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By ukarst

Ukarst : Universitas Kadiri Riset Teknik Sipil
Volume 5 Number 1, (2021).
ISSN (*Online*) 2581-0855
ISSN (*Print*) 2579-4620

Available online at
http://ojs.unik-kediri.ac.id/index.php/ukarst/index

U KaRsT

http://dx.doi.org/10.30737/ukarst.v3i2

Study of Anisotropy Characteristics of Bogor Volcanic Soil

Y. Sulastri [1*], P. P. Rahardjo [2].

[*1] *Departement of Civil Engineering, Parahyangan Catholic University.*

[2] *Lecturer in Departement of Civil Engineering, Parahyangan Catholic University.*

Email: [1] yusi.three@gmail.com*

A R T I C L E   I N F O

Article History :
Article entry : 06-10-2020
Article revised : 14-10-2020
Article received : 19-01-2021

Keywords :
Anisotropy, Strength, Compressibility, Compaction Static

IEEE Style in citing this article :
[14] *R. L. and C. W. C. Parfitt, "Estimation of forms of Fe and Al: a review and analysis of contrasting soils by dissolution and Moessbauer methods," Aust. J. Soil Res., no. 26, pp. 121–144, 2018*

A B S T R A C T

Anisotropy in soil results from the deposition process which describes the characteristics of the soil grains or is caused by stress or from the consequences of stresses caused during deposition and subsequent erosion. All soils behave in general anisotropy and some exhibit undrained shear strength. This study conducted 2 tests, namely the first field testing with original soil samples in the form of CPTu and dilatometer. The CPTu test's objective is to determine the vertical soil parameters, while the dilatometer is to determine the horizontal soil parameters. This study indicates that the indication of anisotropy in all shear strength tests is evident in the results of the CPTu test and the Dilatometer test. TX - UU and consolidation show that the horizontal shear strength (S_{uh}) is greater than the vertical slope shear strength (S_{uv}). In this case, the ratio obtained for shear strength is $S_{uh} = 1.3\ S_{uv}$. And from the results of the consolidation test in the laboratory, it was found that the horizontal compression index parameter ($C_{c\ horizontal}$) was greater than the vertical ($C_{c\ vertical}$) and the horizontal coefficient of consolidation (C_h) is greater than the vertical coefficient of consolidation (C_v).

1. Introduction

Volcanic soils cover 1% of the Earth's surface yet support 10% of the world's population, including some of the highest human population densities. This is usually attributed to their high natural fertility [1]. However, this is true only in part. Such soils represent the surface areas of our planet that are being replenished with new minerals escaping from the interior of the Earth [2]. However, some deep magmatic processes do lead to an imbalance of elements in volcanic soil parent materials that can impact plants and animals' health growing in or on them. In contrast, all other soils express various stages of the degradation (weathering) of these minerals.

Volcanic soils cover more than 124 million hectares of the Earth's surface. The major areas of volcanic soils rim the Pacific, where oceanic plate subduction produces extensive

ISSN (*Online*) 2581-2157
ISSN (*Print*) 2502-9304

rhyolitic and andesitic volcanism [1]. Major areas of volcanic soils occur in Chile, Peru, Ecuador, Colombia, Central America, the United States, Kamchatka, Japan, the Philippines, Indonesia, New Zealand, and the independent island states of the southwest Pacific. Basaltic volcanism dominates in the islands of the Pacific, Indian and Atlantic oceans where the new lithosphere is being added to existing plates, such as in Iceland or where hot mantle plumes pierce through the lithosphere, as in Hawaii [3].

Anisotropy in soil results from the deposition process which describes the characteristics of the soil grains or is caused by stress or from the consequences of stresses caused during deposition and subsequent erosion [3]. All soils behave in general anisotropy, and some exhibit undrained shear strength. The latter phenomenon shows the result of anisotropy for changes in the effective shear strength parameter with the direction used in the shear stresses [2][4]. The undrained shear strength of soft soil anisotropy was given by Bjerrum, Ladd, et al., And Jamiolkowski et al. The anisotropy undrained shear strength in NC was greater at lower plasticity values [5][6].

The same undrained direct shear strength for vertical sample orientation, the specimen is shifted as with the horizontal test orientation, and the specimen is tested horizontally[7]. Research in London soil with samples taken at a tilt orientation of 30 ° from the horizontal direction [8]. The sample was then reconsolidated and tested with an unconfined compression test. It was found that the shear strength obtained was 28% smaller than the samples taken with a vertical orientation [9]. The continued research on London land with vertically and horizontally oriented samples. The results obtained from horizontal samples are 15 - 39% stronger [10].

This is consistent with the results of research where the ratio of horizontal stress to vertical stress is between 1.5 - 2.5 at a depth of 30 m on London soil [11]. A series of tests on San Francisco soil. The samples were tested under anisotropy and isotropy conditions in the undrained consolidation test with the TX-CU test, and the results showed that the samples in the anisotropy condition were 10% stronger than the samples in the isotropy condition [12].

A collected data from 42 soil sites tested by triaxial under anisotropy and isotropy conditions. The results obtained by normalized undrained shear strength with effective soil pressure in anisotropy conditions are between 75% - 100% compared to isotropy conditions [13], testing with the Cuboidal Shear Device. Kaolin and mixture with consolidated silt were used as samples. The anisotropy ratio (Suh / Suv) was obtained between 0.68 - 2.00 [14].

http://dx.doi.org/10.30737/ukarst.v3i2

Ukarst : Universitas Kadiri Riset Teknik Sipil.
Volume 5 Number 1, (2021).
ISSN (*Online*) 2581-0855
ISSN (*Print*) 2579-4620

Another series of tests with Direct Simple Shear on Boston Blue Clay. The results show that the anisotropy conditions of soil shear strength at various slope orientations have different values [15]. Anisotropy conditions can be found in many jobs in the field. Make a lot of research done to study it. An illustration of the presence of anisotropy in the shear strength of undrained soils in the field [11]. Taking the slope model in the Duncan field shows the anisotropy of the undrained soil shear strength along the possible slip circle. The shear strength value will change along with slip according to tilt orientation, and this study aims to know the anisotropy characteristics of Bogor Volcanic Soil.

2. Research Method

This study conducted 2 tests, namely the first field testing with original soil samples in the form of CPTu and dilatometer. The CPTu test's objective is to determine the vertical soil parameters, while the dilatometer is to determine the horizontal soil parameters. The second is laboratory testing with compacted soil samples through Index properties, Triaxial UU, and consolidation testing. Sampling test in sharing the orientation of the tilt angle of 0 ° and 90 ° [9]. From the triaxial test results, the strength parameters are c and phi, while for consolidation in the laboratory, the compression index (C_c) and the vertical direction coefficient of consolidation (C_v) were obtained.

2.1 Description and Technical

The compacting scheme in the field is shown in Figure 1.

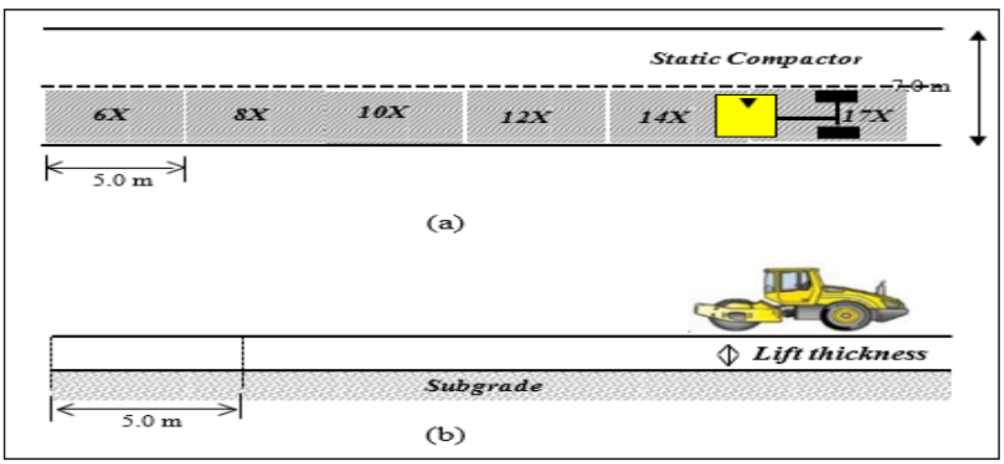

Figure 1. Field Compaction

From Figure 1a it can be seen that the top view of the compacting scheme in the field shows that the compaction technique is carried out on several blocks, each 5m long and the

http://dx.doi.org/10.30737/ukarst.v3i2

ISSN (*Online*) 2581-2157
ISSN (*Print*) 2502-9304

compaction is done using a static compactor machine on the lift thickness layer as shown in Figure 1b.

2.2 Sampling Technique

The soil to be tested is a type of volcanic soil taken from Lido Theme Park's tourist area - Bogor. Soil samples taken were undisturbed soil, including original soil samples 1 tube, field compacted soil samples 6 block samples with the type of compaction 6x, 8x, 10x, 12x, 14x, and 17x.

2.3 Data Analysis Technique

Tests were carried out on compacted soil by testing Fill Weight, Moisture Content, Specific Gravity, Atterberg Limits, Sieve and Hydrometric Analysis, Triaxial UU with 0 ° and 90 ° tilt orientation, and Consolidation Test with 0 ° and 90 ° slope orientation. The test was carried out at the Laboratory of Soil Mechanics, Department of Civil Engineering, Parahyangan Catholic University.

The tests carried out are below.

1. The Fill Weight is very useful in evaluating volcanic soil, namely the ratio between soil weight and volume in the field's original state.
2. The water content test is used to determine the moisture content of a soil sample, namely the ratio between the weight of water and the dry soil's weight.
3. The specific gravity test includes determining the soil's density using a pycnometer bottle, the soil being tested must pass sieve No. 40.
4. The Atterberg limit test is carried out to determine the soil sample's liquid limit, plastic limit, and plasticity index.
5. The sieve analysis test aims to determine the percentage of soil sample grain size used.
6. A hydrometer test is needed to obtain the percentage value of fine-grained soil in the sample.
7. Triaxial Test UU
8. A consolidation test is conducted to obtain pre-consolidation pressure, consolidation coefficient in the vertical and horizontal direction, and soil compression coefficient.

http://dx.doi.org/10.30737/ukarst.v3i2

Ukarst : Universitas Kadiri Riset Teknik Sipil.
Volume 5 Number 1, (2021).
ISSN (*Online*) 2581-0855
ISSN (*Print*) 2579-4620

2.4 Definition of Variable Operations

2.4.1 CPTu

The use of the Cone Penetration Test (CPT) in Indonesia is gaining popularity because of its ease of use and generally consistent test results. However, the mechanical ponder test cannot measure the resistance of the tip of the sondir in very soft soils [16]. The development of the electronic sondir test has also received great attention. With the addition of a pore water pressure sensor, this test can better predict soil parameters and provide continuous soil profiles as a field test tool. This electronic sondir test accompanied by measuring pore water pressure is then known as the CPTU or Piezocone Penetrometer Test.

Although the piezo-cone test was introduced in 1970 in Indonesia, this test was only known more generally in 1990 [17]. The piezo-cone test results' interpretation includes predictions of soil behavior type, undrained shear strength and drained shear strength, stress history, compressibility, soil permeability, and consolidation coefficient. On soft soils undergoing consolidation (under consolidating), the CPTU test can estimate the degree of consolidation and identify the soil layer that is currently consolidating [5].

2.4.2 Dilatometer

The pressure readings-A and B in the field must be corrected for membrane stiffness, the initial reading of the manometer, and the filler pins' elevation to determine the pressure P_0 and P_1 using the following formula below.

$$P_0 = 1.05\,(A - Z_M + \Delta A) - 0.05\,(B - Z_M - \Delta B)$$

$$P_1 = B - Z_M - \Delta B$$

Where :

ΔA, ΔB = correction value obtained from membrane calibration

ZM = initial reading of the manometer at atmospheric pressure

The corrected stresses, namely P0 and P1, are then used to become A and B values in interpreting. The correlation was obtained by calibrating the DMT results with good parameters. Most of these correlations form the basis of current interpretations [18]. Interpretation is developed by first determining three parameters of DMT, namely:

1. Material index, I_D
2. Horizontal stress index, K_D
3. Modulus of the dilatometer, E_D

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3. Results and Discussions

3.1 Result Laboratory Soil Compaction

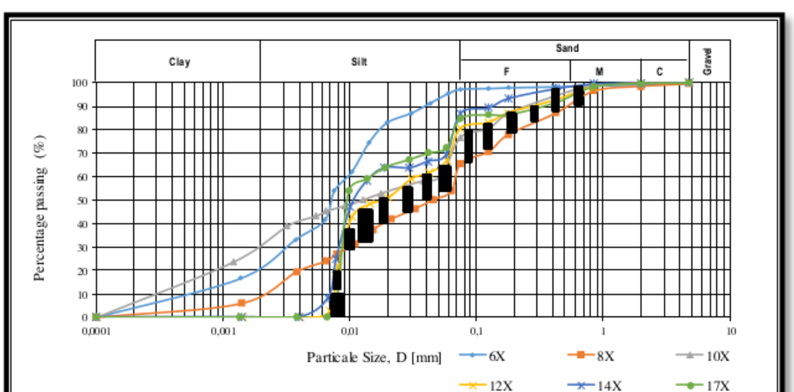
Soil samples from compaction testing in the field are tested in the laboratory with testing which includes index properties testing which includes Fill Weight, Moisture Content, Specific Gravity, Atterberg Limit, Sieve and Hydrometric Analysis and Engineering Properties which include Triaxial UU and Consolidation with a slope orientation of 0 ° and 90 °. In Figure 2 the results of the test.

Resume of Laboratory Testing Results								
Sample No.				6X	8X	10X	12X	14X
Depth				0.00 - 0.20 M	0.00 - 0.20 M	0.00 - 0.20 M	0.00 - 0.20 M	0.00 - 0.20 M
Indek Properties		symbol	unit					
1.	Fill Weight	γ	t/m^3	1,540	1,598	1,602	1,433	1,548
2.	Moisture Content	ω	%	48,02	52,45	50,56	48,05	46,73
3.	Specific Gravity	Gs	-	2,44	2,44	2,59	2,41	2,46
	Void Ratio	e	-	1,35	1,33	1,44	1,49	1,34
	Porosity	n	-	0,57	0,57	0,59	0,60	0,57
	Degree of saturation	Sr	%	86,99	96,32	91,23	77,73	86,21

Figure 2. Resume of Laboratory Test

3.1.1 Grain Size Analysis

The filter and hydrometer tests were carried out on 6x, 8x, 10x, 12x, 14x, and 17x ground samples. Based on the results of the grading test graphs shows that there are 2 groups of soil types. The first group is black shading with a relatively uniform gradient size with a grain size of 0.01 mm, namely the silt's dominant type. The second group odometer with a yellow shading color, namely the dominant type of clay.



http://dx.doi.org/10.30737/ukarst.v3i2

Ukarst : Universitas Kadiri Riset Teknik Sipil.
Volume 5 Number 1, (2021).
ISSN (*Online*) 2581-0855
ISSN (*Print*) 2579-4620

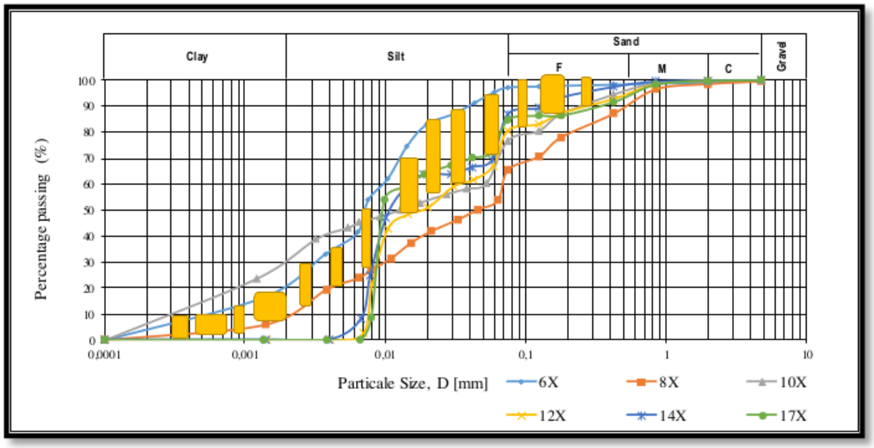


Figure 3. Grain Size Analysis

3.1.2 Atterberg Limit

Limits and plasticity indexes were carried out on 6x, 8x, 10x, 12x, 14x, and 17x ground samples (Table 1 Results of Atterberg limits test). In Figure 4, the Cassagrande Chart shows that the soil classification is in the ML and MH areas, which are Allophan soil types, according to Wesley in Figure 4. Figure 5 Number of Rolls - LL and IP show that more grinding will affect soil behavior. The number of rolls - LL and PL indicate that the more turns, the LL and IP values are higher [19][20].

Fine-grained soil characteristics depend on Atterberg boundaries and natural water content. Figure 4 and Figure 5 show the distribution of the cavity ratio, moisture content, Atterberg Limit, Liquidity Index, and Plasticity - depth index based on laboratory tests. As shown in the figure below, the distribution of water content is generally between the plastic limit and the liquid limit and the soil in its plastic state [21]. Meanwhile, the value of the void ratio varies between 1.7 – 1.2 in Table 1. These data were found to be consistent, with the ratio decreasing with soil depth.

Table 1. Results of Void Ratio

Index Properties	symbol	unit	Sample No.				
			6X	8X	10X	12X	14X
Void Ratio	e	-	1.35	1.33	1.44	1.49	1.34

Source : Laboratory Testing of the Department of Civil Engineering, Parahyangan Catholic University.

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Table 2. Results of Atterberg limits test

	Compaction (X)					
	6	**8**	**10**	**12**	**14**	**17**
Liquid Limit (LL or w_L) (%):	65	71	41	47	47	49
Plastic Limit (PL or w_P) (%):	56	53	30	34	35	37
Plasticity Index (PI) (%):	9	18	11	13	12	12

Source : Laboratory Testing of the Department of Civil Engineering, Parahyangan Catholic University.

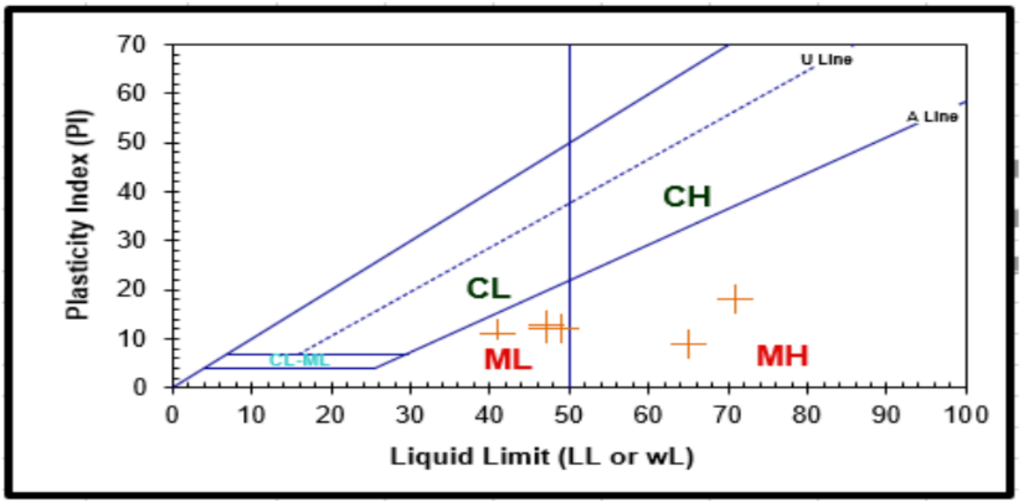

Figure 4. Casagrande Chart

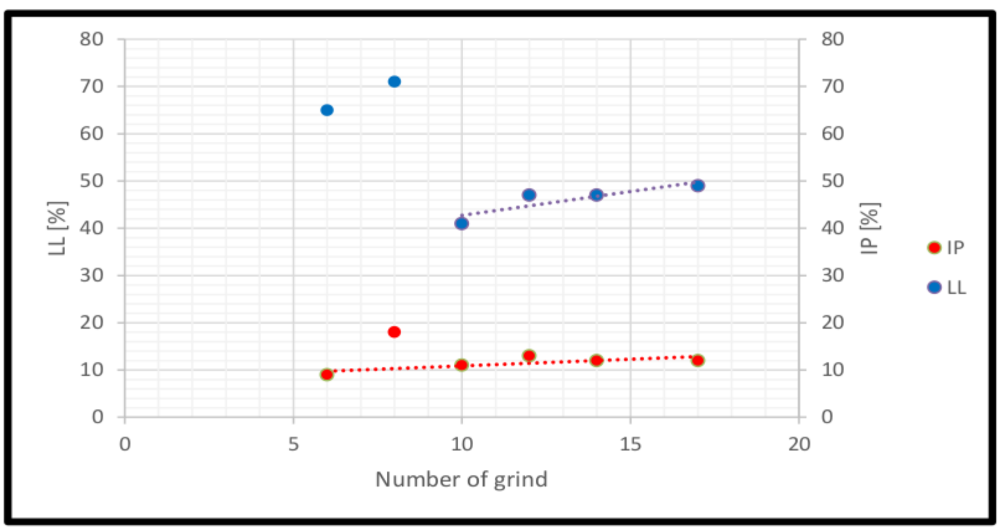

Figure 5. Compaction, LL, and IP

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Liquid Limit and Soil Plasticity Index were carried out on 6x, 8x, 10x, 12x, 14x, and 17x ground samples. The Casagrande chart shows that the soil classification is in the ML and MH areas, which are Allophan's soil types, according to Wesley, 2010. The number of mills - LL and IP indicates that the more crushed land will affect soil behavior. The number of grinds - LL and PL indicate that the more grinding, the LL and IP values are higher.

3.1.3 Triaxial Unconsolidated Undrained (UU)

Figure 6 shows that for volcanic soils the more grinding will affect the value of the inner shear angle to increase, while in cohesion (c), the more grinding on the soil will affect c which remains or decreases.

Table 3. Results of Triaxial Unconsolidated Undrained

Compaction	$C_{Horizontal}$	$C_{Vertical}$	Ø $_{Horizontal}$	Ø $_{Vertical}$
(X)	kg/cm^2	kg/cm^2	°	°
6	0.43	0.52	10.75	9.44
8	0.38	0.17	17.97	15.34
10	0.36	0.33	27.96	23.52
12	0.22	0.25	19.32	17.29
14	0.09	0.07	25.22	18.37
17	0.15	0.14	43.93	39.78

Source : Laboratory Testing of the Department of Civil Engineering, Parahyangan Catholic University.

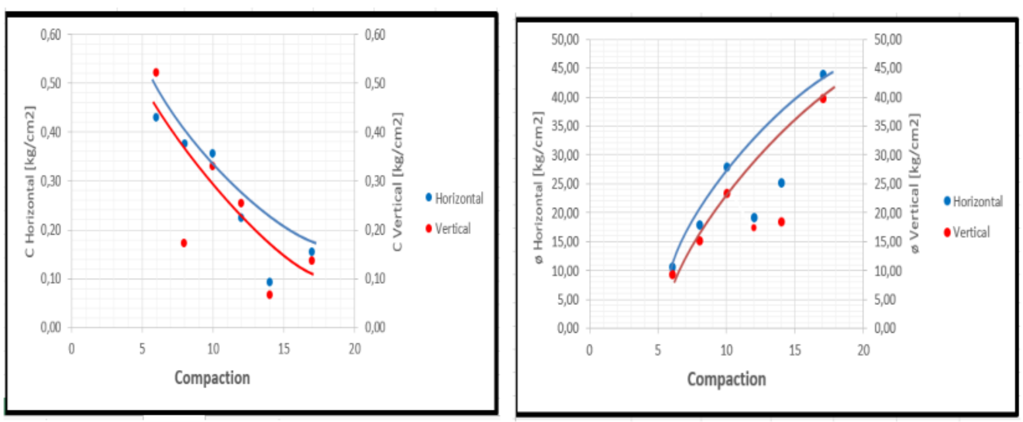

Figure 6. Compaction, Ø $_{Horizontal}$, and Ø $_{Vertical}$

http://dx.doi.org/10.30737/ukarst.v3i2

ISSN (*Online*) 2581-2157
Yusi Sulastri / Ukarst Vol. 5, No. 1 (2021)
ISSN (*Print*) 2502-9304

The graph shows that for volcanic soil, more rubbing will affect the value of the inner shear angle to increase, while in cohesion (c), more rubbing on the soil will affect c, which is constant or decreases.

Based on the calculations in Figure 6, it can be seen that this volcanic soil sample shows anisotropic properties.

$C_{Horizontal} = 1,3\ C_{Vertical}$

$\emptyset_{\ Horizontal} = \emptyset_{\ Vertical}$

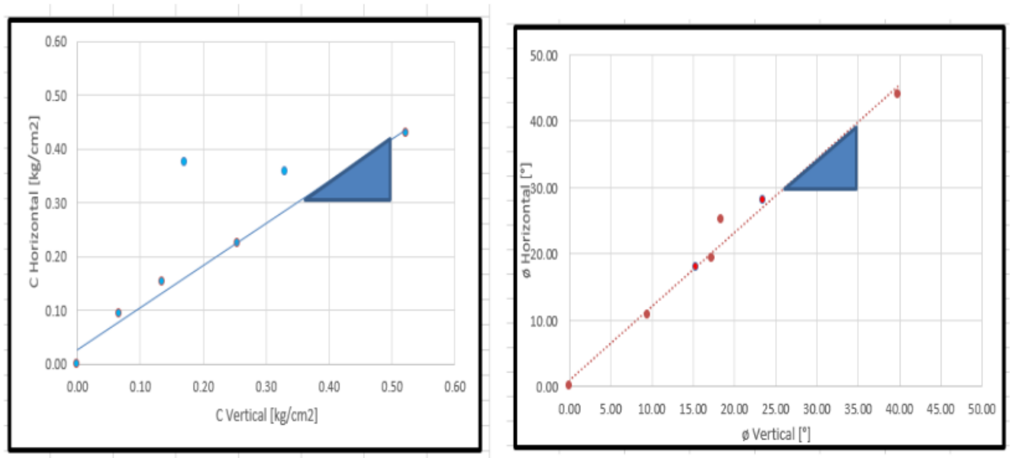

Figure 7. $C_{Horizontal}$ VS $C_{Vertical}$

Based on these calculations, it can be seen that this volcanic soil sample shows anisotropy properties.

3.1.4 Consolidation

Consolidation testing was carried out on 6x, 8x, 10x, 12x, 14x, and 17x ground samples by taking the test sample in the direction of the orientation of the tilt angle of 0 ° (Vertical) soaking and not immersing and 90° (Horizontal) soaking and not immersing. This sample of volcanic seeds' compressibility is getting more and more crushed, and the value of C_c and C_v decreases [22]. The horizontal coefficient of consolidation horizontal (C_h) is greater than the vertical (C_v). The following are the results of consolidation tests on soil samples in various grinds:

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Table 4. Results of Consolidation

COMPACTION	HORIZONTAL				VERTICAL			
	UNSATURATED		SATURATED		UNSATURATED		SATURATED	
	C_c	C_V	C_c	C_V	C_c	C_V	C_c	C_V
(X)	-	cm^2/s	-	cm^2/s	-	cm^2/s	-	cm^2/s
6	0.5209	0.0090	0.6257	0.0113	0,4454	0.0033	0.4958	0.0052
8	0.4619	0.0091	0.4849	0.0049	0,3298	0.0041	0.3783	0.0058
10	0.4620	0.0056	0.5149	0.0089	0,3154	0.0057	0.3458	0.0078
12	0.3352	0.0076	0.4667	0.0049	0,2353	0.0050	0.3484	0.0054
14	0.4359	0.0068	0.4584	0.0078	0,4319	0.0038	0.3901	0.0064
17	0.2559	0.0050	0.3130	0.0103	0,4232	0.0084	0.3899	0.0064

Source : Laboratory Testing of the Department of Civil Engineering, Parahyangan Catholic University.

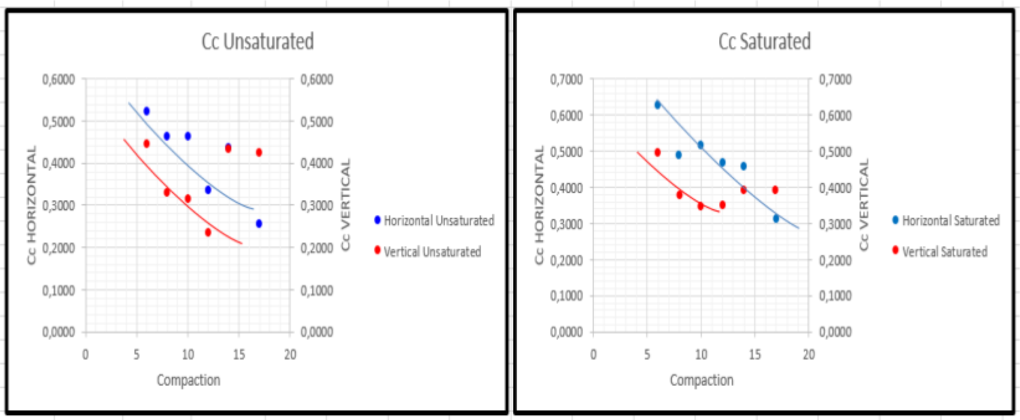

Figure 8. C_c Unsaturated and C_c Saturated

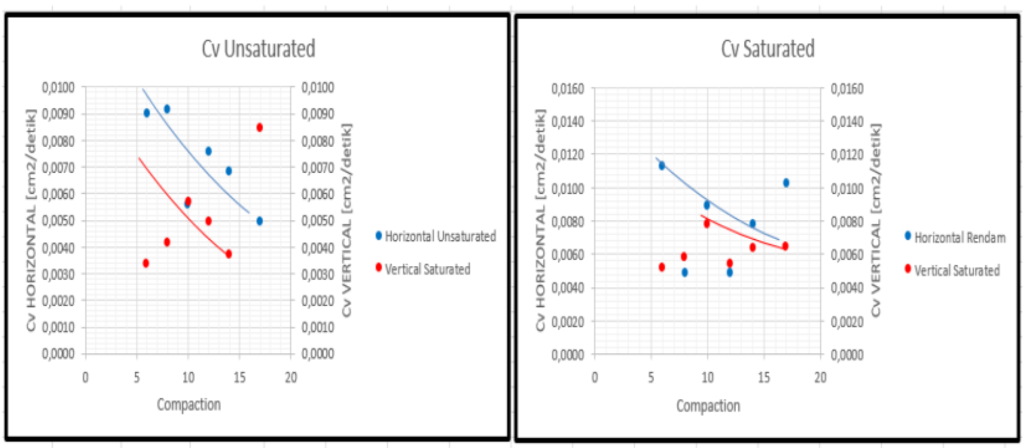

Figure 9. C_v Unsaturated and C_v Saturated

ISSN (*Online*) 2581-2157
ISSN (*Print*) 2502-9304

In Figure 8 and Figure 9, the compressibility of this volcanic soil sample, the more grinding it will give the Cc and Cv values decreasing. The horizontal Cc value is greater than the vertical Cc value, as well as the horizontal Cc value is greater than the vertical Cv value.

3.2 Result CPTu and Dilatometer

Based on Figure 10, the CPTu test shows a modulus value of 515.56 kg /cm^2. Meanwhile, the dilatometer test results obtained a modulus value of 672.23 kg /cm^2. So that the modulus value in the horizontal direction is greater than the vertical direction and is based on Figure 10. Based on the CPTu test, the Cu value was 0.59 kg /cm^2. Meanwhile, from the dilatometer test results, the Cu value was 0.72 kg /cm^2 so that the horizontal direction of C_u value is greater than the vertical direction.

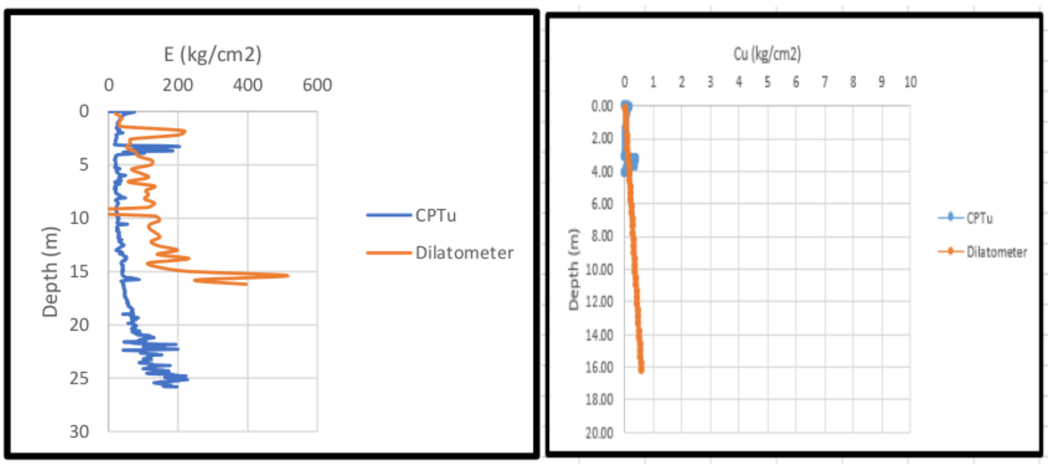

Figure 10. Depth V_x E and Depth V_s Cu

http://dx.doi.org/10.30737/ukarst.v3i2

Ukarst : Universitas Kadiri Riset Teknik Sipil. ISSN (*Online*) 2581-0855
Volume 5 Number 1, (2021). ISSN (*Print*) 2579-4620

4. Conclusion and Suggestion

4.1 Conclusion

From this study, it can be concluded that; (1) the volcanic soils in the Theme Park Lido Bogor area are silty clay deposits, anisotropy testing is carried out in the field and the laboratory; (2) the CPTu test shows a modulus value was 515.56 kg /cm^2, from the dilatometer test results, the modulus value was 672.23 kg /cm^2; (3) the C_u value was 0.59 kg /cm^2, the C_u value was 0.72 kg /cm^2; (4) the horizontal shear strength (S_{uh}) is greater than the vertical slope shear strength (S_{uv}). In this case, the ratio obtained for shear strength is S_{uh} = 1.3 S_{uv}, the horizontal coefficient of consolidation ($C_{horizontal}$) greater than the consolidation vertical ($C_{vertical}$).

4.2 Suggestion

Further research is needed using different slope orientations to obtain the shear strength of undrained soils in various slope orientations. It is necessary to carry out further studies regarding the ratio of undrained shear strength in vertical and horizontal orientation (S_{uv} / S_{uh}) for volcanic soil.

http://dx.doi.org/10.30737/ukarst.v3i2

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ISSN (*Print*) 2502-9304

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