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Research Paper

Effect of Depth on Folding Type Ground Anchor Tensile Force in Soft Soil

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ABSTRACT

Soft soil is one type of soil that is commonly found in Indonesia, but in construction, this type of soil is often a problem, namely for soil stability in the process of making building structures. In an effort to determine the stability of the soil or slope, an anchor is used as a measuring medium. Several structures have used anchors and have been developed for various purposes such as slope reinforcement, retaining walls, tunnel stability, and so on. This research aims to analyse the effect of the depth of folding type soil anchor on the tensile force and to analyse the comparison of the tensile force of laboratory experimental testing results with full-scale field testing. The research method was carried out by testing the tensile force of laboratory-scale folding type anchors with depths of 30cm, 60cm and 90cm and field-scale tests using folding type anchors with depths of 100cm, 200cm and 300cm. From the results of tests that have been carried out in the laboratory and the field, it can be concluded that the folding type model anchor does not need to be designed too deep because the anchor has a critical limit where even though the depth is increased it no longer adds a greater maximum tensile force. In addition, the comparison of the tensile force of the laboratory experimental test results with the field full-scale testing.resulted in similar properties of the maximum tensile test results..

1. Background

Indonesia as an archipelago has more than 3,700 inhabited islands and 80,000 km of coastline. Coastal areas are generally used by residents to carry out various activities.

Various infrastructure and amenities must be created along the shore in order to support activities including industrial areas, ports, fishery activities, agricultural, government locations, and tourism regions.

Soft soils can be found in Indonesia's coastal regions almost everywhere, including inland and offshore. Numerous tasks are completed, particularly for structures in shore and offshore locations associated to resource exploitation, which call for the construction of infrastructure such floating breakwaters, mooring dolphins, floating docs, floating offshore platforms, floating homes, and so forth. Stability is needed for each of these buildings, both temporary and permanent.. The fundamental issue for structures along the coast or offshore is stability due to the movement of seawater, which occurs both vertically due to tides and horizontally due to currents, wind, and waves. An anchor is used as a measuring medium in an effort to gauge the stability of the slope or soil. Several structures have used anchors and have been developed for various purposes such as slope reinforcement, retaining walls,

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tunnel stability, and so on. To get the maximum tensile force, it is necessary to study the tensile force of the anchor (tensile force) in certain soil conditions, in order to obtain the amount of anchor tensile force to be planned, until the soil does not collapse (failure).

In determining the tensile force on the folding type soil anchor, what is done is to make several variations in the treatment of folding type soil anchors, namely variations in density in soft soil conditions (soft, qc = 14-40kg/cm2). Determining the maximum tensile force, it is necessary to study the tensile force of the anchor (tensile force) to the depth, with the condition of the variation above, in order to obtain the amount of the tensile force of the anchor.

Modelling of anchor tensile tests using a test box column test by varying the density with the aim of observing the tensile strength of the anchor. A number of laboratory and field test results published to determine the tensile force of plate anchors for short-term conditions buried in soft soil is summarised by Das (1990) where the equation for determining the short-term force of plate anchors is as follows:

$$Qu = Qo + Wa + Fs$$

with :

Qu = Gross tensile force of the anchor

Qo = Net tensile force

Wa = effective weight of the anchor plate and

Fs = mud suction force which is a function of Cu and k.

Qo price according to Vasic (1971):

$$Qo = A(\gamma H + Fc.Cu)$$

with :

A = Area of the anchor plate

γ = Volume weight of saturated soil

Fc = Break out factor

Cu = Undrained cohesion.

Furthermore, Fc is a function of Cu and the anchor planting ratio. Referring to Das (1990):

$$Fc = n(H/D) \leq F^{*}c = 9$$

The value of n ranges from 2 - 5.9 depending on the value of cu. For each anchor model, a depth of 120 cm was used with variations in density qc = 15 - 30 kg/cm2, qc = 30-40 kg/cm2. The density in the test column was measured using a Hand Penetrometer. After that, it was allowed to stand and then tested. The tensile test was carried out using a tool with a schematic diagram of the tensile test tool. After observation, the tensile force for all tested anchor models was analysed. The results can be determined from the behaviour of the relationship between load and tensile deformation during the test.

Based on this, this research was conducted to analyse the effect of the depth of the folding type soil anchor on the tensile force as well as to analyse the comparison of the tensile force of the laboratory experimental test results with the field full-scale test.

2. Methodology

2. 1. Location and Time of Research

The research locations were 2 places, namely in the Environmental Geotechnics and Soil Mechanics laboratories of the Department of Civil Engineering, Hasanuddin University, Gowa Regency, and full-scale testing was carried out in the field at a location in the swamp area in Tamalanrea.

The research time was conducted on 8 October 2019 for laboratory scale and 12 June 2022 for field scale.

2. 2. Material Preparation

The soft soil used as a test medium in this study is soil taken from the location around the Nusa Tamalanrea Indah housing estate, Tamalanrea District, Makassar city.

2. 3. Tool Preparation

2.3.1. Preparation of Laboratory Test Equipment

- Soil physical properties testing tools: sieve and hydrometer analysis test equipment, moisture content test equipment, tools for soil physical properties testing. soil specific gravity (GS) test, soil volume weight test, Atterberg limits test.
- Soil mechanical properties testing equipment: direct shear, unconfined compression test (UCT).
- Folding anchor: the anchor model used is folding type soil anchor consisting of 4 leaves, made of BJ. 37 quality steel with a thickness of 4 mm. the model is not rigid (flexible) can be closed and open like an inverted umbrella.

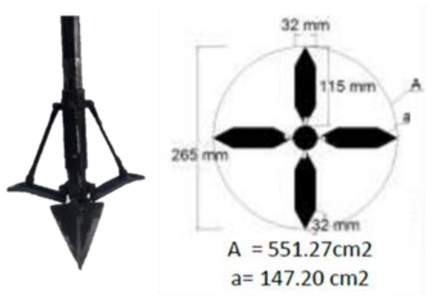

Fig 1. **Folding Anchor**

- Testing Tub: a testing container named The round-shaped test column is made of steel plate with a thickness of 4 mm, measuring 120 cm in diameter and 150 cm in height, equipped with a Loading Frame testing instrument made of H beam steel profile.

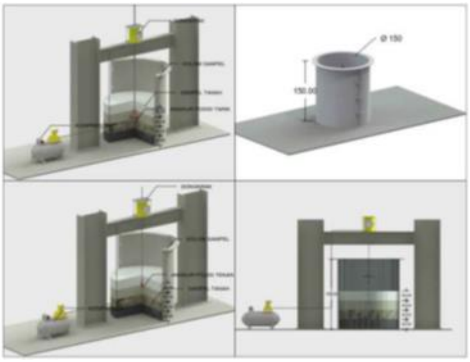

Fig 2. **Testing Tub**

- Anchor Insertion and Withdrawal: The equipment used to insert the anchor into the soil in the test column and to pull the anchor (which provides tensile load) at a predefined depth are hydraulic jacks with holes in the centre that have a 30 ton force.
- Readings deformation tensile model measured by using a dial indicator (dial gauge).
- Compressor: a device used for hydraulic pumping so that the jack can press and pull the anchor in the test tub.
- Meter to measure anchor displacement when inserted (pierced) and withdrawn.

2.3.2. Field Test Equipment Preparation

- Ground Drilling Machine: a tool used to insert (pierce) and pull the ground anchor, equipped with a dial indicator (dial gauge)

2. 4. Sample Testing

2.4.1. Physical Properties Test

- Soil specific gravity testing refers to the rules of SNI 03-1964-2008/ASTM D854-88 (72), The tools used are Pycnometer with 50 ml style, Sieve no.4, Oven, Scales, Hot Plate, Thermometer, Soaking Cup.
- Water content testing refers to the rules ASTM D 2216-(71). The tools used were oven, scales, desiccators and cup.
- Hydrometer analysis testing is adjusted to the rules of SNI 03-3423-1994. The tools used are No. 200 sieve, 125 ml glass cylinder, 1000 ml glass cylinder, suspension stirrer (string apparatus), rubber cover with the same diameter as the measuring cup, porcelain cup (mortar), thermometer, stopwatch, destilai water, disperse material (reagment).
- The sieve analysis test is adjusted to the rules of SNI 03-1968-1990. The tools used are sieves, scales, stopwatches, and distilled water.
- Liquid limit (LL) testing equipment, refers to the rules of SNI 03-1967-1990. The tools used are liquid limit gauge, invented by Casagrande Sieve no.4, glass plate, grooving tool, container, scales, oven.
- Plastic limit (PL) testing tool and plasticity index (PI) referring to the rules of SNI 03-1968-1990. The tools used were porcelain cup, pestle, glass plate, no.40 sieve and a 3 mm wire.

2.4.2. Mechanical Properties Test

- Unconfined Compression Test (UCT) was conducted using ASTM D2166-06 and SNI 3638-2012 standards.
- Direct Shear testing is conducted to obtain the soil shear force. This test was conducted using SNI 03-3420-1994 and ASTM D-3080-04 standards.

3. Result and Discussion

3.1 Laboratory Test Results

3. 1. 1. Laboratory Scale Soft Soil Physical and Mechanical Characteristics Test Results

Testing the characteristics of the physical and mechanical properties of the soil was carried out to classify the type of soil, which was used in the study. Based on the results and laboratory testing, the following data were obtained:

The table shows the value of the anchor tensile force that the anchor can withstand up to the point where the soil deforms (collapses) or the value of the anchor tensile force is constant (no significant increase or decrease).

Table 1. **Characteristic Properties of Soil on Laboratorium Test**

No.	Test Type	Unit	Testing Results
	Characteristic Physical Properties		
1.	Specific gravity of soil (Gs)	-	2,73
2.	Water Content (ω)	(%)	54,00
3.	Atterberg Limits		
	Shrinkage Limit	(%)	54,50
	Plastic Limit (PL)	(%)	19,60
	Liquid Limit (LL)	(%)	19,60
	Plasticity Index	(%)	34,90

4.	Sieve Analysis and Hydrometer		
	Gravel	(%)	0,00
	Sand	(%)	12,60
	Silt	(%)	50,40
	Clay	(%)	31,00
Classification			
	USCS		CH
Characteristic Mechanical Properties			
5.	UCS (*Unconfined Strength*)	kg/cm^2	1,0014
6.	*Direct Shear*	*degree*	16^0 46'

3. 1. 2. The Effect of Depth on the Tensile Force of Folding Anchors

Tests were conducted at the Soil Mechanics Laboratory of Hasanuddin University to determine the depth to the tensile force of the folding anchor.

This test will be conducted on clay soil with variations in soil depth. Where, each variation that has been described in the research methodology, starting from the variation of soil depth of 30 cm, 60 cm, and 90 cm. The results of the folding anchor tensile force test can be seen in the following table.

Table 2. **Tensile Force of Anchor on Laboratorium Test**

No.	Anchors Displacement (mm)	Tensile Force (Kg) Depth 30 cm	Depth 60 cm	Depth 90 cm
1	0	0	0	0
2	20	25	50	80
3	40	50	125	180
4	60	100	225	260
5	80	175	300	330
6	100	250	375	410
7	120	310	425	480
8	140	325	475	530
9	160	320	500	540
10	180		500	540
11	200		500	540
12	220		500	540
13	240		500	540

The table shows the value of the anchor tensile force that the anchor can withstand up to the point where the soil deforms (collapses) or the value of the anchor tensile force is constant (no significant increase or decrease).

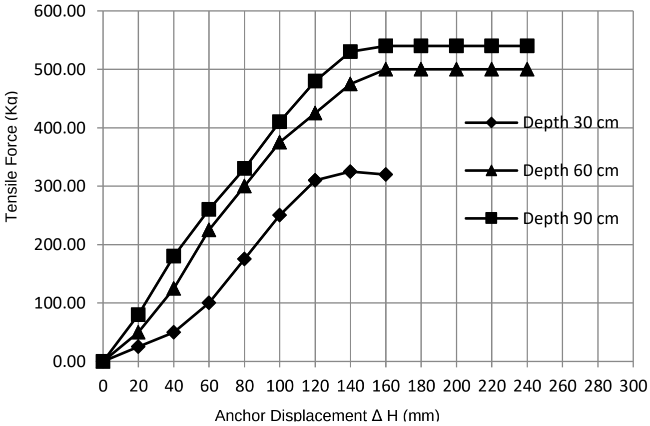

Fig 3. **Anchor Displacement Graphic**

Based on the graph above, we can see and observe the effect of depth variations that occur in folding soil anchors, namely:

1. A depth of 30 cm indicated by line "30 cm" with a maximum tensile force (P1) of 325 kg.
2. A depth of 60 cm indicated by line "60 cm" with a maximum tensile force (P2) of 500 kg.
3. A depth of 90 cm indicated by line "90 cm" with a maximum tensile force (P3) of 540 kg.

3.2 Field Scale Test Results

3. 2. 1. Field Scale Soft Soil Physical and Mechanical Characteristics Test Results

Physical and Mechanical Characteristic Testing is carried out to determine the classification of the field soil used in the research according to the plan or not.

Based on the results of laboratory testing, the characteristic data are obtained as in the following table:

Table 3. **Characteristic Soil Properties on Field Test**

No.	Test Type	Unit	Testing Results
Characteristic Physical Properties			
1.	Specific gravity of soil (Gs)	-	2,71
2.	Water Content (ω)	(%)	15,24
3.	Atterberg Limits		
	Shrinkage Limit	(%)	13,47
	Plastic Limit (PL)	(%)	16,47
	Liquid Limit (LL)	(%)	28,43
	Plasticity Index	(%)	11,95
	Sieve Analysis and		

4.	Hydrometer		
	Gravel	(%)	0,00
	Sand	(%)	9,40
	Silt	(%)	48,83
	Clay	(%)	41,77
Classification			
	USCS		CL
Characteristic Mechanical Properties			
5.	UCS (*Unconfined Strength*)	kg/cm^2	0,256
6.	Direct Shear	degrees	20^0 6'

3. 2. 2. The Effect of Depth on the Tensile Force of Folding Anchors

This test will be conducted on clay soil with variations in soil depth. Where, each variation that has been described in the research methodology is, starting from a variation in soil depth of 100 cm, 200 cm, and 300 cm. The results of the folding anchor tensile force test are as follows:

Table 4. **Tensile Force of Anchor on Field Test**

No.	Displacement of anchor (cm)	Tensile Force (Kg)		
		Depth 100 cm	Depth 200 cm	Depth 300 cm
0	0	0	0.00	0.00
1	10	192.33	307.72	384.65
2	20	269.26	346.19	384.65
3	30	269.26	423.12	461.58
4	40	307.72	500.05	538.51
5	50	346.19	538.51	576.98
6	60	384.65	538.51	576.98
7	70	307.72	538.51	576.98
8	80	269.26	538.51	576.98
9	90	192.33	538.51	576.98
10	100	192.33	538.51	576.98
11	110		538.51	576.98
12	120		538.51	576.98
13	130		538.51	576.98
14	140		538.51	576.98

The table shows the value of the anchor tensile force that the anchor can withstand up to the point where the The soil is deformed (collapsed) or the value of the anchor tensile force is constant (no significant increase or decrease).

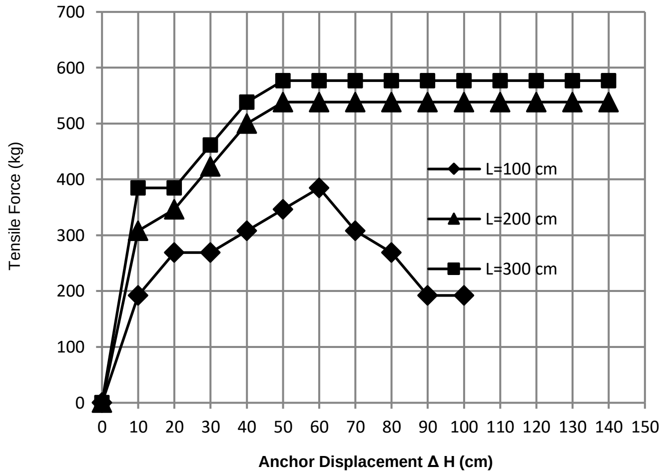

Fig 4. **Anchor Displacement Graphic**

Based on the graph above, we can see and observe the effect of depth variations that occur in folding soil anchors, namely:

1. A depth of 100 cm indicated by line "100 cm" with a maximum tensile force (P1) of 384.65 kg.
2. A depth of 200 cm indicated by line "200 cm" with a maximum tensile force (P2) of 538.51 kg.
3. A depth of 300 cm indicated by line "300 cm" with a maximum tensile force (P3) of 576.98 kg.

3.3 Comparison of Laboratory Test Results and Full Scale Field Tests

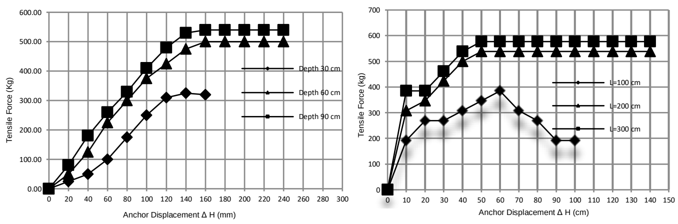

Fig 5**. Comparison of Tensile Force Between Laboratorium Test and Field Test**

In laboratory tensile tests at depths of 30 cm and 60 cm with anchor displacement intervals of every 20 mm, the behaviour of the tensile load relationship with displacement intervals is very much increased. whereas at depths of 60 cm, and 90 cm, the behaviour of the tensile load is similar and the maximum tensile load is not too different. Similarly, in the full-scale tensile tests in the field at depths of 100 cm and 200 cm with anchor displacement intervals of every 10 cm, the behaviour of the load tensile while at depths of 200 cm, and 300 cm, it can be seen that the behaviour of the tensile load is similar and the maximum tensile load is not too far different, indicating that, folding type model anchors do not need to be designed too deep. curves are seen for all anchor models where at the beginning of the steep curve up to a certain level of load increase until there is no more load increase. in this condition the maximum tensile force has been reached. then it can be seen that there is no more load increase until a certain anchor displacement. This shows that The depth of anchor insertion/piercing has a critical limit where even if the depth is increased, it will no longer be able to increase the maximum tensile capacity.

4. Conclusion

From the test results that have been carried out in the laboratory and field, it can be concluded that the increase in tensile force from P1 to P2 is quite significant while the increase in tensile force from P2 to P3 is insignificant, indicating that, folding type mode anchors do not need to be designed too deep because the anchor has a critical limit where even if the depth is increased it no longer adds a greater maximum tensile force. In addition, the comparison of the tensile force of the laboratory experimental test results with the field full-scale test results in similar properties of the maximum tensile test results.

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Symbols and abbreviations

A	Area of the anchor plate
ɣ	Volume weight of saturated soil
Fc	Break out factor
Cu	Undrained cohesion
Qu	Gross tensile force of the anchor
Qo	Net tensile force
Wa	Effective weight of the anchor plate and
FS	Mud Suction Force Which Is A Function Of Cu And K