Slope Reinforcement Using Gabion Retaining Wall on Angke River in Perumahan Curug Residence Griya Elok West Bogor District

Muhamad Lutfi, Nurul Chayati, Rulhendri Rulhendri, Muhammad Khaerul Insan, Yayan Handrianto

Civil Engineering, Universitas Ibn Khaldun Bogor, INDONESIA

E-mail: mlutfi@ft.uika-bogor.ac.id and yayan.handrianto@gmail.com

| Submitted: May 23, 2023 | Revised: June 05, 2023 | Accepted: January 19, 2024 |

| Published: May 20, 2024 |

ABSTRACT

Bogor City is located between 106,480 E and 6,360 S and has an average altitude of at least 190 m, a maximum of 350 m, slope between 0.3%, 4-15%, 16-30% and above 40% with a distance of approximately 60 km from the capital, surrounded by Mount Salak, Mount Pangrango and Mount Gede. Bogor City has annual rainfall between 3500-4000 mm with an area of 4,992.30 Ha, between 4000-4500 mm with an area of 6,424.65 Ha, and between 4500-5000 mm with an area of 433.05 Ha mainly in December to January. (kotabogor.go.id). On 27 April 2019, landslides occurred due to heavy rain in Perumahan Curug Residence Griya Elok Jalan Parvi Bojong Neros RT. 03/ 07, Curug Village, West Bogor District, Bogor City. It is necessary to plan the retaining wall to mitigate the impacts of the landslide disaster. The access road in Curug Residence is an asphalt road with a width of 2.5 m, this causes only small vehicles to be able to pass in the area. In consideration of the narrow access road, heavy equipment cannot enter the Curug Residence landslide location, in order to deal with landslides, a gabion-type retaining wall will be applied. The gabion retaining wall is more efficient and practical with narrow road access because it can be done directly on site and does not require any heavy equipments. The results of the analysis of gabion retaining walls can be concluded as follows, the dimensions of the gabion retaining wall construction are 9.5 meters high, the width of the foot slab is 1.58 meters, and the thickness of the wall top section slab is 0.79 meters. After the calculation, the result of stability factor to shear is 3,624 > 1,5 and stability to bolsters is 5,858 > 1,5. Then it can be concluded that the gabion retaining wall is safe against danger of shear, bolsters and soil bearing capacity. The construction cost is Rp2.735.000.000 and requires 127 days or 3 months and 1 week of construction work.

Keywords: landslide; mitigation; gabion retaining wall; engineering design; cost budget plan.

INTRODUCTION

The city of Bogor is famous for its high rainfall, so the city earned the nickname City of Rain. Climatic conditions in Bogor City on average each month are at a temperature of 26ºC, with the lowest temperature at 21.8ºC, with the highest temperature at 30.4ºC. The average rainfall each year is 3500 - 4000 mm with the largest rainfall in December and January (Central Bureau of Statistics of West Java Province, 2019). Landslides often occur in the rainy season, after a dry season that causes the soil surface to crack and become more porous. When the soil is cracked, it is easier for rainwater to infiltrate into the soil, making the water content in the soil became saturated. The water accumulated at the bottom of the slope triggers lateral movement, making it easy to move down the slope of the land, leading to landslides. Data from the Bogor City Regional Disaster Management Agency report, there was a landslide on April 26, 2019 at 17.00 WIB at Curug Residense Griya Elok Housing, Jalan Parvi Bojong Neros RT.03/07 Curug Village, West Bogor District, Bogor City. The condition of the access road to the location is not wide enough for large vehicles and heavy equipment to pass, so that only small vehicles can pass. The type of retaining wall that is considered appropriate based on these conditions uses gravity type DPT with gabion type.

Implementing a retaining wall (retaining wall) is an effective method for strengthening and stabilizing the soil so that it does not erode or landslide. retaining walls that suit the needs and

pISSN 2302-4240
eISSN 2655-2086

Volume 13, Issue 2, June 2024, pp.348-362
DOI: http://dx.doi.org/10.32832/astonjadro.v13i12 http://ejournal.uika-bogor.ac.id/index.php/ASTONJADRO

conditions of the location, such as gravity walls, cantilever walls, pile walls, or segmental (modular) retaining walls (Lutfi M et.al, 2023); (Muktadir R et.al, 2023); (Gibran R et.al, 2024).

The foundation is an important part of a retaining wall. Use reinforced concrete or other recommended materials to ensure the foundation is able to withstand the wall load and soil pressure. Drainage system around the foundation to prevent water accumulation which can increase soil pressure on the walls. Usually a drainage pipe and a layer of granular material are used. With the right approach and careful implementation, retaining walls can be an effective solution to prevent erosion and landslides, maintain soil stability, and improve the safety and aesthetics of the surrounding area (Darmawan A et.al, 2022); (Pratama SD et.al, 2024).

Soil Classification

According to (Terzaghi, 1993: 4-5) based on the origin of the compiler, the soil can be divided into two major groups, namely as a result of weathering by physically and chemically, and formed from organic materials. If the result of weathering is still in its original place is called residual soil, if it has moved is called transported soil.

Residual soils occurring in temperate or semi-arid climates are usually stiff and stable and do not extend to great depths. However, especially in hot humid climates where solar irradiation is takes much longer times, residual soils may extend to depths of several hundred meters. These soils may be strong and stable, but they may contain highly compressible material around poorly weathered chunks of rock. Under these circumstances, they can cause difficulties for foundations and other types of construction.

Transported soil or what is commonly called organic soil is usually formed in its place, either through the growth and decay of successive plants such as peat moss, or through the accumulation of skeletal fragments of inorganic material or organism skins. This means that what is meant by organic soil is soil that can be a composition of organic or inorganic elements that can be the result of rock weathering with a mixture of decaying plant material.

Sand and gravel are non-cohesive aggregates composed of angular fragments, usually formed from unaltered rocks or minerals. Particles up to 2 mm in size are called sand, those 2 mm to 200 mm are called gravel, while those larger than 200 mm are known as boulders.

Hardpan is a soil that is highly resistant to drilling penetration. Most of these soils are found to be well graded, very dense, and cohesive aggregates of mineral particles.

Inorganic silt is a fine-grained soil with less plasticity or non-plasticity at all. The least plasticty types usually contain sedimentary quartz grains, sometimes called rock fluor, while the highly plasticty ones contain flake-like particles and are known as plastic silts. Due to its fine texture, inorganic silt is often mistaken for clay, but can actually be distinguished without laboratory testing. If shaken in the palm of the hand, a layer of saturated inorganic silt will release water, giving the surface a shiny appearance. Subsequently, if it is flexed between the fingers of the hand, the surface becomes faint again. After drying, the layer becomes brittle, and dust can be removed by rubbing fingers. Silt is impermeable, but when loose, it can rise into a drill hole or excavation like a viscous liquid. This type of soil is very unstable.

Organic silt is a slightly plastic, fine-grained soil with a mixture of finely separated particles of organic materials. It may also contain partially decayed bark and plant fragments. The color of the soil varies from light gray to dark gray, in addition it may contain H2S, CO2, and various other gases from plant decay that will give the soil a unique smell. The permeability of organic silt is very low while the compressibility is very high.

Clays are aggregates of microscopic and submicroscopic particles derived from the chemical decay of rock constituents and are plastic with moderate to high moisture content. In the dry state it is very hard and not easily peeled off with just a finger. The permeability of clay is very low, in a state with high water content (wet) clay is sticky.

Organic clays are clays whose important physical properties are partly influenced by the presence of separated organic matter. In the saturated state organic clays tend to be very compressible, but in the dry state their strength is very high. Their color is usually dark gray or black, and they may have a pungent smell.

Peat is a slightly fibrous aggregate derived from macroscopic and microscopic fragments of vegetation. Its color varies between light brown and black. Peat is also compressible, making it almost always impossible to support a foundation. Various techniques have been tried to build earthen embankments on top of peat layers without the risk of collapse, but the settlement of the embankments still tends to be large and continues at a diminishing rate over the years.

Earth Pressure

According to (Das, 1994), retaining structures such as retaining walls, basement walls, and steel sheet piles are commonly used to retain soil masses with vertical slopes. In order to properly plan retaining structures, it is necessary to know the horizontal forces that act between the retaining structure and the retained soil mass. The horizontal force is caused by horizontal pressure.

Earth Pressure at Rest

Figure 2.4(a) shows a soil mass bounded by a frictionless wall AB installed to an infinite depth. A soil element located at depth (z) will be subjected to vertical pressure σv and horizontal pressure σh in the form of effective pressure and total pressure, while the shear stress in the upright and flat planes is neglected.

If the wall AB is at rest, where the wall does not move in either direction to the right or left of its initial position, the soil mass will be in a state of "elastic equilibrium". The ratio of horizontal pressure and vertical pressure is called the "coefficient of earth pressure at rest, K_0".

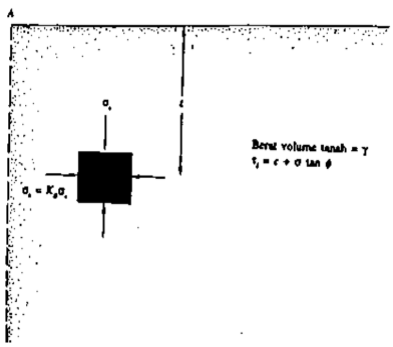

Figure 1. Earth Pressure at Rest

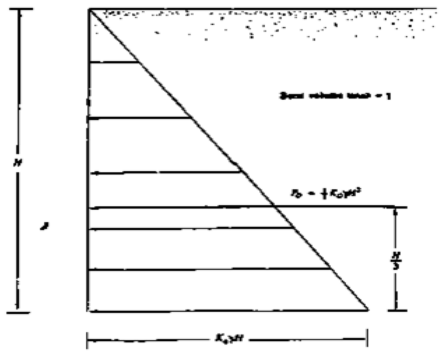

Figure 2. Earth Pressure Distribution at Rest on Retaining Walls.

Rankine's Active Earth Pressure

Plastic equilibrium in soil is a state in which every point in the soil mass is in the process of collapsing. Rankine's theory of soil stress investigates the state of stress in a soil that is in plastic equilibrium. In Figure 1 a soil mass as shown in Figure 2 is shown. The soil is bounded by a wall with a smooth surface (AB) installed to an infinite depth. The principal vertical and horizontal (total and effective) stresses in the soil element at a depth (z) are σv and σh, respectively.

If the AB wall is not allowed to move at all, then σh=$K0\ \sigma v$. However, if the AB wall is allowed to move away from the soil mass slowly, the main stress in the horizontal direction will decrease continuously. Eventually, a state of plastic equilibrium will be reached when the conditions of stress in the soil element and slack in the soil occur. This state is called the "Rankine active condition", the pressure σa acting on the vertical plane (which is the principal plane) is the Rankine active soil pressure. The value of σa can be calculated using the equation obtained from deriving the functions γ, z, c, and ø from Figure 2.

pISSN 2302-4240
eISSN 2655-2086

Volume 13, Issue 2, June 2024, pp.348-362
DOI: http://dx.doi.org/10.32832/astonjadro.v13i12 http://ejournal.uika-bogor.ac.id/index.php/ASTONJADRO

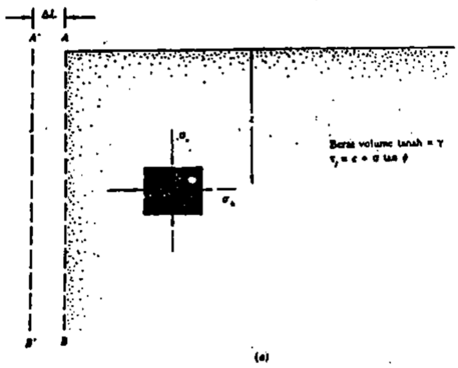

Figure 3. Rankine's Active Earth Pressure.

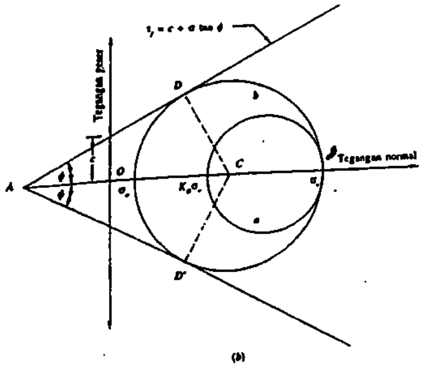

Figure 4. Mohr's Circle on Active Earth Pressure

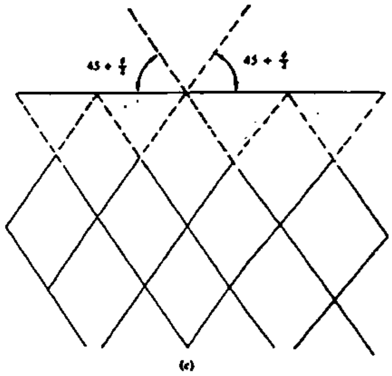

Figure 5. State at Rankine's Active Earth Pressure

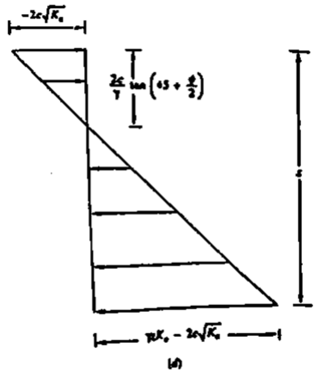

Figure 6. Rankine's Active Earth Pressure Distribution on Retaining Walls

Rankine's Passive Earth Pressure

Rankine's passive earth pressure can be described by figure 5, where AB is a smooth wall of infinite depth. The initial stress state in a soil element can be seen in the Mohr circle in figure 6. As the wall is slowly pushed into the soil mass, the principal stress σh will increase continuously, leading to a state of stress in the soil element. In this state, soil collapse will occur, known as the Rankine passive state. In addition, the lateral soil pressure (σ_p), which is the main stress, is called Rankine's passive soil pressure. The value of σ_p can be calculated using the following equation:

$$\sigma_p = \sigma_v tan^2\left(45 + \frac{\emptyset}{2}\right) + 2c\, tan\left(45 + \frac{\emptyset}{2}\right)$$

$$\sigma_p = \gamma_z tan^2\left(45 + \frac{\emptyset}{2}\right) + 2c\, tan\left(45 + \frac{\emptyset}{2}\right)$$

The derivation of the function is similar to the derivation for active conditions according to Rankine. For non-cohesive soils (c=0) the active earth pressure can be calculated using the following equation:

$$\sigma_p = \sigma_v tan^2\left(45 + \frac{\emptyset}{2}\right)$$

Or

$$K_p = \frac{\sigma_p}{\sigma_v} = tan^2\left(45 + \frac{\emptyset}{2}\right)$$

Where Kp is Rankine's Passive Earth Pressure Coefficient.

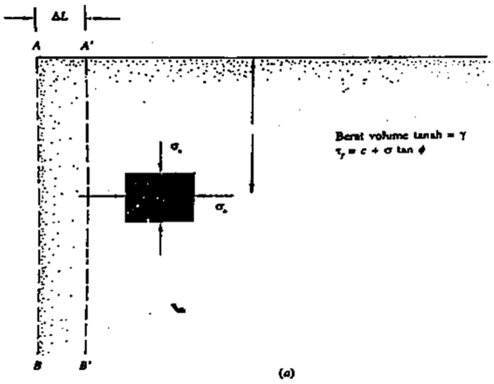

Figure 7. Rankine's Passive Earth Pressure

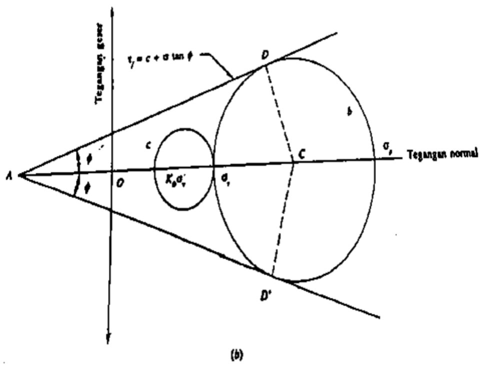

Figure 8. Mohr's Circle on Rankine's Passive Earth Pressure

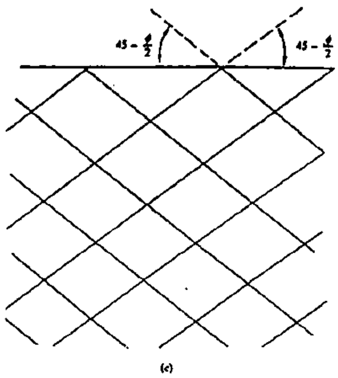

Figure 9. State at Rankine's Active Earth Pressure

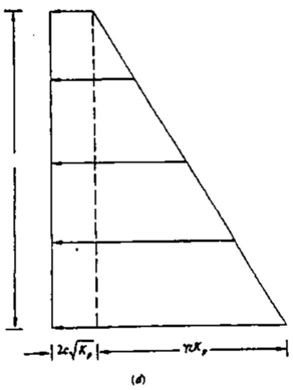

Figure 10. Rankine's Passive Earth Pressure Distribution on Retaining Walls

Retaining Wall

According to Suryolelono (2004), a retaining wall or also commonly called a retaining wall is a construction built to hold soil or prevent the collapse of steep soil or slopes built in place, the stability of which cannot be guaranteed by the soil slope itself, as well as to obtain an upright plane. Retaining walls are used to resist lateral earth pressures generated by unstable soil or native soil. This is influenced by the condition of the topographic features of the place when earthworks are carried out such as embankment or soil cutting.

Retaining walls are used to prevent materials from collapsing. In general, the function of retaining walls is to withstand the magnitude of soil pressure due to poor soil parameters so that landslides can be prevented, as well as to protect the slope of the land and complement the slope with a solid foundation. Retaining walls are classified into seven types, namely:

Gravity Wall

Gravity walls are retaining walls made of unreinforced concrete or masonry. A small amount of concrete reinforcement is sometimes provided on the wall surface to prevent surface cracks due to temperature changes. In gravity type retaining walls in planning there must be no tensile stress in any slice of the body. For this reason, in planning this type of retaining wall, the following points need to be considered (see Figure 2.8).

a. Generally, the width of floor plate B is set at 0.5 - 0.7 H.

b. Thickness of foot and heel (H/8 - H/6)

c. Foot and heel width (0.5 - 1)d (d =foot width)

Semi-Gravity Wall

pISSN 2302-4240
eISSN 2655-2086
Volume 13, Issue 2, June 2024, pp.348-362
DOI: http://dx.doi.org/10.32832/astonjadro.v13i12 http://ejournal.uika-bogor.ac.id/index.php/ASTONJADRO

A semi-gravity wall is a gravity wall that is slightly slender. Because it is slender, concrete reinforcement is required in the structure, but only in the wall. Concrete columns, which function as pegs, are installed to connect the wall and the foundation.

Cantilever Wall

The shape of this wall is an inverted letter "T" or like the letter "L" and each section is calculated as a cantilever. These walls are generally made of reinforced concrete. For walls that are not too high, the cantilever type is quite economical. The height of this wall is approximately 6 to 7.5 meters.

Counterfort Wall

A counterfort wall is a wall consisting of a thin reinforced concrete wall whose interior is supported at a certain distance by a vertical slab or wall called a counterfort. The space above the foundation slab, between the counterforts is filled with dredged soil.

Reinforced Earth Wall

A reinforced earth wall is a wall consisting of a wall of soil fill reinforced with certain materials made of geosynthetics or metal.

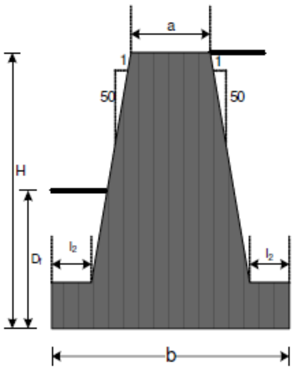

Figure 11. Gravity Wall

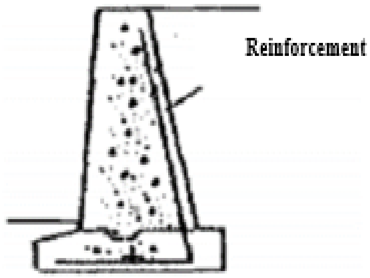

Figure 12. Semi-Gravity Wall

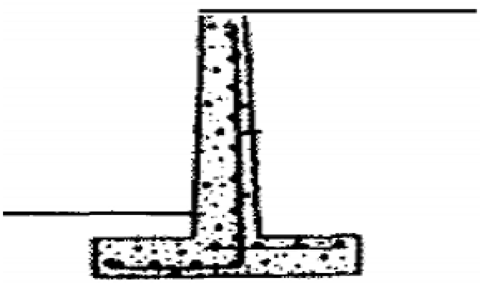

Figure 13. Cantilever Wall

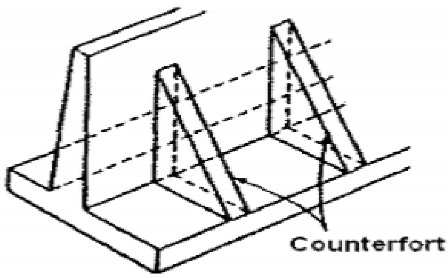

Figure 14. Counterfort Wall

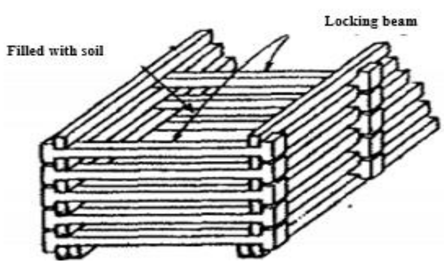

Figure 15. Reinforced earth wall

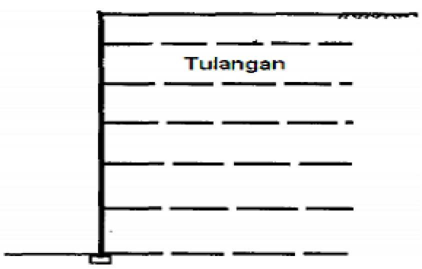

Figure 16. Reinforced earth wall

Lateral Earth Pressure

Lateral earth pressure is the force generated by the pressure of the soil behind a retaining structure. Lateral earth pressure analysis is reviewed at the condition of plastic equilibrium, which is when the soil mass in the right condition will collapse. If the analysis does not match what actually happens, it can lead to design errors (Hardiyatmo, 2011).

Non-cohesive soils or granular soils are those soils that have no cohesion (c = 0) such as sand, gravel. When the subgrade surface is horizontal, the active earth pressure (*Pa*) at any depth z from the subgrade surface to the top of the retaining wall is expressed by Eq:

$$Pa = Ka\, z\, \gamma \qquad (1)$$

where:

$$Ka = \frac{1-\sin\varphi}{1+\sin\varphi} = tg^2\left(45 - \frac{\varphi}{2}\right) \qquad (2)$$

Active Earth Pressure (*Pa*) for a retaining wall of height H is expressed by Eq:

$$Pa = 0.5\, H^2\, \gamma\, Ka \qquad (3)$$

With the force center at H/3 from the base of the retaining wall.

The case of a non-cohesive backfill soil (c = 0) whose surface slopes behind the retaining wall, with the back wall surface being smooth, is considered. The lateral stresses acting on the vertical plane of the soil element (the plane parallel to part of the back wall surface) will be parallel to the surface of the backfill soil.

The earth pressure on a wall with a sloping backfill surface can be determined with the help of Mohr's circle or by considering the balance of the soil that is about to collapse.

Active Earth Pressure (*Pa*) for a retaining wall of height H is expressed by Eq:

$$Pa = 0.5\, H^2\, \gamma\, Ka \qquad (4)$$

With the direction of the pressure working line parallel to the surface of the backfill and acting at a height of H/3 from the base of the retaining wall.

The passive earth pressure for a sloping ground surface is determined in the same way. In the equation, it can be seen that there is a possibility of negative Pa, which means that there is a tensile force acting on the soil. In the part of the soil that suffers from the tensile force, the soil cracks. The cracks, when filled by rainwater, not only reduce cohesion but also result in additional lateral earth pressure due to hydrostatic pressure.

The critical depth (*hc)* which expresses the depth of the cracked soil, occurring when *Pa* = 0, can be obtained:

$$hc = \frac{2c}{\gamma\sqrt{Ka}} \qquad (5)$$

by considering the above equation, at ground level (z = 0) the value of *Pa* will be equal to,

$$Pa = -2c\tan(45^o - \varphi/2) = c\sqrt{Ka} \qquad (6)$$

When the soil is in a passive state,

$$Pp = \gamma\, z\, Kp + 2c\sqrt{Kp} \qquad (7)$$

On the ground level,

$$Pp = 2c\sqrt{Ka} \qquad (8)$$

The amount of active and passive earth pressure forces on a retaining wall with cohesive backfill soil is expressed by the following equations:

(1) Total Active Earth Pressure:

$$Pa = 0.5\, \gamma\, H^2\, Ka - 2cH\sqrt{Ka} \qquad (9)$$

(2) Total Passive Earth Pressure:

$$Pp = 0.5\, \gamma\, H^2\, Kp - 2cH\sqrt{Kp} \qquad (10)$$

Where:

Pa = Total Active Earth Pressure (kN)

pISSN 2302-4240
eISSN 2655-2086

Volume 13, Issue 2, June 2024, pp.348-362
DOI: http://dx.doi.org/10.32832/astonjadro.v13i12 http://ejournal.uika-bogor.ac.id/index.php/ASTONJADRO

Pp = Total Passive Earth Pressure (kN)
H = Uplift wall height (m)
γ = Volume weight of backfill soil (kN/m^3)
c = Cohesion of backfill soil (kN/m^2)

The active and passive earth pressure diagrams for cohesive soils are shown in the Figure below.

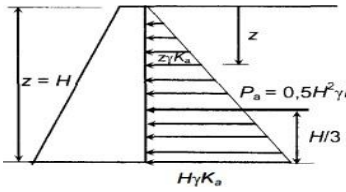

Figure 17. Pressure diagrams for horizontal subsoil surfaces

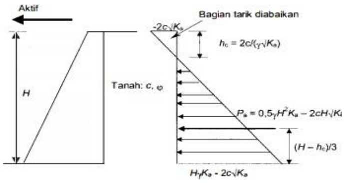

Figure 18. Active earth pressure diagram

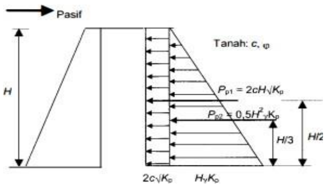

Figure 19. Passive earth pressure diagram

RESEARCH METHODS

The implementation time of this research starts from November 2021 to October 2022, with the research location in the Curug Residence Griya Elok Housing Area Jalan Parvi Bojong Neros RT. 03/07 Curug Village, West Bogor Subdistrict, Bogor City. The research stages carried out are first, explaining about the beginning of the research implementation, in the research stages must be clear in order to get the desired results. The second stage, data collection of soil parameters, namely taking soil samples to be tested in the laboratory. The third stage is the analysis of data obtained by laboratory tests. The fourth stage designs the Gabion type gravity wall whether it is safe or not against the working load. The last stage is the conclusion of the calculation of the cost budget plan and work figure (asbuild drawing).

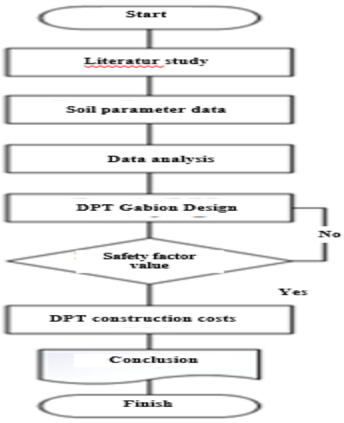

Figure 20. Flowchart

Figure 21. Research Location

RESULTS

Shape and Dimensions of Retaining Wall

The retaining wall to be planned is a gabion type with a length of 30 meters and a height of 11 meters on the river slope. Before analyzing the stability of the gabion, the first step that is needed is to design the dimensions of the gabion-type retaining wall.

The parameters of the gabion-type retaining wall based on the planning data are as follows:

Table 1. Dimensions of Gabion Retaining Wall

No.	Data	Value	Units
1.	Height of Retaining Wall	9,50	m
2.	Footing Foundation Height	1,58	m

3.	Top Section Width	0,79	m
4.	Foundation Base Width	1,58	m

Retaining wall dimensions show as figure 22 and 23 below.

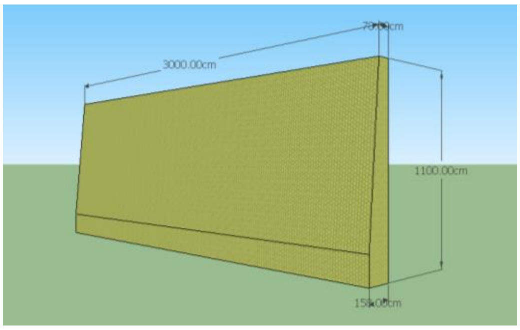

Figure 22. 3D section of retaining wall

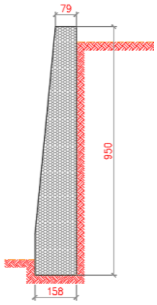

Figure 23. Retaining wall section cutout

Geotechnical Data

In every predesign project, complete data is needed in order to obtain results that are in accordance with reality, so it is necessary to conduct soil investigations, both in the field and in the laboratory. Based on the results of laboratory tests, soil parameter data for gabion-type retaining wall construction are shown in Table 2 below.

Table 2. Soil Parameters

No.	Data	Notation	Value	Units
1.	Ground water level	MAT	0,00	m
2.	Surface slope angle	i	0,00	^{o}
3.	Friction angle between wall and soil	$\emptyset$	26,54	^{o}
4.	Inclination angle of ground collapse	δ	90,00	^{o}
5.	The angle of inclination of the wall to the soil	β	0,00	^{o}
6.	Cohesion	c	0,00	kN/m^2
7.	Dry soil unit weight	γ_{dry}	18,64	kN/m^3
8.	Saturated soil unit weight	γ_{sat}	16,43	kN/m^3
9.	Effective soil unit weight	γ'	6,62	kN/m^3
10.	Water unit weight	γ_w	9,81	kN/m^3
11.	Soil friction angle	θ	39,81	^{o}

Load Data

Based on the predesigned analysis gabion-type retaining walls, the loads shown in Table 3 below.

Table 3. Load Data

No.	Data	Notation	Value	Units
1.	Surface uniform load	q	10,00	kN/m^2
2.	Masonry unit weight	g_b	14,70	kN/m^3
3.	Gravity Acceleration	g	9,81	m/sec^2

Analysis of Loads

pISSN 2302-4240
eISSN 2655-2086
Volume 13, Issue 2, June 2024, pp.348-362
DOI: http://dx.doi.org/10.32832/astonjadro.v13i12 http://ejournal.uika-bogor.ac.id/index.php/ASTONJADRO

The retaining wall with a height of 11 meters is planned to withstand a uniform load of 10 kN/m2 using a gabion-type retaining wall.

Active Earth Pressure

Calculation of active earth pressure for gabion-type retaining wall construction using the Rankine Method, the formula used from equation 1.

Active Earth Pressure Coefficient

$Ka = \frac{1-\sin\varphi}{1+\sin\varphi} = tg^2(45 - \frac{\varphi}{2})$

$Ka = \frac{1-\sin\ (39{,}81°)}{1+\sin\ (39{,}81°)}$

Ka = 0.328

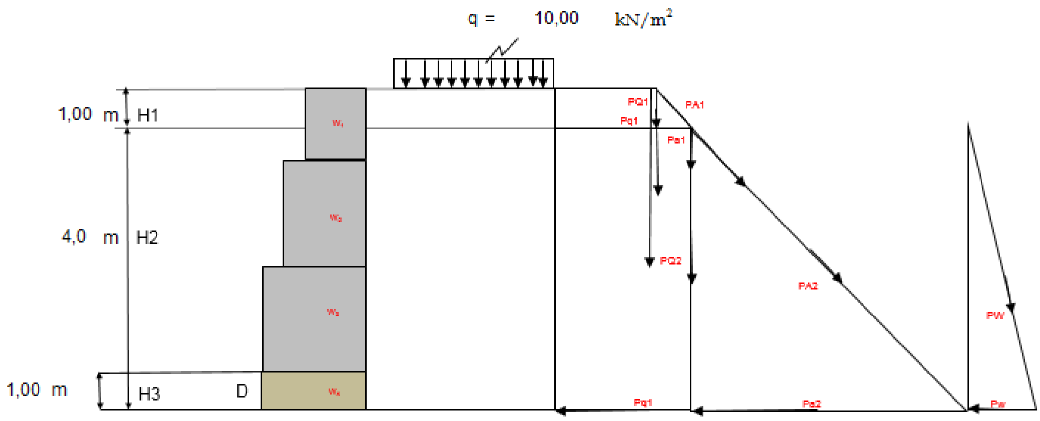

Figure 23. Active Earth Pressure Diagram

Force Components

pq1 = q × Ka
= 10 × 0.328
= 3.279 kN/m^2
pq2 = (q + □$_{dry}$ × H1) × Ka
= (10 + 18,64 × 1) × 0.328
= 9.392 kN/m^2
Force
PQ1 = pq1 × H1
= 3.279 ×
= 3.279 kN/m^2
PQ2 = pq2 × H2
= 9.392 × 4.00
= 37.568 kN/m^2
Geostatic Pressure
Pa1 = γ_{dry} × H1 × KAE x (1-Kv)
= 18,64 × 1 × 0.328 x (1-0)
= 6.113 kN/m^2
Pa2 = γ_{dry} × H2 × KAE x (1-Kv)
= 11.67 × 4 × 0.328 x (1-0)
= 8.688 kN/m^2
Earth Pressure
PAE1 = 0.5 × Pa1 × H1
= 0.5 × 6.113 × 1
= 3.056 kN/m^2
PAE2 = 0.5 × Pa2 × H2
= 0.5 × 8.688 × 4

= 17.376 kN/m^2
Water-Inducted Stress
P_w = $\gamma_w \times H3$
= 9.81 × 4
= 39.24 kN/m^2
Water Pressure
PW = $(0.5 \times P_w \times H3)$
= 0.5 × 39.24 × 1
= 78.48 kN/m^2
Total Active Earth Pressure
ΣPa = PAE1 + PAE2 + PQ1 + PQ2
= 3.056 + 17.376 + 3.279 + 37.568
= 61.280 kN

Retaining moment of retaining wall

The loads acting on the gabion-type retaining wall are divided into several data, each of which is in the form of moment data against point o shown in table 4, total active earth pressure data (ΣPa) shown in table 4, and total passive earth pressure data (ΣPp) shown in table 5.

Table 4. Total Active Earth Pressure (ΣPa)

Force	P (kN)	Pa (kN) Pa x Cos φ	Arm (Z) (m)	Ma (kNm)
PAE1	3,056	2,734	0,333	0,911
PAE2	17,376	15,545	1,333	20,726
Pw	78,480	70,210	1,333	93,613
PQ1	3,279	2,934	0,500	1,466
PQ2	75.744	33,609	2,000	67,218
	ΣPa = 139,760	Σ = 125,032		ΣM = 183,9365

Table 5. Total Passive Earth Pressure (ΣPp)

Force	P	Arm (Z)	Mp
	(kN)	(m)	(kNm)
P_{PE}	0,000	0,333	0,00000

Vertical force and moment force against the rear footing.

Table 6. Vertical force and moment force

No.	Weight (W) (kN)	Arm (X) (m)	Moment (Mw) (kNm)
1	5,819	2,771	16,123
2	7,185	2,678	19,241
3	8,551	2,585	22,104
4	9,917	2,492	24,714
5	11,284	2,399	27,070
6	12,650	2,306	29,172
7	14,016	2,213	31,020
8	15,382	2,120	32,614

pISSN 2302-4240
eISSN 2655-2086
Volume 13, Issue 2, June 2024, pp.348-362
DOI: http://dx.doi.org/10.32832/astonjadro.v13i12 http://ejournal.uika-bogor.ac.id/index.php/ASTONJADRO

9	16,748	2,027	33,954
10	18,115	1,934	35,041
11	19,481	1,841	35,873
12	20,847	1,748	36,451
13	22,213	1,656	36,775
14	23,580	1,563	36,846
15	24,946	1,470	36,662
16	26,312	1,377	36,225
17	27,678	1,284	35,533
18	45,890	1,191	54,649
19	110,556	2,375	262,571
20	83,017	2,375	197,166
21	15,833	2,375	37,604
	Σ = 540,022		Σ = 1077,409

Stability Analysis of Gabion-type Retaining Walls

Retaining walls should be designed to remain secure against, stability against sliding, stability against overturning, and stability against the soil bearing capacity.

Stability Against Shear

The calculation of stability against shear resistance uses the formula from equation 2.15, assuming that δb = φ, i.e.

Rh = 540,02 x tan 39,81 + 0,64 x 4,75 + 0,000

Rh = 453,127 kN/m

Fgs $= \frac{\Sigma Rh}{\Sigma Ph}$

Fgs $= \frac{453,127}{125,032}$

Fgs = 3,624 > 1.5

Because *Fgs* = 3,642 > SF = 1.5, then the stability against shear means SAFE.

Stability Against Sliding

The calculation of stability against sliding resistance uses the formula from equation 10.

$F_{gl} = \frac{\Sigma M_w}{\Sigma M_{gl}} \geq 1,5$

$F_{gl} = \frac{1077,409}{183.937}$

$F_{gl} = 5,858$

Because F_{gl} = 5,858 > SF = 1.5, then the stability against sliding means SAFE.

Stability Against the Soil Bearing Capacity

The calculation of stability against the soil bearing capacity uses the Hansen Method (1970).

$xe = \frac{\Sigma Mw - \Sigma Ma}{\Sigma W}$

$xe = \frac{1077,41 - 183,9}{540,022} = 1,655\text{m}$

$e = \frac{B}{2} - xe \quad < \quad e = \frac{B}{6}$

$e = \frac{4,74}{2} - 1,655 \quad < \quad e = \frac{4,74}{6}$

e = 0,72 m < 0,8 m……….. (OK)

The angle of inclination of the resultant load in the vertical direction

$\delta = \text{arc tg } \frac{\text{H}}{\text{V}}$
$\delta = \text{arc tg } \frac{183{,}937}{1077{,}409} = 9.69°$

Load inclination factor:
$i_q = \left(1 - \frac{0{,}5\ H}{V + A'ca\ ctg\ \phi}\right)^5$
$= \left(1 - \frac{0{,}5 - 183{,}937}{1077{,}409 + 3{,}309\ x\ 0{,}64\ x\ -0{,}01046}\right)^5 = 0{,}640$
$i_\gamma = \left(1 - \frac{0{,}7\ H}{V + A'ca\ ctg\ \phi}\right)^5$
$= \left(1 - \frac{0{,}7 - 183{,}937}{1077{,}409 + 3{,}309\ x\ 0{,}64\ x\ -0{,}01046}\right)^5 = 0{,}5292$
$i_c = \left(1 - \frac{1 - iq}{Nc\ tg\ \phi}\right)$
$= \left(1 - \frac{1 - 0{,}640}{30{,}14\ tg\ 39{,}81}\right) = 0{,}626$

Depth Factor:

$d_c = 1 + 0.4 \times \frac{\text{D}}{\text{B}}$
$d_c = 1 + 0.4 \times \frac{1{,}00}{4{,}75} = 1{,}084$
$d_q = 1 + 2 \times \frac{\text{D}}{\text{B}} \times tg\ \phi\ (1 - sin\ \phi)^2$
$d_q = 1 + 2 \times \frac{1{,}00}{4{,}75} \times tg\ 39{,}81\ (1 - \sin 39{,}81)^2 = 1{,}045$
$d_\gamma = 1$

Ultimate Soil Bearing Capacity:

$q_u = d_c\ i_c\ c\ N_c + d_q\ i_q\ df_\gamma\ N_q + d_\gamma\ i_\gamma\ 0.5\ B\gamma\ N_\gamma$
q_u = (1,084 x 0,63 x 0,64 x 30,14) + (1,045 x 0,640 x 1,00 x 6,62 x 18,40) + (1 x 0,5292 x 0,5 x 4,75 x 15,00 x 15,07)
$q_u = 378{,}75\ kN/m^2$

Safety Factor Against Soil Bearing Capacity

Calculated based on the effective foundation width, i.e. the foundation pressure to the subgrade is equally distributed, then:

$q = \frac{\text{V}}{\text{B}'}$
$q = \frac{540{,}022}{3{,}30903} = 163{,}197$ kN/m^2

Where,
q = Pressure due to structural loads
V = Total vertical load
B' = Effective width of foundation

Safety Factor
$F = \frac{\text{qu}}{\text{q}}$
$F = \frac{378{,}751}{163{,}197} = 2{,}32083 > 2$ ……. **Safe**

Cost Budget Plan Analysis

pISSN 2302-4240
eISSN 2655-2086
Volume 13, Issue 2, June 2024, pp.348-362
DOI: http://dx.doi.org/10.32832/astonjadro.v13i12 http://ejournal.uika-bogor.ac.id/index.php/ASTONJADRO

The results of the analysis of the calculation of the construction cost of gabion-type retaining walls are as follows.

Tabel 7. Retaining Wall Cost Budget Plan

No	Detail	Units	Quantity	Unit Price (Rp)	Total Price (Rp)
I	**Preparation**				
1.1	Mobilisation and Demobilisation	Ls	1,00	5.000.000,00	5.000.000,00
1.2	Mutual Check, Asbuilt Drawing	Ls	1,00	72.000.000,00	72.000.000,00
1.3	Report and Documentation	Ls	1,00	1.000.000,00	1.000.000,00
					78.000.000,00
II	**Construction Phase**				
2.1	Cleaning Works	Unit	1,00	2.000.000,00	2.000.000,00
2.2	Land Excavation (Mechanical)	M^3	8,25	448.071,47	3.696.589,63
2.3	Landfill	M^3	16,20	67.126,00	1.087.441,20
2.4	Gabions Construction	M^3	2.046,00	1.173.015,53	2.399.989.744,38
					2.406.773.805,21
			Total		**2.484.733.805,21**
			Total + 10 % Tax		2.733.251.185,73
			Total + Tax (Rounded Up)		**2.735.000.000,00**

CONCLUSION

Based on the analysis of gabion-type retaining wall planning in the Curug Residence Griya Elok Housing Area on Jalan Parvi Bojong Neros RT. 03/07 Curug Village, West Bogor Subdistrict, Bogor City can be concluded as follows the dimensions of the gabion retaining wall construction obtained a height of 9.5 meters, a foot plate width of 1.58 meters, and a peak wall plate thickness of 0.79 meters. Stability against sliding on gabion-type retaining walls is obtained as Fgs = 3.624 > SF = 1.5 and for stability against rolling Fgl = 5.858 > SF = 1.5, then stability against sliding and stability against rolling is safe. Meanwhile, the stability of soil bearing capacity is found to be safe. The total construction cost required to make gabion-type retaining walls is Rp. 2,735,000,000.

REFERENCES

Badan Standardisasi Nasional. 2017. Persyaratan Perancangan Geoteknik. SNI 8460-2017. Badan Standardisasi Nasional. Jakarta.

Badan Standardisasi Nasional. 2013. Persyaratan Beton Struktural Untuk Bangunan Gedung, SNI 03 2847-2013. Badan Standarisasi Nasional. Jakarta.

Hardiyatmo. H.C. 2002. Teknik Fondasi I, Beta Offset. Yogyakarta.

Hardiyatmo. H.C. 2012. Tanah longsor dan erosi. Gadjah Mada University Press. Yogyakarta.

Hardiyatmo. H.C. 2015. Analisis dan Perancangan Fondasi 2, cetakan pertama, Gadjah Mada University Press. Yogyakarta.

Lutfi, M., Rustama B., dan Fadhila M.L.T. 2022. Finite Element Method Modelling Of Steel Sheet Pile Structure On Deep Foundation Excavation. Astonjadro Vol. 11 Hal. 371-381.

Mukarom, Ahmad, 2022, Analisa Dinding Penahan Tanah Pada Lereng Jalan Tebing Tinggi Kabupaten Lahat. Skripsi Universitas Muhammadiyah Palembang. Palembang.

Pranata, Heri. 2010. Analisis Dinding Penahan Tanah Dengan Perhitungan Manual Dan Kontrol Gaya-Gaya Dalam Yang Bekerja Pada Dinding Penahan Tanah Dengan Metode Sap2000 Plane-Strain. Tugas Akhir. Universitas Negeri Yogyakarta. Yogyakarta

Terzaghi, K. dan Peck, R. B., (1993), Mekanika Tanah dalam Praktik Rekayasa, Erlangga, Jakarta.

Wagola, Erwin Syaiful, dan Mentari Rasyid. 2020. Analisis stabilitas dinding penahan tanah tipe kantilever pada landfill TPA Kota Masohi Kabupaten Maluku Tengah Provinsi Maluku. Rekayasa Sipil 14.1 (2020): 70-74.

Yusuf, A., & Dona, K. (2017). Perencanaan Dinding Penahan Tanah Sungai Way Batanghari Kota Metro dengan Metode Revetment Retaining Wall. Tapak Vol.6, 158

Wagola, Erwin Syaiful, dan Mentari Rasyid. 2020. Analisis stabilitas dinding penahan tanah tipe kantilever pada landfill TPA Kota Masohi Kabupaten Maluku Tengah Provinsi Maluku. Rekayasa Sipil 14.1 (2020): 70-74.

Yusuf, A., & Dona, K. (2017). Perencanaan Dinding Penahan Tanah Sungai Way Batanghari Kota Metro dengan Metode Revetment Retaining Wall. Tapak Vol.6, 158.

Lutfi, M., Chayati, N., Rulhendri, R., Taqwa, F. M. L., & Ramadan, F. R. (2023). Analysis of Cantilever Retaining Wall as Landslide Mitigation on a Tributary of Cisadane River Bogor City. ASTONJADRO, 12(3), 687–697. https://doi.org/10.32832/astonjadro.v12i3.7013

R Muktadir, S Syaiful, FML Taqwa, (2023). ANALISIS STABILITAS LERENG DENGAN MENGGUNAKAN PERKUATAN SOLDIER PILE (STUDI KASUS RUAS JALAN DI PAPUA BARAT). INTER TECH 1 (2), 63-71.

R Gibran, S Syaiful, R Rulhendri. (2024). PERANCANGAN JALUR SALURAN DRAINASE GUNA MENANGGULANGI BANJIR PADA PERUMAHAN WARGA. SINKRON: Jurnal Pengabdian Masyarakat UIKA Jaya 2 (1), 44-59.

A Dermawan, S Syaiful, A Alimuddin, F Fachruddin. (2022). Analisis Stabilitas Dinding Penahan Tanah (Studi Kasus: Desa Mekarjaya, Kecamatan Ciomas, Kabupaten Bogor). Rona Teknik Pertanian 15 (2), 67-81.

S Dharmawati Pratama, P Hadi, Hamkah, Mansyur, P Haerul, H Arman, IA Arifuddin, I Andi, S.Syaiful. (2024). MANAJEMEN PROYEK INFRASTRUKTUR. Tohar Media. Makassar, 1-153.