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Handling Landslides with Type Cantilever (Case study: KM – 38 Semoi Sepaku Road North Penajam Paser Regency East Kalimantan)

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***Abstract*— *The planning of a retaining wall on the KM – 38 Semoi Sepaku road section (STA 10+200) was carried out as a measure to deal with land that has the potential for landslides and the possibility of serious road damage. Handling landslides of cantilever type retaining walls aims to determine dimensions, calculate the working load, analyze stability control: sliding, overturning, soil bearing capacity and landslides, calculate reinforcement for the cantilever type and budget costs. Based on the results of the cantilever wall calculations, the top width is 0.5 m, the bottom width is 0.6 m, the wall length is 5.4 m, the foundation width is 4.2 m and the foundation height is 0.6 m. The stability values of SF sliding = 2.86, SF overturning = 3.33, SF bearing capacity = 8.42 and SF landslides = 1.751. Stem (main steel) D19 – 100 mm, stem (distribution steel) D16 – 150 mm, toe slab and heel slab (main steel) D19 – 100 mm, distribution steel D13 – 100 mm and anchor steel (dowel) D19 – 100 mm. The budget is Rp. 752,546,963.00,-*

***Keywords*— *Landslides: Cantilever: Stability.*

I. INTRODUCTION

Landslides are the movement of masses of rock, debris and soil on a slope that move due to gravity and disruption of the balance of forces acting between the soil/rock's own weight and its ability to withstand the load (Cruden, 1991).

In order to handle the slopes around the road body on the KM – 38 Semoi Sepaku road (STA 10+200) which have the potential for landslides and to prevent the possibility of serious road damage, landslide prevention has been carried out by constructing a 6 meter high cantilever type retaining wall and 20 meters long.

A retaining wall is a structure designed and built to withstand lateral soil pressure when there is a change in soil elevation that exceeds the shear angle in the soil. The construction of this retaining wall can keep the infrastructure safe from overturning and shearing and collapse along the line of the retaining wall.

In this research, planning will be carried out for handling cantilever type earth retaining walls. This retaining wall is carried out to determine the safety factor for the cantilever type, reinforcement and cost budget.

II. LITERATUR REVIEW

According to Hardiyatmo 2003, lateral earth pressure is the force generated by the pushing of the soil behind the soil structure. The amount of lateral pressure is greatly influenced by changes in the location (displacement) of the retaining wall and the properties of the soil.

A. Earth Pressure Theory According to Rankine

Rankine's earth pressure theory ignores the friction between the retaining wall and the embankment behind it.

Active earth pressure coefficient, K_a :

$$K_a = tg^2\,(45° - \phi/2) \tag{1}$$

Active earth pressure, P_a:

$$P_a = ½ \,.\, H^2 \,.\, \gamma \,.\, K_a \tag{2}$$

Passive earth pressure coefficient, K_p :

$$K_p = tg^2\,(45° + \phi/2) \tag{3}$$

Passive earth pressure, P_p:

$$P_p = ½ \,.\, D^2 \,.\, \gamma \,.\, K_p \tag{4}$$

where :

ϕ : friction angle in the soil (°)
H : active soil depth (m)
γ : volume weight of soil (kN/m^3)
D : depth of passive soil (m)

B. Loading

The load acting on the embankment/structure will have a different effect on the soil, the effect of the load will be in accordance with the form of the load itself.

1) Line load

Line loads can be concrete walls, fences, channels and others (Fig. 1.). Lateral earth pressure due to line load per unit width (q), can be calculated using the Boussinesq equation (Hardiyatmo, 2014).

$$\sigma_h = \frac{4 \,.\, q \,.\, m^2 \,.\, n}{\pi \,.\, H \,.\, (m^2 + n^2)^2} \quad > \; 0,4 \tag{5}$$

$$\sigma_h = \frac{q \,.\, 0,203 \,.\, n}{H \,.\, (0,16 + n^2)^2} \quad \leq \; 0,4 \tag{6}$$

where:

σ_h : lateral earth pressure (kN/m^2)
q : line load per unit width (kN/m)
H : depth of retaining wall (m)

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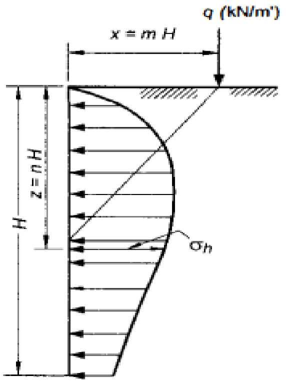

Fig. 1. Line load (Hardiyatmo, 2014)

2) The load is distributed evenly lengthwise

Terzaghi's (1943) equation in Hardiyatmo (2014) can be used to calculate lateral earth pressure due to the load being evenly distributed lengthwise (Fig. 2.), with the following equation:

$$\sigma_h = \frac{2 \cdot q}{H} \cdot (\beta - \sin\beta \cdot \cos 2\alpha) \quad (7)$$

where α and β are angles (in radians).

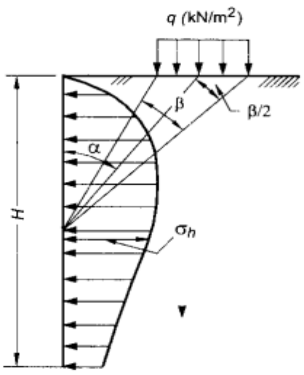

Fig. 2. Load distributed evenly lengthwise (Hardiyatmo, 2014)

C. Stability of Retaining Walls

1) Analysis of sliding

The safety factor against shear (Fig. 3.) can be expressed using the following equation:

$$SF_{(sliding)} = \frac{\Sigma F_R}{\Sigma F_D} > 1.5 \quad (8)$$

where :

ΣF_R : total horizontal resisting force (kN)

ΣF_D : total horizontal driving force (kN)

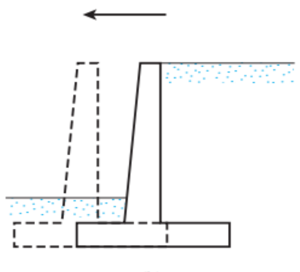

Fig. 3. Failure due to shear (Das, 2007)

2) Analysis of overturning

The force acting on the cantilever is based on the assumption that the active Rankine pressure acts along the vertical plane AB drawn through the heel of the structure (Das, 2007) (Fig. 4.).

$$SF_{(overturning)} = \frac{\Sigma M_R}{\Sigma M_D} > 2.0 \quad (9)$$

where :

ΣM_R : total of resistance moments (kNm)

ΣM_D : total of overturning moments (kNm)

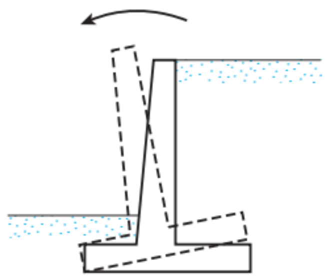

Fig. 4. Failure due to overturning (Das, 2007)

3) Analysis of bearing capacity

The vertical pressure transmitted to the soil by the base plate of the retaining wall must be checked against the ultimate bearing capacity of the soil (Fig. 5.).

$$SF_{(bearing\ capacity)} = \frac{q_u}{q_{max}} > 3.0 \quad (10)$$

$$q_u = 0.5.B.\gamma.N_\gamma + c.N_c + D_f.\gamma.N_q \quad (11)$$

$$q_{max} = \frac{V}{B}\left(1 \pm \frac{6.e}{B}\right) \quad (12)$$

where :

q_u : ultimate bearing capacity of the soil (kN/m^2)

q_{max} : The maximum pressure that occurs between the base of the foundation and the soil (kN/m^2)

B : foundation width (m)

γ : soil volume weight (kN/m^3)

c : soil cohesion (kN/m^2)

D_f : foundation depth (m)

V : vertical force (kN)

e : eccentricity (m)

N_γ N_c, N_q : soil bearing capacity factor

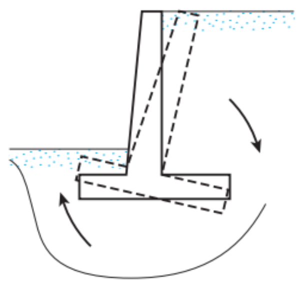

Fig. 5. Failure due to the bearing capacity of the soil (Das, 2007)

4) Slope Stability

The simplified Bishop method (Bishop, 1955) assumes that the forces acting on the sides of the slice have a resultant equal to zero in the vertical direction (Fig. 6.).

$$SF=\frac{\sum_{i=1}^{i=n}[c'b_i+(W_i-u_ib_i)tg\varphi']\left(\frac{1}{\cos\theta_i(1+tg\theta_i\,tg\,\varphi'/F)}\right)}{\sum_{i=1}^{i=n}W_i\sin\theta_i} > 1.5 \quad (13$$

Where:
c' : effective soil cohesion (kN/m^2)
b_i : width of the slice –i (m)
W_i : weight of the soil slice –i (kN)
u_i : pore water pressure at the slice –i (kN/m^2)
ϕ' : effective angle of friction in the soil (°)
θi : angle of the slice –i (°)

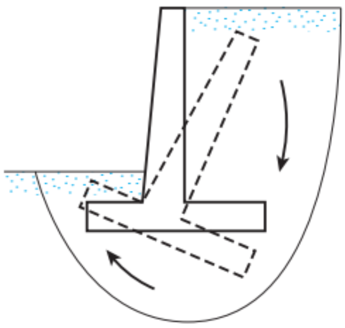

Fig. 6. Failure due to landslides (Das, 2007)

D. Cantilever Type Retaining Wall Reinforcement

1. Vertical walls (Stem)

Factored moments, $M_u = 0.5.K_a.\gamma.y^2.(y/3).(1.2) + 0.5.K_a.q.y^2.(1.6)$

Factored latitude force, $V_u = 0.5.K_a.\gamma.y^2.(1.2) + K_a.q.y.(1.6)$

where:
q : even load (kN/m^2)
γ : soil volume weight (kN/m^3)
y : distance (m)

2. Foundation Wall (Toe and hell slab)

Factored moments, $M_u = M_{\text{due to soil reaction}} - M_{\text{due to the weight of the plate + soil}}$

Factored latitude force, $V_u = V_{\text{due to soil reaction}} - V_{\text{due to the weight of the plate + soil}}$

III. Research Methodology

The research location for the retaining wall is in Fig. 7. namely the KM – 38 Semoi Sepaku road (STA 10+200).

Data for the KM – 38 Semoi Sepaku road section was obtained from CV. Rima Cipta Consultant.

The boring test results at the Bor-1 point (Table 1.) at a depth of 6 m are hard soil with N-SPT 33. The soil sample is dominated by yellow clay and gray clay.

According to laboratory tests, the soil is dominated by CL (Clay) or clay according to the USCS classification. The volume weight is between 16.3 – 16.4 kN/m^3.

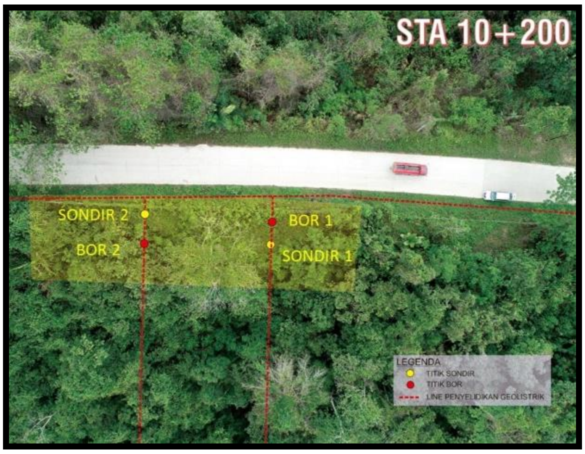

Fig. 7. Location of the KM-38 Semoi Sepaku road section

TABLE 1. Data from Soil Investigation Results

No. BH	Depth	Density, γ	Direct Shear	
			ϕ	C
	(m)	(kN/m^3)	(°)	(kN/m^2)
BH-01	1.50 - 2.00	16.4	16.228	53.74

Fig. 8. shows the design of a cantilever type retaining wall as follows:

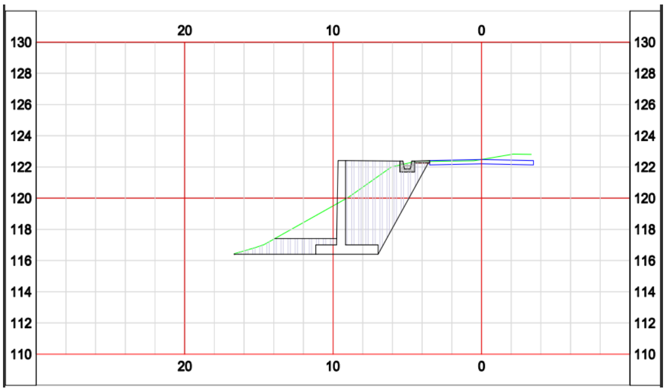

Fig. 8. Cantilever type retaining wall design

The research stages for dealing with landslides using the cantilever type on KM – 38 Semoi Sepaku Road are as follows:

1. Determine the location;
2. Data collection;
3. Planning the dimensions of the retaining wall;
4. Control stability against sliding, overturning, soil bearing capacity and landslides;
5. Reinforcement
6. Calculate the cost budget for the type of retaining wall;

The following are the systematic stages of research contained in the research flow chart in Fig. 9. as follows:

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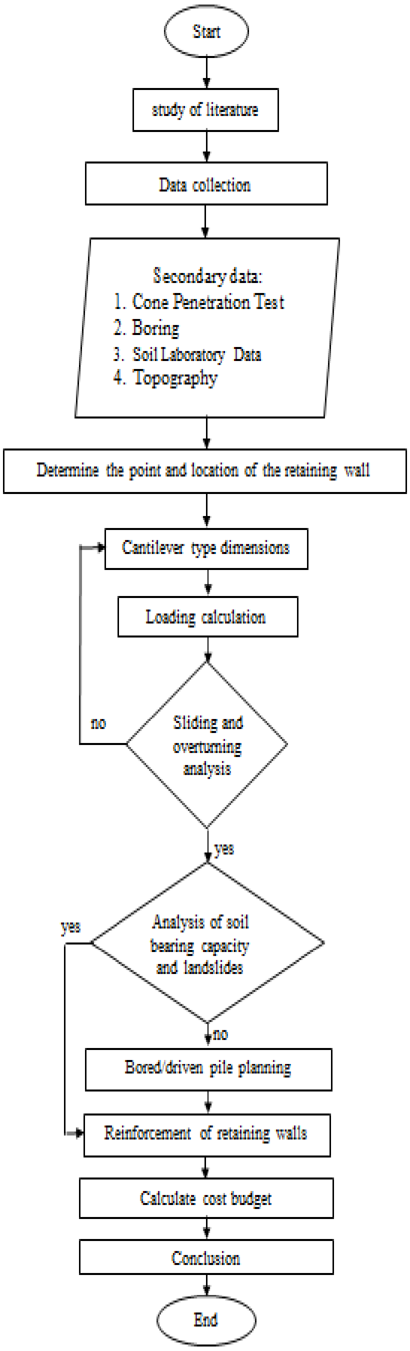

Fig. 9. Flowchart for Handling Landslides

IV. Results and Discussion

A. Planning for Retaining Walls

Based on the results of soil drilling tests, the following data was obtained:

γ_{soil} = 16.4 kN/m^3
c = 53.74 kN/m^2
ϕ = 16.228°
δ = 2/3.ϕ = 2/3 . (16.228.ϕ) = 10,82°

Landfill uses soil correlation based on Whitman, Robert (1962), which is as follows :

$\gamma_{landfill}$ = 17,00 kN/m^3
c = 10 kN/m^2
$\phi_{landfill}$ = 30°
δ = 2/3.ϕ = 2/3 . (30°) = 20°

1) Dimensions of retaining walls

The dimensions of the cantilever type retaining wall (Fig. 10.) are carried out based on SNI 8460:2017 as follows:

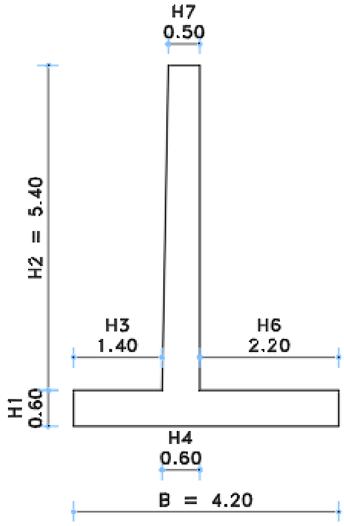

Fig. 10. Cantilever dimensions

B. Soil Lateral Pressure Calculation

Because at the back of the retaining wall, backfill soil is used with a slope of 60° pulled from the bottom of the retaining wall and at the front of the retaining wall, it is planned to backfill the original soil which has been backfilled to a height of 1 meter as shown in Table 2.

TABLE 2. Lateral earth pressure

No.	Active earth pressure	Distance from O	Overturning moment, M_G
	P_a (kN)	y (m)	(kNm)
1.	102	2	204
	Pasive earth pressure	Distance from O	Resistance moment, M_R
1.	P_p (kN)	y (m)	(kNm)
	25.50	0.33	8.50

C. Calculation of Active Pressure and Loading

All calculations of active earth pressure and loading can be seen in Table 3. for cantilevers.

TABLE 3. Cumulative active earth pressure and loading on cantilever type retaining walls

No.	Horizontal Pressure	Overturning Moment, M_G
	(kN)	(kN.m)
	Active earth pressure (P_a)	
1.	102	204
	Line load (q)	
2.	4.12	12.00
	The load is distributed evenly lengthwise (q)	
3.	1.45	16.78
4.	3.10	35.96
	$\sum P_{active}$ = 110.66	$\sum M_G$ = 268.74

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D. Calculation of DPT Weight and Resistance Moment

A sketch of the regional division of the retaining wall can be seen in Fig. 11. and Table 4.

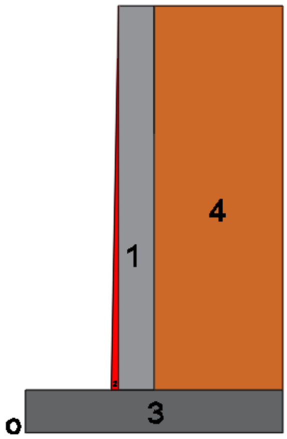

Fig. 11. Sketch of the division of a cantilever type retaining wall

TABLE 4. Material weight and moment about O due to vertical force

No.	Area	Weight, W	Distance from O, x	Resistance moment, M_R
	(m^2)	(kN)	(m)	(kNm)
1.	2.7	67.50	1.75	118.13
2.	0.27	6.75	1.47	9.90
3.	2.52	63.00	2.10	132.30
4.	11.88	201.96	3.10	626.08
		ΣW=339.21		ΣM_R=886.40

E. Stability Control

The results of the analysis of stability calculations for cantilever type retaining walls are summarized in Table 5 below:

TABLE 5. Results of soil retaining wall stability calculations

No.	Stability	Safety Factor (SF)	Remark
1.	Sliding (SF > 1.5)	2.86	safe
2.	Overtuning (SF > 2.0)	3.33	safe
3.	Soil bearing capacity (SF > 3.0)	8.42	safe
4.	Landslides (SF > 1.5)	1.75	safe

F. Calculation of Reinforcement in Cantilever Type Retaining Walls

The recapitulation results of reinforcement calculations for cantilever type retaining walls are in Table 6. and Fig. 12. as follows:

TABLE 6. Recapitulation of the use of reinforcement in cantilever type retaining walls

No.	Item	Remark
1.	Stem (main steel)	D 19 – 100 mm
2.	Stem (distribution steel)	D 16 – 150 mm
3.	Toe slab (main steel)	D 19 – 100 mm
4.	Heel slab (main steel)	D 19 – 100 mm
5.	Distribution steel	D 13 – 100 mm
6.	Anchor steel (dowel)	D 19 – 100 mm

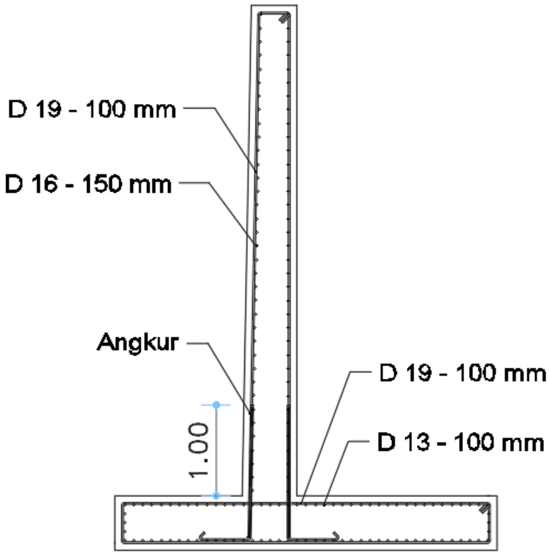

Fig. 12. Reinforcement in a cantilever type retaining wall

G. Quantity Calculation

A recapitulation of the quantity of cantilever type retaining walls can be seen in Table 7. below.

TABLE 7. Recapitulation of cantilever quantities

No.	Work Item	Volume	Unit
III	Earthworks		
3.1. (1a)	Ordinary digging	365.4	m^3
3.2. (2b)	Selected embankmen from Excavations	758.0	m^3
VII	Structure		
7.1 (6)	Medium quality concrete fc' 25 MPa	109.8	m^3
7.3 (3)	Reinforcing Steel, U32 deform	15.256	kg

H. Cost Budget Calculation

The results of the analysis of cost budget calculations for cantilever type retaining walls are summarized in Table 8 below:

TABLE 8. Results of recapitulation of retaining wall costs

No.	Retaining wall type	Cost Recapitulation
1.	Cantilever type	Rp. 752,546,963.00

V. CONCLUSION

From the calculations and discussions that have been carried out, conclusions can be drawn, namely as follows:

1. Top width 0.5m, bottom width 0.6m, vertical walls 5.4m, foundation height 0.6m and foundation width 4.2m.
2. Based on safety factor, sliding = 2.86 (>1.5), overturning = 3.33 (>2), soil bearing capacity = 8.42 (>3) and landslides = 1.751 (>1.5).
3. Stem (main steel) D19 – 100 mm and stem (distribution steel) D16 – 150 mm. Toe slab and heel slab (main steel) D19 – 100 mm, distribution steel D13 – 100 mm and anchor steel (dowel) D19 – 100 mm.
4. Based on the budget for a cantilever type retaining wall of Rp. 752,546,963.00,-

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REFERENCES

[1] Aswanto, M. "Perencanaan Penahan Tanah 15 m dengan Dinding Kantilever di Perimeter Swichyard Skyland Jayapura", *Jurnal Konstruksia*, vol.11, no.1, pp. 63-71, 2019.

[2] Febrialdi, M.D., Tanjung, D., Hasibuan, M.H.M. "Analisa Dinding Penahan Tanah Pada Proyek Paket Peningkatan Jalur Kereta Api KM 8+900 – 9+100 Lintas Medan – Binjai", *Jurnal Teknik Sipil (JTSIP)*,vol. 1, no. 2, pp. 151-158, 2022.

[3] Das, B.M., *Principles of Foundation Engineering*, Sixth Edition, Canada: Thomson Canada Limited, pp. 358, 2007.

[4] Hardiyatmo, H.C., *Analisis dan Perancangan Fondasi I*, Third Edition, Yogyakarta: Gadjah Mada University Press, pp. 473-474, 2014.

[5] Hardiyatmo, H.C., *Mekanika Tanah II*, Third Edition, Yogyakarta: Gadjah Mada University Press, pp. 483, 2003.

[6] M. A. Syafi'i, M. M. Rohman, Soedarsono and Pratikso, "Perencanaan Dinding Penahan Tanah Kantilever dengan Menggunakan Program Plaxis (Studi Kasus : Jalan Kumudasmoro Kelurahan Gisikdrono Kota Semarang)," in *Prosiding Konferensi Ilmiah Mahasiswa Unissula (KIMU) 4 Universitas Islam Sultan Agung*, Semarang., pp. 246-254, 2020.

[7] Malawy, R.M., Gandi, S., Sarie, F. "Analisis Penggunaan Dinding kantilever untuk Mengatasi Kasus Keruntuhan Lereng di Kota Muara Teweh Kabupaten Barito Utara, *Jurnal Kacapuri Jurnal Keilmuan Teknik Sipil*, vol. 4, no. 2, pp. 121-130, 2021.

[8] Nasional, B.S., *Tata Cara Perhitungan Struktur Beton Untuk Bangunan Gedung*, 2002.

[9] Nasional, B.S., Persyaratan Perancangan Geoteknik, 2017.

[10] Salehudin, Rohani, Hasyim. "Analisis Stabilitas Dinding Penahan Tanah Model Kantilever Sungai Sesaot Kabupaten Lombok Barat", *Sade*, vol. 1, no. 2, pp. 81-85, 2021.