Countermeasures analysis of landslide in the cikeusal village of Tasikmalaya regency

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Abstract. The construction of telecommunication towers aims to improve customer service. So that advances in the field of communication and information technology can be felt by residents who are far away in remote parts of the country. The construction of this tower must be planned as well as possible, especially for areas prone to landslides because towers are usually placed in higher areas. The landslide incident at the location of the telecommunication tower in Cikeusal Village, Tasikmalaya Regency can be used as an evaluation for other areas prone to landslides. The landslide can endanger the settlements under the tower. Field investigations are carried out as a basis for making plans to overcome landslides. The analysis was performed using Plaxis 2D software. The results of the strengthening analysis after the erosion prevention were carried out (with several stage), the factor of safety was 1.805 at section B and 3.228 at section C. The recommendations are given for landslide prevention are replacing the old retaining wall with the new one gradually, adding a column in the middle of the retaining wall, adding bored piles under the retaining wall, making drain pipe on the retaining wall to accommodate water flow from the ground surface, replacing the old stairs for access roads that were affected by landslides with new stairs and made with 2 applications so that the slope of the stairs is not too steep, as well as making a foundation for the stairs. It is hoped that the landslide occurrence and the results of the analysis of slope stability in Cikeusal Village, Tasikmalaya Regency can be used as evaluation material in the construction of telecommunication towers for landslide-prone areas.

1. Introduction
Landslides have been common in Indonesia, especially during the rainy season. Landslides are common on plateaus with steep slopes [1]. Based on InaRISK analysis, Tasikmalaya Regency, West Java Province is an area with a moderate to high hazard class category that is prone to potential flood and landslide hazards. There are 25 sub-districts in the medium to high hazard class for the potential flood hazard and 35 sub-districts in the landslide hazard [2] One of them is Cikeusal Village which is in Tanjungiaja District, Tasikmalaya Regency.

Cikeusal Village is one of the areas on the border between West Java and Central Java which has unstable soil and is prone to natural disasters. Regional conditions like this should be a concern for local governments in carrying out development and regional development. Just as there was a landslide in the telecommunication tower in Cikeusal Village. This tower was built to improve...
telecommunications services to consumers so that residents in this village area can reach the telecommunications network, especially in the digitalization era with the current pandemic condition. This incident also happened in Cisewu, Garut, West Java, and in Sukaresmi Village, Sukabumi Regency, West Java [3][4]. The type of landslide that occurred in the Cikesal area is a local landslide that can be handled more easily than other landslides. However, because of the landslide, it will still endanger the settlements of the population below it. Landslides that occurred in the Cikeusal area were caused by a layer of embankment soil at a depth of 0 to 2 meters that were not completely compacted and the occurrence of rain with high intensity for one month and the condition of the retaining wall which suffered a lot of damage. A retaining wall is a structure designed and built to withstand lateral (horizontal) earth pressure. An important factor in designing and constructing a retaining wall is to ensure that it does not move or collapse under the applied loads [5][6][7][8]. However, with the lack of friction on the retaining wall, rainwater entering the soil pores causes a decrease in soil adhesion and decreases soil shear strength. Water that enters the drainpipe is trapped in it causing the retaining wall to crack and unable to withstand its load and the moving soil load causing landslides. Therefore, urgent treatment is needed to prevent ongoing landslides. First, an investigation is carried out in the field to collect data on conditions after the landslide which will later be used as a basis for analyzing preventing landslides. The landslide that occurs can be seen in Figure 1. Then an analysis is carried out using Plaxis 2 D software with various conditions needed to obtain the required factor of safety (FOS). In general, the value of FOS ≥ 1.25 is a normal design to provide an estimate of the FOS in slope stability analysis [9]. The parameters generated in the slope stability analysis are the failure plane shape and the FOS [10].

![Landslide Area](image1.png)

2. Methods
This research was conducted in Cikeusal, Tasikmalaya, West Java, where there is a telecommunications tower was threatened by landslides. The results of the investigation activities in the field obtained conditions as below.
2.1. Field Investigation Survey

2.1.1. Condition of foundation.
The condition of the foundation in the site area cannot be seen and predicted in detail, because it needs regular checks and special analysis such as horizontality checks. Horizontality is the horizontal state of a building, used to determine the continuous shift of a building or structure. From the results of field checks and based on Figure 2 and 3, the horizontality results for each pedestal can be explained in Table 1.

![Figure 2. Horizontally Tower](image1)

![Figure 3. Horizontally Tower Position](image2)

| Reference Point | Elevation (mm) | Difference (mm) |
|-----------------|----------------|-----------------|
| A               | 0              | 0               |
| B               | 270            | +270            |
| C               | 0              | +0              |
| D               | 370            | +370            |

2.1.2. Condition fence and access road.
The condition of the fence in the site area was partially damaged in the area affected by the landslide, the damage to the fence was caused by the damage to the retaining wall because the fence was supported directly on the retaining wall. The condition of the access road at the site is partially damaged, namely the steep descent of the stairs caused by a landslide at the site (Figures 4 and 5).
Figure 4. Condition of access road after a landslide

Figure 5. The condition of the fence after the landslide

2.1.3. Condition of retaining wall
Based on the results of the survey, the condition of the retaining wall with little difficulty causes rainwater that enters the ground to become groundwater pressure which imposes a burden on the retaining wall. Meanwhile, soil that is exposed to rainwater causes the adhesion between the soil to decrease and the soil moves to impose a retaining wall. The dimensions of the retaining wall are not able to withstand moving soil loads and withstand groundwater pressure, resulting in a landslide in the fenced area as shown in Figure 6.

Figure 6. Condition of Retaining wall after Landslide
2.2. Slope Stability Reinforcement Analysis with Plaxis 2D

There are several stages for planning and countermeasures for landslides by applying several reinforcements. The first stage is replacing the existing retaining wall with a new retaining wall. The implementation of the work is to gradually remove the old retaining wall within 2.4 m to be replaced with a new retaining wall. The second stage with adding columns in the middle of the retaining wall to withstand the load so that those above it do not directly burden the retaining wall. The purpose adding piles under the retaining wall to withstand all forces on the retaining wall.

2.2.1. Material modelling.

The behavior of soil and rock under load is generally non-linear. This behavior can be modeled with various equations including the Mohr-Coulomb model, Hardening Soil Model, Soft Soil Model, and Soft Soil Creep Model. In this analysis, the Mohr-Coulomb model is used which requires 5 parameters, namely Cohesion (c), Shear Strength (ϕ), Modulus Young (E_ref), Poisson’s Ratio (ν), Dry unit weight (γ_dry), and Saturated unit weight (γ_sat).

| Parameter                          | Layer 1                  | Layer 2                  | Layer 3                  | Retaining wall       | Units   |
|-----------------------------------|--------------------------|--------------------------|--------------------------|----------------------|---------|
| Model Material                    | Mohr-Coulomb             | Mohr-Coulomb             | Mohr-Coulomb             | Elastik Plastis      | -       |
| Type Material Behavior            | Type Undrained           | Type Undrained           | Type Undrained           | Type Non-Porous      | -       |
| Saturated unit weight of Soil     | γ_unsat                  | 16.33                    | 17.5                     | 21                   | 23.5 kN/m^3 |
| above the Phreatic Line           |                          |                          |                          |                      |         |
| Saturated unit weight of Soil     | γ_sat                    | 18                       | 19                       | 22                   | 23.5 kN/m^3 |
| below the Phreatic Line           |                          |                          |                          |                      |         |
| Horizontal Permeability           | k_x                      | 0.00864                  | 0.00864                  | 0.00864              | - m/day  |
| Vertical Permeability             | k_y                      | 0.00864                  | 0.00864                  | 0.00864              | - m/day  |
| Young's modulus (constant)        | E_ref                    | 1400                     | 3000                     | 6750                 | 20,000.000 kN/m^2 |
| Poisson’s ratio                   | ν                        | 0.3                      | 0.3                      | 0.3                  | 0.15    |
| Cohesion                          | c_ref                    | 11.2                     | 24                       | 54                   | kN/m^2  |
| Friction                          | ϕ                        | 32                       | 54                       | 40.937               | °       |
| Dilatancy angle                   | ψ                        | 0                        | 0                        | 0                    | °       |

The cohesion value (c) and internal friction angle (ϕ) are obtained from the results of the Direct Shear soil test from laboratory analysis. Because the soil element has been deformed well past the
peak stress, so the remaining stress is the residual stress. In this case, the representative shear strength is the residual shear strength. Young's modulus ($E_{ref}$) is obtained from testing the triaxial law method, for the preliminary design it can be used $E_{ref} = 2 to 8q_c$ [11]. Poisson’s ratio value for clay is in the range 0.3 - 0.4 [12]. Using the Mohr-Coulomb model Poisson's ratio value is taken as 0.3. The value of the dilatancy angle ($\phi$) = 0°, for the shear angle depends on the type of soil layer in Table 2, an explanation of the soil parameters is given.

2.2.2. Model and simulation.

Figure 7. General Layout
The modeling is carried out using cross-sectional data (section profile) of slopes with reinforcement in the form of retaining walls. Figure 7 shows general layout of the location of the telecommunication tower. An overview of the design model for slope stability reinforcement with retaining walls and bored piles can be shown in Figure 8 and Figure 9, where the analysis is carried out in section B and section c as the impact of the landslide. The soil layer is modeled into 3 soil layers.

![Figure 8. B-section Contour Design in Conditions after Landslide](image)

![Figure 9. C-section Contour Design in Conditions After Landslide](image)

2.2.3. Slope Stability Analysis on Plaxis.
After the general description of the control for the existing condition and reinforcement has been completed, the next step is to enter the required soil parameters in the analysis as shown in Table 2 and Table 3 as well as in Figure 8 and Figure 9.

### Table 3. Material Design Parameters in Landslide Simulation

| Parameter         | Symbol | Pile | Units     |
|-------------------|--------|------|-----------|
| Modulus of Elasticity | E      | 22.000.000 | kN/m²     |
| Diameter          | d      | 0.3  | m         |
| Pile length       | L      | 3    | m         |

2.2.4. Calculation input.
Slope formation material parameters, FOS calculation, and slope failure interpretation are the three main components of the slope stability study. [13]. The calculation stages are divided into four stages:

a. The initial phase is the default of the program (phase 0)
b. The gravity loading stage is the phase where the initial stress and strain due to the soil load itself and external loads are calculated (phase 1)
c. The multiplier stage will be selected after pressing the Define button. At this stage, there are many levels of variation.
d. The calculation phase of the factor of safety (FOS), which is the phase where the slope stability due to phases 1 and 2 is calculated.

Plaxis calculation for the 3 phases can be seen in Figure 10.
3. Results and discussion

The first before in slope stability analysis, there are three important aspects to consider. The first concerns the slope-forming substance's material qualities. The second step is to calculate the factor of safety, and the third step is to define the slope failure definitions [13]. According to [5], FOS more than 1.25 is considered a rare landslide. Slopes with a lower safety factor have a higher risk of failure than slopes with a higher FOS [14].

3.1. Slope Stability Analysis Results with Plaxis

Retaining walls on slopes receive loads from the outside, namely tower loads, fence loads that support directly on the retaining wall, and soil loads that move to push the retaining wall. The input value of the load is 60 kN/m² as uniform load showed by blue arrow in downward direction in figure 11.a.
In Figures 11 and 12 the largest ground motion occurs in the built tower area. This can occur due to the high intensity of rain that affects the soil load and the condition of the dimensions of the retaining wall which is not able to withstand the load and the lack of difficulty in the retaining wall which causes an increase in load water pressure on the retaining wall. Figures 11.b and 12.b show the slipping zone's area potential, as well as the total regional displacement. At the reinforcement analysis stage, the slope FOS value for section B is 1.805, which is greater than the required 1.25 (Figure 11.c), while for section C, it is 3.228 (Figure 12.c). The function of the retaining wall is to withstand the earth pressure load in the tower area. While the function of the bored pile is to withstand the load transferred from the fence load and the retaining wall load. With conditions like the above, the condition of the slopes with reinforcement is in a safe condition.

Based on the results of the analysis, obtained FOS from strengthening condition at section B is 1,805 and at section C is 3,288. This value is greater than the minimum required slope stability FOS (1,25). As a result, the safety condition at the slope's foot, could be achieved [5], [15]. In planning for reinforcement using retaining walls, a drainpipe is also needed on the retaining wall to accommodate the flow of water from the ground so that it does not enter the retaining wall and reduce the quality. The last stage with replacing the existing stairs for access roads that were affected by landslides with new stairs with dimensions of 30x20 cm steps with 2 stair traps made so that the slope of the stairs is not too steep, the stairs foundation is made in the form of columns and portals at the top of the stairs close to site area.
Figure 12. (a) Displacement Strengthening Condition Section C, (b) Condition of failure, (c) FOS Strengthening

4. Conclusion
Based on slope stability analysis using Plaxis 2D software, several recommendations are given to prevent landslides. The recommendations include making a new retaining wall, adding a column in the middle of the retaining wall, making a drainpipe on the retaining wall, adding bored piles under the retaining wall, and replacing the existing stairs as an access road to the tower. These measures have the potential to strengthen the slope, with safety factor value more than 1.25. As a result, the safe condition could be achieved. To improve this research, it is necessary to carry out further analysis related to the effect of soil stability on extreme groundwater level conditions. So that it can be more anticipated during the heavy rainy season.
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References
[1] Abidin H, Andreas H, Surono M, and Hendrasto M 2004 On the Use of GPS Survey Method for Studying Land Displacements on the Landslide Prone Areas 1–13
[2] BNPB Sejumlah Kerusakan Fisik Saat Banjir dan Longsor Terjang Tasikmalaya,” https://bnpb.go.id/berita/sejumlah-kerusakan-fisik-saat-banjir-dan-longSOR-terjang-tasikmalaya.-
[3] Salimah A, Ammar M, Rahmawati D, Yelvi, and S.Widya S T 2020 Landslide Analysis Study and Cisewu Countermeasures in District, Garut Regency, West Java in IOP Conference Series: Materials Science and Engineering 771, 1
[4] Salimah A, Hasan M F R, Suripto S, Yelvi Y, and Sasongko I H 2019 Analisis Stabilitas Dan Perkuatan Lereng Menggunakan Plaxis2D Di Desa Sukaresmi Sukabumi, Jawa Barat Jukung (Jurnal Tek. Lingkungan) 5 2 29–36
[5] Bowles J 1979 Physical and Geotechnical Properties of Soils (Tokyo: McGraw-Hill)
[6] D B M and S K 2014 Principle of Geotechnical Engineering
[7] Hardiyatmo H C 2002 Teknik Fondasi I (Yogyakarta: Beta Offset)
[8] Hastuty I P and Prambudi R 2020 Analysis of slope stability by the planning of cantilever retaining wall reinforcement using the application of Plaxis (case study: Substation Panyabungan sta 0+060) IOP Conf. Ser. Mater. Sci. Eng. 851 1 0–6, 2020.
[9] Ramadhan R, Munirwansyah M, and Sungkar M 2019 Faktor Keamanan Stabilitas Lereng pada Kondisi Eksisting dan Setelah Diperkuat Dinding Penahan Tanah Tipe Counterfort dengan Program Plaxis Reka Buana J. Ilm. Tek. Sipil dan Tek. Kim 5 1 1
[10] Zheng H, Liu D F, and Li C G 2005 Slope stability analysis based on elasto-plastic finite element method Int. J. Numer. Methods Eng 64 14 1871–1888
[11] kézdí A 1974 Handbook of Soil Mechanics (Amsterdam: Elsevier Pub. Co)
[12] Marchenko, Mosicheva I, and Aniskin A 2018 Estimation of Poisson’s ratio of soil using stiffness of loose soils
[13] Rocscience Inc 2001 Application of the Finite Element Method to Slope Stability no.1
[14] Mohammadinia A, Arulrajah A, Haghhighi H, and Horpibulsuk S 2017 Effect of lime stabilization on the mechanical and micro-scale properties of recycled demolition materials Sustain. Cities Soc 30 58–65
[15] Tsuchida T, Athapaththu A. M. R. G, Kawabata S, Kano S, Hanaoka T, and Yuri A 2014 “Individual landslide hazard assessment of natural valleys and slopes based on geotechnical investigation and analysis,” Soils Found 54 4 806–819