Application of Wrap-Around Reinforced Structure at Hilly Road Repair Case in Thailand & Taiwan

Amie Wang, Nana Chen , Pei Hsuan Wu &Chin Ming Chang
ACE Geosynthetics Co., Ltd. Taichung, Taiwan

Nuttapong Kovittayanun
CeTeau FarEast Ltd. Bangkok, Thailand

Nipon Ingsrisawang
Department of Highways, Thailand

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ABSTRACT: Transport infrastructure could be one of the major factors to speed up the urban development. Back to the earlier stage in Taiwan, in order to shorten the traveling time which means to save transportation costs simultaneously, intricate highway systems across the whole island were drawn up to connect cities and cities. Cities are over used and the traffic is congested. The tourism industry sees the advantage to get resort land plans in the hilly areas; the high significance of hilly road projects is well seen recently. As a result of lying in the circum-Pacific seismic zone and the marine tropical zone, Taiwan comes with fragmental geology and succumbs to attacks of server tropical storms. Slope failure, erosion, collapse or road damage happened frequently after torrential rain. The reconstruction is required. In light of the economic concerns such as easy construction, short construction duration as well as simple construction crew, warp-around reinforced construction method is strongly recommended. Providing difficulty of obtaining or delivering backfill material is observed and the quality of the in-site soil is up to the standard as backfill material, it is worthy to consider and accept the wrap-around reinforced construction method. The construction cost is wisely reduced otherwise. In this paper, several road projects which successfully applied wrap-around reinforced construction method with Geogrid, in Thailand and Taiwan will be briefly introduced.

1 INTRODUCTION

Due to the limitation of land and the lack of natural resource, export is the main economic development in Taiwan. In the past, many highway systems were constructed to meet the rapid industry development and saved the time and cost of transportation. The fast growth of urban population and the popularization of leisure industry enhanced the use of hilly road in recent years. Taiwan has higher ratio of collapse at hilly road than other countries owing to two reasons – the fragmental geology since Taiwan is located in circum-Pacific seismic zone; and the attacks by typhoon and torrential rain frequently during the summer and autumn.

Wrap-around reinforced construction method is provided with simple construction equipment, short construction period, low terrain limit, low labor cost and so on. In this paper, three successful hilly road repair projects applied wrap-around reinforced con struction method will be introduced as well as the attention for the construction method.

2 CASE HISTORY

2.1 *Case 1 Pingtung County Highway 35*

2.1.1 *Project Summary*

The Project was located in the Country Highway 35 (5k+000), Majia Township, Pingtung County, Taiwan. According to the static from Central Weather Bureau, the accumulated precipitation in Pingtung area exceeded 1,380mm within one month, from 7th July, 2006 through 9th August, 2006, after the continuous typhoon attacks – Ewiniar, Bilis, Kaemi, Saomai and Bopha. Torrential rain brought about subgrade collapse to the two-land highway and caused traffic disruption.

The site investigation data from the design company indicated that the side ditches had suffered from impeded drainage for a long time because of clogging problem. The rainfall brought by sudden downpour overflowed the ditches easily, flowed towards the lower level of slope and converged onto the lower elevation of down slope. After long-term erosion, soil loss occurred at the slope toe and extended to both sides of upstream, causing collapse failure which scouring came up first and it later became headward erosion resulted in traffic disruption. (see Figure 1.)

2.1.2 *Design and Construction*

According to the drilling report, the soil layer from the top of borehole to depth of 0.8 meters was loose backfill layer, and from 0.8 meters deep extended to the bottom of borehole, 10m in depth, was shale layer - unit weight of 22.9 kN/m^3, friction angle of 35°, uniaxial compression strength of 300 kPa. The design parameters of backfill soil are unit weight of 19 kN/m^3, friction angle of 28° and cohesion of 2 kPa. To regain the traffic connection, the design company adopted reinforced retaining wall of height between 16 to 18 meters after considering the conditions that the geology of the bottom of erosion gully was more vulnerable than both sides and construction on hilly road is limited by terrain. Soil nail was designed at the rear area of first and second stages of the retaining wall, the deepest part of the collapse, to avoid slope stabilization problem which may result from inadequate buried length of geogrid in limited site. Meanwhile, micro-piles were furnished in the foundation to enhance sliding resistance of the structure. Lastly, interior and exterior drainage systems were included to complete the design. The construction started from the bottom of collapsed slope by means of reinforcement method layer by layer to the top. When the layer came to expect height, soil nail was set by drilling machine. (see Figure 2. & 3.)

2.2 *Case 2 Taiwan Provincial Road No. 7A*

2.2.1 *Project Summary*

During two and half months, from 16th July to 29th September 2008, Taiwan was attacked by six typhoons – Kalmaegi, Fung-Wong, Nuri, Sinlaku, Hagupit and Jangmi. According to the statistic from Central Weather Bureau, the accumulated precipitation brought by four of the six typhoons exceeded 945mm in Yilan area. Heavy rain damaged section 1k+300 and 1k+500 of Taiwan Provincial Road No. 7A, which is next to Lanyang River Basin. Due to the damage, the traffic was only available in single lane.

The field investigation stated that Lanyang River was in spate after the torrential rain brought by typhoons. Strong current scoured the foundation of roadway and the scouring of soil at downslope toe led to the collapse of upper roadway. (see Figure 4.& 5.)

2.2.2 *Design and Construction*

Owing to the main damage issue of this project - scouring at slope toe, to prevent from recurrence damage and consider the economical and convenient construction method, the design company took the solution of reinforcement structure to construct 40-meter-long and 80-meter-long repair projects along the original road line. Cast-in-place drilling concrete piles – diameter of 1 meter, length of 12 meters – were driven into the foundation of both reinforced structures and 8-meters-hight semi-gravity retaining walls were constructed at the top of piles as the waterfront protection structures. These protection structures offered sliding resistance and slope stabilization on the base of slope toe. Moreover, after the completion of upper reinforced structure, the whole structure contributed passive resistance to the roadway base to strengthen the stability of roadway. Here good permeability materials, sand and sandy gravel, were used as the backfill soil for the reinforced retaining wall.

Since there was an existing revetment below section 1k+300, the buried length of reinforced material was extended to the rear of the revetment to ensure the stabilization of the whole structure. Part of the revetment was knocked away under the use of temporary retaining structure for proceeding construction. Geogrid GG250-II and GG160-II were proposed to the three-stage reinforced retaining wall, the slope ratio of 1 : 0.3 (V : H), stage height of 5 meters and buried geogrid length of 8 meters.

As regards section 1k+500, sliding failure happened to front existing retaining structure. Considering the stabilization of existing slope under construction, 6-meters-long soil nails were driven in the rear of reinforced structure to enhance the stabilization of inherent slope. The vertical and horizontal spacing between soil nails were 3 meters; the offset distance between reinforced slope and front RC wall was 4 meters. To diminish the lateral force of front revetment, the foundation of reinforced slope went deep into 2 meters. Reinforced slope was built with geogrid GG240-II and GG120-II. Its slope ratio was 1 : 0.5 (V : H) and it was divided into five to six stages. Stage heights varied with topography and buried geogrid lengths were 17 meters, 15 meters, 13 meters, 11 meters, 9 meters and 7 meters varied with the elevation.

The two reinforced structures have several design features in common:

- Use of geogrid, made of multifilament polyester yarns and coated with PVC, as reinforced material
- Facing system with soil bags
- External drainage system at offset of each stage
- Drainage pipe in the interior of the structure and drainage board at the rear of backfill soil.
- Most important of all, thanks to the good permeability of granular soil used for the backfill area, the construction progress was not delayed by rainfall.

The design achieved an artificial structure combining safety, excellent drainage and eco-landscape. (see Figure 6. ~ 8.)

2.3 *Case 3 Ranong-Pato Road*

2.3.1 *Project Summary*

This hilly road repair case was located at Km.8 Ranong-Pato Road, Ranong Province, Thailand. During heavy rainy season, roadway was inundated easily owing to the blockage of ditches. A great deal of rainwater converged and flowed downwards to the slope of roadway, the slope surface was eroded by rainwater steadily as a result of lacking in drainage system. Simultaneously, plenty of water infiltrated into soil layer, leading to the loss of shear strength of deep soil layer and causing circular sliding. Eventually, the roadway upon the slope collapsed, resulting in only single traffice lane was passable subsequently. (see Figure 9.)

2.3.2 *Design and Construction*

To restore the convenience of transportation, the designer, Department of Highways, adopted reinforced structure - total design height of 8 meters, the slope of less than 70 degrees (V : H = 1 : 0.5) - to give consideration to economical and convenient construction method after surveying two factors, the structure to be repaired was downslope of the roadway and the particle at site was sandy soil. Two-stage, each was 4 meters in height, reinforced structure was applied for this repair construction and RC slab was constructed to protect the toe of this reinforced structure. According to stability analysis, geogrid GG100-II was proposed as the reinforced material for this structure and the design buried geogrid length was 3 meters. In order to make the appearance of the reinforced structure go well with the green surrounding, facing design of wrap-around with piled soil bags was put to use for this construction. Moreover, to prevent the structure from the damage caused by erosion problem due to the lack of drainage system, the designer configured transverse intercepting ditches and vertical gutters respectively as drainage system at the boundary between reinforced structure, RC slab and the surface of original slope.

3 REASONS AND TYPES OF FAILURE

According to the aforementioned failure cases, the reasons and types of failure are summarized as follows:

- Terrain factor: the site was at mountain area or right next to riverbank.
- Geology factor: the vulnerable terrain under excessive-weathering in case 1 and case 2 and geology of soft soil in case 3.
- Climatic factor: in Taiwan, torrential rainfall occurs mostly in the summer and autumn.
- Human factor: for example, overhigh roadway surface, poorly designed drainage system or the blockage problem of culvert.

In accordance with Taipei City Geotechnical Manual for Slope Safety, the causes of slope project failure can be sorted into shallow sliding failure, debris flow, surface soil erosion, circular sliding, dip-slope sliding and so on [1]. Comparing the failure conditions of aforementioned cases, the failure type of these three cases were classified as circular sliding, the common failure of slope land project.

4 INTRODUCTION OF WRAP-AROUND REINFORCED CONSTRUCTION METHOD

Reinforced structure is composed of soil, reinforced material, facing system and drainage system. The advantages of wrap-around reinforced construction method include simple construction equipment, short construction period, low labor cost and, etc. Since it is not easy to get natural aggregate in Taiwan, the benefit of using in-site soil as the backfill material helps lower construction cost greatly. What follows are the attention points of this construction method.

4.1 *Backfill Soil*

Backfill soil takes highest proportion among the elements of reinforced structure. The engineering properties of soil and the control of in-site compaction have a great deal to do with the success of the reinforced structure. Normally, granular sandy soil is proposed as the backfill material. However, owing to the difficulty of obtaining natural aggregate in Taiwan, in-site soil is usually used as backfill material for repair projects to reduce construction material cost and shorten construction period. Nevertheless, this method shall be based on the professional evaluation by experienced civil engineer after the site investigation. Supposing the in-site soil contains too much fine particle or high plasticity material, to avoid structure deformation, lime and cement are the additives to improve the in-site soil. Furthermore, what is also important is the compaction of backfill soil layer by layer. For reinforced slope, the compaction density shall be controlled between 90 ~ 95%.

4.2 *Reinforced Material*

Reinforced material is the main resource providing soil with tensile strength. The interaction - offering structure stabilization - is coming from the cooperation between the laying of reinforced material with suitable length calculated by engineer and the effective compaction of backfill soil. In addition, soil nail or other slope protection structure can be considered to form an assistant structure with the limited construction terrain available.

4.3 *Drainage System*

Reinforced structure is composed of soil and reinforced material primarily, appreciated drainage system, including interior and exterior systems, are needed according to the site conditions to prevent the effect of erosion by the rainfall of torrential rain. Soil bag with gravel, drainage board and drainage sheet are the common materials for interior drainage system helping eliminate the seepage from original slope in the rear of reinforced structure. Exterior drainage system is usually made of concrete or shotcrete method on the top and surface of slope structure. Drainage culvert is suggested to protect soil from weakening caused by infiltration providing that underflow and culvert are found during the excavation. (see Figure 12)

4.4 *Facing System*

Facing system performs the function of averting erosion on slope surface and inhibiting lateral deformation of the structure simultaneously. Wrap-around facing system is piled soil bags with reinforced material wrapped back and anchored. Steel sheet can be welded on the bucket of excavator to smooth the slope surface. Woody formwork is another choice for the construction.

4.5 *Lateral Edge-Closing*

During construction, the installation problem commonly forms on the boundary between original soil layer and the both sides of the reinforced structure. The designer may consider adopting longitudinal ditch or wrap-around facing - which extends 1.5 ~ 2 meters in length into the structure - at the interface to this problem. This design is to avoid erosion problem caused by new drainage channel which occurs at the interface during torrential rain. (see Figure 13)

5 CONCLUSION AND SUGGESTION

The designer should pay more attention on the drainage system and its long-term maintenance, especially the repair project in mountain area owing to the terrain limit and harsh weather during the rainy season, particularly when the geology is excessive-weathering.

Simple construction equipment, low terrain limit, short construction period and low labor cost are all the advantages of wrap-around reinforced construction method. In the place where natural aggregate is not easy to get, taking the professional evaluation from experienced civil engineer after the site investigation and approved in-site soil as backfill material are beneficial to lower construction cost and shorten construction period.

We anticipate that the successful experience of these projects could be the reference cases for hilly road repair project in Thailand and other countries.

REFERENCE

Nan Shan Zhou et al., “Taipei City Geotechnical Manual for Slope Safety”, Department of Economic Development, Taipei City Government, Taiwan (2003).


Figure 1: Case 1 before construction.

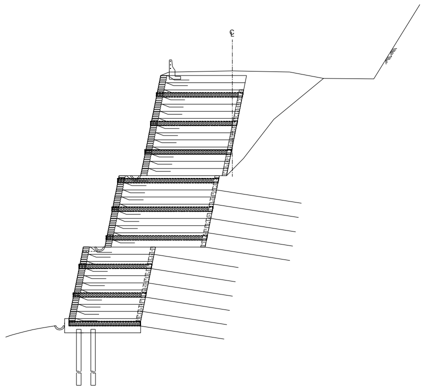
Figure 2: Case 1 design cross section.


Figure 3: Case 1 after construction.


Figure 4: Case 2(1k+300) before construction.


Figure 5: Case 2(1k+550) before construction.

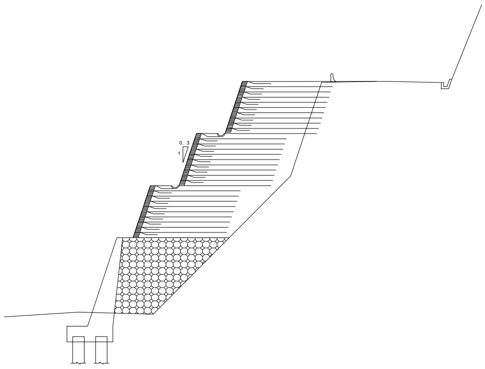
Figure 6: Case 2(1k+300) design cross section.

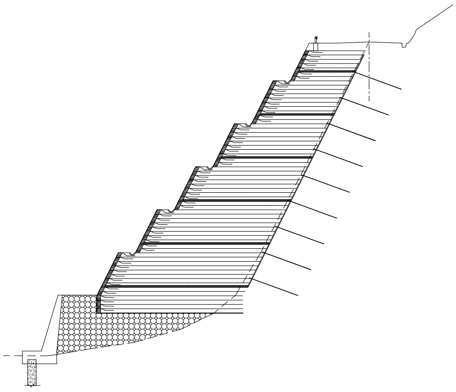
Figure 7: Case 2(1k+550) design cross section.


Figure 8: Case 2 after construction.

Figure 9: Case 3 before construction.


Figure 10: Case3 after construction.

Figure 11: Drainage system.


Figure 12: Lateral construction.