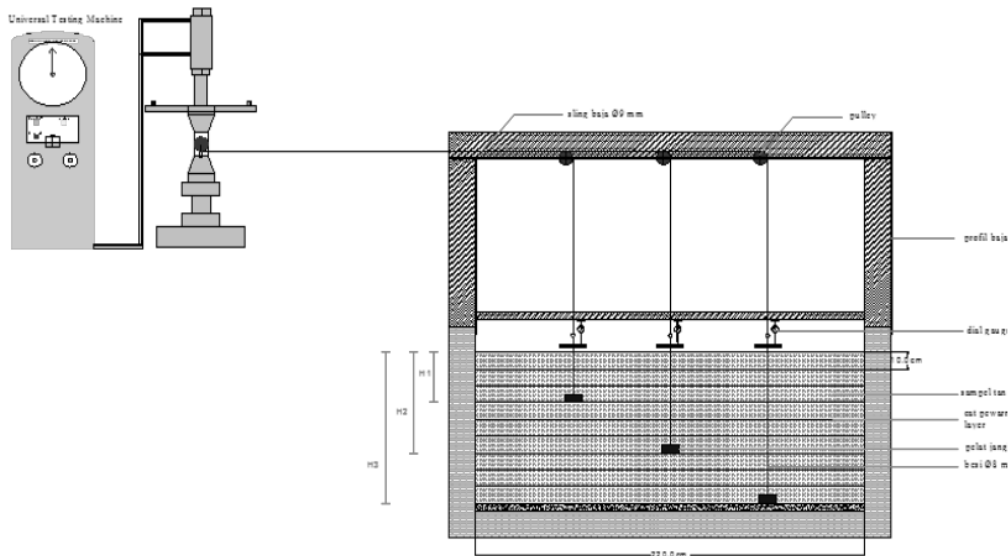


Figure 2. Laboratory Model

Pullout capacity was determined from the graph at the condition of constant load with increasing displacement (Figure 5). It can be seen that the performance of the anchors depending on the model of anchors (Table 1).

Relationship between Equivalent Diameter and Pullout Capacity

The change of equivalent diameter in relation to the increase of pullout capacity is illustrated in Table 2. The increase of equivalent diameter yields the increase of pullout capacity. It is very clear that the anchor model A1 to B5, the pullout capacity increase by 16,393 %, while the anchor model A1 to B4 was found at 27,322 %, and A1 to B3 is 50,273 %. At the depth of 60 cm the increase of pullout capacity of the A1 to B5 was found at 4 %, A1 to B4 is 8 % and A1 to A3 is 18,72 %. At the depth of 90 cm , pullout capacity increase by 5,077 % for A1 to B5, 10,307 % from A1 to B4, and 26,923 %. For A1 to B3.

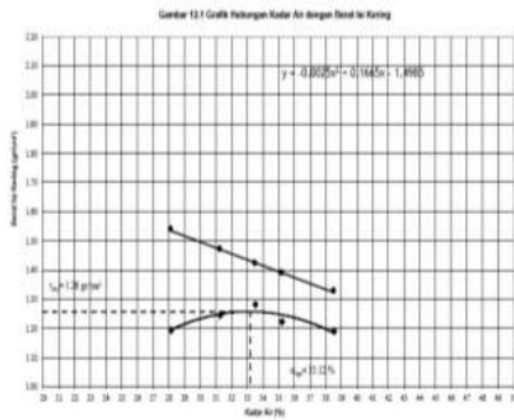
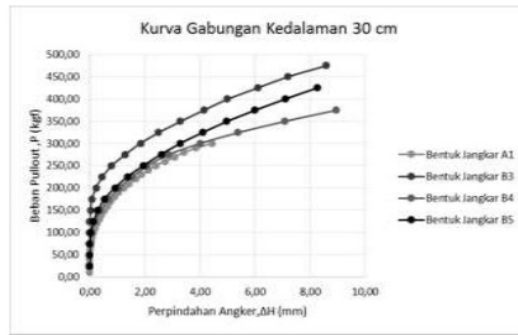


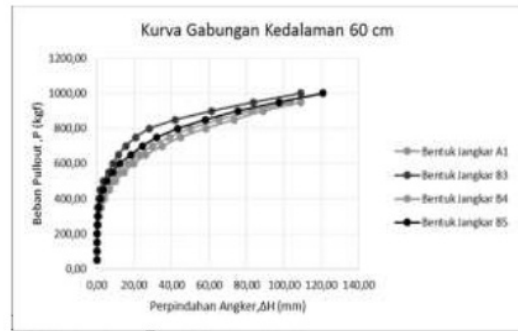
Figure 3. Optimum water content and density of soil

Slip Failure in the Soil due to Pulling of Anchor

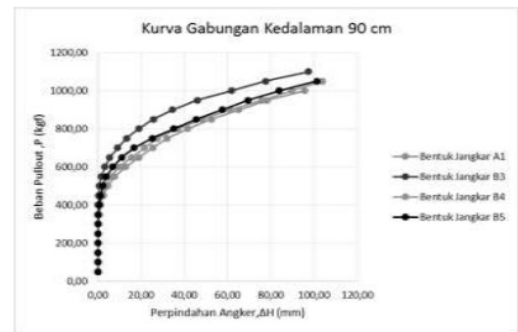
The results also show failure mechanism of the soil as impact of pullout stress increasing (figure 6). At the depth of 30 cm, slip of the soil is imminent at the surface. Compared to that, at the depth of 60 cm, the slip failure was seen from the anchor plate to the surface (shallow anchor). Its form looks like cone with the area increasing as it approaching to the surface. In contrast, 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.



(a)



(b)



(c)

Figure 4. Load vs Displacement of anchor models

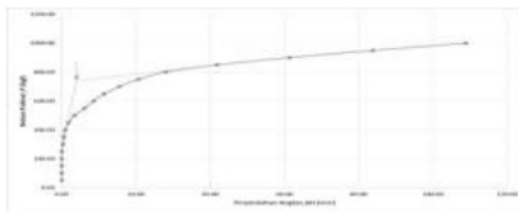


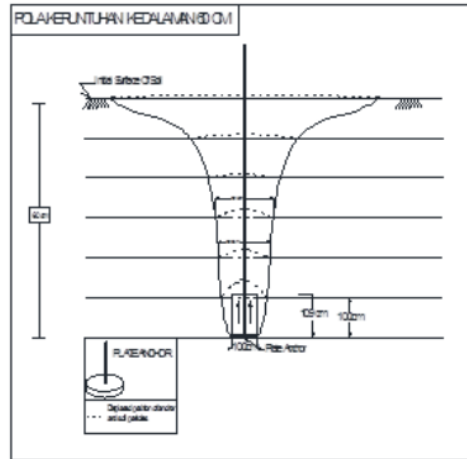
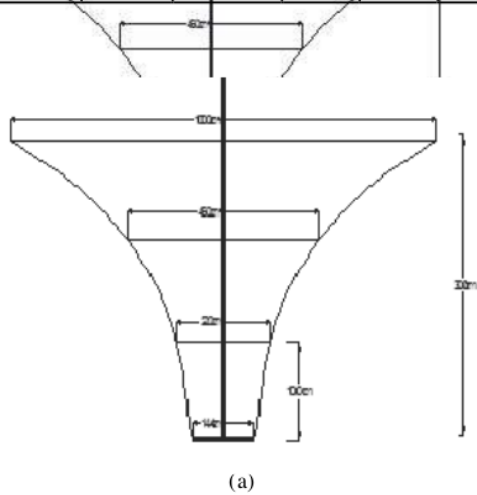
Figure 5, Determination of Pullout Capacity of the anchors

Table 1. Pullout Capacity of the Anchor Models.

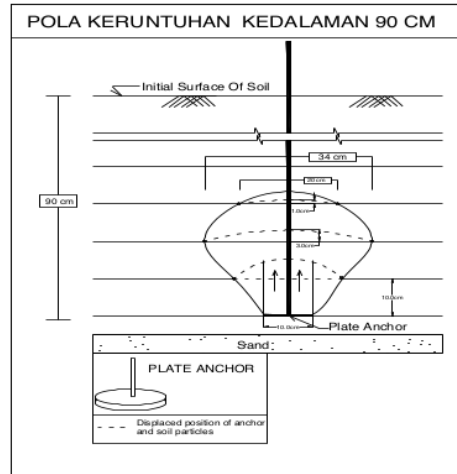
No	Bentuk Jangkar	Pu (kgf)		
		30 cm	60 cm	90 cm
1	A1 (Lingkaran)	183	625	650
2	B3 (Tiga daun)	275	742	825
3	B4 (Empat Daun)	233	675	717
4	B5 (Lima Daun)	213	650	683

Table 2. Relationship between Equivalent Diameter and Pullout Capacity.

Tipe Jangkar		A1 (Lingkaran)	B3 (Tiga Daun)	B4 (Empat Daun)	B5 (Lima Daun)
Diameter equivalent (mm)		100	182,60	145,92	125,92
Perubahan diameter equivalent (%)		-	82,6	45,92	25,92
Perubahan Kapasitas cabut batas (%)	Kedalaman 30 cm	-	50,27	27,32	16,39
	Kedalaman 60 cm	-	18,72	8,00	4,00
	Kedalaman 90 cm	-	26,92	10,31	5,08



(b)



(c)

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

CONCLUSION

1. Pullout capacity of the anchors at the depth is influenced significantly by equivalent diameter. We found that the anchors with larger equivalent diameter yield larger pullout capacity.
2. The depth of anchoring also effect on pullout capacity. The deeper anchoring, the larger pullout capacity will be. In this case, the depth of 60 cm yields double pullout capacity compared to anchoring at 30 cm deep for the A1 model. For B3 model, it was found at 1.6 times while B4 accounted for 1.89 times.

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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