Effect of vertical distance of geogrid layers on slope stability

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Abstract. The landslide that occurred on the Meulaboh - Geumpang road section on May 10, 2017, resulted in the interruption of land transportation connecting West Aceh Regency and Pidie Regency, Aceh Province. The landslide on this road had an impact on the obstruction of logistics distribution and other needs from the direction of Meulaboh to Geumpang and vice versa. Based on these problems, the appropriate solution is needed in the prevention and planning of slopes to prevent landslides from happening again. This research was carried out by analyzing the slope stability under natural slope conditions and analyzing the slope stability of the conditions given slope reinforcement in the form of geogrids. Slope stability analysis is performed using the finite element method. The slopes are given alternative geogrid reinforcement with varying vertical distances. The variation of vertical geogrid distance is adjusted to the condition of the curve of the natural slope collapse before reinforcement. Based on the analysis of slope stability for natural conditions without reinforcement (existing condition), the safety factor values (SF) obtained at STA 84 + 280 and STA 84 + 910 were respectively 1.14 and 1.16. The results of the analysis of the slope stability that has been given reinforcement show that the vertical geogrid distance influences the slope safety factor.

1. Introduction

Indonesia has diverse geological and geomorphological structure conditions. One of the various structural conditions is the existence of a slope. Slopes can occur naturally or be formed by humans with a specific purpose. If the surface forms a slope, then the soil mass component above the slip plane tends to move downward due to gravity. If the gravity component is large enough, then it can cause landslides on the slope [1].

Landslides in Aceh have been occurring very often, especially on provincial roads. Like a landslide (figure 1) that occurred on Wednesday (10/5/2017) night around 04:00 GMT. It caused Meulaboh-Geumpang transportation links on Thursday (11/5/2017) to be totally paralyzed. Meulaboh-Geumpang Street is a road that connects West Aceh Regency with Pidie Regency. This road is used by residents to transport staples or vegetables from Pidie Regency to West Aceh Regency, and vice versa.

Based on these problems, it is necessary to find the right solution in handling slides due to unstable slope conditions. The research location is on Meulaboh - Geumpang street, namely STA 84 + 280 and STA 84 + 910, which are located in Lancong Village, Sungai Mas District, West Aceh Regency. The handling of landslides is done by strengthening the slopes using geogrid.
In line with the increasing use of slopes for various human interests, it is necessary to develop the concept of slope stability which aims to overcome the problem of slope collapse. An understanding of the factors associated with slope collapse, slope analysis, and selection of effective slope strengthening methods is needed to achieve this goal.

The stability of slopes should be very thoroughly analyzed since their failure may lead to loss of human life as well as colossal economic loss. The failure of a mass of soil located beneath a slope is called a slide [2]. The aims of slope stability [3] are:

- To understand the development and form of natural slopes and processes that occur in different natural conditions;
- To assess slope stability in short-term and long-term conditions;
- To assess the possibility of natural slopes and artificial slopes;
- To analyze and to understand the mechanism of collapse and the factors that cause it.

The value of safety factor $\geq 1.25$ is a normal design to provide an estimate of the safety factor in the slope stability analysis. This is important to ensure that the slope design is safe and to prevent unexpected factors during analysis and construction such as incorrect data, analysis errors, work skills, and the lack of field supervision [4].

The slope stability analysis at this location was analyzed by using Finite Element Method [5], which the calculation process is faster and more efficient. The slope at this location is the artificial slope. The slope stability analyses give the output of safety factor at STA 84 + 280 and STA 84 + 910, which respectively is 1.14 and 1.16. These safety factors are less than 1.25; it means the slope unstable. So, the geogrid is used as the reinforcement.

Geogrids [1] can be used to strengthen slopes with sharp or steep slopes. The use of geogrids as a retaining wall is a development of the concept of reinforced earth discovered by Vidal in France in the mid-1960s. Reinforced earth walls with reinforced soil systems are a soil reinforcement system using metal strips with enclosure elements from panels - concrete or steel panels. Geogrid stress transfer mechanism involves two components, namely horizontal ground friction on the surface of the grid and passive resistance or called horizontal ground support to the transverse grid. An example of a geogrid is shown in figure 2.

Holes between the ribs in geogrids allow soil and rock aggregates to enter and create high friction resistance. Polymer geogrids have been used in the construction of walls with sharp, and even vertical slopes such as abutments.

The variation of vertical geogrid distance is adjusted to the condition of the curve of the natural slope collapse before reinforcement. The vertical distances of geogrid layers are 0.2m, 0.4m, and 0.6m. The results of the analysis of the slope stability that has been given reinforcement show that the vertical geogrid distance influences the slope safety factor.
2. Methodology
There are two locations in this study, Km 84 + 280 and Km 84 + 910. The coordinates of the study location are shown in the following table 1.

| Point | STA   | Coordinate                      |
|-------|-------|---------------------------------|
| A     | 84 +280 | N 4 30 39.6828 - E 96 7 46.5852 |
| B     | 84+910  | N 4 30 37.9692 - E 96 7 48.6052 |

2.1. Preparation
The preparation stages are a series of activities, before the starting data collection and the processing, which include:
- Literature study of existing problems;
- Determining data requirements;
- Direct survey to the research location to find out the conditions in the field and the initial data collection needed.

2.2. Collecting data
The data in this study consisted of primary data and secondary data. Primary data includes measurements of slope geometry, location coordinates, documentation, data from soil sample testing in the laboratory, and modeling of slope conditions. Whereas the secondary data needed is the map of West Aceh Regency, map of research location points, parameter of Young modulus value, permeability, and Poisson ratio.

2.3. Soil sampling
Soil sampling for this study was carried out by the Pit Test Method. Pit Test Method is a soil investigation by manually digging the soil to the desired depth, then taking samples using a steel tube as an undisturbed sample. The samples were three samples at each research location. Samples consisted of disturbed and undisturbed soils on the Meulaboh-Geumpang Road STA 84 + 280 and STA 84 + 910.

2.4. Slope stability analysis
Slope stability analysis has three stages: the data input, the calculation, and the data output. Slope stability was analyzed using Finite Element Method which requires the slope modeling that suitable with the existing data to obtain accurate results. The existing slope geometry in the Meulaboh-Geumpang Road Section Km 84, at the point of view, can be seen in figure 3 below.
The soil parameters used as input in Finite Element Method were obtained from the laboratory testing and the literature. The parameters obtained from laboratory testing are:
- Wet volume weight ($\gamma_b$);
- Dry volume weight ($\gamma_d$);
- Cohesion (c); and
- Friction angle ($\phi$).

Parameters obtained from literature sources are:
- Dilatancy angle ($\Psi$);
- Young Modulus (E);
- Poisson ratio ($\nu$);
- Permeability (k).

The research method, which is carried out in the study of the use of geogrids as slope reinforcement, can be seen in the research flowchart in figure 4.

3. Results and discussion
Slope stability analysis is carried out for existing- and reinforced slopes. Table 2 shows the results of the analysis conducted for the existing slope. Table 3 shows the results of the reinforcement analysis with variations in the thickness of the geogrid layer.

| No. | STA (Km) | Safety Factors |
|-----|----------|----------------|
| 1   | 84+280   | 1.14           |
| 2   | 84+910   | 1.16           |

Table 2 shows that the safety factor is less than 2.5. It means that the existing slope for both points of study location is unstable and even landslides occurred at that location. Therefore, reinforcement for these slopes is needed. The geogrid with variations of vertical distance of geogrid layers was chosen in this study.
**Figure 4. Research method.**

**Table 3** The result of slope stability analysis for the reinforced slope.

| No | STA   | Vertical Distance of Geogrid Layers |
|----|-------|-------------------------------------|
|    |       | 0.2 m  | 0.4 m  | 0.6 m  |
| 1  | 84+280| 1.71    | 1.54    | 1.37    |
| 2  | 84+910| 2.27    | 2.02    | 1.7     |
The slope stability analyses, shown in table 3, explain that the thickness of the geogrid layer significantly affects the stability of the slope. The closer the geogrid vertical distance on the slope, the slope safety factor is increasing.

4. Conclusion
There are several conclusions that can be drawn from this study. The safety factor of the existing slope obtained at STA 84 + 280 and 84 + 910 from the slope stability analysis using Finite element method are 1.14 and 1.16. It means that the landslides occur. The use of geogrids can increase the slope safety factor. The safety factor will increase when the vertical distance of the geogrid gets closer.

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