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Retaining Wall Reinforcement of Road Hill Slope of Selacau-Lagadar, West Bandung: A Case Study

Yanyan Agustian[1], Asep Setiawan[2], Raden Herdian Bayu AshSiddiq[3]

Abstract---The problem that is often found in areas with high rainfall is frequent landslides. Various methods are carried out by giving strength to the soil so that deformation does not occur like an artificial or natural slope. Selacau-lagadar road in West Bandung is located in an area with steep cliffs and frequent landslides. This study was conducted to evaluate the use of cantilever concrete wall retaining walls to overcome landslides in the cut-down roads of the Selacau -adar road in West Bandung. Soil properties obtained from field investigation and laboratory experiments were used as parameters in determining the design of the retaining wall. The calculation results show that based on the soil properties, the chosen retaining wall, the type of cantilever concrete wall, is the desired safety factor if viewed from three factors, namely: the resistance to overturning, sliding and bearing capacity of the soil where the retaining wall will constructed.

Keywords---Excavation, elasto-plastic, nonlinear behaviour

I. Introduction

Shifting and collapse of the slope that cannot stand due to lateral pressure will cause material loss and will take lives, so that zone is a critical zone. This requires the planning of slope stability techniques, especially at the location of road segments that indicate landslides will occur so that it is expected not to endanger the use of surrounding communities.

The Sulacau-Lagadar road section which is located at West Bandung, is a regency road and is a connecting road from one area to another in the Bandung regency. The location of the road section is in the hills with steep slopes so landslides often occur. The occurrence of instability on the slope is a problem that needs attention, so the cause of landslides marked by a shift from the ground wall can be identified to be followed up in the form of stabilization either by adjusting the slope or by using reinforcement or retaining wall.

The purpose of this study is to obtain a soil parameter on the slope resistant to both vertical and horizontal loads, it is necessary to conduct a soil study which includes geotechnical research of the soil to determine a retaining wall design on the slopes of the road section. This research is limited to studies including:

1. Relationship of soil shear strength parameters to the slope of the excavation wall in the absence of a retaining wall.
2. Soil retaining wall as a slope stabilizer.

[1]*Civil Engineering Department, Faculty of Engineering, Widyatama University Indonesia*
yanyan.agustian@widyatama.ac.id
[2]*Civil Engineering Department, Faculty of Engineering, Widyatama University Indonesia*
asep.st@widyatama.ac.id
[3]*Civil Engineering Department, Faculty of Engineering, Widyatama University Indonesia*
raden.herdian@widyatama.ac.id

3. The amount of horizontal or lateral stresses and the magnitude of the moment that occurs as a factor for sliding (unstability).

This article also conveys the results of a study about slope strengthening analysis that can applied to overcome slope hill deformation at the study area road section. The analyses were performed to obtain the dimensions of retaining wall so that can withstand landslides[3]. From this analysis can determined the most appropriate type of reinforcement.

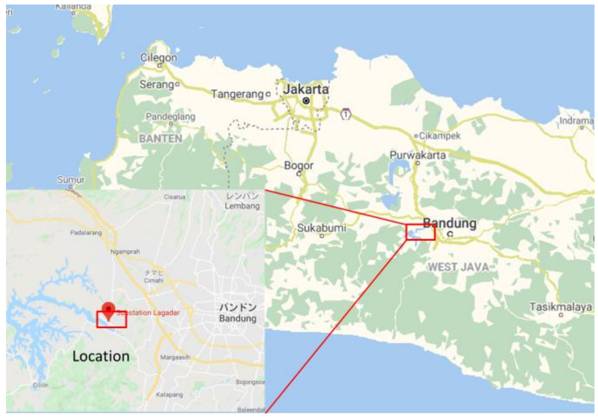

Figure 1. The location of the study area

Soil properties

Data from the results of field and laboratory surveys are needed as input data for the study material. The method of taking original soil is by drilling at locations at three depths for one drill location point. Soil samples were taken to determine the physical properties of the soil, Atterberg boundaries and soil shear strength parameters (φ and c).

The data collected is analyzed by empirical methods or the use of analytical formulas and computer programs to prove analytically against hypotheses. These calculations include: Characteristics and parameters of the shear strength of the slope, effect of horizontal / lateral pressure on the slope wall ground and he stability of the cantilever wall.

The steps that were taken during the land survey survey activities were as follows:

1. Conducting a review of all soil and material data, then conducting soil and material investigations as long as they will be overcome, which will be conducted based on direct surveys in the field or by inspection in the laboratory.

2. Drilling and Sampling are intended to get more thorough information, namely:

-Type of soil

- Structure of Soil Layers

- Index and Sub-Surface Engineering Properties

Drilling must be carried out to a specified depth or after sufficient information is obtained about the location of hard soil layers, rock types and thickness. If before reaching into the specified layer has been found hard soil / stone, drilling must continue through the hard layer as deep as approximately 3 meters, depending on the type of rock and sub-structure building loads.

How to clarify soil types should be done according to ASTM / AASHTO or Road Material Inspection Manual (MPBJ). For each drill hole being worked on, records must be made: location, elevation of drilling surface, date of drilling commencement, date of completion and equipment used.

From hydrometer testing and Grain Size Accumulation Curve (ASSHTO Classification) the value of the soil fraction is clay, silt and sand and clay% can be estimated the most dominant mineral content in the soil.

Triaxial testing was carried out in three stages: saturation, consolidation and shearing. The saturation stage is stopped if the value of B value> 0.9, the consolidation stage done so that pore water pressure is the same as back pressure after it is done shearing to find out the amount of resistance from the ground to failure. From the shearing data, a mohr circle is made to find out the parameters shear strength. Table 1 below provides a summary of the test results for all the sample.

Retaining wall is a construction that serves to hold loose or natural soil and prevent sloping ground collapse or a slope whose stability cannot be retained by the land slope alone [3]. The retained soil actively encourages the structure the wall so that the structure tends to be rolled away or will be displaced.

Table 1. Soil properties

No	Soil properties	Symbol	Value	Unit
1	Soil Unit Weight	γ_d	18	kN/m3
2	Internal firction angle	φ	25	°
3	Soil cohession	c	15	kN/m3
4	Bearing capacity	q_d	300	kN/m3
5	Pore ratio	e	2.25	
6	Poroucity	n	0.45	
7	Plasticity Index	PI	14	%

II. Method of Analyses

Retaining wall is a construction that serves to hold loose or natural soil and prevent sloping ground collapse or a slope whose stability cannot be retained by the land slope alone. The retained soil actively encourages the structure. The retaining wall serves to support the soil as well prevent it from danger of landslides. This could be due to the burden of rain water, heavy soil itself and due to the live load working above it. The use of retaining wall was also performed in temporary earth works[1].

There are several types of soil retaining walls, in this study the cantilever wall retaining walls was used. This wall consists of a combination of walls with reinforced concrete shaped T. The construction stability is obtained from the weight of the wall itself anchoring and weight of the ground above the heel of the tread. There are 3 parts to the structure which functions as a cantilever, namely the vertical wall, the heel tread and toe. Usually the height of this wall is not more than 6-7 meters.

For the calculation of lateral cohessive soil pressure in the retaining wall, as shown in Figure 2. The calculation is based on the Rankine and Coulomb equations by considering stress conditions in the Mohr circle [2].

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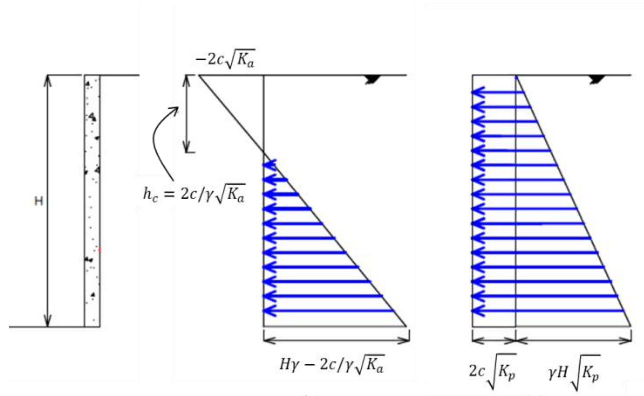


(a) (b) (c)

Figure 2. Lateral stress on cohesive soil : (a) Excavated soil with retaining wall reinforced, (b) active lateral stress diagram and (c) passive lateral stress diagram

By using Mohr's circle we can get an equation for the horizontal direction soil pressure σ_a (active pressure) and σ_p respectively [4]:

$$\sigma_a = \gamma z tg^2\left(45° - \frac{\varphi}{2}\right) - 2ctg(45° - \frac{\varphi}{2}) \quad (1)$$

$$\sigma_a = \gamma z tg^2\left(45° + \frac{\varphi}{2}\right) + 2ctg(45° + \frac{\varphi}{2}) \quad (2)$$

Thus, the total pressure acting on the retaining wall :

$$P_a = \frac{1}{2}H^2K_a - 2cH\sqrt{K_a} \quad (3)$$

$$P_p = \frac{1}{2}H^2K_p + 2cH\sqrt{K_p} \quad (4)$$

And the moments are :

$$M_a = P_a\frac{H}{2} \quad (5)$$

$$M_p = P_p\frac{H}{3} \quad (6)$$

Where ;

P_a : active lateral pressure (kN/m^2)

P_p : passive lateral pressure (kN/ m^2)

P_0 : Lateral pressure at rest (kN/ m^2)
K_{as} : Coefficient of active pressure
K_p : Coefficient of passive pressure
K_0 : Coefficient at rest
γ: Unit Weight of soil (kN/ m^2)
h : Thickness of soil
M_a : Moment at active pressure (kN/ m)
M_p ; Moment at passive pressure (kN/ m)
c : cohesion of soil (kN/ m^2)

The amount of lateral pressure is one of the main factors calculated to plan the retaining wall. Lateral stresses that occur can cause sliding and rolling. In addition, the important thing that must be considered is the structure and implementation of construction in the field. Therefore, the stability of the retaining wall must be taken into account, among others, the stability of the ground against the dangers of rolling, sliding, and bearing capacity. So that the construction of the retaining wall is safe, and no collapse occurs.

Stability Against Sliding

Due to lateral forces such as active soil pressure Pa acting, then retaining wall of the earth can be shifted. The lateral forces of P_a will get resistance from passive P_p ground pressure and friction between the base walls and soil.

$$SF = \frac{\sum Rh}{\sum Ph.} \geq 1.5 \qquad (7)$$

ΣRh = c x B + SW x tanϕ

ΣRh = Wall resistance against sliding (kN)
ΣPh = Total lateral stress (kN)
ΣW = Total weight of concrete wall (kN)
B = Width of foundation (m)
A safe factor against basic foundation shifts is taken 1.5 [5].
SF ≥ 1.5 for granular subgrade
SF ≥ 2 for cohesive soils

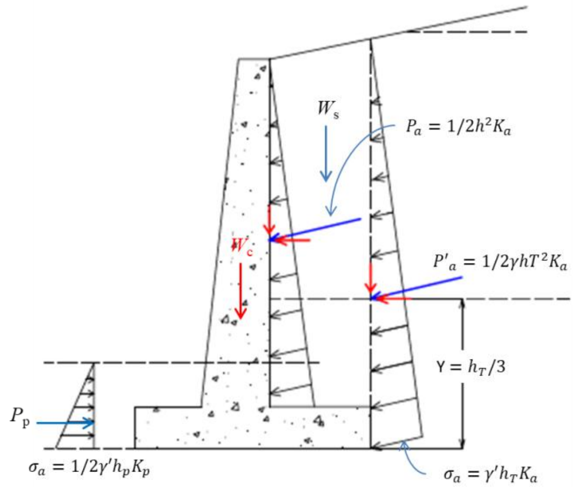


Figure 3. Stresses acting at cantilever retaining wall

Strength against overturning

Lateral ground pressure caused by a soil behind the wall tends to topple the wall with a center of rotation at the tip of the foot front of the foundation plate. This overthrowing moment is countered by moments of heavy consequences own retaining wall and moments due to the weight of the soil on the foundation plate.

$$SF = \frac{\sum Mt}{\sum Mg\,.} \geq 1.5 \qquad (10)$$

ΣMt = Moment against overturning (kN)

ΣMg = Moment that caused overturning (kN)

The safe factor for overturning depends on the type of soil, namely:

SF ≥ 1.5 for granular subgrade

SF ≥ 2 for cohesive soil

Stability against the Collapse of the bearing capacity

Contact pressure on subgrade foundation shall be larger than allowable soil stress. Land allowable stress equal to= ultimate bearing capacity divided by safety factor F (F≥3).

The ultiimit (*q*u) bearing capacity for the foundation extends using the Terzaghi method.

$$SF = \frac{q_u}{q_a.} \geq 1.5 \qquad (9)$$

q_u = Ultimate bearing capacity (kN/m^2)
q_a = Allowable bearing capcity (kN/m^2)

III. Results

With economic considerations and construction work which is relatively easy but structurally able to hold the soil from the landslides, a cantilever retaining wall type soil retaining wall is chosen in addition to the height not exceeding 6 meters so that the bending moment that occurs is not too large on the retaining wall. But still a reliable calculation must still be done to get the right design so that the results are economical and structurally reliable in term of economic and safety.

Based on the characteristics of the soil at the site, several designs were made taking into account safety factors. Trying a number of dimensional variations so that the SF value is obtained. The slope is stated in safe condition if it has a safety number of more than 1.5. The results of the slope reinforcement dimensions as seen on Fig. 4.

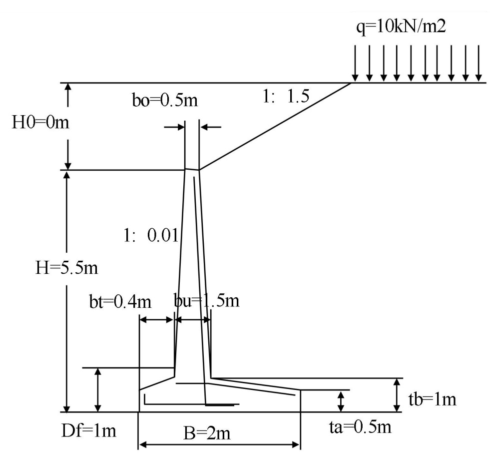


Figure 4. Cantilever retaining wall design dimension

Total loading

Teble1. Weight calculation result

Self Weight

	Dimension(m)		A	W	Arm length (m)		Moment (kNm/m)	
	width b	height h	(m^2)	(kN/m)	x	y	$W \cdot x$	$W \cdot y$
Wwall①	0.045	4.500	0.101	2.47	0.43	2.50	1.06	6.18
②	0.500	4.500	2.250	55.13	0.70	3.25	38.32	179.17
③	0.955	4.500	2.149	52.65	1.26	2.50	66.50	131.63
Base④	0.400	0.500	0.100	2.45	0.27	0.67	0.65	1.63
⑤	1.500	0.500	0.750	18.38	1.15	0.75	21.14	13.79
⑥	0.100	0.500	0.025	0.61	1.93	0.67	1.18	0.41
⑦	2.000	0.500	1.000	24.50	1.00	0.25	24.50	6.13
Back⑧	0.955	4.500	2.149	38.68	1.58	4.00	61.19	154.72
⑨	0.100	4.500	0.450	8.10	1.95	3.25	15.80	26.33
⑩	0.100	0.500	0.025	0.45	1.97	0.83	0.89	0.37
⑪	0.000	0.000	0.000	0.00	0.95	5.50	0.00	0.00
⑫	0.000	0.000	0.000	0.00	2.00	5.50	0.00	0.00
Σ	—	—	8.999	203.42	—	—	231.23	520.36

Weight $W_o =$ 203.42 kN/m

Excebtricity $x_o =$ 1.137 m $y_o =$ 2.558 m

Table 2. Summary of the total load

	Vertical	Horizontal	Load location		Moment	
	V(kN/m)	H(kN/m)	x(m)	y(m)	V· x	H· y
Self Weight	203.42	40.68	1.14	2.56	231.23	104.07
Load	0.00	0.00	1.47	0.00	0.00	0.00
Earth pressure	53.62	56.94	2.00	1.83	107.23	104.39
Σ	257.04	97.63	—	—	338.46	208.47

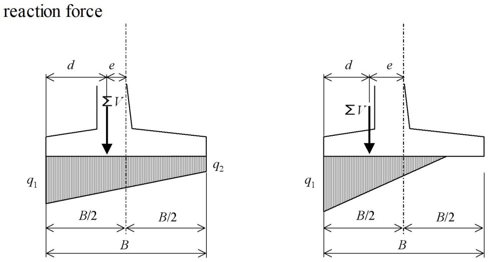
Vertical $\Sigma V =$ 257.035 kN/m

Horizontal $\Sigma H =$ 97.626 kN/m

Stress location $d = \dfrac{\Sigma Vx - \Sigma Hy}{\Sigma V} =$ 0.506 m

Center $e = \dfrac{B}{2} - d =$ 0.494 m > B/6

Ground reaction force



$e \le \dfrac{B}{6}$ $e > \dfrac{B}{6}$

$$\left.\begin{matrix} q_1 \\ q_2 \end{matrix}\right\} = \frac{\Sigma V}{B}\left(1 \pm \frac{6e}{B}\right) \qquad q_1 = \frac{2\Sigma V}{3d},\ q_2 = 0$$

$q_1 =$ 338.82 kN/m^2

$q_2 =$ 0.00 kN/m^2

$q_{max} =$ 338.82 kN/m^2

Safety factor check

(1) Overturning check

Width $B =$ 2.00 m Center $e =$ 0.494 m

SF $F_t = \dfrac{B}{2e} =$ 2.02 > 1.50 SAFE

(2) Sliding check

Vertical	$\Sigma V=$	257.04	kN/m
Horizontal	$\Sigma H=$	97.63	kN/m
Firction	$\mu=$	0.6	

Passive stress at embedment

Depth	$D_f=$	1.00	m
Soil Unit weight	$\gamma_1=$	19.00	kN/m^3
Internal firction angle	$\varphi_1=$	30.00	°

Coefficeint Kp

Base on Rankine $K_P = \tan^2\left(\frac{\pi}{4}+\frac{\phi}{2}\right) =$ 3.00

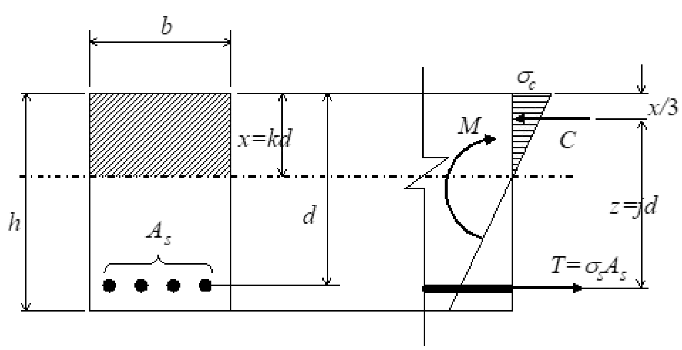
Passsive eart pressure $P_P = \frac{1}{2}\gamma D_f^2 K_P =$ 28.5 kN/m

$F_s = \frac{\Sigma V\mu + 0.5P_P}{\Sigma H} =$ 1.73 > 1.20 SAFE

(3) Bearing capacity check

Ultimate	$qu=$	900.0	kN/m^2
Allowale	$qa=$	338.82	kN/m^2

FS = qu/qa = 2.66 > 2.00 SAFE



Young M. $n = \frac{E_S}{Ec} = 15$ Ratio $np = n\frac{A_S}{b \cdot d} =$ 0.04343

$k = \sqrt{(np)^2 + 2np} - np =$ 0.254 $j = 1 - \frac{k}{3} =$ 0.915

Bending moment	$M=$	133173952	N · mm
Sear force	$S=$	83270	N

Concrete compressve stress

$\sigma_c = \frac{2M}{k \cdot j \cdot b \cdot d^2} =$ 0.6 N/mm^2 < $\sigma_{ca}=$ 12.0 N/mm^2
SAFE

Rebar tensile stress

$\sigma_s = \frac{M}{A_S \cdot j \cdot d} =$ 25.6 N/mm^2 < $\sigma_{sa}=$ 270.0 N/mm^2
SAFE

Concrete shear forece average

$\tau_m = \frac{S}{b \cdot d} =$ 0.059 N/mm^2 < $\tau_{ca}=$ 0.59 N/mm^2
SAFE

IV. Conclusions

Before handling using a retaining wall, it is known that the study area, the slope conditions selacau-lagadar section road at West Bandung generally experienced landslides caused by soil conditions that are classified as having low mechanical properties. In planning a retaining wall, planners need to know or understand the location to be built retaining wall. So that the planning of the retaining wall can be taken into account precisely according to field conditions.

This study begins with a survey and field investigation and continues with testing the sample in the laboratory. Laboratory tests show that the soil in the study area is predominantly composed of clay and sandy silt with an average plasticity index of 14. Several sites show traces of collapse from the slopes. The soil fraction is dominated by silt and silt and less loose sand. One slope sample slope is taken and analyzed to see the slope stability. The results show that the slope is very high possibility to collapse so that it requires handling using a retaining wall.

The results of the selection and calculation of the retaining wall in the form of cantilever concrete walls show that the design made is resistant to overturning, slides and sufficient soil bearing capacity. With a safety factor for overturning of 2.2 of a minimum of 1.5, sliding 1.7 of a minimum of 1.5 and a bearing capacity of 2.66 of 2.0 minimum required.

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