Analysis of slope stability by the planning of cantilever retaining wall reinforcement using the application of Plaxis (case study: substation Panyabungan sta 0+060)

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Abstract. Slope is a natural surface appearance that has height differences. Slope stability is very closely related to landslide or ground movement which is a natural process of soil mass displacement from higher ground to lower ground. Unstable slopes are very dangerous to the surroundings; therefore, an analysis of slope stability is highly needed. In this research, Plaxis are used to planning cantilever retaining wall reinforcement with the aim to determine the safety factor value of the slope condition before and after was given reinforcement. Slope stability was analyzed in three conditions: the original condition before reinforcement, the condition with the planning of cantilever retaining wall reinforcement. The safety factor value in the slope condition with cantilever retaining wall reinforcement was 1.567 > 1.3 (Safe). Deformation value was 453,280 x 10^-3 m. Cantilever retaining wall safety factor against gulling was 2.528 > 2 (Safe). Safety factor against shear was 2.683 > 1.5 (Safe). Safety factor against bearing capacity was 3.704 > 3 (Safe).

1. Introduction

Retaining wall is a structure that is designed and built to withstand lateral (horizontal) soil pressure when there is a change in ground elevation which exceeds the at-rest angle in the ground. A crucial factor in designing and constructing a retaining wall is to ensure that the retaining wall does not move or collapse due to gravity [1][2][3].

The ground lateral force behind the retaining wall depends on the internal friction angle of soil (φ) and cohesion (c). The lateral force increases from top to the very bottom of the retaining wall. If not planned properly, the ground pressure will push the retaining wall, causing construction failure and landslide. Failure is also caused by the groundwater behind the retaining wall that is not dissipated by the drainage. For this reason, it is very crucial for a retaining wall to have a good drainage system to reduce hydrostatic pressure and increase soil stability [4][5].

The retaining wall design using Lateral soil pressure analysis, it is a force caused by the force of soil behind the retaining wall. The value of lateral pressure is highly affected by the displacement of retaining wall and the properties of soil. Safety Factor (SF) of slope can be calculated using various methods. Safety Factor is a comparative value between restraining force and driving force. The data needed in the calculation of the safety factor of slope are [1][6]:

a. Data of slope (especially needed for the making of slope cross section) namely the angle of slope and the height of slope or the length of slope from the foot to its peak.

b. Data of soil mechanics such as internal friction angle (Ø), bulk density of soil (γ), cohesion (c) and water content (w).
2. Methodology
The Soil Investigation was carried out at the substation Panyabungan, covering the stages:
1. Cone Penetration Test (CPT) and hand boring data.
2. Laboratory data like weight dry density, weight wet density, cohesion.
3. Retaining wall data as retaining wall type, elevation of bottom, base width and retaining wall height.

This analysis was conducted to determine the slope safety factor of the original condition and of the condition with cantilever retaining wall reinforcement using Plaxis. Plaxis (Finite Element Code for Soil and Rock Analysis) is the result of a finite element program for analyzing deformation and geotechnical stabilization. In this study, plain strain modeling is commonly used for longitudinal structure modeling. The steps in calculating the safety factor on Plaxis include the following [7][8]:
1. Plaxis input, like plain strain, basic element with 15 nodes to analyze by producing accurate stresses and collapsed loads.
2. Geometry modelling
   Modelling used 2D, where the geometry obtained is soil layers and retaining walls.
   The parameters of cantilever retaining wall are as follows:
   1. $\gamma$ (specific gravity) = 24 kN/m$^3$
   2. $E$ (modulus of elasticity) = 3,028 x 107 kN/m$^2$
   3. $\nu$ (Poisson ratio) = 0,15
3. Input parameter of material

| Table 1. Soil parameter |
|-------------------------|
| **layer** | **depth (m)** | **type of soil** | **layer thickness (m)** | **MAT** | **$\gamma_{dry}$ (kN/m$^3$)** | **$\gamma_{sat}$ (kN/m$^3$)** | **Kx (m/day)** | **Ky (m/day)** | **Es (kN/m$^2$)** | **$\nu$** | **c (kN/m$^2$)** | **$\phi$** | **$\Psi$** |
| 1 | 0,00-0,80 | Organic clays & mixed soils | 0,80 | 17 | 17 | 7,77x10$^{-3}$ | 1,56x10$^{-1}$ | 5377,91 | 0,3 | 20 | 31 | 1 |
| 2 | 1,00-2,00 | Clayey-sands and silts | 1,00 | 18 | 18 | 8,64x10$^{-3}$ | 1,73x10$^{-1}$ | 14341,1 | 0,3 | 17 | 33 | 3 |
| 3 | 2,20-4,00 | Moderate sands | 1,80 | 16,42 | 16,42 | 8,64 | 1,72 | 22065 | 0,3 | 1 | 38,7 | 8,7 |
| 4 | 4,20-6,00 | Dense or cemented sands | 1,80 | 5,00 | 5,89 | 15,89 | 12,96 | 2,59 | 19613,3 | 0,3 | 1 | 38,1 | 8,1 |
| 5 | 6,20-10,00 | Moderate sands | 3,80 | 6,89 | 16,89 | 8,64 | 1,72 | 22555,3 | 0,3 | 1 | 39 | 9 |
| 6 | 10,20-11,40 | Clayey-sands and silts | 1,20 | 7,33 | 17,33 | 8,64x10$^{-3}$ | 1,73x10$^{-1}$ | 18160,7 | 0,3 | 18 | 32 | 2 |
| 7 | 11,60-13,00 | Moderate sands | 1,40 | 6,84 | 16,84 | 8,64 | 1,72 | 24026,3 | 0,3 | 1 | 40,6 | 10,6 |
| 8 | 13,20-14,20 | Dense or cemented sands | 1,00 | 7,37 | 17,37 | 12,96 | 2,59 | 26478 | 0,3 | 1 | 41,8 | 11,8 |
| 9 | 14,40-56 | Very shell sands, lime-rocks | 41,60 | 12 | 22 | 100 | 20 | 51484,9 | 0,2 | 27 | 46 | 16 |
4. General meshing

![General meshing](image)

**Figure 1.** General meshing

5. Initial condition.
   Initial condition requires a calculation of water pressure and initial water pressure.

![Initial Condition](image)

**Figure 2.** Initial Condition

6. Plaxis calculation
   The calculation phase is created automatically by the program, where the safety factor value will be obtained.

7. Plaxis output
   The output plaxis is a deformation value

3. Research results

3.1. Initial Condition of Slope
   The Plaxis calculation process in the initial condition consists of two phases; those are the slope initial condition phase and the calculation of safety factor. In this initial condition, the slope safety factor was 1.16 < 1.3 (Not Safe). The output of Plaxis was a deformation value of 216.88 x 10^{-3} m. Geometry modelling of slope is in accordance with field investigation data where evenly distributed loads equal to 10 KN / m² in accordance with SNI 8460: 2017.
3.2. Slope Condition with Cantilever Retaining Wall Reinforcement

In the planning of this cantilever retaining wall reinforcement, using SNI 8460:2017 geotechnical design requirements regulation.

![Figure 3](image_url)

**Figure 3.** Dimension Requirements for The Planning of Cantilever Retaining Wall
(Source: SNI 8460:2017)

On this slope, cantilever retaining wall with the height of 10 meters was planned.

![Figure 4](image_url)

**Figure 4.** Dimension of Cantilever Retaining Wall

This standard reinforcement used cantilever retaining wall with the height of 10 m and was constructed at the points where quite high deformation values were found in the original slope analysis. In this condition the cantilevered soil retaining wall is placed at points x = 104 m and y = 15 m. The foundation of the front at the point x = 100.5 m and y = 5 m. While the foundation of the back at the point x = 107.5 and y = 5 m. The thickness of the cantilevered retaining wall foundation is 1 m.
The result of the running of Plaxis 2D can be seen in Figure 8 below.

For the safety factor with the application of cantilever retaining wall, with Plaxis Calculation a value of 1.56 > 1.3 (safe) was obtained. The Plaxis result also showed the slope total deformation with the planning of cantilever retaining wall reinforcement value of 453.28 x 10^-3 m.
The safety factor value in the condition of slope with cantilever retaining wall reinforcement using Plaxis was 1.567. The safety factor value obtained was bigger than 1.3. This value indicated that the slope condition became safe with the use of cantilever retaining wall reinforcement. Plaxis output also produce deformation value where the total deformation value of the slope with cantilevered retaining wall retaining plan is 453.28 x 10^{-3} m.

4. Conclusion
1. The safety factor value in the initial condition of slope by Plaxis analysis was 1,19. The value showed that the slope condition was still not very stable.
2. The safety factor value in the condition of slope with cantilever retaining wall reinforcement by Plaxis was 1.57, the value showed that the slope condition became safe with the application of cantilever retaining wall reinforcement. Deformation value of 453.28 x 10^{-3} m was obtained on Plaxis.

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