Gabion Wall Slope Stabilization for Pejagan – Prupuk Road Widening (STA 116+450)

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ABSTRACT

The Pejagan – Prupuk road section continues to experience an increase in the interest of motorists, especially goods vehicles. In order to anticipate escalation of the traffic volume, road widening need to be planned to increase road capacity. The widening of the Pejagan – Prupuk road section needs to be done carefully. Road widening is carried out at an elevation of 4 meters from the subgrade so that a fairly unstable slope of the road body will be formed. The slope of road widening are modelled without reinforcement by using a Limit Equilibrium Method (LEM) software. It generate Factor of Saferty (FS) value of 0.84, which means the slope is in an unstable condition. Unstable embankment slopes could be treated with geotextile and gabion. Furthermore, these reinforcements were used to stabilize the embankment slope. Based on a reinforcement modeling, gabion combined with geogrid as an alternative reinforcement was able to increase FS of embankment slope more than 1.5.

Keywords : road widening, embankment reinforcement, gabion, geogrid

INTRODUCTION

Roads are one of the important infrastructures in realizing the economic and social development of a region. The easier road access an area has, the better development potential it will have. Along with developments that occur, roads have a role in the smooth mobilization of people, goods or services. The more developed a region is, the required road access will increase both in terms of quality and capacity.

The Pejagan – Prupuk Road section is part of the national road section in Central Java Province which connects the North Coast route (Pantura) to cities in the southern region of Java Island. Initially this road was built as an inspection route for irrigation canals. However, there are road users who use this road as an alternative route from Pejagan to go south or vice versa. This inspection road section was then developed to concrete pavement construction by the Provincial Government of Central Java. After the development occurs, there were increased amount of vehicles pass through the Pejagan – Prupuk road especially heavy vehicles. Thus, this road segment is an alternative in mobilization because it is connected to the Trans Java Toll Road access in the Pejagan area. Furthermore, the status of this road was changed to a national road and became the responsibility of the Ministry of PUPR through Balai Besar Penanganan Jalan Nasional Jawa Tengah-DI Yogyakarta. Based on the conditions discussed, there appears to be an increasing interest from motorists to pass through the

Pejagan – Prupuk road section, especially after an increase in construction. For this reason, it is necessary to plan for increasing the capacity of the Pejagan – Prupuk road section by widening the road. Location of Pejagan – Prupuk road and the area of study are shown in Figure 1.

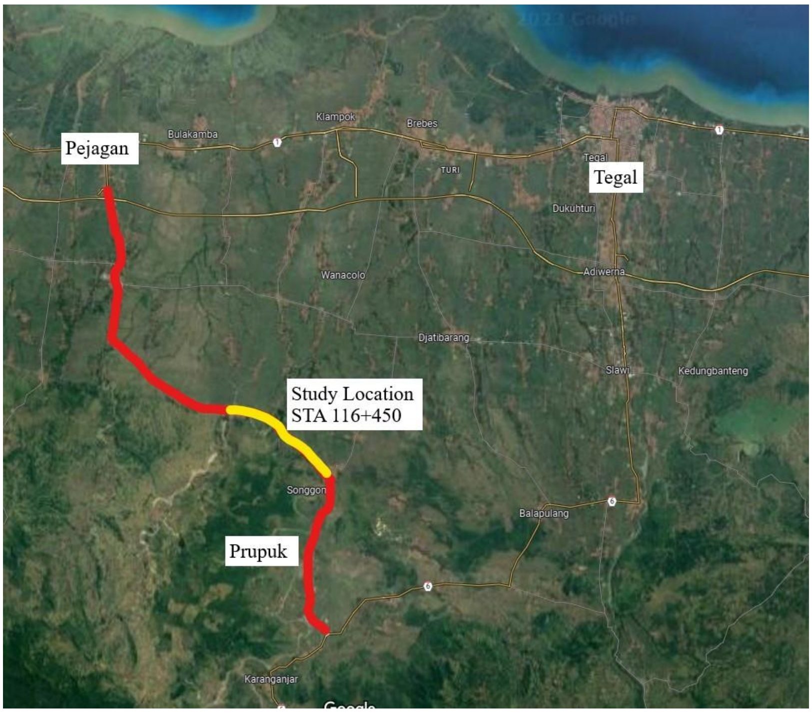

Figure 1**.** Pejagan – Prupuk Road
(Satker PJN Wil. I Provinsi Jawa Tengah, 2020)

The current condition of the Pejagan – Prupuk road are reconstructed by BBPJN Jateng-DIY. The left side of the road is dominated by road slopes as high as 3.0-5.0 meters leading to the paddy fields, some of which have existing retaining walls made of masonry. Apart from the paddy fields, at several points on the left side of the road there are small irrigation canals. While on the right side of the road there is an irrigation canal which is wider than the road body and quite deep. The condition and cross section of this road can be seen in Figure 2 and Figure 3.

Figure 2. Condition of Pejagan – Prupuk Road
(Satker PJN Wil. I Provinsi Jawa Tengah, 2020)

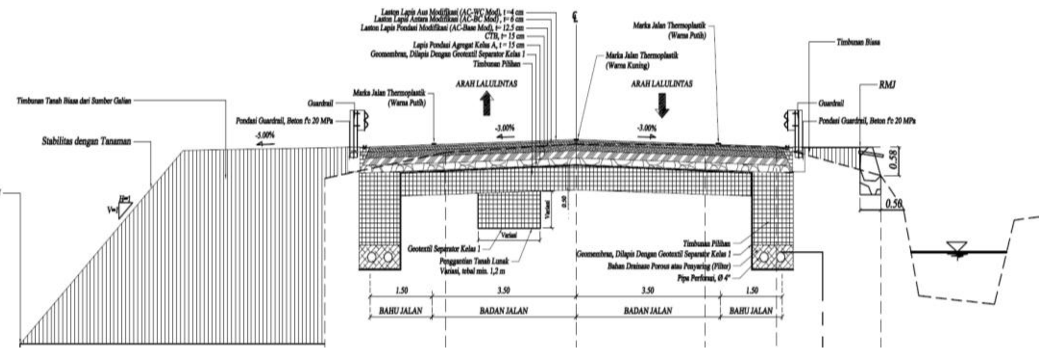

Figure 3. Cross Section of Pejagan - Prupuk Road

A study conducted using geogrid-reinforced gabion systems (Gabion-Faced Geogrid-Reinforced Retaining Wall, GF-GR-RW). The study location is in South Gippsland, Victoria, on the southeastern side of Australia which is an area prone to slope failure. To demonstrate the effect of road embankment reinforcement, it is done by modeling the cut slope (6 meters high) for the road without reinforcement and modeling the road slope with GF-GR-RW. Based on the results of these studies, strengthening the GF-GR-RW can increase the stability of the road slope from FS value of 1.04 to 1.55.(Wang et al., 2021)

Based on the description given regarding increasing driver interest, the existing condition of the road and the study at past, this research was conducted to prevent sliding due to the presence of a high and steep slope by planning gabion reinforcement. So it won't do any damage to the road body in the future.

LITERATURE REVIEW

Slope Stability Analysis with Limit Equilibrium Method

Analysis of soil slope stability is generally carried out based on the limit equilibrium method (LEM), plastic limit theory, and numerical methods such as the finite element method (FEM). In the limit equilibrium method approach, the soil layer is modeled in a simple manner and cannot display construction stages, whereas in numerical methods such as program-assisted finite element, modeling can be performed in a complex manner and can display construction stages. The safety factor of these two methods can give different results due to the different approach methods used. (SNI 8460:2017)

The limit equilibrium method uses a comparison between the slope resisting forces to the acting forces. In using a LEM program to obtain Factor of Safety (FS) the equation (GEO5 User's Guide, 2018) are shown as follows :

$$FS = \frac{X_{pas}}{X_{act}} > FS_{req} \qquad \text{.....(1)}$$

Where :

FS = computed safety factor
X_{pas} = a variable resisting the failure (resisting force, strength, capacity)
X_{act} = a variable the causing failure (sliding force, stress)
FS_{req} = required factor of safety

Gabion-Geogrid Reinforcement

Gabion is a special retaining wall that has a working mechanism like a gravity type retaining wall. Beronjong is made of rectangular piles of woven wire and filled with boulders. The gabion dimensions are more or less the same as gravity type retaining walls, with a base width of approximately 0.5 H – 0.7 H. The required safety factor for gabion (SNI 8460:2017) are shown at Table 1.

Table 1. Required Safety Factor for Gabion Wall

No	Safety Factor	Required Value
1	Overturning	≥ 2
2	Slip	≥ 1,5
3	Bearing Capacity	≥ 3
4	Overall Stability	≥ 1,5

DATA COLLECTION

Soil Investigation

Data obtained from the results of field tests at STA 116+450 are cone penetration test (CPT) data. Based on results of CPT that shown on Figure 4., the soft soil has found by the cone resistance value (qc) from the CPT below 20 kg/cm^2 (Mochtar 2012) to a depth of 17.4 meters This soil data is used to determine soil parameters by entering the value of the qc and friction ratio (Fr) into the graph at Figure 5. Soil layer classification at the location are shown at Table 2.

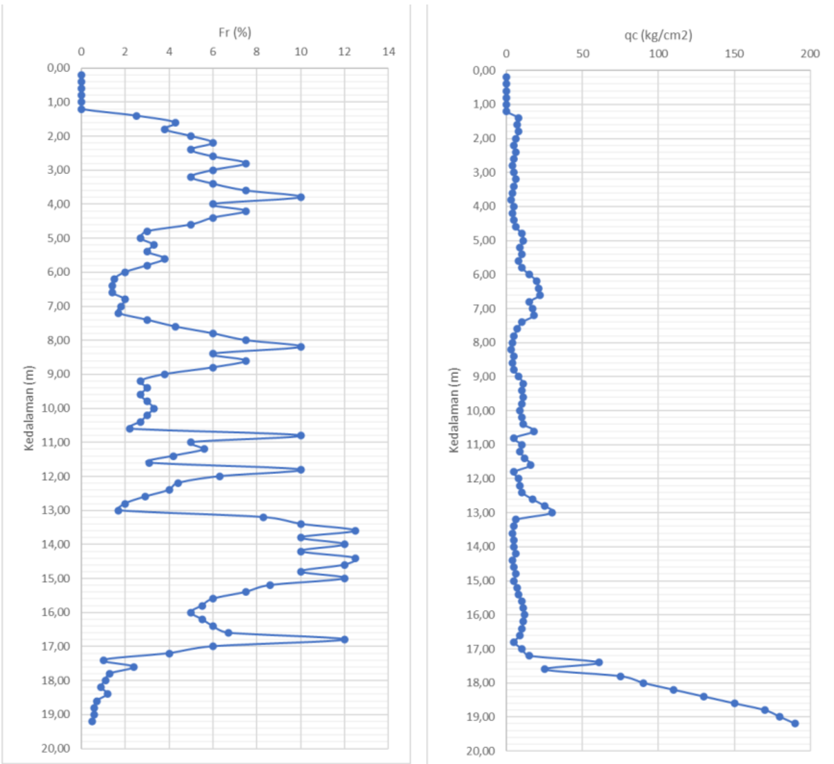

Figure 4. Cone Penetration Test Graph

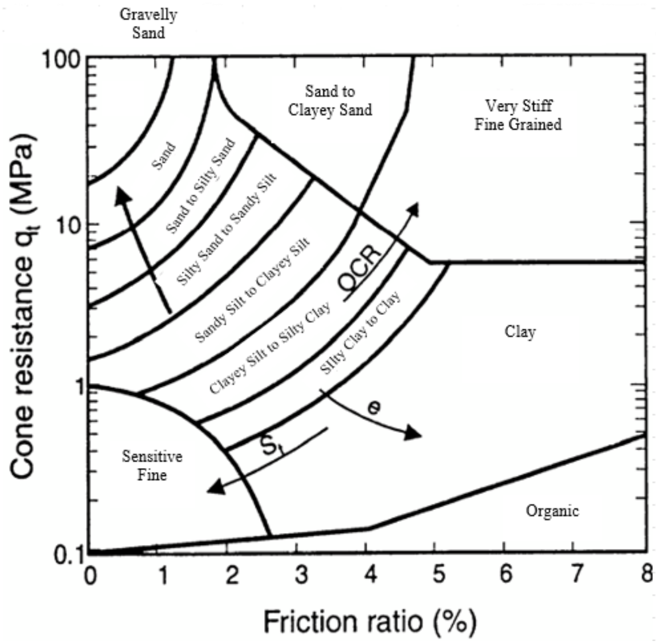

Figure 5. Soil Classification Based on Cone Resistance and Friction Ratio (Robertson et al., 1986 in Arya Pranantya et al., 2018)

Table 2. Soil Layer Classification at STA 116+450

Layer	Depth (m)	qc Average (kg/cm^2)	Fr Average (%)	N-SPT Estimation	Consistency	Soil Type
1	0,00 - 4,60	5,41	5,83	1,4	V. Soft	Clay
2	4,60 - 13,00	11,50	3,96	2,9	Soft	Clay
3	13,00 - 17,20	9,18	5,60	1,9	V. Soft	Clay
4	17,20 – 19,20	118,10	1,03	29,5	Dense	Sand

RESEARCH ANALYSIS

Road Widening Model

Road modeling of the existing road and widening was carried out based on the cross section that shown on Figure 3. The widening is the addition of 2 lanes with a total length of 7 meters to the left side of the road. The road widening cross section is shown on Figure 6. Due to modeling at GEO5 software, the widened road is simplified only the left side of the road. This simplified modeling is shown on Figure 7.

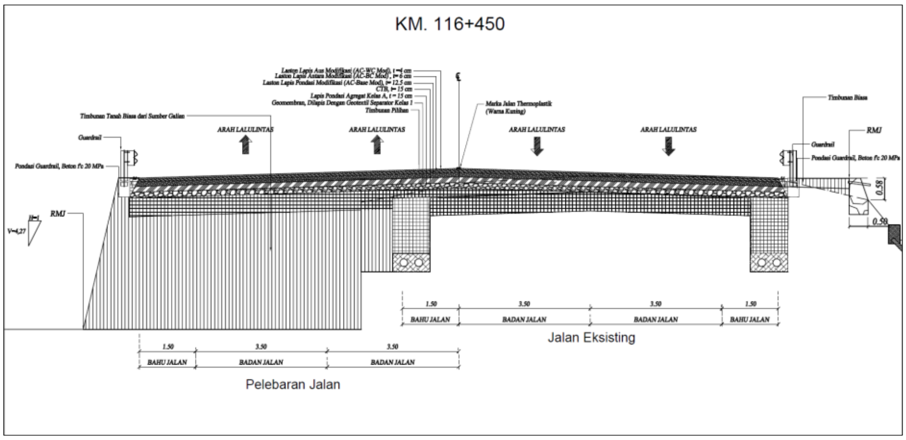

Figure 6. Road Widening Cross Section

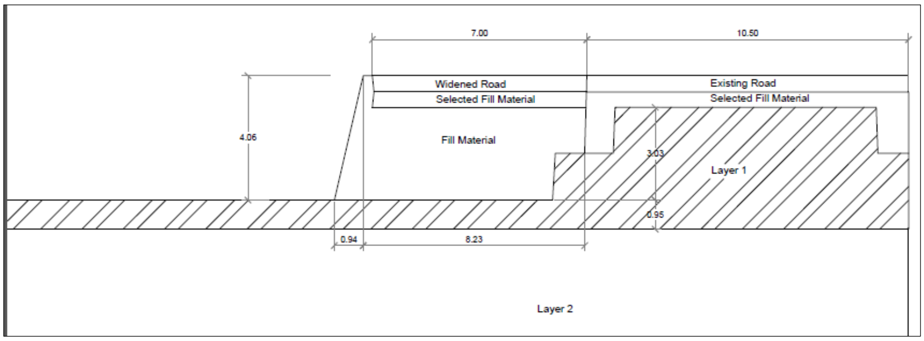

Figure 7. Simplified Widening Model

Slope Stability Analysis Without Reinforcement using LEM Program

The GEO5 Stability program requires input several of soil parameters such as soil unit weight (γ), effective cohesion value (c_{ef}), effective internal friction angle (ϕ_{ef}), elastic modulus (E_{def}), Poisson's ratio (v). These soil layers parameters are shown on Table 3. Soil parameters for fill material are shown on Table 4.

Table 3. Input Parameters of Soil Layer

Parameters	Soil Layer			
	Layer 1	**Layer 2**	**Layer 3**	**Layer 3**
Unit Weight (kN/m^3)	14.70	15.45	14.95	18.20
Stress State	effective			
Angle of Int. Friction (°)	10	15	13	33.695
Cohesion of Soil (kPa)	4.510	9.583	6.310	0
Poisson's Ratio	0.4	0.4	0.4	0.3
Type E_{oed}	constant			
Settlement Analysis	insert Edef			
Deform Modulus (MPa)	3.788	8.050	5.300	35.430
Calc. Mode Uplift	standard			
Sat. Unit Weight (kN/m^3)	14.70	15.45	14.95	18.20
Soil Foliation	not considered			

Table 4. Input Parameters of Fill Material

Parameters	Fill Material	
	Disposal	Selected
Unit Weight (kN/m^3)	18.15	18.19
Stress State	effective	
Angle of Int. Friction (°)	25.05	30
Cohesion of Soil (kPa)	10.6	0
Poisson's Ratio	0.3	0.3
Type E_{oed}	constant	
Settlement Analysis	insert Edef	
Deform Modulus (MPa)	10	3900
Calc. Mode Uplift	standard	
Sat. Unit Weight (kN/m^3)	18.15	18.19
Soil Foliation	not considered	

The widened road is modeled on GEO5 without reinforcement. Analysis shows the slope is in unstable condition with FS value of 0.84. Slope model are shown on Figure 8.

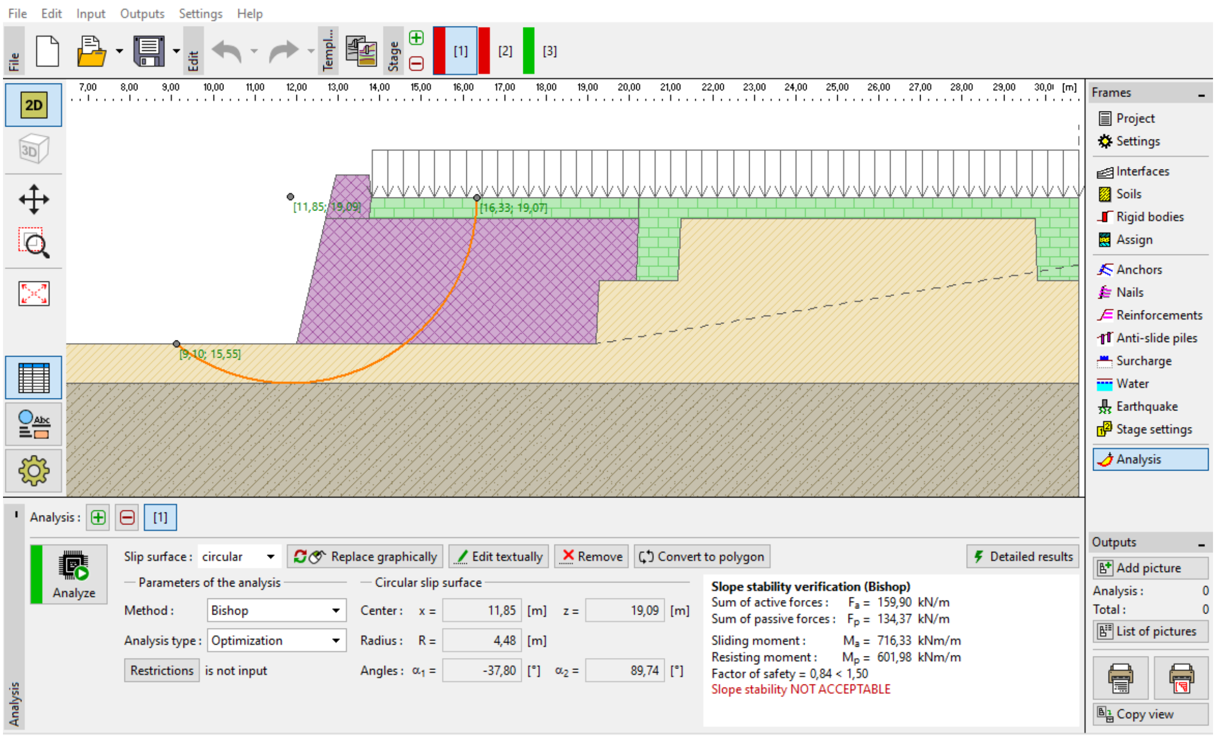

Figure 8. Slope Stability of Widened Road Model Without Reinforcement

Slope Stability Analysis With Gabion Wall Reinforcement using LEM Program

As shown in Figure 8, slope must be reinforced in order to increase the FS value above 1.5. slope must be reinforced. Gabion wall combined with geogrid were used to reinforced these slope. Besides soil parameter, reinforcement material parameter need to be inputted. Filler material used for gabion wall are rubble stone. Geogrid reinforcement used as a mesh reinforcement has ultimate tensile strength of 80 kN/m. Before input this parameter, allowable tensile strenght must be calculated as follows:

$$T_{allow} = \frac{T_{ult}}{FS_{ID} \times FS_{CR} \times FS_{CD} \times FS_{BD}} \quad \text{.....(2)}$$

$$= \frac{80\ ^{kN}/_{m}}{1.1\times2.0\times1.2\times1.1} = 27.55\ ^{kN}/_{m}$$

Input materials for gabion wall and geogrid reinforcement are shown at Table 5.

Table 5. Input Parameter of Reinforcement Material

Parameters	Value
Rubble Stone Unit Weight (kN/m^3)	15
Angle of Int. Friction (°)	30
Cohesion (kPa)	0
Geogrid Mesh Tensile Strength (kN/m)	27.55
Spacing of Vertical Partition (m)	0.5

Gabion wall combined with geogrid geometry are shown in Figure 9. Safety factor of gabion wall must checked for overturning, slip, bearing capacity and overall stability as shown at Table 1. Overturning and slip safety factor generated from the analysis are 13.43 and 7.724 respectively. It shown in Figure 10.

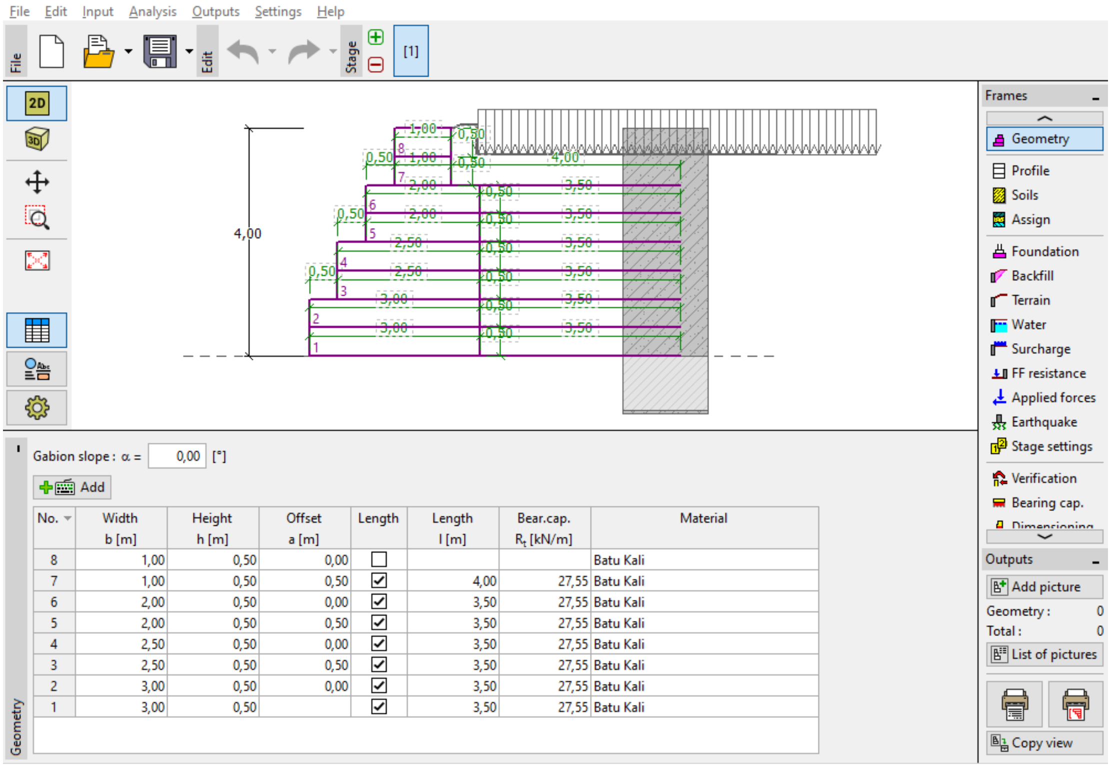

Figure 9. Geometry of Gabion Wall and Geogrid Reinforcement Model

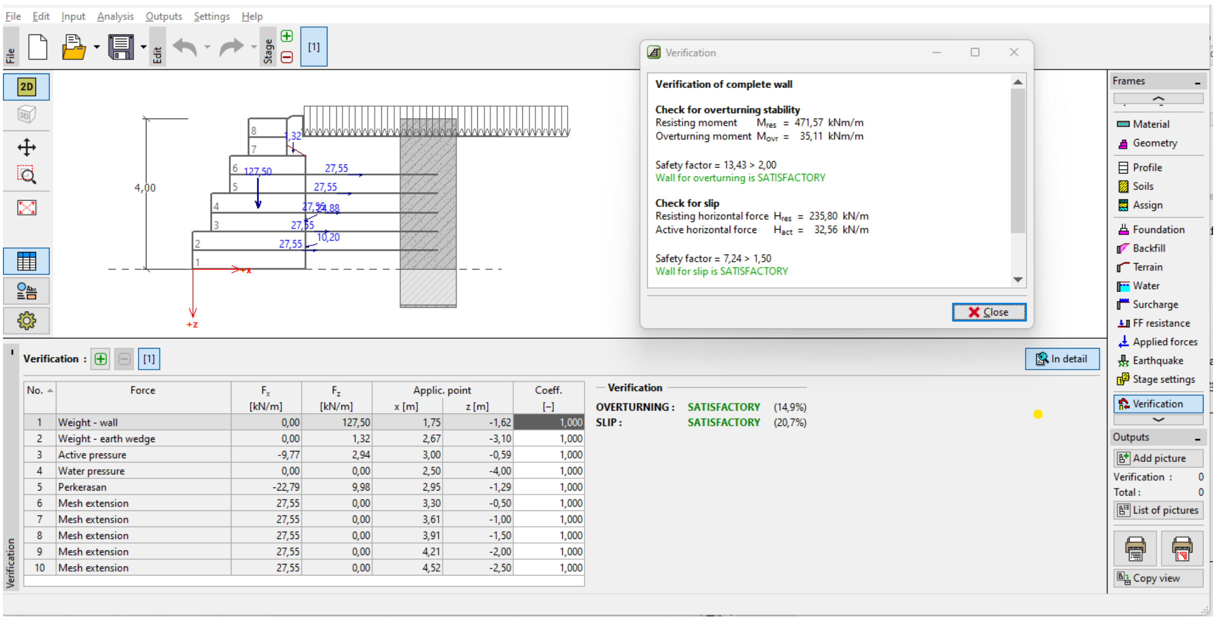

Figure 10. Safety Factor of Overturning and Slip

Safety factor of gabion wall bearing capacity generated from GEO5 analysis are 3,16. It passes the requirements of >3. Bearing capacity analysis with GEO5 are shown at Figure 11. Furthermore the slope stability are analyzed with the same slip surface as non-reinforced model. Slope stability are satisfactory with value of 1,59 passes the requirement of >1,5. Slope stability analysis with GEO5 are shown at Figure 12.

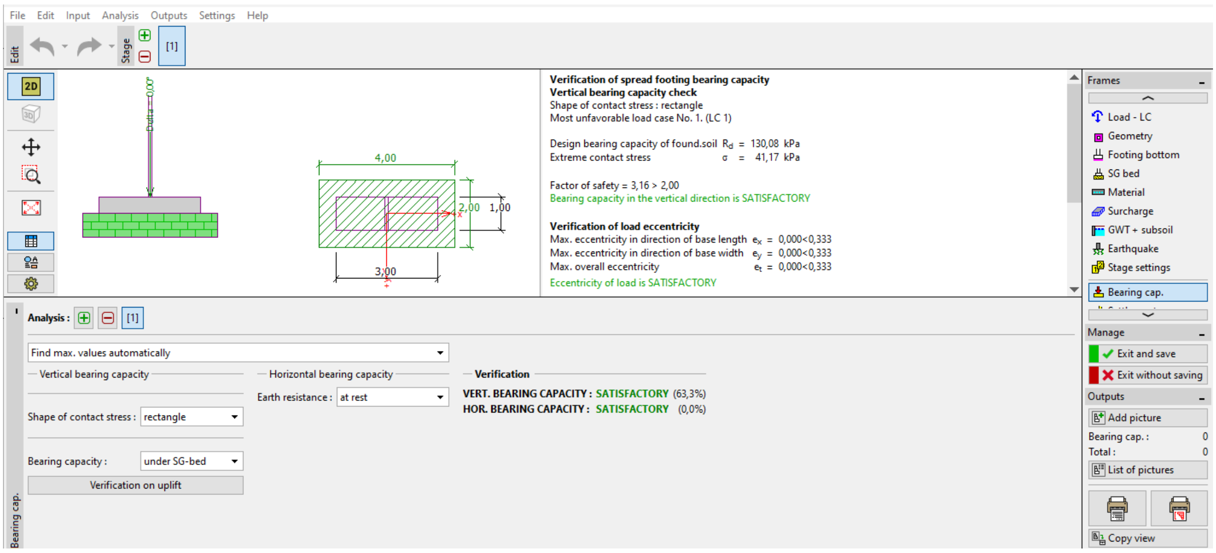

Figure 11. Bearing Capacity Analysis of Gabion Combined with Geogrid Reinforcement

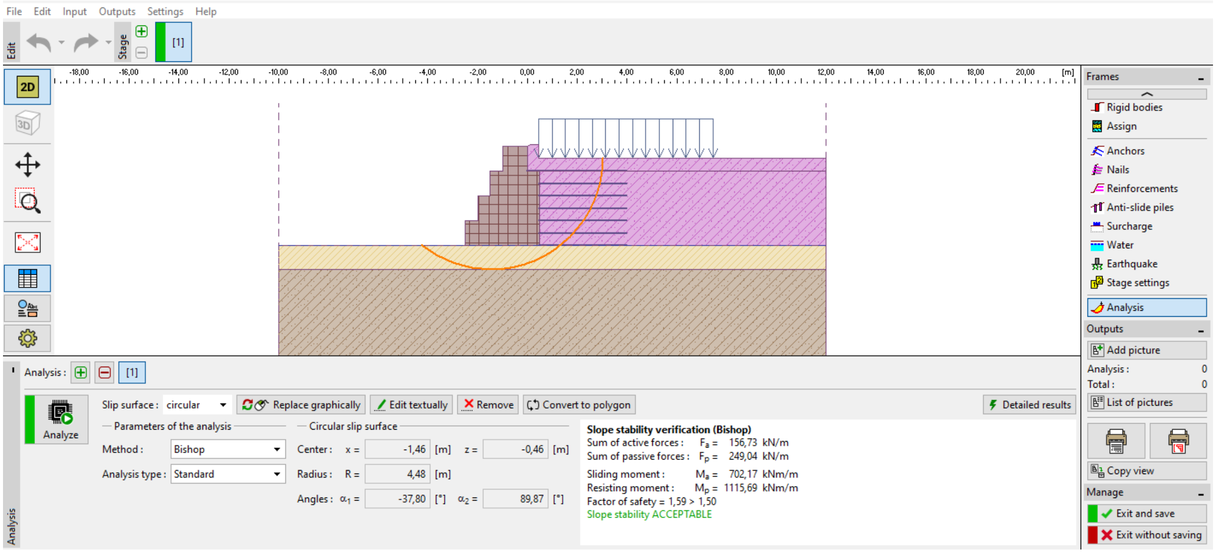

Figure 12. Slope Stability Analysis of Gabion Combined with Geogrid Reinforcement

CONCLUSION

Based on the result of modeling analysis, it can be concluded that:

1. Slope of widened road without reinforcement are at unstable condition based on safety factor of slope stability generated by GEO5 only reach 0.84 below the requirements of >1.5
2. Gabion wall combined with geogrid reinforcement could increase stability of widened road slope with safety factor of overturning, slip, bearing capacity and slope stability are 13.43, 7.24, 3.16 and 1,59 respectively. All of it were passes the minimum requirement.
3. Another type of reinforcement must be modeled as an reinforcement alternative

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