Design of Leading Type Retaining Walls: Case Study in Perumnas IV Padang Bulan, Jayapura City

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Abstract

Jayapura City is one of the Papua Province's capital cities with an increasing population. One of the areas in Jayapura City, especially Perumnas IV Padang Bulan, is surrounded by hills. Infrastructure development in the densely packed Perumnas IV Padang Bulan area and increasingly narrow land has forced the local community to build infrastructure under the foot of the hills. Infrastructure development under the foot of the mountains is very prone to landslides or soil movement. There is a retaining wall planned so that the movement of the soil is restrained by the retaining wall so that no landslides occur, which endanger the community in the Perumnas IV Padang Bulan area. From a survey of the Perumnas IV Padang Bulan area in the form of topographic data and cone penetration data (CPT), contour data and cone penetration results (CPT) data were obtained for QC and fs values, then soil type classification was carried out with empirical correlation approaches, then active earth pressure calculations were carried out and passive from Rankine's theory. As well as planning a safe leaning type retaining wall. From the results of the planning that has been done, the plan obtained is a leaning type retaining wall with concrete material, the height of the retaining wall reaches 3.1 meters, and the width of the foundation is 2 meters. Safe against overturning, shearing, and soil-bearing capacity.

Keywords: *Planning, Retaining Wall, Leaning Type.*

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A. INTRODUCTION

The land is an essential aspect of construction planning. Because on the ground stood a building. Therefore, paying attention to the soil stability factor is very important. One of the methods used to control the stability of the soil so that it does not experience a slide is to build a retaining wall. One way to anticipate the occurrence of landslides is by building a retaining wall. Retaining walls withstand lateral earth pressure caused by piled-up soil or unstable original soil. This building is widely used in projects: irrigation, highways, ports, and others (Zhang et al., 2022). Foundation elements, such as basement buildings, and abutments, besides functioning as the lower part of the structure, also function as a retaining ground around it. The stability of the retaining wall is obtained mainly from the self-weight of the structure and the weight of the soil above the foundation plate. The magnitude and distribution of earth pressure on the retaining wall depend on the movement of the soil relative to the wall (Tadesse et al., 2022).

Perumnas IV Padang Bulan Jayapura Papua is a housing complex located in a lowland area at the foot of a hill or slope. This area is also prone to flooding if heavy or moderate rain lasts for 3 hours or more (Korwa et al., 2021). From the research results, the stability analysis of the slopes of Perumnas IV Padang Bulan showed that the slope

was unstable (see Figure 1). If this slope is left unchecked and becomes unstable and then a landslide occurs, then the watershed has the potential to be buried by landslide material (Fan et al., 2019).

Figure 1. Location of Perumnas IV Padang Bulan

River areas buried by landslide material can block the flow of water and overflow so that residential areas are inundated by overflow water or flooding. Therefore, there is a need for treatment so that the value of the slope safety factor increases and the slope status becomes stable or safe (Wu et al., 2020). Unstable slopes need reinforcement or proper handling so that the FS value increases and landslides do not occur. Therefore, there is a need for treatment to improve the slope safety factor (FS) value so that the slope becomes stable and no landslides occur (Lan et al., 2020).

In this study, we chose slope treatment using a leaning-type retaining wall as an alternative treatment. The purpose of the design study of retaining walls is to determine the most appropriate dimensions to be used as an alternative for handling unstable slopes.

B. LITERATURE REVIEW

1. Design

Due to its relationship with the decision-making process, planning activities are fundamentally an effort to select among the many accessible options. In other words, planning establishes priorities based on available resources and predetermined long-term objectives. Conyer and Hill both shared this viewpoint. According to this view, actual planning activities also involve imagination and bravery in offering an evaluation of the current situation and the future (Lent & Brown, 2020). However, creativity and courage cannot be done blindly. In this regard, Friedmann reminded the importance of integrating science and practical knowledge in planning activities. This is in line with the opinion of Kelly and Becker, who stated that planning is an effort carried out rationally to face the future (Shneiderman, 2020).

However, Setiadi said that applying science and practical knowledge cannot fully guarantee planning credibility. According to Setiadi, apart from science and practical knowledge, planning also needs to be supported by intuition. If science and

practical knowledge represent the power of rationality and intellect, then intuition represents the presence of wisdom (Wang et al., 2022). Thus, real planning is not an activity that solely relies on "brain work"; further than that also has to rely on "heart work". This optimal combination of "brain work" and "heart work" allows planning activities to take place in a situation where scientific values blend with human values and more holistic values of life (De Moya & Pallud, 2020).

According to Kaufman, as cited by Harjanto, planning predicts what is required to attain valid and worthwhile objectives. Planning, according to Bintoro Tjokroaminoto, is the process of carefully arranging activities to be carried out to achieve specific goals. According to Pramuji Atmosudirdjo, planning is the process of calculating and determining what will be done to attain specific objectives, who will execute it, when, where, and how (Escandon-Bailon et al., 2021). Siagian defines planning as the entire mental and deliberative process of selecting what to do in the future to attain predetermined objectives. Planning, according to Dior, is the process of arranging a collection of future decisions to achieve specific goals (Rofiyanti et al., 2021).

These expert opinions imply that planning involves activities such as thinking, calculating, selecting, determining, and so on. All stages of this activity are carried out to achieve certain goals (Lee et al., 2019). In essence, planning is the process of making judgments on various possibilities (choices) regarding future objectives and techniques to be followed to attain the desired goals, as well as systematically and continually monitoring and assessing the results of their execution (Badham et al., 2019).

Referring to expert opinions about this planning, it can be concluded that planning is an effort made by humans to make choices from the many available alternatives. The purpose of making choices is to achieve a better future. The things chosen should be the things that are most likely to achieve the intended goals following the capacity of the resources (Bonab et al., 2023). Efforts to make choices need to prioritize the nature of wisdom and scholarship. The result of making this choice is referred to as a plan. In addition to explaining the options that have been made, the plan also explains the reasons for making those choices and how to implement them (Al-Dabbagh, 2020).

2. Earth Retaining Wall

A retaining wall is a building that stabilizes certain soil conditions generally installed in unstable cliff areas. Types of construction include masonry with mortar, empty masonry, concrete, wood, and so on (Palma et al., 2020). The primary function of the earth retaining construction is to hold the land behind it from the danger of landslides due to objects above the ground, such as pavement and construction of roads, bridges, and vehicles; soil weight; and water weight (Fernández et al., 2020).

There are several types of retaining walls, namely:

a. With wood

Usually used in buildings that are not permanent, such as scaffolding buildings for foundation excavation, with short spans, the lateral load is relatively light. If

used in permanent construction, the preservation of materials and protection of materials used from weathering must be considered (Melenbrink et al., 2020). Timber driving is challenging work, a pusher cap is required. Driving in hard or gravelly soil tends to separate the stakes. However, this material has a disadvantage: a relatively short service life (Freschet et al., 2021).

b. With concrete
This material is usually used in permanent buildings, such as sheet piles with a reasonably long span. The advantages of this material include fast and easy to obtain, easy to transport, easy to form according to the desired structure, and the soil against the effects of weather. The disadvantage of this material is its weight, which is quite large (Bertino et al., 2021).

c. With Steel material
This material is also used in permanent buildings with a reasonably long span. This material has the advantages of having a relatively small weight, making work more accessible and practical, and having good strength. The disadvantages of this type of material are the order grace period and the danger of corrosion (Amran et al., 2022).

C. METHOD

This research will be carried out using slope stability analysis using the Fellenius method. The choice of this method is because this method assumes that the forces acting on the right and left sides of any direction have a zero result in the direction perpendicular to the landslide plane. Retaining wall planning research was carried out at the Perumnas IV study location in Padang Bulan using bishop calculations simplified with Geostudio rock software (Slope/W) to find the value of the slope safety factor. All studies of retaining wall analysis will control the bearing capacity of the soil, the control of shear, and the control of overturning. Data collection was carried out through topographical data using theodolite and GPS, as well as sondir data and hand drills. Furthermore, the data will be analyzed to find research conclusions (Hardiyatmo, 1994).

D. RESULT AND DISCUSSION

Based on the data collection process, topographical data is obtained from cross sections. The following is a picture of the cross-section on the most critical plane and soil statistics sequentially in layer one, starting from the soil surface.

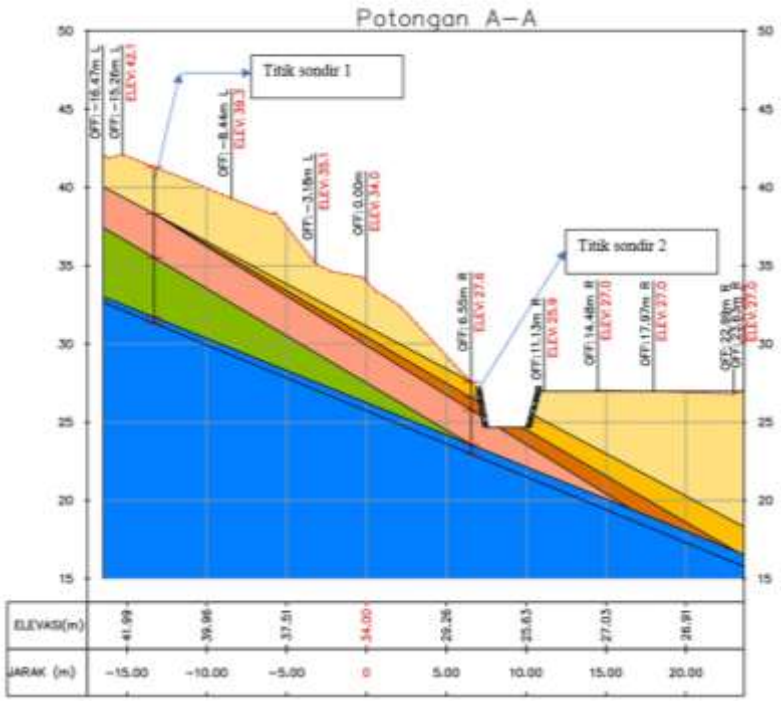

Figure 2. Topographic Data in the form of Cross Sections

Furthermore, based on the research results, it can be seen that the physical and technical characteristics of the field are based on slope stratification. The following table describes the nature and technical aspects of the land.

Table 1. Physical and Technical Properties of Soil Layers Based on Slope Stratification

Soil Layer	Unit Weight γ,	C	Inner Sliding Angle	Classification
	(kN/m3)	T/m2	ϕº	
1	14.8	10.3	20.0	Slightly Chewy Clay
2	15.5	11.5	20.0	Clay or silty clay
3	17.5	43.8	35.0	Compacted sand, silty sand, or compacted loam and silty loam
4	15.9	24.7	27.5	Chewy clay or silty loam
5	19.5	53.3	35.0	Compacted sand, silty sand, or compacted loam and silty loam
6	29.9	99.4	35.5	Compacted sand, gravelly sand, coarse sand, very dense silty sand.

Furthermore, based on the data above, it is possible to determine the landslide area. The following will describe the slope stability analysis and the plan for placing walls to retain the soil.

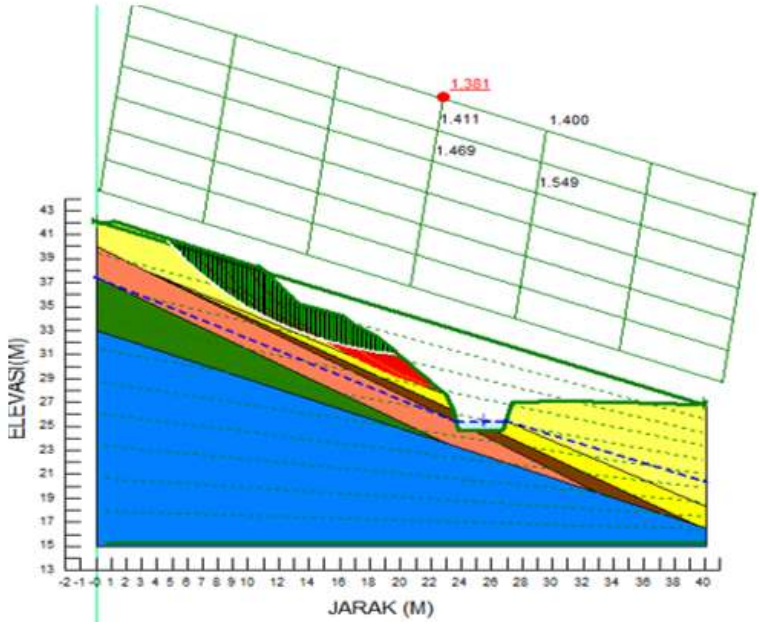

Figure 3. Slope Stability Analysis of the Bishop Method Using Geostudio2018 Software

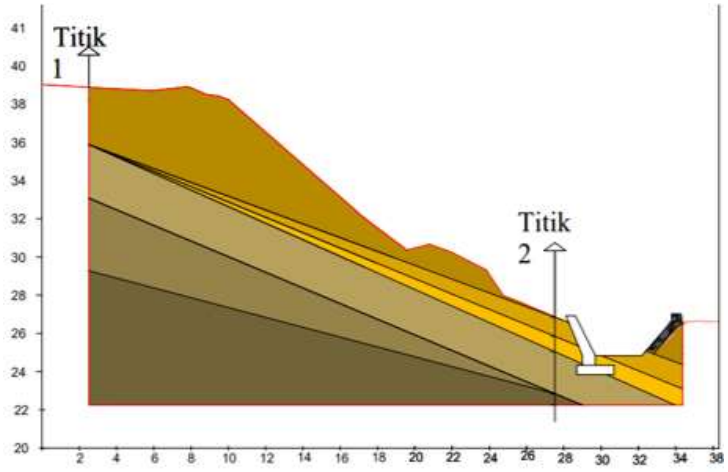

Figure 4. Retaining Wall Placement Plan

From the data collection process results, the results of the calculation of retaining walls were obtained. Below is a table of earth pressure calculations.

Table 2. Soil Data Used in Calculation of Earth Pressure

No	Soil Layer	Type of soil	Sliding Angle (ϕ)	Layer Height (h)	Soil Volume Weight (γb)
				(m)	(t/m3)
1	Soil Layer 2	Clay or silty clay	20	1.216	1.58
2	Soil Layer 3	Compacted sand, silty sand, or compacted loam and silty loam	35	0.931	1.78
3	Soil Layer 4	Chewy clay or silty loam	27.5	0.566	1.62

Next will be seen the recapitulation of the calculation of the coefficient of active and passive soil. The table below will show the coefficient values of these two soils as follows:

Table 3. Recapitulation of Active Soil Coefficient Calculations

Soil Layer	Active Soil Coefficient Value
Soil Layer 2	0.391
Soil Layer 3	0.235
Soil Layer 4	0.307

Table 4. Recapitulation of Passive Earth Pressure Coefficient Calculations

Soil Layer	Passive Soil Coefficient Value
Soil Layer 2	1.317
Soil Layer 3	2.497
Soil Layer 4	1.749

Furthermore, it can be seen the vertical and horizontal earth pressure based on the value of the calculation of the active and passive earth pressure coefficients through the image below:

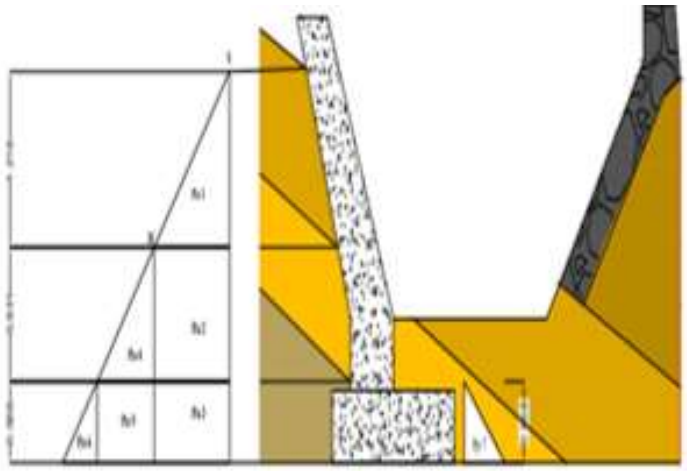

Figure 5. Active and Passive Soil Diagrams

Then the results of active and passive earth pressure calculation recapitulation can be seen in the two tables below as follows:

Table 5. Recapitulation of Active Earth Pressure Calculations

No	Segment Name	Active Earth Pressure	Unit
1	Pa 1	0.457	t/m^2
2	Pa 2	0.362	t/m2
3	Pa 3	0.159	t/m2
4	Pa 4	0.181	t/m2
5	Pa 5	0.159	t/m2
6	Pa 6	0.080	t/m2
7	**∑Pa**	**1.398**	**t/m^2**

Table 6. Recapitulation of Passive Earth Pressure Calculations

No	Segment Name	Passive Earth Pressure	Unit
1	Pp7	0.992	t/m2
2	∑Pp	0.992	t/m2

After seeing the results of the calculation of active and passive earth pressure recapitulation, then it can be seen the recapitulation of active and passive earth pressure calculations as below:

Table 7. Calculation Of Active Earth Pressure Moments

No	Segment Name	Active Earth Pressure Moment	Unit
1	MPa1	1.681	t/m^3
2	MPa2	0.734	t/m^3
3	MPa3	0.045	t/m^3
4	MPa4	0.622	t/m^3
5	MPa5	0.045	t/m^3
6	MPa6	0.015	t/m^3
7	**∑MPa**	**3.141**	**t/m^3**

Table 8. Recapitulation of Passive Earth Pressure Moment Calculations

No	Segment Name	Passive Earth Pressure Moment	Unit
1	MPp7	0.219	t/m^3
2	**∑MPp**	**0.219**	**t/m^3**

After finding the results of the recapitulation of passive earth pressure moment calculations, the next step is to look at the recapitulation results of the retaining wall dimension data.

Table 9. Recapitulation of Earth Retaining Wall Dimension Data

No	Name	Information	Base	Height	Unit
1	Segment 1	Triangle	0.70	2.20	m
2	Segment 2	Rectangular	0.70	0.50	m
3	Segment 3	Rectangular	2.00	0.50	m

Next is to look at the calculation of the area and weight of the retaining wall. Below is the data for calculating the area of retaining walls:

Table 10. Retaining Wall Area Calculation Data

No	Name	Information	Base	Height	Wide	Unit
1	Segment 1	Triangle	0.700	2.3	1.380	m^2
2	Segment 2	Rectangular	0.700	0.5	0.350	m^2
3	Segment 3	Rectangular	2.00	0.5	1.000	m^2
Total Area					**2.730**	m^2

Table 11. Recapitulation Data of Retaining Wall Weight Calculation

No	Name	Information	γ concrete	DPT Weight	Unit
1	Segment 1	Triangle	2.2	3.036	T
2	Segment 2	Rectangular	2.2	0.770	T
3	Segment 3	Rectangular	2.2	2.200	T
∑W				**6.006**	**T**

Then the next step is to calculate the distance to point O on the retaining wall. Below is the result of a recapitulation of the calculation data for the moment arm of the retaining wall:

Table 12. Recapitulation of Retaining Wall Moment Arm Calculation Data

No	Name	Information	Moment Arm Distance	Unit
1	Segment 1	Triangle	1.231	m
2	Segment 2	Rectangular	0.650	m
3	Segment 3	Rectangular	1.000	m
∑LMW			**2.881**	**m**

After calculating the distance to point O, the moment calculation is carried out on the retaining wall. The following is a table containing data for calculating the weight of retaining walls:

Table 13. Recapitulation Data of Retaining Wall Weight Calculation

No	Name	Information	DPT Weight	Moment Arm Distance	DPT Moment	Unit
1	Segment 1	Triangle	3.036	1.231	3.737	t/m
2	Segment 2	Rectangular	0.770	0.650	0.501	t/m
3	Segment 3	Rectangular	2.200	1.000	2.200	t/m
∑MW					6.438	t/m

A retaining wall with a predetermined dimension, stability against overturning is essential because the retaining wall construction will overturn and rotate through a turning point if the construction is unable to resist the acting force so that generally, a retaining wall is categorized as safe if the construction has reached a safety factor value of SF> 2.

$Fgl = \frac{\sum MW + \sum MP}{\sum MPa} > 2$ …….. Safe

$= \frac{6{,}438 + 0{,}219}{3{,}141} > 2$ ……..Safe

= 2,12 > 2 ……. Safe

The displacement of the retaining wall is caused by active earth pressure, which produces a horizontal force on the retaining wall. The ability of stability against shear depends on the resistance force that occurs in the construction plane with the soil at the base of the foundation. In theory, the value of the safety factor is determined by retaining walls that are safe from shearing, namely SF> 2.

$Fgl = \frac{\sum W}{\sum Pa + tan\emptyset} > 2$ …….. Safe

$= \frac{6,006}{1,398+\tan 27,5^0} > 2$ …….. Safe

= 3,13 > 2 ……. Safe

E. CONCLUSION

A retaining wall designed leaning type. The planned retaining wall has fulfilled the safety factor from the danger of overturning, shearing, and the danger of insufficient soil carrying capacity. The carrying capacity of the soil obtained from the calculation results = 135,357 > 3, which means it is safe. Then the rolling SF obtained from the calculation results = 2.3 > 2, which means it is safe. Finally, the shear SF obtained from the calculation results = 3.394 > 2, which means it is safe.

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