REVIEW OF INTERNATIONAL GEOGRAPHICAL EDUCATION

ISSN: 2146-0353 • © RIGEO • 11(1), MARCH, 2021

www.rigeo.org

Research Article

Efficiency Study of Cantilever Retaining Walls In "Mountain Breeze" Housing Bandung: A Geographical Analysis

Asep Setiawan[1]
Department of Civil Engineering, Widyatama University, Indonesia

Fuad Hasan[2]
Department of Civil Engineering, Widyatama University, Indonesia

[1] Corresponding Author: Email: asep.st@widyatama.ac.id

Abstract

The construction of retaining walls must be based on the calculation of stability and safety factors because errors that occur in the construction of retaining walls can be fatal, namely property loss and can cause fatalities. It is a geographical analysis and the purpose of this study is to determine the efficiency of the base width of the cantilever type retaining wall in the "MOUNTAIN BREEZE" housing in Bandung Regency so that it is stable against overturning, shearing, and soil bearing capacity. One way to make efficiency is to make changes to the width of the base. From the results of research on retaining walls with base width (L) = 1 m, 2 m, 3 m, and 3.5 m, it can be seen that the most efficient and stable base width against overturning, shearing, and soil bearing capacity is 3.5 meters.

Keywords

Dinding Penahan Tanah, Efisiensi, Stabil

To cite this article: Setiawan, A.; and Hasan, F. (2021) Efficiency Study of Cantilever Retaining Walls In "Mountain Breeze" Housing Bandung: A Geographical Analysis. *Review of International Geographical Education (RIGEO), 11(1), 552-562. doi: 10.48047/rigeo.11.1.39*

Submitted: 20-01-2021 • **Revised:** 15-02-2021 • **Accepted:** 25-03-2021

Introduction

Retaining wall is a construction that serves to stabilize the soil condition which is generally installed in unstable cliff areas. Types of construction include masonry with mortar, masonry blanks, reinforced concrete, and wood and so on. The construction of retaining walls must be based on the calculation of stability and safety factors because errors occur in the construction of retaining walls that can be fatal, namely property losses and can cause fatalities. One example that we can see is the Mountain Breeze Bandung housing development project which is located on hills and contoured land. Therefore, it is necessary to design a retaining wall that is truly stable and efficient. Stable in terms of strength to support the magnitude of the overturning force, shear force and bearing capacity. In addition, dimensional planning must pay attention to the efficiency side. One way to make efficiency is to make changes to the width of the base. Based on the above background, it can be formulated the problem in this study is the extent to which the influence of the width of the base of a retaining wall on the stability due to overturning, shearing, and soil bearing capacity The purpose of this study is to determine the efficiency of the base width of the cantilever type retaining wall in the "MOUNTAIN BREEZE" housing so that it is stable against overturning, shearing, and soil bearing capacity.

Literature Review

Earth Retaining Wall

Based on how to achieve stability, retaining walls are classified as follows (Ilyichev, Nikiforova, & Konnov, 2021):

a. Gravity Wall
b. This wall is usually made of pure concrete (without reinforcement) or from stone masonry. The stability of the construction is obtained only by relying on the construction's own weight. Usually, the wall height is not more than 4 meters.
c. Cantilever Retaning Wall
d. Cantilever retaining walls are made of reinforced concrete consisting of a vertical wall and floor tread. Each act as a beam or cantilever plate. The stability of the construction is obtained from the self-weight of the retaining wall and the weight of the soil above the heel of the tread (hell). There are 3 structural parts that function as cantilevers, namely the vertical wall (steem), the heel of the tread and the toe of the tread (toe). Usually, the height of this wall is not more than 6 -7 meters.
e. Counterfort wall
f. If the active earth pressure on the vertical wall is large enough, then the vertical wall and heel need to be combined (contrafort). Contrafort functions as a vertical wall tension binder and is placed on the embankment with a certain distance interval. Contrafort walls will be more economical to use if the wall height is more than 7 meters.

Lateral Earth Pressure

Lateral earth pressure is an important planning parameter in a number of engineering problems for foundations, retaining walls and other structures that are underground. All of this requires quantitative estimation of lateral stresses in construction works, both for planning analysis and stability analysis.
In principle, the condition of the soil in its position there are 3 possibilities, namely (Jabarullah, Surendar, Arun, Siddiqi, & Krasnopevtseva, 2020):

a. In Silent State
b. In Active State
c. In a Passive State

Retaining Wall Stability

There are several things that can cause the collapse of the retaining wall, including:

a. Overthrowing
b. Shift
c. The collapse of the bearing capacity

Therefore, in planning a retaining wall, the first step that must be done is to determine the size of the retaining wall to ensure the stability of the retaining wall. Retaining walls must be stable against overturning, shearing, and the bearing capacity of the soil.

Stability Against Overturning

Lateral earth pressure caused by the backfill behind the retaining wall, tends to overthrow the wall with the center of rotation at the forefoot of the foundation. This overturning moment is countered by the moment due to the self-weight of the retaining wall and the moment due to the weight of the soil above the foundation plate (Montesi, 2021).
In Figure 1. below, a diagram of the soil pressure on the retaining wall that will be reviewed is shown, in this case it is a cantilever type retaining wall (assuming the earth pressure is calculated by the Rankie formula).

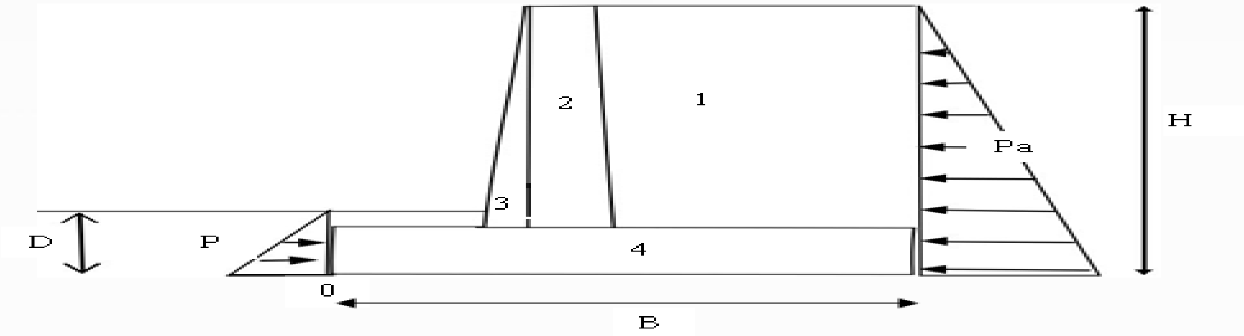

Figure 1. Earth Pressure Diagram for Cantilever Wall

The safety factor against gulg is defined as (viewed from the foot/point O in the figure):

$$SF_{roll} = \frac{\sum M_o}{\sum M_R}$$

Where:

Mo = sum of the moments of the forces that cause the moment at point O.
MR = number of moments resisting overturning about point O.
The moment that produces the roll:

$$\Sigma MO = P_h \left[\frac{H}{3}\right]$$

Where horizontal soil pressure, Ph = Pa, active soil pressure (if the ground surface is flat). The safety factors are:

$$SR_{roll} = \frac{M1+M2+M3+M4}{Pa(\frac{H}{3})}$$

Factors of safety against overturning, depending on the type of soil, namely:

a. 1.5 for granular subgrade
b. 2 for cohesive subgrade.

Stability Against Shift

The forces that displace the retaining wall are resisted by:

- Force between the soil and the base of the foundation
- Passive earth pressure in front of the retainer

The factor of safety for shear stability can be expressed by the formula:

$$SF_{sliding} = \frac{\sum FR}{\sum Fd}$$

Where:

$\sum FR$ = sum of forces resisting horizontal forces
$\sum Fd$ = sum of the forces pushing on

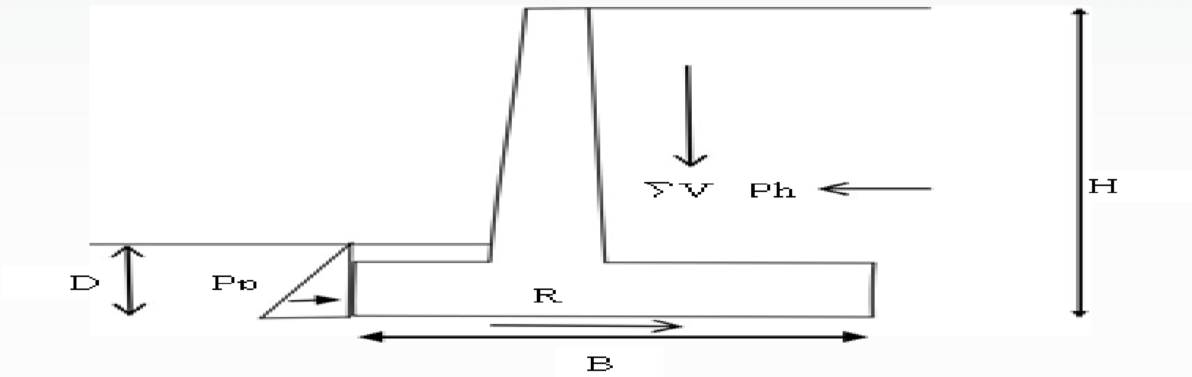

Figure 2. Control of Wall Base Shift

From Figure 2. above, the shear strength of the soil at the base of the wall:

s = tan δ + ca
Where:

δ = shear angle between the soil and the base of the wall
ca = adhesion between the soil and the base of the wall.
Forces that hold on to the base of the wall:
R = s (cross-sectional area of the base) =
s (Bx1) = B tan + Bca
B = sum of vertical forces = ΣV
So, R = (ΣV) tan + Bca

Figure 2. shows that Pp is also a horizontal resisting force, so that:

FR = (ΣV) tan + Bca + Pp
And
Fd = Ph

$$SF_{sliding} = \frac{(\sum V) \tan \delta + Bca + Pp}{Ph}$$

The minimum permissible limit for shear safety factor is 1.5 In most cases, Pp is used to calculate the factor of safety against shear, where the shear angle and cohesion c are also reduced
k1= – 2/3 and k2= c – 2 /3 c
k1Ø& ca = k2c

$SF_{sliding} = \frac{(\sum V) \tan k1\emptyset + Bk2c + Pp}{Ph}$

Stability Against Carrying Capacity

Moment at point C

Mnet = ∑MR - ∑Mo (∑MR and ∑Mo obtained from rolling stability)

If the resultant at the base of the wall is at point E

$\overline{Œ} = \overline{X} = \frac{Mnet}{\sum V}$

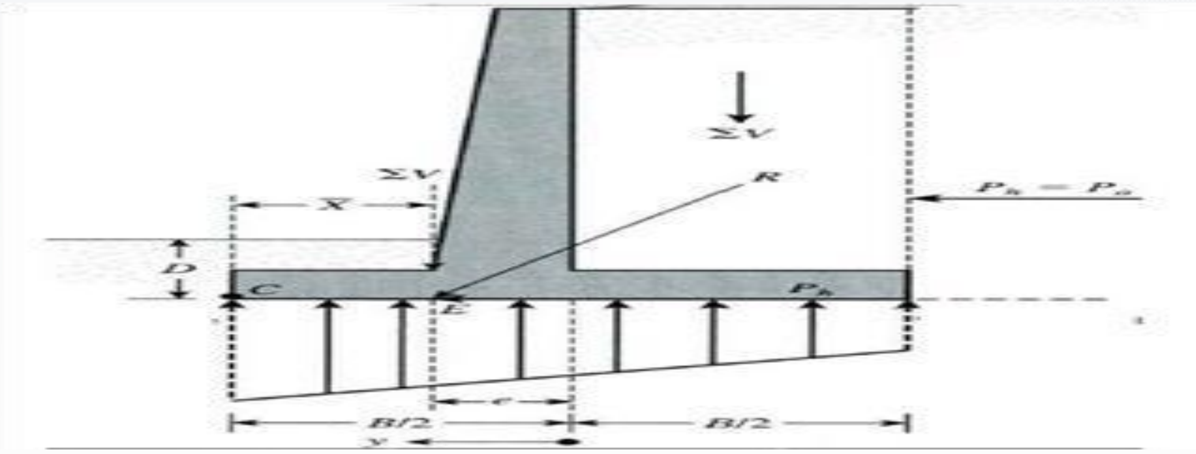

Figure 3. Control of Carrying Capacity Collapse

- The eccentricity can be obtained from $e = \frac{B}{2} - \overline{Œ}$

Or

$e = \frac{B}{2} = \frac{\sum MR - \sum Mo}{\sum V}$

The pressure distribution at the base of the retaining wall can be calculated as follows:

$q = \frac{\sum V}{A} \pm \frac{Mnet\ y}{I}$

where:

$Mnet = (\sum V)\ e$

$I = (\frac{1}{12})(1)\ (B^3)$

For maximum and minimum values, y = B/2

$q_{max} = \frac{\Sigma V}{B}[1 + \frac{6e}{B}]$

$q_{min} = \frac{\Sigma V}{B}[1 - \frac{6e}{B}]$

The bearing capacity of the soil is calculated using the Hansen equation:

qu = c * Nc * Fcd * Fci + q * Nq * Fqd * Fqi + 0.5 * γ * B' * Nγ * Fγd * Fγi

Where:

q = γ*D

$B' = B - 2e$

$F_{cd} = 1 + 0{,}4\frac{D}{B_t}$

$F_{qd} = 1+2 \tan Ø\, (1 \sin Ø) \frac{D}{B_t}$

$F_{\gamma d} = 1$

$F_{ci} = F_{qi} = (1- \frac{\psi^0}{900^0})^2$

$F_{\gamma i} = (1 - \frac{\psi^0}{\psi 0})^2$

$T^0 = \tan^{-1} (\frac{P_h}{\Sigma V})$

Notes:

N_c, N_q, N_γ = Terzaghi. bearing capacity factor
The factor of safety against failure of the bearing capacity is defined as:

$SF = \frac{q_u}{q} \geq 3$

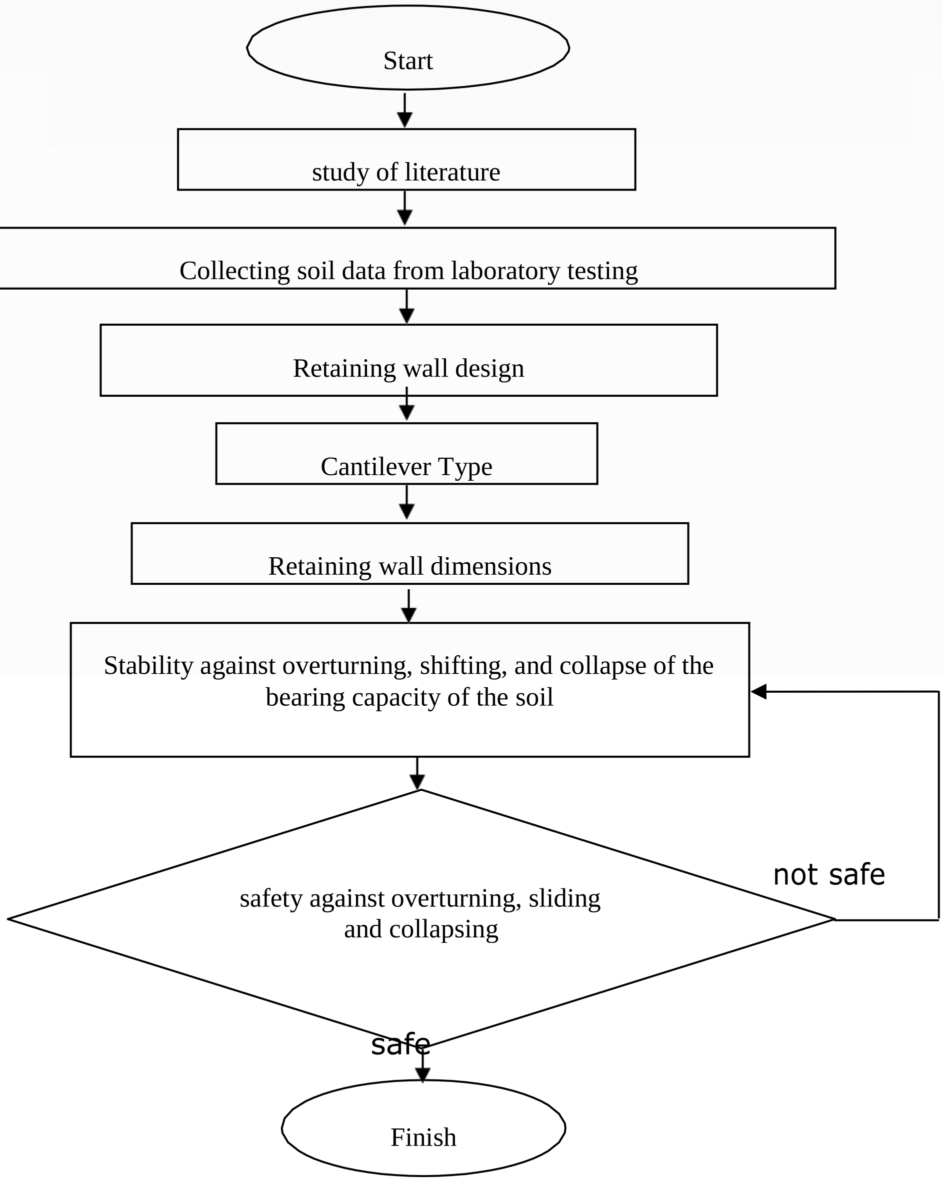

Figure 4. Research Process Flowchart

Methodology

This research begins with identifying the problem, determining the topic/title, conducting a preliminary survey, to find out the current conditions at the research site, and collecting data.
The data collection method used includes secondary data, which prioritizes how to take data from the results of soil testing carried out in a laboratory in Bandung. Accompanied by conducting field observations on the retaining wall of the housing project "Mountain Breeze"
After the necessary data is obtained, then with the relevant literature and related to the discussion in this study, the data is processed and analyzed to determine the efficiency of the width of the base on the retaining wall so that it is stable against overturning, shearing, and soil bearing capacity. The location of this research is in the housing "Mountain Breeze" Bandung Regency, West Java Province.

Data Processing and Analysis

Data Tanah

For the purposes of planning the retaining wall, soil data is needed at the location of the "Moutain Breeze" housing on Jl. Raya Banjaran, Bandung Regency. The geological condition of the soil around the planning location is categorized as clay/cohesive soil. Soil parameters that need to be known for planning retaining walls are:

Cohesion (c) and friction angle (Ø) were obtained by conducting a direct shear test in the laboratory. Density of soil () was also obtained by testing in the laboratory.
The design uses a concrete weight of 24 kN/m^3.
The soil data obtained from laboratory testing are as follows:

Table 1.
Soil Data from Laboratory Testing

γ(kN/m^3)	c (kN/m^2)	Ø (^{0})
17	20.03	18.34
18.3	12.1	24.156
17.2	7.09	15.27

Retaining Wall Design

Determining The Dimensions of The Retaining Wall

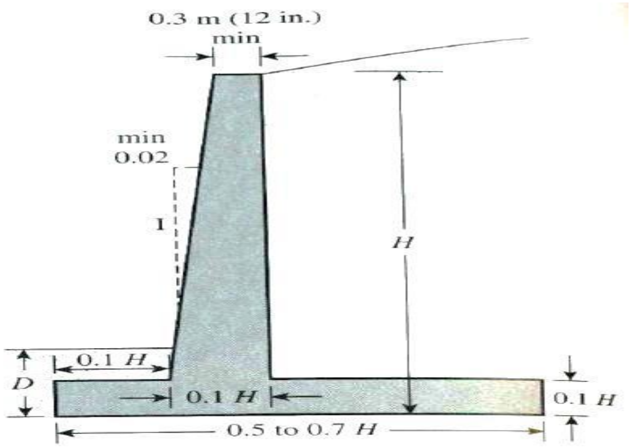

Figure 5. Minimum Size Composition of Cantilever Retaining Wal

Based on the standard size in Figure 5. above, a wall plan is carried out by entering the base width value to get the most efficient base width. In this study, experiments were carried out by taking the values of L = 1 m, 2 m, 3 m, and 3.5 meters.

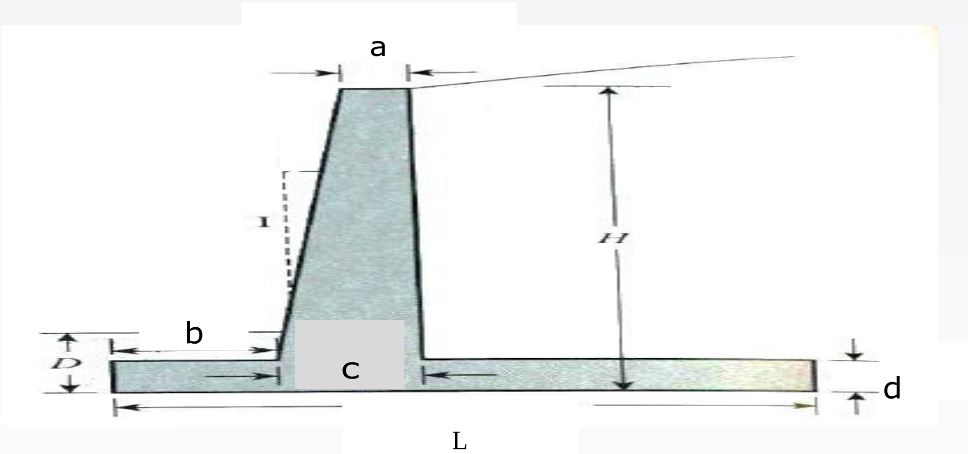

Figure 6. Retaining Wall Dimension Design

- Height of retaining wall (H) = 7 m
- For width a (min 0.3) = 0.3 m
- For width b (0.1 H) = 0.7 m
- For width c (0.1H) = 0.7 m
- For width L = 3.5 m
- For height d (0.1H) = 0.7 m
- For height D = 1 m

Calculating Ground Pressure
The soil data is known as follows:

- Density of soil (γ) = 18.3 kN/m^3
- Shear angle(Ø) = 24.2^o
- Cohesion (c) = 12 kN/m^2
- Water volume weight (γw) = 9.81 kN/m^3

Table 2.
Calculation of Earth Pressure

Active Earth Pressure Coefficient (Ka)	0.4
Passive Earth Pressure Coefficient (Kp)	2.4
Active Earth Pressure (Pa)	121.25 kN/m
Passive Ground Pressure (Pp)	59.14 kN/m

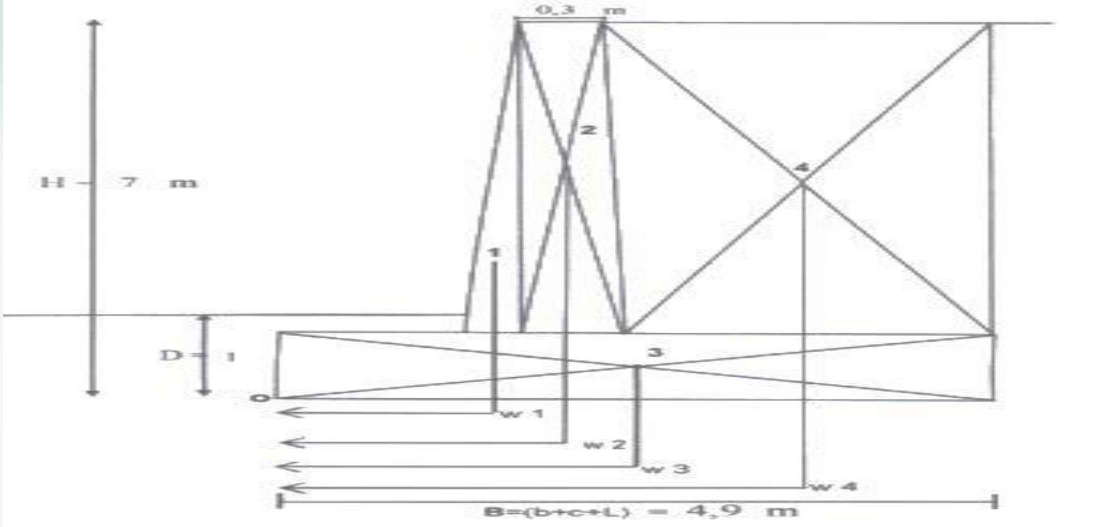

Figure 7. Vertical Forces and Working Moments

Table 3.
Calculation of Vertical Force and Working Moment

Part	Large (m2)	Weight/Unit of Length (kN)	Moment Distance from Point 0 (m)	Moment about point 0 (kNm)
(1)	(2)	(3)	(4)	(5 = 3*4)
1	1.26	30.25	0.97	29.232
2	1.89	45.36	1.3	56.7
3	3.43	82.32	2.45	201.684
4	22.05	403.515	3.16	1271.07
	∑V = 561.435		∑Mg = 1558.69	

From the calculation results obtained the number of retaining wall safety against overturning, shearing and bearing capacity in the following table:

Table 4.
Calculation Of the Safety Factor of The Base Width L of The Retaining Wall

L (m)	1	2	3	3,5
SF_{roll} (≥ 2)	1.2	2.6	4.4	5.5
$SF_{sliding}$ (≥ 2)	1.7	2.37	3.04	3.38
$SF_{bearing\ capacity}$ (≥ 3)	1	1.6	2.55	3.05

Based on the table above, it is known that there is an increase in the number of safeties for every change in the width of the base. For L = 1 meter the retaining wall is not safe against overturning, shearing, and bearing capacity factors. Because the safety factor after the calculation is still below the required safety factor.

For L = 2 & L = 3, the retaining wall is stable against overturning and shearing forces. But not yet stable to carrying capacity.

For L = 3.5, the calculation results show that the safety factor obtained is above the required safety factor. So that the planned retaining wall with L = 3.5 meters is able to withstand the overturning and shearing forces and the bearing capacity.

For more details, see the following graph:

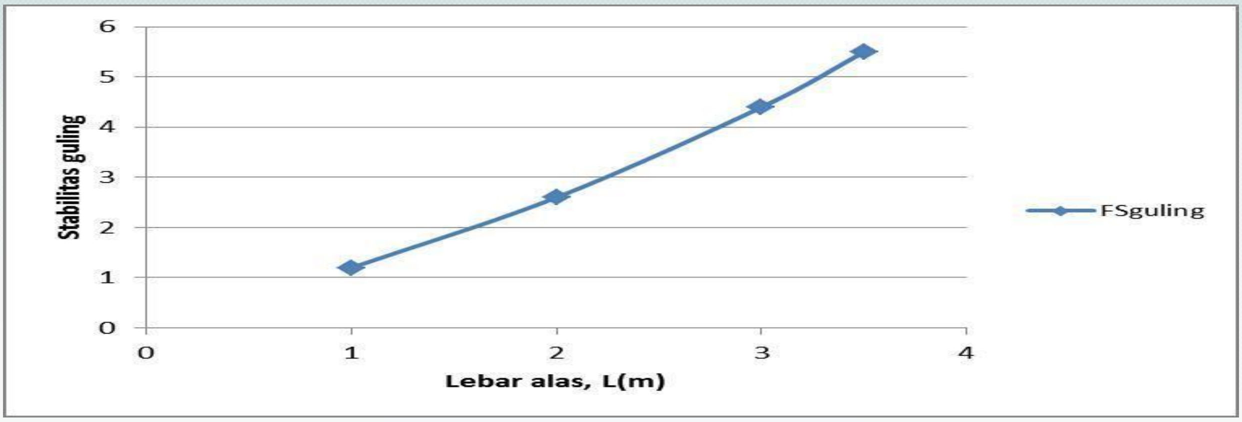

Figure 8. The relationship between changes in the width of the base to the overturning safety factor.

From Figure 8 above, it can be seen that with a base width of 1m – 3.5 m, the retaining wall has a rolling stability (FSguling) between 1.2 to 5.5. This means that the wider the base of the retaining wall, the greater the rolling stability.

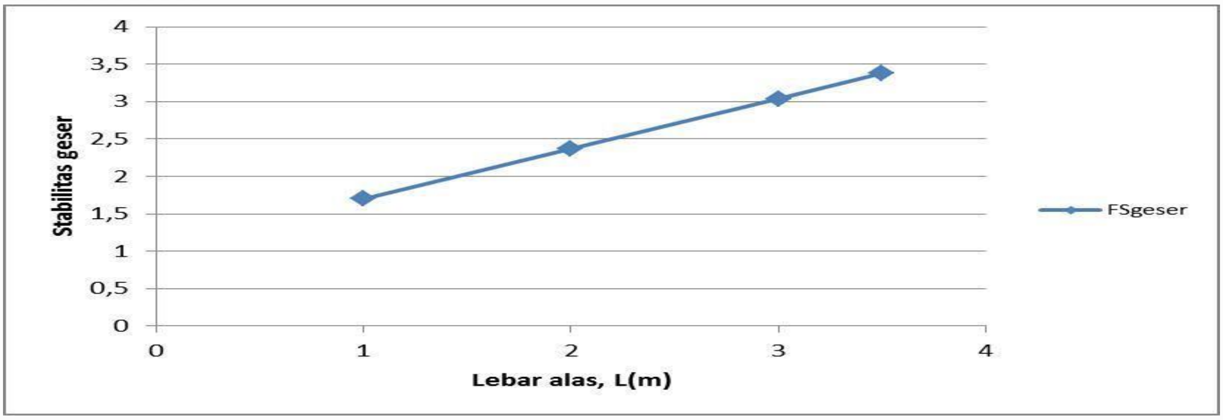

Figure 9. The Relationship Between Changes in The Width of The Base and The Shear Factor of Safety

From Figure 9 above, it can be seen that at a base width of 1m – 3.5m, the retaining wall has a shear stability (F_{shear}) between 1.7 to 3.38. This means that the wider the base of the retaining wall, the greater the shear stability.

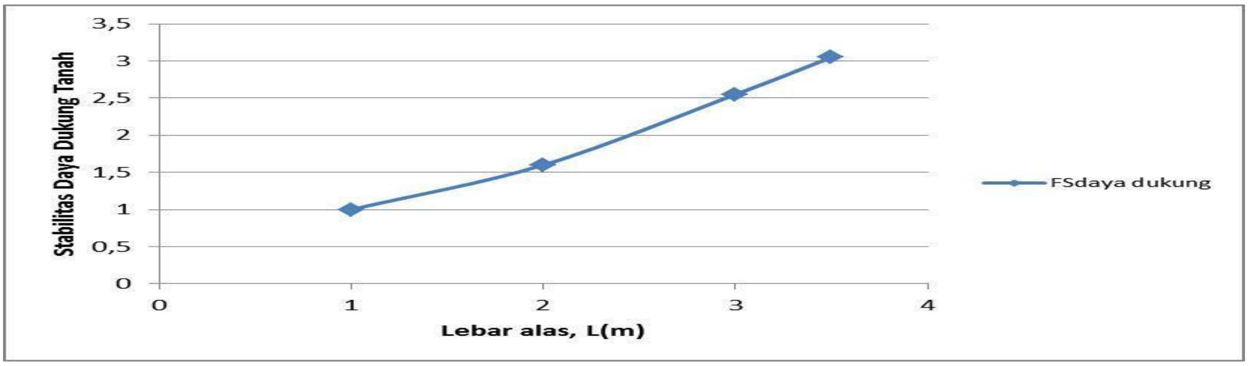

Figure 10. The Relationship of The Change in The Width of The Base to Bearing Capacity Safety

Factor.

From Figure 10 above, it can be seen that at a base width of 1m – 3.5m, the retaining wall has a bearing capacity stability (FS bearing capacity) between 1 to 3.05. This means that the wider the base of the retaining wall, the greater its stability to bearing capacity.

Conclusion

Based on the design of the cantilever type retaining wall using laboratory test soil data at the "Mountain Breeze" housing location with a base width (L) of 1 to 3.5 meters, it was found that:

a. The overturning stability (FSguling) of the retaining wall faces a safety factor at a base width of 2 meters L. The tendency of the Fsguling value to increase along with the increase in the width of the retaining wall base.
b. The shear stability (Fsgeser) of the retaining wall faces a factor of safety at an alias L width of 2 meters. The tendency of the Fs shift value to increase along with the increase in the width of the retaining wall base.
c. The stability of the failure of the soil bearing capacity (supporting capacity) of the retaining wall meets the safety factor at the base width L of 3.5 meters. the tendency of the value of the bearing capacity Fs to increase along with the increase in the retaining wall.
d. From the 3 things above, it can be seen that the most efficient base width for the cantilever type retaining wall in the "Mountain Breeze" housing to be stable against overturning, shearing, and the bearing capacity of the soil is 3.5 meters.

References

Ilyichev, V., Nikiforova, N., & Konnov, A. (2021). *Technological Soil Mechanics in Underground Construction.* Paper presented at the IOP Conference Series: Materials Science and Engineering.

Jabarullah, N. H., Surendar, A., Arun, M., Siddiqi, A. F., & Krasnopevtseva, T. O. (2020). Microstructural Characterization and Unified Reliability Assessment of Aged Solder Joints in a PV Module. *IEEE Transactions on Components, Packaging and Manufacturing Technology, 10*(6), 1028-1034. doi:10.1109/TCPMT.2020.2972027

Montesi, M. (2021). Soil Structure Interaction Using p–y Analyses for Earth Retaining Structures *IFCEE 2021* (pp. 1-11).