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Slope Deformation of Road Shoulder and Retaining Wall Evaluation at Rancacili-Rancasari Road, West Jawa

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Abstract

Damage that is often found on the road is the collapse of the shoulder of the road even worse is the slope of the shoulder and this can be caused by the bearing capacity of the road that is not sufficient to withstand the live load that passes through the road and this is compounded by the absence of retaining walls on the slope. The Rancacili-Rancasari road section is a national alternative road that many vehicles pass by. In some places on the road, cracks occur and land subsidence occurs which can cause landslides on the shoulder of the road. The objective of this study is to evaluate the use of retaining walls to overcome landslides on the shoulder of the road. Taking into account the properties of the soil and the properties of the soil in the area, as an input parameter calculation, an appropriate and safe desgn is determined for the retaining wall type of self-weight retaining wall. By using the basic theory of earth pressure coloumb's theory, a lateral pressure calculation is performed that works on the wall and combined with the trial wedge of lateral pressure theory, then calculates the total load received by the wall to find the safety factor of the wall relationship with resistance to rotation, sliding and its bearing capacity.

Keywords : Landslide, retaining wall, safety factor

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I. INTRODUCTION

Landslides are one of the disasters that often occur in Indonesia. The causes can vary. High rainfall and topographic conditions in much of Indonesia allow for landslides. There are also causes caused by natural damage caused by human error such as environmental destruction, improper design on a sloped land, poor carrying capacity of the soil to hold the structure above it in sloping areas and so on. One of the many landslide events that often occur is landslides on the shoulder of the road caused by the absence of a retaining wall next to the shoulder of the road which causes the slope eroded by river water and the slope to collapse or live load that is too large to pass the road so that the burden received by the road outside the limits of its bearing capacity so that the slope failures. Based on the report from BPBN (National Disaster Management Agency) at the end of 2019, in West Java within a period of one year (2019) there were 111 landslide events that caused the death of 5 people, damaged 85 houses and d 582 people was evacuated[1].

The study object is Rancacili-Rancasari section road where is located at eastern Bandung, West Jawa. Rancacili road is an alternative road that connects the national road (Sukarno-Hatta road) and the provincial road. The road is not too big but because it is an alternative road, the road is mostly passed by motorized vehicles ranging from two wheels to 4 medium size wheels. Figure 1. shows its location.

This article conveys the results of a study about slope strengthening analysis that can applied to overcome landslides land on the Rancacili road section. The analyses was performed so get the dimensions that can withstand landslides. From this analysis can determined the most appropriate type of reinforcement.

Figure 1. The location of the study area

II. METHOD OF ANALYSES

Landslides is a natural phenomenon in the form land mass movements in search new balance due to interference from the outside which causes a reduction soil shear strength and increasing stress soil[2]. In general, landslides caused by a parameter reduction soil shear strength and increasing stress soil. Reduction of shear strength parameters soil caused by increasing levels ground water and decreasing the bond between the grains soil. Retaining force in support Slope stability is determined by strength he shoved. The shear strength of the soil is internal ground strength in holding friction along the plane of collapse.

Soil material collapse caused by critical combination of normal stress (σ_n) and shear stress (τ_f). The relationship between shear stress and stressnormal to Mohr-Coloumb failure criteria can be stated in Eq. 1 as follows[3]:

$$\tau_f = c + \sigma_n \tan \emptyset \qquad (1)$$

τ_f = shear strength of soil (kg/cm^2)
c = soil cohesion (kg/cm^2)
σ_n = Normal stress (kg/cm^2)
φ = internal friction angle (^{o})

In earth pressure coulomb's theory As shown in Fig. 1, earth slides on the ground behind the retaining wall with a wedge-shaped mass. Assuming, the earth pressure acting on the wall was determined. Even in Coulomb's theory of earth pressure, when falling and pushing the retaining wall (working state), the retaining wall pushes the ground behind and the earth mass pushes up can be considered (passive state).

From the fit, the active earth pressure and the passive earth pressure are calculated. In coulomb's theory of earth pressure friction can be taken into account. Also, if the back of the retaining wall is inclined or even if the surface is inclined, the applicability is wide because the earth pressure can be calculated. In the case of non-adhesive soil, in the active state shown in Fig. 2(a), it acts on the soil rule the forces are the soil mass *W*s, the reaction force *R* of the ground and the reaction force *P* of the retaining wall. These three forces form a force triangle, and the resultant force is zero. Similarly for the passive state as shown in Fig. (2) However, a force triangle is formed, and the earth pressure can be calculated geometrically from this triangle. In Fig. 2, θ is the inclination angle of the back of the wall, and *i* is the inclination of the ground behind the wall. Angle, β is the angle of the slip surface generated on the ground behind the wall, δ is the distance between the back of the wall and the ground the friction angle, and Φ is the shear resistance angle of the ground behind.

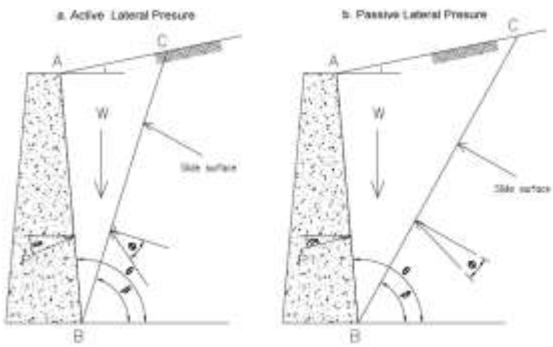
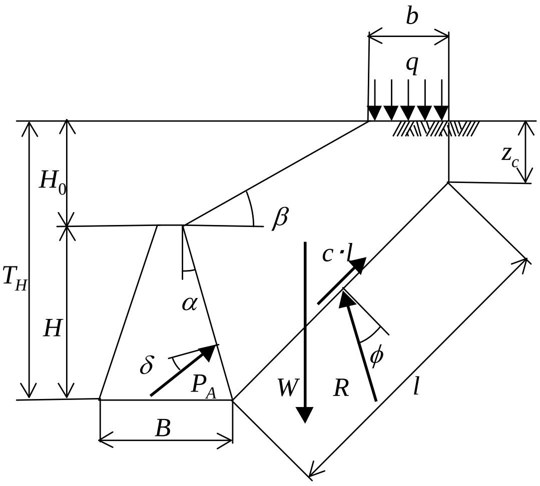


Figure 2. Coulomb's theory of earth pressure

Based on general Coloumb lateral earth pressure trial wedge theory of lateral pressure acting on a retaining wall has been developed[4].

$$P_A = \frac{W \sec\theta \sin(\omega - \phi + \theta) - cl\cos\phi}{\cos(\omega - \phi - \alpha - \delta)} \tag{2}$$

$$\theta = \tan^{-1} k_H \tag{3}$$



$$W = \frac{\gamma}{2\cos\alpha}\left\{\frac{\cos(\omega-\alpha)}{\sin\omega}T_H{}^2 - \frac{\cos(\alpha-\beta)}{\sin\beta}H_0{}^2 - \frac{\cos\alpha}{\tan\omega}z_c{}^2\right\} + \left(\frac{T_H - z_c}{\tan\omega} + H\tan\alpha - \frac{H_0}{\tan\beta}\right)q \tag{4}$$

$$l = \frac{T_H - z_c}{\sin\omega} \tag{5}$$

Figure 3. Trial Wedge Theory of lateral pressure acting on a retaining wall

In the trial wedge theory, it is considered that the state just before the retaining wall is about to be pushed down by the back ground and about to fall, two "sliding surfaces" are assumed here. One is the slip between the wall and the ground, and the other is the slip of the ground itself. However, for the latter, we do not know where the sliding surface is. It is known that the angle ω that this sliding surface makes with the horizontal plane is larger than the internal friction angle φ of the ground (as explained earlier, the ground is stable if the inclination angle is less than the internal friction angle). This will not exceed 90 degrees

Therefore, let's consider the "state immediately before starting to slide", assuming a sliding surface at an appropriate place in the upper range. What is about to slide out here is a triangular mass formed by the three sides of "wall," "slide surface of the ground," and "ground surface," as shown in the figure above. Wedge ".

Next, let's consider the balance of forces acting on each side of this mass. First of all, the mass W of the mass, which, of course, acts vertically. The reaction force *P* generated on the wall (this is the value of "earth pressure" we are seeking) acts in the direction perpendicular to the wall, so if the wall has an inclination α, it will Lean against it. Furthermore, there is a wall friction angle δ (as described previously), so the final tilt angle is α + δ.

The last is the reaction *R* from the soil on the underside of the mass. This is a force perpendicular to the sliding surface and at an angle of ω to the vertical plane, but due to the internal friction angle φ of the soil, it results in an angle of ω-φ.

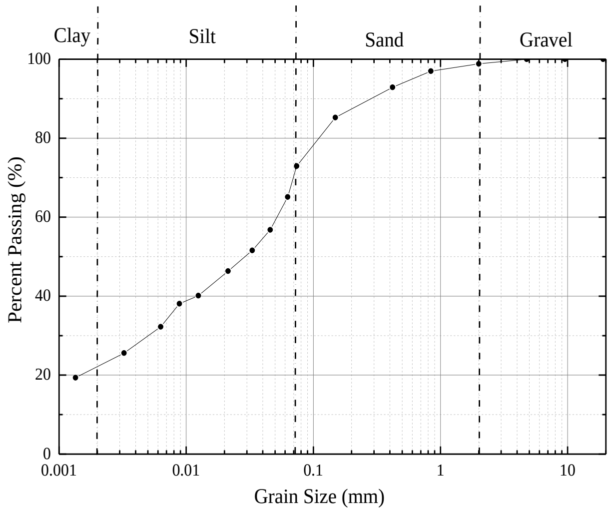
III. SOIL CHARACTERISTICS

To get the parameters land required good field testing and laboratory. Field Testing by conducting a boring and sampling test. Besides that, to find out the capacity soil support is also DCP. Subsequent soil samples were taken to laboratory for testing laboratory. Test the soil parameters conducted in the laboratory including water content, unit weight, specific gravity, consistency, grain size distribution and shear strength of soil.

Data collecting is consist of primary and secondary data collection. Primary data means data obtained from direct observation ites such as: location review and measurement with the aim of observing the situation research site, taking photos, site observations, taking samples and analysis. Secondary data means data obtained from other parties concerned with the planning done.

Table 1. Soil properties

No	Soil properties	Symbol	Value	Unit
1	Soil Unit Weight	γ_d	20	kN/m3
2	Internal firction angle	φ	35	°
3	Soil cohession	c	0	kN/m2
4	Bearing capacity	q_d	300	kN/m2
5	Pore ratio	e	2.25	
6	Porocity	n	0.54	
7	Plasticity Index	PI	15	%



GRADATION (%)			CLASSIFIED GRADING PASS (%)		
Gravel	(Retain # 10, Pass # 2)	1.16	Sieve # 10	(2.00 mm)	98.84
Sand	(Retain # 200, Pass # 10)	25.90	Sieve # 40	(0.425 mm)	91.88
Silt & Clay	(Pass # 200)	72.94	Sieve # 200	(0.074 mm)	72.94

Figure 4. Grain size distribution of site area

Table 2 Average CBR value

No	CBR From DCP (%)	Soil Classification	Road Condition
1	5.00	CL	Good
2	3.00	CH	Waevy
3	2.70	CH	Damage
4	3.00	MH	Damge

The results of physical properties of soil parameters tests in this layer are as follows: Plasticity Index 15%, moisture content 22.40%, density of soil particle 2.548 g/cm^3 and unit weight 1.609 g/cm^3. The grain size distribution analysis results in the study area shows that the gap-graded soil with no contain on D_{10}, D_{30} 0.0045 mm, and D_{60} 0.054 mm.

The results of the survey of the field conditions around the location are in arid areas and surrounded by weeds and bushes. This condition causes the water content in the subgrade is not maintained so that when there is seasonal change causes the subgrade to expand easily. Another case with the environment around the shady pavement where the conditions of balance water levels are maintained despite changes season. This factor causes there locations that have potential expansive soil.

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IV. RESULTS

The retaining wall is a structure designed and built to withstand lateral pressure (horizontal) land when there is changes in ground elevation beyond the at-rest angle in the ground[5]. The important factors in designing and build retaining walls are trying to keep the wall anchoring the ground or not moving the land is landslide due to gravity. Lateral ground pressure behind retaining wall hung to the shear angle in the ground (φ) and cohesion (c). Lateral pressure increases from the top to the very bottom on the retaining wall. If not well planned, soil pressure will push the retaining wall causing failure construction and slide.

Self-Weight Retaining Wall

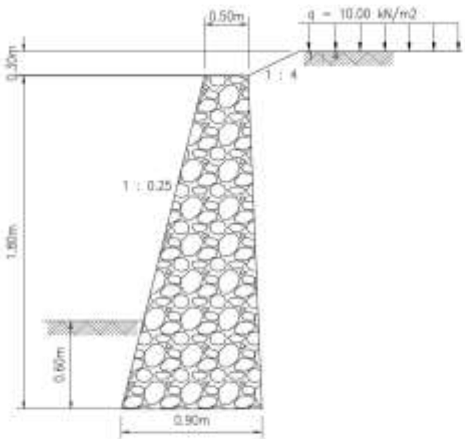


Figure 5. Dimension of retaining wall design

Based on the characteristics of the soil on the site, several designs were made taking into account safety factors. Of the three types of reinforcement The trial and error to a number of dimensional variations so SF values are obtained. Slope declared in safe condition if has a safety number of more than 1.5. The results of the analysis of the reinforcement is as follows.

(1) Self wegiht

Weight	$W_c = \frac{\gamma_c}{2}(b_u + B)H$	=	29.0	kN/m
Inertia	$H_c = W_c \cdot k_H$	=	0.0	kN/m
Gravity center	$x_c = \frac{B}{2} + \frac{H}{6} \cdot \frac{2b_u + B}{b_u + B}(n_f - n_r)$	=	0.56	m
	$y_c = \frac{H}{3} \cdot \frac{2b_u + B}{b_u + B}$	=	0.81	m

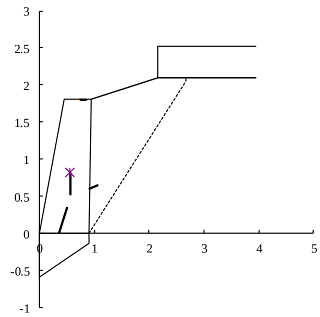
H=	1.80	m	H_0=	0.30	m
β=	14.04	°	α=	-1.59	°
γ=	24	kN/m³	φ=	29	°
c=	0.4	kN/m²	δ=	19.33	°
q=	10.00	kN/m²	θ=	0.000	°

$$z_c = \frac{2c}{\gamma}\tan\left(\frac{\pi}{4} + \frac{\varphi}{2}\right) = 0.05 \text{ m}$$

ω (°)	b (m)	l (m)	W (kN/m)	P_A (kN/m)
45	0.800	2.899	55.135	14.316
46	0.730	2.850	52.616	14.512
47	0.662	2.803	50.182	14.649
48	0.596	2.759	47.825	14.729
49	0.532	2.716	45.542	14.756
50	0.470	2.676	43.326	14.731
51	0.410	2.638	41.175	14.657
52	0.352	2.601	39.083	14.536
53	0.295	2.567	37.048	14.369

Active sliding angle	ω_A=	49	°
Total of Active Pressure	P_A=	14.76	kN/m
Vertical	P_{AV}=	4.50	kN/m
Horizontal	P_{AH}=	14.05	kN/m
Coefficient	K_A=	0.380	$(=2P_A/(\gamma H^2))$
Active Pressure Location	y_A=	0.60	m
	x_A=	0.92	m

(3) Total of Load



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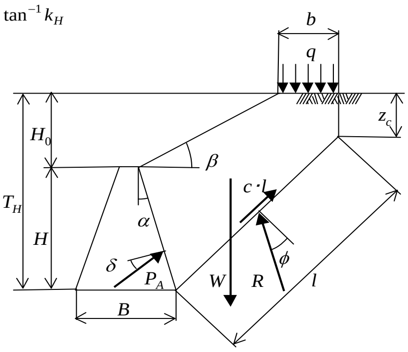
(2) Active pressure

$$P_A = \frac{W\sec\theta\sin(\omega-\phi+\theta) - cl\cos\phi}{\cos(\omega-\phi-\alpha-\delta)}$$

$$\theta = \tan^{-1} k_H$$



$$W = \frac{\gamma}{2\cos\alpha}\left\{\frac{\cos(\omega-\alpha)}{\sin\omega}T_H^{\ 2} - \frac{\cos(\alpha-\beta)}{\sin\beta}H_0^{\ 2} - \frac{\cos\alpha}{\tan\omega}z_c^{\ 2}\right\} + \left(\frac{T_H - z_c}{\tan\omega} + H\tan\alpha - \frac{H_0}{\tan\beta}\right)q$$

$$l = \frac{T_H - z_c}{\sin\omega}$$

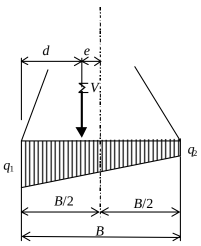
Load	V(kN/m)	H(kN/m)	x(m)	y(m)	$V\cdot x$	$H\cdot y$
Wall	29.00	0.00	0.56	0.81	16.24	0.00
Pressure	4.50	14.05	0.92	0.60	4.14	8.43
∑	33.50	14.05	–	–	20.38	8.43

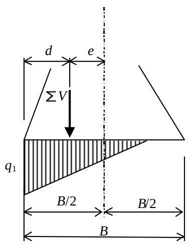
Total stress location $d = \frac{\Sigma Vx - \Sigma Hy}{\Sigma V} =$ 0.357 m

Centre of gravity $e = \frac{B}{2} - d =$ 0.093 m

Force receive by ground $q_1 =$ 60.3 kN/m² $q_2 =$ 14.1

$q_{max} =$ 60.3 kN/m²





$e \le \frac{B}{6}$

$$\left.\begin{matrix} q_1 \\ q_2 \end{matrix}\right\} = \frac{\Sigma V}{B}\left(1 \pm \frac{6e}{B}\right)$$

$e > \frac{B}{6}$

$$q_1 = \frac{2\Sigma V}{3d},\ q_2 = 0$$

(4) Analyses of Rotation resistance

Bottom width	$B=$	0.90	m	Excentricity	$e=$	0.093

Safety factor $F_t = \frac{B}{2e} =$ 4.84 > 3.00 SAFE

(5) Anlyses of sliding resistance

Vertical	$\sum V=$	33.50	kN/m
Horizontal	$\sum H=$	14.05	kN/m
Firction	μ=	0.68	

Passive Pressure

$D_f =$ 0.60 $\gamma_1 =$ 19.00 kN/m³

$\varphi_1 =$ 30.00 $c_1 =$ 0.00 kN/m²

$$K_P = \tan^2\left(\frac{\pi}{4} + \frac{\phi_1}{2}\right) = 3.00$$

$$P_P = \frac{1}{2}\gamma_1 D_f^{\ 2} K_P + 2c_1 D_f\sqrt{K_P} = 10.26 \text{ kN/m}$$

Safety factor $F_s = \frac{\Sigma V\mu + 0.5P_P}{\Sigma H} =$ 1.99 > 1.50 SAFE

(6) Bearing capacity analyses

Limit bearing capacity	$q_d=$	290.0	kN/m²
Max bearing capacity	$q_{max}=$	60	kN/m²

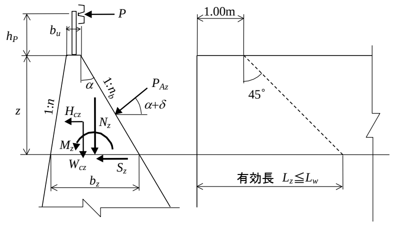
Safety factor $F_s = \frac{q_d}{q_{max}} =$ 4.81 > 3.00 SAFE

(7) Safety factor calculation results

Item	Evaluation Item	Calculation	Relation	Value	Judge
	SF	4.84	>	3.00	SAFE
Sliding	SF	1.99	>	1.50	SAFE
Bearing capacity	SF	4.81	>	3.00	SAFE

(8) Stress

Cross section



Elemnt widht based on depth from top of wall z $b_z = b_u + (n + n_b)z$

Stress based on self weight

$$W_{cz} = N_{cz} = \frac{z\gamma_c}{2}\left\{2b_u + (n+n_b)z\right\}$$

$$H_{cz} = S_{cz} = W_{cz}k_H$$

$$M_{cz} = \frac{2b_u + b_z}{b_u + b_z}\left\{\frac{zW_{cz}}{6}(n_b - n) + \frac{zH_{cz}}{3}\right\}$$

Depth from top z (m)	Thickness of element b_z (m)	Axial stress N_{cz} (kN/m)	shear force S_{cz} (kN/m)	Moment M_{cz} (kN-m/m)
0.00	0.50	0.00	0.00	0.00
0.09	0.52	1.06	0.00	-0.01
0.18	0.54	2.15	0.00	-0.03
0.27	0.56	3.29	0.00	-0.06
0.36	0.58	4.47	0.00	-0.11
0.45	0.60	5.69	0.00	-0.17
0.54	0.62	6.96	0.00	-0.25
0.63	0.64	8.26	0.00	-0.35
0.72	0.66	9.60	0.00	-0.46
0.81	0.68	10.99	0.00	-0.59
0.90	0.70	12.42	0.00	-0.73
0.99	0.72	13.89	0.00	-0.90
1.08	0.74	15.40	0.00	-1.08
1.17	0.76	16.95	0.00	-1.28
1.26	0.78	18.55	0.00	-1.50
1.35	0.80	20.18	0.00	-1.75
1.44	0.82	21.86	0.00	-2.01
1.53	0.84	23.58	0.00	-2.29
1.62	0.86	25.34	0.00	-2.60
1.71	0.88	27.14	0.00	-2.93
1.80	0.90	28.98	0.00	-3.28

V. Conclusions

Test results for soil samples on the road Rancacili-Rancasari, shows that subgrade is a loamy soil has a high plasticity on which to base AASHTO system of soil types including classification A-7-5 and A-7-6. From the results of the potential classification development based on boundary values liquid indicates that the subgrade has high development potential. For test results direct development (direct measurement) which are further classified [6] shows that the soil layer the basis for entering the classification of development potential all one. Development strain results the biggest is 13.94% while the smallest amounted to 0.17%. With development potential height becomes one of the causes of damage pavement at this location.

For retaining wall selected is a type of self-weight retaining wall for ease of manufacture. The calculation results show that the design made is resistant to duling, slides and sufficient soil carrying capacity. With a safety factor for bolsters of 3 out of a minimum of 1.5, sliding 3 of a minimum of 3 and a carrying capacity of 3 of 3 minimum required.

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