Slope Stability for Landslide in Road Preservation Working Packages Ende-Wolowaru and Junction-Kelimutu STA 8+425

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ABSTRACT

On the Ende-Kelimutu national road section at STA 8+425, according to the identification and field survey, the landslide that occurred at this point was caused by high rainfall intensity and geological factors of the slope. As the road supervisor, the Balai Pelaksanaan Jalan Nasional (BPJN) of East Nusa Tenggara has designed a landslide treatment using a combination of cantilever walls and drilled poles. Soil investigation data at STA 8+425 shows that the slope is dominated by sand with N-SPT values above 15 to a depth of 14.45 meters. When making design improvements, a number of rainfall data from several weather observation stations are needed, in order to determine the effect of rainwater infiltration on the landslides that occur. This study aims to determine the influence of rainwater infiltration on the occurrence of landslides at the study site, where the results of the analysis conducted with Geostudio prove the truth. Modeling with the combination of SEEP/W and SLOPE/W, the FS value before the landslide was 2.302 and then decreased to 0.35 during the landslide.

Keyword : raod asset management, landslide, SEEP/W, SLOPE/W

INTRODUCTION

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One of the assets of land transportation infrastructure that obtained attention now is the road. Road construction can support the developing economy, industry, trade, people and good mobility, regional development (Ari Widayanti, 2019). The Ende-Kelimutu National Tourism Strategic Area (KSPN) is one of the areas that has the main function of tourism or has the potential for national tourism development which has an important influence in several aspects, such as economic, social and cultural growth, empowerment of natural resources, environmental carrying capacity, and defense and security. The Ende-Kelimutu KSPN can be accessed using several national roads from Ende City as the district capital as shown in Figure 1 below.

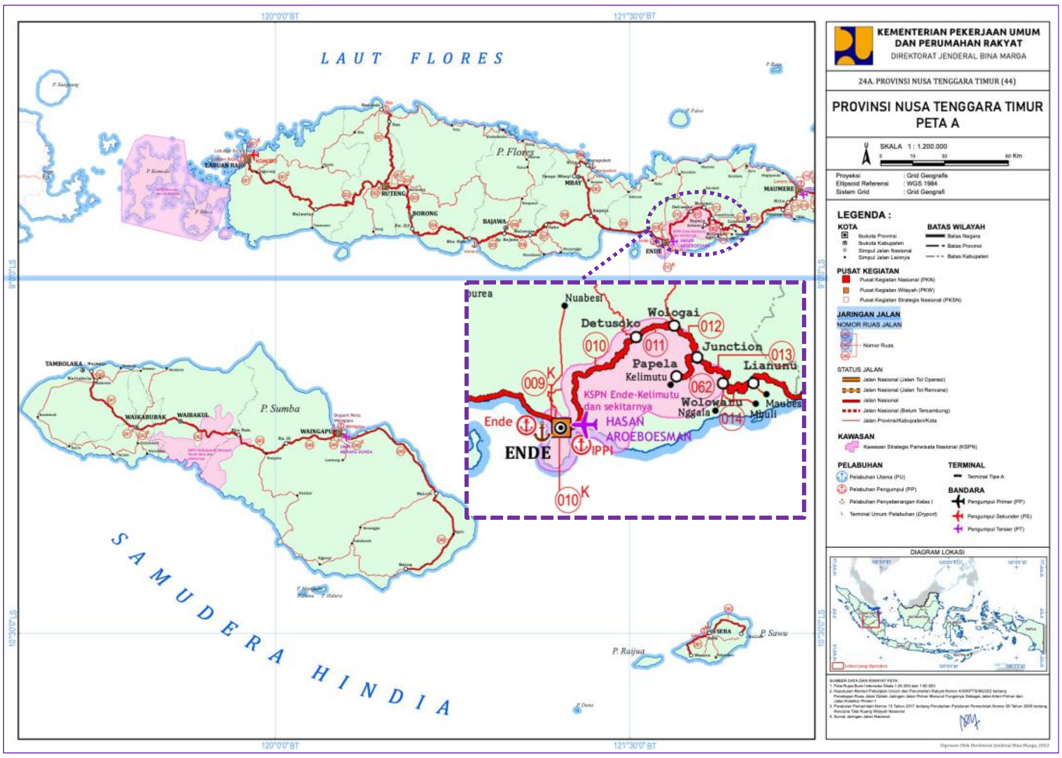

Figure 1. Map of National Road Network in Flores Island, NTT

The Road Network is measured based on the performance of the road network in performing its functions. The primary function of a road network can be described as three primary functions: connecting different nodes, transporting traffic, and covering an area. These primary functions can be reduced to two sub-functions (Suprayitno 2010; Suprayitno 2014; Suprayitno 2015; Suprayitno 2016; Suprayitno 2018; Suprayitno & Soemitro 2019).

Landslides in a place are indicative of the potential for similar events in that location. This would indicate that there should be risk mitigation in the future so that buildings under construction are not damaged by landslides. Muka and Wibowo (2021) said that risk is a function of the value of threat, consequence and vulnerability. The goal of risk management is to create a level of protection that reduces vulnerability to potential threats and consequences. In terms of managing the risk of landslides that will occur, it is necessary to evaluate the existing infrastructure during its operational or lifetime. Suprayitno et al (2020) stated that during the life span, infrastructure evaluation should be conducted periodically to assess the quality of the infrastructure.

The Kelimutu Lake area can be reached from Ende Regency only via the national road. If accessed via H. Hasan Aroeboesman Ende Airport, the journey to the location passes through the foot of Mount Kelimutu. The road network is a fundamental need for a county or country, so the road network must be in good condition (Babo and Suprayitno, 2019), but road locations that pass through a mountainous or hilly topography usually have a commonly occurring problem. In infrastructure development, elevation adjustment is needed because many infrastructures are built on hills and valleys. This situation causes the infrastructure to be built on embankment slopes or excavation slopes. Slopes, whether embankment slopes, excavation slopes or natural slopes, must be engineered to be stable and safe. Unstable embankment slopes can have the potential to cause landslides that can cause damage to the infrastructure built on them (Shoffiana et all, 2022).

Figure 2. Landslides points

LITERATUR REVIEW

Safety Factor

Ray and De Smedt (2009) suggest a clacification of slope stability associated with safety factors, as shown in Table 1. In this table, slopes are categorized as unstable when FS is less than 1, quasi stable when FS is in range between 1 and 1.25, moderate stable when FS is in range between 1.25 and 1.5 and stable when FS more than 1.5.

Table 1. Classification on Slope Stability (Ray and De Smedt, 2009)

Safety Factor	Slope stability class	Remarks
FS>1,5	Theoretically stable	Only major destabilizing factors cause instability
1,25 <FS<1,5	Moderately stable	Moderate destabilizing factors cause instability
1<FS<1,25	Quasi stable	Minor destablizing factors can cause instability
FS<1	Unstable	Stablizing factors are needed for stability

Rain Intensity

The main triggering factor for landslides is rainwater. Rain is thought to be the main cause of landslides (Brand, 1994 in Lim et.al, 1996 in Prasetiyowati, 2007). The increasing water content in the soil can be triggered by rain in a certain period, so that the effective stress is reduced and as a result the shear stress in the soil is also reduced (Suryolelono, 2001).

He daily rainfall data obtained will be converted first to hourly rainfall data with the Mononobe formula (Atikah et al., 2017), as shown in equation 2.6 as follows:

$$i = \frac{R_{24}}{24}\left(\frac{24}{t}\right)^{2/3} \quad \ldots \quad (1)$$

Where:
i : rain intensity (mm/hour; m/hour)
t : time (duration) of rainfall (hours)
R_24 : maximum rainfall height in 24 hours (mm)

Atikah et al (2017) stated that the intensity of rain that occurs in the Indonesian region has a duration of 5-7 hours, so the middle value of the intercal is often used as a reference in calculating hourly rainfall derived from daily rainfall data. Atikah et al (2017) stated that the intensity of rain that occurs in the Indonesian region has a duration of 5-7 hours, so the middle value of the intercal is often used as a reference in calculating hourly rainfall derived from daily rainfall data.

$$Q = 0,278 \times C \times I \times A \qquad \ldots(2)$$

where:

I : rain intensity
C : the value of the flow coefficient
A : catchment area

Load Factor

Slope stability analysis shall consider live load, dead load and earthquake load as per the designation of excavation and embankment slopes. A surcharge load of 10 kN/m2 shall be applied to account for loads acting on the top surface of the slope unless otherwise required by the designation. Pseudo-static analysis of excavated slopes, as well as of embankments, more specialized seismic loads are advised according to the geology and seismicity of the area and the importance of the slope.

Table 2. Traffic load for stability analysis of off-road load fund

The Road Class	The Traffic Load (kPa)	The Other Load (kPa)
I	15	10
II	12	10
III	12	10

The influence of earthquake loads is taken into account if excavation or embankment slopes are planned to be built near residential areas or built with strategic importance criteria, namely under the condition that they should not collapse or cut off transportation routes after a planned earthquake. The plan earthquake for excavation and embankment slopes is set with a probability of exceeding the magnitude during the 50-year plan life of 2% or equivalent to a return period of 500 years with reference to the earthquake map contained in the circular letter of the Minister of Public Works No. 12/SE/M/2010.

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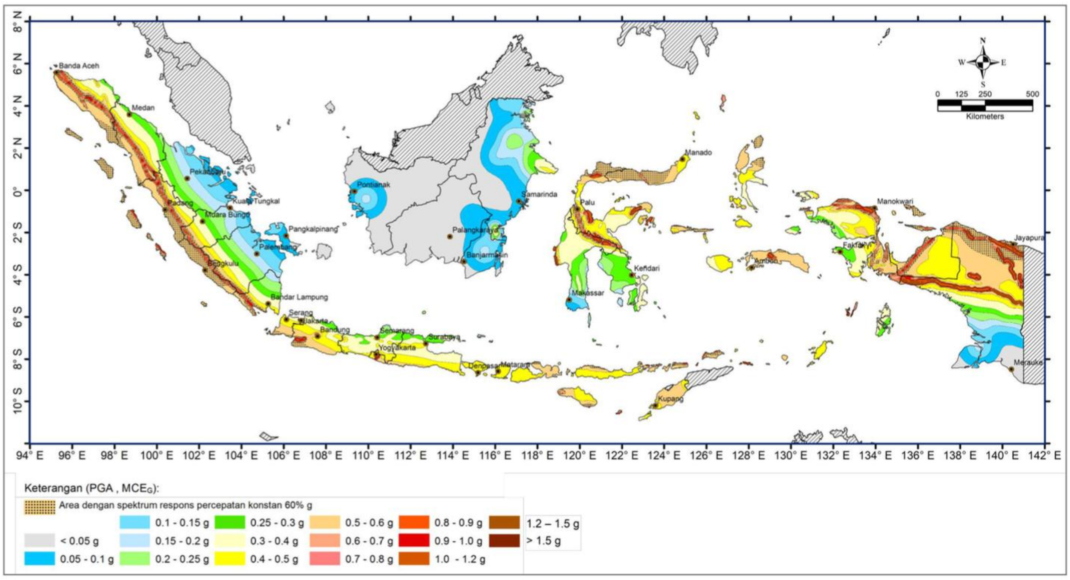

Figure 3. Earthquake Acceleration Map of Indonesia Region
(Source: Indonesia Earthquake Hazard and Source Map, 2017)

Analysis of Slope Stability

The slope stability analysis is commonly based on the concept of plastic limit equilibrium. The main goal of slope stability analysis is to determine the factor of safety of a potential landslide. Therefore, a stable or unstable slope is judged by its factor of safety. Stability is very dependent on the cohesion (c) and the angle of friction in the soil (ϕ). Generally, the drier the soil, the higher the factor of safety, while the more saturated the soil, the lower the factor of safety.

The triggers for slope stability are generally caused by rising water tables that increase the degree of soil saturation and pore water pressure, resulting in effective stress and shear strength of the soil. In the slope stability analysis, there are several assumptions used, namely:

1. Slope failure is occurring along the surface of the landslide plane and can be considered as a 2-dimensional in plane problem
2. The landslide soil mass is considered as a massive object.
3. The shear resistance of the soil mass at every point along the landslide plane is independent of the orientation of the landslide surface, or in other words, the shear strength of the soil is considered isotropic.

The factor of safety is determined with respect to the averaged shear stress all along the potential landslide plane, and the averaged soil shear strength all along the landslide surface.Thus, the soil shear strength may be exceeded at certain points on the landslide plane, even though the calculated safety factor is greater than 1.

RESEARCH METHOD

Slope stability modeling begins with the process of converting the original slope topographic survey data in the field that has been drawn in the form of dfx files (autocad) into the SEEP/W and SLOPE/W programs in the form of soil layer regions. After the shape of the existing slope is formed, soil data such as permeability and hydraulic conductivity of each soil layer is input in each region according to the type of soil layer along with the groundwater level. In the rainwater infiltration modeling process, several variations of rainfall are used which are grouped in a certain duration of time, namely rainfall at T=1 hour, T=3 hours, and

T=5 hours which will be used as parent analysis in the calculation of slope safety numbers in SLOPE/W.

Parent analysis in SEEP/W then in the calculation of the number of slope safety in SLOPE/W. The results of N-SPT correlation in the field that has been corrected, resulting in soil parameters in the form of soil specific gravity (γ), cohesion (c), inner friction angle (ϕ), then inputted along with the loads acting on the STA 8+425 slope model that has been made. The calculation of the safety number of slopes is grouped into several variations of slope conditions, namely:

1. Initial slope of rainy conditions, FS ≥ 1.5 requirements
2. Initial slope of rainy conditions + Vehicle Load, FS ≥ 1.5 requirements
3. Initial slope of rainy conditions + Earthquake Load, condition FS ≥ 1.1
4. Initial slope of rainy conditions + Combination load (Vehicle + Earthquake), condition FS ≥ 1.5

RESEARCH METHOD

The data used at the landslide location at STA 8+425 is secondary data consisting of:

1. Topographic data at the landslide location on the Junction-Kelimutu road section, STA 8+425:
2. Soil test data used from only 1 point, at the landslide location,
3. Rainfall data for 9 years, starting from 2014 to 2022, released by Meteorological Station Klas III Fransiskus Seda Sikka, Maumere Regency, East Nusa Tenggara Province.

Table 3. Recapitulation of Soil Parameters at STA 8+425

Depth (m)	Thickness (m)	Soil description	N-SPT $_{corr}$	Soil consistency
0-2,45	2,45	Brown, clay silty sand	12,5	Stiff clay
2,45-4,45	2	Black, coarse sand with clay	48,19	Very dense sand
4,45-6,45	2	Black, coarse sand	57,097	Very dense sand
6,45-8,45	2	Black, coarse sand with gravel	61,697	Very dense sand
8,45-10,45	2	Black, coarse sand with gravel	61,697	Very dense sand
10,45-12,45	2	Black, coarse sand	61,697	Very dense sand
12,45-14,45	2	Black, coarse sand	61,697	Very dense sand

Source : Anonym (P2JN, NTT)

Table 4. Sikka Regency Rainfall Data 2014-2022

Month/Year	2014	2015	2016	2017	2018	2019	2020	2021	2022
Januari	77,7	168,5	98,7	168,9	170,9	123,7	80,7	222,2	280,1
Februari	156,1	261,3	232,1	133,9	80	57,3	179,4	243,7	399,2
Maret	116,7	117,8	155,1	92,2	155,8	245,5	172,8	228,3	211,8
April	110,4	59,6	23,1	195,1	22,8	30,1	101,9	151,9	69,6
Mei	16,9	15,8	103,2	20,1	11,2	36,5	77,6	75,5	23,9
Juni	16	19,8	59,8	79	13,4	41	27,7	29,2	161,4
Juli	73,9	11,6	60,6	168,3	38	5,5	3,4	29,2	26,3
Agustus	4	2,1	7,6	12,7	51,1	0,7	13,1	63,7	30,4
September	-	4,4	107,9	1,7	5,2	2,5	18	222	186,8
Oktober	5,7	-	34	5,9	5	-	205,9	128,6	155,9
November	3,5	11,2	139,8	74	371,1	25,3	156,5	401,7	265,8
Desember	151,8	43,5	108,3	136,2	148,9	83	256	80	95,5

Table 5. Recapitulation of Water Flux Calculation Results

Duration (hour)	**Design Rain fall Intencity (I_{15}) (mm)**	**Volume flow rate (Q_{15}) (m^3/sec)**	**Water flux (m^3/sec/m^2)**
1	147,158	0,0022828	0,0000913
2	92,704	0,0014381	0,0000575
3	70,746	0,0010974	0,0000439
4	58,400	0,0009059	0,0000362
5	50,327	0,0007807	0,0000312

RESEARCH METHOD

In modeling using SEEP/W, after entering the permeability and hydraulic conductivity parameters, the soil is assumed to be in a saturated and unsaturated state. Rainwater infiltration greatly affects the saturation condition of the soil itself. Waterflux data that has been obtained in the calculation of rainfall, will be used to model rainwater infiltration. In this modeling, the groundwater level obtained from borelog testing is also included in order to see the changes in groundwater level towards rainwater infiltration. To determine the effect of rainfall duration on the slope safety number, rainwater was grouped based on rainfall duration as mentioned in the research method. The results of the analysis using SEEP/W will then be used as the basis (parent analysis) in slope modeling with SLOPE/W. Rainwater modeling can be seen in Figure

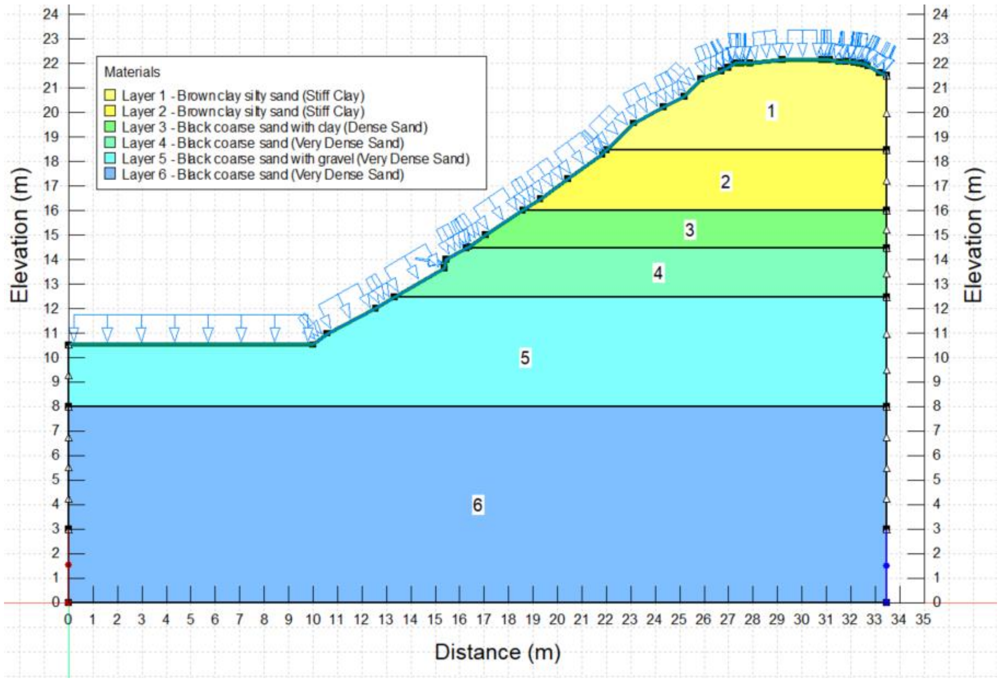

Figure 4. Rain Infiltration Modeling on STA 8+425 Slope with SEEP/W

From **Figure 4** it can be seen that the runoff discharge (water flux) of rainwater infiltrated into the soil through each soil layer and some of it flows evenly on the surface of the slope.

The infiltration model that has been done as in **Figure 4**, then used as a parent analysis to determine the safety number of slopes when rain occurs using SLOPE/W. In **Figure 4** can be seen modeling the effect of rain infiltration on the number of slope safety. **Table 5** shows the recapitulation of slope safety numbers with modeling conditions and rainfall variations.

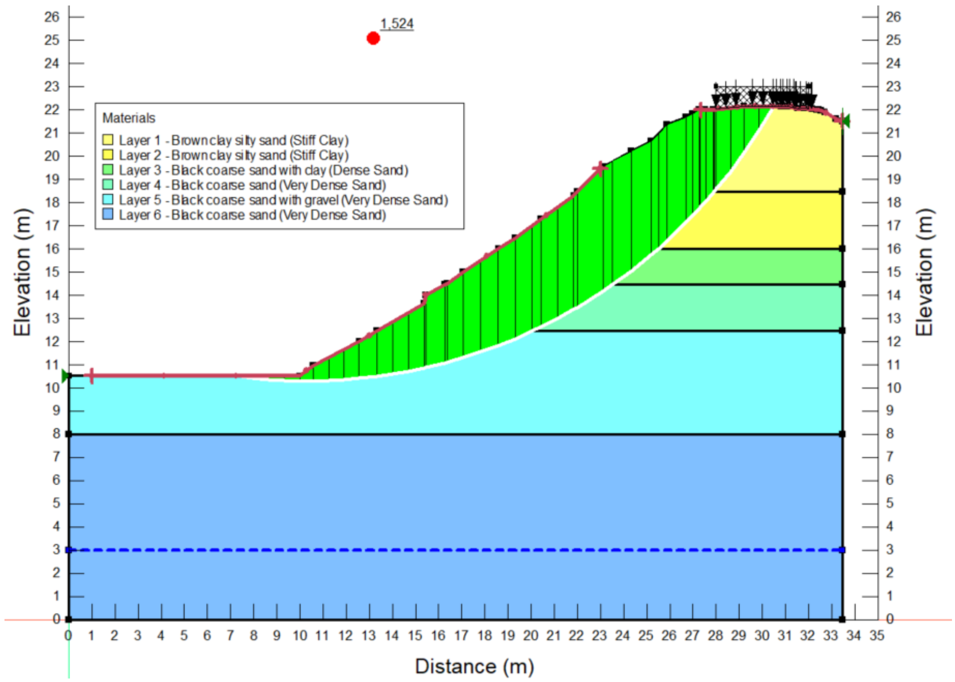

Figure 5. Modeling of Slope Stability due to the effect of Rain Infiltration with SEEP/W

Table 6. Recapitulation of Slope Factor of Safety Values with Rain Infiltration with SLOPE/W

Modeling Conditons	Rainfall Variation Models	FS Values		FS Terms
		Fellenius	Morgenstern-Price	
Initial Slope	Rain duration of 1 hour in 1 day	2,302	2,335	FS≥1,50
	Rain duration of 3 hour in 1 day	2,302	2,335	
	Rain duration of 5 hour in 1 day	2,302	2,335	
	Rain duration of 1 hour in 7 day	2,302	2,335	
	Rain duration of 3 hour in 7 day	2,302	2,335	
	Rain duration of 5 hour in 7 day	2,302	2,335	
	Rain duration of 1 hour in 28 day	2,302	2,335	
	Rain duration of 3 hour in 28 day	2,302	2,335	
	Rain duration of 5 hour in 28 day	2,302	2,335	
Initial Slope+Vihacle Load	Rain duration of 1 hour in 1 day	2,231	2,283	FS≥1,50
	Rain duration of 3 hour in 1 day	2,231	2,283	
	Rain duration of 5 hour in 1 day	2,231	2,283	
	Rain duration of 1 hour in 7 day	2,231	2,283	
	Rain duration of 3 hour in 7 day	2,231	2,283	
	Rain duration of 5 hour in 7 day	2,231	2,283	
	Rain duration of 1 hour in 28 day	2,231	2,283	
	Rain duration of 3 hour in 28 day	2,231	2,283	
	Rain duration of 5 hour in 28 day	2,231	2,283	
Initial Slope+Earth Quake Load	Rain duration of 1 hour in 1 day	1,555	1,596	FS≥1,10
	Rain duration of 3 hour in 1 day	1,555	1,596	
	Rain duration of 5 hour in 1 day	1,555	1,596	
	Rain duration of 1 hour in 7 day	1,555	1,596	
	Rain duration of 3 hour in 7 day	1,555	1,596	
	Rain duration of 5 hour in 7 day	1,555	1,596	
	Rain duration of 1 hour in 28 day	1,555	1,596	
	Rain duration of 3 hour in 28 day	1,555	1,596	
	Rain duration of 5 hour in 28 day	1,555	1,596	
Initial Slope+Earth Quake Load+Vihacle Load	Rain duration of 1 hour in 1 day	1,524	1,577	FS≥1,10
	Rain duration of 3 hour in 1 day	1,524	1,577	
	Rain duration of 5 hour in 1 day	1,524	1,577	
	Rain duration of 1 hour in 7 day	1,524	1,577	
	Rain duration of 3 hour in 7 day	1,524	1,577	
	Rain duration of 5 hour in 7 day	1,524	1,577	
	Rain duration of 1 hour in 28 day	1,524	1,577	
	Rain duration of 3 hour in 28 day	1,524	1,577	
	Rain duration of 5 hour in 28 day	1,524	1,577	

Table 5 shows the recapitulation of slope modeling results to find the slope safety number of each rainfall time variation model. In general it can be seen that from this modeling, with each different rainfall variation model does not change the slope safety number.

Using SLOPE/W

In modeling using SLOPE/W, this slope modeling condition is only carried out when the initial slope receives working loads and is not given the influence of rain infiltration. Where when rain occurs the slope gets water infiltration and also bears the maximum working load which is a combination of vehicle loads and earthquake loads.

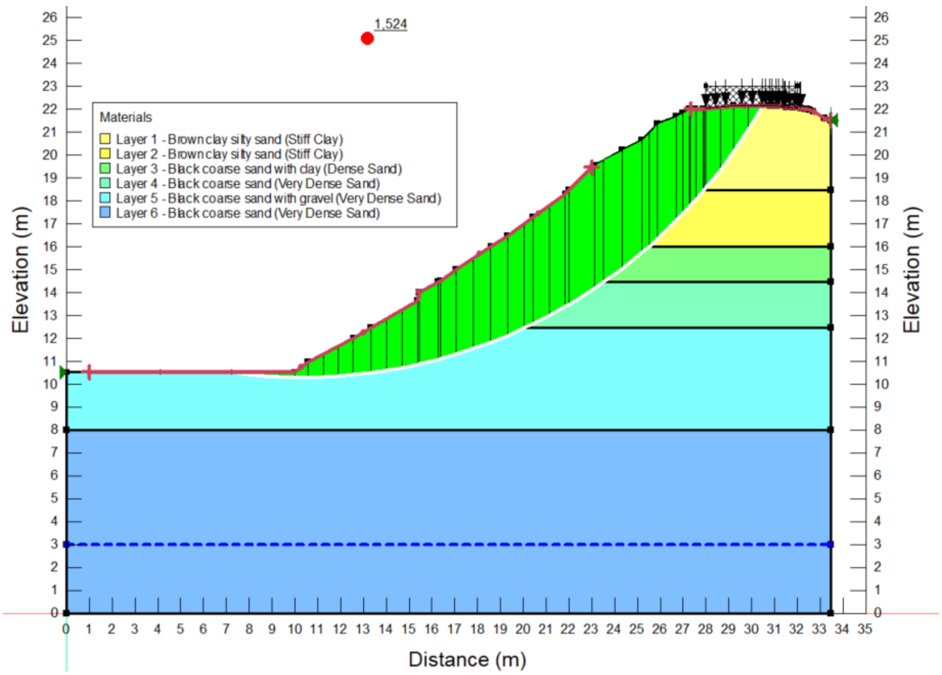

Figure 6. Slope Stability Modeling without the Influence of Rain Infiltration with SLOPE/W

Table 7. Recapitulation of Slope Factor of Safety Values during Rain Infiltration with SLOPE/W

Modeling Conditons	Rainfall Variation Models	FS Values		FS Terms
		Fellenius	Morgenstern-Price	
Initial Slope	Without rain	2,302	2,335	FS≥1,50
Initial Slope+Earth Quake Load	Without rain	1,555	1,596	FS≥1,10
Initial Slope+Vihacle Load	Without rain	2,231	2,283	FS≥1,50
Initial Slope+Earth Quake Load+Vihacle Load	Without rain	1,524	1,577	FS≥1,10

ANALYSIS OF LANDSLIDE AT STA 8+425

In the analysis that has been done to obtain the number of slope safety with slope modeling in rainy and non-rainy conditions as shown in **Table 7**. From the comparison of the security value of the slope in **Table 7** it can be seen that the length of time the rainfall event does not affect the security number of the slope. Slope safety numbers from several conditions and rainfall variation models used do not change and tend to stabilize at 1.5 where according to Ray and De Smedt, 2009 the slope is categorized as stable and only major disturbances can create instability.

Table 8. Recapitulation of Slope Factor of Safety Values during Rainy and Non-Rainy Conditions

Modeling Conditions	Rainfall Variation Model	FS Values		FS Terms
		Fellenius	Morgenstern-Price	
Initial Slope+Earth Quake Load+Vihacle Load	Without rain	1,524	1,577	FS≥1,10
Initial Slope+Earth Quake Load+Vihacle Load	Rain duration of 1 hour in 1 day	1,524	1,577	FS≥1,10
	Rain duration of 3 hour in 1 day	1,524	1,577	
	Rain duration of 5 hour in 1 day	1,524	1,577	
	Rain duration of 1 hour in 7 hari	1,524	1,577	
	Rain duration of 3 hour in 7 day	1,524	1,577	
	Rain duration of 5 hour in 7 day	1,524	1,577	
	Rain duration of 1 hour in 28 day	1,524	1,577	
	Rain duration of 3 hour in 28 day	1,524	1,577	
	Rain duration of 5 hour in 28 day	1,524	1,577	

The facts in the field on the STA 8+425 slope during heavy rains, as shown in Figure 7, the slope experienced landslides that contradict the results of the slope stability modeling that has been done in the previous stage. Therefore, it is necessary to do a reverse analysis modeling of the existing conditions with the assumption that the soil in layers 1 and 2 which is clay soil has a tendency to behave like sand when heavy rain occurs.

Figure 7. Landslide at STA 8+425

Data Analysis of Behaving Like Sand Soil

In modeling the slope with the assumption that the soil in layers 1 and 2 behaves like sand aims to examine the landslide event at STA 8+425 where the initial safety number value of the slope FS = 1.5 which should be stable but in the existing conditions a landslide occurs.

The difference between the original soil and behaving like sand is the value of cohesion (c) and internal angle of friction (ϕ). In the existing soil condition, the parameter values are the same as in the N-SPT test results, while in the behaving like sand soil the soil is assumed to be the same as sand. The assumptions and approaches made at this stage were applied to the modeling because the landslide occurred during very heavy rainfall. During heavy rains, rainwater carries the fine particles in the clay out of the slope, leaving only the larger particles such as gravel and sand.

Assuming the behavior of behaving like sand in layers 1 and 2, it can be determined that the cohesion value (c) is equal to 0 and the internal angle friction (ϕ) of sand = 30 as shown in Table 5.5. The soil data was then reused to perform soil modeling on the behaving like sand condition to obtain the new slope safety values due to the changes as shown in **Figure 4.**

Table 9. Soil Data Behaving Like Sand on STA 8+425 Slope

Layer	Thickness (m)	N-SPT field	Initial Soil Parameters			Soil Parameter Behaving Like Sand		
			γ (kN/m3)	c (kPa)	ϕ (°)	γ (kN/m3)	c (kPa)	ϕ (°)
Brown, clay silt sand (Stiff Clay)	3,7	15	18	50	30	18	0	30
Brown, clay silt sand (Stiff Clay)	2,45	15	18	50	30	18	0	30
Black, coarse sand with clay (Dense Sand)	1,55	43	21	0	40	Initial soil parameters		
Black, coarse sand (Dense Sand)	2	48,5	21	0	45			
Black, coarse sand with gravel (Very Dense Sand)	4,45	60	22	0	45			
Black, coarse sand (Very Dense Sand)	4	60	22	0	45			

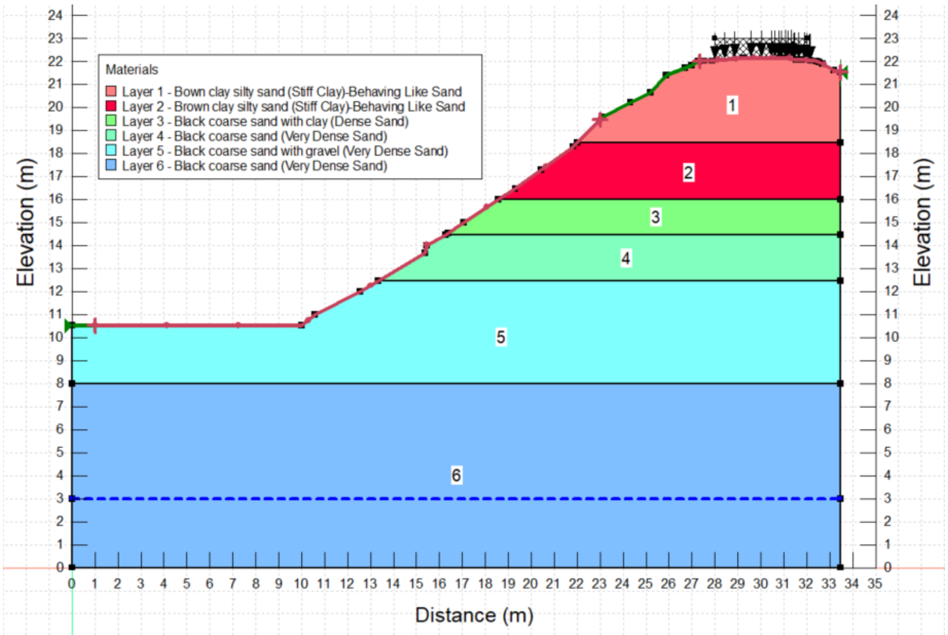

Figure 8. Slope Stability Analysis of Behaving Like Sand Condition

After modeling the conditions for layers 1 and 2 that behave like sand, a comparison of the slope safety numbers between the original conditions and the behaving like sand conditions is shown in **Table 10**. From the results of the comparison of the safety numbers in **Table 10** it can be seen that, when heavy rain occurs using the assumption of behaving like sand there is a decrease in the safety number of the slope where the slope has a landslide with the condition that the FS≤1.1 value in seismic conditions and FS≤1.5 in static conditions. Thus it can be concluded that indeed the heavy rain factor results in changes in the cohesion value of the soil, where this conclusion is the same as the factors causing the landslide stated in the Geotechnical report of the Satker P2JN BPJN NTT.

Table 10. Comparison of Slope Factor of Safety Values with Variation of Modeling Condition

Modeling Conditons	**Rainfall Variation Models**	**FS Values**		**FS Terms**
		Fellenius	**Morgenstern-Price**	
Intial Slope (*Behaving Like Sand Condition*)	Rain duration of 1 hour in 1 day	0,82	0,82	FS≥1,50
	Rain duration of 3 hour in 1 day	0,82	0,82	
	Rain duration of 5 hour in 1 day	0,82	0,82	
	Rain duration of 1 hour in 7 day	0,82	0,82	
	Rain duration of 3 hour in 7 day	0,82	0,82	
	Rain duration of 5 hour in 7 day	0,82	0,82	
	Rain duration of 1 hour in 28 day	0,82	0,82	
	Rain duration of 3 hour in 28 day	0,82	0,82	
	Rain duration of 5 hour in 28 day	0,82	0,82	
Initial Slope+Earth Quake Load+Vihacle Load (*Behaving Like Sand Condition*)	Rain duration of 1 hour in 1 day	0,35	0,35	FS≥1,10
	Rain duration of 3 hour in 1 day	0,35	0,35	
	Rain duration of 5 hour in 1 day	0,35	0,35	
	Rain duration of 1 hour in 7 day	0,35	0,35	
	Rain duration of 3 hour in 7 day	0,35	0,35	
	Rain duration of 5 hour in 7 day	0,35	0,35	
	Rain duration of 1 hour in 28 day	0,35	0,35	
	Rain duration of 3 hour in 28 day	0,35	0,35	
	Rain duration of 5 hour in 28 day	0,35	0,35	

CONCLUSION

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

1. In the modeling of slope stability at the research site using the largest working load and variations in rainfall time for 1 hour, 3 hours and 5 hours did not reduce the safety number of slopes STA 8+425.
2. From the results of the slope stability analysis conducted using Geostudio with the approach of behaving like sand in the stiff clay layer during heavy rains, it can be concluded that rain is the cause of landslides. The landslide that occurred during heavy rain at STA 8+425 was also proven to be true in accordance with the Geotechnical Report of the P2JN BPJN NTT Satker. The results of the modeling with Geostudio obtained the slope safety number before the landslide was 1.524 which decreased to 0.35.

NOTE. This paper has been presented in ICIFAM #2 2023, Surabaya, 26-27 June 2023, organized by Institut Teknologi Sepuluh Nopember (ITS), Surabaya, Indonesia. ICIFAM – International Conference on Infrastructure & Facility Asset Management.

REFERENCES

[1] Atikah, Dewi et al, (2017), "Pengaruh Hujan Pada Stabilitas Lereng Di Jalan Tol Gempol – Pandaan". *Jurnal Teknik Pengairan. Vol 8. Nomor 1. May 2017. Pages 79-88.*

[2] Boba, Frans de Jesus & Hitapriya Suprayitno, (2019). "Road Network Connectivity Quality Assesment for Timor Leste National Road Network". *Journal of Infrastructure and Facility Asset Management – Vol. 1, Issue 2, September 2019, Pages 113-121*

[3] BSN] Badan Standarisasi Nasional. (2017). SNI 8460:2017. Persyaratan Perancangan Geoteknik. Badan Standarisasi Nasional. Jakarta.

[4] Hardiyatmo, H. C, 2005. *Mekanika Tanah 1.* PT. Gramedia Pustaka Utama, Jakarta.

[5] Hardiyatmo, H. C, 2012. *Tanah Longsor dan Erosi – Kejadian dan Penanganannya 1.* Gadjahmada University Press, D.I. Yogyakarta.

[6] Harijan, Harijan (2022). Analisis Stabilitas Lereng Ditinjau Dari Pengaruh Infiltrasi Air Hujan Dan Perkuatan Geometri Lereng Studi Kasus: Kelongsoran Lereng Di Dusun Kondoruba (Km. 25+575 - 26+100) Preservasi Jalan Kalukku-Salubatu-Mambi-Malabo, Sulawesi Barat. *Master thesis.* Institut Teknologi Sepuluh Nopember. Surabaya.

[7] Hidayat, Rokhmat et all (2017) "Analisis Stabilitas Lereng Pada Longsor Desa Caok, Purworejo, Jawa Tengah". *Jurnal Sumber Daya Air. Vol. 14 No.1, Mei 2018. Pages 63- 74.*

[8] Muka, I Wayan and Wibowo Agung (2021). "Implementation of Risk Management in Property Projects". *Journal of Infrastructure and Facility Asset Management – Vol. 3, Issue 1, April 2021, Pages 60-74*

[9] Munir, Abdul Ssalam, (2018). "Kestabilan Lereng Menggunakan Program Slope/W Pada Pit Gn-10 Pulau Gag Kabupaten Raja Ampat Papua Barat". *Jurnal Geomine, Vol. 6, No. 3: December 2018. Pages 157-162.*

[10] Ramadhan, Rizky et all (2020). "Faktor Keamanan Stabilitas Lereng pada Kondisi Eksisting dan Setelah Diperkuat Dinding Penahan Tanah Tipe Counterfort dengan Program Plaxis". Jurnal, Reka Buana: *Jurnal Ilmiah Teknik Sipil dan Teknik Kimia, 5(1). Pages 1 – 11.*

[11] Sebayang, Anakta et all (2022). "Analisis Faktor Keamanan Lereng Terhadap Longsoran Jalan Trikora Dengan Penanganan Dinding Penahan Tanah". *Jurnal pendidikan teknik bangunan dan sipil, Vol 8, No. 2 December 2022. Pages 35-42.*

[12] Setiawan, L.C., dkk (2018). "Analisis Stabilitas Lereng Batuan Dengan Metode Perkuatan Ground Anchor & Soil Nailing Di Labuan Bajo, NTT". *Jurnal Mitra Teknik Sipil, Vol. 1, No.1 Agustus 2018, Pages 102-110.*