Emergency Works and Landslide Remediation using Geosynthetics Reinforced Soil Structures – Recent Indonesian Case Studies

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ABSTRACT: Landslides like any other natural disaster are unpredictable. These events may compromise the function of some infrastructures or structures around the affected area. Mitigation measures or emergency works must be performed as soon as possible to regain the function of the affected infrastructure. Reinforced soil structure is one of the most suitable solution to be applied to restore the landslide slope and prevent future landslide disaster. Reinforced soil structures built using geosynthetics have shown many advantages for emergency works or landslide remediation if compared to conventional retaining structures such as mass gravity and cantilever walls. This paper aims to give explanation about the advantages of performing remediation works using reinforced soil structure with polymer as the primary reinforcement. Two completed projects are presented to provide author’s experience regarding the application of the reinforced soil structure and proper construction process for emergency works and landslide remediation in Indonesia.
Keywords: landslide, remediation, polymer, reinforcement

1 INTRODUCTION

The term of landslide refers to several forms of mass wasting that include a wide range of ground movements such as rockfall, deep-seated slope failures, mudflows and debris flows. Numerous factors can cause soil slope to landslide such as earthwork which change the shape of slope, erosion, rainfall, or earthquake. In Indonesia, most of the cases of landslide occur during the heavy rainfall. Consequently, the saturation process that causes by rainfall weakening the slope stability due to its excess pore water pressure. Furthermore, due to a rise of ground water level, the pore water pressure will increase and finally reducing the shear strength of the soil until the retaining structure or soil slope cannot withstand its own mass.

Certainly, the occurrence of landslide has impacts on the surrounding environment, both socially or economically. For instance, if a landslide occurs in the slope of a mountainous area, the whole access to the mountain would be blocked and eventually would disrupt the local economy around. By performing a quick remediation technique and procedure the risk and losses can be minimized. There are several types of remediation for stabilizing the landslide slope which are:

1. Geometry modification;
2. Surface erosion control;
3. Drainage techniques;
4. Retaining structure, such as mass gravity or reinforced soil structure.

Reinforced soil structure is one of the permanent solution to construct cost and time effective soil structures in an environmentally friendly and sustainable manner. This method consumes less time in terms of construction period due to its simplicity and does not require time to be able to regain its strength (curing time), unlike concrete structure. Another advantage is that it permits the use of any available filling-material on site which usually the landslide soil material itself. In addition, this system also does not require any special equipment or specific labour expertise, the only heavy equipment needed are excavator and soil compactor. Hence, reinforced soil structure is the recommended method to restore the slopes after landslide and any other emergency works related.

2 REINFORCED SOIL STRUCTURE

Conventional gravity and cantilever wall systems made of masonry or concrete act as rigid units and have served the industry well for centuries. This system works by resisting the lateral earth pressure by virtue of their large mass (Figure 1). However, a new system of retaining wall was introduced in the 1960s by H. Vidal with Reinforced Earth (Koerner, R.M. 2005). Reinforced soil structure works by utilizing the tensile strength from several layers of reinforcement elements in the compacted soil filling to improve the stability of the structure. Reinforced soil structures usually consist of the tensile reinforcing elements in the filling soil, facing panel unit and drainage system.

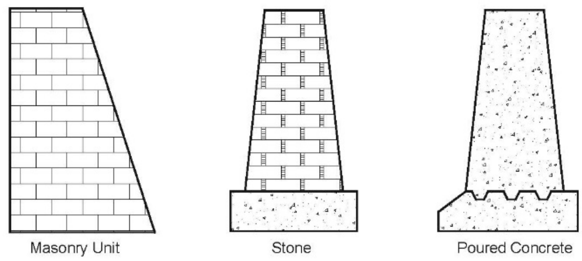

Figure 1 Typical section of a conventional gravity retaining walls
(source: https://commons.wikimedia.org/wiki/File:Gravity_Walls.jpg)

There are several types of facing unit in the reinforced soil structure, namely, concrete panel, anchored gabion, wrap around geotextile or geogrid. Each facing system has its own advantages and disadvantages. Accordingly, the decision of the facing type shall consider all the aspects from installation, availability of facing material, site difficulties, economical aspects, to the drainage system. In order to allow the run-off water to flow before saturating the structural backfill soil, the structure must be permeable enough. For instance, by contrast to the impermeable behaviour of concrete material, granular soil is more permeable so that it is required to be placed behind the concrete facing or panel.

While, the most commonly used for reinforcement materials are steel meshes, steel strips and geosynthetics in the form of woven geotextiles, geogrids and geocomposites. But, in cases of the landslide remediation or emergency works, steel strips are not suitable due to its stiff and heavy form that require a lot of effort and time to be installed. Therefore, geosynthetic considered as the most suitable material for this occasion because of its form and weight that easy to handle and install.

Geosynthetic have been known a long time ago and well accepted in this construction industry. For the retaining soil structure, the primary function of the geosynthetics needed is reinforcement. This reinforcement works thanks to its tensile strength that can resist the stress and deformation in the structure. Some type of geosynthetic that can be applied for the reinforcement function are geogrid, geotextile, or geocomposite.

Reinforced soil structure offers more flexibility that the structure can accommodate differential settlement and give the structure better capability in terms of drainage. Recently, this system is becoming more often applied in private and government projects even for landslide remediation or emergency works. The main factors that driving the choice of this systems are their cost-effectiveness, flexibility and most importantly the construction period to construct this structure that is relatively faster in terms of implementation than the other permanent solutions such as concrete and masonry walls.

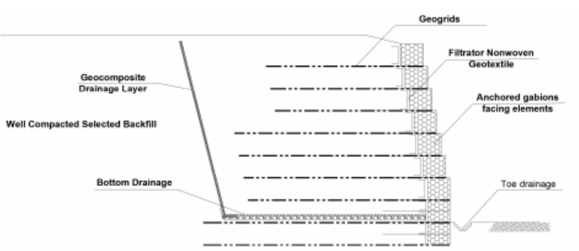

Figure 2 Typical section of a reinforced soil slope combining polymeric reinforcements (geogrids) and steel wire mesh reinforcements (anchored gabions and steel wrap around units)

3 Leuwigoong Dam Access Road - Garut

3.1 Project Background

Leuwigoong Dam was built for irrigation purpose for citizens agricultural lands in Garut regency, West Java Province, Indonesia. As seen from figure below that the stone masonry at the access road along 45 meters collapsed on 24th November 2017. This incident happened after heavy and continuous rain the night before.

Figure 3 Site condition on 27th November 2017

This structure allegedly collapsed due to poor quality of backfilling compaction so that the run-off water from the rain can infiltrate inside the embankment. This also compounded by the poor drainage system on the retaining wall which not enough permeable to allow water flow from the backfill to outside the structure.

The client needs a low-impact, environmentally friendly and time-cost effective integrated solution to prevent any construction delay of the restoration of the gravity wall due to the urgency of the usage of the access road. The Geotechnical investigation given by the client is only the Standard Penetration Test (SPT) since the structure was already built a few years ago and according to that information, the project site is classified as the loose and medium dense material.

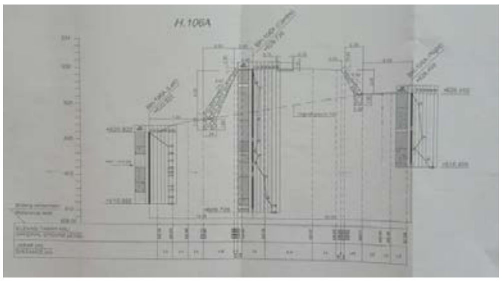

Figure 4 Soil stratigraphy based on bore hole test.

3.2 Solution

The proposed solution is a 8 m reinforced soil structure, using woven geogrids with the commercial name MacGrid as a primary reinforcement and anchored gabions (Terramesh System) will act as a front wall fascia unit to maintain stability in the front of the structure and protect the structure from surface erosion.

Terramesh System are reinforcing elements made up of hexagonal double twisted steel wire mesh type 8x10, forming a facing gabion and a variable length reinforcement according to the project. The steel wire used for manufacturing Terramesh System units is heavily galvanized. A polymer coating in compliance with EN 10245-1 having a nominal thickness of 0,50 mm is then applied to provide additional protection against environmental agents (UV rays, rain, etc.). The reinforcement base panel, front panel and gabion box lid of the Terramesh System are manufactured from one continuous panel of mesh; the back panel is factory connected to the base panel. The facing section of the unit is formed by connecting the back panel and diaphragms to the main unit; the gabion facing is divided into uniformly partitioned cells by internal diaphragms. Steel ring fasteners or coated lacing wire are used to connect units and to close and secure them.

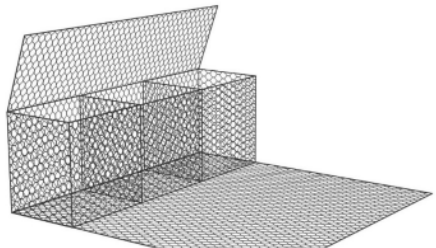

Figure 5 Terramesh System as facing unit

The manufacturing speed rate for producing Terramesh is relatively fast depending on needs. Units that delivered to site were folded and compressed in bundles weighting differently according to the unit as well as wire/mesh size and measuring approximately 3.1x2.1 m in plan and 0.4 m in height. Moreover, type and size determine the number of units per bundle. The Terramesh can be delivered in large numbers at once with this bundle form.

Figure 6 Bundles of Terramesh System.

Anchored gabions (Terramesh) are filled at the site with suitable stones to form a flexible and permeable modular system suitable as reinforcement and fascia of MSE walls. Polyester woven geogrids (MacGrid) with an Ultimate Tensile Strength (UTS) of 150 kN/m were used as primary reinforcement, enabling the soil to perform better than it would in its unreinforced state so that the structure can accommodate greater loads and stand at steeper angles. Geogrids were installed with a vertical spacing of 1 m and a length of 6 m. Reinforcement of Terramesh systems rely on the strength of friction and interlocking between plaiting panels and increasing the shear strength of the soil in the form of the embankment behind the Teramesh unit and serves to cut the local collapse line. To prevent the backfill soil to penetrate out to the facing, non-woven geotextiles which acts as separator and filter were applied behind all the Teramesh facing. The figure below the typical cross section of the proposed solution.

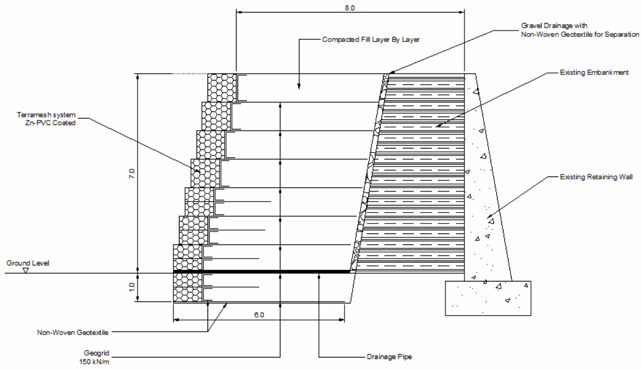

Figure 7 Typical Retaining Structure Cross Section.

The backfilling soil was transported by trucks and unloaded with the help of heavy equipment. The use of heavyweight machinery close to the facing (within 1 m from the facing) as well as track vehicles in contact with geogrid reinforcement shall be avoided. Vibratory rollers of adequate dimensions was used in function of the filling material (as per ASTM D3282). Light vibration compactor has been used for the area close to the facia to minimize any damage to the facia units.


Figure 8 Installation of Terramesh and MacGrid as Reinforced Soil Structure

In addition, the internal drainage system inside the structure has been done by placing available permeable material, namely, rock or gravel. The thickness of the rock material is 30 cm and wrapped with geotextile as separator. And for the horizontal drainage applied by using drainage pipe with proper inclination to collect and channel the water out.


Figure 9 Installation of Gravel as a Drainage Material

The construction process is repeated until it reaches the designed height. The total construction time of this reinforced soil structure were completed in 6 weeks from January to February 2018 (see Figure 9).


Figure 10 View of the Reinforced Soil Structure during construction (left) and almost completed (right)

4 Bukit Kemuning Road – Batam

4.1 Project Background

The project site is located in Bukit Kemuning, Batam and adjacent to the local housing. The area is subjected to high intensity of rainfall and surrounded by hills and mountains. Due to the heavy rainfalls and poor drainage system of the road, the rain water run-off from the mountain and triggered a massive landslide. The landslide occurance affected the local residence near the area. Some houses were damaged, and residents were evacuated. Moreover, the accident has also disrupted the traffic. The Ministry of Public Works planned to repair the damage road and rehabilitate the existing soil profile in order not to cause greater losses.


Figure 11 Rain Water Run-off Situation (left) and Condition after Collapse (right)

In this project, soil investigations were carried out using the Standard Penetration Test (SPT). The SPT test was performed at a depth of 5 m from the existing road and the testing was executed to a depth of 9 m. From the results of the SPT test, it was found that the value of N SPT was quite high and the type of soil was dominated by gravelly silt. The groundwater elevation indicated in 1.4 meters depth. The SPT test results obtained are as follows.

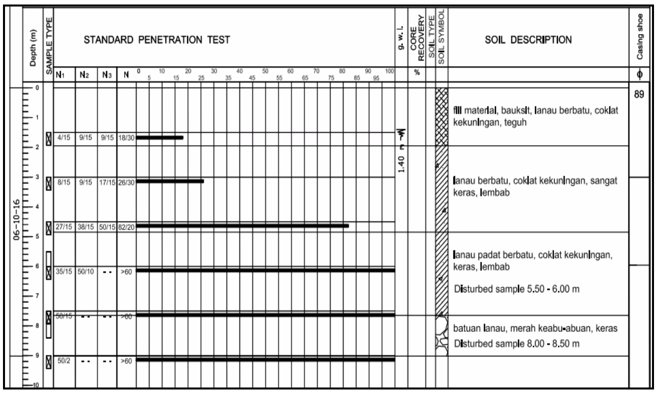

Figure 12 Standar Penetration Test (SPT) Result

4.2 Solution

The Public Works decided to repair the road and improve the drainage system, so that this problem can be avoided in the future. The original proposal from the consultant was a gravity mass retaining structure made from gabion with woven geotextile as the primary reinforcement and separately placed behind the gabion wall as the separator. Due to its massive structure, the remediation act shall be difficult to realize due to limitation of funds and time, so that the client asked for an alternative solution in order to generate both cost and construction schedule optimization. It is important to note that the client must restore the function of the road as soon as possible to reduce the risk of loss of the local community.

Therefore, a retaining soil structure with the combination of anchored gabion facing and geogrid reinforcement was adopted. The structure itself can reach 14 m maximum height with the combination between anchored gabion facing and polymer reinforcement. The proposed system was the combination of Maccaferri's Terramesh System and High Strength Geogrids Paralink. The geogrid ultimate tensile strength (UTS) is 300 kN/m. The system was provided with an internal drainage using a 30 cm thick rock layer wrapped with geotextile.

This new technical proposal can be concluded that the retaining soil structure was found to be more cost and time effective compared to the original one. The retaining soil structure proposed requires only one layer of anchored gabion as the facing instead using the massive gabion structure as the mass gravity wall.

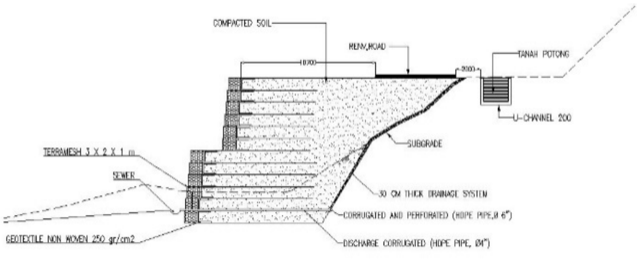

Figure 13 Typical Cross Section of Reinforced Soil Structure Bukit Kemuning Road in Batam

Static and seismic analysis had been performed, checking global stability, internal stability and stability as retaining wall (sliding, overturning and bearing capacity) using Maccaferri internal software Macstars W. Maccaferri provided support to the contractor with product installation training and supervision.

The geogrids are supplied in rolls with 4.5 m width and 200 m long. The total weight of each roll geogrid (Paralink) approximately around 900 kg. Geogrids are arranged before the Terramesh facing units, from the front of facing up to the length required by the design. The laying direction will be in the rolling direction that having greater resistance has to be placed perpendicularly to the facing.

Figure 14 Paralink Installation (Left) and Terramesh Installation (Right)

Selected backfill material for the embankment body was silty sand soil, compacted every 25 cm thick lift. Structural filling installation and compaction procedures are illustrated in Figure 15.

Figure 15 Backfill and Compaction Procedures

Figure 16 View of the Completed Access Road Remediation

5 Conclusions

Remediation works after landslide needs to be performed immediately to minimize the risk or losses that can be caused. Reinforced soil structure is one of the most suitable solution to restore the slopes after landslide and any other emergency works related. This method proved to be more effective in terms of construction time and cost compared to the other solutions. This paper presented two cases that applied reinforced soil structures with polymer reinforcement as the remediation method after landslide occurrence in Indonesia.

The first case history is the remediation of 45 m access road for Leuwigoong Dam in Garut regency, West Java. Landslide happen after heavy rain all night long and allegedly collapsed due to poor drainage system of the existing retaining structure. Reinforced soil structure was applied using woven geogrid as the primary reinforcement and anchored gabion as a structural facing and secondary reinforcement. The internal drainage system inside the structure has been done by placing available permeable material, namely, gravel. The thickness of the gravel material is 30 cm and wrapped with geotextile as separator. Furthermore, the horizontal drainage applied by using drainage pipe with proper inclination to collect and channel the water out.

The second case is the remediation of 100 meters road in Bukit Kemuning road in Batam. The existing slope collapsed under continuous exposure to high intensity rainfall and as a result, adjacent residential areas were damaged. Consequently, the Reinforced soil structure was chosen as the alternative solution to optimize cost and construction schedule from the original solution which was mass gravity wall in the form of gabions. This choice allowed the owner to deliver the project on time and within the target budget. The selection of the system was also guided by the system fascia permeability, flexibility and construction ease. Reinforced soil structure proposed was anchored gabion and high strength geogrid 300 kN/m. The construction itself was completed in approximately 4 months.

6 References

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