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Analysis of Retaining Wall Calculation Using Manual Method and Plaxis Software on the Kuningan (Cipasung) – Majalengka (Cikijing) National Road Boundary Section STA.51+850

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A R T I C L E I N F O

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A B S T R A C T

Landslide disasters are one of the risks that greatly threaten road stability, so proper handling is needed to solve the problem of landslides on national roads. The purpose of this study is to analyze the calculation of soil retaining walls using the manual method and Plaxis Software, in order to obtain a soil retaining wall that is safe to use, namely by calculating the stability of the soil retaining wall and the safety factors of the soil retaining wall. In addition, in the preparation of this study, data is needed to be used as material for processing analysis data such as soil data, dpt dimension data, spt data, rainfall data, drill log data, earthquake data The results of the analysis of manual calculations on the stability of type 1 and type 2 soil retaining walls show that the results are safe while the safety factor value from the Software Plaxis analysis shows safe results.

INTRODUCTION

Landslides are a serious problem for highway and slope safety, so effective handling efforts are needed to deal with landslide problems so that the affected area does not expand further (Wihardi et al., 2018). Landslides are caused when the soil mass moves down the slope because the thrust of the soil is greater than the force acting on the slope. (Maulidah et al., 2023).

National Road Boundary Kuningan (Cipasung) - Majalengka (Cikijing) STA. 51 + 850 is a cross-district national road. This road is an area with very steep cliff terrain and slopes, the area is surrounded by hills, when in excessive rain makes the intensity of rainwater high which results in landslides in the area.

Based on primary data obtained through interviews with the Head of the PPK Office 3.4 (Commitment Making Officials). West Java Province, that the National Road of the Kuningan (Cipasung) - Majalengka (Cikijing) STA. 51+850 at the point with the exact coordinates -7.024086, 108.388230 have landslides occurred 7 times from 2017 - 2024. The last landslide occurred on March 5, 2024 at 21.00 WIB, there was heavy rainfall. This caused soil movement with a width of 10 meters so that there were slope and cliff landslides in the STA. 51 + 850 where the location is a corner. The occurrence of slope and cliff landslides resulted in the road body being covered by landslide materials so as to cut off road access from Kuningan to Cikijing and vice versa, and 3 (three) units of food stall buildings were destroyed by avalanche materials.

LITERATURE REVIEW

1. (Kusuma Adji & Maha Agung, 2021) : This study aims to analyze safety factors (SF) in relation to slope stability: sliding, rolling, and soil support capacity. The method used is to use the modeling of the backpile without reinforcement in the Plaxis application.
2. (Mina et al., 2019): This study aims to find out how to overcome slope landslides by using gabion talud with a bore pile foundation and concrete pavement. The method used in this study is using the Fellenius and Bishop Method with manual calculations and Rocscience Slide Software.
3. (Isdianto & Agustina, 2023): This study aims to find out whether the construction of the soil retaining wall meets the requirements of Indonesian National Standard Number 8460 – Year 2017, concerning the value of safety factors for soil slopes. The method used in this study is using Plaxis Program Modeling.

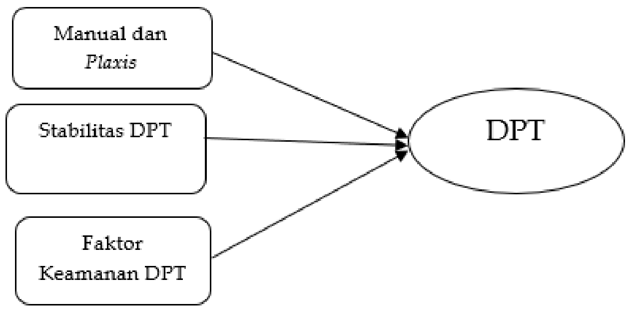


Figure 1. Frame of Mind

METHODOLOGY

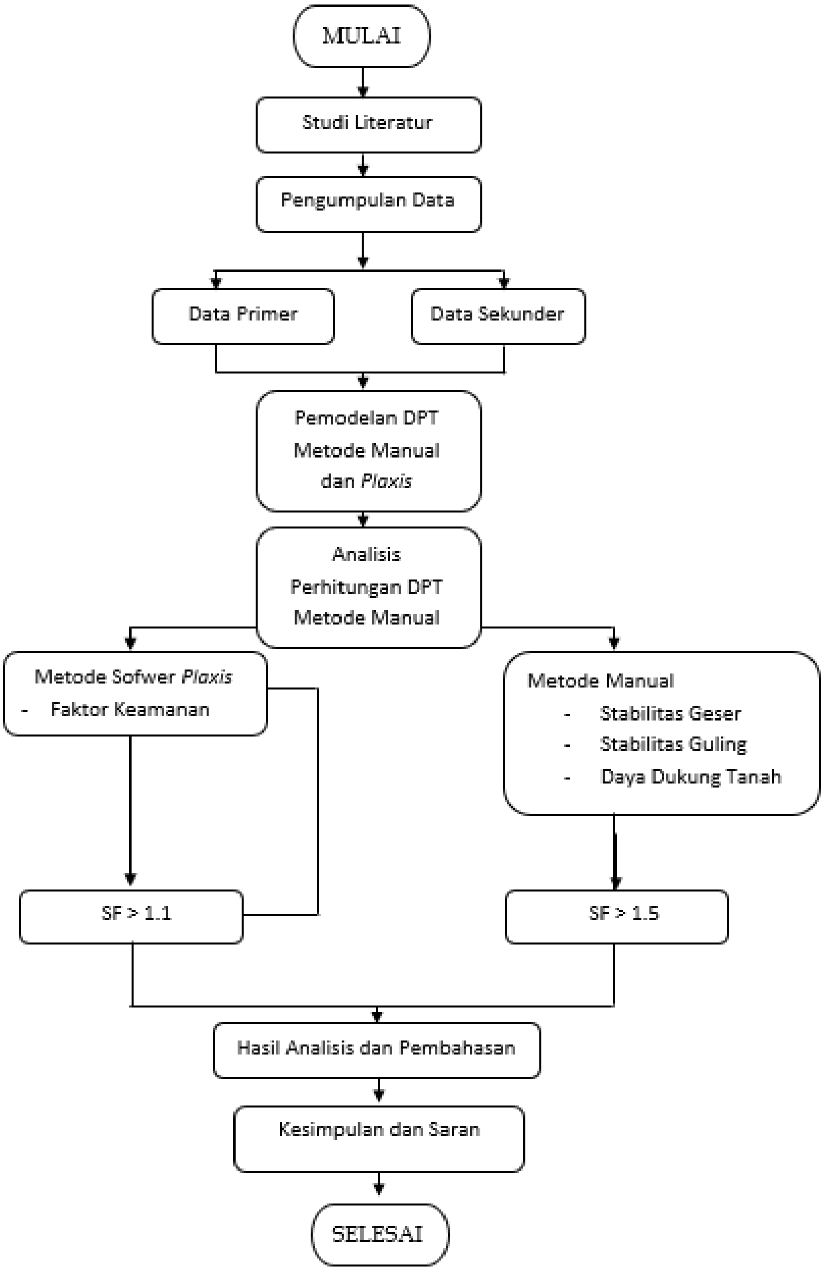


Figure 2. Research Flowchart

The method used in this study uses the Manual Method and the Plaxis Software Method. The manual method aims to be used as a material in analyzing the stability of rolling, shear and safety factors without including earthquake and rain loads, while for Plaxis softwaer it is intended to analyze the slip, deformation, and safety factor values. From these two methods, data obtained from the P2JN (National Road Planning and Supervision), PPK 3.4 (Commitment Making Official), and BMKG (Meteorology, Climatology, and Geophysics Agency) offices are needed.

RESEARCH RESULTS

Manual Calculation

Type 1 Soil Retaining Wall

Table 1. Soil Parameters

SOIL PARAMETERS		
NO	DESCRIPTION	UNIT
1	Soil Specific Gravity (γw)	18.20 KN/m3
2	Dry Soil Specific Gravity (γd)	13.69 KN/m3
3	Type Gravity of Water (γair)	2,701 KN/ m3
4	Specific gravity of kali stone (γstone)	25 KN/m3
5	Soil Cohesion (c)	18.7 KN/m2
6	Load Evenly (q)	14,492 KN/m2
7	Deep shear angle (∅)	30th

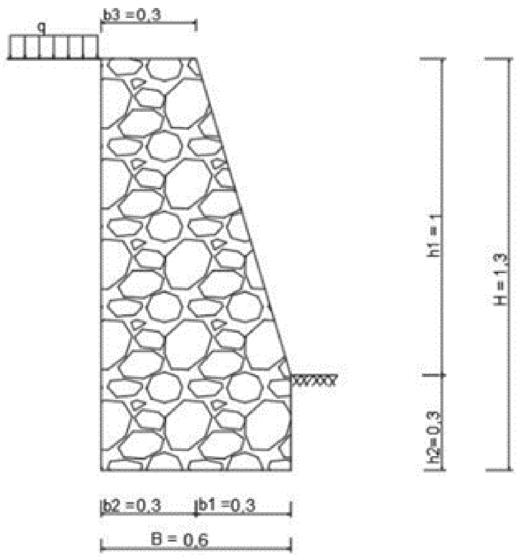


Figure 2. Details of Type 1 Soil Retaining Wall

This gravity model earth-retaining wall is designed using river stone, with a total wall length of 66 meters, which is reviewed per 1 meter elongated.

Table 2. Soil Retaining Wall Dimensions

DIMENSIONS OF SOIL RETAINING WALLS		
NO	DESCRIPTION	UNIT
1	Surface Height DPT (h1)	1 m
2	Water height in front of the wall (h2)	0,3 m
3	Total height (H)	1,3 m
4	Top wall thickness (b3)	0,3 m
5	Bottom wall thickness (b2)	0,3 m

6	Thickness of the lower wall (b1)	0,3 m
7	Total thickness of the bottom wall (B)	0,6 m

Calculating Active and Passive Ground Pressure Coefficients

Ka = Tan2 (45 -)$\frac{\emptyset}{2}$

= Tan2 (45 –)$\frac{\emptyset 30}{2}$

= 0.333

Kp = Tan2 (45 +)$\frac{\emptyset}{2}$

= Tan2 (45 +) $\frac{30}{2}$

= 3

Calculating Active Soil and Sand Pressure

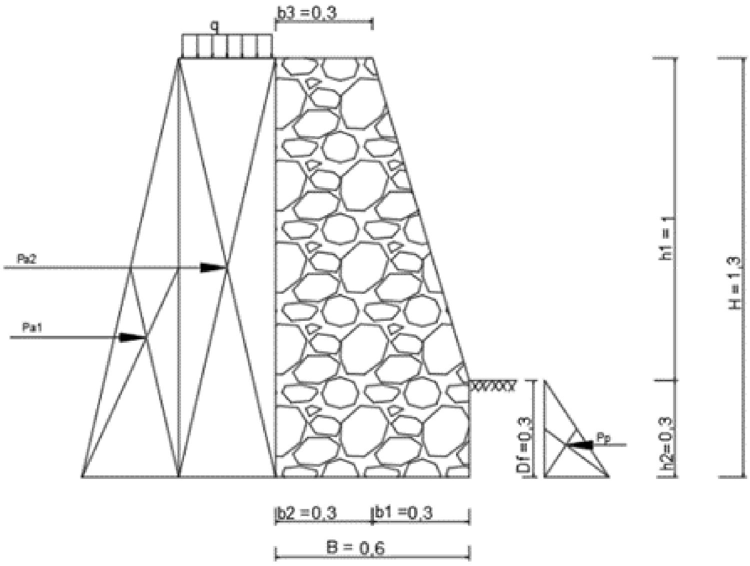


Figure 3. Active Ground Pressure

Calculating Active Soil Pressure

Table 3. Active Ground Pressure

PA1	**PA2**	**∑PA**
= x γb x H$\frac{1}{2}$ 2 x ka x 1	= q x Ka x H x 1	= Pa1 + Pa2
= x 18,20 x 1,69 x 0,333 x 1$\frac{1}{2}$	= 14,136 x 0,333 x 1,3 x 1	= 5,126 + 6,126
= 5,126 KN	= 6,126 KN	= 11,252 KN

Active Moments

Table 4. Active Moments

MGL1	MGL2	∑MGL
= Pa1 x x H$\frac{1}{3}$	= Pa2 x x H$\frac{1}{2}$	= Mgl1 + Mgl2
= 5,126 x x 1,3$\frac{1}{3}$	= 6,126 x x 1,3$\frac{1}{2}$	= 2,221 + 3,982
= 2.221 KN/m	= 3.982 KN/m	= 6.203 KN/m

Calculating Passive Ground Pressure

Table 5. Passive Ground Pressure

'Pp	∑Ph
= x γb x x Kp x 1$\frac{1}{2}$ $\frac{h2}{2}$	= ∑Pah – Pp
= x 18,20 x 0,32 x 3 x 1$\frac{1}{2}$	= 11,252 – 2,457
= 2,457 KN	= 8,759 KN

Self-Calculating Weight of Soil Retaining Wall

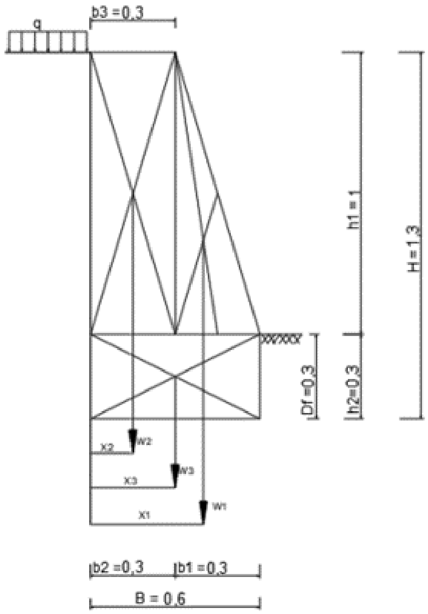


Figure 4. Self Weight Retaining Wall Construction

Table 5. Recapitulation of Forces and Moments of Ground Retaining Wall

VERTICAL STYLE (KN)	DISTANCE TO 0 OR ARM (M)	MOMENT (KN/M)
W1 = 7.5	X1 = 0,2	1,5
W2 = 15	X2 = 0,5	7,5
W3 = 1.3	X3 = 0,65	0,731
Load Evenness (q) = 14,136	0,045	0,636
∑W = ∑V = 23.63		∑Mw = 10,636

Table 6. Active Soil Pressure and Soil Retaining Wall Moment recapitulation

Active Ground Pressure (KN)	Arm (m)	MOMENT (KN/M)
Pa1 = 5,126	0,433	2,22
Pa2 = 6,126	0,650	3,39
∑Pa = 32,55		∑Mgl = 6.20

Calculating Stability Against Shear Force

Rh = c x H x ∑W x tan ∅
= 18,6 x 1,3 x 23,63 x tan 30
= 37,950 KN/m

Fgs = $\frac{\sum Rh}{\sum Ph}$ = 37,950/(8,795)
= 4,3 > 1,5 OK

Calculating Stability Against Rolling Force

Fgl = $\frac{\sum Mw}{\sum Mgl}$
= $\frac{10,357}{6,2}$
= 1,67 > 1,5 OK

Calculating Soil Bearing Capacity Stability

Soil with a shear angle of ∅ = 30o using the bearing capacity factor of meyerhoft shear angle 30o

Table 7. Meyerhoft carrying capacity factors

ϕ	Nc	Nq	Nγ	Nq/Nc	tan ϕ	ϕ	Nc	Nq	Nγ	Nq/Nc	tan ϕ
0	5,14	1,00	0,00	0,20	0,00	26	22,25	11,85	12,54	0,53	0,49
1	5,38	1,09	0,07	0,20	0,02	27	23,94	13,20	14,47	0,55	0,51
2	5,63	1,20	0,15	0,21	0,03	28	25,80	14,72	16,72	0,57	0,53
3	5,90	1,31	0,24	0,22	0,05	29	27,86	16,44	19,34	0,59	0,55
4	6,19	1,43	0,34	0,23	0,07	30	30,14	18,40	22,40	0,61	0,58
5	6,49	1,57	0,45	0,24	0,09	31	32,67	20,63	25,99	0,63	0,60

Vesic Source (1973)

- Calculating ultimate capacity (Qult)

  Qult = c x Nc + Df x γb x Nq + 0,5 x B x γb x Nγ
  = 18,7 x 6,19 0,3 x 18,20 x 1,43 + 0,5 x 0,6 x 18,20 x 0,34
  = 125,417 KN/m²

  Xe = ∑Mw − $\frac{\sum Mgl}{\sum V}$
  = 10,367 − $\frac{6,2}{23,6}$
  = 0,176 m

  e = B 2 - Xe
  = 0,6 2 – (0,176)

$= 0{,}124 \quad > \quad H\,6 = \frac{0{,}6}{2} = 0{,}83$

- Effective width

B′ $= B - 2e$

$= 0{,}6 - 2(0{,}124)$

$= 0{,}353$ m

A′ $= B' \times 1$

$= 0{,}353 \times 1$

$= 1{,}058\ m^2$

q′ $= \frac{V}{A'}$

$= \frac{23{,}63}{1{,}058}$

$= 22{,}338\ KN/m^2$

- Safe factor against support capacity collapse

F $= \frac{Qult}{q'}$

$= \frac{125{,}417}{22{,}338}$

$= 5{,}6 \quad > \quad 3$ OK

Type 2 Soil Retaining Wall

Table 8. Soil Parameters

SOIL PARAMETERS		
NO	**DESCRIPTION**	**UNIT**
1	Soil Specific Gravity (γw)	18.20 KN/m3
2	Dry Soil Specific Gravity (γd)	13.69 KN/m3
3	Type Gravity of Water (γair)	2,701 KN/m3
4	Specific Gravity of Kali Stone (γstone)	25 KN/m3
5	Soil Cohesion (c)	18.7 KN/m2
6	Load Evenly (q)	16,806 KN/m2
7	Deep shear angle (Ø)	30th

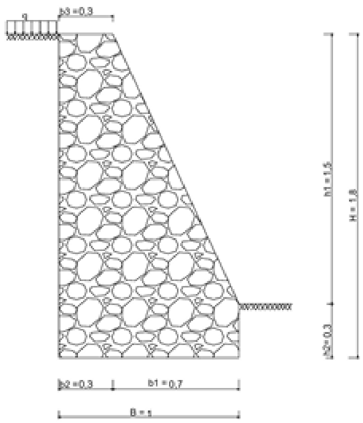


Figure 5. Details of Type 2 Soil Retaining Wall

Table 9. Soil Retaining Wall Dimensions

DIMENSIONS OF SOIL RETAINING WALLS		
NO	**DESCRIPTION**	**UNIT**
1	Surface Height DPT (h1)	1,5 m
2	Water Height in Front of the Wall (h2)	0,3 m
3	Total height (H)	1,8 m
4	Top Wall Thickness (b3)	0,3 m
5	Bottom Wall Thickness (b2)	0,3 m
6	Thickness of the lower wall (b1)	0,7 m
7	Total thickness of the bottom wall (B)	1 m

Calculating Active Soil Pressure Coefficient and Passive Soil

Ka $= \tan^2 (45 - \frac{\varnothing}{2})$

$= \tan^2 (45 - \frac{30}{2})$

$= 0{,}333$

Kp $= \tan^2 (45 + \frac{\varnothing}{2})$

$= \tan^2 (45 + \frac{30}{2})$

$= 3$

Calculating Active and Passive Ground Pressure

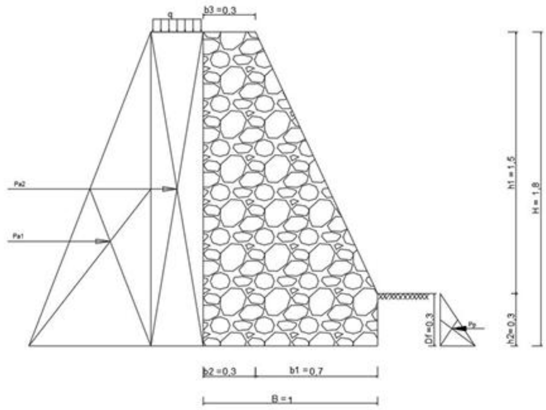


Figure 6. Active Ground Pressure

Calculating Active Soil Pressure

Table 10. Active Ground Pressure

PA1	**PA2**	**∑PA**
$= \frac{1}{2} \times \gamma b \times H^2 \times ka \times 1$	= q x Ka x H x 1	= Pa1 + Pa2
$= \frac{1}{2} \times 18{,}20 \times (1{,}8)^2 \times 1$	= 16,806 x 0,333 x 1,8 x 1	= 9,828 + 10,084
= 9,828 KN	= 10,084 KN	= 19,912 KN

Active Moments

Table 11. Active Moments

MGL1	MGL2	∑MGL
= Pa1 x x H$\frac{1}{3}$	= Pa2 x x H $\frac{1}{2}$	= Mgl1 + Mgl2
= 9,828 x x 1,8$\frac{1}{3}$	= 10,084 x x 1,8$\frac{1}{2}$	= 5,897 + 9,075
= 5.897 KN/m	= 9.075 KN/m	= 14.972 KN/m

Calculating Passive Ground Pressure

Table 12. Passive Ground Pressure

Pp	∑Ph
= x γb x x Kp x 1$\frac{1}{2}$ $\frac{h2}{2}$	= ∑Pah – Pp
= x 18,20 x 0,32 x 3 x 1$\frac{1}{2}$	= 19,912 – 2,457
= 2,457 KN	= 17,455 KN

Self-Calculating Weight of Soil Retaining Wall

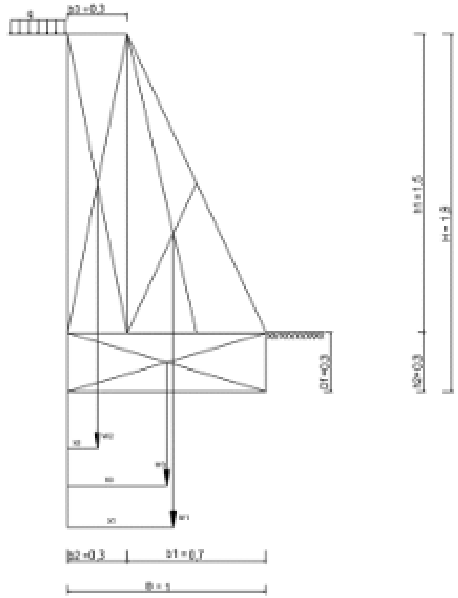


Figure 7. Self Weight Retaining Wall Construction

Calculating Distance or Arm

Table 13. Recapitulation of Forces and Moments of Ground Retaining Wall

Vertical Style (KN)	Distance to 0 or Arm (m)	Moment (KN/m)
W1 = 11.25	X1 = 0,467	5,250
W2 = 37.50	X2 = 0,5	18,750
W3 = 2.63	X3 = 0,90	2,363

Load Evenness (q) = 16.806	Xq = 0,105	1,765
∑W = ∑V = 51.38		∑Mw = 28,127

Table 14. Active Soil Pressure and Soil Retaining Wall Moment recapitulation

Active Ground Pressure (KN)	**Arm (m)**	**Moments (KN/m)**
Pa1 = 9,828	0,600	5,90
Pa2 = 10,084	0,9	9,08
∑Pa = 19,912		∑Mgl = 14.97

Calculating Stability Against Shear Force

Rh = c x H x ∑W x tan ∅
= 18,7 x 1,8 x 51,38 x tan 30
= 63,321 KN/m

Fgs = = 3,6 > 1,5 OK $\frac{\sum Rh}{\sum Ph}$ $\frac{63,321}{17,455}$

Calculating Stability Against Rolling Force

Fgl ≥ 1.5 for cohesive soil

Fgl = $\frac{\sum Mw}{\sum Mgl}$
= $\frac{28,127}{14,97}$
= 1,88 > 1,5 OK

Calculating Soil Bearing Capacity Stability

Soil with a shear angle of ∅ = 30o using the bearing capacity factor of Meyerhof shear angle 30o

Table 15. Meyerhoft carrying capacity factors

ϕ	Nc	Nq	Nγ	Nq/Nc	tan ϕ	ϕ	Nc	Nq	Nγ	Nq/Nc	tan ϕ
0	5,14	1,00	0,00	0,20	0,00	26	22,25	11,85	12,54	0,53	0,49
1	5,38	1,09	0,07	0,20	0,02	27	23,94	13,20	14,47	0,55	0,51
2	5,63	1,20	0,15	0,21	0,03	28	25,80	14,72	16,72	0,57	0,53
3	5,90	1,31	0,24	0,22	0,05	29	27,86	16,44	19,34	0,59	0,55
4	6,19	1,43	0,34	0,23	0,07	30	30,14	18,40	22,40	0,61	0,58
5	6,49	1,57	0,45	0,24	0,09	31	32,67	20,63	25,99	0,63	0,60

Vesic Source (1973)

Calculating ultimate capacity (Qult)

Qult = c x Nc + Df x γb x Nq + 0.5 x B x γb x Nγ
= 18,7 x 30,14 + 0,3 x 18,20 x 18,40 + 0,5 x 1 x 18,20 x 22,40
= 867,922 KN/m2

Vehicle = $\frac{\sum Mw - \sum Mgl}{\sum V}$

$$= \frac{28{,}127 - 14{,}97}{51{,}38}$$

$$= 0{,}256$$

$$e = -\ Xe\ \frac{B}{2}$$

$$= -0{,}256\ \frac{1}{2}$$

$$= 0.244 \quad < \quad \frac{H}{6} = = 0.3 \frac{1{,}8}{6}$$

Effective width

$$B' = B - 2e$$

$$= 1 - 2(0{,}244)$$

$$= 0{,}512 \text{ m}$$

$$A' = B' \times 1$$

$$= 0{,}512 \times 1$$

$$= 0{,}512 \text{ m2}$$

$$q' = \frac{\Sigma V}{A'}$$

$$= \frac{51{,}38}{0{,}512}$$

$$= 100{,}318 \text{ KN/m2}$$

Safe factor against support capacity collapse

$$F = \frac{Qult}{q'}$$

$$= \frac{867{,}922}{100{,}318}$$

$$= 8{,}7 \quad > \quad 3 \text{ OK}$$

Plaxis Software Analysis

The results of the analysis of soil retaining walls with even load loading, rainfall load, and earthquake load.

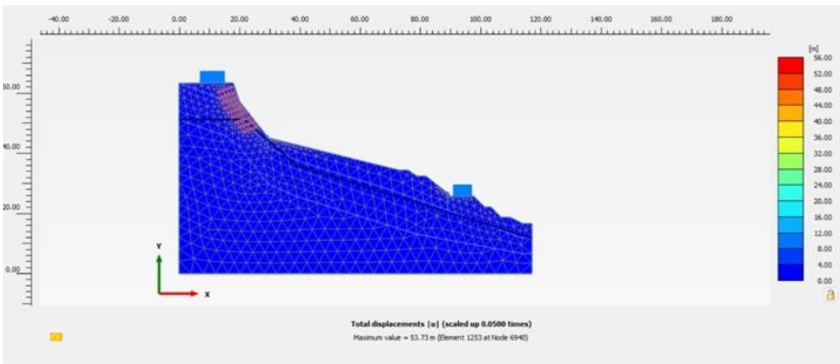


Figure 8. Evenly Load Slip Field Results

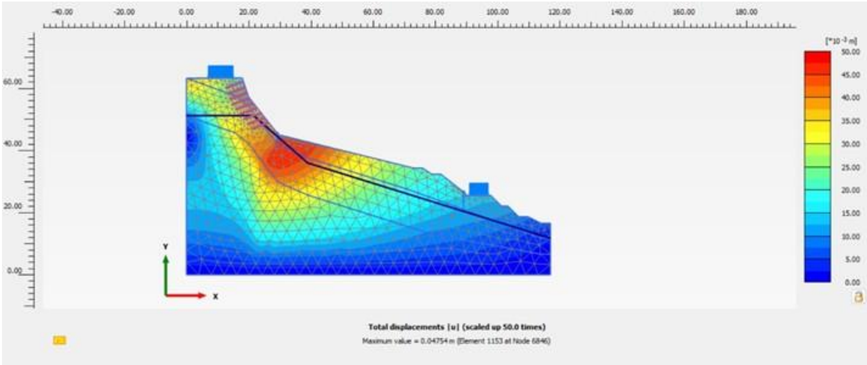
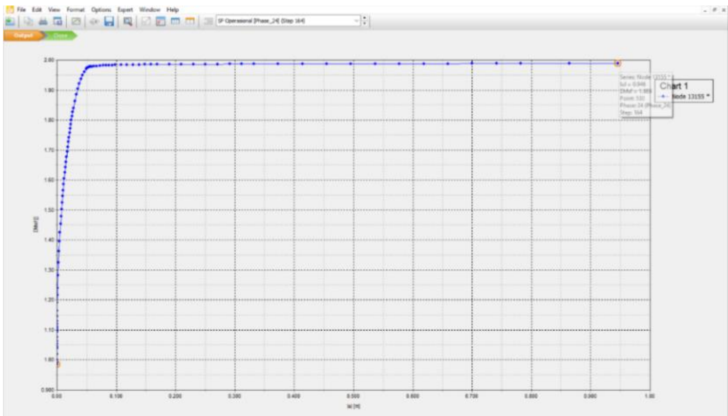


Figure 9. Deformation Results When Operating Load Evenly

Based on the results of the analysis using Plaxis with an even load of 14.136 Kn/m2, it shows that the slope condition is still in a stable state. However, the load causes deformation on the slope that directly intersects with the road load. This condition is caused by an increase in ground tension due to distributed loads. The red color in the analysis results indicates an unstable zone, while the blue color indicates a safe area.



Graph 1. The results of the Evenly Loaded SF from the results of the Evenly Loaded Analysis obtained the SF value of 1,989.

From the results of the DPT Calculation Analysis using Plaxis 2D V24 which is reinforced with Soil Nailling with an even load, a safety factor value of 1.989 was obtained. The FS value has an FS value of > 1.5 (SNI 8460:2017) so it is safe.

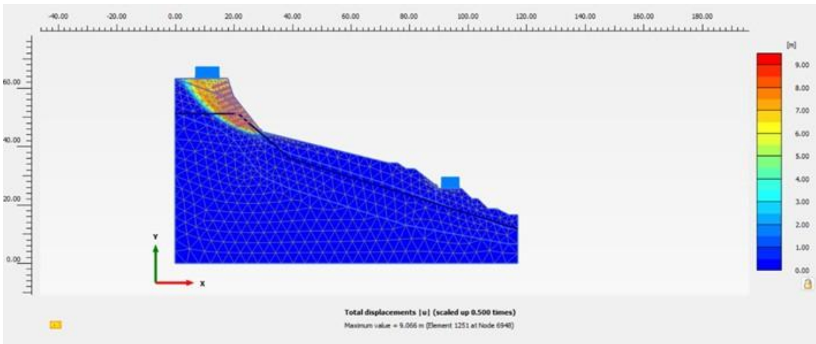


Figure 10. Result of Evenly Load Slippage + Rainfall Load

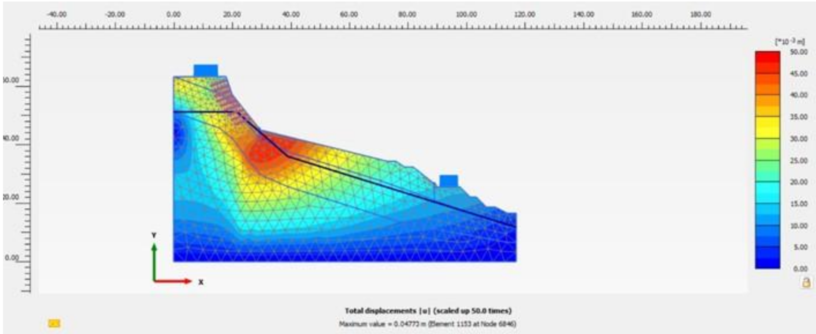
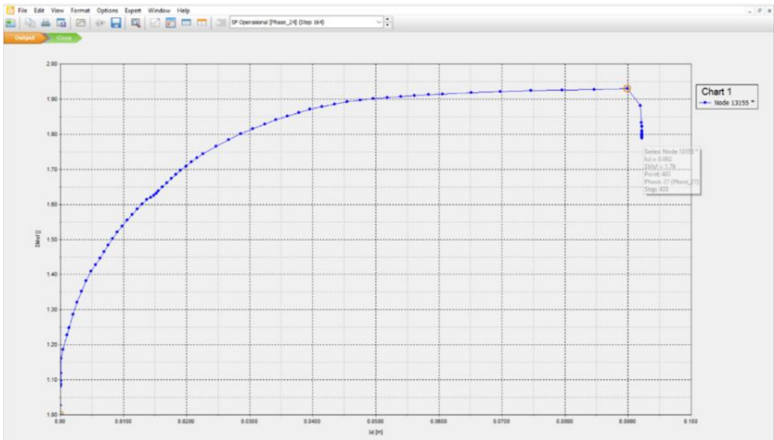


Figure 11. Result of Evenly Load Deformation + Rainfall Load

Based on the results of slope analysis using Plaxis with an even load of 14,136 Kn/m2 and a rainfall load of 230 mm/day, it shows that water infiltration into the soil mass causes an increase in pore water pressure and a decrease in shear strength parameters, so that the stability of the slope decreases compared to dry conditionsThen for the red color in the analysis results shows unstable zones, while blue indicates a safe area.



Graph 2. Results of Uniform Load + Rainfall Load Analysis

From the results of the DPT Calculation Analysis using Plaxis 2D V24 which is reinforced with Soil Nailling with an even load, a safety factor value of 1.79 > 1.5 (SNI 8640:2017) was obtained.

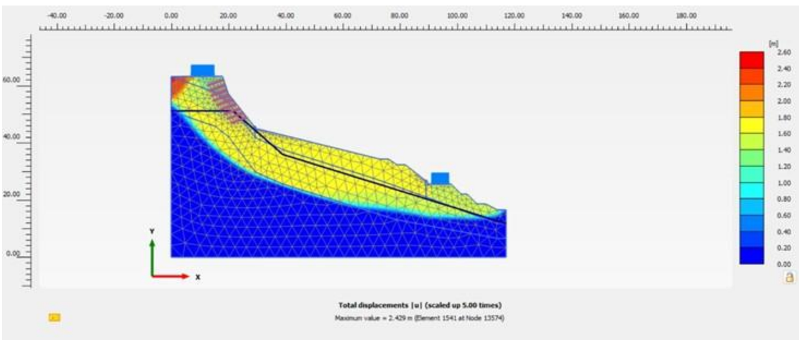


Figure 12. Results of Flat Load Slippage + Earthquake Load

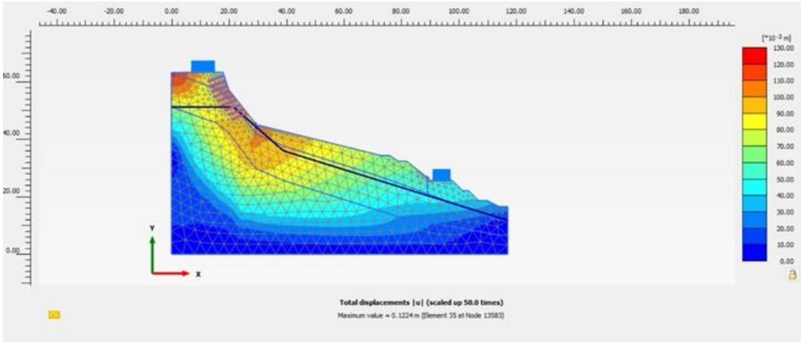
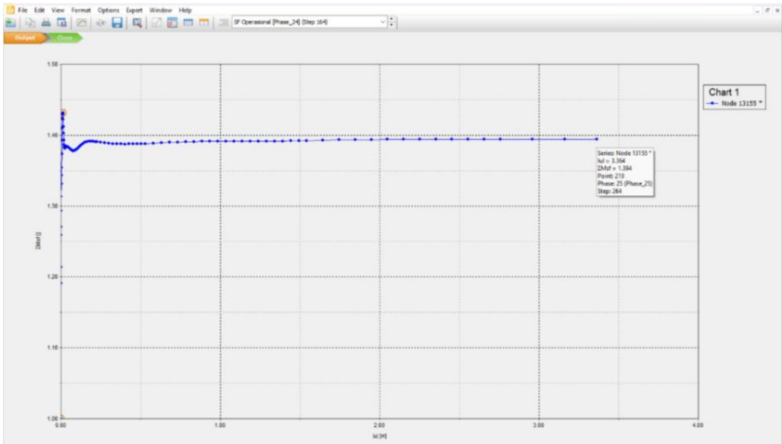


Figure 13. Results of Evenly Load Deformation + Earthquake Load

Based on the results of the DPT analysis, Plaxis was used with an even load of 14.136 Kn/m2 and an earthquake load of 1.8 g. The results of the analysis showed that the increase in earthquake load had a significant effect on slope stability conditions. The earthquake load increases the horizontal force acting on the soil mass, leading to a decrease in safety factors and increased deformation, especially at the top of slopes that are more sensitive to vibration.



Graph 3. Results of Flat Load Slippage + Earthquake Load

From the results of the DPT Calculation Analysis using Plaxis 2D V24 which is reinforced with Soil Nailling with an even load, an SF value of 1.394 > 1.1 was obtained (SNI 8460:2017)

Table 16. Results of Analysis with Groundwater Level

USING GROUNDWATER AT A DEPTH OF 12 METERS	
BURDEN	**SF**
Load Evenly	1,989
Evenly Loaded + Rainfall Load	1,79
Uniform Load + Earthquake Load	1,394

DISCUSSION

Based on the results of the analysis of the manual calculation of the soil retaining wall, the stability values of DPT Type 1 shear force (SF = 4.5) and stability of DPT Type 2 shear force (SF = 3.6) were obtained. then the results of the analysis of the manual calculation of the soil retaining wall obtained the stability values of the type 1 DPT bolster (SF = 1.67) and the stability of the Type 2 DPT bolster (SF = 1.88).

Meanwhile, the results of the plaxis software analysis using groundwater at a depth of 12 m obtained the SF value at the Equal Load of 1.989, the SF value at the Equal Load + Rainfall Load (SF = 1.79) and the SF value at the Equal Load + Earthquake Load (SF = 1.394). Then the results of the plaxis software analysis without using groundwater value SF at Flat Load (SF = 2.004), SF value at Average Load + Rainfall Load (SF = 1.827), and SF value at Average Load + Earthquake Load (SF = 1.572).

From the results of the analysis of the calculation of the soil retaining wall using the manual method (meyerhoft) and the plaxis software above, it shows that the slope is in a safe condition because of the SF > value.

CONCLUSIONS AND RECOMMENDATIONS

The results showed that the instability of the soil retaining wall was influenced by the additional load from traffic activities on it, the increase in water pressure due to high rainfall, and the dynamic load arising from earthquake activity. All three factors simultaneously increase the lateral thrust acting on the retaining structure. Therefore, the phenomenon of landslides in soil retaining wall systems is the result of dynamically changing mechanical and hydrological conditions, requiring a comprehensive design approach that is adaptive to environmental conditions.

Technical recommendations for landslide handling in Landslide handling on slopes can be carried out gradually based on the needs of time. In the short term, efforts that can be made include cleaning landslide materials, installing tarpaulins or geotextiles to cover the slope surface, and creating temporary drainage to reduce water runoff. In the medium term, structural repairs can be carried out through the installation of gabions, simple retaining walls, reinforcement with soil nails or geogrids, and improvements to underground drainage systems to stabilize slope conditions.

Meanwhile, in the long term, the handling is directed towards more permanent slope reconstruction, such as the construction of soil retaining walls designed according to geotechnical analysis, reconteur or reshaping the slope to make it more sloping, as well as the application of deep-rooted vegetation as natural reinforcement and sustainable erosion control

ADVANCED RESEARCH

Further research is suggested to explore variations of slope reinforcement methods using other more diverse types of reinforcement, so that alternative solutions can be obtained that are optimal for specific geotechnical conditions. In addition, the analysis can be extended by utilizing three-dimensional-based software, such as Plaxis 3D, to produce a picture of slope behavior that is closer to actual field conditions and improve the accuracy of slope stability evaluations.

Furthermore, it is necessary to make variations on geometric parameters, such as changes in slope angle and distance between nails, to obtain a more effective and efficient reinforcement configuration in resisting deformation and landslide potential.

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