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Research Paper

Slope Reinforcement using X Type Block in Precipitation

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ABSTRACT

This study was applied research by using experimental method to determine the effectiveness of slope type reinforcement block X on slopes with rainfall (precipitation). The output data of was the amount of deformation on the slopes and the ratio of the deformation of slope reinforcement. Based on the results of the study, the slopes loaded without reinforced with block X with the provision of rainfall experienced a collapse in 28 minutes. The deformations occurred just before the failure occurred were vertical deformation of 8 mm and horizontal deformation of 10 mm. Afterwards, the slopes with block X type 1 reinforcement after being loaded for 24 hours, has remained no collapse. The deformations occurred are (1) vertical deformation of 8 mm and (2) 10 mm of horizontal deformation

1. Introduction

Slope is the surface of the earth which forms a certain angle of inclination with the horizontal plane. Slopes can be formed naturally due to geological processes; or because they are made by humans. Slopes that are formed naturally include hillsides and river cliffs, while man-made slopes include excavations and embankments for roads and railways, dams, river embankments and canals and open-pit mines. A landslide is the collapse of a soil mass located on a slope, so that the movement of the soil mass occurs downwards and outwards. Avalanches can occur in various ways slowly or sudden; and with or without visible signs.

Slope stability analysis should be based on accurate models of subsurface material condition, groundwater condition and possible loadings on the slope. Without an adequate geological model, the analysis can only be carried out using a rough approximation. Therefore, the usefulness of the analysis results can be questioned. The behaviour of soil structure is greatly dependent on the characteristics of the soil both under and surrounding. In the 1990s, the analysis of the design of various types of earthworks was based on a deterministic model analysis. Even though the approach has been widely used. In fact, almost the soil properties are highly variable and the possibility of being homogeneous is extremely rare (Listyawan, 2006). The concept of analysis with a probability approach is the latest solution to overcome inaccuracy of the deterministic model.

Slope reinforcement or ‘retaining wall’ is a building that functions to stabilize certain soil conditions generally installed on unstable cliff areas. The retained soil or granular material pushes against the wall and tends to

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make the wall roll and slide. This is caused by 3 (three) forces acting on the retaining wall, which must remain in equilibrium, namely gravity load from the retaining wall or additional weight, lateral pressure from the ground, and soil bearing capacity.

The stresses in the structure must be within the permissible values and the loads must be carried properly so that excessive settlement does not occur. One of the alternative designs for slope reinforcement is the use of retaining walls.

A retaining wall is a building built to prevent material from sliding according to its natural slope where its stability is influenced by topographical conditions. As if an earthwork is done, such as embankment or earth cutting, especially when the road is built bordering a river or lake, the retaining construction is built to protect the slope of the soil and complement the slope with a solid foundation. In addition, retaining walls are also used to withstand soil piles and pressures due to other loads, such as uniform loads, line loads, water pressure, and earthquake loads.

2. Literature Review

2.1 Slope Stability

Soil tends to move downward on non-horizontal ground. This ground movement is caused by gravity. If the weight component of the soil affected by the gravity is too large, where its shear resistance capability is exceeded, a slope failure will occur. The strength of the soil's resistance to the forces is called 'stability'. Therefore, the ability of the soil to resist horizontal forces against the forces is called 'slope stability' (Hardiyatmo, 2003).

Analysing slope stability is not an easy agenda. In the analysis, there are many influencing factors. These factors include the condition of the soil in layers, the shear strength of the soil, the flow of water seepage in the soil, and other factors. According to Terzaghi (1950), the causes of slope failure are divided into two, namely due to natural influences (internal effects) and external influences (external effects). The internal influence is a landslide that occurs without any change in external conditions or an earthquake. A common example of this condition is the effect of increasing pore water pressure in the slope. Meanwhile, the external influence is the effect that causes an increase in the shear force without any change in the shear strength. Common examples of this condition are human efforts to sharpen cliff slopes or deepen soil excavation, and river erosion (Hardiyatmo, 2003).

Fig. 1. Soil Compaction and Slope Construction

2.2 Slope Failure

Evaluating the stability of the slope is relatively important. Nowadays, slope stability increases along with the number of cases of slope failure. Various observations made on slope behavior that are often accompanied by slope failure, have led to the development of changes in soil parameters over time.

In determining various cases of slope failure, it must be started by considering the fundamental requirements in slope stability. The fundamental requirement is that the shear strength of the soil must be greater than the shear stress acting on the slope. Therefore, the occurrence of slope failure is caused by two conditions, namely: The reduced shear strength of the soil on the slope and the increase of the shear stress acting on the soil to reach equilibrium (Duncan et al., 2014).

2.3 Effect of Precipitation on Landslides

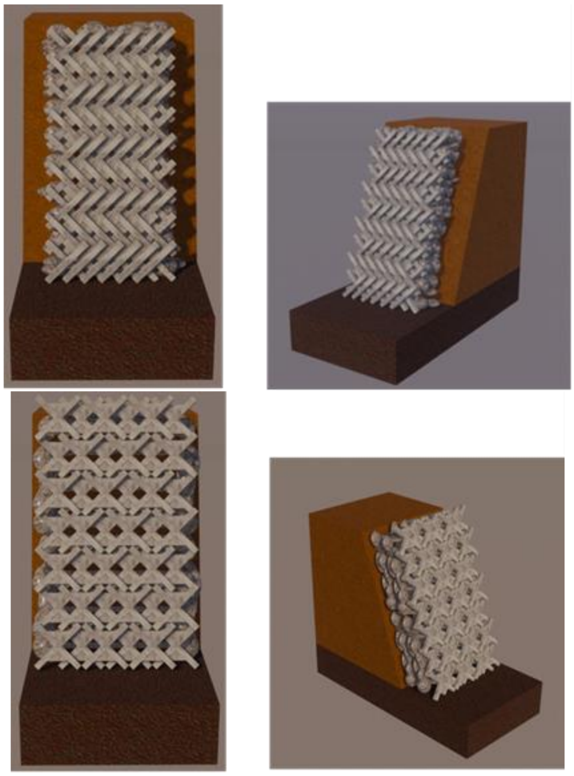

Fig. 2. Installation Scheme of Blocks X Type 1 and 2

Landslides on slopes are very common during long periods and high intensity of rain. The possibility of landslides is greater in some areas that have a tendency of high rainfall, steep slopes, and have fine-grained soil. This slide is common in the tropics.

Rain that falls to the ground has large kinetic energy to destroy soil particles and can make soil condition remains unstable. The amount of rainfall determines the strength of the dispersion, the carrying capacity, and the damage to the soil. When rain falls on a plot of land, the rain will partially infiltrate into the soil until the soil condition is saturated. Soil erosion by water occurs when the soil is saturated, making it difficult to infiltrate. Then, the water flows over the surface and transports the soil particles. Somehow, soil erosion is the movement of soil grains by wind or water (Sitepu, 2017).

3. Materials and Methods

3.1 Slope Making

In this study, before the slope was formed, the subgrade was made as a layer of hard soil. Hard soil was made from soil that had been removed without mixed with sand. Hard soil was made by static compaction to a height of 20 cm. After the subgrade was formed, slopes were made using soil that had been mixed with sand with a predetermined composition. The slope was made with a height of 80 cm from the subgrade and a slope of 70o. The water content used was on the dry side based on the results of the compaction test as many as 14.3% with a soil density of 1.21 gr/cm^3. Illustrations of soil compaction and slope formation could be seen in Fig. 1.

Fig. 3. Load Testing Equipment with Precipitation

3.2 Reinforcement Blocks and Testing Instruments

After the slope was formed, the reinforcement block was installed. The installation system of the reinforcement blocks of types 1-2 was similar. Reinforcement blocks were arranged sideways, and the block legs were stacked on top of each other so that the installed blocks supported each other to form reinforcement.

During the process of installing the reinforcement blocks, crushed stone was also inserted into the cavities that were formed. Crushed stone served as a slope coating, retaining block reinforcement, and filling voids between blocks. In both types of reinforcement blocks, the blocks were installed as many as 6 pieces per row and stacked up until the slope surface was covered. The installation system of X type 1 and type 2 reinforcement blocks was depicted in three-dimensional modeling (Fig 2).

After the reinforcement system using the block was installed, then the next step was to install test support tools and data reading instruments during the test. The Schematic of slopes, reinforcement, and instruments that were ready for the next test could be seen in Fig. 3.

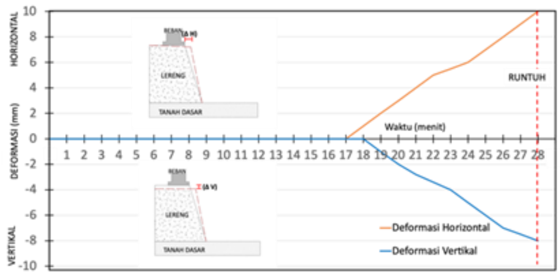

Fig. 4. Magnitude of the deformation of the unreinforced slope based on time to fail

3.3 Slope Reinforcement Ratio

The slope reinforcement deformation ratio was the ratio between the deformation that occurs on the slopes that have been given type 1 X block reinforcement, and the deformations that have been given X type 2 block reinforcement. The slope reinforcement deformation ratio should be able to see the effectiveness of each type of reinforcement block. In this study, the deformation ratio was the Vertical Deformation Ratio (R_V) and Horizontal Deformation Ratio (R_H).

The slope reinforcement deformation ratio () was obtained by the formula in Equation (2) as follows: $R\partial$

$$R\partial = \frac{Deformation\ of\ the\ slope\ using\ the\ type\ 1\ X\ block}{Deformation\ of\ the\ slope\ using\ the\ type\ 2\ X\ block}$$

where,

R∂ = Slope Reinforcement Deformation Ratio
R∂V = Vertical Deformation Ratio
R∂H = Horizontal Deformation Ratio
∂V1 = Slope Vertical Deformation with Block X Type 1
∂V2 = Slope Vertical Deformation with Block X Type 2
∂H1 = Horizontal Slope Deformation with Block X Type 1

4. Results and Discussion

4.1 Loading Test with Precipitation

The loading test was carried out on the slopes that had been formed. The loading test was carried out in three stages.

The first stage of testing was carried out without using a reinforcement block. This test was conducted to determine the behavior of the slopes when loaded under conditions of precipitation. The results of the first testing were used as a comparison for the second and the third testing.

The second testing was carried out using type 1 block X reinforcement. The second testing was carried out using type 2 block X reinforcement. The results of the second and the third testing were used to determine the effectiveness of each type of reinforcement block.

During the tests, an approach was used using independent variables, dependent variables, and control variables. In this test, the independent variable was the installation of X block reinforcement type 1, type 2, and without block installation, while the dependent variable was the slope behavior in the form of deformation and the time taken for deformation to occur. The control variables in this test were burden, rainfall intensity, and slope.

4.1.1 Unreinforced Slope Loading Test

Unreinforced slope loading tests were carried out during the time the slope collapsed. The output data generated from the first testing was the time it takes for a landslide to occur, the width of the avalanche, and the depth of the avalanche.

The loading time required for the slope to slide was 28 minutes. The rain continued during the test period with an intensity of 29.7 mm/hour. In addition, the vertical movement of the slope surface began to occur in the 18th minute as the maximum slope reduction before finally experiencing a landslide of 8 mm. The horizontal movement of the lip of the slope began to occur in the 17th minute, thus maximum horizontal movement of the lip of the slope before a landslide of 10 mm occurred.

4.1.2 Slope Loading Test with Block X Type 1 Reinforcement

At this stage, the formed slopes were given reinforcement using block X type 1. The output data generated from the testing was the amount of deformation that occurred on the slope and the time it needed for a certain deformation to occur.

At this stage, the loading was carried out for 24 hours. During the loading, the rain continued to be carried out with an intensity of rainfall of 29.7 mm/hour. The horizontal deformation begins to occur after loaded and rained for 16 hours. To the end of the test, the horizontal deformation that occurred was 5 mm. Horizontal deformation occurred after loaded and rained for 14 hours. To the end of the test, the vertical deformation was 7 mm (Fig. 5).

4.1.3 Slope Loading Test with Block X Type 2 Reinforcement

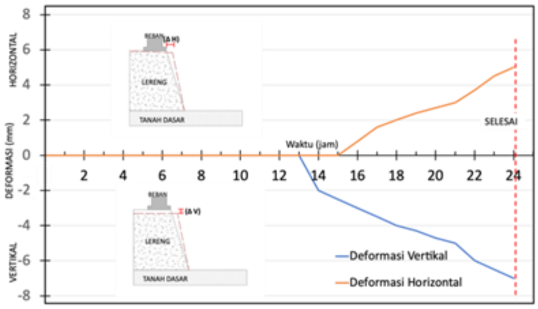

Fig. 5. Deformation against time on slope with block X type 1 reinforcement

In this test, the slopes were given reinforcement using block X type 2. The output data generated from the testing was the amount of deformation on the slope and the time it had taken for a certain deformation to occur.

At this stage, the loading was carried out for 24 hours. During the loading, the rain continued with an intensity of rainfall of 29.7 mm/hour. The horizontal deformation began to occur after loaded and rained for 18 hours. To the end of the test, the horizontal deformation was 5 mm. Horizontal deformation began to occur after loaded and rained for 14 hours. To the end of the test, the vertical deformation was 8 mm (Fig. 6).

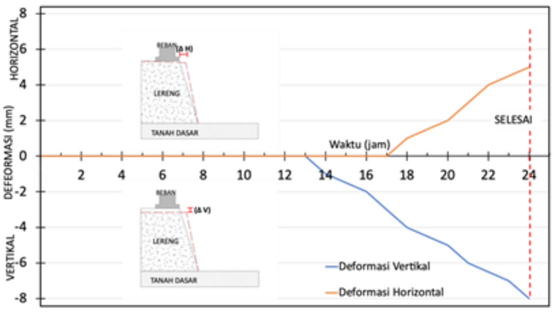

Fig. 6. Deformation against time on slope with block X type 2 reinforcement

4.2 Slope Reinforcement Deformation Ratio

After the test was completed, the deformation values of the unreinforced slopes, the slopes with the reinforcement of block X type 1, and the slopes with the reinforcement of block X type 2 were obtained. The output data of this deformation value was used to calculate the deformation ratio value of the reinforced slope for each reinforcement block X.

4.2.1 Ratio of Slope Reinforcement Vertical Deformation

The vertical slope deformation ratio was obtained by comparing the vertical deformation of the slope reinforced slope block X type 1 with the slope reinforced block X type 2. The ratio of the vertical deformation of the slope reinforced slope to time was shown in Fig. 7.

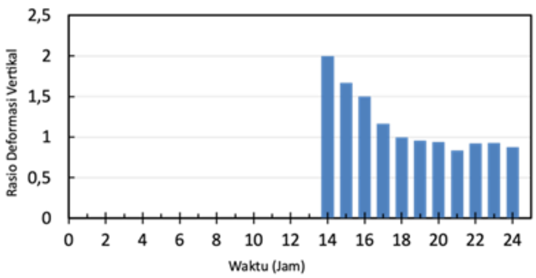

Fig. 7. Slope reinforcement vertical deformation ratio diagram between block X types 1 and type 2

The figure indicated that the deformation started from the 14th hour. From the 14th - 17th hour, the deformation on the slopes with type 1 block X reinforcement was larger. After the 18th hour, the deformation that occurred on the slopes with X type 1 block reinforcement was smaller, and it happened until the test was completed for 24 hours.

4.2.2 Ratio of Slope Reinforcement Horizontal Deformation

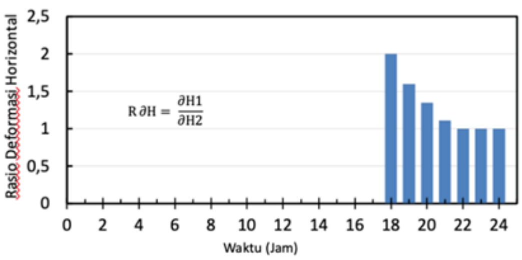

Fig. 8. Horizontal deformation ratio diagram of slope reinforcement between type 1 and type 2 X blocks

The vertical slope deformation ratio was obtained by comparing the horizontal deformation of the slope reinforced slope block X type 1 with the slope reinforced slope block X type 2. The ratio of the horizontal deformation of the reinforced slope to time was shown in Fig 8.

Based on the figure, the deformation started from the 18th hour to the 21st hour. This indicated that the deformation on the slope with the reinforcement of X type 1 block was larger. After the 21st hour, the deformation that occurred on the slopes with X block type 1 reinforcement was the same as on the slopes with X block type 2 reinforcement. This happened until the test was completed for 24 hours.

5. Conclusions and Recommendations

The landslide occurred after 28 minutes. In testing the load on the slopes with block X type 1 reinforcement with precipitation, there was deformation on the slope surface without landslides. After loaded for 24 hours, the horizontal deformation was 5 mm, while the vertical deformation was 7 mm. In testing the loading on the slopes with block X type 2 reinforcement with precipitation, there was deformation on the slope surface without landslides. In addition, after loaded for 24 hours, the horizontal deformation was 5 mm and the vertical deformation was 8 mm.

The value of the slope reinforcement deformation ratio obtained from the slope loading test by giving rainfall (precipitation) after 24 hours showed that the value obtained at the beginning of the deformation was more than one; and less than one at the end of the test, so that the value of the slope reinforcement system in block X type 1 was more effective in resisting vertical deformation. Furthermore, the value obtained at the beginning of the deformation was more than one; and the value was equal at the end of the test (R∂V R∂H R∂H).

Further research needed to do with a larger scale approaching the field scale, especially on the mechanical properties of slope soil after loading, such as shear strength. Besides, we suggested further research to study variations in block installation schemes and the number of blocks used to obtain the most effective and efficient results as well as to analyze the slope stability and strength of the reinforcement block.

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