Interaction studies between geotextile and fill material

Kurnia Syawaludin, Andryan Suhendra, J L Lie, I G Mahardika
Civil Engineering Department, Faculty of Engineering, Bina Nusantara University
Jakarta, Indonesia 11480

Corresponding author: asuhendra@binus.ac.id

Abstract. As the growth in geotechnical science, there are a lot of new innovations that are used for solving geotechnical problems. One of those innovations is geotextile. This geotextile is often used in earth fill as reinforcement with function to increase the shear strength of existing fill and related with the interaction between geotextile and fill material. Based on this fact, this research is conducted to know the interaction of soil type to geotextile. The result of the research shows that all of the tested soil shear strength parameter comparison are below 1 (0.23; 0.29; 0.24 for C of clay comparison), (0.65; 0.77; 0.98 for $\phi$ of clay comparison), (0.53; 0.66; 0.67 for $\phi$ of sand comparison), and (0.53; 0.66; 0.67 for $\phi$ of coarse aggregate comparison). So it could be concluded that the shear strength of fill material and geotextile material is lower than the shear strength of fill material without geotextile.

Keywords: geotextile, shear strength, interaction

1. Background
As the growth of geotechnical science, there are a lot of innovations made to improve material so it could give optimal strength, one of them being in earth fill project. Nowadays, earth fill project uses geosynthetic material, one of them is geotextile. The use of geosynthetic materials is very common and very effective as one of the solution in earth fill structure.

Geotextile is one of geosynthetic material that is made of polymer and shaped as cloth or carpet. Geotextile has varying use, such as filter, separator, and reinforcement. This research discusses interaction between geotextile with fill material. Parameter measured in this research is the friction between geotextile and soil, which is stated in shear strength. The shear strength parameter is gotten from direct shear strength with three fill materials that will be used, i.e. clay, sand, and gravel.

2. Problem Statement
This study is conducted to determine the friction between geotextile and several types of soil i.e. clay, sand, and gravel. There are 3 types of geotextiles used in this research, i.e. woven geotextile, nonwoven geotextile, and composite geotextile. The research is conducted by using direct shear test between the geotextile material and three types of soil to get the behaviour shear strength between geotextile and soil. The result of this research is expected to be a good reference in usage or analysis of geotextile material on earth fill.
3. Research Methods
The steps of this research start by preparing all the materials needed. The prepared materials are clay, sand, and gravel that passing ¾” and 3/8” sieve, and retained on no. 4 sieve. These 3 materials are used because they are the commonly used material in earth fill project, such as earth fill in highway project, railways, runways, and other earth fill projects. The testing conducted is direct shear test. According to ASTM D-3080-04, the testing sample needs to represent the site condition. The testing conducted is direct shear test between geotextile and clay, sand or gravel. Another direct shear test is also conducted between the materials themselves without geotextile.

Each testing is conducted with 20 test samples, for direct shear test between clay and woven geotextile, sand and geotextile, coarse aggregate and woven geotextile, each 20 samples. The same thing is also conducted with direct shear strength test between fill material and nonwoven geotextile, and test between fill material and composite geotextile. Also with direct shear strength test between clay without geotextile, sand without geotextile, and gravel without geotextile, each 20 samples, so the total sample used in this research is 240 samples. The flowchart diagram of the research is as shown in Figure 1 below.

![Research Flow Chart](image)

**Figure 1.** Research Flow Chart

The research steps start from problem statement based on the determined topic. Then, the material and tools start to be prepared, then prepare the direct shear test tool. After all tools and materials prepared, then the testing is conducted based on the determined procedure. There are two types of testing, which are direct shear strength between geotextile and soil, and direct shear strength of soil without geotextile. There are 3 fill material used in this research, which are clay, sand, and gravel. The result of all testing will be compared between the shear strength of soil and geotextile, and soil without geotextile. From these test results, it is expected the behaviour of friction between soil and geotextile.
is then be concluded. The geotextile specifications and types that will be used in this research are shown in Tables 1-3.

| Table 1. Specification of Woven Slit Film Geotextile |
|-----------------------------------------------|
| **Properties** | **Test Method** | **Units** |
|----------------|----------------|----------|
| Raw Material   | -              | Polypropylene |
| Colour         | -              | Black    |
| **PHYSICAL**   |                |          |
| Wide width tensile strength | ASTM D 4595 | kN/m | 33 |
| - Machine Direction |             |         |
| - Cross Machine Direction |           |         |
| Wide width tensile elongation | ASTM D 4595 | % | 11 |
| - Machine Direction |             |         |
| - Cross Machine Direction |           |         |
| Trapezoid Tearing Strength | ASTM D 4533 | N | 760 |
| - Machine Direction |             |         |
| - Cross Machine Direction |           |         |
| Mullen Burst    | ASTM D 3786 | kN/m² | 4990 |
| CBR Puncture Strength | ASTM D 6421 | N | 5180 |
| Index Puncture Resistance | ASTM D 4833 | N | 700 |
| **MECHANICAL**  |                |          |
| **HYDRAULIC**  |                |          |
| Apparent Opening Size | ASTM D 4751 | mm | 0.28 |
| Permeability    | ASTM D 4491 | cm/sec | 0.03 |
| Permittivity    | ASTM D 4491 | Sec⁻¹ | 0.42 |
| Flow rate       | ASTM D 4491 | l/m²/min | 1050 |

| Table 2. Specification of Composite Geotextile |
|-----------------------------------------------|
| **Properties** | **Unit** |
| Characteristic short term tensile strength (MD) | kN/m | 50 |
| Characteristic short term tensile strength (CD) | kN/m | 14 |
| Strain at short term strength | % | 10 |
| Partial factor-creep rupture at 120 years design life | - | 1.55 |
| Creep limited strength at 120 years design life | kN/m | 32.3 |
| Partial factor construction damage in clay, silt or sand | - | 1.02 |
| Partial factor-environmental effects soil environment pH<11 at 120 years design life | - | 1.10 |
4. Testing Method
To identify the other soil parameter, several tests will be carried out i.e. Atterberg Limit tests to determine the Liquid Limit, Plastic Limit of the soil, Sieving Test to determine the gradation of soil particles.

4.1. Sieving Test
This testing is conducted to calculate the comparison between fine and coarse aggregate to be mixed and have the desired gradation in analytical and sieve way. Apart from that, this test also provides a picture of fine aggregate gradation.

4.2. Atterberg Limit Test (Plastic Limit and Liquid Limit)
The test is conducted for clay to find the soil type, which is Liquid Limit, and Plasticity Limit.

4.3. Direct Shear Test
The test conducted in this research is direct shear test with direct shear tool. The test goal is to find the shear strength between the geotextile material and soil, and soil without geotextile. All the data obtained from the test are compared and then a conclusion of the shear strength behaviour could be obtained.
Shear strength can be measured directly by giving a constant vertical load to the sample and giving particular shear strength constantly and slowly to keep the pore pressure zero until maximum shear strength obtained. Normal stress could be obtained from a division of normal force with the shear plane surface; this concept is explained with the following formula:

\[
\sigma_n = \frac{P}{A}
\]

Where:
- \(\sigma_n\) = Normal Stress \((\text{kg/cm}^2)\)
- \(P\) = Normal Load \((\text{Kg})\)
- \(A\) = Shear Plane Surface Area\((\text{Cm}^2)\)

When the testing is conducted, the shear stress value is obtained by calculating the shear strength that is obtained from the maximum load ring dial reading after being multiplied with the proving ring calibration value (LRC), then the shear force is divided by the area of shear box.

\[
\tau = \frac{G \times \text{Proving Ring Calibration}}{A}
\]

Where:
- \(\tau\) = Shear stress \((\text{Kg/cm}^2)\)
- \(G\) = Shear force obtained from the maximum load ring dial reading
- \(A\) = Shear box area
- Proving ring calibration = 0.464 kg/div

5. Test and Analysis Result
Before the direct shear test conducted, several other tests are conducted to determine the soil characteristic that become the research sample. The test results are shown in Tables 4-8.

| Sieve no. | Diameter (mm) | Retained weight (gr) | Retained weight (gr) | Retained percentage (%) | Passing percentage (%) |
|----------|----------------|----------------------|----------------------|-------------------------|------------------------|
| 4        | 4.8            | 0                    | 0                    | 0                       | 100                    |
| 8        | 2.4            | 30.4                 | 30.4                 | 3.04                    | 96.96                  |
| 16       | 1.2            | 73.4                 | 103.8                | 10.38                   | 89.62                  |
| 30       | 0.6            | 142.6                | 246.4                | 24.64                   | 75.36                  |
| 50       | 0.3            | 351.8                | 598.2                | 59.82                   | 40.18                  |
| 100      | 0.15           | 375.4                | 973.6                | 97.36                   | 2.64                   |
| 200      | 0.75           | 26                   | 999.6                | 99.96                   | 0.04                   |
| pan      | 0.4            | 1000                 | 100                  | 100                     | 0                      |

1000
### Table 5. Sieving Test Result of Clay

| Sieve no. | Diameter (mm) | Retained weight (gr) | Retained weight (%) | Passing percentage (%) |
|-----------|---------------|----------------------|---------------------|------------------------|
| 4         | 4.75          | 0                    | 0                   | 100                    |
| 10        | 2             | 47                   | 47                  | 4.7                    | 95.3 |
| 16        | 1.1           | 109                  | 156                 | 15.6                   | 84.4 |
| 40        | 0.420         | 107                  | 263                 | 26.3                   | 73.7 |
| 100       | 0.149         | 116.3                | 379.3               | 37.93                  | 62.07|
| 200       | 0.074         | 100.6                | 479.9               | 47.99                  | 52.01|
| Pan       |               | 520.1                | 1000                |                        |      |

### Table 6. Sieving Test Result of Gravel

| Sieve no. | Diameter (mm) | Retained weight (gr) | Retained weight (%) | Passing percentage (%) |
|-----------|---------------|----------------------|---------------------|------------------------|
| 3/4       | 19.1          | 142.4                | 142.4               | 14.24                  | 85.76 |
| 3/8       | 9.52          | 660.4                | 802.8               | 80.28                  | 19.72 |
| 4         | 4.76          | 147.8                | 950.6               | 95.06                  | 4.94  |
| 8         | 2.4           | 38.8                 | 989.4               | 98.94                  | 1.06  |
| 16        | 1.1           | 2.8                  | 992.2               | 99.22                  | 0.78  |
| 30        | 0.6           | 0.4                  | 992.6               | 99.26                  | 0.74  |
| 50        | 0.3           | 1.0                  | 993.6               | 99.36                  | 0.64  |
| 100       | 0.15          | 2.6                  | 996.2               | 99.62                  | 0.38  |
| Pan       |               | 3.8                  | 1000                | 100                    | 0     |

### Table 7. Liquid Limit Test Result of Clay

| Can no.       | 1  | 2  | 3  | 4  | 5  |
|---------------|----|----|----|----|----|
| Number of blows | 28 | 31 | 32 | 33 | 34 |
| Wet soil weight + can | 60.8 | 54.3 | 58.2 | 57.5 | 58.5 |
| Dry soil weight + can | 39.8 | 38.4 | 41.5 | 41.8 | 43.1 |
| Can weight | 9  | 9  | 9  | 9  | 9  |
| Dry soil weight | 30.8 | 29.4 | 32.5 | 32.8 | 34.1 |
| Water weight | 21 | 15.9 | 16.7 | 15.7 | 15.4 |
| Water content | 68.182 | 54.082 | 51.385 | 47.866 | 45.161 |

### Table 8 PL (Plastic Limit) Test Result

| Test Result          | Value | Value |
|----------------------|-------|-------|
| Wet soil weight + can (gr) | 20.6  |       |
| Dry soil weight + can (gr) | 17.8  |       |
| Can weight (gr) | 9     |       |
| Dry soil weight (gr) | 8.8   |       |
| Water weight (gr) | 2.8   |       |
| Water content (%) | 31.82 |       |
Based on Table 7 and Table 8, the value of Liquid Limit (LL) and Plasticity Index (PI) values are 78.78% and 46.96%.
Based on USCS, the soil is classified as clay with high plasticity. Figure 2 shows the gradations of Gravel, Sand and Clay.

![Figure 2. Gradation Curves of Gravel, Sand, and Clay](image)

After all preliminary tests done, process is continued with direct shear test for all types of soil, and also in conditions of without geotextile, woven geotextile, nonwoven geotextile, and composite geotextile. The direct shear test result then plotted as shown in following Figures 3-14.

![Figure 3. Shear Strength Test Clay without Geotextile](image)

![Figure 4. Shear Strength Test Result Clay with Woven Geotextile](image)

![Figure 5. Shear Strength Test Result Clay with Nonwoven Geotextile](image)

![Figure 6. Shear Strength Test Result Clay with Composite Geotextile](image)
Figure 7. Shear Strength Test Result Sand without Geotextile

Figure 8. Shear Strength Test Result Sand with Woven Geotextile

Figure 9. Shear Strength Test Result Sand with Nonwoven Geotextile

Figure 10. Shear Strength Test Result Sand with Composite Geotextile

Figure 11. Shear Strength Test Result Gravel without Geotextile

Figure 12. Shear Strength Test Result Gravel with Woven Geotextile
Based on the average result value from each type of testing, the value of $c$ and $\varphi$ for all tests can be summarised in Table 9 and 10 below.

### Table 9. Cohesion ($c$) Result for All Tests

| Material   | Natural $c$ (kPa) | Woven $c$ (kPa) | Nonwoven $c$ (kPa) | Composite $c$ (kPa) |
|------------|------------------|-----------------|---------------------|---------------------|
| Clay       | 24.48            | 5.66            | 7.03                | 5.89                |
| Sand       | 0                | 0               | 0                   | 0                   |
| Gravel     | 0                | 0               | 0                   | 0                   |

### Table 10. Average Friction Angle Value ($\varphi$) for All Tests

| Material   | Natural $\varphi$ (°) | Woven $\varphi$ (°) | Nonwoven $\varphi$ (°) | Composite $\varphi$ (°) |
|------------|----------------------|---------------------|------------------------|-------------------------|
| Clay       | 22.3°                | 14.8°               | 17.6°                  | 21.9°                   |
| Sand       | 41.4°                | 36.2°               | 37.4°                  | 39.1°                   |
| Gravel     | 57.1°                | 39.3°               | 45.7°                  | 45.5°                   |

Based on the cohesion and friction angle result from each test, the ratio between cohesion value from soil shear strength without geotextile and with geotextile can be summarised in Tables 11-13.

### Table 11. Ratio of cohesion and friction angle between clay with geotextile and clay without geotextile

| Condition                  | Rinter ($c$) | Rinter ($\varphi$) |
|----------------------------|--------------|--------------------|
| Clay + Woven Geotextile    | 0.23         | 0.65               |
| Clay + Nonwoven Geotextile | 0.29         | 0.77               |
| Clay + Composite Geotextile| 0.24         | 0.98               |

### Table 12. Ratio of friction angle between sand with geotextile and sand without geotextile

| Condition                  | Rinter ($\varphi$) |
|----------------------------|--------------------|
| Sand + Woven Geotextile    | 0.87               |
| Sand + Nonwoven Geotextile | 0.90               |
| Sand + Composite Geotextile| 0.94               |


**Tabel 13.** Ratio of friction angle between gravel with geotextile and gravel without geotextile

| Condition                          | $R_{int}$ ($\varphi$) |
|------------------------------------|------------------------|
| Gravel + Woven Geotextile          | 0.53                   |
| Gravel + Nonwoven Geotextile       | 0.66                   |
| Gravel + Composite Geotextile      | 0.67                   |

6. Conclusion

- Shear strength of soil and geotextile material is lower than shear strength of soil without geotextile.
- For cohesion parameter, the highest cohesion ratio value is found at clay and nonwoven geotextile with $R_{int}$ value of 0.29.
- For clay material, the highest friction angle ratio value is found at clay and composite geotextile with $R_{int}$ value of 0.98.
- For friction angle parameter of sand material, the highest friction angle ratio value is found at sand and composite geotextile with $R_{int}$ value of 0.94.
- For friction angle parameter of gravel, the highest friction angle ratio value is found at gravel and composite geotextile with $R_{int}$ value of 0.67.

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