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STUDY OF BEHAVIOR MECHANICALLY STABILIZED EARTH WALL (MSE-WALL) WITH SAND ON THE MODEL TEST IN THE LABORATORY

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ABSTRACT

Different types of field conditions coupled with rapid technological developments gave birth to innovations in the construction of retaining walls. One type of landslide deterrence construction that began to be developed in Indonesia is the Mechanically Stabilized Earth Wall or often called the MSE wall. The main components of the MSE wall are backfill material, lateral reinforcement and facing panel. In this final project, research will be conducted to observe the behavior of MSE wall systems on a laboratory scale.

The study was conducted by planning the innovation of the facing panel form and the variation in the number of reinforcement layers. The variations of reinforcement are 1 layer, 2 layers, 3 layers, 4 layers and without reinforcement. The reinforcement used is sack as a substitute for geotextile woven with selected pile material is sand. In testing the prototype of the MSE wall, a dial gauge is used to find out the deformation, while for loading it uses a jack-push tool.

From these tests, the data obtained in the form of shifts, lateral stresses, and the maximum load of the results of the study showed that the application of reinforcement can affect the amount of lateral stress, shifting, and load. The minimum lateral stress is 0.023 kg/cm^2 and the maximum load that can be held by the MSE wall is 75 kg.

Keywords: retaining wall, Mechanically Stabilized Earth, facing panel, soil reinforcement

1. INTRODUCTION

The retaining wall is a type of civil construction that continues to experience development as infrastructure development advances. In general, the retaining wall is known as landslide prevention, building with the principle of supporting the landfill or unstable native land. However, the different types of field conditions accompanied by rapid technological developments gave birth to innovations in the construction of retaining walls. Both in terms of geometry, materials, methods of implementation to change the retaining wall of the land into a multifunctional building.

One type of landslide deterrence construction that began to be developed in Indonesia is the Mechanically Stabilized Earth Wall or often called the MSE wall. This type of soil retaining wall carries the concept of a retaining wall that is mechanically stabilized using geotextile reinforcement or metal. The main components of MSE walls are backfilled material, lateral reinforcement and facing panel elements (Jiang, Han, Parsons., & Cai, 2015). The main advantages of MSE walls compared to conventional retaining walls (concrete and masonry) are economical, easy, fast implementation and flexible structure so that it can withstand greater settlement differences. Plus facing panels that can be made of various shapes and textures for aesthetic considerations or arrangement of bricks, wood, and oval can also be used to display harmony with the environment (Berg, Design, and Construction of Mechanically Stabilized Earth Walls and Reinforced Soil Slopes - Volume I, 2009).

In this final project, research will be conducted to observe the behavior of MSE wall systems on a laboratory scale. The research was carried out by planning, innovation in the form of facing panels and variations in reinforcement according to the landslide field of the retaining wall. Testing will be carried out on soils without strength and with reinforcement. The reinforcement used is sack as a substitute for geotextile woven with selected pile material is sand. In testing the prototype of the MSE wall, a dial gauge is used to find out the deformation while for loading it uses a jack-push tool.

2. THEORETICAL STUDY

2.1 Retaining Wall

The retaining wall is a Geotechnical building that is used to prevent steep ground collapse and has the stability that cannot be held by the land itself (Sosrodarsono & Nakazawa, 2000).

According to (Pratama, 2014) the retaining wall serves to support the soil and prevent it from the danger of landslides. Both due to the burden of rainwater, the weight of the land itself and due to the burden of working on it.

Soil retaining walls are used to withstand lateral soil stress caused by poor soil or unstable soil. This building is widely used in projects: irrigation, highways, ports, and others. The foundation elements, such as basement buildings, abutments, besides functioning as the bottom of the structure, also function as a barrier to the surrounding land. (Hardiyatmo, 2011)

2.2 Mechanically Stabilized Earth Wall

Mechanically Stabilized Earth Wall or often called MSE wall is a structure of retaining wall in the form of a combination of facing panels and soil piles reinforced with geotextile or metal materials.

The reinforcement element functions as a layer of soil reinforcement which also holds the concrete panels on the outside so that a stable and strong structure is formed (Mitchell, 1987). The facing panel section made of various types of materials with attractive designs will provide artistic beauty while protecting the danger of vandalism (Berg, 2009).

Based on SNI 8460: 2017 it is stated that the main advantages of MSE walls compared to conventional retaining walls are economical, easy, and fast implementation. This structure is flexible, can withstand greater settlement differences than conventional retaining walls.

2.3 Stability of MSE Wall

In the MSE wall, the structure must be stable both due to the influence of internal and external forces. External stability or external stability (external stability) MSE walls have the same criteria as in conventional soil retaining wall structures. Internal stability or internal stability (internal stability) requires that the structure must be integrated and can stand alone by the influence of external forces as well as due to its weight.

A. External Stability

The external stability of the MSE wall depends on the ability of the soil mass to withstand external loads without the risk of structural collapse. These loads include lateral pressure on the ground behind the structure and the loads acting on it.

The collapse of the MSE wall must be reviewed against several mechanisms, namely (Hardiyatmo, 2014):

1. Shifting to the base of the wall (Figure 2.1 (1))
2. The toppling of the front legs on the wall (Figure 2.1 (2))
3. The collapse of the carrying capacity of the subgrade (Figure 2.1 (3))
4. Collapse due to global slope erosion (Figure 2.1 (4))

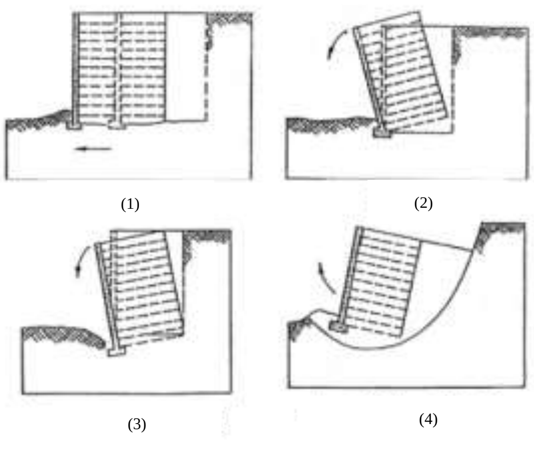


Figure 2. 1 External collapse mechanism for MSE walls

Because of the flexibility of MSE walls, the safety factor for the four potential external failures is generally smaller than the safety factor for concrete cantilever walls and gravity-type walls. Table 2.1 based on (BSNI, SNI 8460: 2017 Concerning Geotechnical Design Requirements, 2017) summarizes the safety factors for the four potential failures of external stability along with suggested corrective measures.

Table 2. 1 Summary of minimum safety factors for potential external failures (extracted from FHWA NHI-00-043)

No.	potential for external failure	minimum safety factor	other requirements	corrective steps if the safety factor is not met
1	lateral slide at the base	1,5	-	Renew L
2	bolster moment	2	e < L/6	Renew L
3	bearing capacity	2,5	-	fix foundation land or deepen dm
4	global stability	1,3	-	Renew L or fix foundation land
Information:				
L is the length of reinforcement				
e is the eccentricity of forces				

B. Internal Stability

The internal stability analysis includes an analysis of the MSE wall structure for the following risks (Hardiyatmo, 2011):

1. Breakdown of reinforcement
2. Unplugging of retaining zone (passive zone)

2.4 Landslide Field Location of MSE Wall

Landslide surfaces for vertical walls with soils reinforced with reinforcing reinforcement (such as geotextiles) are generally considered to coincide with Rankine landslide fields (Figure 2.2), i.e. The collapse occurs in an angled plane (45 ° + φ / 2) to the plane horizontal. Therefore, for soils that are reinforced with geotextiles, the lateral earth pressure coefficient (Ka) is used in the calculation of lateral earth pressure.

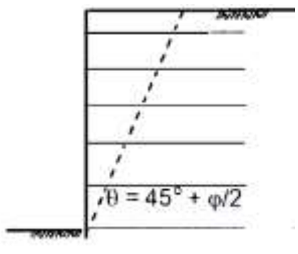


Figure 2. 2 Rankine landslide shape

In research (Sadat, Huang, Bin-Shafique, & Rezaeimalek, 2018) the maximum increase in strain for each reinforcement layer occurred in the plane (45 ° + φ / 2), and the lower layer had the greatest increase in strain among all reinforcement layers. While the maximum stress is in the uppermost reinforcement layer just below the load placement (Ahmadi & Bezuijen, 2018). Further research shows that the embankment load, friction angle, tensile stiffness, reinforcement length, and MSE wall height have a significant effect on horizontal and vertical motion, and pressure in geosynthetics.

(Prasasti, Munawir, & Suroso, 2014) conducted a study of variations in layers and vertical distances between geotextiles on the carrying capacity of a continuous foundation on the sand slope modeling with a density of 74%. In this research, we can see that based on an analysis of BCIqu and BCIs values that occur, the maximum placement of geotextile locations is when geotextile is installed at a ratio L / H = 0.59 and Sv / H = 0.15.

The latest research references in modeling this retaining wall are based on research conducted by (Gunanta, 2014) and (Pratama, 2014) with peat heaps and flexible reinforcement. Flexible reinforcement in the form of tarpaulin and polypropylene which are used as an alternative reinforcement material for peat can increase the strength of the retaining wall. And from the research, it was found that the wider the flexible reinforcement of tarpaulin and polypropylene on the retaining wall, the smaller the shift and lateral stress. Whereas for a retaining soil without direct reinforcement, it collapses due to lateral stress before loading, as well as the manual calculation that has been obtained SF value (Safety Factor) from stability to shear and stability to rolling as well as stability to the carrying capacity of the soil far below the value SF permission.

2.5 Collapse Limit of MSE Wall

The limit of lateral deformation of permits for retaining walls and/or embedded walls is determined by the condition of the soil, the depth of excavation and the distance and condition of the closest building whose magnitude is determined with the formula as listed in Table 2.2.

Table 2. 2 Maximum limit of lateral deformation of the wall

Maximum limit of lateral deformation in the wall	**the location of the closest building or existing infrastructure**			
	Zona 1	Zona 2	Zona 3 (x/H > 2)	
Information:	(x/H < 1)	(1 < x/H < 2)	Soil Tipe	Soil Tipe
x = distance from excavation boundary			A	B
H = depth of excavation				
δw = deformation of wall				
maximum deformation permit limits	0,50%	0,70%	0,70%	1,00%

Source: (BSNI, SNI 8460: 2017 Concerning Geotechnical Design Requirements, 2017)

Information:

a) Type A soils include: over consolidated stiff clays and silts, residual soils, and medium to dense sands.

b) Soil Type B includes: soft clays, silts, organic soils, and loose fills

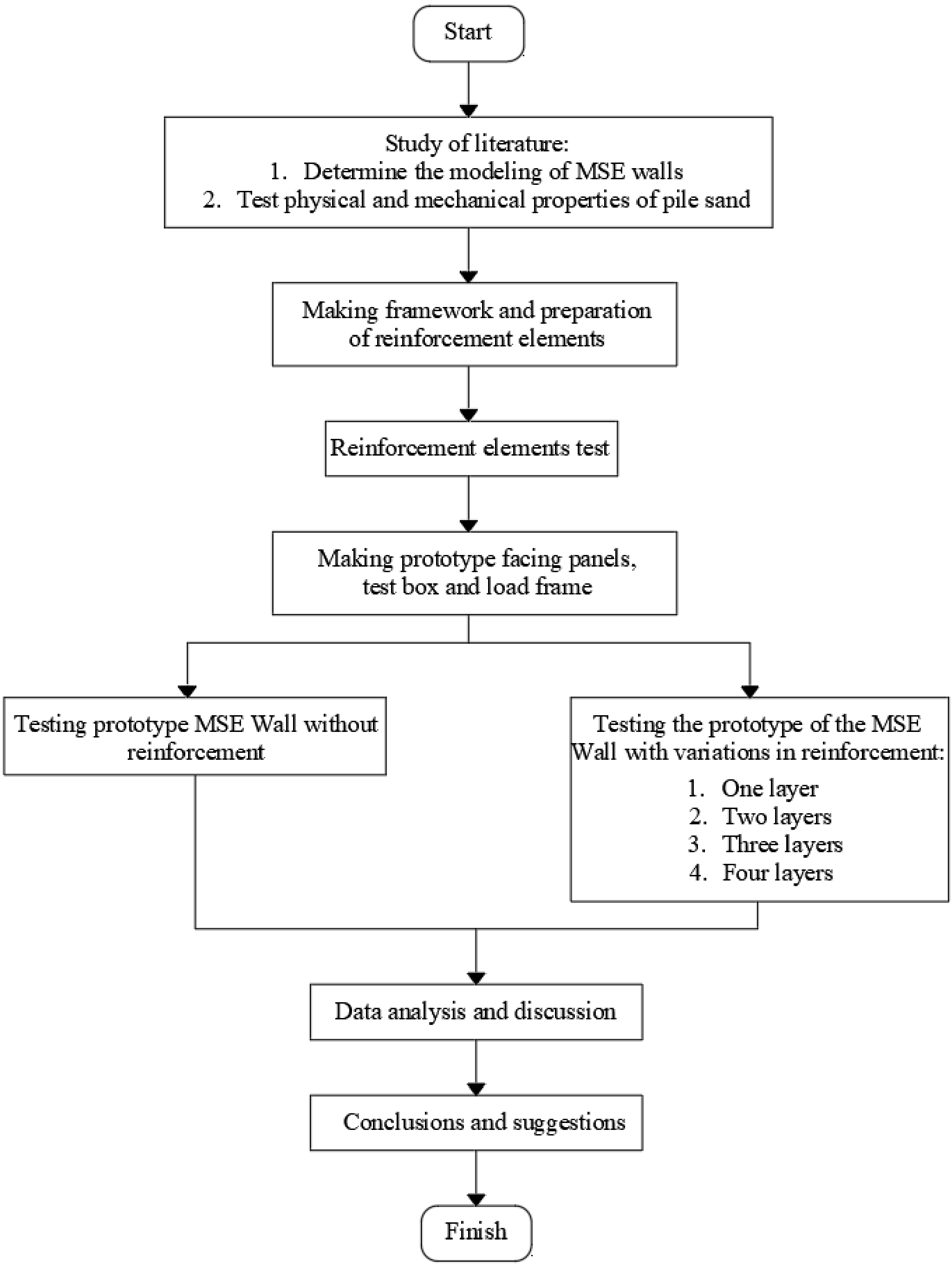
In this study the soil used was and sand soil as high as 50 cm with moderate to solid density so the maximum deformation permit limit (δw / H) was 0.7%.

δw = 0.7% x 50 cm = 035 cm

So the allowable deformation limit is 3.5 mm. Because in this study the state of the MSE wall was reviewed in a state of collapse (ultimate), the collapse limit was set to 7 mm.

3. METHOD

3.1 Flowchart



3.2 Material

A. Sack

The reinforcement material used is of synthetic sheet type, namely rice sacks (Figure 3.1).

Figure 3. 1 Sack as reinforcement material (idwebdesainer.com)

This synthetic material has a thickness of about 0.1 mm. In this study, 75 cm x 105 cm sacks were used.

B. Sand

The embankment soil used in this study is loose sand (Figure 3.2). Before testing the MSE wall, the sand is tested for its physical and mechanical properties.

Figure 3. 2 Sand as landfill material (liputan6.com)

C. Plywood

The material used for the prototype facing panel and leveling pad is plywood 9 mm thick. This material is used to facilitate the manufacture of relatively small MSE wall components. Plywood material is also able to survive so as not to shrink compared to ordinary wood.

The material used in vertical joints is nails. The facing panel with reinforced joints used steel elbows which are welded and then shaped as in Figure 3.3.

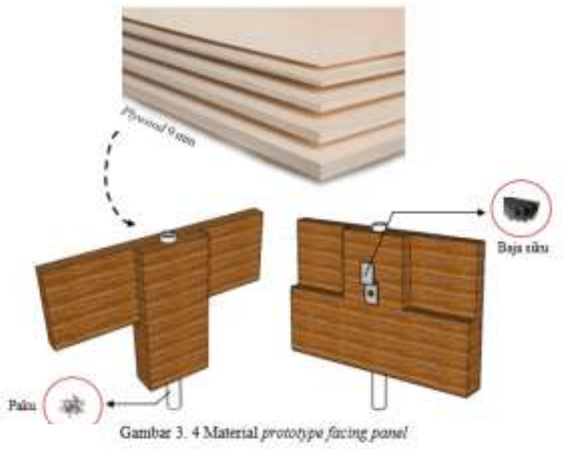


Figure 3. 3 Material prototype facing panels

3.3 Tools

The tools used in this study can be seen in the following figure:

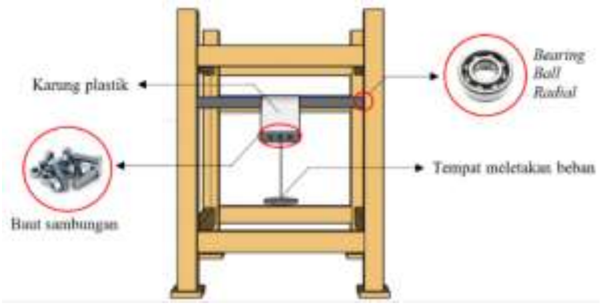


Figure 3. 4 Tensile strength test equipment

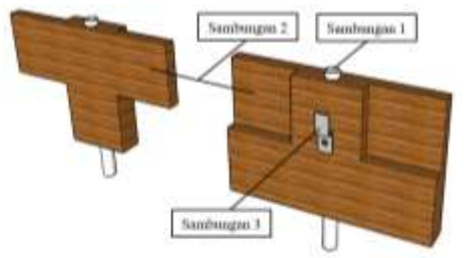


Figure 3. 5 Facing panel prototype

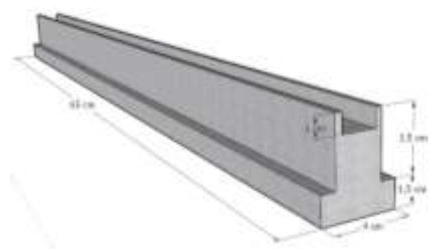


Figure 3. 6 Leveling pad prototype

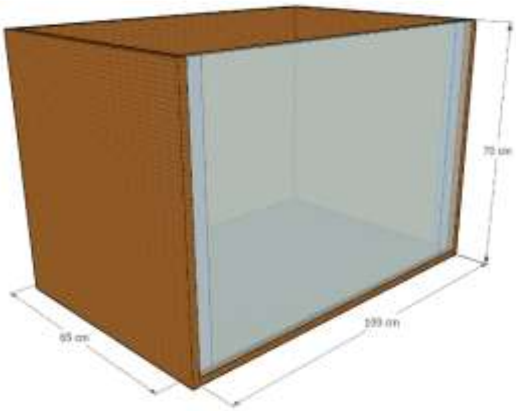


Figure 3. 7 Test box

length of deformation measured

Figure 3. 8 Push press jack

Figure 3. 9 Proving dial

Figure 3. 10 Dial gauge

3.4 Research Procedure

A. Material Tensile Strength Test

Sacks of rice and banners are each cut 10 cm wide and 105 cm long, then spread with one end tied to the test equipment and the other end connected to the loading device. At both ends of the test, the object is given a bolt connection. Then the load is placed gradually until it reaches the tear strengthened material state.

test specimens are marked

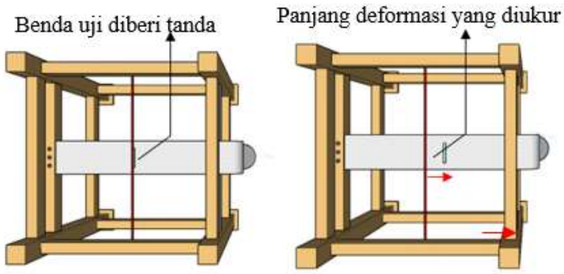


Figure 3.11 Illustration of deformation measurements on test specimens

Data obtained from this test are the total load and deformation that occurs when the reinforcement is torn. Deformation is obtained by placing the thread transversely as in Figure 3.11. Before being given a load, the test object is first marked on an area parallel to the yarn. When the load is placed, the deformation can be calculated, by measuring the distance of the mark on the test specimen to the thread using a ruler. The load used in this test is used for consolidation testing with a weight of 1 kg to 10 kg. The load and deformation are recorded until the test object is torn or broken at an ultimate state of ultimate strength.

B. Collapse Test of MSE Wall *Prototype*

The steps of testing the MSE prototype wall begin by positioning the leveling pad as the foundation wall of the MSE. Then mounted facing panel until it reaches a height of 50 cm. After that, the sand begins to be put into the test box as high as 1 facing panel and compacted using a pounding tool or hammer. Then the sack that has been cut according to the size of the box is spread on the sand. Reinforcement is installed each as high as 1 facing panel (10 cm) and varies from 1-5 layers.

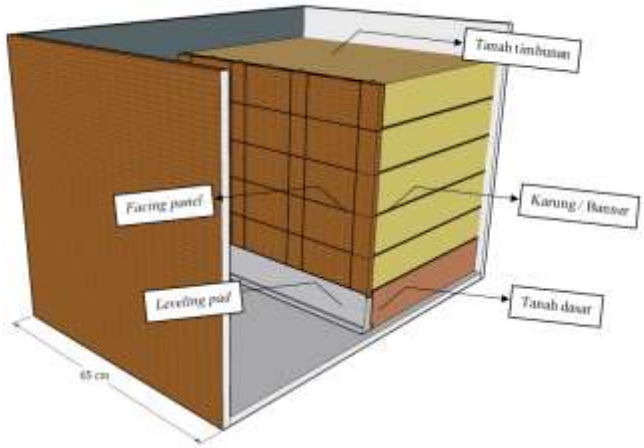


Figure 3. 12 3D modelings of MSE wall prototype

If all components are installed as shown in Figure 3.12, the prototype is ready to be tested using a jack push tool (Figure 3.13). From the jack, it can be seen that the maximum load for each variation of reinforcement installed. And to find out the deformation that occurs, a dial gauge is mounted in 3 pieces, namely above the middle section reinforcement, in front of the facing panel the top and the middle part.

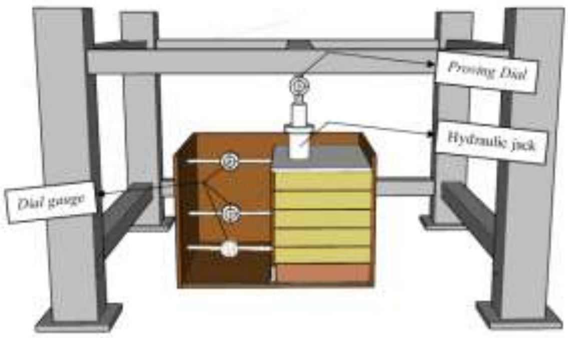


Figure 3. 13 Illustrations of MSE wall prototype testing

4. RESULT AND DISCUSSION

4.1 Material Test Results

This test is carried out to determine the tensile strength value of the reinforcement material used in testing the MSE prototype wall. The average tensile strength value obtained from 3 samples of test specimens is 0.039 kg/cm^2.

4.2 Physical and Mechanical Properties Test Results

The test results obtained are presented in Table 4.1 and Figure 4.1

Table 4. 1 Test results of physical and mechanical properties of soil

Parameter	Result	Unit
Water content	7,88	%
Volume weight	1,96	$gram/cm^3$
Friction angle	37	°

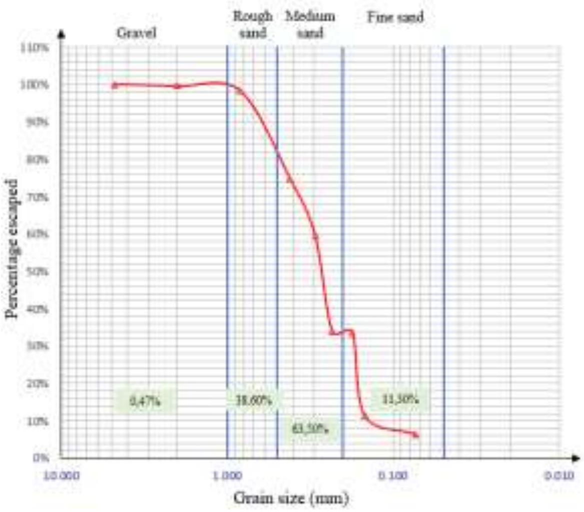


Figure 4. 1 Filter analysis graph

4.2 Test Results of MSE Wall

After testing the loading with variations in the number of reinforcement 1, 2, 3, 4 and without the reinforcement results obtained maximum loading and maximum stress. The maximum load is obtained when the MSE wall has been deformed beyond the maximum deformation of 7 mm. This condition is considered an ultimate collapse or the MSE wall has collapsed.

Table 4.2 Recapitulation of MSE Wall test results

Variation in the amount of reinforcement	1st Dial (up) (mm)	2nd Dial (middle) (mm)	3rd Dial (down) (mm)	Maximum deformation (average) (mm)	Maximum load (kg)	Maximum stress (kg/cm^2)
Without reinforcement	12	10	8	10,000	4	0,00123
1	11	12	1,5	8,167	15	0,00462
2	12	10	1	7,667	19	0,00585
3	12	8	2	7,333	39	0,01200
4	12	8	1	7,000	75	0,02308

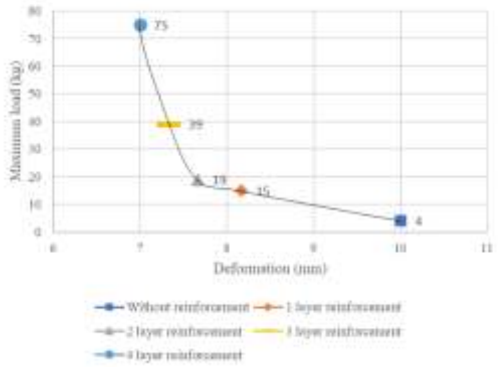


Figure 4. 2 The curve of the relationship between maximum load and deformation

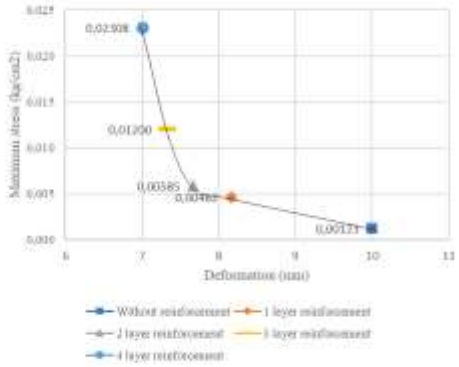


Figure 4. 3 The curve relationship between maximum stress and deformation

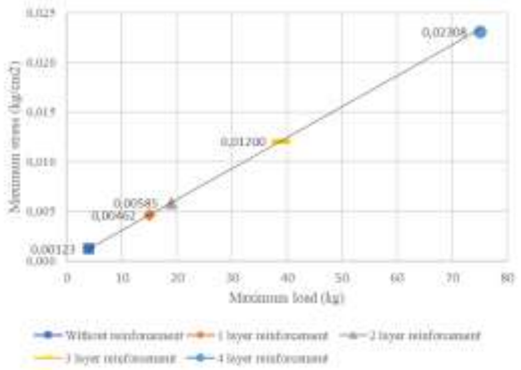


Figure 4. 4 The curve relationship of maximum load and maximum stress

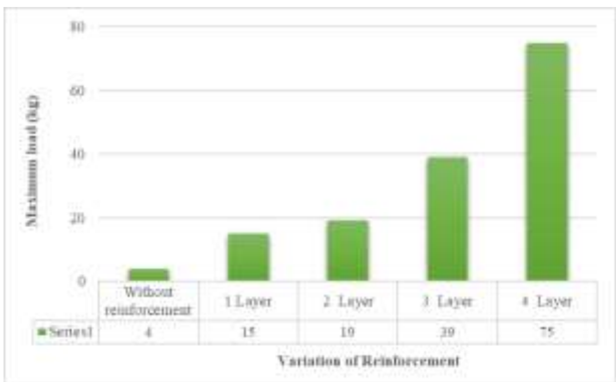


Figure 4. 5 The relationship of the variation of the reinforcement to the maximum load graph

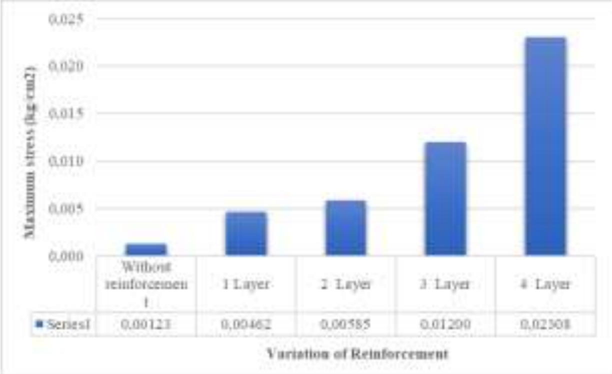


Figure 4. 6 The relationship of the variation of the reinforcement to the maximum stress graph

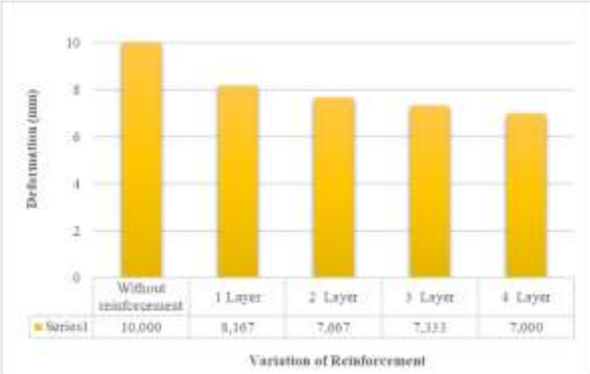


Figure 4. 7 The relationship of the variation of the reinforcement to deformation graph

From Figure 4.5 it can be seen that the more layers of reinforcement that are given the greater the maximum load that can be carried by the MSE wall. As with the maximum load, the maximum stress that occurs is also getting greater as more and more layers of reinforcement are given as can be seen in Figure 4.6. While from Figure 4.7 it can be seen that the deformation is getting smaller according to the number of reinforcement layers given.

Then to see the difference in the MSE wall without reinforcement and using 1 - 4 layers of reinforcement than an analysis of the increase and decrease in the value of the load, stress, and deformation of the MSE wall without reinforcement with each variation of the MSE wall using reinforcement. Calculation results can be seen in Table 4.3.

Table 4. 3 The value of the difference in increase and decrease in load, stress, and deformation between variations in reinforcement

Difference	Load (kg)			Deformation (mm)			Stress (kg/cm^2)		
Without & 1 layer	α1	11	275%	β1	1,833	18%	Δ1	0,003	275%
Without & 2 layer	α2	15	375%	β2	2,333	23%	Δ2	0,005	375%
Without & 3 layer	α3	35	875%	β3	2,667	27%	Δ3	0,011	875%
Without & 4 layer	α4	71	1775%	β4	3,000	30%	Δ4	0,022	1775%

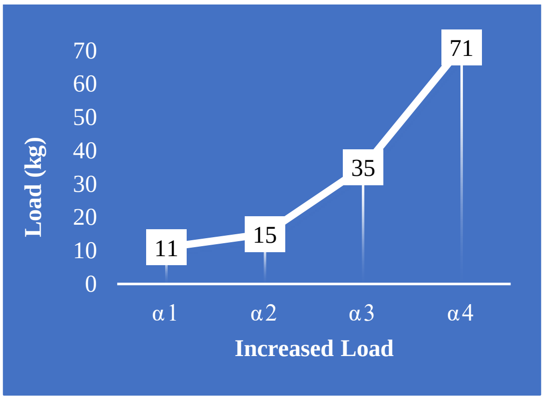


Figure 4. 8 The curve of increasing increment increases MSE wall load without reinforcement with 1, 2, 3 and 4 layers of reinforcement

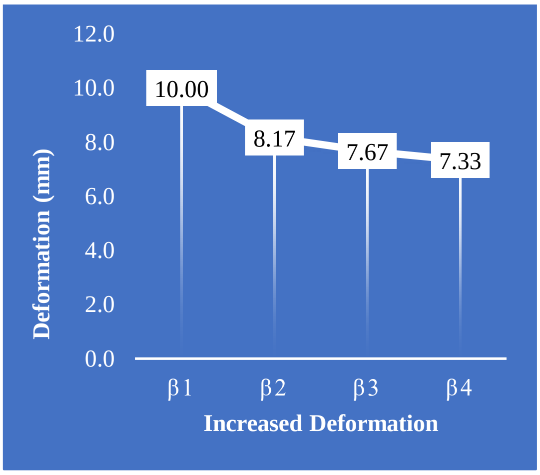


Figure 4. 9 Curve increment difference increment of MSE wall stress without reinforcement with 1, 2, 3 and 4 layers of reinforcement

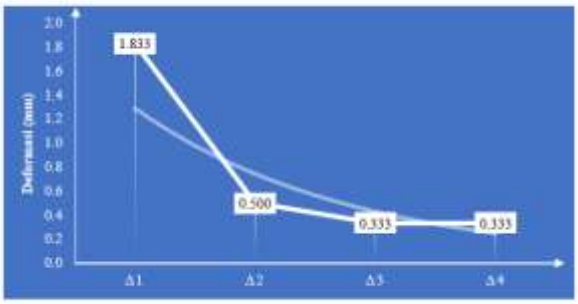


Figure 4. 10 The curve of increasing the difference in value decreases deformation of the MSE wall without reinforcement with 1, 2, 3 and 4 layers of reinforcement

The calculation results in Table 4.3 are presented in the form of curves in Figure 4.8, Figure 4.9 and Figure 4.10. The three curves show the difference in the increase in load, the difference in stress increase and the difference in deformation reduction between the MSE walls without reinforcement with 1, 2, 3 and 4 layers of reinforcement. It can be concluded that the difference of data increases directly proportional to the increasing number of layers of reinforcement in the MSE wall.

From the results of the research conducted it can be concluded that the more layers of reinforcement, the greater the maximum load and maximum stress that can be withstood from the MSE wall with the sack strength. In inverse proportion to loading and stress, the more layers of reinforcement the smaller the deformation that occurs. So, the reinforcement of the sack given to the prototype can reduce the deformation of the MSE wall and reduce lateral stress, this results in the MSE wall becoming stronger.

5. CLOSING

5.1 Conclusion

From the results and discussion, the following conclusions can be drawn:

1. Based on the tensile strength test conducted on the reinforcement material, it is known that the tensile strength value of the sack used as a reinforcement is 0,039 kg/cm^2.
2. Based on the test results of physical and mechanical properties of sand, soil used as a pile material has a water content of 7,88%, a volume weight of 1,96 gr/cm^3 and a friction angle of 37^o.
3. The bearing capacity that occurs on the slope with reinforcement increases compared without using reinforcement. Where more and more reinforcement layers are used, the carrying capacity that can be resisted increases.
4. The maximum load and maximum stress that can be carried by the MSE wall is the largest in the 4 layers of reinforcement, 75 kg with the stress of 0,023 kg/cm^2.
5. The more layers of reinforcement, the greater the maximum load and maximum stress that can be withstood from the MSE wall. In inverse proportion to loading and stress, the more layers of reinforcement the smaller the deformation that occurs.
6. Sacks used as an alternative soil strengthening material can increase the strength of the MSE wall prototype.

5.2 Suggestion

The analysis in this study is a complex matter that must be very thorough and controlled in its implementation, therefore for further research, it is hoped that this research can be more perfect by paying attention to the following matters:

1. It is necessary to have an analysis and variations in the installation of reinforcement that can be known as a safety factor to get optimum results. Because in this study only aims to determine the behavior of the wall MSE has not gotten optimum or effective results.
2. There is a need for variations in the number of geotextiles used in more research because it allows the addition of carrying capacity that occurs in this study is not optimal.
3. We recommend that the prototype facing panels used in each variation also differs, but have the same specifications to avoid damage or deflection that occurs due to repeated use during the collapse test.
4. In the next research, innovation can be done on the pile material and also the reinforcement material on the MSE wall.
5. In this study, modeling uses a laboratory scale so that there are limitations in adjusting the prototype to the field conditions and the results of the test of this model cannot be transferred directly to a full-scale MSE wall. Therefore, the analysis of the data from this research still needs improvement and further research on a field scale.

REFERENCES

Ahmadi, H., & Bezuijen, A. (2018). Full-Scale Mechanically Stabilized Earth (MSE) Walls Under Strip Footing Loads. *Geotextiles and Geomembranes*, 297-311.

Arifin, B. (2006). Uji Model Dinding Penahan dengan Timbunan Diperkuat Perkuataan Fleksibel. *Journal SMARTek, Vol.4 No.4*, 233-241.

Berg, R. R. (2009). *Desiggn and Construction of Mechanically Stabilized Earth Walls and Reinforced Soil Slopes – Volume II.* United States: U. S. Department of Transportation Federal Highway Administration.

BSNI. (2017). *SNI 8460:2017 Tentang Persyaratan Perancangan Geoteknik.* Jakarta: Badan Standardisasi Nasional.

Das, B. M. (1995). *Mekanika Tanah (Prinsip-prinsip Rekayasa Geoteknis) Jilid 2.* Jakarta: Penerbit Erlangga.

Departemen, P. U. (2009). *PP No. 003/BM/2009 Tentang Perencanaan dan Pelaksanaan Perkuatan Tanah dengan Geosintetik.* Jakarta Selatan: Departemen Pekerjaan Umum.

Elias, V., Christoper, B. R., & Berg, R. R. (2001). *Mechanically Stabilized Earth Walls and Reinforced Soil Slopes Design & Construction Guideline* . United States: U.S. Department of Transportation Federal Highway Administration.

Golakiya, H. D., & Lad, M. D. (2015). Designe and Behaviour of Mechanically Stabilized Earth Wall . *Journal of Emerging Technologies and Innovative Research*, 145-153.

Gunanta, R. (2014). Uji Model Dinding Penahan Tanah dengan Timbunan Gambut Menggunakan Perkuatan Fleksibel Polypropiline. *Jurnal Teknik Sipil dan Lingkungan Vol 2 No.3*, 373-381.

Hardiyatmo, H. C. (2011). *Analisis & Perancangan Fondasi Bagian I (Edisi ke-2).* Yogyakarta: Gadjah Mada University Press.

Jiang, Y., Han, J., Parsons., R. L., & Cai, H. (2015). *Field Monitoring of Mechanically Stabilized Earth Walls to Investigate Secondary Reinforcement Effects.* Kansas: Kansas Department of Transportation.

Mitchell, J. K. (1987). *Reinforcement of Earth Slopes and Embankments.* Washington, D. C.: National Cooperative Highway Research Board.

Pratama, D. S. (2014). Uji Model Dinding Penahan Tanah dengan Timbunan Gambut Menggunakan Perkuatan Fleksibel Terpal. *Jurnal Teknik Sipil dan Lingkungan Vol.2 No.3*, 477-482.

Pusat Penelitian dan Pengembangan Jalan dan Jembatan, B. P. (2009). *Perencanaan dan Pelaksanaan Perkuatan Tanah dengan Geosintetik.* Jakarta Selatan: Departemen Pekerjaan Umum.

Rosihun, M., & Endaryanta. (2011). Analisis Stabilitas Talud Bronjong UIN Sunan Kalijaga Yogyakarta. *INERSIA, Vol VII No.2*, 182-201.

Sadat, M. R., Huang, J., Bin-Shafique, S., & Rezaeimalek, S. (2018). Study of the Behavior of Mechanically Stabilized Earth (MSE) Walls Subjected to Differential Settlements. *Geotextiles and Geomembranes*, 77-90.

Sosrodarsono, I. S., & Nakazawa, K. (2000). *Mekanika Tanah & Teknik Pondasi.* Jakarta: PT Pradnya Paramita.