CASE STUDY OF THE CAUSES OF FAILURE OF COMBINATION OF GABION AND GEOTEXTILE CONSTRUCTION TO HANDLE LANDSLIDES ON THE SLOPE OF KARIANGAU SUBSTATION, BALIKPAPAN, EAST BORNEO

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CASE STUDY OF THE CAUSES OF FAILURE OF COMBINATION OF GABION AND GEOTEXTILE CONSTRUCTION TO HANDLE LANDSLIDES ON THE SLOPE OF KARIANGAU SUBSTATION, BALIKPAPAN, EAST BORNEO

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ABSTRACT

The slope of the GI Kariangau, Balikpapan, East Kalimantan uses a combination of gabion and geotextile construction to handle landslides on the slopes. However, there was a failure that indicated deformation of the gabion reinforcement and damage to the geotextile sheet. The failure of the reinforcement was caused by a landslide on the slope. This design begins with the collection of the necessary secondary data. Then proceed to calculate the stability of the gabion reinforcement at each level. This was followed by modeling the slope using the Geo5 2020 slope stability demo version program to get the safety factor value. Analysis of the program was carried out under various conditions, namely slopes before and after reinforcement, excavation at the foot of the slopes, and variations in groundwater level. From the results of the analysis, the value of the slope safety factor before and after being reinforced was 5.46 and 5.76. An increase in the value of the safety factor before and after the reinforcement of gabions shows that gabions play a role in increasing slope stability. The value of the slope safety factor before and after the landslide was 5.46 and 0.78. The decrease in the value of the slope safety factor before and after excavation activities shows that excavation has an effect on reducing the value of slope stability but is still within safe limits. Rain conditions affect reducing the value of soil parameters so that it affects the strength of the slopes. The failure of the combined construction of gabion reinforcement and geotextiles was caused by a decrease in the value of the shear strength of the soil due to saturated soil conditions in the gabion reinforcement area.

Keywords: *slope, gabion, slope stability, Geo5, safety factor*.

I. INTRODUCTION

A slope is a sloping land surface that connects two places with different heights. A slope can potentially landslide if its stability is disturbed. In the world of civil engineering, several constructions are used as soil retainers to increase slope stability to prevent landslides, such as gabions, geotextiles, and retaining poles.

In this case, the slopes of the GI Kariangau-Balikpapan, East Kalimantan are reviewed, which uses a combination of gabion construction and geotextiles as an effort to increase slope stability. However, when excavation activities were carried out at the foot of the slope, failures in the gabion and geotextile construction were seen as shown in Figure 1.1.

Figure 1.1 Deformation of Shapes in Gabion Construction.

Based on these problems, it is necessary to analyze to determine the alleged causes of the failure of the combination of gabion construction and geotextiles in handling slope failure.

II. LITERATURE REVIEW

2.1 Slope Collapse

A slope is a structure made of soil and rock that connects two places with different elevations. Slopes can occur scientifically or artificially. If the soil surface is sloping, then the weight of the soil parallel to the slope will cause the soil to move downwards (Das, 1995).

2.2 Landslide Mechanism

Mechanically the slope will collapse if it is caused by two things, namely increased shear stress and weakened shear strength. Ralph and Peck (1967) mention that the main cause is that in areas where landslides have occurred, it is likely that there will not be another landslide, so construction activities will begin in that area. However, if the landslide area is likely to occur again, the slightest construction will cause landslides.

2.3 Slope ReinforcementSlope Strength

2.3.1Control

a. Setting the Slope Geometry

By changing the geometry of the slope by cutting or filling can reduce the driving force of the landslide mass and increase the retaining force so that the value of slope stability increases.

b. Control of Surface Water

One way that can be done to control surface water is to plant plants on the surface of the slope and arrange waterways on the surface of the slope. In this way, the water will not stagnate and flow without erosion on the slopes.

c. Controlling Seepage Watertable

Lowering the groundwater of slopes by controlling seepage water is generally quite difficult and requires careful investigation. The methods commonly used are infiltration wells and drainages.

2.3.2 Mooring and Other Actions

Mooring is done by providing certain constructions that are permanent. There are two methods of mooring that can be done, namely anchoring for soil and rock.

2.3.3 Soil Mechanical Reinforcement (Geotextile)

According to Hardiyatmo (2007) in Chasanah (2012), geotextile is a material in the form of sheets made of polymer textile materials and can transmit water. In general, geotextiles are used when constructing retaining soil and strengthening road pavement materials.

2.4 Lateral Earth Pressure

Lateral earth pressure is divided into 3, namely:

1. Resting earth
   pressure This soil pressure is caused by the presence of a mass of soil that is in balance on the retaining wall.
2. Active earth pressure
   Active earth pressure is the pressure that pushes the retaining wall to move forward.
3. Passive earth pressure
   While pressure tries to resist the push from active earth pressure.

2.5 Slope Stability

In Hardiyatmo (2003) slope stability is also known as stability analysis on a sloping ground surface.

2.5.1 Criteria for Safety Factors

The value of the safety factor against slope failure according to Bowles, JE in Sagita (2017) can be seen in Table 2.1.

Table 2.1 Value of safety factor against avalanches.

SF value	Likelihood of landslides
SF < 1.07	Landslides are common
1.07 < SF < 1.25	Landslides have occurred
SF > 1.25	Landslides are rare

In addition, referring to SNI 8460 of 2017 Slope safety factor required for stability analysis soil slopes are shown in Table 2.2 and Table 2.3.

Table 2.2 Values of Safety Factors for Soil Slopes

Costs and Consequences of Slope Failure	Uncertainty level of analytical conditions	
	Low[a]	High[b]
Repair costs are proportional to the additional costs of designing more conservative slopes	1.25	1.5
Repair costs are greater than the additional costs for designing slopes more conservative	1.5	2.0 or more

[a]The level of uncertainty in the analysis conditions is categorized as low, if the geological conditions can be understood, the soil conditions are uniform, the soil investigation is consistent, complete and logical to the conditions in the field.

[b]The level of uncertainty in the analysis conditions is categorized as high, if the geological conditions are very complex, the soil conditions vary, and the soil investigation is inconsistent and unreliable.

Table 2.3 Recommended safety factor values for rock

slopes Rock slope conditions	Recommended safety factor values
Permanent	1.5
While	1.3

2.5.2 Slope Stability

Slope stability analysis is finding the safety factor value in the potential landslide area. In general, this is done based on the boundary balance approach, plastic limit theory, and numerical (finite element) methods.

a. Empirical and Graphical

Methods This method is used for slope stability analysis in short-term and long-term conditions using the experience of planners.

b. Analytical/Numerical

Method Boundary balance method is performed by calculating the balance of forces and moments, as in the modified Bishop, Janbu, and Spencer methods.

While the finite element method in calculating slope stability does not use the assumption of landslide field, but finds a weak plane to get the value of the safety factor.

2.5.3 Stability of Retaining Walls

In order to prevent landslides, the retaining wall needs to be made in a stable condition determined by the value of the safety factor. This value is obtained by comparing the resisting force and the driving force of the landslide as follows:

$$SF = \frac{\text{resisting force}}{\text{driving force}}$$

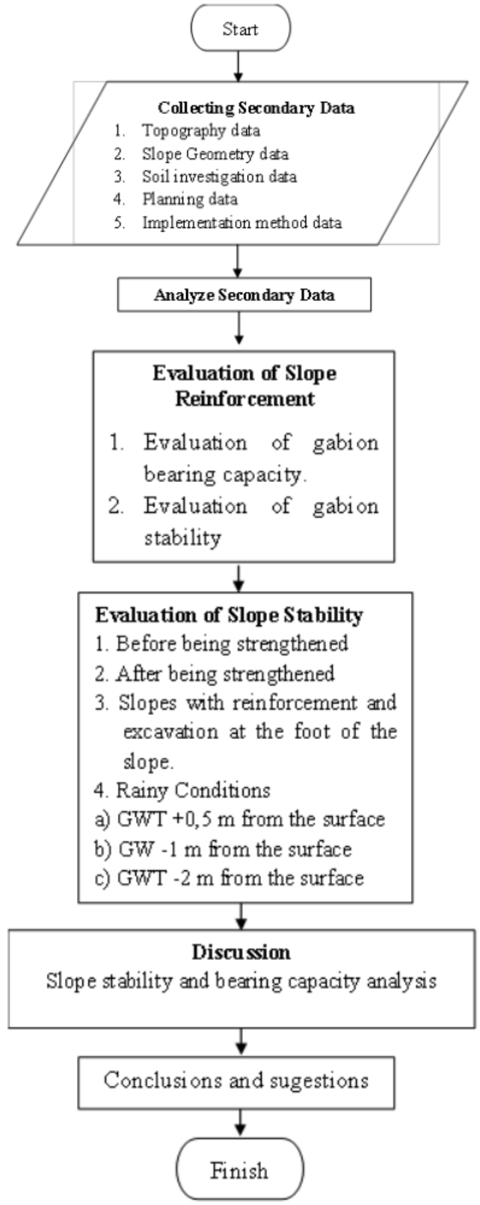
2.6 Gabion Wire

Gabions According to SNI 03-0090-1999, Wire gabions are box-shaped woven steel wires coated with zinc, filled with rocks to prevent erosion. Usually gabions are placed on river bank cliffs to protect rivers from erosion due to scouring of river water.

2.7 Slope Stability Analysis with the Geo5 Program

Geo5 is a program used in the geotechnical field to solve environmental problems related to soil. In the Geo5 program, analytical methods and finite element methods are used by modeling slopes such as real conditions in the field so that the value of the safety factor and the slide line can be known.

III. DESIGN METHODOLOGY



IV. RESULTS AND DISCUSSION

4.1 Data InterpretationData

4.1.1 Interpretation Phase 1 Soil Investigation

In the initial soil investigation, drilling was carried out at 6 different points as shown in Figure 4.1.

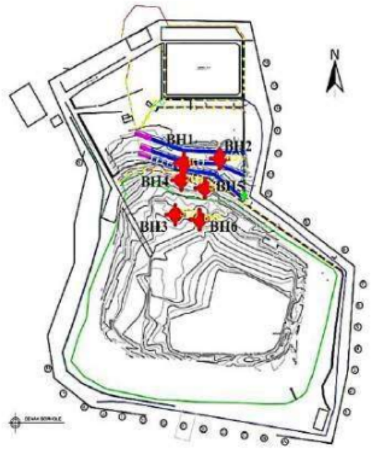


Figure 4. 1 Sampling Location Point Stage 1

a. Point BH 1 (GWL = -3.60 m)

Depth (m)	N_{SPT}	Forecast Soil Type	Consistency
2	7	Clay	Medium
4	12	Sandy Clay	Medium
6	28	Sandy Clay	Very stiff
8	30	ClaySandy	Very stiff
10	41	Sandy Clay	Very Hard
12	>50	Sandy Clay	Very Hard
14	>50	Sandy Clay	Very Hard
16	>50	Sandy Clay	Very Hard
18	>50	Coal	HardCoal
20	>50	Coal	HardCoal

b. Point BH 2 (GWL = -4 , 20 m)

Depth (m)	N_{SPT}	Forecast Soil type	Consistency
2	5	clays	Medium
4	5	Clay	Medium
6	12	Clay Sand	Rigid
8	39	Clay Sand	Very Hard
10>	50	clays	Very Hard
12>	50	clays	Very Hard
14>	50	clays	Very hard
16>	50	clays	Very hard

c. point 3 BH (GWL = -2.30 m)

Depth (m)	N_{SPT}	Forecast Soil type	Consistency
2	9	Clay	stiff
4>	50	Silt	Very hard
6	18	clayspebbly	Very stiff
8	26	clay	is very stiff
10	41	Sandy Clay	Very Hard
12	>50	Coal	Very Hard
14	>50	Clay	Very Hard
16	>50	Coal	Very Hard
18	>50	Sandy Clay	Hard Coal
20	>50	Sandy Clay	Hard Coal

d. Point BH 4 (GWL = -3.10 m)

Depth (m)	N_{SPT}	Soil Type Forecast	Consistency
2	4	silt Sand	Medium
4	7	silt	Medium
6	29	silt Sandy	Highly rigid
8	51	Clay Sand	Highly rigid
10	76	Clay Sand	Very Hard
12>	50	Clay Sand	Very Hard
14>	50	Coal	Very Hard
16>	50	Coal	Very Hard

e. point BH 5 (GWL = -3.15 m)

Depth (m)	N_{SPT}	Forecast Soil type	Consistency
2	6	Silt	Medium
4	12	Silt	Kaku
6	16	Siltpebbly	Kaku
8>	50	Clay Sand	Very Hard
10>	50	Clay Sand	Very Hard
12>	50	Clay Sand	Very Hard
14>	50	Clay Sand	Very Hard

f. pointBH 6 (GWL = -0.05 m)

Depth (m)	N_{SPT}	ForecastSoil type	Consistency
2	2	Clay	Soft
4	4	Clay	Medium
6	18	Clay	stiff
8	32	Clay	Very stiff
10	44	clays	Very Hard
12	>50	Coal	Very Hard
14	>50	Coal	Very Hard
16	>50	GlueSandy silt	Very Hard
18	>50	Sandy Clay withCoal	Very Hard

Based on the results of the soil investigation, it can be concluded that the top layer of topsoil around the test points BH1, BH2, and BH3 is clay, while around the test points BH4, BH5, and BH6 are silt, with varying layer thickness.

4.1.2 Interpretation of Phase 2 Soil Investigation Data

In the second phase of the soil investigation, drilling was carried out at 3 different points as shown in Figure 4.2.

Figure 4. 2 Locations for Stage 2 Sampling.

Based on the data from the 2nd soil test, it can be concluded as follows:

a) At HB-1 (Level 3) the soil is of medium consistency (medium) which is seen based on the qu value of 0.674 kg/cm^2 and 0.751 kg/cm^2. In addition, based on the k permeability values of 1.20 x 10^{-5} and 7.52 x 10^{-6}, it is considered a low-permeability soil, which means it has a slow nature of draining water out of the soil and poor drainage properties.

b) At HB-2 (Level 2) the value of qu shows 0.854 kg/cm^2 which is included in the medium consistency (medium). Meanwhile, the value of k permeability of 1.20 x 10^{-5} and 9.02 x 10^{-6} means that it is classified as with low permeability, which means it has a slow nature of draining water out of the soil and poor drainage properties.

c) At HB-3 (Level 3) the value of qu is 0.201 kg/cm^2 which includes soil with a very soft consistency, which means this soil has a low infiltration rate and poor drainage properties.

4.2 Soil Statigraphy

Based on the results of the interpretation of the soil investigation data, a soil layer stratigraphy can be made. In making soil layer stratigraphy, interpretation data is used on BH1, BH4, and BH3 with a distance between points of *borehole* 50 m and 56 m, so that the soil layers that make up the slopes can be seen in Figure 4.3.

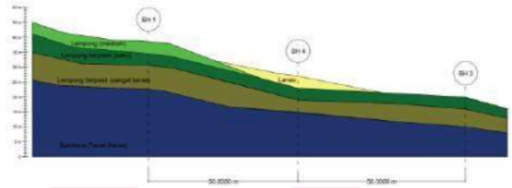


Figure 4.3 Statigraphy of Soil Layers

The value of soil parameters is obtained by using a correlation relationship with the value of N obtained as shown N_{SPT} and soil type, then the parameter values used for each soil layer are in Table 4.1.

Table 4. 1 Parameter Values Each layer Soil

Soil Type	H (m)	□ (kN / m3)	c_u (kN / m2)	φ (°)
Silt	4	16	25	20
Clay (medium)	4	16	30	20
sandy clay (stiff)	4	18	50	22
Sandy loam (very hard)	4 – 8	18	100	25
Coal (hard soil)	>4	22	200	35

4.3 Analysis of Gabion Stability

The value of the safety factor for calculating the stability of gabions is used assumptions according to Bowles in Hardiyatmo (2011) which suggests based on the type of soil, namely FS 1.5 for granular subgrade and FS 2 for cohesive subgrade. Because the subgrade in this design is clay soil which is a cohesive soil, the value of the safety factor 2.

4.3.1 Analysis of Level 1 Gabion Stability

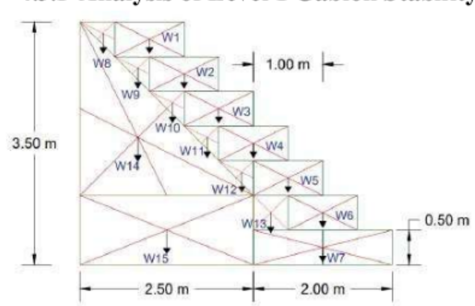


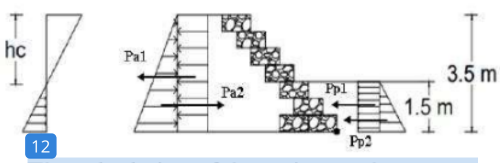
Figure 4.4 Gabion Dimensions Level 1 Distribution

The results of the calculation of the weight unit length for gabions *level* 1can be seen in Table 4.2.

Table 4. 2 Recapitulation of Calculation of Self-Weight Gabions *Level* 1

Section	b (m)	h (m)	γ (kN/m3)	W (kN)	X (m)	M (kNm)
D1	1	0,5	20	10	3,5	35
D2	1	0,5	20	10	3	30
D3	1	0,5	20	10	2,5	25
D4	1	0,5	20	10	2	20
D5	1	0,5	20	10	1,5	15
D6	1	0,5	20	10	1	10
D7	2	0,5	20	20	1	20
D8	0,5	0,5	16	2	3,667	7,333
D9	0,5	0,5	16	2	3,167	6,333
D10	0,5	0,5	16	2	2,667	5,333
D11	0,5	0,5	16	2	2,167	4,333
D12	0,5	0,5	16	2	1,667	3,333
D13	0,5	0,5	16	4	1,25	5
D14	3	2,5	16	60	4	240
D15	3	1	16	48	3,5	168
TOTAL				**202**		**594,667**

Based on the results of the above calculations, the self-weight of gabions at level 1 is 202 kN with a total moment of 594,667 kNm.



The calculation of the active earth pressure moment is described in Table 4.3.

Table 4.3 Recapitulation of Active Earth Pressure Gabions Level 1

	Pa (kN/m)	x (m)	M (kNm)
Pa1	-120,274	1,75	-210,480
Pa2	46,291	1,166667	54,006
Total	**-73,983**		**-156,474**

In the above calculation, the results of the active earth pressure are negative. According to Hardiyatmo (2011) this shows the existence of a tensile force acting on the soil. As a result, the part of the soil that experiences tension becomes cracked. These cracks if filled with rainwater, can reduce the value of soil cohesion.

The depth that expresses the depth of the soil experiencing tension can be obtained:

$$h_{□} = \frac{2□}{□\sqrt{□□}}$$

$$= \frac{2\times 25}{16\times\sqrt{0472}} = 4{,}547 \text{ m}$$

So, the height of the active soil pressure that pushes the gabion reinforcement is obtained

$$h = □ - h_{□}$$

$$= 35 - 4547 = -0349\ □$$

Thus, it is assumed that only the active earth pressure due to the working embankment soil load is (Pa) 46.291 kN with a moment (Ma) 54.006 kNm.

The calculation of the passive earth pressure moment is described in Table 4.4.

Table 4. 4 Recapitulation of Passive Earth Pressure Moments

	Pp (kN/m)	x (m)	M (kNm)
Pp1	222.384	0.750	166.788
Pp2	44.509	0.500	22.255
Total	**266.893**		**189.043**

a. Stability

$$□□_{□□□□} = \frac{□□_{□}}{□□□□□□□□□□□□□}$$

$$= \frac{(□_{□}+□_{□□})}{□_{□□}}$$

$$= \frac{594667 + 189043}{54006}$$

$=14{,}511 > 2$ ....**OK**

b. Slide Stability

$$□□_{□h□□□} = \frac{□□□□□(\tfrac{2}{3}\emptyset) + \tfrac{2}{3}□□ + □_{□}}{□_{□}}$$

$$= \frac{202\times □□\tfrac{2}{□}□□□□ (\tfrac{2}{3}25) + \tfrac{2}{3100}\times + 266893\ 462919952>}{}$$

$=2\ 2$..................... **OK**

c. Carrying

Carrying Capacity Factor Table 4.5Terzaghi

∅	Nc	Nq	N□
20	17.69	7.44	3.64
21	18.92	8.26	4.31
22	20.27	9.19	5.09
23	21.75	10.23	6.00
24	23.36	11.40	7.08
25	25 .13	12.72 Ultimate	8.34

- bearing capacity

$$□_{□} = □□_{□} + □_{□}□_{□} + 05□□□_{□}$$

$$= 100 \times 2513 + 27 \times 1272 + 05 \times 18 \times 2 \times 8.34$$

$$= 3006560 \text{ kN/m}^2$$

- Net ultimate bearing capacity

$$\square_{\square\square} = \square_{\square} - \square_{\square}$$
$$= 3006560 - 27$$
$$= 2979560 \text{ kN/m}^2$$

- Net foundation pressure

$$\square_{\square} = \square - \square_{\square}$$
$$= 202 - 27 = 175 \text{ kN/m}^2$$

- Safety factor

$$\square = \frac{\square_{\square\square}}{\square_{\square}}$$
$$= \frac{2979560}{175} = 17026$$

- Permissible bearing capacity

$$\square_{\square} = \frac{\square_{\square}}{\square}$$
$$= \frac{3006560}{17026} = 175 \text{ kN/m}^2$$

- Eccentricity

$$\square = \frac{\square}{2} - \frac{\square_{\square} - \square_{\square\square}}{\square_{\square}}$$
$$= \frac{2}{2} - \frac{584667 - 54006}{202} = (-)1677$$
$$\frac{\square}{6} = \frac{2}{6} = 0.333$$

If e > B/6 then,

$$\square_{\square\square\square} = \frac{2\square}{3\times(\frac{\square}{2} - \square)}$$
$$= \frac{2\times 202}{3\times(\frac{2}{2} - (-1677))}$$
$$= 50{,}314 \text{ kN/m}^2 < q_a = 175 \text{ kN/m}^2 \textbf{ OK}$$

So it can be said reinforcement Gabions at level 1 are safe to use. The same calculations were carried out on level 2 and 3 gabions, so that the stability values of gabions were obtained as shown in Table 4.6.

Table 4.6 Recapitulation of Gabion Stability Values

Level	Stability	SF	Safe Conditions	Ket.
1.	Rolling Stability	14,511	2	Safe
	Shear Stability	9,952	2	Safe
	bearing capacity	$\square_{\square\square\square}$ = 50,314 kN/m^2	q_a = 175 kN/m^2	Safe
2.	Stability	Overturning373,530	2	Safe
	Shear Stability	28,473	2	Safe
	bearing capacity	$\square_{\square\square\square}$ = 65,344 kN/m^2	q_a = 412,76 kN/m^2	Safe
3	Stability	Rolling406.662	2	Safe
	Shear Stability	46,010	2	Safe
	bearing capacity	$\square_{\square\square\square}$ = 65,344 kN/m^2	q_a = 394.4 kN/m^2	Safe

Based on the calculation of the stability of the three levels of gabions, it can be said that the calculation of the gabion design and the embankment used already meets the value of the safety factor. This is in accordance with the initial goal of PT. PLN East Kalimantan Development Main Unit that the use of gabion construction to protect the slope surface from being eroded.

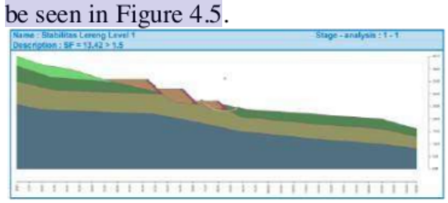
4.4 Analysis of Slope Stability ProgramGeo5

In analyzing the stability of the slope use Geo5 2020 program *demoversion* by incorporating modeling existing slope into the program. A safety factor of 1.5 is used referring to SNI 8460:2017 as shown in Tables 2.2 and 2.3.

4.4.1 Slope Stability Analysis with Gabion Reinforcement at Each Level

This analysis is needed to determine the role of each level of gabion whether it is safe against landslides.

The value of the safety factor against landslides for slopes level 1,2 and 3 based on the results of the Geo5 program analysis can be seen in Figure 4.5.



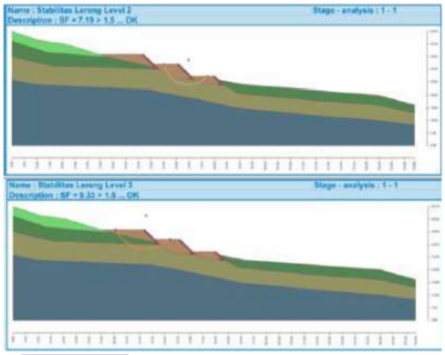


Figure 4.5 Value of Slope Safety Factor with Gabion Reinforcement at Each Level

Based on the results of the analysis with the Geo5 2020 program, the following results were obtained:

1. The value of the safety factor on the slope level 1 is 13.42 > 1.5 (SAFE)
2. The value of the safety factor on the slope level 2 is 7.19 > 1.5 (SAFE)
3. The value of safety factor on the slope level 3 is 9.33 > 1.5 (SAFE)

From these results, it can be said that the use of gabion reinforcement at each level is safe.

4.4.2 Analysis of Slope Stability without Reinforcement

An unreinforced slope stability analysis was conducted to determine the condition of the slope safety value before using reinforcement. The value of the safety factor against landslides on the slopes before being given reinforcement based on the results of the Geo5 2020 program analysis can be seen in Figure 4.6.

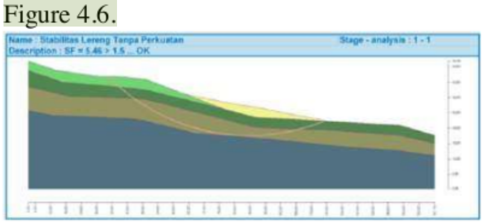


Figure 4.6 Results of Slope Stability Analysis Before Reinforcement

Based on Figure 4.6, the slope safety factor value is 5.46>1.5 which indicates the slope can be said to be safe against landslides.

4.4.3 Analysis of Slope Stability with Reinforcement

After obtaining the value of the safety factor on the slope without reinforcement, then an analysis is carried out on the slope with only the reinforcement of gabions. This is done to determine the effect of gabion reinforcement on the slope safety factor in landslides, which can be seen in Figure 4.7.

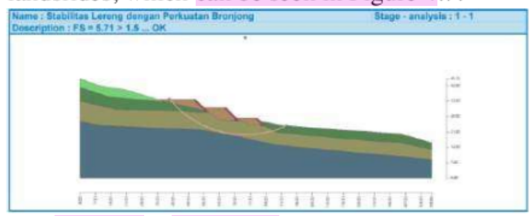


Figure 4.7 Results of Slope Stability Analysis with Gabion Reinforcement.

Next, an analysis of the slopes with additional geotextile reinforcement was carried out as in field conditions. This is done to determine the role of geotextiles on the value of the slope safety factor, which can be seen in Figure 4.8.

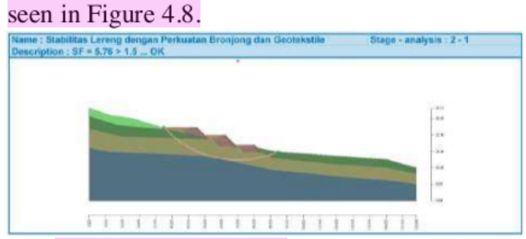


Figure 4.8 Results of Slope Stability Analysis with Geotextile Reinforcement.

Based on Figure 4.6 and the image above, the following results are obtained:

1. The value of the safety factor on the slope before reinforcement is 5.46>1.5 (OK)
2. The safety factor value on the slope with gabion reinforcement is 5.71>1.5 (OK)
3. The value of the safety factor on the slopes with reinforced gabions and geotextiles is 5.76> 1.5 (OK).

By comparing the value of the safety factor of the slopes before and after reinforcement is applied, it is seen that there is an increase. This shows that the combination reinforcement of gabions and geotextiles is able to provide a role in increasing slope stability against landslides.

4.4.4 Analysis of Slope Stability with Excavations at the Foot of the Slope

There are excavation activities at the foot of the slope as shown in Figure 4.9 with an estimated excavation dimension of 8m x 8m x 2m. This excavation was carried out after the slope was reinforced with gabions and geotextiles with an estimated distance of excavation to level 1 reinforcement of gabions of 50-80 m.

Figure 4. 9 Excavation Activities at the Foot of the Slope.

It is necessary to make a model on the program to determine the effect of the excavation on the value of the slope safety factor. The value of the safety factor can be seen in Figure 4.10.

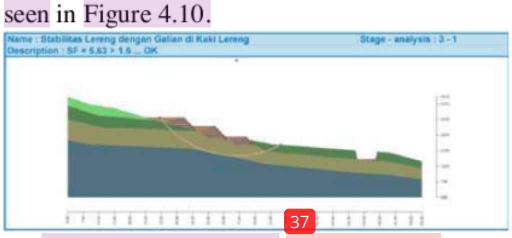


Figure 4. 10 Results of Slope Stability Analysis with Excavations at the Foot of the Slope

Based on Figure 4.10, the slope safety factor value is 5.63> 1.5 indicating the slope is safe against landslides. However, when compared to the slope without excavation, this value decreased from 5.76 to 5.63 after excavation at the foot of the slope. This shows that excavation activities at the foot of the slope affect the value of the slope safety factor against landslides. However, the decline that occurs in this condition the slope can still be said to be safe from landslides.

4.4.5 Analysis of Slope Stability with Variations in Groundwater

To determine the effect of rain conditions on slope failure, it is necessary to model it in the Geo5 program. This condition is modeled by providing variations in the groundwater table on the slopes. Some of the conditions used are the ground water level as high as 0.5 m above the surface as a model when heavy rain occurs, 1 m below the ground surface, and 2 m below the ground surface, can be seen in Figure 4.11.

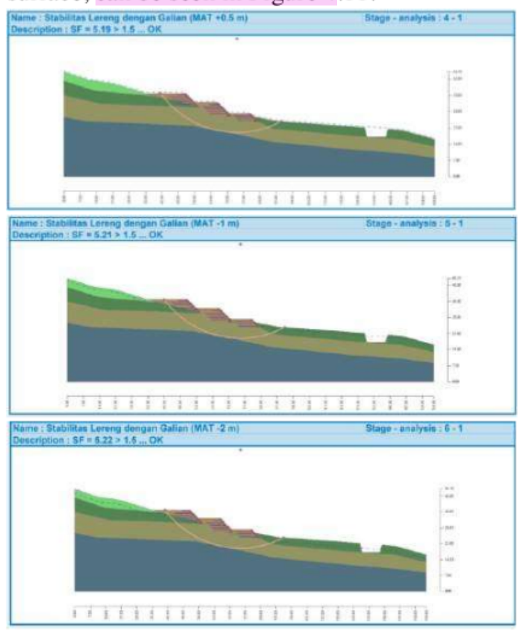


Figure 4. 11 Results of Slope Stability Analysis with Advance Groundwater +0,5 m, -1m, and -2 m

Based on analysis of slope safety factor with the variation of the ground water level, the results are as follows:

1. Value on slope safety factor with MAT 0 m of 5.19> 1.5 (SAFE)
2. The value of the safety factor on the slope with MAT -1 m is 5.21> 1.5 (SAFE)

3. The value of the safety factor on the slope with MAT -2 m is 5.22> 1.5 (SAFE)

From these results, it can be said that the rain conditions modeled with variations in the groundwater level affect reducing the value of the slope safety factor which was originally 5.63 down to 5.19 when heavy rains are modeled with a groundwater level of 0.5 above the surface. However, the decrease in the safety factor that occurs still meets the minimum value of the slope safety factor of 1.5 so that the slope is still said to be safe from landslides.
The recapitulation of the analysis of the slope safety factor values using the Geo5 2020 program can be seen in Table 4.7.

Table 4.7 Value of Slope Safety Factor with Geo5 Program

No.	Slope Conditions	SF	Safe Requirements	Note
1.	Gabions at Level 1	13.42	1.5	Safe
2.	Gabions at Level 2	7.19	1.5	Safe
3.	Gabions at Level 3	9.33	1.5	Safe
4.	Unreinforced	5 ,46	1.5	Safe
5.	Gabion Reinforcement	5.71	1.5	Safe
6.	Gabion and Geotextile Reinforcement	5.76	1.5	Safe
7.	Excavation at the Foot of Slope	5.63	1.5	Safe
8.	MAT +0.5m	5.19	1.5	afely
9.	MAT -1 m	5.21	1.5	Safe
10.	-2 mMAT	5,22	1.5	Safe

Based on analysis of the safety factor of slope stability using Geo5 program in 2020 obtained the value of the safety factor meet the minimum requirements of 1.5. However, this is not in accordance with the conditions that occur in the field, where there is a failure in the construction of a combination of gabions and geotextiles.

4.5 Reviewing Conditions in the Field After Landslides Occurredlandslides

After analyzing the stability of the slopes, it was found that the slopes were safe from. This of course does not explain the cause of failure in the construction of a combination of gabion reinforcement and geotextiles. Therefore, it is necessary to review the condition of the slopes in the field after a landslide occurs. Some of the damage that occurred in the reinforcement construction of gabions and geotextiles can be seen in Figures 4.12 and 4.13.

Figure 4.12 Deformation of Gabion Construction Form

Figure 4.13 The Damage of Geotextile Joints

Damages that occurred to the reinforcement of gabions and geotextiles was caused by landslides due to soil movement. In addition, when observing conditions in the field, it was also found that there were natural pipe holes formed due to the flow of water coming out of the soil as in Figure 4.14 and there was a flow of water that came out due to being trapped in the embankment soil as in Figure 4.15.

Figure 4. 14 Formation of a Natural Piping Hole Due to Water Flows from the Ground

Figure 4. 15 Source of Water that Comes Out of Stockpiled Soil

This condition is certainly different from the results of the initial data interpretation, where the groundwater level is found to be quite deep with a range of 3 m below the surface. Therefore, it is necessary to review the results of the geoelectric survey to determine the condition of underground water flow on the slopes.

4.6 Review of Geoelectrical Survey Results

Based on the results of observations in the field, it can be seen that there are several sources of water that come to the surface from the ground when the weather is sunny. Therefore, a re-analysis of the geoelectric survey data was carried out to determine the presence and distribution of underground water flows.

This geoelectric measurement was carried out by PT. Bangun Prima Semesta with 2-dimensional measurements. It should be noted that this measurement is carried out during the rainy season, with the advantage of being able to clearly see the difference between zones that are saturated with water and those that are not. The location of data collection used as many as 4 paths, can be seen in Figure 4.16. With point 0 for each track starting from the east side and the distance between the electrodes is 5 m.

Figure 4. 16 Geoelectrical Trajectory Plan

After conducting 4 geoelectrical tests with a depth of 36 m for each track, the results of the geoelectrical interpretation are obtained as shown in Figure 4.17 (composition from the most north to south path).

In zones 1 and 2 the water flows from north to south which was originally at a depth of 6 m to a depth of more than 10 m.

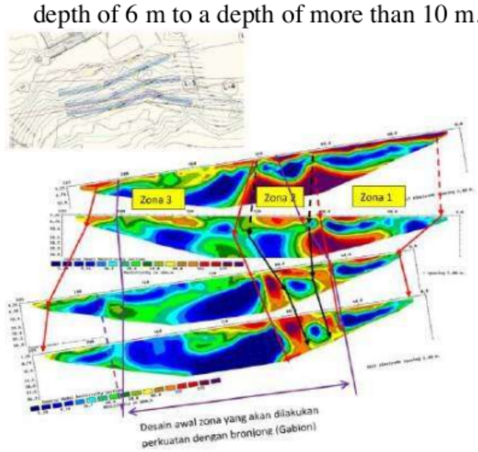


Figure 4.17 Direction of Water Flow

While in zone 3 the water flow from north to south which was originally at a depth of 6 m on track 3 until it comes to the surface on tracks 2, 1, and 4. In zone 3 there are also seepage points/bottom water sources land.

These results indicate that the soil on the surface in zone 3 where there is gabion reinforcement, especially paths 2, 1, and 4 is saturated with water. This is not under the results of soil investigation 1 on the Kariangau slope which is used as a reference in modeling the soil layers that make up the Kariangau slope. Therefore, it is necessary to out a *back analysis* carry or to determine the value of the soil parameter during a landslide.

4.7 Analysis of Slope Stability using *Back Analysis*

According to Arif (2016) *back analysis* is a method used by modeling slopes during landslide conditions so that rock parameter values are obtained. While Metriani, et al. (2019) assumes that back analysis needs to be carried out in order to find out the value of material parameters with a safety factor value of < 1.

Based on the results of the geoelectric survey, it was found that the soil was saturated with water, especially in the part where gabion and geotextile reinforcement were made. This condition is not following with the initial soil assumption. Therefore, it is necessary to do a back analysis to determine the value of the soil parameters that are close to the conditions in the field during landslides. The back analysis is done using the program in 2020 Geo5 *demo version* by *trial and error*. Assuming the soil is saturated with water so that the soil parameters are lowered to obtain a safety factor value close to 1.

4.7.1 Results of Back Analysis

After a back analysis using the Geo5 2020 demo version program shown by trial and error, the soil parameter values are obtained as in Table 4.8. The modeling condition used in the back analysis is when there is heavy rain which is modeled with the groundwater level as high as 0.5 m above the ground surface as shown in Figure 4.18. This is because landslides on the slopes occur during the rainy season.

Table 4. 8 Parameters Result ofBack Analysis

Soil Type	□ **(kN/m^3)**	**c_u (kN/m^2)**	**(°)**
Gabions	20	-	-
Embankment	14	12	0
Clay (medium)	14	12	0
Sandy clay (rigid)	14	15	0
Sandy loam (very hard)	15	18	0
Coal (hard soil)	22	200	35

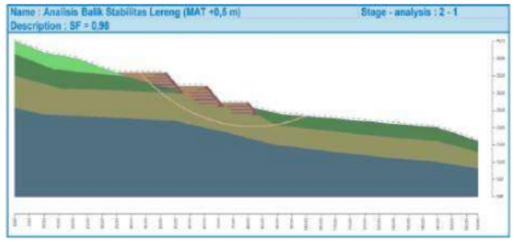


Figure 4. 18 Results of Reverse Analysis of Slope Stability with MAT +0.5 m

Based on the figure above, the slope safety factor value is 0.98 < 1, 07. Referring to Bowles (1991), this value indicates that the slope is sliding. This is in accordance with the conditions in the field where there is ground movement or landslides occur on the slopes. So that the value of the soil parameters that make up the slopes from the back analysis in Table 4.8 can be said to be close to the soil conditions in the field.

4.7.2 Reanalysis of Slope Stability with Back Analysis Parameters

After obtaining soil parameter values that are close to conditions in the field from the back analysis results, it is necessary to re-analyze slope stability using actual soil parameters to get the actual slope safety factor value. The value of the slope safety factor after excavation and with a groundwater level of 0.5 m above the surface can be seen in Figure 4.19.

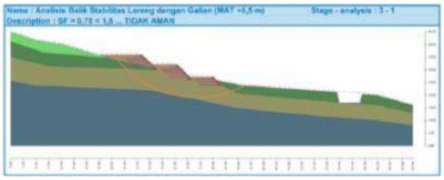


Figure 4.19 Value of Slope Safety Factor with Excavation and MAT +0.5 m.

Based on the picture above, the slope safety factor value is 0.78, which value does not meet the safety requirements for the slope safety factor of 1.5. It can be said that the slope is experiencing a landslide.

So it can be said that due to the movement of underground water flow that flows to the surface based on geoelectric results in the area of gabion and geotextile reinforcement, as well as heavy rains in the rainy season, the soil becomes saturated with water. This causes a decrease in the value of the soil parameter, thereby reducing the value of the slope stability factor of safety against landslides.

V. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Based on the calculation and analysis of slope stability of the Kariangau Substation, Balikpapan Regency, East Kalimantan Province using the Geo5 2020 program, it can be concluded as follows:

1. The value of the safety factor when the slope conditions were given gabion and geotextile reinforcement was 5.46 and after the slope given the construction of gabions and geotextiles is 5.76.
2. The value of the safety factor of the slope before being given gabion reinforcement is 5.46, while after being given the reinforcement of gabion the value of the slope safety factor is 5.71. This increase in value indicates that gabion reinforcement plays a role in increasing slope stability against landslides.
3. The value of the slope safety factor before the landslide is 5.46. While the value of the safety factor after a landslide is 0.78.
4. The value of the slope safety factor before the excavation activity was 5.76, while after the excavation the value became 5.63. This decrease in value shows that excavation activities have an effect on reducing the value of slope stability against landslides but are still within safe limits.
5. The value of the slope safety factor with MAT -2 m conditions is 5.22, for MAT -1 m conditions the safety factor value is 5.21, while for MAT conditions +0.5 m (very heavy rain) the safety factor value is 5.19. So it can be said that the variation of groundwater level as an assumption of rain conditions affects the value of slope stability. In addition, rain conditions also reduce the value of soil parameters which greatly affect the strength of the slopes in resisting landslides.
6. The failure of the construction of a combination of gabion reinforcement and geotextiles in an effort to handle landslides at the Kariangau Substation, Balikpapan Regency, East Kalimantan Province was due to a decrease in the value of soil shear strength due to saturated soil conditions in the gabion reinforcement area. Soil conditions become saturated due to water seepage from the soil, as well as rainwater infiltration during the rainy season.

5.2 Suggestions

From the design, the following are suggested:

1. It is advisable to use the latest 2021 version of the Geo5 program with a license in analyzing slope stability so that the calculation analysis in the program can be saved and reopened whenever needed.
2. Different programs can be used in slope stability analysis, as a comparison with different methods.

REFERENCES

Arif, Irwandy. 2016. *Geoteknik Tambang*. Gramedia. Jakarta: Pustaka Utama.

Badan Standarisasi Nasional (SNI 03-0090-1999). 1999. Bronjong Kawat.

Badan Standarisasi Nasional (SNI 8460:2017). 2017. Persyaratan Perancangan Geoteknik.

Chasanah, Uswatun. 2012. *Analisis Stabilitas Lereng dengan Perkuatan Geotekstil Menggunakan Progran Geoslope*. Surakarta. Tugas Akhir Program Sarjana Strata Satu (S1) Teknik Sipil Universitas Sebelas Maret.

Das, Braja M. 1995. *Mekanika Tanah (Prinsip-Prinsip Rekayasa Geoteknik) Jilid II*. Jakarta: Erlangga.

Direktorat Jendral Cipta Karya. *Buku B Panduan Perencanaan Struktur IPLT*. Jakarta: Kementrian PUPR.

FHWA. 2006. *Design and Construction of Driven Pile Foundations, Reference Manual-Volume I*. U.S. Department of Transportation.

Gambar Desain Pekerjaan Perkuatan Lereng dan Drainase Pembangunan Extension 2 Line Bay, Gardu Induk. 150 kV Kariangau, Kalimantan Timur. PT. ITS Kemitraan.

Hakam, Abdul. 2010. *Stabilitas Lereng dan Dinding Penahan Tanah*. Universitas Andalas Press: Padang.

Haryandito, C. Hary. 2003. *Mekanika Tanah II Edisi 3*. Yogyakarta: Gajah Mada University Press.

Haryandito, C. Hary. 2011. *Analisis & Perancangan Fondasi Bagian I Edisi ke-2*. Yogyakarta: Gajah Mada University Press.

Jaya, M. Ariansyah. 2017. *Konstruksi Bronjong Sebagai Alternatif Penanganan Longsor di Daerah PLTA WAY Semangka Desa Sidomulyo Kecamatan Semaka Kabupaten Tanggamus*. Bandar Lampung. Tugas Akhir Program Sarjana Strata Satu (S1) Teknik Sipil Universitas Lampung.

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Laporan Akhir Survey Geolistrik Resistivitas 2D. Institut Teknologi Sepuluh November. Surabaya

Lubis, Erwin Ananda dan Yulian Firmana Arifin. 2020. *Kombinasi Geotekstil dan Bronjong untuk Penanganan Kelongsoran*. Buletin Profesi Insinyur 3(1) (2020) 039–044.

Metriani, Riri, dkk. 2019. *Analisis Balik Kestabilan Lereng dengan Menggunakan Metode Bishop yang Disederhanakan pada Front II Existing Tambang Quarry PT. Semen Padang, Sumatera Barat*. Jurnal Bina Tambang, Vol.4 No.4.Jurusan Teknik Pertambangan. Fakultas Teknik Universitas Negeri Padang.

Nugroho, Cendana Putri, dkk. *Analisis Stabilitas Lereng Embung Dengan Menggunakan Kombinasi Dinding Penahan Kantilever dan Tiang (Pile) Dengan Bantuan Perangkat Lunak*. Malang. Teknik Sipil. Fakultas Teknik. Universitas Brawijaya.

Nur, Alfian. 2018. *Study Analisa Perbandingan Dinding Penahan Tanah Type Bronjong Dan Geotekstil Dengan Type Kantilever Ruas Jalan Batas Kota Tenggarong – Sp.3 Senoni – Kota Bangun Sta. 3+500 Provinsi Kalimantan Timur*. Samarinda. Jurnal Teknik Sipil. Fakultas Teknik. Universitas 17 Agustus 1945.

Sagita, E.F, dkk. 2017. *Analisis Stabilitas Lereng dengan Perkuatan Bronjong Menggunakan Software Geoslope di Desa Tambakmerang, Girimarto, Wonogiri*. Surakarta. E-Jurnal Matriks Teknik Sipil. Universitas Sebelas Maret.

Warman, Reza Satria. 2019. *Kumpulan Korelasi Parameter Geoteknik dan Fondasi*. Kementrian Pekerjaan Umum dan Perumahan Rakyat Direktoral Jendral Bina Marga. Jakarta.

Widyawati, Nur Endah. 2017. *Desain Alternatif Penanganan Longsoran Dengan Dinding Kontrafort Ruas Jalan Padang Batung – Batu Laki, Kabupaten Hulu Sungai Selatan, Provinsi Kalimantan Selatan*. Banjarbaru. Surakarta. Tugas Akhir Program Sarjana Strata Satu (S1) Teknik Sipil Universitas Lambung Mangkurat.

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