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Application of geogrid reinforced structure for abutment construction in Taichung, Taiwan

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ABSTRACT: The construction is an abutment foundation case crossing Daija River, which is situated in Shengang Interchange of National Highway No. 4 in Taichung Houli District. The bridge abutment, constructed with reinforced concrete, is 20 meters in height, and presents a U-shaped reinforced retaining wall structure with four tiers. The construction adopts the composite engineering method using reinforced concrete with reinforced retaining wall to build the earth abutment as an elevated-bridge structure crossing Daiji River in Taichung. Because the original slope is easy to be scoured by rainwater and causes it collapsed, a wrapped-around reinforced retaining wall is built to protect the abutment structure. Two drainage layers are also installed in each tier to efficiently discharge groundwater from the back of the abutment. Instead of traditional concrete retaining wall, using reinforced retaining wall to build the abutment has the benefits of fast installation and effectively providing structural safety. In order to prevent the structure from collapsing or sliding, the facing uses Soil bag erosion control bag to provide a space for vegetation to grow for protecting the slope.

1 BACKGROUND

The construction is located in Houli District of Taichung, Taiwan (Fig. 1) with the total length of 2973km, and its purpose is to solve the traffic problems in Houli. The location of Taichung Houli District is between Da'an River and Dijia River, which relies on the viaducts to connect with external traffic. When the rainy season or typhoon season is coming, the flashy flood from the river often causes many bridges to be destroyed.

In order to reduce the travel time of the residents from Houli District to the metropolitan area in Taichung, the government plans to build a connecting road between Shengang Interchange of National Highway No. 4 and Houli District. The connecting road needs to cross Dajia River, which is Taiwan's fourth largest river.

Figure 1. Site Location

2 GEOLOGICAL CONDITION

The total length of construction is 2973km, and the reinforced abutment is located at the end of the construction location. According to Figure 2, there are three boreholes in the construction site. The site geological condition is known from the geotechnical investigation report, showing the borehole depth is 35 m; the geological condition of borehole BH-2-2 of 0.0 - 3.8 m is yellow-brown silty clay, while 3.8 m-35 m is dense gravel with yellow-brown soil. The other two boreholes of 0 - 35 m is a dense gravel with yellow-brown soil.

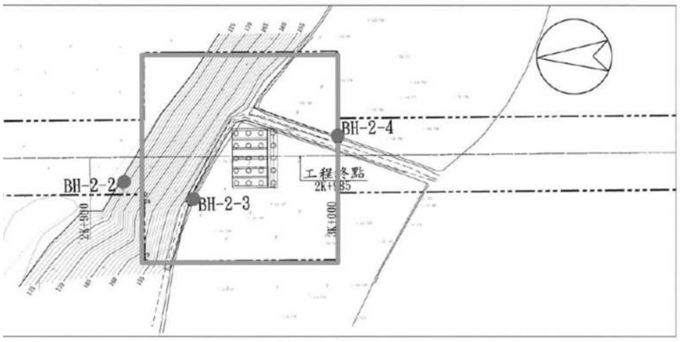

Figure 2. Borehole Location

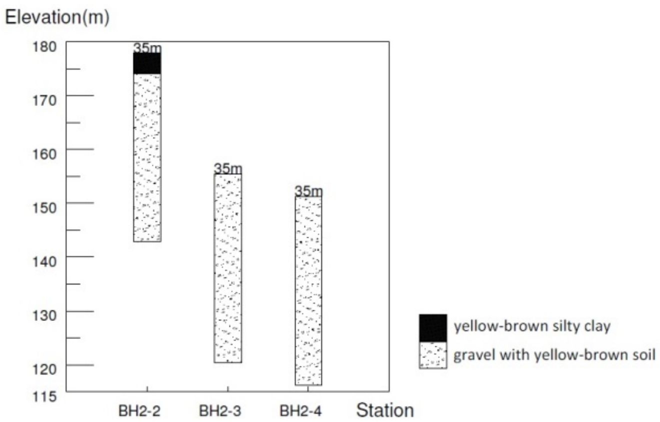

Figure 3. Boring Logs

3 CONSTRUCTION DESIGN

3.1 *Design concept*

The abutment is located next to the excavated slope. According to actual geotechnical investigation data, the soil is identified as granular gravel. The exposed slope eroded in years by rainwater may be collapsed and endangers the abutment foundation. Thus, the geogrid wrap-around reinforced retaining system is designed to wrap around whole abutment and eroded slope. The whole structure of reinforced retaining wall is composed of geogrids, soil bag, drainage sheets, permeable nonwoven geotextiles, clear gravels and in-situ soils. Each material plays an important role in building the reinforced retaining system. Using geogrids can increase the soil cohesion and enhance the soil strength. The wall facing with erosion control mats stacked is capable to protect the soil from being washed away by rainwater erosion. The wall facing is easy for vegetation growth that can increase green sceneries and become as a protection layer to prevent collapse. The drainage system consists of drainage sheets, gravels and permeable nonwoven geotextiles. Nonwoven geotextiles utilized to separate in-situ soils and clear gravels make the soil not lose in the drainage layer due to rainwater infiltration, causing the drainage layer to be blocked. Compared with the use of traditional concrete retaining method and reinforced retaining method for constructing retaining wall with 20 meters in height, the concrete retaining wall requires higher construction cost, and longer construction period. Therefore, reinforced retaining wall is adopted.

3.2 *Design parameters*

In order to know the geological condition, drilling operation for geology is conducted in this project. There are three boreholes located around the abutment (BH-2-2, BH-2-3 and BH-2-4) as Figure 2 and Figure 3. The parameters of the soil for carrying out the design analysis can be estimated based on the test results and empirical evaluation.

Table 1. Soil parameters

Soil parameters			
Soil description	Unit Weight (ϒ)	Cohesive (c)	Angle of friction (ϕ)
Yellow-brown silty clay	17.7 kN/m^3	0kPa	26°
Gravel with yellow-brown soil	21.6 kN/m^3	0kPa	40°

3.3 *Section design*

The location of the abutment observed from the site is easy to be eroded by rainwater in the long term, causing the slope to be scoured and collapsed. Also, the original slope is not easy to grow vegetation, so the design of reinforced retaining wall is to protect the abutment structure and the original slope, allowing the entire structure to be completely integrated with site terrain.

The design section of the abutment (Figure 4), according to different terrain elevation, designs two to four tiers of reinforced retaining wall. Each tier is 2 m in height and is installed drainage layer with clear gravels to discharge water for whole structure. The tallest height of the structure is 20 m. On the top of the structure designs a four-way road, using wrapped-around reinforced facing to hydroseed on the surface after construction, and to prevent from losing soil. The specification of geogrid adopts is shown in Table 1.

The structure of the whole reinforced retaining wall presents a U shape (Fig. 5). The design purpose of wrapped-around abutment is to protect the abutment foundation and the native terrain. The properties of exterior vegetation of wrapped-around retaining wall allow the terrain to return to its natural state, and also prevent the native terrain from being easily scoured by rainwater.

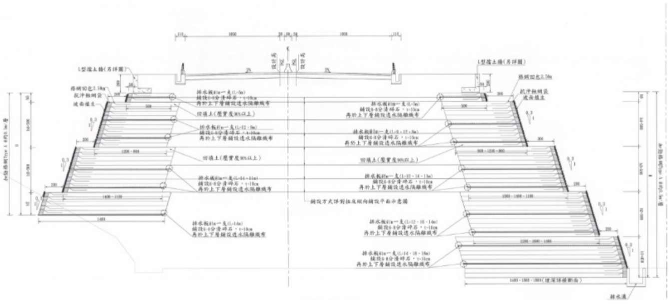

Figure 4. Standard Drawing of Reinforced Retaining Wall

Table 2. Geogrid Strength

Geotextile item	GeoGrid GG210-I
Nominal tensile strength (MD/CD) (kN/m)	210/70
Ultimate elongation (MD) (%)	8~15
Tensile strength at 5% Strain (kN/m)	≧100
Remark	Need to provide Creep Performance, Durability, Chemical and Installation Damage test report

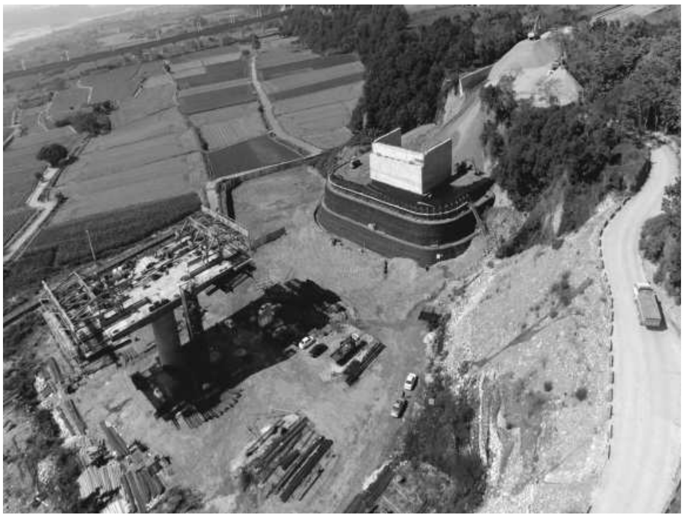

Figure 5. Site photo

3.4 *Construction process*

The total height of reinforced retaining wall is around 20 meters, divided into four layers, and each for 4.5 meters to 5 meters. Two layers under the setback are 2 m, and above the setback are 3m. Each tier is installed two layers of drainage systems, which are composed of drainage sheets with 6-8” clear gravels. Permeable nonwoven geotextiles are laid on the upper and lower layers for separation. The design of reinforced retaining wall utilizes wrapped-around facing. Lay geogrids and reserve the length to wrap around. Stack soil bags up to 500 mm and wrap around geogrids. The soil bag has anti-erosion function for avoiding soil from losing, and after the construction is completed, the surface of stacked soil bags can be hydroseeded for vegetation to grow.

1. Site preparation: Normally, reinforced retaining wall requires foundation excavation with rolling and compaction.
2. Wrapped-around facing and drainage system installation: After site preparation is completed, lay geogrids on the soil and reserve the length for facing and wrap-around. The wrapped-around height for each layer is 500 mm, backfilling and compacting twice to keep the soil compaction of 90%. First, install drainage materials with spacing according to the design. Backfill clear gravels on the foundation. Then lay a layer of nonwoven geotextile to separate the upper soil and permeable clear gravels.
3. Laying Geogrid: This project is fully laid geogrids with tensile strength of 210kN/m. The embedded depth of geogrid is varied based on the design.
4. Backfilling and compaction: Compact the soil to 25 cm with road roller; backfill the soil, and repeat backfilling and compaction until reach 50 cm of thickness.
5. Compaction test: Each layer conducts a field density test. This project adopts the nuclear densometer to test compaction; the compaction must be above 90% for acceptance, or the soil needs to conduct compaction again.
6. Second layer construction: Repeat the aforementioned steps until the wrapped-around retaining wall (the main structure of reinforced retaining wall) is completed.
7. Hydroseeding: After the reinforced retaining wall is completed, hydroseed on the wall surface for increasing green scenery and beautifying the structure.

4 CONCLUSION

In order to protect the main abutment structure, rigid concrete is used to build the abutment pier and its foundation as the main component, whereas wrapped-around reinforced earth structure is constructed in the surrounding abutment. The wrapped-around reinforced earth structure presents a U shape, which completely covers the entire abutment. The design reinforced retaining wall is thus more capable to protect the abutment form being scoured by flashy rainwater or Daija River stream, and prevent from endangering the structure. Also, it can enhance the bearing capacity and service life of the abutment. The reinforced earth structure used composite engineering method with the design height 20 meters, which is divided into 4 tiers, and each for 5 meters in height.

This reinforced structure provides the stability of bridge abutment, prevents the scour and erosion process of Dajia River, and also sustains the vehicle loads above bridge abutment. It significantly enhances the abutment’s safety and serviceability. The construction process utilizes a large number of excavation soils to backfill, which can greatly save construction costs. The exterior of the structure is completely integrated with the original scenery, due to its ability to provide a space for vegetation to grow. Overall, the structure compromises the social, economic, and environmental aspect of sustainable engineering.

5 REFERENCES

XIE SHENG Engineering Consultants Ltd. 2016. *Drawing of Shengang Interchange of National Highway No. 4*, Taichung, Taiwan.