Geofoam: A potential for Indonesia’s soil problem II

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Abstract. Indonesia is a country with a fair amount of hills and mountains. Having a tropical climate and high rainfall, landslides/slope failures are a common occurrence in Indonesia. According to the Indonesian National Board for Disaster Management, 355 slope failures occurred in 2019, with 81 casualties. To aggravate the problem, global warming and climate change result in extensive dry period and higher intensity rainfall. Slope failures can become more frequent in the near future. Common mitigation of slope failure includes construction of retaining structures, or by reducing water infiltration by the use of shotcrete. In this paper, the use of geofoam to mitigate slope failures is introduced, followed by a case study.

Keyword: geofoam, potential, soil problem

1. Introduction

Slope failure is one of the most commonly occurring natural disasters in Indonesia. More than 200 instances of slope failures occurred yearly for the past 10 years (Figure 1). In 2019, 355 slope failures occurred, in which more than 80% happened in Java island [1]. Fortunately, amongst the natural disasters, it is possible to mitigate slope failure.

To prevent slope failures, the mechanism triggering a slope failure has to be understood. Slope failures usually occur during or after rainfall [2, 3]. This is because rainfall infiltration results in loss
of matric suction [4]. Matric suction is “additional” strength due to partial saturation of soil. As this strength is not permanent and dependent on degree of saturation of the soil, it is regarded as “apparent cohesion”. Apparent cohesion reduces with increasing degree of saturation and eventually diminishes to zero when the soil is near saturation. Therefore, one of the methods to mitigate slope failures is by reducing or preventing water from infiltrating into the soil. Shotcrete is the most common method to achieve this. Mitigation of slope failure can also be achieved by constructing retaining system.

A less known method to mitigate slope failure is to use geofoam. Geofoam is a light-weight material used to replace soil fill. Geofoam’s density is only 1-3% of traditional soil fill [5, 6] and it is relatively impermeable to water. Therefore, geofoam structures can be built with relative ease at any weather conditions [7, 8]. Benefits of using geofoam compared to shotcrete or retaining system is: maximizing available right-of-way; reduction of construction duration and traffic impact; reduction of labour and future maintenance [9]. For more details on geofoam property and its usage for embankment construction, one can refer to the author’s previous publication [6].

2. Geofoam for slope stabilization

Geofoam has been extensively used for slope stabilization as well as slope extension [10, 11, 12]. Figure 2 illustrates how geofoam can be used to stabilize slope. Geofoam is used to replace weak soil, as it is a self-standing material (material capable of standing vertically), it does not contribute to lateral disturbing force. In addition, having a very low density, geofoam also has minimal contribution to vertical disturbing force. This is the working principles of slope stabilization using geofoam.

![Figure 2. Stabilization of slope using geofoam [11]]
3. Case Study in Puncak

Slope failure occurred adjacent to a villa located in a housing complex at Puncak, a mountain pass near Bogor, Indonesia. Figure 3 shows the slope post-failure. Surveying and soil investigation (3 boreholes and 6 cone penetration tests) were conducted to obtain the contour of the slope and soil profile respectively. Figure 4 shows the surveying results and location of the soil tests. Figure 5 shows the idealized cross section and soil profile from the soil investigation results. The soil types and soil parameters are listed in Table 1.

![Figure 3](image1.png)  
**Figure 3.** Photograph of the slope post-failure from the base (left); from the side (right)

![Figure 4](image2.png)  
**Figure 4.** Contour of the slope post-failure
Figure 5. Idealized soil profile for the slope

| Soil region | Soil type    | Unit weight(kN/m³) | Friction angle (°) | Cohesion (kPa) | Young’s Modulus (kPa) |
|-------------|--------------|--------------------|--------------------|----------------|-----------------------|
| 1           | Firm clay    | 17.0               | 28                 | 25             | 12000                 |
| 2           | Soft clay    | 16.0               | 25                 | 20             | 8000                  |
| 3           | Very Stiff clay | 18.0           | 32                 | 40             | 25000                 |
| 4           | Hard clay    | 19.0               | 32                 | 50             | 40000                 |
| 5           | Very hard clay | 19.5            | 32                 | 80             | 60000                 |
| 6           | Andesite     | 21.0               | 42                 | 0              | 75000                 |
| -           | Compacted fill | 18               | 35                 | 5              | 35000                 |

The initial proposed solution is to strengthen the slope using 12 rows of soil nails, and construct a mechanically stabilized earth (MSE) system to make the slope gentler. Figure 6 shows the initial proposed solution and slope stability analysis using limit equilibrium software GEO5. The factor of safety obtained is 1.73. Since limit equilibrium software cannot take into account the construction process, finite element software PLAXIS is used to analyze the deformation caused by the construction process. Figure 7 shows the calculation results. Halfway through the construction, failure is triggered as the additional burden from the MSE system is too high to be resisted by the soft clay layer. Therefore, this solution cannot be used and alternative solution has to be sought.

The slope failure occurred in November 2018 while the soil investigation and design were carried out from February to April 2019. During the 6 months period, no further slope failure occurred. This is because tarpaulin was placed at the top of slope (Figure 3) as temporary solution to reduce rainfall infiltration. An alternative solution using geofoam as impermeable layer is designed for.

Figure 8 shows the final solution. MSE system is still used for the first 4 meters, from then geofoam is used to shape the surface protection. The geofoam used is EPS15 with a unit weight of 14.4 kN/m³ and stiffness of 2500 kPa at 1% strain. The geofoam surface is covered by 10 cm of cement to fixate the geofoam as well as protect the geofoam from any possible petroleum exposure. Due to the reduction of load by using geofoam, this method of stabilization is possible to construct. The soil nail required has also been reduced from 12 rows to 3 rows. Factor of safety obtained from this solution is 1.66, which meets the requirement by Indonesian Standards > 1.5 [13].
**Figure 6.** Proposed solution using MSE system, FoS = 1.73

**Figure 7.** Failure occurs in the middle of construction
4. Conclusions and discussion

From the analysis, several lessons can be learnt. Limit equilibrium analysis has to be counterchecked with finite element software to take into account deformation that occurs during construction process. Second lesson is slope stabilization using fill system may result in destabilization of the slope. In cases like this, light-fill material such as geoslope provides an excellent solution as show cased by the current case study. This paper intends to introduce usage of geofoam as an effective slope stabilization material, and hopefully reduces the occurrence of slope failures/landslide in Indonesia.

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