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Geosynthetic Reinforced Road Structure as Fast Rehabilitation for a Typhoon Disaster

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ABSTRACT: Disasters are increasingly difficult to predict due to severe climate change. In addition to disaster prevention, it is an urgent task to prepare for post-disaster restoration and prevent secondary damage to the environment to reduce the impact of disasters. The construction site in this paper is located on the primary trunk road which connects eastern and western Taiwan. Due to major typhoon disasters, the slope below the road severely collapsed. It needs to be repaired in a short period to reduce the impact on transportation and economy. Considering the issue of time-urgency and cost-saving, geosynthetics reinforced structure in accordance with concrete retaining wall and pile foundation was constructed as road embankment. In addition to achieve a rapid recovery after disaster, the construction method also lowers carbon emission environmental impact. In this paper, geosynthetic reinforced structure has been proved as a sustainable solution for disaster recovery.
Keywords: disaster recovery, geosynthetics reinforced structure, carbon emissions, green engineering

1. INTRODUCTION

Since the discovery of the greenhouse effect as one of the causes of climate change, green engineering for energy conservation and carbon reduction have gradually been introduced into the design and construction of engineering projects (Heerten, 2012). In recent years, Reinforced Concrete (RC) retaining structures have been partially replaced by Geosynthetics Reinforced Structures (GRS), which excludes the casting and curing time of concrete, to shorten the construction time and disaster recovery process. Compared to GRS, RC structure also demands higher material quantity, transportation cost, and environmental impact (WRAP, 2010).

This paper presents a case study of slope rehabilitation project using a composite structure made of pile foundation, RC wall, and GRS. The case is located in the southern part of Taiwan, specifically in Pingtung County, Provincial Highway No. 9 470K+500, adjacent to Fenggang River. In 2013, Typhoon Kong-Rey was attacking Taiwan with heavy rainfall, in which the concentrated rainfall rise upon 250 to 300 mm within a single day (JTWC, 2013). Rapid change of precipitation rate caused a fluctuation in the adjacent river water level. The impact of high energy and high velocity in the river stream was an accelerated scouring of soil. Thus, a slope failure was occurred beneath Provincial Highway No. 9 (Figure 1).

Figure 1 Slope Failure below Highway Embankment

2. SITE DESCRIPTION

Pingtung County of Taiwan was geologically located above Chaochow Formation, Quaternary Terrace Deposit, and Quaternary Alluvium Deposit. Chaochow Formation consists of slate, a metamorphic rock, with thinly bedded sandstone. Terrace Deposit and Alluvium Deposit are younger sediment from Quaternary period and made of sand, silt and gravel. The SPT-N value of the foundation soil is equal to 20 – 50 ([(1)] Chen, et al. 2017).

Taiwan is located in the orogenic belt from obduction of micro-oceanic plate into Eurasian continental plate. The orogeny movement resulting in a fractured basement rock with several geologic structure such as fault and fold (Sibuet and Hsu, 2004). In this case, only a fractured basement rock is observed, without any occurrence of fault and fold nearby.

The site is located adjacent to Fenggang River. It is one of the major river contributed to a high sediment erosion in Taiwan, especially during the typhoon season ([(2)] Chen, et al. 2017). The main river has 41 km length with average elevation of 698.3 m and average slope of 28.4^o.

3. DESIGN

In the design part, several factor need to be considered upon (FHWA-NHI-00-043). First, the main cause of collapsed slope is scouring phenomenon in the toe of the slope. Therefore, the new constructed slope should be made to prevent any damage from the scouring. The occurrence of typhoon and earthquake are also a main concern in this structure. Typhoon will results in river stream fluctuation, whereas earthquake will impact the overall stability of the structure.

The collapsed slope is 150 m in length and 22 m in height. At the bottom, all-casing pile foundations were built to deal with the scouring phenomenon from Fenggang River. On the top of pile foundations, a semigravity RC wall was designed to deal with the fluctuation of river stream due to typhoon impact. For the upper structure, two-tiered GRS consists of geogrids, soil bags, and water culvert was installed (Figure 2).

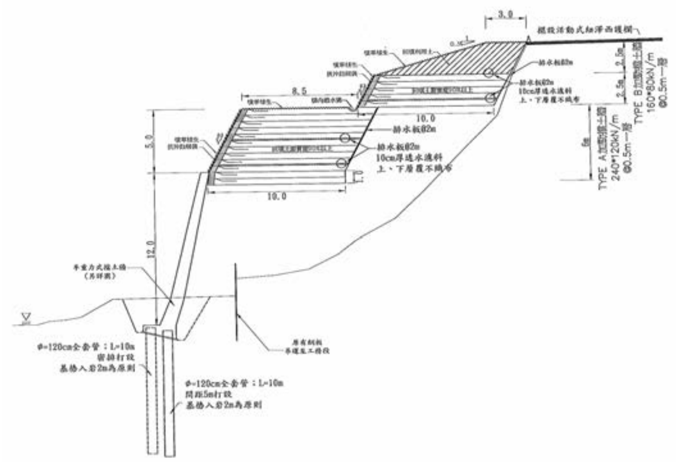

Figure 2 Design Drawing of Composite Structure

3.1 All-casing pile foundation

The foundation was set with double-row cased piles with a diameter of 1.2 meters (Figure 3). The outside piles were set at intervals of 2 meters in a row, and the interval of rear piles was set as 5 meters. The depth of each pile is about 10 m with an initial drill penetration of at least 2 meters into the rock sublayer. A total of 155 piles were installed to transfer the vertical load into metamorphic basement rock and improve the bearing capacity of the whole structure. Furthermore, a reduced influence of riverbed scouring was expected, and the sliding drive force raised by the earth pressure of slope was resisted.

Figure 3 The All-Casing Pile Installation

3.2 Semigravity RC retaining wall

The semigravity RC retaining wall was constructed on the top of pile foundation and connected to the pile cap (Figure 4). Taking into account the highest water level, the wall high was raised up to 12 meters. The main function of the RC retaining wall is to prevent the main structure from being damaged by the impact of debris flow during typhoon season and resist the lateral earth pressure from the backfill.

Figure 4 Semigravity RC Retaining Wall Construction

3.3 Geosynthetics Reinforced Structure

The upper structure above highest water level was constructed as a geogrid reinforced slope (Figure 5) to a certain height and then backfilled with soil to the level of road base. According to the safety stability analysis, the geogrid reinforced slope was considered to be divided into two stages. The lower stage used geogrid with an ultimate tensile strength of 240 kN/m and the upper stage utilized 160 kN/m separately. The embedded length of the geogrid for both stages is 10 meters. The backfilled material utilized the collapsed soil in the construction site and the dredged sand from the river. Besides the mechanically stabilized components, the design of drainage in the structure is greatly important as well, the drainage system composed of drainage board, non-woven geotextile and gravel, are placed into the structure to guide and drain the water pressure inside the geogrid reinforced slope. The facing system of the GRS was piled up soil bags as the vegetation medium. Above the GRS, a soil slope with a gradient of 1:0.3 and 2 meter height was backfilled and compacted as the road base.

Figure 5 The Installation of GRS

3.4 Drainage System

In order to discharge the water from heavy rain on the slope, the design of the drainage box culvert under the road surface was also carried out. The overflow from the road surface and upper slope can be collected by the drainage system and then transported into the adjacent river. In this structure, drainage system will prevent the cohesion-loss from the soil, which is caused by surface water infiltration (Figure 6).

Figure 6 Drainage System for Surface Erosion Measurement

3.5 Hydroseeding

Hydroseeding, a plantation work using a mixture of seed and mulch, was performed after the completion of GRS installation (Figure 7). The main function of hydroseeding is to control the surface erosion using vegetation growth, while it also provides an aesthetical function to enhance the appearance of the whole GRS structure. Overall, hydroseeding has a beneficial impact on the environment aspect by lowering the carbon footprint from the construction work.

Figure 7 Hydroseeding

4. SAFETY STABILIZATION ANALYSIS

The overall structure was analyzed by commercial software STEDwin for global safety and stabilization under normal, rainstorm and earthquake conditions (Figure 8). The soil parameters for analysis were set as follows in Table 1 according to the geological report for the construction site. The analysis result demonstrates that the composite structure made of pile foundation, RC wall, and GRS is stable under normal, typhoon, and earthquake conditions. The achieved factor of safety for normal condition (FS_{normal}) is 1.63, typhoon condition ($FS_{Typhoon}$) is 1.27, and earthquake condition ($FS_{earthquake}$) is 1.38.

Table 1. Soil Parameters used for Stabilization Analysis

Parameters	**In-situ soil**	**Backfill soil**
γ (kN/m^3)	18.5	18.5
γ_{sat} (kN/m^3)	20.5	20.5
Cohesion, c (kPa) General/ Storm	10/5	5/3
Friction angle, ϕ (°)	32	30

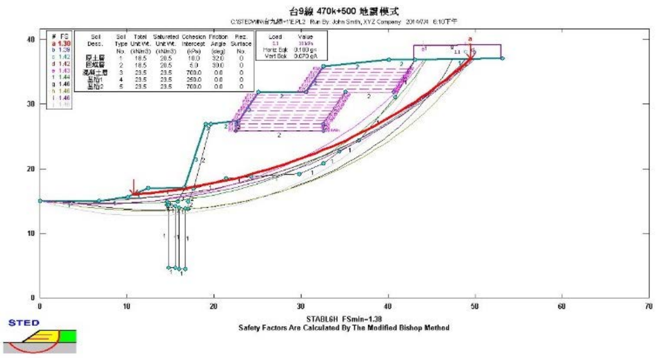

Figure 8. The Global Stabilization Analysis (Presenting Earthquake Model as an Example)

5. CARBON EMISSION

The carbon emissions of the project using the composite construction method are as shown in Table 2 ([1]Chen, et al. 2017). Regardless of planting, the carbon footprint of the traditional construction method with entirely reinforced concrete components is reduced by 30%.

Table 2. Carbon Emission of Each Construction

Structure	**Carbon Emission (TCO_2e)**	
	This Case	**Traditional Method**
Cantilever retaining wall	0	715
Geosynthetics reinforced structure	80.73	0
Semigravity RC retaining wall and pile foundation	1336.65	1336.65
Total	1417.38	2051.65

6. CONCLUSION

Since the structure was completed in 2014, it has been through several natural disasters, such as earthquake and typhoon. In recent years, the structure remains intact with no deformation is observed on the site (Figure 9). Therefore, it can be seen that the GRS is a green engineering method that combines rapid construction with ecological landscapes and carbon reduction. Certainly, although there are so many advantages of GRS, a geological limitation might be a concern. This paper presents a combination between GRS and traditional RC structure to deal with natural hazard, such as typhoon and earthquake. This kind of structure is completely suitable for a country like Taiwan, which has frequent natural disasters. Due to the many advantages of the composite construction method, this method has gradually been welcomed and favoured in Taiwan for disaster recovery process. This paper suggests a sustainable solution for disaster recovery engineering in countries with similar geological conditions to Taiwan.

Figure 9 GRS Structure Condition in 2018

7. REFERENCES

[1]Chen, M.H., Hsu, W.I., and Chung, W.K., 2017, The Development and Application of Carbon Emission Estimation for Highway Construction, *Journal of Taiwan Highway Engineering*, Vol. 43(4), pp. 2 – 29 (in Chinese)

[2]Chen, C-W., Oguchi, T., Hayakwa, Y.S., Saito, H., Chen, H., Lin, G-W., Wei, L-W., and Chao, Y-C., 2017, Sediment Yield during Typhoon Events in Relation to Landslides, Rainfall, and Catchment areas in Taiwan, *Geomorphology (2017)*

FHWA-NHI-00-043, 2001, *Mechanically Stabilized Earth Walls and Reinforced Soil Slopes Design & Construction Guidelines*, U.S. Department of Transportation, Federal Highway Administration, pp. 81-201.

Heerten, G., 2012, Reduction of climate-damaging gases in geotechnical engineering by use of geosynthetics, *Geotextile and Geomembrane*, Vol. 30, February 2012, pp. 43-49

Join Typhoon warning Center (JTWC), 2013, *Annual Tropical Cyclone Report*, pp. 30

Sibuet, J-C., and Hsu, S-K., 2004, How was Taiwan Created, *Tectonophysics* 379, pp. 159 – 181

Waste and Resources Action Programme (WRAP), 2010, *Sustainable geosystems in civil engineering applications*, Geosystems Report