Land Stability at the Final Closing of Waste Final Disposal Supit Urang in Malang City

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***Abstract*—Amount of waste that enters waste final disposal (TPA) Supit Urang is 833.625 m³/day, with a gradual pile pattern up to ± 12 meters. From 2018 until 2020, new cell was being established. On 13th July 2018, landslide hit the active cell area so that it was necessary to close the landfill zone at the TPA. Based on this background, it is necessary to calculate the landfill stability in landfill management until the new cell is done. The stability calculation also anticipates the subgrade strength and remaining waste cell capacity. Research method was carried out by observing the amount of incoming waste, characteristics of waste at the TPA, topography measurement and the results of observations of subgrade strength. In determining the calculation of land stability analysis, Geo 5 program was used. For technical data, topographic measurement was conducted directly at the TPA and compared with existing topography obtained from secondary data. Based on the topography result, it will be determined the contour slice in the field and a total slice of landfill plan. The result of this study shows that the landfill stability depends on subgrade type and landfill structuring at the TPA.**

***Keywords*— Landfill Stability, TPA, Waste Management.**

I. INTRODUCTION

MALANG City is one of the most populous city in East Java Province. According to Malang City in Figures 2018, Malang City has an area of 110.06 km consisting of 5 subdistricts with total population of 861,414 people[1]. It makes Malang City classified as Big City. Most human activities produce waste [2]. The greater the population will affect the amount of waste generated at the Waste Final Disposal (TPA/*Tempat Pemrosesan Akhir*).

Landfill are final repositories for unwanted wastes around the cities. Beside the landfill waste are often burned to conserve space. Landfill especially sanitary landfill represented a improvement over the open dumping. Sanitary landfill can controlled placement of waste, greatly reduced public health risk from waste over the cities. Based on Facilitating the Preparation of the 2016 Malang City Waste Management Master Plan [3], a number of wastes that enters TPA is 400-460 tons/day. The level of waste management service entering to TPA is ±69% from the total population. In TPA Supit Urang, active cell reaches pile height at ±15-20 m. Landfill pattern at TPA Supit Urang uses a gradual piling system. The landfill slope on the edge is 30° which is located ± 10 meters from the cell edge in order to avoid landslides and work accidents at the TPA Supit Urang. According to Malang City Environmental Agency data, landslide hit the active cell area on 13th July 2018. Considering that incident, if the new cell development is done, it is necessary for good and safe active cell closure planning

II. METHOD

This study will review the technical stability of landfill at the closing of the TPA. For cell that has been used as active landfill area, the height of the waste pile has reached the danger limit and there has been erosion in the cell causing casualties. It is necessary to have the management of active cell operations until the development of new cells completed [4]–[7]. This condition makes the active cell feasible to be conducted in technical aspects, financing aspects, and institutional aspects. It is expected that the existence of this study will make waste management better.

The stability of landfill is controlled in broad therm by the following factor :

- The properties of supporting soil
- The strength characteristic and weight of refuse
- Type of cover soil
- Inclination of the slope

Based on these criteria, a detailed calculation of soil reinforcement is needed. Assessment of the stability of solid waste landfills is somewhat less reliable than for soil embankments. The unit weight of refuse and its strength are difficult to determine and could vary over a wide range. Assessment of these variables is largely based on case histories and site-specific investigations [8].

Process of collecting data was conducted by gathering all data that supported the Study of Waste Management at the Cell Closing in TPA Supit Urang. The primary data collection was done by conducting survey at TPA Supit Urang [9] and interview with Provincial Agency of Residential Environment Sanitation Development and Environment Agency in this case Technical Implementation Unit of TPA Supit Urang. Survey of primary data consisted of:

1) Data of total waste entering to TPA which was recorded for 8 days to take the average.

2) Data of waste density obtained from waste weighing survey at active cell.

Waste collection was done by digging a hole in the surface of the landfill in an active cell (1.0 m x 1.0 m x 1.0 m), then weighting the waste which was taken with volume of 1 m³.

3) Data of land contour obtained from survey of active cell topography that will be closed.

The land measurement was conducted with measurement distance at ± each 10 meters. Thus, the overview of land and the slices ware obtained in detail.

4) Data of land stability that consisted of NSPT, Cone Penetration Test (CPT) and lab result of the land for land parameter at the TPA.

5) Setting the height of the waste piles in order to reduce the danger of slope instability.

Slope stability analysis was carried out by calculating the reinforcement of piles above the ground, to prevent potential landslides. Slope stability analysis uses 2 methods in its calculation, which are Limit Equilibrium Method (LEM) and Finite Element Method (FEM). The commonly used method is Limit Equilibrium Method [10]. LEM is one of the methods to determine the number of safety factor (SF) from piles. In contrast to the FEM, the avalanche field is determined by finding the weakest point in the plot of land. FEM does not consider the stress-strain relationship and deformation on the land. LEM is a method that uses equilibrium principle. This method assumes that the avalanche field is possible to occur in landfill. LEM is calculated by dividing the avalanche field to slices (method of slice). The avalanche field assumption can be in the form of *circular* and *planar* (*non circular*), as seen in Figure 1.

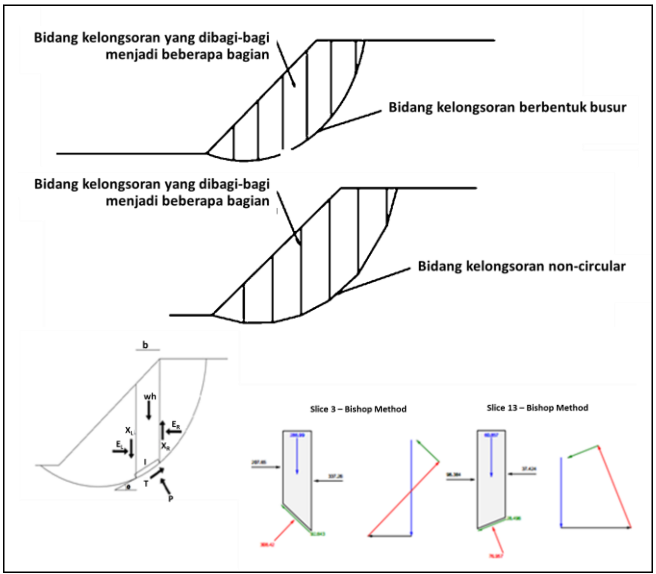

Figure 1. Landslide and Bishop Calculation Method

The calculation for slices was developed by some experts, among others Fellenius, Bishop, Janbu's, Spencer, Morgenstern-Price, Corps of Engineer, Lowe-Karafiath, Sarma and many more. The calculation difference depends on the limit equilibrium and assumptions regarding inter-slice forces. The calculation used is Limit Equilibrium Method (LEM) developed by Bishop. This method uses avalanche calculation of circular shear surface. This method considers the interslice normal stress but does not use interslice shear stress.

Process for finding the number of SF which is feasible to use is by using iterative process at each avalanche field divided by slices path in accordance with formula 1 and 2.

The use of this analysis becomes the basic concept of calculation with Geo 5 program.

6) The calculation of slope stability analysis uses Geo5-2017 program. This calculation is made by Limit Equilibrium Method/LEM.

Avalanche field assumption uses circular shaped field. Slice cut calculation uses interslice forces with the calculation developed by Bishop. The formula used in this method is as below:

$$FS = \frac{1}{\sum W sin\alpha} \sum \left[\frac{c.\beta + W tan\varphi - \frac{c\beta}{FS} sin\alpha . tan\varphi}{m_\alpha} \right] \quad (1)$$

$$m_a = cos\alpha + \frac{sin\alpha tan\varphi}{FS} \quad (2)$$

Where

c : cohesion

β : the width of each slice.

φ : angle of shear resistance

α : the inclination angle between the avalanche field and the center of weight of the slice path

W : weight of each path

W : ɤ x volume of each path

ɤ : specific weight

7) Recontouring Active Land.

The topography measurement will produce contour map from waste cell at the TPA. After contour was formed, the waste was covered by overburden. The overburden (*material tanah penutup*) is in accordance with [11] as described in the Figure2. Recontouring and its compaction processes were carried out gradually in layers by paying attention to the landscape. The landscape was made by considering the remaining service life of active cells and landscape that was in accordance with the landfill stability. The result of this study is expected to be a reference for closing the TPA.

III. RESULTS AND DISCUSSION

A. *Number of Waste Entering the TPA*

Table 1 Survey was conducted by calculating a number of wastes entering the TPA for 8 days. At TPA Supit Urang, there is no weighbridge. The measurement was performed by making assumption of transport truck to 3 types based on volume. Type A is transport equipment, such as dump truck or arm roll with waste volume at 7m³. Type B is transport equipment, such as dump truck or arm roll with equipment, such as dump truck or arm roll with waste volume at 9m³. Type C is transport equipment, such as dump truck or arm roll with waste volume at 11m³. This assumption was taken based on weighing on the nearest weighbridge owned by the Transportation Department and is determined to be the standard weighing record in TPA Supit Urang. The result can be seen on Table1.

Table 1.
Survey Result of Waste Entering TPA

No	Day	Vol. Vehicle unit/day	Vol. Waste m³/day
1	I	112	1.050
2	II	87	855
3	II	92	920
4	IV	55	531
5	V	78	755
6	VI	88	871
7	VII	85	837
8	VIII	90	850
	Number	687	6.669
	Average	86	833.625

B. *Density Measurement at Zone 2 of TPA*

Waste density survey was carried out to determine the specific weight of waste compacted at the TPA. The sampling point was in the active zone at the TPA with the landfill location as seen on Figure 2. Dimensional excavation (1.0 m x 1.0 m x 1.0 m) was with total weight at 508.5 kg. The

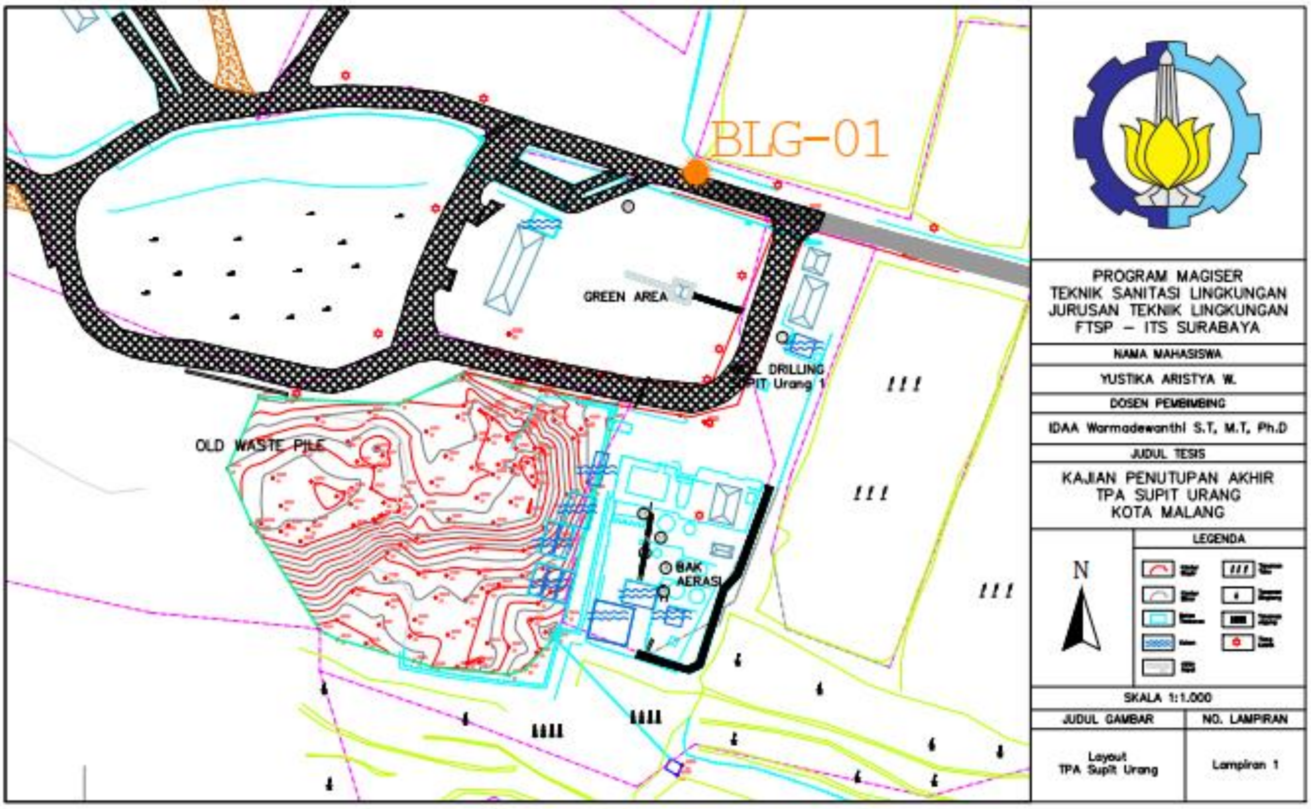

Figure 2. Layout TPA and Zona Contour 2 TPA Supit Urang.

density or specific weight of waste (kg/m³) was:

$$\rho = \frac{m}{v} = \frac{508{,}5\ kg}{1\ m^3} = 508{,}5\ \text{kg/m}^3$$

C. Water Final Cover Material

The final cover system refers to the final cover standart on the sanitary landfill. Layot final cover material as seen on Figure. 3.

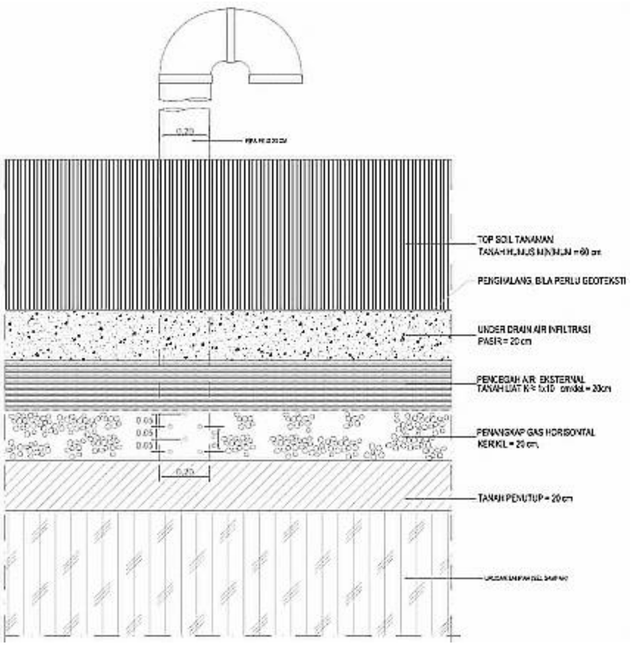

Figure 3. Final Over Material

Arrangement as follows :

a. On the top of the old waste is covered with a 30 cm thick layer of soil. Soil coverd must with compaction when coveb red on the top of waste.

b. Gravel carpet layer with diameter 30-50 mm, this layer has function as horizontal gas catcher, with is associated with vertical gas catchers.

c. Clay layer with 20 cm thick, this clay layer has maximum permeability 1 x 10^{-7} cm/sec.

d. Gravel with a diameter of 30-50 mm, has function as under drain infiltration water. This layer keep the water infiltration in landfill area towards the drainage system. When needed a geotextile layer is installed on the top to prevent the entry of the soil above it.

D. Topography Measurement of Waste Cell

The topography measurement was conducted at Zone 2 of TPA Supit Urang with a land area of 7172.737 m² and depiction of slices cross the land every 10 m. the result of the slices was aimed to know the waste contour and the recontouring plan for TPA closure by using Geo 5 Program.

E. Slope Stability Analysis

The contour measurement, contour interslice and land data were data needed to calculate the slope stability analysis. Survey of land test was made to determine top soil condition and land parameter to be used in the recontouring planning for TPA closure. The land test with CPT and NSPT used Begemen Friction-Cone with a capacity of 250 kg/cm².

The location of land test can be seen on Figure 2. In 4 times testing, there is the best soil result, namely cone point 1 and the worst result at cone point 4. The result of cone at point 1 and point 4 will be studied to determine the advanced parameter as seen on Table 2 and Table 3.

Meanwhile, the NSPT result at point 1 and point 4 was also studied to determine the advanced parameter as seen on Table 4 and Table 5.

Table 2.
Cone Result of Point 1

Depth m	qc kg/cm^2	consistency	Cu ton/m^2	
0.0	0	-	0	
0.2	70	stiff	9.29	
0.4	60	stiff	7.86	
0.6	65	stiff	8.57	
0.8	60	stiff	7.86	
1.0	70	stiff	9.29	8.571429
1.2	80	very stiff	10.67	
1.4	125	very stiff	16.67	
1.6	170	hard	20	
1.8	185	hard	20	
2.0	200	hard	20	17.46667

Table 4.
NSPT Result of Point 1

Depth m	qc kg/cm^2	consistency	Cu ton/m^2	
0.00	0	-	0	
0.20	75	stiff	20.00	
0.40	60	stiff	15.71	
0.60	65	stiff	17.14	
0.80	55	stiff	14.29	
1.00	70	stiff	18.57	17.14286
1.20	75	stiff	20.00	
1.40	125	very stiff	33.33	
1.60	160	hard	40	
1.80	175	hard	40	
2.00	200	hard	40	34.66667

Table 3.
Cone Result of Point 4

Depth m	qc kg/cm^2	consistency	Cu ton/m^2	
0.0	0	-	0	
0.2	15	soft	1.875	
0.4	15	soft	1.875	
0.6	15	soft	1.875	
0.8	20	soft	2.5	
1.0	30	middle	3.75	2.375
1.2	30	middle	3.75	
1.4	30	middle	3.75	
1.6	20	soft	2.5	
1.8	20	soft	2.5	
2.0	20	soft	2.5	3
2.2	20	soft	2.5	
2.4	15	soft	1.875	
2.6	15	soft	1.875	
2.8	20	soft	2.5	
3.0	20	soft	2.5	2.25
3.2	30	middle	3.75	
3.4	40	middle	5	
3.6	40	middle	5	
3.8	30	middle	3.75	
4.0	20	soft	2.5	4
4.2	20	soft	2.5	
4.4	20	soft	2.5	
4.6	30	middle	3.75	
4.8	30	middle	3.75	
5.0	45	stiff	5.7143	3.642857
5.2	50	stiff	6.4286	
5.4	60	stiff	7.8571	
5.6	60	stiff	7.8571	
5.8	65	stiff	8.5714	
6.0	50	stiff	6.4286	7.428571
6.2	40	middle	5	
6.4	35	middle	4.375	
6.6	30	middle	3.75	
6.8	30	middle	3.75	
7.0	20	soft	2.5	3.875
7.2	20	soft	2.5	
7.4	40	middle	5	
7.6	60	stiff	7.8571	
7.8	80	very stiff	10.667	
8.0	120	very stiff	16	8.404762
8.2	125	very stiff	16.667	
8.4	145	very stiff	19.333	
8.6	160	hard	20	
8.8	185	hard	20	
9.0	210	hard	20	19.2

Table 5.
NSPT Result of Point 4

Depth m	qc kg/cm^2	consistency	Cu ton/m^2	
0.00	0	-	0	
0.20	15	soft	3.75	
0.40	15	soft	3.75	
0.60	15	soft	3.75	
0.80	20	soft	5	
1.00	30	middle	7.5	4.75
1.20	30	middle	7.5	
1.40	30	middle	7.5	
1.60	20	soft	5	
1.80	20	soft	5	
2.00	20	soft	5	6
2.20	20	soft	5	
2.40	15	soft	3.75	
2.60	15	soft	3.75	
2.80	20	soft	5	
3.00	25	middle	6.25	4.75
3.20	30	middle	7.5	
3.40	45	stiff	11.42857	
3.60	45	stiff	11.42857	
3.80	30	middle	7.5	
4.00	25	middle	6.25	8.821429
4.20	25	middle	6.25	
4.40	25	middle	6.25	
4.60	30	middle	7.5	
4.80	35	middle	8.75	
5.00	48	stiff	12.28571	8.207143
5.20	50	stiff	12.85714	
5.40	55	stiff	14.28571	
5.60	55	stiff	14.28571	
5.80	65	stiff	17.14286	
6.00	50	stiff	12.85714	14.28571
6.20	45	stiff	11.42857	
6.40	40	middle	10	
6.60	30	middle	7.5	
6.80	30	middle	7.5	
7.00	25	middle	6.25	8.535714
7.20	25	middle	6.25	
7.40	45	stiff	11.42857	
7.60	60	stiff	15.71429	
7.80	75	stiff	20	
8.00	120	very stiff	32	17.07857
8.20	125	very stiff	33.33333	
8.40	150	very stiff	40	
8.60	160	hard	40	
8.80	180	hard	40	
9.00	220	hard	40	38.66667

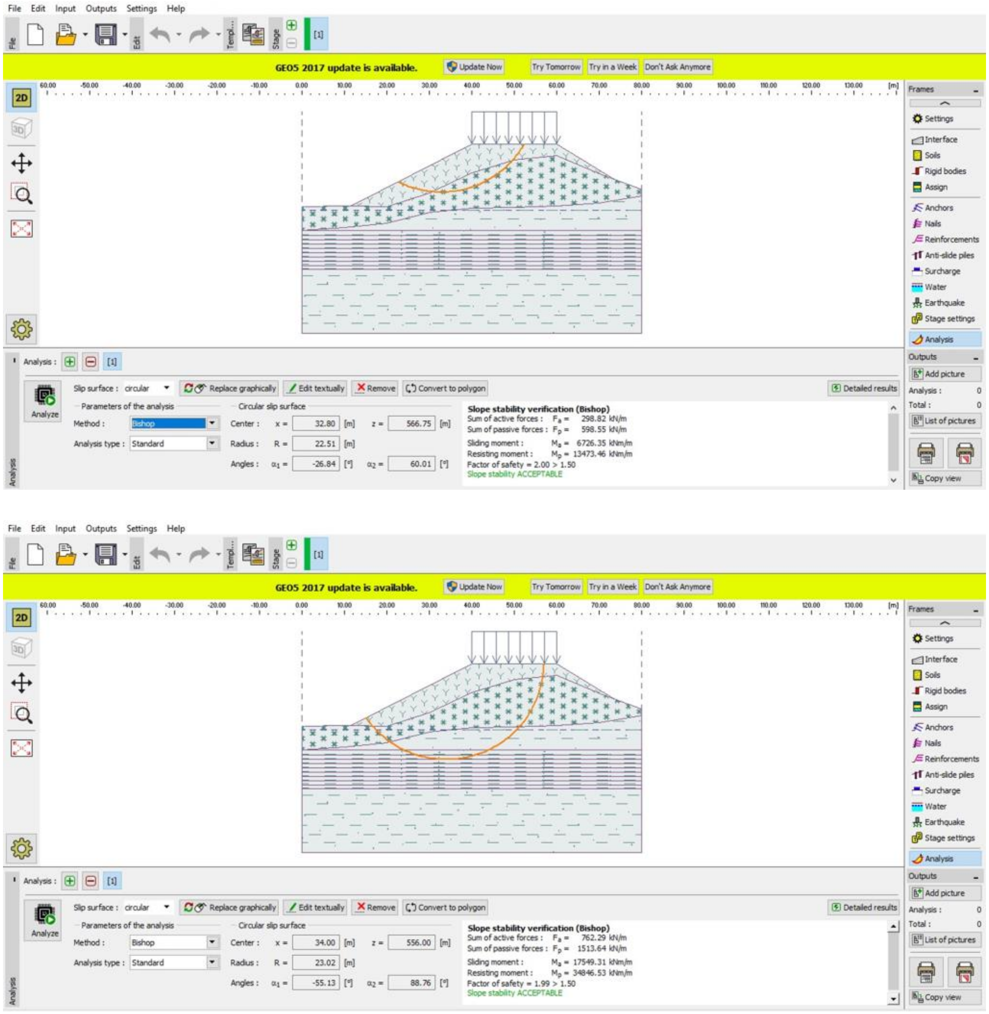

Figure 4. Calculation of Soil Stability With The Geo5 Program

In the slope stability study in Geo-5 program, it is needed parameter γ, Cu and ϕ [12]. The result of the soil test must be correlated based on the bearing capacity of the foundation based on the standart penetration test results. Correlation between N values and soil characteristics that are in accordance as seen as Table 6.

Table 6.
SPT Cohesionless (J.E BOWLES 1984)

Cohessionless Soil					
N (blows)	0 - 3	4 - 10	11 - 30	31-50	>50
γ (KN/m³)	-	12-16	14-18	16-20	18-23
ϕ (°)	-	25-32	28-36	30-40	>35
State	Very Loose	Loose	Medium	Dense	Very Dense
Dr (%)	0-15	15-35	35-65	65-85	85-100
Cohessive Soil					
N (blows)	< 4	4-6	6-15	16-25	>25
γ (KN/m³)	14-18	16-18	16-18	16-20	>20
Qu (kpa)	<25	20-50	30-60	40-200	>100
Consistency	Very Soft	Soft	Medium	Stiff	Hard

These parameters are needed either for land parameter and waste parameter. Specifically for the parameter Cu, it will be converted from the qc obtained from the result of the land test.

1) *Land Parameter*

For land parameter ϕ, it was 0°, while subgrade γ used was 1.6kg/m³. And for Cu as seen on Table 6 and Table 7 as the result of land test that has been converted as follows

2) *Waste Parameter*

In accordance with density calculation of cell at the TPA, it was obtained that γ waste used was 508.5 kg/m³ or 0.5 ton/m³. The calculation of ϕ waste with correlation to γ waste is as follows:

Loose

12-16 = 5
25-32 = 8
For 1 Kn/m³ = 8/5 = 1.6
0.1 ton/m³ = 1.6
0.5 ton/m³ = x
So x = 1.6 x 5 = 8°

Medium

14-18 = 5
25-36 = 9
For 1 Kn/m³ = 9/5 = 1.8
0.1 ton/m³ = 1.8
0.5 ton/m³ = x
So x = 1.8 x 5 = 9°

Medium

16-20 = 5
30-40 = 11
For 1 Kn/m³ = 11/5 = 2.2
0.1 ton/m³ = 2.2
0.5 ton/m³ = x

So x = 2.2 x 5 = 11°

ϕ value used in the calculation later is median, which is ϕ = 9°.

F. Land Stability Calculation with Geo 5 Program

Soil test was taken with CPT and NSPT. Data entered was landfill parameter and subgrade landfill (γ, Cu and ϕ). It was to enter the temporary loading parameter for the designation of heavy equipment and trucks that operated. Slope stability analysis is declared safe if the safety factor >1.5.

The maximum height is planned as high as 15 m because the slope of the final cover material has a grading with a slope of not more than 30 degrees (ratio 1: 3). An example of calculation appears in the below Figure. 4.

IV. CONCLUSION

The conclusion from this study is with the average of vehicles ritase waste carrier at 83 units/day, the number of waste entering to TPA Supit Urang can be estimated at 833.625 m^3/day. The amount of loose waste density at TPA is 256.42 kg / m^3, meanwhile compacted waste density at TPA active zone is 508.5 kg/m^3. Area of TPA active zone which is planned will be closed based on topography measurement at 7172.737m^2. Based on CPT and boring data, it was conducted subgrade analyses with Geo5 program. Recommendation height is 12 meter with a slope angle of no more than 30 degrees. Subgrade analyses and landfill setting which is the basis for the landfill stability in order to avoid landslides.

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