DESIGN OF CONCRETE RETAINING WALL WITH BORED PILE REINFORCEMENT FOR LANDSLIDE MANAGEMENT

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Abstract. Road is one of the transportation infrastructure that plays an important role in supporting regional development, increasing the regional economy, facilitating the mobility of people, goods and services. For this reason, in order to support national economic activities, the Ministry of Public Works and Public Housing through the Directorate General of Highways carries out the planning and construction of several new roads on an ongoing basis. In addition, for existing roads, the Directorate General of Highways needs to carry out maintenance so that existing assets can continue to function. The threat of natural disasters and the instability of road bodies is a serious problem. This can cause damage to the road body and even the road body can be cut off suddenly, resulting in reduced road performance. One of the roads in Maybrat district, precisely in the Ayawasi – Sisu KM 273+500 section, experienced a road collapse that cut off access between districts, resulting in a stagnation of economic activity. Therefore, a landslide handling design is needed so that the road can be accessed again.The design process was carried out through several stages, including Preliminary Survey, Hydrological Survey, Geotechnical and Geological Survey, Topographic Survey, and Planning. In the planning process, the most effective and efficient design will be selected according to field conditions. Slope stability analysis using Slope/W software. Based on the results of the planning, the design of the Concrete Soil Retaining Wall with bored pile reinforcement is used as an alternative treatment because it can be done easily in the field and can overcome the problem of landslides in the area.

Keywords: *Safety factor; Concrete Retaining Wall; Bored Pile; Landslide; Slope-W.*

1. Introduction

This avalanche handling design was carried out because there had been a landslide on the Ayawasi – Sisu KM 273+500 section in Maybrat District. The location is shown in the figure as follows:

Figure 1. Landslide location

Located at coordinates: 0° 56,820' S, 132° 32.575' E is 273.5 km from the city of Sorong. The collapse occurred on the left side of the road in the direction of Ayawasi (*lower slope*). The length of the damage reaches 130 m, and a depth of 30 m to the river below, and the slope angle of the lower slope is 70 degrees. The road shoulder in the form of soil is not hardened, there are no safety railings and warning signs, there are transverse channels that have hung due to the eroded bottom foundation. There is no adequate channel so that water runs over the road. The Upper Slope has avalanche of debris that covers part of the road.

Figure 2. Road Damage Condition Due to Landslide

2. Methods

2. 1. Slope Stability

Slope stability analysis is generally based on the concept of limit plastic equilibrium (limit plastic equilibrium). The purpose of the stability analysis is to determine the safety factor of a potential landslide field. The safety factor is defined as the value of the ratio between the holding force and the driving force. [1]

$$SF = \frac{\tau}{\tau_d} \tag{1}$$

with :

SF = safety factor
τ = maximum shear resistance (kN/m^2)
τ_d = shear resistance occurs (kN/m^2)

SNI 8460-2017 recommends the following safe factor categories [2] :

Table 1. Recommended slope SF value

Rock slope conditions	Recommended safety factor values
Permanent slope conditions	1.5
Temporary condition	1.3

The method of calculating the forces acting on the landslide plane has been developed by several researchers, including: Bishop's rigorous, Spencer's, Sarma's and Morgenstern-Price which provide a more complex way by taking into account the moment force balance. The forces acting on the landslide section are shown in Figure 3. As follows:

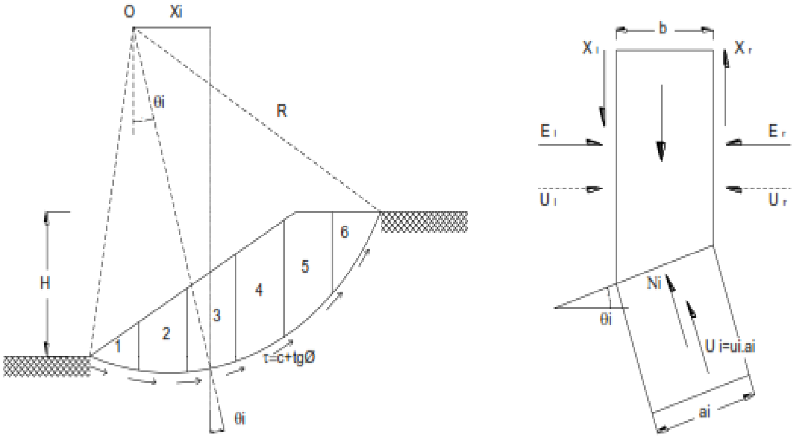


Figure 3. The force acting on the slice of the landslide plane

Soil shear strength parameters consist of cohesion (c) and internal friction angle (φ). According to Mohr-Coulumb [3] gives the following general equation:

$$\tau = c + \sigma tg\varphi \tag{2}$$

with :

τ = soil shear streght (kN/m^2)
c = soil cohesion (kN/m^2)
φ = friction angle (º)
σ = normal stress at the failure surface (kN/m^2) (kN/m^2)

2. 2. Numerical Simulation

Modeling of soil and gabion materials in numerical simulations uses the Mohr-Coulumb Material Model. Determination of soil parameters and reinforcement material parameters requires data analysis, based on the results of field tests, as well as from laboratory tests. Field testing includes 3 deep drill points with varying depths of BH 1 (25 m), BH 2 (25 m), BH 3 (25 m). Laboratory testing is carried out on embankment soil including index properties, direct shear test. The locations for field testing are as follows:

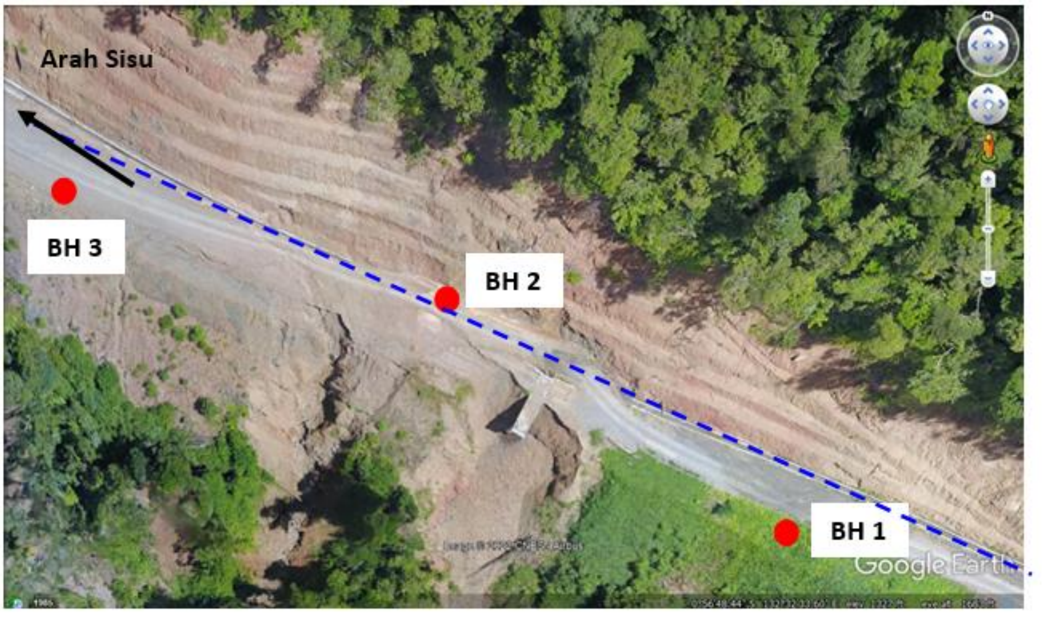


Figure 4. Bore Hole Test Locations

The results of the interpretation of drilling for each drill hole are shown in the following table:

Table 2. Recapitulation Bore Hole results

DEPTH	Ayawasi - Sisu 273+500					
	BH - 10		**BH - 11**		**BH - 12**	
	N-SPT	TYPE OF SOIL	N-SPT	TYPE OF SOIL	N-SPT	TYPE OF SOIL
2	28	Slatestone	18	Slatestone	0	Slatestone
4	15	Slatestone	24	Slatestone	13	Slatestone
6	60	Slatestone	60	Slatestone	13	Slatestone
8	60	Slatestone	60	Slatestone	17	Slatestone
10	60	Slatestone	60	Slatestone	60	Slatestone
12	60	Slatestone	60	Slatestone	60	Slatestone
14	60	Slatestone	60	Slatestone	60	Slatestone
16	60	Slatestone	60	Slatestone	60	Slatestone
18	60	Slatestone	60	Slatestone	60	Slatestone
20	60	Slatestone	60	Slatestone	60	Slatestone
22	60	Slatestone	60	Slatestone	60	Slatestone
24	60	Slatestone	60	Slatestone	60	Slatestone
GWT	**Not Found**		**Not Found**		**Not Found**	

The results of Stratigrafi of drilling for each drill hole are shown in the following figure:

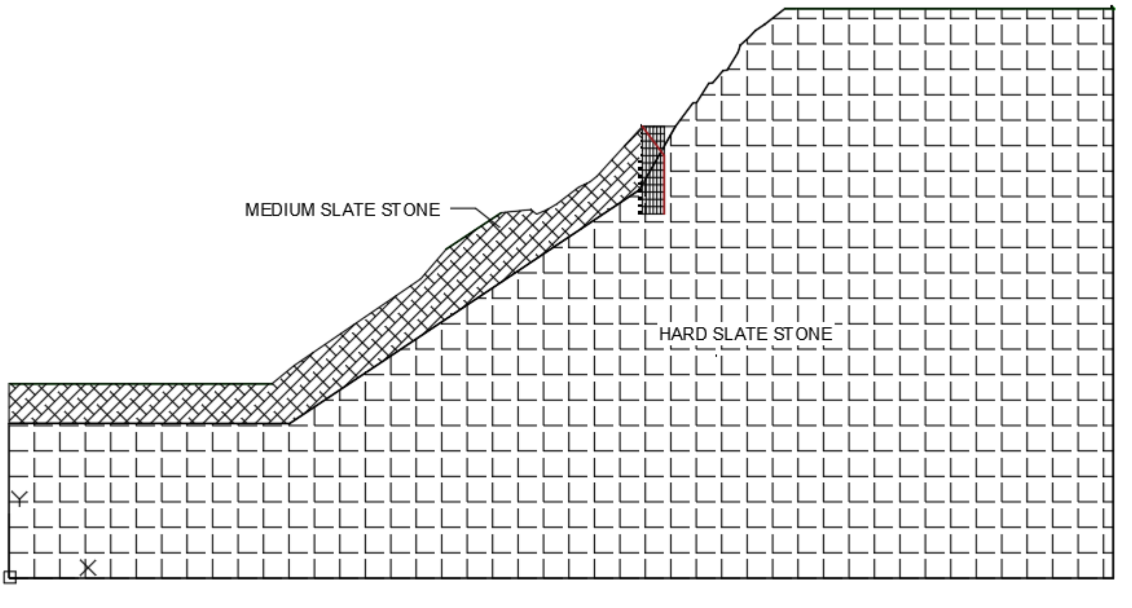
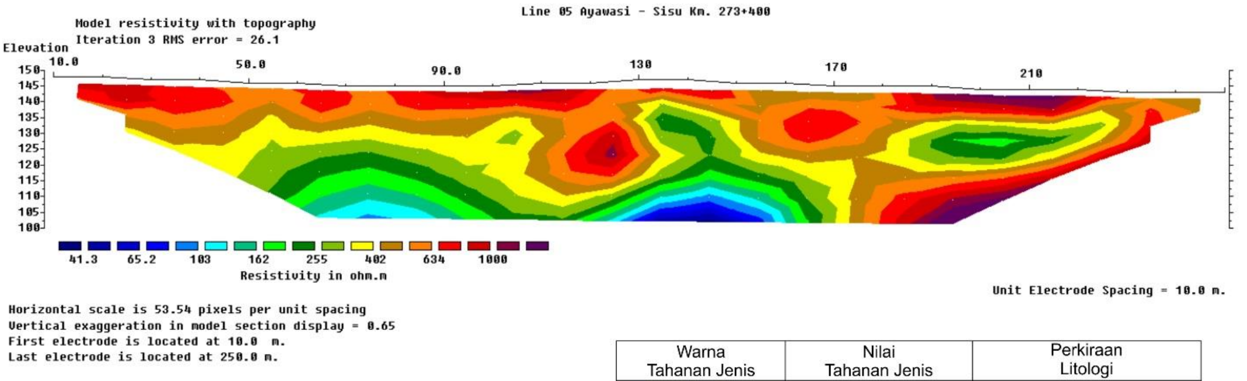


Figure 5. Rock Class Stratigraphy

Based on the results of deep drilling (Table 3 and Fig.5), the soil layer is divided into 2, namely medium shale with a depth of 4 - 6 m with an N-SPT value of 13-28. The next layer is hard shale starting from a depth of 6 m until the end of the drilling. The N-SPT value at this layer is >60. Not Found Groundwater level during drilling.

Based on the geoelectric results in the image above, the electrode distance of 60-90 meters and at the electrodes 120-160 meters at a depth of ± 40-50 meters, there is a layer of landslide/high porosity in the sandstone layer to gravel sand with a specific resistance value of 40 ohm.m to 100 ohm.m.



Warna Tahanan Jenis	Nilai Tahanan Jenis	Perkiraan Litologi
-	< 50 ohm.m	Pasir
-	50 - 100 ohm.m	Pasir kerikil
-	100 - 400 ohm.m	Batupasir
-	> 400 ohm.m	Batugamping

Figure 6. Geoelectric Results

One of the important steps in slope stability analysis is the determination of the parameters of the shear strength of the soil. This parameter is obtained from the results of field testing combined with laboratory testing. In this analysis, soil parameter data from laboratory test results is minimal, so this lab data is not used for analysis. Instead, data from sondir and SPT test results from deep drills are used.

Broadly speaking, the soil layer is divided into 2 parts; Layer 1 and Layer 2. Determination of the shear strength of the soil for each layer is determined by the correlation of the undrained strength value to the SPT value. According to Terzaghi the value of Cu can be estimated. [4]

$$Cu = 2/3\ N \quad (3)$$

with N = SPT value of soil layer

The slope safety value can be obtained by conducting a "Trial Error" on several landslide areas which are generally circular arcs and then the minimum F value is taken as an indication of the critical landslide area.

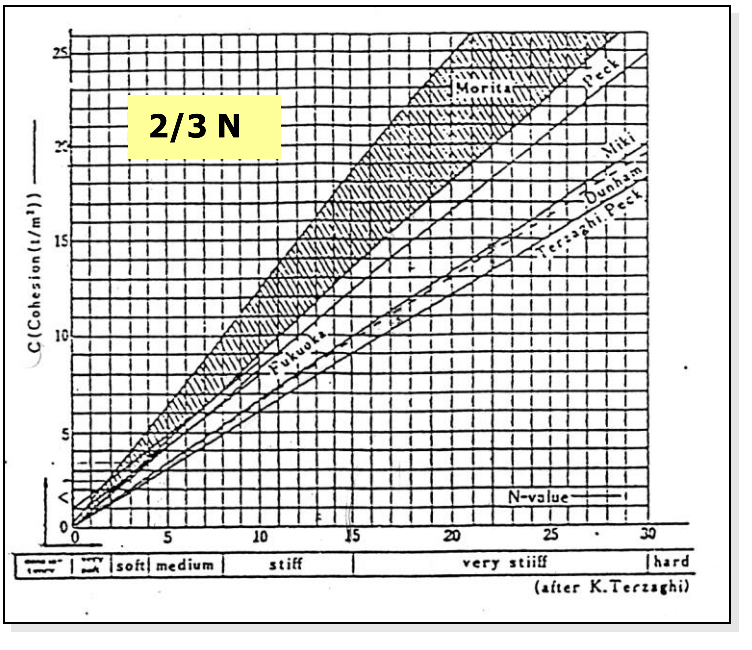


Figure 7. Correlation of Cu and SPT values

The loading used is assumed to be a uniform load of 27 kN/m^2 at the top of the slope because it will be used as an access road. The seismic load used based on Seed (1979) recommends the following kh: 0.30 for close to capable of producing an earthquake of magnitude 6.5. [5]

Correlation of field data to obtain soil design parameters such as internal shear angle, cohesion is done by correlating the N-SPT data to the correlations as shown in Table 3, in order to obtain the soil parameters used for back analysis.

Table 3. Parameters Design

Name	Model	Unit Weight (kN/m3)	Cohesion (kPa)	Phi (°)	Shear Force (kN)	K_h
Mediun Slate Stone	Mohr - Coulomb	18	40	0	-	
Hard Slate Stone	Mohr - Coulomb	19	330	0	-	
DPT	High Strenght	24	-	-	-	
Pile	-	-	-	-	100	
GWL	Peizometric line					
Seismic						0.3

2. 3. Analysis

All stability calculations were performed using the Morgenstern-Price method with entry-exit slip surface definition. Pore -water pressure is determined using the groundwater table.

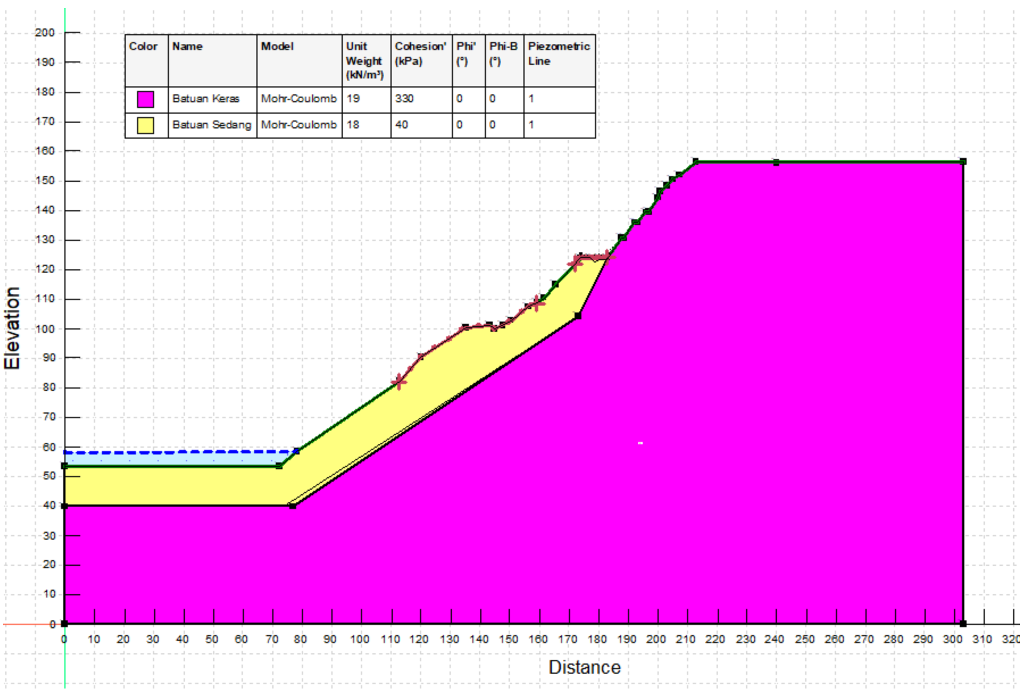


Figure 8. Geometry and Material Properties Slope/W Analysis

Model analysis carried out include:

1. Unreinforced slope
2. Slopes with reinforcement retaining wall without ground water level
3. Slopes with reinforcement retaining wall with ground water level

Performing multiple simulations is a good practice to analyze each failure mode independently. Various possibilities can occur that can result in a landslide. This is generally achieved by adjusting the location of the slip surface search zone. However, it is equally important to make assumptions about the effect of the reinforcing components on the system stability.

In this case study, the additional shear resistance of the gabion basket steel net was not considered. Only the shear resistance mobilized by the rock in the gabion basket is considered. [6]

According to the conditions in the field, in this back analysis it is assumed that the road body has a landslide on the left side of the sisu direction. The road body is assumed to experience a pavement load of 12 kN/m^2 and a traffic load of 15 kN/m^2. In general, the modeling geometry used in this analysis is presented in Fig 8.

3. Results and Discussion

Unreinforced slopes have a factor of safety < 1.5 (Figures 9). As expected, the critical failure mode is an active wedge-like failure with an exit point located at the end.

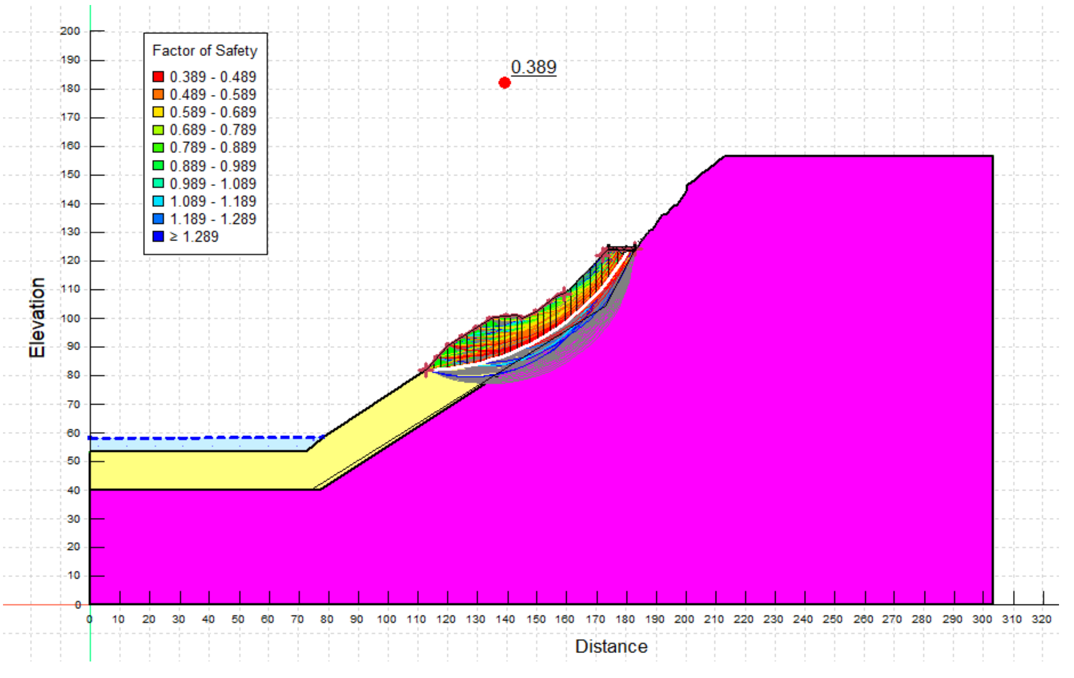


Figure 9. Unreinforced slope

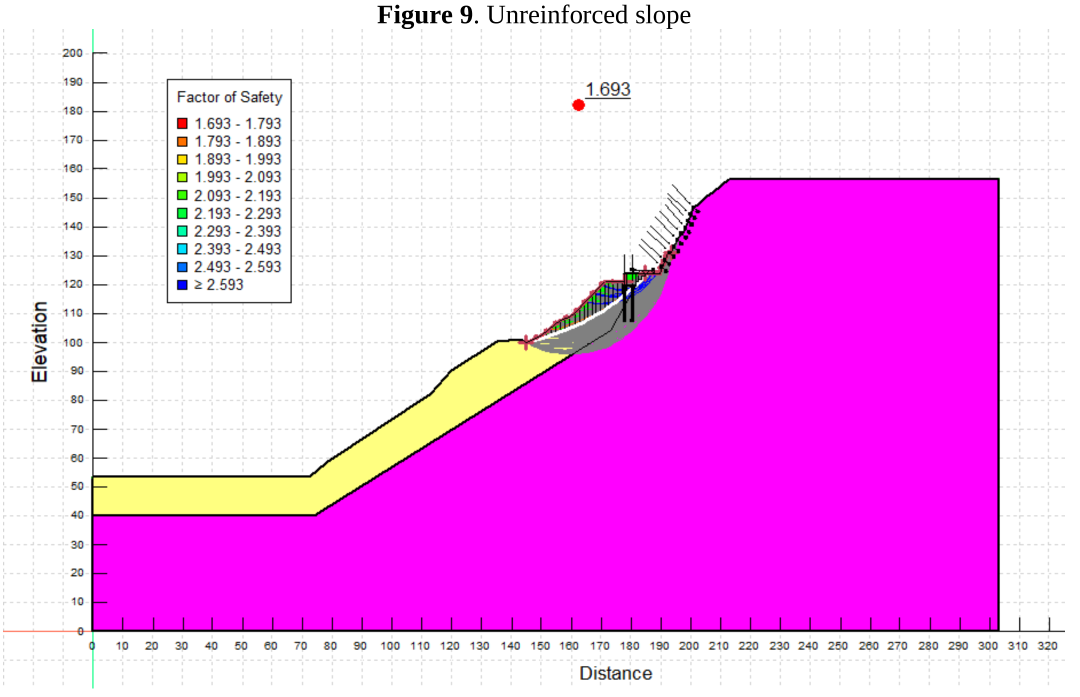


Figure 10. Slopes with reinforcement retaining wall without ground water level

Figure 9 shows the slope modeling of the Ayawasi – Sisu KM 273+500 road segment in the initial conditions. This analysis shows several areas of landslides that may occur. However, there is 1 critical area marked with a white line resulting in a slope safety value of 0.389 (SF < 1.25), this indicates the slope is in an unsafe condition.

Figure 10 Shows slope modeling with reinforced concrete soil retaining walls supported by Bored pile. This analysis shows several landslide areas that may occur, however there is 1 critical area marked with a white line with a safe number = 1.693 (SF> 1.25). This indicates that the slope is in a safe condition.

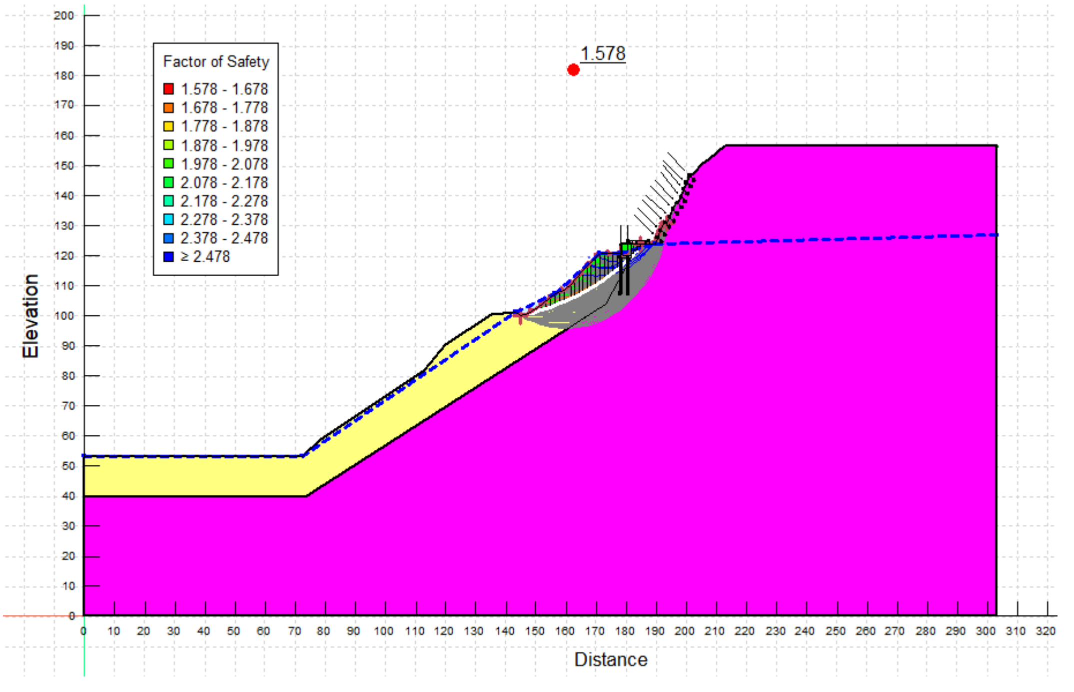


Figure 11. Slopes with reinforcement retaining wall with ground water level

Figure 11 Shows slope modeling with reinforced concrete soil retaining walls supported by Bored pile by adding Gound Water Level (GWL) showing SF = 1,578. This means that the slope is still in a safe condition (SF>1.25). However, the SF has decreased because the groundwater level affects the parameters of the soil shear strength. Water that saturates the soil will reduce its shear strength. In addition, the presence of water will increase the slope load.

In addition, most of the slip surface in the desired zone shows a clean convergence. The recapitulation of the results of the slope stability analysis with Slope/W is as follows:

Tabel 5. Recapitulation of analysis results

No	Type of Model's	Description	Safety Factor	Explanation
1	Model 1	Unreinforced slopes	0.389	Not Safe
2	Model 2	Slopes with reinforcement retaining wall without ground water level	1.693	Safe
3	Model 3	Slopes with reinforcement retaining wall with ground water level	1.578	Safe

After analyzing the model using the Slope/W aid, then a Shop drawing is made that is adjusted to the conditions in the field. The Shop drawings that have been made are as follows:

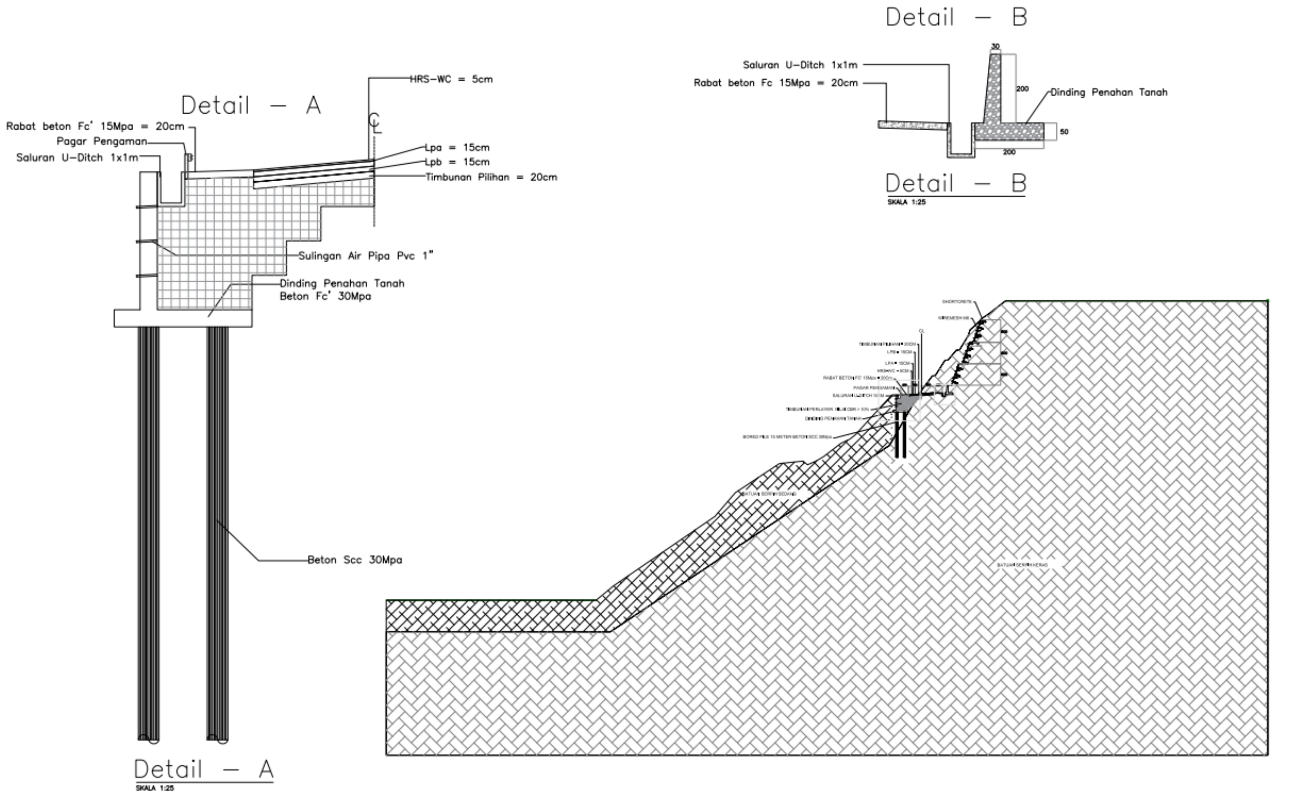


Figure 12. Typical Design Shop Drawing

4. Conclusion and Recommendation

Analysis and evaluation of slope stability using the boundary and finite element equilibrium method shows:

a. The condition of the Existing Slope is not safe, resulting in landslides. This is due to the condition of the soil in the form of embankments that are not compacted properly. In addition, heavy rainfall worsens soil conditions.
b. Handling landslides using retaining walls can increase the safety rate, so that the slope is in a stable condition.
c. Design of the Concrete Soil Retaining Wall with bored pile reinforcement is used as an alternative treatment because it can be done easily in the field and can overcome the problem of landslides in the area.

Recommendation

For further research, the modeling can try the effect of rainfall. so that it can be seen the decrease in soil shear strength parameters due to the infiltration of rainwater into the soil. Modeling can be tried using Plaxis.

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