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IMPROVEMENT OF LANDSLIDE HANDLING ON FILLED LAND IN CIDAHU-CIEURIH ROAD, CIDAHU DISTRICT, KUNINGAN REGENCY

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ABSTRACT

This research is based on the issue of soil landslide in the embankment area of Cidahu - Cieurih Road. Geotechnical analysis involves cone penetration testing, boreholes, and laboratory testing to obtain soil property data. The results indicate the presence of soil layers with different characteristics, such as clay, sand, and silty clay. The analysis method utilizes PLAXIS 3D V20 for slope stability modeling. The modeling results show that the existing slope condition is unsafe, and two alternative treatments are proposed. Alternative 1 involves replacing the existing retaining wall with a new one and adding ribs, resulting in an SF of 1.516. Alternative 2 involves using the existing sheet pile with the addition of a retaining wall and embankment, resulting in an SF of 1.63. This research concludes that Alternative 2, utilizing the existing sheet pile and retaining wall, provides better slope stability results with an SF that meets safety standards.

KEYWORDS *Filled land, Landsslide, Rettaining Wall*

INTRODUCTION

Geotechnical disasters, especially those related to ground movements such as translational landslides, rotational landslides, block movements, rockfalls, soil creep, and mass wasting, are one of the types of natural disasters that frequently occur in various regions of Indonesia (Muntohar, 2010). The impacts of these disasters often result in significant damage to communities, such as infrastructure destruction, economic losses, and even loss of lives. That is why research on geotechnical disasters becomes crucial, especially in efforts to enhance disaster mitigation and management.

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Landslides are a physical phenomenon that occurs in several stages over a period of time. The mass movement of soil has a history consisting of pre-failure slope deformation, the failure itself, and post-failure deformation. Slope failure is the most significant single movement in the history of slope movements, typically involving the formation of the initial sliding surface formation, along with the occurrence of displacement and strain.

Landslides have occurred in embankment soil with a height of 2-3 m in the area of Jalan Cidahu - Cieurih, Cidahu district, Kuningan Regency during embankment work for the development of a land. This landslide was caused by inadequate soil reinforcement, necessitating a redesign of the embankment soil reinforcement.

From the above description, it is important to design and construct retaining structures properly according to soil conditions, embankment height, and pressure faced. A solid and durable retaining structure provides stability and safety to road construction, maintains structural integrity, and protects the surrounding environment. According to Eurocode 7, a retaining wall is a soil support structure that supports at least 2 m of soil, meaning that the ground level in front of the wall is 2 m lower than the ground level behind the wall.

Literature Review

Slope Stability

Landslides can occur on various types of slopes due to the pressure from the weight of the soil itself, exacerbated by the significant influence of seepage groundwater, as well as other external forces acting on the slopes. Craig (1989) stated that gravitational forces and seepage water tend to cause instability in natural slopes, excavated slopes, as well as in embankments and earth dams.

Another factor affecting slope stability is the increase in load on the slope originating from nature itself. This includes rainwater infiltrating into the soil in slope areas not covered by vegetation, causing an increase in soil moisture content. As a result, the soil becomes saturated and its volume increases, thus increasing the load on the slope. Embankment work on slopes without considering the load on the slope can lead to an increased risk of landslides (Nasibu, 2010).

The same applies to artificial slopes, which can be excavation slopes, embankment slopes, or landfill slopes (Chowdhury, 1978). Failure of artificial slopes can occur due to factors similar to natural slope failures, namely reduction in shear strength and increase in shear stress on the soil layers forming the slope. Excavation slopes are slopes designed taking into account the average height of the excavation and the slope angle to maintain slope stability (safety), while considering economic aspects.

There are three main types of soil landslides, as illustrated in Figure 1, which can be described as follows:

a. Rotational slips occur when the soil collapses in a surface shape forming a circular or non-circular curve.
b. Translational slips tend to occur when the soil layers adjacent are relatively shallow beneath the slope surface.

c. Compound slips occur when the adjacent soil layers are at a greater depth. Typically, this type of landslide involves a combination of curved and planar sections.

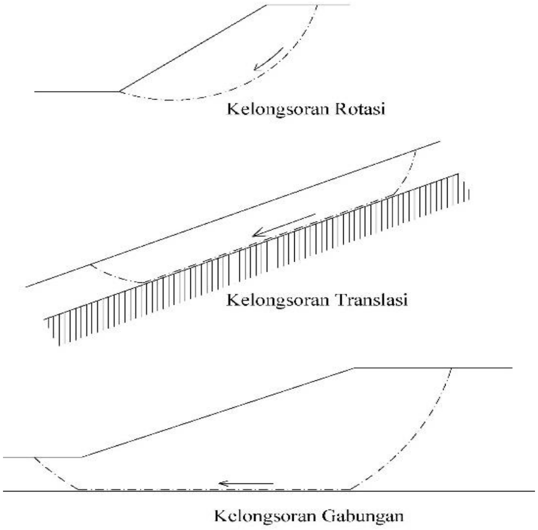


Figure 1. Types of Slope Failures (Craig, 1989)

Slope Stability Analysis

There are several methods used in analyzing slope stability. One of these methods is the Fellinius Method (1927), which is used for circular failure surfaces in all types of soil. This method is practical in its application and assumes that the forces acting on the right and left sides of any slice have a resultant of zero in the direction perpendicular to the failure plane. The Alan W. Bishop Method (1955) is similar to the Fellinius Method (1927), where the forces acting on the slice sides also have a resultant of zero in the vertical direction of the failure plane. However, its use is somewhat complex and requires experimentation, but its results are more meticulous. Additionally, there is the Bishop and Morgenstern Diagram Method (1960), used to calculate safety factors in the effective stress review in slope stability analysis. This method can be applied to both circular and non-circular failure surfaces, but its use is somewhat complex and requires a computer. The Janbu Method (1956) is used for both circular and non-circular failure surfaces, but its application also requires a computer and is somewhat complex.

RESEARCH METHOD

This research is based on the problem that occurred, namely the occurrence of landslides on landfills in the Cidahu area, Kuningan Regency. As shown in **Figure 2**, after identifying the problem, the next stage is primary and skunder data collection. These data are related to soil and topgtafi property data and slope geometry. Then an analysis of the stability of the existing slope and the possibilities of the landslide response design were carried out. As a tool, to calculate and analyze the stability of the slope, applications are used that use the finite element method.

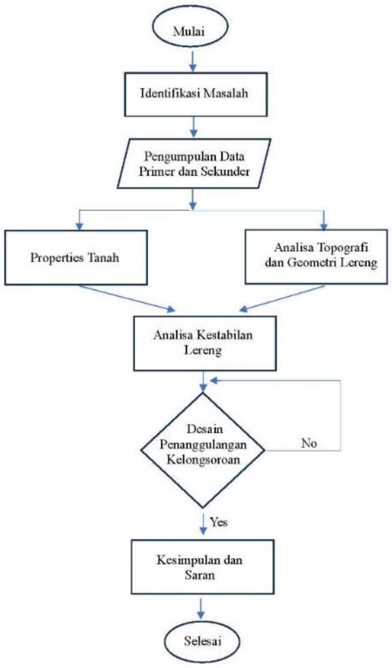


Figure 2. Research flow chart

The researcher conducted a study on previous research results related to the design of retaining walls (DPT) for soil reinforcement, including the research methods, approaches, theoretical studies, and research results. Several previous research findings related to this topic were used as references for this study. Some previous researchers used finite element methods to analyze retaining walls, such as Gazali and Fathurrahman (2019) who investigated the stability of embankments reinforced with wooden sheet piles using Plaxis 2D, Ramadhan et al. (2020) who studied the safety factors of slope stability before and after reinforcement with DPT using finite element methods, and Ayyub et al. (2021) who analyzed gabions using analytical and numerical models with Plaxis 2D. In this study, the approach used for slope stability analysis is the Bishop method, as shown in Figure 3. This approach was chosen based on the assumption that if there is a landslide, the surface of the slip plane will form a circular arc.

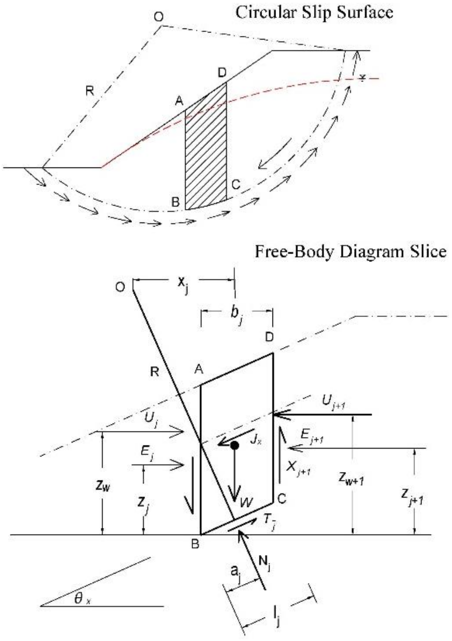


Figure 3. Analysis of slope stability using the method of Bishop (1960)

The approach used in the Bishop method is similar to the approach used in the Bishop-Morgenstern method. Bishop and Morgenstern (1960) developed Bishop's method by incorporating pore water pressure factors. When applied in linear dimensions, the equation can be formulated as follows:

Gaya Vertical.

$$N_j cos\theta_j + T_j sin\theta_j - W_j - X_j + X_{j+1} \tag{1}$$

$$N_j' cos\theta_j = W_j + X_j - X_{j+1} - T_j sin\theta_j - u_j l_j cos\theta_j \tag{2}$$

Pore water clearance ratio (r_u)

$$r_u = \frac{u_j b_j}{W_j} = \frac{\gamma_{w(z_w)j}}{(\gamma Z)_j} \tag{3}$$

Balance of moments

$$\sum T_j = \frac{W_j x_j}{R} = \sum W_j sin\theta_j \tag{4}$$

Safety factor

$$FS = \frac{\tau_f}{\tau_m} = \frac{(\tau_f)_j}{\tau_j} \tag{5}$$

Effective stress analyses

$$FS = \frac{\sum W_j m_j \tan(\varphi')_j}{\sum W_j sin\theta_j} \tag{6}$$

Total stress analyses

$$FS = \frac{\sum (s_u)_j \frac{b_j}{cos\theta_j}}{\sum W_j sin\theta_j} \tag{7}$$

RESULT AND DISCUSSION

Research Area Conditions

Geographical Conditions

Cidahu Village administratively is one of the villages within the Cidahu District of Kuningan Regency, with its boundaries as follows: to the north, it borders Cieurih Village; to the south, it borders Cihideunghilir Village; to the west, it borders Cihideunghilir Village; to the east, it borders Cieurih Village (Figure 4). The total area is 179.189 hectares, and administratively it consists of 5 neighborhood associations (RW) and 22 community units (RT) divided into 5 hamlets.

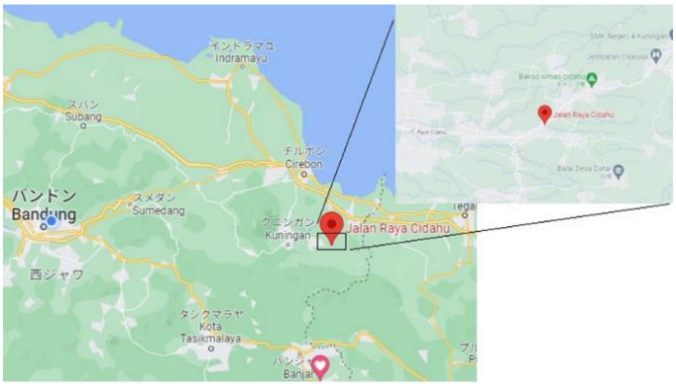


Figure 4. Research Location

Soil Layers and Their Characteristics

Figure 5 depicts the condition of a portion of the landslide area in the research area. Geotechnical investigations were conducted in this area through cone penetration testing and borehole drilling. Some samples were analyzed in the laboratory to obtain soil property data. The results of the interpretation and analysis of this field data are presented in the form of soil profiles, and the soil property data can be found in Table 1.

Figure 5. Condition of Landslide Soil and Completed Reinforcement

Figure 6 shows the correlation results of 3 data points from the surface to a depth of approximately 11 meters in the area where the landslide occurred, covered by a layer of silty clay soil with soft to medium hardness. This is indicated by N values <10, possibly because it is cultivated soil or deposits from the hill layers around it. Below this layer, there is a layer that is quite hard with N values reaching 50. This layer extends on average to a depth of 30 meters or approximately 15 meters in thickness. Beneath this layer, there is a layer with characteristics similar to the first layer, namely silty clay soil but with hardness almost similar to the second layer, with N values approaching 50. For the internal friction angle values, the first and second layers show significant differences, with 7.018.0 kg/cm^2 for the first layer and the second layer ranging from 2533 kg/cm^2.

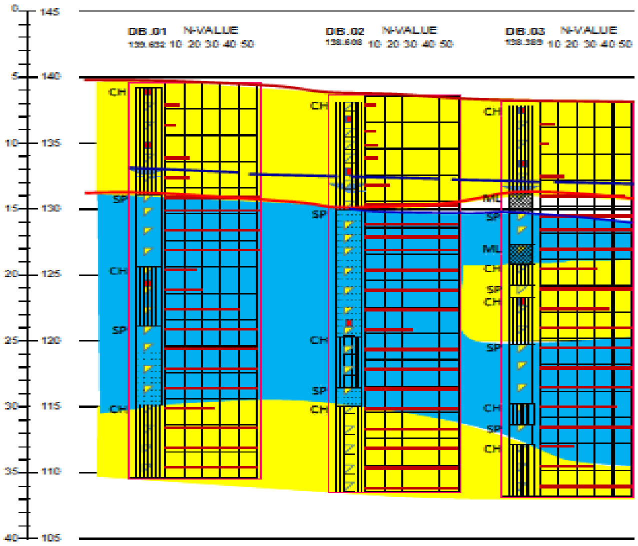


Figure 6. Cross-section of the profile of the soil layer in the study area

Table 1. Laboratory test results of soil properties in the study area

Test	Hasil Test		
	Lapisan ke 1 Silty Clay	Lapisan ke 2 Silty Clayey Silty/ Sand	Lapisan ke 2 Silty Clay
1.Index	Mc = 42~51% ;LL = 60 ~ 81%	Mc = 19~52% ; LL = 36~72%	Mc = 40 ~ 50 % ; LL = 55~80%
Properties	DD = 1,0~1,2 gr/cm^3; PL = 31~35%	DD = 1,0~1,6 gr/cm3; PL = 24~35%	DD =1,0 ~1,2 gr/cm^3; PL = ~ %
	BD = 1,5~1,7 gr/cm^3; PI = 29~47%	BD = 1,5~2,0 gr/cm3; PI = 11~40%	BD =1,5 ~1.8 gr/cm^3; PI =30~45 %
2. UU Triaxial	φ = 7~ 18; C = 11~17 kg/cm^2	φ = 25 ~ 33; C = 23~36 kg/cm2	φ = ~ 0 ; C = ~ kg/cm^2
3.Unconfine	C = kg/cm3 ; f =	C =18 ~ 24 kg/cm^3; f = 1,0 ~ 1,2	C = kg/cm3 ; f =
4. Consolidation	Pc = 1,4 ~ 1,7 kg/cm^2 ; Cv = 0,00161 ~ 0,00169 cm2/sec	Pc = 1,3~1,7 kg/cm2 ; Cv = 0,00158~ 0,00210 cm2/sec	Pc = ~ kg/cm2 ; Cv = ~ cm2/sec
5.Swelling	k = 0,590 ~ 0,913%	k = ~ %	k = ~ %

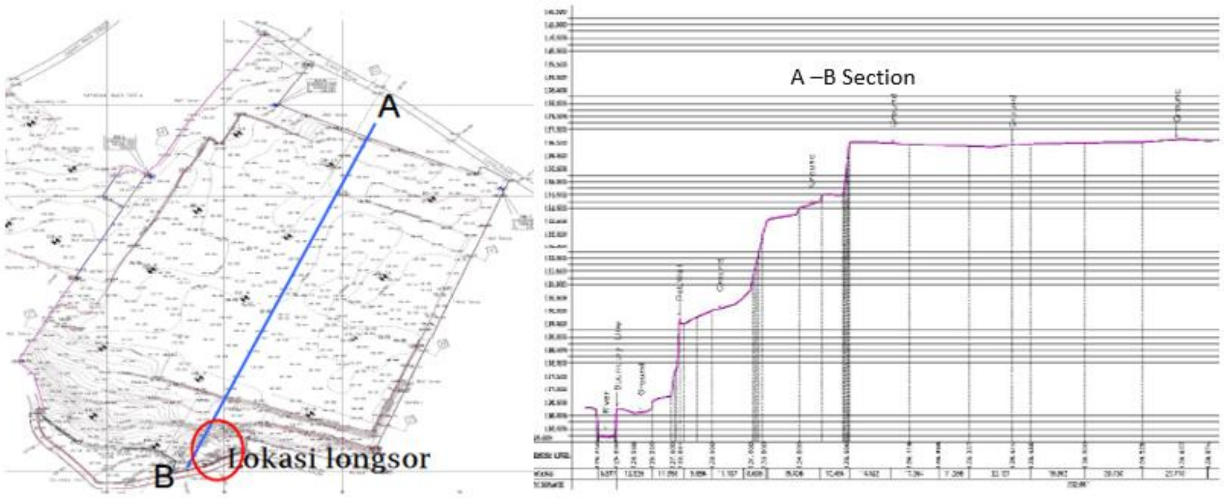


Figure 7. Topography of the study area

Tabel 2. Parameter tanah sebagai input pada pemodelan

Lapisan	NSPT	Kedalaman (m)	Jenis tanah	Jenis sampel	Berat isi tanah		Modulus young	Poisson ratio	Kohesi	Sudut geser
					sat	unsat	E$_{ref}$	μ_s	C$_{ref}$	ø
					kN/m^3		kN/m^2		kN/m^2	°
1	32	0-8	Lempung Kepasiran	Undisturb	17	17	30000	0,2	35	32
2	50	8-14	Pasir	Undisturb	17	20	50000	0,2	42	36

3	50	14-16	Lanau Kelempungan	Undisturb	17	17	20000	0,3	42	36
4	50	16-20	Lempung Kepasiran	Undisturb	18	18	42500	0,3	42	36
5	30	20-24	Lanau Kelempungan	Undisturb	17	13	19000	0,2	24	33
6	32	24-30	Lempung Kepasiran	Undisturb	18	13	40000	0,2	35	32
		Tanah Timbunan			16	16	10000	0,2	20	20

Results of Modeling and Analysis

In this modeling, the use of data involves several types of data:

1. Topography is used to provide information about the variation in the area, elevation contours, and vegetation levels. Here is the topographic map covering the area around the research object. Looking at the results of the Topography Survey in a project area of 9,076 hectares. The main road access is the Cidahu highway located at the hilltop position, so on the left and right sides of the road, the ground conditions descend in tiers with a height difference of about 16 meters and 3 tiers with very steep slopes (Figure 7).
2. Soil parameters and characteristics. The correlation values used still refer to the results of field testing and laboratory testing by observing the types and NSPT in each layer, with results as seen in Table 1 above. Soil parameter data from field testing, laboratory testing results, and correlations used in the analysis using the Plaxis 3D V20 program for layer parameters are shown in Table 2.
3. Structure and load data. This structure data is related to the technical specifications of the materials used and the loads and tolerances of those loads.

The results of slope stability analysis in the area where landslides occurred on the Cidahu road in Cidahu Village, Kuningan Regency, were conducted using the PLAXIS 3D V20 program. It can be seen from Figure 8a, which is the result of modeling from the existing condition, the slip plane with results cannot be further analyzed due to "some soil body collapse" and cannot produce a safety factor (SF) value. From the analysis results above, it can be seen that the slope experienced landslides and required remedial action. It can be seen in Figure 8b with the addition of embankments as retainers; the slip plane and deviatoric strain are too large and produce a safety factor value of 1.18. This value, according to SNI-8460-2017, is considered unsafe because it is less than 1.5; therefore, alternative treatments are performed.

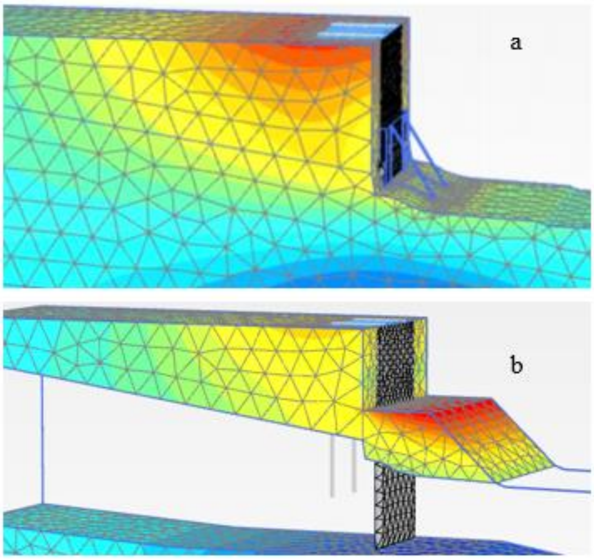


Figure 8. Slip field *exisiting conditions*: a) without reinforcement piles and b) with additional reinforcement piles

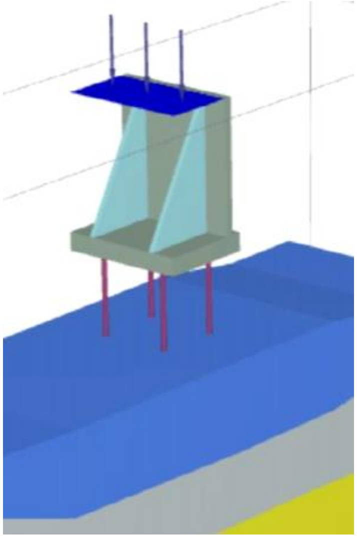
Landslides at the study site occurred after rain, so the main cause of this collapse was the instability of the soil retaining wall when rain occurred. This instability is caused by several factors, such as poor foundation dimension design and low quality of implementation. Along with that, the fall of the pile behind the wall is caused by water seepage from the surface and groundwater flow. This causes compression of the pile behind the wall pair and a fracture on the outer side of the wall in the form of *piping.*

In the initial stage, namely the determination of the analasis phase which aims to determine the number of construction stages and determine the type of calculation, this study uses 6 phases including the initial phase, the initial construction phase (*sheet pile*, stake, *anchor*), the pile phase, the loading phase, the 2nd construction phase (alternative handling 1 &; 2) and the safety condition phase.

Alternative Treatment 1

Alternative treatment 1 is carried out in order to find out other conditions that may be more effective and also remain safe, and also function as additional reinforcement if needed. The model of the handling structure as shown in **Figure 9**., by replacing the existing soil retaining wall with the installation of *a new retaining wall* and the addition of *ribs* on the inside.

Seen in **Figure 10** of gelncir and *deviatoric strain fields* and the results obtained from the results of this analysis the safety factor value of 1.516 based on (SNI-8460-2017) can be said to be safe because > 1.5.



Gambar 9. Model struktur penanganan alternatif 1

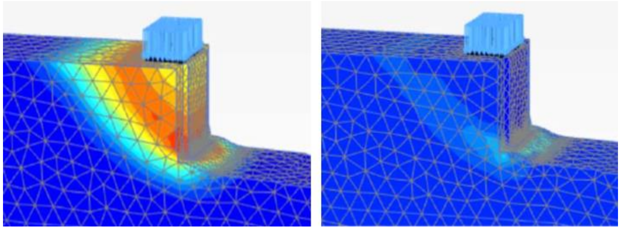


Figure 10. Slip field and *deviatoric strain* handling alternatives

The picture below is a continuation of the results of the analysis of conditions in the field which turns out that the x-direction reaction (horizontal) of the heap soil is not restrained and there is *"some body soil collapse"*. **Figure 11**. Alternative Handling Structure Model 2 involves the existing *sheet pile* with the addition of *a retaining wall* with *rib* on the outside as reinforcement with additional piles. **Figure 12**. the slip and *shading* fields are too large, so by adding additional structures, *shading* and slipping planes are reduced so that after there is an additional structure FS becomes 1.63 based on SNI-8460-2017 it is said to be safe because it is more than 1.50.

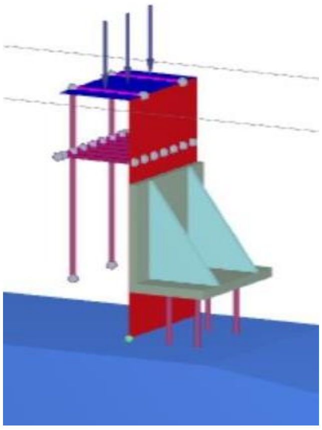


Figure 11. Alternative handling structure model 2

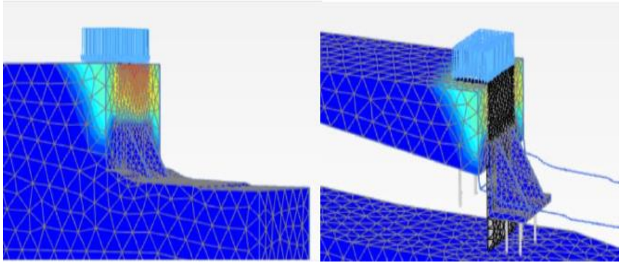


Figure 12. Alternative handling structure model 2

CONCLUSION

Based on the evaluation of slope stability and the calculation of soil retaining walls on the slope on the Cidahu road in Cidahu village, Cidahu Regency, the following results were found: 1. In slope stability analysis using the PLAXIS 3D V20 program, the initial condition (*existing*) is a slope with reinforcement using *anchor beam*, *beam* and *sheet pile* with the addition of piles as reinforcement, it shows that the safety factor (SF) is less safe against landslides, with an SF<1.5 value, which is 1.18.

To address the potential for further slope avalanches, an analysis of soil retaining walls designed to meet safety standards was conducted. The soil retaining wall involves *rettaining wall*, *rib* and *bored pile*. With alternative option 1, namely using a new *retaining wall* with *a rib* on the inside with a *safety factor* of 1.61 and alternative 2 using an existing *sheet pile* with the addition of *a retaining wall* with a rib on the outside and an additional pile and *bored pile* obtained by a *safety factor* of 1.63.

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