Laboratory Study on Shear Strength of Soil using Woven and Non-woven Geotextiles

Yelvi[1], Aisyah Salimah[1], Vatih Abdullah[1]
[1]*Civil Engineering, Politeknik Negeri Jakarta, Depok 16424, Indonesia*

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Abstract: In constructing a construction, it is necessary to identify the type of soil as a place for the foundation and the building to rest on it. The carrying capacity of the soil also varies, in sand that has a uniform gradation when it is saturated, the shear strength will decrease. One way that can be done to increase the shear strength of the soil is to provide reinforcement with the addition of geotextiles. The shear strength parameters used in the planning of the bearing capacity of the soil reinforced by geotextiles are the internal friction angle and the interaction coefficient between the geotextile and the sand. The sample of this study used liquefaction potential sand Bangka using woven and non-woven geotextile reinforcement with a relative density variation of 25%, 50%, 75%. For use geotextiles are installed vertically and horizontally. To get the parameter value of shear strength, Direct Shear testing is carried out. Based on the test results, it is found that Bangka sand is uniform sand with values of Cu <6 and Cc <1. The increase in shear strength in the samples reinforced by geotextile vertically is greater than horizontally at a density of 25% and 50%, while at a density of 75% it states otherwise.

1 INTRODUCTION

Geotextiles have been widely applied in civil engineering projects with various functions. One of its functions is for reinforcement. Some examples of soil reinforcement with geotextiles are soil embankments, slopes, and retaining walls. Soil reinforcement with geotextiles requires knowledge of the soil-geotextile interface behavior for structural stability analysis (Day, 2000). In order to analyze the interface shear strength parameters, several studies have been conducted to understand the shear strength behavior of geotextile-reinforced sand soils. An significant factor in the design of geotextile structures is the interface shear strength. (Omar AH et al. 2019; Punetha et al. 2017; Wang et al. 2016; Brahim et al. 2016; Aldeeky et al. 2016; Hatami and Esmaili 2015; Vieira et al. 2015; Anubhav and Wu. 2015; Dixon and Jones 2005; Bergado et al. 2006). The results generally reveal that the addition of fibers to sandy soils as reinforcement can increase the shear strength compared to unreinforced sand. To improve performance in different soil conditions, strengthening the soil is increasingly important. The reinforcement mechanism is to withstand the soil's tensile deformation, thus increasing the overall resistance of the composite soil matrix through the interface bond resistance limited by the tensile strength of the geotextile. Jewell (1996) has examined the interaction between reinforced soil and geotextiles. There are two conditions in soil interaction with reinforcement, namely direct shear and pull-out conditions. The results showed that the direct shear resistance is the ratio of the interface friction angle to the friction angle in the soil. The mobilization of the interface friction angle is one of the important factors affecting the stability analysis. Some researchers use the Direct Shear Test to understand the shear strength of reinforced soil behavior. The choice of direct shear test installation depends on the interaction mechanism to be reproduced. The reinforcement layer located parallel to the shear plane of the shear box offers laboratory test results in many literature studies. (Palmeira EM, 2008; Takasumi et al. 1991; Tan SA et al. 1998; Cerato AB and Lutenegger AJ 2006; Abu-Farsakh MY et al. 2007; Liu CN et al. 2009; Lopes ML, Silvano R 2010; Hossain B et al. 2012; Anubhav Basudhar PK 2013; Rifa'i, A., 2003; Tuna SC, Altun S 2012; Vieira CS, Lopes ML 2013; Kim D, Ha S 2014; Vangla P, Latha GM 2015; Choudhary AQ, and Krishna AM 2016. Other studies place the

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reinforcement layer perpendicular to the shear plane Jewell RA, Wroth CP 1987; Athanasopoulos GA 1993; Bauer GE, Zhao Y 1994; Palmeira EM 1999; Moayedi H et al. 2010; Saya˜o ASFJ, Sieira ACCF 2012; Jose D et al. 2016. The reinforcement layer was positioned perpendicular to the shear plane in that study to characterize the behavior of the composite materials when the soil and reinforcement are shifted. Based on previous research which has given some evidence that the effect of geotextiles as reinforcement on the soil can increase the interface shear strength. However, not much research has been done on the effect of geotextile placement on sandy soil on the interface shear strength. Therefore, it is necessary to do more research on the effect of geotextile position on the soil on the interface shear strength. So it is hoped that the results of this study can add to the literature that can be used as a reference in geotextile reinforcement analysis to obtain the right design.

2 THEORY

Soil shears the resistance force exerted by soil grains against pressure or pull (Hardiyatmo, 2002). Based on this understanding, when the soil is exposed to freight, it will be held back by soil cohesion which depends on the type of soil and its density, but does not depend on the normal stresses acting on the shear plane and the friction between the grains of soil whose magnitude is directly proportional to the normal stress in the shear plane. Then the shear strength equation can be formulated as follows.

$$\tau = c + \sigma \tan \delta \tag{2.1}$$

(*Note: c = 0 for sand and σ = σ '*)

For the shear strength which is strengthened by Geotextile, the determining parameters are the Mobilization of the Angle of Friction of the *interface* Sand-Geotextile (δ) and Adhesion (c_{sg}).

$$\tau = c_{sg} + \sigma_n \tan \delta \tag{2.2}$$

Determination of shear strength can be carried out Direct shear test utilizing controlled shear stress, where the addition of shear forces is made constant and regulated, or utilizing controlled stress in which the shear stress is applied by adding dead load sustainably, and with the same addition big every time, until it collapses.

3 METHOD

3.1 Soil

The soil sample used in the study was a disturbed sample by selecting Bangka sand which has a uniform gradation. On the soil, the grain size analysis test is conducted first to determine whether the soil is included in the soil criteria that have the liquefaction potential.

3.2 Geotextiles

Material as the interface consists of woven and non-woven types. Woven type is GT 200 (GTX-N-2 High strength polyester) and non-woven type GT 250 PET. The characteristic of woven geotextile is a woven sheet with a polyester base material which has a uniform tensile strength. This type weights 200 gr / m2. The tensile strength value for the long direction is 4.15 kN / m and the transverse direction is 6.38 kN / m. Non-woven geotextile is a non-woven sheet that functions as separation, filtration, protection, and drainage. This type weights 250 gr / m2. The tensile strength value for the long direction is 8.87 kN / m and the transverse direction is 11.76 kN / m. The tensile strength test of the two types of geotextiles refers to the technical standard test ASTM D4595. Geotextile used is woven and non-woven can be seen in Figure 1.

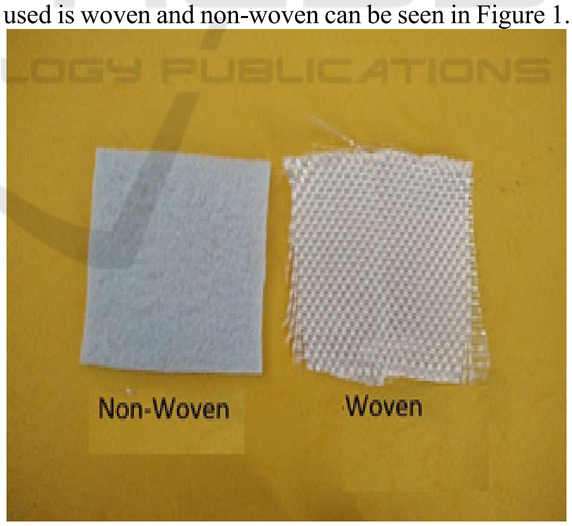

Figure 1 Woven and Non-Woven Geotextiles

3.3 Sample Preparation and Testing Phase

3.3.1 Sample Preparation

The dry weight of sand is prepared for the relative density of 25%, 50%, and 75%, respectively. For sand soil without geotextile reinforcement, the sand soil is directly put into the shear box. Then it is saturated and ready for the shear test. As for sand soil with geotextile, a sand-geotextile soil sample is prepared according to the position of the geotextile placement in the shear box. If the position is parallel to the sliding direction, then testing is carried out every one layer, two layers, and three layers. Meanwhile, if the direction is perpendicular to the sliding direction, only one layer is sufficient for each woven and non-woven. After the sand-geotextile soil has been put into the shear box, it is saturated and ready for the shear test, then it is put into the shear box.

3.3.2 Testing Procedure

The test is divided into two stages. The first is testing to obtain the physical properties of the soil according to the provisions of the 1989 Annual Book of ASTM Standards and followed by testing the shear strength under static loads with the direct shear test. As many as 15 samples were made, namely sand without using geotextiles, sand using Woven and Non-Woven geotextiles which were installed horizontally and vertically. Each treatment had a different density, namely 25%, 50%, and 75%.

4 ANALYSIS AND DISCUSSION

The result of the Analysis of shieve, it shows that the sandy soil of Bangka the entry into an area that is potentially liquefied and can be seen in Figure 4.1

The USCS classification system is used to see the uniformity coefficient and curvature of grading. From the graph, it can be seen that the values of

$D_{60} = 0.4$, $D_{10} = 0.15$, $D_{30} = 0.21$

$$Cu = \frac{D_{60}}{D_{10}} = \frac{0.4}{0.15} = 2.666$$

$$Cc = \frac{D_{30}^2}{D_{60} \times D_{10}} = \frac{0.21^2}{0.4 \times 0.15} = 0.735$$

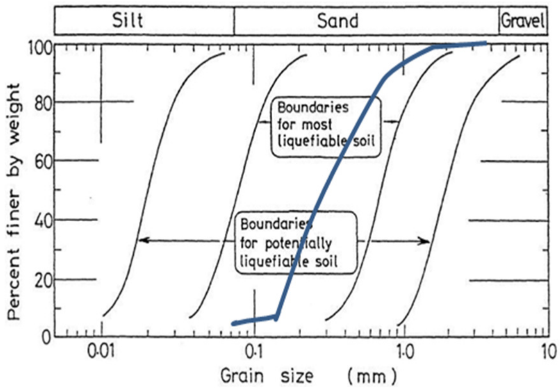

Figure 2 Grading boundary curve between soils that have the potential for liquefaction (Tsuchida, 1970)

Well graded sand if Cu > 6 and 1 < Cc < 3, both criteria must be fulfilled, otherwise it is classified as poorly graded. From the Cu and Cc values obtained, Bangka sand is considered to be poorly graded with uniform gradations. The following is a summary of the Bangka sand soil property index which is presented in Table 1.

Table 1 Soil Property Index Soil

Properties	Value
γd max	18.92 kN/m^3
γd min	14.69 kN/m^3
Gs	2.644
e_{max}	0.799
e_{min}	0.397
D50	0.32 mm
D10	0.15 mm
D60	0.4 mm
D30	0.21 mm
Cu	2.666
Cc	0.735

Table 2 Results of the interaction coefficient between sand and geotextile (c_{sg})

Sample Treatment	Relative Density (Dr%)		
	25%	50%	75%
	c_{sg}	c_{sg}	c_{sg}
Woven Vertical	0.035	0.021	0.02
Horizontal Woven	0.032	0.021	0.01
Vertical Non-Woven	0.059	0.058	0.053
Horizontal Non-Woven	0.008	0.005	0.004

Table 3 Results Comparison of shear angle values after and before (δ and ∅) use of geotextiles

Sample Treatment	Relative Density (Dr %)		
	25%	50%	75%
	δ/φ	δ/φ	δ/φ
Without Geotextile	1	1	1
Vertical Woven	1.23	1.24	1.29
Horizontal Woven	1.29	1.28	1.24
Vertical Non-Woven	1.21	1.27	1.3
Horizontal Non-Woven	1.49	1.44	1.37

Based on the results of the shear test, the shear strength parameter is obtained, so that the equation used to obtain the shear strength value ($\tau f = \sigma \tan \varphi$) pure sand and $\tau = c_{sg} + \sigma \tan \delta$) for sand reinforced geotextile with the assumption of normal stress of 1 unit. Table 4 shows the results of the calculation of shear strength.

Table 4 The sand shear strength with the assumption of normal load 1 unit

Sample Treatment	25%	50%	75%
	τ (kg / cm^2)	τ (kg / cm^2)	τ (kg / cm^2)
Without geotextile	0669	0615	0589
Woven vertical	0.681	0712	0.819
Woven horizontal	0717	0743	0767
Non-woven vertical	0696	0770	0861
Non-woven horizontal	0846	0851	0877

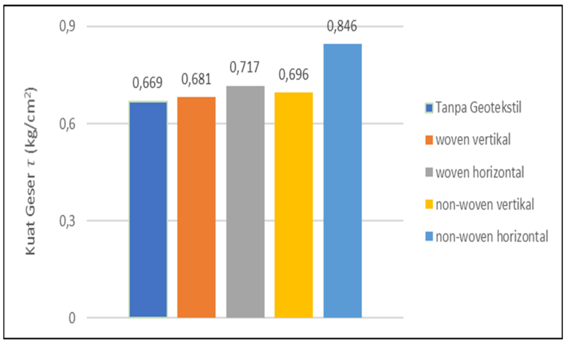

Figure 3 Graph relationship shear strength (kg / cm^2) with sample tests on the density of 25%

Shear strength sand after the addition of geotextile on the density of a 25% increase, with strong maximum shear on samples of sand by geotextile non-woven horizontally by 0.846 kg/cm^2 and a minimum in samples of sand by woven geotextile vertically by 0.681 kg/cm^2.

The increase in the pure shear strength with vertical woven geotextile reinforced sand was 1.8%, and the pure sand with horizontal woven geotextile reinforced sand was 7.2%. Pure sand with sand reinforced with non-woven geotextiles vertically by 4.1% and pure sand with sand reinforced by horizontal non-woven geotextiles by 26%. The horizontal use of geotextiles indicates a greater increase than the use of vertical geotextiles based on data on the increase in sand shear intensity at a density of 25%.

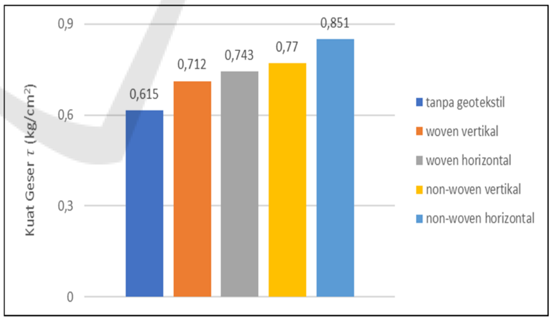

Figure 4 Graph of the relationship of shear strength (kg / cm^2) with the Test Sample at a density of 50%.

The shear strength of sand after the addition of geotextiles at a density of 50% has increased, with the maximum shear strength in sand samples given horizontal non-woven geotextiles of 0.851 kg /cm^2 and minimum sample was woven geotextile sand by vertically by 0.712 kg / cm^2.

The increase in pure shear strength with vertical woven geotextile reinforced sand was 15.7%, pure sand with horizontal woven geotextile reinforced sand was 20.8%. pure sand with vertical sand reinforced by non-woven geotextiles by 25.2% and pure sand with horizontal non-woven geotextile reinforced sand by 38.3%. Based on the data on the increase in the shear strength of sand at a density of 50%, the horizontal use of geotextiles shows a greater increase than the use of vertical geotextiles.

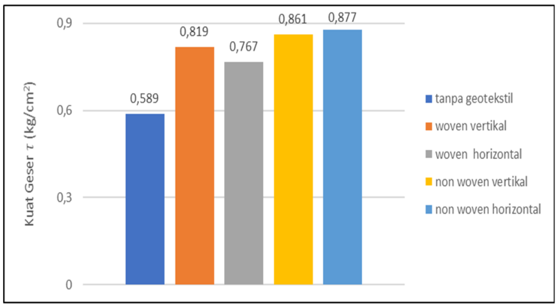

Figure 5 Graph of the relationship of shear strength (kg / cm^2) with the Test Sample at a density of 75%

The Shear strength of sand after the addition of geotextiles at a density of 75% has increased, with the maximum shear strength in sand samples given horizontal non-woven geotextiles of 0.877 kg/cm^2 and minimum sample by woven geotextile sand horizontally by 0.767 kg / cm^2.

The increase in pure shear strength with vertical woven geotextile reinforced sand was 39%, and the pure sand with horizontal woven geotextile reinforced sand was 30.2%. Pure sand with vertical sand reinforced by non-woven geotextiles amounting to 46.2% and pure sand with horizontal non-woven geotextile reinforced sand by 48.9%. Based on the data on the increase in the shear strength of sand at a density of 75%, the average increase in the use of geotextiles vertically shows a greater increase than the use of horizontal geotextiles, namely 42.6% versus 39.6%.

5 CONCLUSION

Based on the actual results of this research, it can be inferred as follows:

1. Shear strength of pure sand or without geotextile reinforcement decreases with each increase in the average relative density of 6.15%
2. Vertical has an increase with each addition of relative density by an average of 9.75%.
3. The shear strength of sand that is reinforced with woven geotextiles installed horizontally has an increase with each addition of an average relative density of 3.4%.
4. The shear strength of sand that is reinforced with non-woven geotextiles installed vertically has an increase with each addition of an average relative density of 11%.
5. The shear strength of sand that is reinforced with non-woven geotextiles installed horizontally increases with each addition of an average relative density of 1.8%.
6. The increase in shear strength in geotextile reinforced samples vertically is greater than horizontally at a density of 25% and 50%, whereas at a density of 75% states the opposite.

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