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The Stability Analysis of Retaining Soil Walls Protecting Banu Canal, Ngantru Village, Ngantang District, Malang-Indonesia

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ABSTRACT

The frequent occurrence of landslides in the Ngantang District, Malang Regency, especially in Ngantru Village, is caused by topographic conditions, where the area is hilly because it is located at the foot of Mount Kelud. Likewise, along the Banu Irrigation Area Channel there are points prone to landslides, especially in the upstream part. These landslides result in the channel breaking so that the irrigation water supply is disrupted. DPT (Soil Retaining Wall) is a building structure whose role is to maintain the stability of the soil on sloping land. The existence of this wall is expected to be able to prevent the soil from moving or landslides. Therefore, to protect the Banu Irrigation Area Channel, a DPT construction was built where the DPT details used were stone masonry construction or the Gravity Wall type. With a total height of 3.9 m, the bottom sole width is 1.00 m and the upper sole width is 0.50 m. The purpose of this paper is to analyze whether the existing DPT is safe against the forces that work, especially analyzing its stability, then comparing it with other DPT designs with the cantilever wall type. Based on the analysis of calculations for the Existing gravity type Earth Retaining Wall, the stability figures for soil bearing capacity σ max= 23.76 > 15.012 (safe), stability against sliding hazards Fgs=3.321 ≥ 1.5 (safe), and stability against sliding hazards Fgs=3.321 ≥ 1.5 (safe) are obtained. = 6.26 > 1.5 (safe) while for cost calculations the value obtained is IDR 180,390,000.00 (One Hundred and Eighty Million Three Hundred and Ninety Thousand Rupiah). Meanwhile, for the analysis of the comparative soil retaining wall for the cantilever type, the stability figures for soil bearing capacity σ max= 25.92 > 15.012 (safe), stability against sliding hazards Fgs=3.55 ≥ 1.5 (safe), and stability against overturning hazards were obtained. SF= 6.64 > 1.5 (safe).

Keywords: Retaining wall, stability analysis, Gravity Wall, Cantilever Wall

1. INTRODUCTION

Soil in slope areas often cause landslides, especially on land where there is no vegetation. It is also supported by the type of soil that is prone to landslides, so the possibility of landslides will increase, especially during the rainy season. To overcome the problem of sliding on slopes, you can build retaining walls which are usually made of river stone or concrete [1].

A retaining wall is a building structure that is used to hold the soil or provide stability to the soil. The retaining wall is a construction that functions to hold loose or natural soil and prevent the collapse of sloping soil or slopes whose density cannot be guaranteed by the soil slope itself [2], [3].

The topographic conditions in the Ngantang sub-district area, which contains many hills, have resulted in many areas that have the potential for landslides. Likewise, in the Banu Irrigation Network in the upstream section, the channel is located on a hillside, making it prone to landslides. Through the Cliff Strengthening Rehabilitation Sub-Activity Program in the D.I Banu Improvement Work, Ngantru Village, Ngantang District, this is an effort by the relevant Department to strengthen the security structure of the Banu Irrigation Channel to prevent landslides.

The agricultural sector is the main sector supporting the economy of the people of Ngantru Village. Potatoes are a superior crop apart from other food crops such as carrots, onions, cabbage and also rice. These agricultural commodities are of course supported by the availability of irrigation water that irrigates the residents' rice fields. This irrigation water comes from the Banu DAM Intake which is channeled through the Banu Irrigation Channel, apart from Ngantru Village itself, the Banu Irrigation Channel serves 156 Ha of rice fields [4], [5], [6]. The Banu Irrigation Channel service areas are in Sidodadi Village, Ngantru Village and Banturejo Village.

Slopes can be formed naturally or man-made. Slopes consist of natural slopes, slopes made on native soil and slopes made from compacted soil. On every slope the possibility of landslides always exists. Landslides occur due to an imbalance between the pushing force on the slope which is greater than the resisting force on the slope. Technically, landslides occur if the slope safe ty factor does not meet (Fk<1.5) [7].

Landslide prevention can be carried out as a preventive measure in areas that have the potential for landslides as well as repairs in areas where landslides have occurred but have not yet completely collapsed. There are two ways to stabilize slopes, namely reducing the driving force or moment that causes landslides and increasing the resisting force or moment that resists landslides, including by; using counter weight, namely filling soil at the foot of the slope, namely installing piles or retaining walls [8].

With these conditions and based on the importance of protecting the Banu Irrigation Channel, it is necessary to plan the retaining walls appropriately to obtain a suitable design in terms of stability.

2. RESEARCH SIGNIFICANCE

Soil from the perspective of Civil Engineering is a collection of minerals, organic materials and relatively loose sediments that lie on bedrock [9]. Soil is generally defined as a collection of parts that are solid and not bound together (including perhaps organic material), the voids between these materials contain air and water [8], [10]. Relatively weak bonds between grains can be caused by carbonates, organic substances, or oxides that precipitate between the particles. The space between the particles can contain water, air, or others [11], [12]. The destruction process in forming soil from rocks occurs physically or chemically. Physical processes include erosion due to wind blowing, erosion by water and glaciers, or splitting due to freezing and melting of ice in rocks, while chemical processes produce changes in the mineral composition of the original rock. One of the causes is water which contains alkaline acids, oxygen and carbon dioxide [13], [14].

3. RESEARCH METHODS

The research location is precisely at the coordinates 7°54'18.0"S 112°22'03.7"E, Ngantru Village, Ngantang District.

Fig. 1. Research Location

Technical Data

Data obtained from project data for Building Rehabilitation Building Strengthening Cliffs Improvement of D.I Banu, Ngantru Village, Ngantang District, terlihat pada tabel 1.

Tabel 1. Data Project

Volume weight of water (γw)	:	9,81kN/m3
Soil volume weight (γt)	:	1,81kN/m3
Volume weight of stone masonry (γ)	:	22,00kN/m3
Volume weight of concrete masonry (γ)	:	24,00kN/m3
Soil density (Gs)	:	0,70kN/m3
Water content (W)	:	0,56
Pore number (e)	:	0,72
Soil cohesion (c)	:	0,41kN/m2
Shear angle (φ)	:	25o

The dimensions of the retaining wall are shown in table 2.

Table 2. Dimensions of retaining walls

Long (l)	: 23m
Type	: Gravitasi Wall
Foundation depth (Df)	: 0,90m
Retaining wall height (H)	: 3,00m
Total retaining wall height (H1)	: 3,90m
Top width (B1)	: 0,50m
Foundation width (B2)	: 1,00m

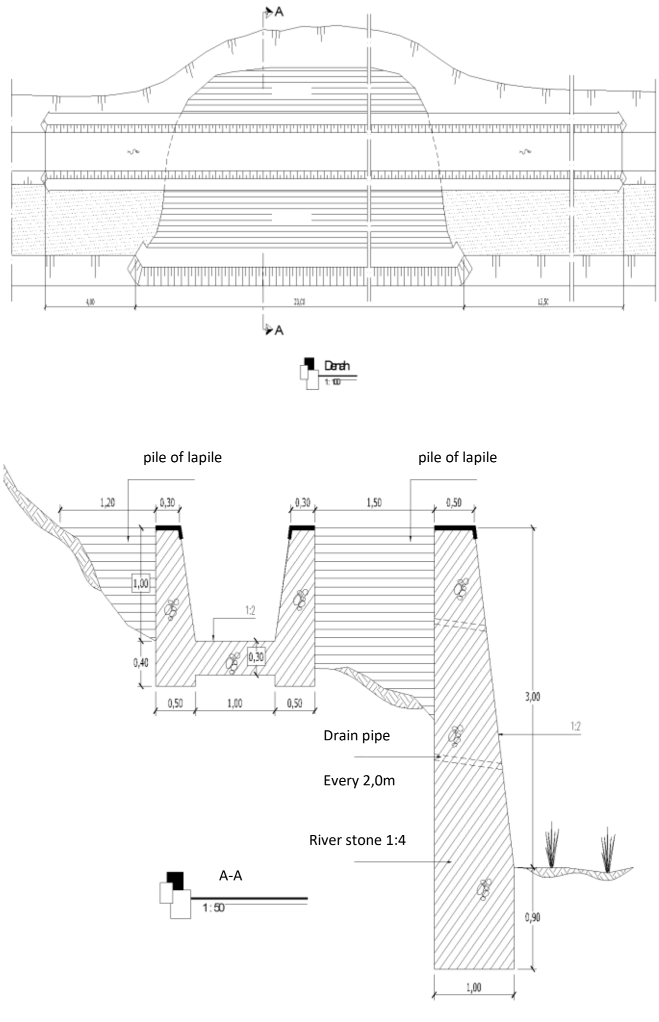

Fig. 2 Work Plan

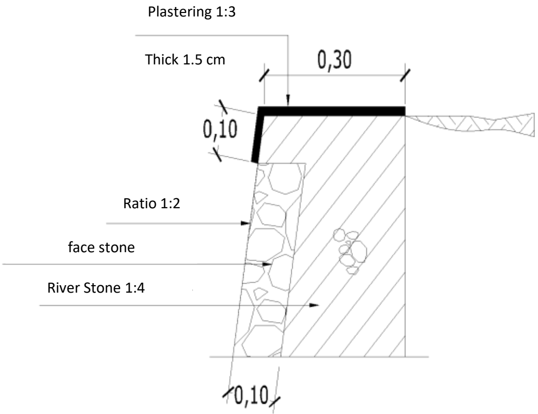

Fig. 3 Cross Section and Stucco Details

Slope Stability Analysis

Stability analysis on a sloping ground surface is called slope stability analysis. Slope stability analysis is carried out to determine the safe ty factor of natural slopes, excavations and land fill [15], [16]. The stability of a slope is expressed by a safe ty factor. The safe ty factor is the comparison between the resisting force and the driving force on the slope [16], [17]). Below is the slope safe ty factor equation:

Table 3. Slope Safe ty Factor Values [18]

Safe ty Factor Value	Landslide Intensity Events
F < 1,07	Landslides occur frequently (unstable)
1,07 < F < 1,25	Landslides have occurred (critical)
F > 1,25	Landslides are rare (stable)

Lateral Earth Pressure

Lateral earth pressure is the force caused by the pushing of the soil behind the earth retaining structure. The amount of lateral pressure is greatly influenced by changes in the location of the retaining wall and the properties of the soil. Analysis of lateral earth pressure is considered in plastic equilibrium conditions, namely when the soil mass in the right conditions will collapse [19], [20]. The amount of ground pressure is determined by:

a. Active, passive and stationary earth pressure coefficients
b. Soil cohesion
c. The load acting on the surface of the embankment.

Earth Pressure at Rest

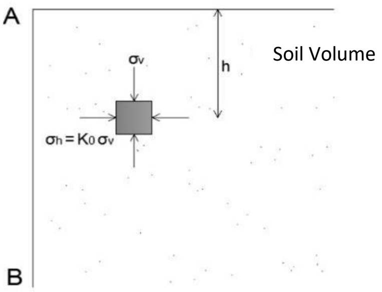

Fig. 4. Earth Pressure at Rest

Since $\sigma v = \gamma h$, then $\sigma h = Ko\ (\gamma h)$

So the earth pressure coefficient at rest can be represented by the empirical relationship [21]).

$Ko = 1 - \sin \phi$

Po = $\underline{1}$ Ko γ H2

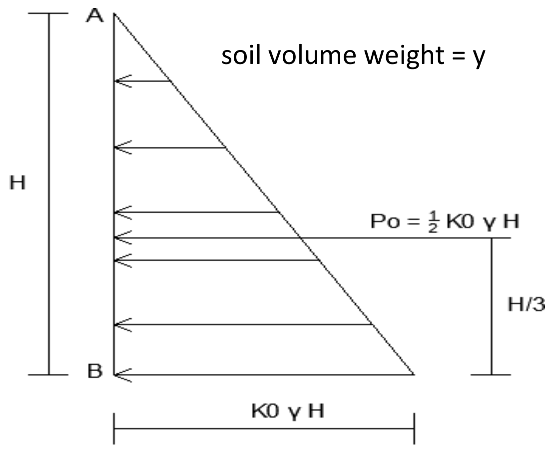

Fig. 5. Earth Pressure Distribution at Rest

Active Earth Pressure

Pa = ½ γ H2 Ka

Where the Ka price for flat land is:

$$Ka = \frac{1 - sin\Phi}{1 + sin\Phi} = \tan 2(45° - \Phi)^{1/2}$$

Where, γ = soil density (g/cm3), H = wall height (m), Φ = soil friction angle (°)

So,

Pa = ½ γ H2 Ka - 2c $\sqrt{Ka}$ H

Passive Earth Pressure

P = ½ γ H2 Kp

Where the Kp price for flat land is:

$$Kp = \frac{1 + sin\Phi}{1 - sin\Phi} = \tan 2(45° - \Phi)^{\frac{1}{2}}$$

So,

Pp = ½ γ H2 Ka + 2c $\sqrt{K}$p H

Retaining wall

A retaining wall is a building structure that is used to hold the soil or provide stability to the soil. The Concrete Construction 2, it is stated that, A retaining wall is a construction that functions to retain loose or natural soil and prevent soil collapse [22], [23]sloping slopes or slopes whose density cannot be guaranteed by the slope of the land itself.

a retaining wall is a construction that is used to withstand lateral earth pressure caused by landfill or unstable original soil [24], [25]). The stability of a retaining wall is obtained mainly from the structure's own weight and the weight of the soil above the foundation plate. The magnitude and distribution of earth pressure on retaining walls is very dependent on the lateral movement of the soil relative to the wall. Types of retaining walls [26], [27] Gravity Walls, Cantilever Walls, Reinforcing Walls, Buttress Walls.

a. Gravity Wall (Gravity Wall):

These walls are usually made from pure concrete (without reinforcement) or from river stone masonry. Construction stability is achieved only by relying on its own weight.

b. Cantilever Wall (Cantilever Wall)

Cantilever walls are made of reinforced concrete which is composed of a vertical wall and a floor tread. Each of them acts as a beam or cantilever plate. Construction stability is obtained from the self-weight of the retaining wall and the weight of the soil above the heel of the site (hell). There are 3 structural parts that function as a cantilever, namely the vertical wall (steem), the heel of the tread and the toe of the tread (toe).

c. Counterfort Wall

If the active soil pressure on the vertical wall is large enough, then the vertical wall and heel sections need to be joined together (counterfort). Contrafort functions as a tensile tie for vertical walls and is placed in embankments at certain intervals.

d. Butters Wall (Buttrers Wall)

This wall is almost the same as the counterfort wall, the only difference is that the counterfort is placed in front of the wall. In this case, the counterfort structure functions to carry compressive stress. In this wall, the heel is shorter

Stability of Retaining Walls

Soil pressure and forces acting on retaining walls can affect the stability of retaining walls. The use of materials in the construction of retaining walls provides reinforcement to the soil mass, enlarging the embankment behind the retaining wall. Reinforcement also reduces the potential for lateral forces which can cause horizontal displacement of the retaining wall due to vertical loads which are transferred into active soil pressure [28], [29]The stability of retaining walls can be assessed in terms of overturning, shearing and soil bearing capacity.

Stability Against Overturning

It is said that the building is considered safe against overturning if the force that causes the resisting moment is smaller than the force that causes the overturning moment [25]. The safe ty factor against overturning (Fgl) is defined as [28].

$$\text{Fgl} = \frac{\sum Mw}{\sum Mgl} \geq 1{,}5$$

$$\sum \boldsymbol{Mw} = \text{W}$$

$$\sum \boldsymbol{Mgl} = \sum \boldsymbol{Pahh1} + \sum \boldsymbol{PavB}$$

Where, $\sum Mw$ = moment that resists overturning (kN.m), $\sum Mgl$ = moment that causes overturning (kN.m), W = sum of the weight of the wall and the weight of the soil above the foundation (kN), B= width of the foot of the retaining wall (m), $\sum Pah$ = total horizontal forces (kN), $\sum Pav$= total vertical forces (kN).

Safe ty Against Sliding

The forces that shift the retaining wall will be resisted by friction between the soil and the base of the foundation, passive soil pressure when in front of the embankment retaining wall. To determine safe ty against shear (Fgs) it can be calculated using the equation below:

$$Fgs = \frac{(\text{V .F}) + \left(\frac{2}{3}.\text{c .B}\right) + \sum \text{Pp}}{\sum \text{Pa}} = \geq 1{,}5$$

Where, Fgs = shear safe ty factor, V= Self weight of construction (kN/m), F= Coefficient of friction between the retaining wall and the soil, (F= tan φ), C= Soil cohesion (kN/m2), B= wall width soil support (m), $\sum Pa$= Total active earth pressure force (kN).

$\sum Pp$ = Total passive earth pressure force (kN)

Soil Bearing Capacity Safe ty Factor

Ultimate soil bearing capacity, for soil shear angles with data obtained from graphs [30].

$$q_u = \left(\frac{1}{3}.\ c\ .\text{Nc}\right) + (\gamma_t \cdot D_f \cdot \text{Nq}) + (0{,}4 \cdot \gamma_t \cdot \text{B} \cdot \text{N}\gamma)$$

Where

qu = ultimate bearing capacity (kN/m^2)

c = cohesion between the soil and the base of the retaining wall (kN/m^2)

γ = soil volume weight (kN/m)

Df = foundation depth (m)

B = width of the foundation base (m)

Ø = soil friction angle (°)

Nc,Nq,Nγ = bearing capacity factor

The values of Nc, Nq, Nγ in graphic form given by Terzaghi can be seen in table 4.

Table 4. Soil Bearing Capacity Factor Values

Φ	General shear failure			Local shear failure		
	Nc	Nq	Nγ	Nc'	Nq'	Nγ'
0	5,7	1,0	0,0	5,7	1.0	0,0
5	7,3	1,6	0,5	6,7	1,4	0,2
10	9,6	2,7	1,2	8,0	1,9	0,5
15	12,9	4,4	2,5	9,7	2,7	0,9
20	17,7	7,4	5,0	11,8	3,9	1,7
25	25,1	12,7	9,7	14,8	5,6	3,2
30	37,2	22,5	19,7	19,0	8,3	5,7
34	52,6	36,5	30,0	23,7	11,7	9,0
35	57,8	41,4	42,4	25,2	12,6	10,1
40	95,7	81,3	100,4	34,9	20,5	18,8
45	172,3	173,3	297,5	51,2	35,1	37,7
48	258,3	287,9	780,1	66,8	50,5	60,4
50	347,6	415,1	1153,2	81,3	65,6	87,1

Load Acting on Retaining Walls

a) Dead Load

Dead load consists of the self-weight of components including parts or fittings that are permanently attached. All loads attached to the building are classified as dead loads. Calculation of dead load can be calculated using the load itself based on the weight satyan values.

a) Live Load

Live loads consist of loads that are not fixed in terms of position, intensity or time span, such as water pressure, embankment material, wind loads, mud loads, active and passive earth pressure. Determining the value of the live load is generally accompanied by the maximum load contained in the building structure. Larger loads may occur but with a small duration so they are too low to be used in design.

c) The weight of the building depends on the materials used to make the building.

For preliminary planning purposes, a volume weight price for stone masonry of 22 kN/m³ (≈ 2,200 kgf/m³) may be used [31].

Work Volume Calculation

Before calculating the volume of work, first look carefully and carefully at the work drawings to be calculated. This volume calculation is the first step in preparing a Cost

Budget Plan (RAB). The formula for calculating the volume of work will not be the same as the others depending on the work item. For this reason, the formula for calculating the volume of work items is as follows:
a) Volume for work item area (m^2) = Length x Width
b) Volume for cubication of work items (m^3) = Length x Width x Height
c) Volume for work item length (m_1) = Length.

RESULTS AND DISCUSSION

1. Existing Condition (Gravity Wall)

a. Calculation of Active and Passive Earth Pressure

Active Soil Pressure Coefficient

$Ka = \tan^2 (45° - \varphi)\, \frac{1}{2}$

$= \tan^2 (45° - 25)\, \frac{1}{2}$

$= 0{,}41$

- Active Earth Pressure

$Pa = ½\, \gamma\, H^2\, Ka$
$Pa = ½ \,.\, 4 \,.\, (3)^2 \,.\, 0{,}41$
$Pa = 7{,}38$ kN/m
$Pa2 = ½ \,.\, \gamma_d .\, Ka. \sqrt{Ka.Df}$
$Pa_2 = ½ \,.\, 4 \,.\, 0{,}41 \,.\, \sqrt{0{,}41} \,.\, 3$
$Pa_2 = 0{,}91$ kN/m
$Pa3 = ½\, \gamma\, H2$
$Pa_3 = ½ \,.\, 4 \,.\, 0{,}41$
$Pa_3 = 1{,}80$ kN/m
Pa total= $Pa_1 + Pa_2 + Pa_3$
Pa total= 10,09 kN/m

- Active Moments

$Ma_1 = Pa_1 \,.\, (½ \,.\, H_1) + H_2$
$= 7{,}38 \,.\, (½ \,.\, 3) + 0{,}9$
$= 11{,}97$ kN/m
$Ma_2 = Pa_2 \,.\, (½ \,.\, H_1)$
$= 0{,}91 \,.\, (½ \,.\, 3)$
$= 1{,}36$ kN/m
$Ma_3 = Pa_3 \,.\, (½ \,.\, Df)$
$= 1{,}8 \,.\, (½ \,.\, 0{,}9)$
$= 0{,}81$ kN/m
Ma total= $Ma_1 + Ma_2 + Ma_3$
Ma total= 14,14 kN/m

- Koefisien Tekanan Tanah Pasif

$Kp = \tan^2 (45° + \varphi)\, \frac{1}{2}$
$= \tan^2 (45° + 25)\, \frac{1}{2}$

$= 2{,}46$

- Tekanan Tanah Pasif

$Pp = ½ \,.\, \gamma \,.\, Df$
$Pp = ½ \,.\, 4 \,.\, 0{,}9$
$Pp = 1{,}80$ kN/m
$Pp_2 = \frac{1}{3}\, \gamma d\ Df\ Kp + 2\ c\ \sqrt{Kp}\ Df$
$Pp_2 = \frac{1}{3}\ 4\ 0{,}9\ 2{,}46 + 2\ 0{,}41\ \sqrt{2{,}46 0{,}9}$
$Pp_2 = 4{,}17$ kN/m
$Pp_3 = ½ \,.\, \gamma \,.\, Df2$
$Pp_3 = ½ \,.\, 4 \,.\, 0{,}92$
$Pp_3 = 1{,}62$ kN/m
Pa total= $Pp_1 + Pp_2 + Pp_3$
Pa total= 7,59 kN/m

- Momen Pasif

$Mp_1 = Pp_1 \,.\, (½ \,.\, H_1) + Df$
$= 1{,}80 \,.\, (½ \,.\, 3) + 0{,}9$
$= 4{,}32$ kN/m
$Mp_2 = Pp_2 \,.\, (½ \,.\, Df)$
$= 4{,}17 \,.\, (½ \,.\, 0{,}9)$
$= 1{,}88$ kN/m
$Mp_3 = Pp_3 \,.\, (½ \,.\, Df)$
$= 1{,}62 \,.\, (½ \,.\, 0{,}9)$
$= 0{,}73$ kN/m
Mp total= $Mp_1 + Mp_2 + Mp_3$
Mp total= 6,93 kN/m

b. Calculation of Construction Self-Weight

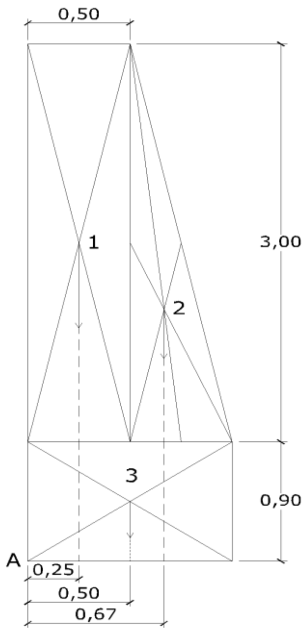

Fig. 6. Center of gravity of existing soil retaining walls

- Field Own Weight:

$P_1 = p \,.\, l \,.\, \gamma$
$= 3 \,.\, 0{,}5 \,.\, 22$
$= 33$ (kN/m)
$P_2 = ½\, (a \,.\, t) \,.\, \gamma$
$= ½\, (0{,}5 \,.\, 3) \,.\, 22$
$= 16{,}5$ (kN/m)
$P_2 = p \,.\, l \,.\, \gamma$
$= 1 \,.\, 0{,}9 \,.\, 22$
$= 19{,}8$ (kN/m)

Table 5. Moment Calculation Results for Soil Retaining Walls

No	Distance to Point A (m)	Own Weight (kN/m)	Point A Moment (kNm)
1	0,25	33,00	8,25
2	0,67	16,50	11,06
3	0,50	19,80	9,90
Amount:		69,30	29,21

c. Carrying Capacity

Ultimate bearing capacity:

$$q_u = \left(\frac{1}{3}\cdot c \cdot Nc\right) + (\gamma_t \cdot D_f \cdot Nq) + (0{,}4 \cdot \gamma_t \cdot B \cdot N\gamma)$$

Nc, Nq, Ny is the soil bearing capacity factor obtained from the Terzaghi table based on the shear angle φ= 25°.

Table 6. Soil Bearing Capacity Factor Values

Φ	General shear failure			Local shear failure		
	Nc	Nq	Nγ	Nc'	Nq'	Nγ'
0	5,7	1,0	0,0	5,7	1.0	0,0
5	7,3	1,6	0,5	6,7	1,4	0,2
10	9,6	2,7	1,2	8,0	1,9	0,5
15	12,9	4,4	2,5	9,7	2,7	0,9
20	17,7	7,4	5,0	11,8	3,9	1,7
25	25,1	12,7	9,7	14,8	5,6	3,2
30	37,2	22,5	19,7	19,0	8,3	5,7
34	52,6	36,5	30,0	23,7	11,7	9,0
35	57,8	41,4	42,4	25,2	12,6	10,1
40	95,7	81,3	100,4	34,9	20,5	18,8
45	172,3	173,3	297,5	51,2	35,1	37,7
48	258,3	287,9	780,1	66,8	50,5	60,4
50	347,6	415,1	1153,2	81,3	65,6	87,1

So

Nc = 25,1

Nq = 12,7

Nγ = 9,7

Po = Df . γ

= 0,9 . 5,81

= 5,229 kN/m2

qu = $(1/3 . c . Nc) + (Df . Nq) + (0{,}4 . \gamma . B . N\gamma)$

= $(1/3 . 0{,}41 . 25{,}1) + (0{,}9 . 12{,}7) + (0{,}4 . 5{,}81 . 1 . 9{,}7)$

= 21,883 kN/m2

Net ultimate carrying capacity:

Qun = qu – Po

= 21,883 – 5,229

= 16,654 kN/m2

Net foundation pressure:

qn = qun – Po

= 16,654 – 5,229

= 11,425 kN/m2

Safe ty factor (f):

F = $\frac{qun}{qn}$

= $\frac{16{,}654}{11{,}425}$

= 1,458 kN/m2

Permit carrying capacity:

qa = $\frac{qu}{f}$

= $\frac{21{,}883}{1{,}458}$

= 15,012 kN/m2

d. Safe ty factors regarding soil bearing capacity, stability against sliding and overturning

- Stability to soil bearing capacity

∑M = 29,205 kNm

V=∑G = 69,3 kN/m

e = ½ . B - $\frac{\sum M}{\sum G}$

= ½ . 1 - $\frac{29{,}205}{69{,}300}$

= 0,079

e permission= $\frac{1}{6}$. B = 0,167

carrying capacity stability:

σ maxs = $\frac{2 . V}{2 .((\frac{H}{B})-e)}$> qa

= $\frac{2 . 69{,}3}{2 .((\frac{3}{1})-0{,}167)}$> qa

= 23,760 > 15,012 (safe)

- Stability against shear

F = tan φ

= tan (25)

= 0,37

$$Fgs = \frac{(V . F)+\left(\frac{2}{3} . c . B\right)+\sum Pp}{\sum Pa} = \geq 1{,}5$$

$$Fgs = \frac{(69{,}3 . 0{,}37)+\left(\frac{2}{3} . 0{,}41 . 1\right)+7{,}59}{10{,}09} = \geq 1{,}5$$

Fgs = 3,32 = ≥ 1,5 (safe)

Stability against overturning

SF = $\frac{\sum M+\sum Ma}{\sum Mp}$> 1,5

SF = $\frac{29{,}21 + 14{,}14}{6{,}93}$> 1,5

SF = 6,26> 1,5 (safe)

2. Comparative Construction (Cantilever Wall)

a. Calculation of Active and Passive Earth Pressure

- Active Earth Pressure Coefficient

Ka = tan2 (45° - φ) $\frac{1}{2}$

= tan2 (45° - 25) $\frac{1}{2}$

= 0,41

- Active Earth Pressure

Pa = ½ γ H^2 Ka

Pa = ½ . 4 . (3)2 . 0,41

Pa = 7,38 kN/m

Pa2= ½ . γ_d. Ka.$\sqrt{Ka.Df}$

Pa2 = ½ . 4 . 0,41 . √0,41 . 3

Pa2 = 0,91 kN/m

Pa3 = ½ γ H2

Pa3 = ½ . 4 . 0,41

Pa3 = 1,80 kN/m

Pa total= Pa1 + Pa2 + Pa3

Pa total= 10,09 kN/m

- Active Moments

Ma1 = Pa1 . (½ . H1) + H2

= 7,38 . (½ . 3) + 0,9

= 11,97 kN/m

Ma2 = Pa2 . (½ . H1)

= 0,91 . (½ . 3)

= 1,36 kN/m

Ma3 = Pa3 . (½ . Df)

= 1,8 . (½ . 0,9)

= 0,81 kN/m

Ma total= Ma1 + Ma2 + Ma3

Ma total= 14,14 kN/m

- Passive Earth Pressure Coefficient

Kp = tan2 (45° + φ) $\frac{1}{2}$

= tan2 (45° + 25) $\frac{1}{2}$

= 2,46

• Passive Earth Pressure

Pp = ½ . γ . Df
Pp = ½ . 4 . 0,9
Pp = 1,80 kN/m
Pp2 = $\frac{1}{3}$ γd Df Kp + 2 c √Kp Df
Pp2 = $\frac{1}{3}$ 4 0,9 2,46 + 2 0,41 √2,460,9
Pp2 = 4,17 kN/m
Pp3 = ½ . γ . Df2
Pp3 = ½ . 4 . 0,92
Pp3 = 1,62 kN/m
Pa total= Pp1 + Pp2 + Pp3
Pa total= 7,59 kN/m

• Passive Moment

Mp1 = Pp1 . (½ . H1) + Df
= 1,80 . (½ . 3) + 0,9
= 4,32 kN/m
Mp2 = Pp2 . (½ . Df)
= 4,17 . (½ . 0,9)
= 1,88 kN/m
Mp3 = Pp3 . (½ . Df)
= 1,62 . (½ . 0,9)
= 0,73 kN/m
Mp total= Mp1 + Mp2 + Mp3
Mp total= 6,93 kN/m

b. Calculation of Construction Self-Weight

• Self Weight of Field:

P_1 = p . l . γ
= 3 . 0,5 . 24
= 36 (kN/m)
P_2 = ½ (a . t) . γ
= ½ (0,5 . 3) . 24
= 18 (kN/m)
P_2 = p . l . γ
= 1 . 0,9 . 22
= 21,6 (kN/m)

Table 7. Moment Calculation Results for Soil Retaining Walls

No	Distance to Point A (m)	Own Weight (kN/m)	Point A Moment (kNm)
1	0,25	36,00	9,00
2	0,67	18,00	12,06
3	0,50	21,60	10,80
Amount		75,60	31,86

3. Carrying Capacity

a. Ultimate bearing capacity:

$$q_u = \left(\frac{1}{3} . c . Nc\right) + (\gamma_t . D_f . Nq) + (0{,}4 . \gamma_t . B . N\gamma)$$

Nc, Nq, Ny is the soil bearing capacity factor obtained from the Terzaghi table based on the shear angle φ= 25°.

Based on table 4, Carrying capacity calculation

So
Nc = 25,1
Nq = 12,7
Nγ = 9,7
Po = Df . γ
= 0,9 . 5,81
= 5,229 kN/m2
qu = (1/3. c . Nc) + (Df . Nq) + (0,4 . γ . B . Nγ)
= (1/3 . 0,41 . 25,1) + (0,9 . 12,7) + (0,4 . 5,81 . 1 . 9,7)
= 21,883 kN/m2

Net ultimate carrying capacity
Qun = qu – Po
= 21,883 – 5,229
= 16,654 kN/m2

Net foundation pressure
qn = qun – Po
= 16,654 – 5,229
= 11,425 kN/m2

Safe ty Factor (f):
F = $\frac{qun}{qn}$
= $\frac{16,654}{11,425}$
= 1,458 kN/m2

Permit carrying capacity
qa = $\frac{qu}{f}$
= $\frac{21,883}{1,458}$
= 15,012 kN/m2

b. Safe ty factors regarding soil bearing capacity, stability against sliding and overturning

- Stability to soil bearing capacity

∑M = 29,205 kNm
V=∑G = 69,3 kN/m
e = ½ . B - $\frac{\sum M}{\sum G}$
= ½ . 1 - $\frac{29,205}{69,300}$
= 0,079
e ijin = $\frac{1}{6}$. B = 0,167

Bearing capacity stability:
σ maks = $\frac{2 \, . \, V}{2 \, .((\frac{H}{B}) - e)}$> qa
= $\frac{2 \, . \, 75,6}{2 \, .((\frac{3}{1}) - 0,167)}$> qa
= 25,92 > 15,012 (safe)

- Stability against shear

F = tan φ
= tan (25)
= 0,37

$$Fgs = \frac{(V . F) + \left(\frac{2}{3} . c . B\right) + \sum Pp}{\sum Pa} = \geq 1,5$$

$$Fgs = \frac{(75,6 \; . \; 0,37) + \left(\frac{2}{3} . 0,41 . 1\right) + 7,59}{10,09} = \geq 1,5$$

Fgs = 3,55 = ≥ 1,5 (safe)

Stability against overturning

$$SF = \frac{\sum M + \sum Ma}{\sum Mp} > 1,5$$

$$SF = \frac{31,86 + 14,14}{6,93} > 1,5$$

SF = 6,64> 1,5 (safe)

5. CONCLUSIONS

1. Dimensions of Earth Retaining Walls for both Gravity type and Cantilever type have details:
   a. Length (l): 23 m
   b. Foundation depth (Df): 0.90 m
   c. Retaining wall height (H): 3.00 m
   d. Total retaining wall height (H1): 3.90 m
   e. Top width (B1): 0.50 m
2. Foundation width (B2): 1.00 m Analysis of the stability of the Gravity Type earth retaining wall obtained the Stability figures for the soil Bearing Capacity σ max= 23.76 > 15.012 (safe), Stability against Shear hazards Fgs=3.321 ≥ 1.5 (SAFE), and Stability against the danger of overturning SF= 6.26 > 1.5 (safe). Analysis of the stability of the Cantilever Type earth retaining wall obtained the stability figures for soil bearing capacity σ max= 25.92 > 15.012 (safe), Stability against sliding hazards Fgs=3.55 ≥ 1.5 (safe), and Stability against overturning hazards SF= 6.64 > 1.5 (safe)

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7. AUTHOR CONTRIBUTIONS

Conception and design: Suhudi, Fifi Damayanti
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