CHANGES OF GEOTECHNICAL PROPERTIES OF WASTE EMBANKMENT FOR STABILITY ANALYSIS AT PIYUNGAN DISPOSAL SITE

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ABSTRACT

The increment of human population increase waste production anddisposal site requirement significantly. Because of site acquisition for new disposal site is difficult, some efforts are needed to maintain the stability of waste embankmentto maximize the capacity of disposal site.The location of this research is TPST Piyungan (Piyungan disposal site), Yogyakarta. This research are expected to obtainthe changes of geotechnical properties which are engineering and mechanical properties for stability analysis in waste embankment and then can be used as reference for design and development of the Piyungan disposal site. The experiment aboutgeotechnical properties of different waste's age is obtained by taking samples from early, medium, and the oldest wastein the disposal site.The result of this researchshowing properties of waste changes from time to time. The organic content of waste has decreased from 72.41% to 43.68%, the specific gravity of waste has increased along with reduced organic content from 1.82 to 2.05. The density test using sandcone showed an increase dry density from 0.43 kg/cm^3 to 0.89 kg/cm^3. The value of waste permeability decreased but not very significant. Based on direct shear test, friction angle is increase from 35.02° to 41.98 ° with the 0 kPa cohesion. The longer the age of waste, shear strength is increasedalong with the decrease of organic content and the increase of density. Changes in these parameters can be a reference to support the stability and development of infrastructure in waste embankment. Based on stability analysis of waste embankment, the stability of existing waste embankment at Piyungan disposal siteis in stable condition with 2.290 safetyfactor. The capacity of the embankment can be increased up to ±10 m height from existing and slope angle up to 30° with reinforcement that generates a safety factors 1.683.

Keywords: waste properties; stability; disposal site.

A. INTRODUCTION

Consumptive behavior of human from time to time is increasing, the increase in this behavior increases the amount of waste. Waste is a residual activity of human being and from natural process. The waste will be sorted and recycled and the remaining waste that cannot be recycled will be disposed to disposal site.According to the Statistics of D.I. Yogyakarta province (2012), waste in Yogyakarta City is transported to Piyungandisposal site in 2012 with722 m^3/day amount of waste. Increment ofwaste production will increasedisposal site area requirement. Because the difficulties of site acquisition for new disposal site, some efforts are needed to maintain the stability of waste embankment to maximize the capacity of disposal site. This research are expected to obtained the characteristics and slope stability of waste embankment for design and maximize the capacity of Tempat Pembuangan Sampah Terpadu (TPST) Piyungan disposal site.

B. LITERATURES AND BASIC THEORY

1. Waste

According UU No. 18 tahun 2008 of Indonesia Law, waste is the solid residual material of human activity and the other process. With theincreaseof population the consumption of society is increasing as well, which creates an increase of waste from time to time. The increment amount of waste is not balanced with waste recycling.

Decomposition or weathering is a process of biodegradation that converts organic materials into water, CO^2, energy, and other weathering materials. Decomposition process involves two main stages:

a. The first stage is decomposition of microorganisms against raw materials (waste) into simple chemical components, in this stage the metabolic activity of microorganisms is generating heat.

b. The second stage cleaning or purifying of weathering material (compost). The depletion of food sources slows the activity of microorganisms. As a result, the heat is reduced and the compost becomes dry and brittle resulting in materials with a lot of nutrient.

Waste classificationin Zekkos (2008) can be achieved by looking at the parameters reviewed such as grain size, type of waste, shear strength parameters, and others. Table 1 shows the existing waste classification system based on the author, the classification type, and the parameters used.

Table 1. Waste classification

Author	Basis for Differentiation	Parameter Used for Differentiation
Turczynski (1988)	Waste type	Density, shear parameters, liquid/plastic limit, permeability
Siegel et al. (1990)	Material groups	Part of composition
Landva and Clark (1990)	Organic, inorganic materials	Degradability (easily, slowly, non) Shape (hollow, platy, elongated, bulky)
ADEME (1993)	Particle size distribution and composition	Size, material groups, moisture content and degradability
Grisolia et al. (1995)	Degradable, inert, deformable material groups	Strength, deformability, degradability
Kölsch (1996)	Material groups	Size, dimension
Manassero et al. (1997)	Soil-like, other	Index properties
Thomas et al. (1999)	Soil-like, non soil-like	Material groups
Dixon & Langer (2006)	*Shape-related subdivisions*	*Material groups, size, dimensions, shape related properties, degradation potential*

(source: Zekkos, 2008)

2. Shear Strength

The shear strength of waste is important in analyzing the stability of disposal site during operation or after completion of its service life time. The shear strength parameters illustrated by Mohr-Coulumb failure criteria (c = cohesion, φ = internal friction angle) are often used to calculate shear strength parameters in waste material. These shear strength parameters can be measured directly through laboratory testing, field scale testing, and back calculate of either existing or failing slopes (Brieither et al, 2012).

The problem in the waste stability is to get the proper shear strength parameters for the waste and to develop an appropriate analysis. A combination of theoretical analysis and field studies should be done to investigate the stability of the waste embankment (Bagchi, 2004). Shear strength parameters affect the decomposition process, but the significant effect is shown at friction angle parameter (φ), while for the cohesion value (c) does not show the correlation with the decomposition process (Bareither et al, 2012). The shear strength parameters (c and φ) of standard laboratory test should be reduced by 15-25% (Bagchi, 2004).In Babu (2014) it is mentioned that the shear strength value range of some previous researchers depends on the testing method seen in Table 2.

Table 2. Previous researchers about shear strength

Author	Friction Angle (φ)	Cohesion (c)	Testing Method
Landva and Clark (1986)	38° – 42°	16 – 19 kPa	-
Garb and Valero (1995)	20° – 39°	0 – 28 kPa	Small direct shear
Garb and Valero (1995)	34°	17 kPa	Undrained triaxial test

(source: Babu, 2014)

3. Safety Factor

The safety factor is defined as the ratio value between the bearing force and the driving force Eq. 2.1.

$$SF = \frac{\tau}{\tau_d} \quad (2.1)$$

With τ is the maximum shear resistance which can be deployed by the soil, τ_d is the shear stress that occurs due to the gravity of the soil when the soil will move (or the shear force mobilized by the soil to maintain balance), and SF is the safety factor. According to Mohr-Coulumb's theory, the maximum shear resistance (τ) that can be mobilized by the soil alonglandslide is expressed by Eq. 2.2.

$$\tau = c + \sigma tg\varphi \quad (2.2)$$

With c = cohesion, σ = normal stress, φ = friction angle in the soil. The values of c and φ are the shear strength parameters along the landslide plane. In the same way, we can write the sliding stress equation (τ_d) due to the soil load and other loads on its landslide in Eq. 2.3.

$$\tau_d = c_d + \sigma tg\varphi_d \quad (2.3)$$

With c_d and φ_d is the cohesion and friction angle that occur or needed for balance in the landslide field. The safety factor is found in Eq. 2.4.

$$SF = \frac{c + \sigma tg\varphi}{c_d + \sigma tg\varphi_d} \quad (2.4)$$

In non-homogeneous soil and seepage flows occur in soil, a more suitable way to determine stability of slope is using the method of slice (Hardiyatmo, 2012). The normal force acting at a point in the landslide circle is mainly affected by the weight of the soil above that point. In the slice method, the landslide mass of the soil is divided into several vertical slices. Then, the balance of each slice is given as at Figure 1. There are several methods that can be used in slope stability analysis shows in Table 3.

Table 3. Static equilibrium conditions satisfied by limit equilibrium method

Method	Force-Equilibrium x	Force-Equilibrium y	Moment Equilibrium
Ordinary method of slice	No	No	Yes
Bishop's simplified	Yes	No	Yes
Janbu's simplified	Yes	Yes	No
Corps of Engineers	Yes	Yes	No
Lowe and Karafiath	Yes	Yes	No
Janbu's generalized	Yes	Yes	No
Bishop's rigorous	Yes	Yes	Yes
Spencer's	Yes	Yes	Yes
Sarma's	Yes	Yes	Yes
Morgenstern-Price	Yes	Yes	Yes

(source: Abramson et al, 1995)

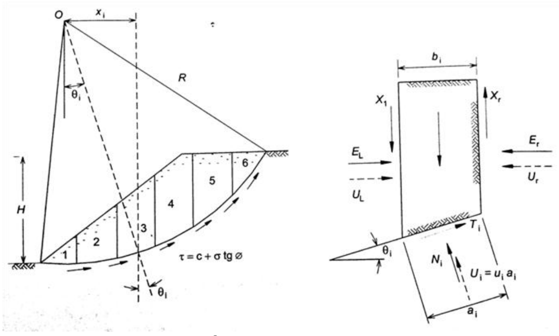

Figure 1. The forces act on the slice method (source: Hardiyatmo, 2012)

Bowles (1984) suggests that general slope stability is a field strain analysis because the ratio between the length and the cross section of the slope is very large. Bowles proposed a safety factor (*SF*) value associated with the rate of landslide events, as presented in Table 4.

Table 4. Bowles safety factor

Safety Factor (*SF*)	Landslide Intensity
<1.07	Usually occur
1.07 ≤ *SF* ≤ 1.25	Once occur
>1.25	Rarely occur

(source: Bowles, 1984)

If referring to standardization of Indonesia (SNI 03-1962-1990) concerning about Procedures for Landslide Prevention there are several requirements for safety factor to be considered as in Table 5.

Table 5. Safety factor by standardization of Indonesia (SNI 03-1962-1990)

Risk	Load Condition	Shear Strength Parameter: Maximum A	Maximum I	Residual A	Residual I
High	Earthquake	1.50	1.75	1.35	1.50
	Without Earthquake	1.80	2.00	1.60	1.80
Medium	Earthquake	1.30	1.60	1.20	1.40
	Without Earthquake	1.50	1.80	1.35	1.50
Low	Earthquake	1.10	1.25	1.00	1.10
	Without Earthquake	1.25	1.40	1.10	1.20

Note: A (accurate), I (inaccurate)
(source: SNI 03-1962-1990)

Referring to the Regulation of the Minister of Public Works of the Republic of Indonesia Number 03/PRT/M/2013 on the Implementation of Infrastructure and Solid Waste Facility in Handling Household Waste and Similar Waste to Household Waste, it can be seen that:

a. Waste density at least 600 kg/m^3 with a maximum slope angle of waste embankment is 30°.
b. The use of benching at certain altitudes. Recommendation of using bench is minimum 5m wide of bench for every 5m height.
c. The minimum criterion requirement of Safety Factor is 1.30 for the temporary slope embankment and 1.50 for the permanent slope.

C. RESEARCH METHOD

1. Data and Sample

The location of this research is at Piyungan disposal site (Tempat Pembuangan Sampah Terpadu (TPST) Piyungan), Dusun Ngablak, Kelurahan Sitimulyo, Kecamatan Piyungan, Bantul Regency, Yogyakarta can be seen at Figure 2.

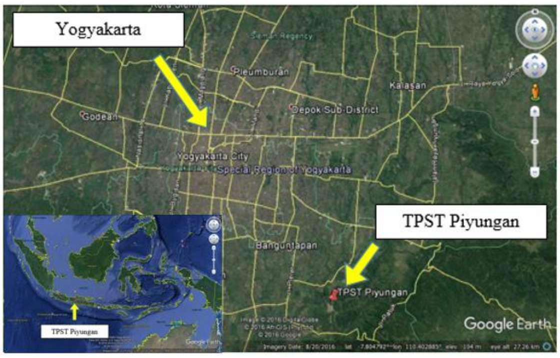

Figure 2. Location of Piyungan disposal site

The type and source of data for this research can be seen in Table 6.

Table 6. Source of data

No.	Data	Type	Source
1	Disposal site Geometry	Secondary	Balai PISAM
2	Waste Properties	Primer	Laboratory and In Situ Test
3	Documentation	Primer	In Situ

Samples were taken in disturb condition considering the difficulty of undisturbed sampling on municipal waste. Threespots in the area selected to be the sampling area where representing early, medium, and old condition of waste using pit test.To obtain the field density, flied density test which is using sand cone is needed.There are several laboratory test conducted in this research. The test to find organic waste content, direct shear test is used to find shear strength parameter of waste, and permeability test. Laboratory test need some adjustment, that is:

a. Size of waste material tested ± 20 mm
b. Destructive materials were ignored, such as nails, sharp material fragments.
c. The density of the waste was adjusted to the density in the field

2. Waste Stability Analysis

Slope stability in Piyungan disposal siteis modeled using Slope/W program based on limit equilibrium method which stability calculation is based on the force that occurs in each of the pieces. The waste material on Slope/Wis approached by Mohr-Coulumb failure criteria. In this research for stability analysis of the waste embankment there are two base model which are waste embankment without reinforcement and waste embankment with reinforcement.The method is used in stability analysis which are Ordinary, Janbu, and Morgenstern-Price. The influence of water in this analysis is ignored.

D. RESULTS AND DISCUSSION

1. Changes of Geotechnical Properties

The location of the research is the Piyungan disposal site, Yogyakarta (-7.870819°; 110.430242°). Piyungan disposal site with total area of 11 Ha consists of 5 Ha disposal site and 6 Ha for supporting facilities. Piyungan disposal site is surrounded by forests, hills, and several houses. Based on the regional geological map of Yogyakarta at Figure 3 it can be seen that the location of Piyungan disposal site is in the Semilir formation which is a interbedded tuff-breccia, pumice breccia, dacite tuff and andesite tuffs and tuffaceous claystone, the age of Similir formation is tertiary-miosene.

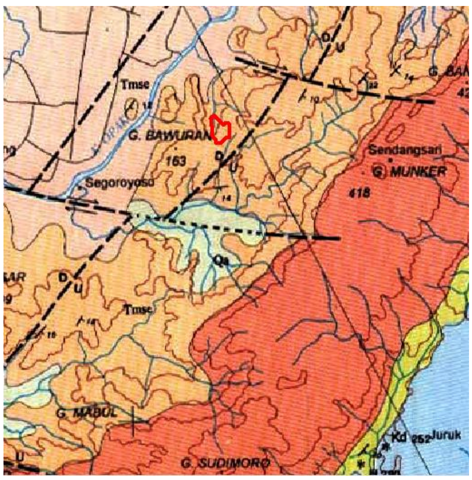

Figure 3. Geological map

Figure 4. Rock condition of surrounding area

At Figure 4 shows the rock surrounding Piyungan disposal site, the siltstone is inserted between the sandstones layers. Waste embankment at Piyungan disposal site have ±35 m of height from the slope toe which has been operating since 1995 can be seen at Figure 5.

Figure 5. Waste embankment condition

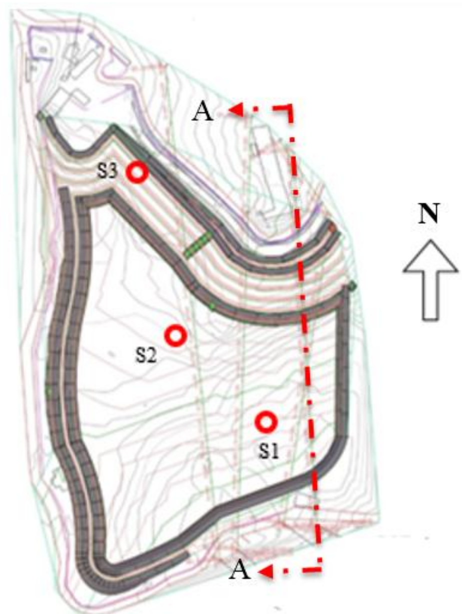

Figure 6. Sampling location

Figure 6 shows the sampling location consist of 3 samples at the top, middle, and bottom. It aims characteristic of the waste embankment from time to time in which the top site represents a relatively early waste, the middle site being waste deposited in the medium time period, and the bottom one is representing the nature of the longest buried waste. The next discussion for the top sample will be called Sample 1 (S1), the sample in the middle is called Sample 2 (S2), and the bottom is called Sample 3 (S3). Analysis section is section A-A from Figure 6.

One of the ways to categorize waste is to look at the organic content of the waste (Landva and Clark in Zekkos, 2008), to determine the value of organic content by testing the ash content first which the value will be used to determine the organic content of the waste. From the test results that have been done, the results are shown in Table 7.

Table 7. Test results of organic waste content

Sample	Ash Content (%)	Organic Content(%)
S1	27.59	72.41
S2	30.14	69.86
S3	56.32	43.68

In Table 7 the organic content of waste from time to time is decreased, which identifies that in the samples taken decomposition process and showed that the three samples are taken with different periods of accumulation. One of the parameters of the waste is the specific gravity (*Gs*) which is dimensionless. The Specific gravity values of waste at Piyungan disposal site can be seen in Table 8.

Table 8. Test results of specific gravity

Sample	Specific gravity
S1	1.82
S2	1.93
S3	2.05

In Table 8 there is an increment of waste embankment at the Piyungan disposal site, which is from 1.82 to 2.05. When compared with the value of organic content, the increase of specific gravity of waste is inversely related to its organic content. The less organic content the greater the specific gravity of waste, but it should be remembered that the reduction of organic content cannot significantly increase the specific gravity of waste because in the waste embankment is dominated by inorganic materials in plastic form where the value of specific gravity relatively low.

Based on field density test using sand cone method, obtained bulk density (γ_b), moisture content (w), dry density (γ_d) are seen in Table 9.

Table 9. Field density

Sample	w (%)	γ_b (kg/cm^3)	γ_d (kg/cm^3)
S1	95.19	0.85	0.43
S2	148.97	1.50	0.60
S3	63.48	1.45	0.89

From the result of field density test in Table 9 can be seen that the density of waste embankment has increased from time to time. According to Babu (2014) the minimum and maximum solid field density varies from 0.4 to 1.6 gr/cm^3, the field density of the waste at the Piyungan disposal siteis in the range of criteria. In terms of dry density (γ_d), the result is 0.43 to 0.89 gr/cm^{3}which have a low value when compared to the typical soil such as dry density of sand (1.43 to1.86 gr/cm^3).

Permeability of waste embankment is obtained by permeability test using raw cell in the laboratory, based on the results of the test can be seen in Table 10.

Table 10. Permeability test result

Sample	k (cm/s)
S1	4.32×10^{-5}
S2	4.43×10^{-5}
S3	3.27×10^{-5}

From Table 10 it can be seen there is a decrease value of waste permeability, but the changes of permeability is not very significant. The problem of stability analysis of the waste embankment is to get the proper shear strength parameters for the waste and to develop an appropriate analysis. Based on direct shear test in the laboratory the value of shear strength can be seen in Table 11.

Table 11. Shear strength parameter

Sample	Laboratory Test		Engineering Judgment
	c (kPa)	φ (°)	φ(°)
S1	0	46.70	35.02
S2	0	48.13	36.10
S3	0	55.98	41.98

In Table 11 it can be seen that the increase of waste friction angle from the relatively earliest waste to the oldest waste from 35.02° to 41.98°, but for the cohesion value is 0 kPa. The reduced of organic levels and changes of densityare affecting the increase of shear strength parameter.

2. Analysis of Waste Stability

In this research for stability analysis of the waste embankment there are two principal analyzes which are waste embankment without reinforcement (Figure 7) and waste embankment with reinforcement (Figure 8). In this analysis there will be four different scenarios for waste embankment without reinforcement which is shown in Table 4.6.Bench geometry with reinforcement are created to improve stability of the waste embankment. In this analysis there arethreescenarios using bench geometry with reinforcement as in Table 12.

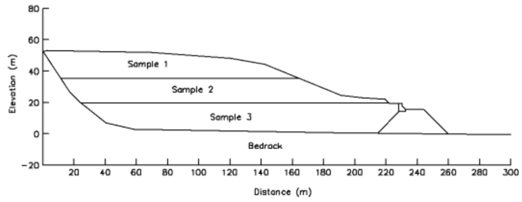

Figure 7. Model without reinforcement

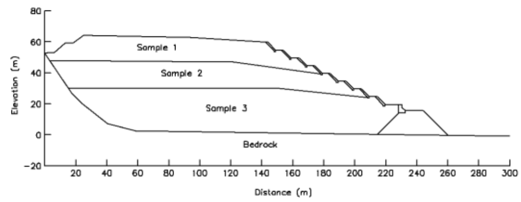

Figure 8. Model with reinforcement

Table 12. Modelling condition without reinforcement

Name	Description
Scenario 0	Height of Embankment is 36 m, slope angle 26° (initial condition)
Scenario 1	Height of Embankment is increased up to 10 m from initial conditions, slope angle 26°
Scenario 2	Height of Embankment is increased up to 10 m from initial conditions, slope angle 30°
Scenario 3	Height of Embankment is increased up to 10 m from initial conditions, slope angle 34°

Table 13. Modelling condition with reinforcement

Name	Description
Scenario 1	Height of Embankment is increased up to 10 m from initial conditions, slope angle 26 ° , with bench geometry and reinforcement
Scenario 2	Height of Embankment is increased up to 10 m from initial conditions, slope angle 30 ° , with bench geometry and reinforcement
Scenario 3	Height of Embankment is increased up to 10 m from initial conditions, slope angle 34 ° , with bench geometry and reinforcement

The results of the analysis can be seen in Table 14, in the existing condition, the height of the waste embankment reach 36 m from the toe with 26° slope angle. From the four scenarios we can see that there is a significant change of safety factor from scenario 0 to scenario 1 due to the increase of embankment height.

Table 14. Value of Safety Factor

Scenario	Safety Factor					
	Without Reinforcement			With Reinforcement		
	O	J	M-P	O	J	M-P
0	2.301	2.290	2.440	-	-	-
1	1.720	1.716	1.764	2.005	1.940	2.276
2	1.489	1.484	1.533	1.736	1.683	1.991
3	1.287	1.285	1.319	1.454	1.418	1.648

Method: Ordinary (O), Janbu (J), Morgenstern-Price (M-P)

Table 14 shows Janbu's method gives the value of the lowest safety factor compared with other methods, therefore the result of Janbu's method will be used in further analysis.

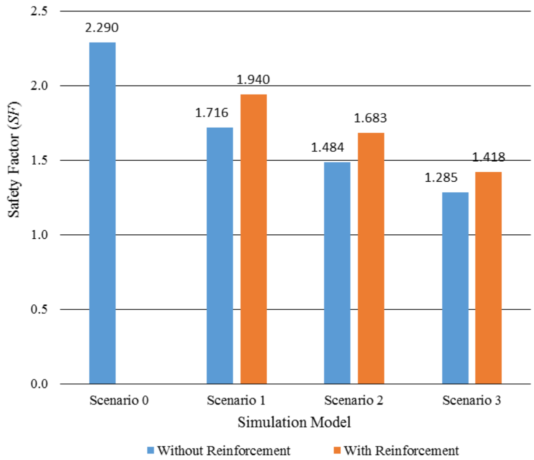

Figure 9. Comparison of the safety factor of each model

At Figure 9 is indicated the decrease of the safety factor for each model.The higher and sloping the waste embankment the smaller the safety factor. The addition of the reinforcement on the model gives a significant increase which is sufficient to make the slope more stable. The value of the safety factor generated from the analysis is compared with the existing references and regulations. There are some regulation and references of safety factor:

a. Bowles (1987) minimum safety factor > 1.07
b. Referring to the Standardization of Indonesia (SNI 03-1962-1990) the value of safety factor at Piyungan disposal site is included in low risk, without earthquake modeling, with maximum shear strength parameters with less accurate data accuracy resulting in a minimum safety factor is 1.40
c. Referring to the Regulation of the Minister of Public Works of the Republic of Indonesia Number 03/PRT/M/2013 minimum safety factor for waste embankment in disposal site is 1.50.

Based on the regulation can be seen the suitability of the safety factor for each model in Table 15 and Table 16.

Table 15. Without reinforcement

Model	SF	Control		
		Bowles >1.07	SNI ≥1.40	Public Works ≥1.50
Scenario 0	2.290	√	√	√
Scenario 1	1.716	√	√	√
Scenario 2	1.484	√	-	-
Scenario 3	1.285	√	-	-

√ = fulfilled - = unfulfilled

Table16. With reinforcement

Model	SF	Control		
		Bowles >1.07	SNI ≥1.40	Public Works ≥1.50
Scenario 0	-	-	-	-
Scenario 1	1.940	√	√	√
Scenario 2	1.683	√	√	√
Scenario 3	1.418	√	√	-

√ = fulfilled - = unfulfilled

The results show that the existing condition (scenario 0) safety factor is 2.290 (stable condition), while the optimum scenario without reinforcement is scenario 1 with the safety factor 1.716. In Reinforcement condition, scenario 2 is the most optimumresult with safety factor 1.683 with the slope angle 30°.

E. CONCLUSION

The conclusions of this research is the occurrence of changes in waste parameters either engineering or mechanical properties are based on the age of waste (decomposition process). For the mechanical properties of the waste as organic content decreased from 72.41% to 43.68%, the specific gravity increased from 1.82 to 2.05, the dry density of the field also increased from 0.43 kg/cm³ to 0.89 kg/cm³ . The value of waste permeability decreased but not very significant. For the shear strength parameters increase from time to time, where the friction angle value changed from 35.02° to 41.98° and the obtained cohesion value is

0 kPa, the reduced of organic levels and changes of particle shape affect the increase of shear strength parameter.

From the analysis that has been done can be seen that Janbu's method gives the value of the lowest safety factor compared with other methods. From the all scenarios we can see that there is a significant change of safety factor from scenario 0 to scenario 1 due to the increase of embankment height. In the model without reinforcement the optimum scenario is scenario 1 scenario with safety factor 1.716. The most optimum model with reinforcement is scenario 2, the capacity of the embankment can be increased up to ±10 m height from existing and slope angle up to 30° with safety factor 1.683.

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