Protection of Pier Foundation of Zhongsha Bridge at Zhuoshui River

Yu-Chi Chao
ACE Geosynthetics Enterprise Co., Ltd., Taichung City, Taiwan (sales@geoace.com)

Chih-Hao Chen
ACE Geosynthetics Enterprise Co., Ltd., Taichung City, Taiwan (sales@geoace.com)

Bwo-Fon Wu
ACE Geosynthetics Enterprise Co., Ltd., Taichung City, Taiwan (sales@geoace.com)

Chia-Wen Wu
ACE Geosynthetics Enterprise Co., Ltd., Taichung City, Taiwan (sales@geoace.com)

Yan-Shun Chen
Civil Engineer

ABSTRACT: Zhongsha Bridge located at Zhuoshui River is part of Sun Yat-sen Freeway, the traffic artery in Taiwan. Over the years its pier foundations were exposed because of continuous erosion and deposition. The farmland on the river bank adjacent to the bridge was also in great danger due to the floods in typhoon seasons. With a view to solving the problems, geotextile tubes ACETube® were used to build a multilayer structure to fortify the pier foundations and enhance the embankments with geotextile mattresses ACEFormer™ covering the surface of the geotextile tubes to prevent them from external damages. The construction method with geosynthetics reduced concrete and made good use of in-situ sand and soils which proved to be eco-friendly and cost-effective.

Keywords: erosion, pier foundation, embankment, geotextile tube, geotextile mattress

1. INTRODUCTION

The river reach near Zhongsha Bridge faced continuous impact of fluvial processes, including erosion and deposition. What's worse, the job site happened to be on the outer concave bank of the river where erosion problem was far more serious and, thus, the foundations of the piers were severely undermined by the flowing water. With the soils being washed away bit by bit, the foundations were exposed. The situation was much more life-threatening during typhoon seasons when large-scale floods with sediments struck the exposed foundations and jeopardized the drivers on the bridge. On the other hand, the muddy floods always submerged the farmland adjacent to the river and put the residents and their property in great danger. Therefore, it was urgent to fortify the pier foundations and enhance the protection of the embankments on the river banks.

2. BRIDGE (PIER) REVETMENT PROTECT

2.1 Traditional Method

Weirs (Fig.2-1) by the traditional method are commonly built to alter river flow and treated as a barrier composed of concrete blocks, among which reinforcing bars are used as connection materials. In most cases, weirs are built on certain positions based on riverbed height. One of weirs functions is to protect riverbeds and to maintain groundsill of rivers.

Other regular traditional methods are Riprap protection (Fig.2-2) and Gabion protection (Fig.2-3). Riprap is made from rock or other materials such as concrete blocks and pebbles used to armor shorelines, streambeds or bridge abutments so that it may take the form of protection. The main concern while design is weight of riprap rocks. In other words, strength of protection mainly depends upon weight of riprap rock. We must take both riprap sizes and flow velocity into consideration if Riprap method is used for protection projects.

A gabion made of galvanized steel wire is something like a cage or box filled with rocks, concrete or pebbles. Gabion walls and gabion baskets are used to stabilize the slope, riverbanks or shorelines against erosion. It is so-called Gabion protection method. Strength of a gabion depends on the steel wire with the characteristic of flexibility. When erosion occurs in stream beds or bridge abutments, gabions may deform due to outside instability and structure weight so that the gabion structure could prevent further erosion from river flow.

Fig. 2-1 Weir (photo by website)

Fig. 2-2 Rip-Rock (photo by website)

Fig. 2-3 Gabion (photo by website)

2.2 New Geosynthetic Method (ACETube® and ACEFormer™)

Revetment protection with Geotextile tube as Fig2-4, ACETube® is made of high-strength synthetic fabric. In order to maintain an environmental scenario, it is an eco-friendly way to take advantage of in-situ resources. While ACETube® is filled with in-situ soil (river sand, sea sand or sludge), it not only can stabilize the embankments, but also prevent shoreline erosion from water flow or waves. Thanks to the characteristics of high permeability, acid-alkali and UV resistance on geotextile, ACETube® can be treated as a semi-permanent structure. These advantages make long-term use possible.

Revetment protection with Geotextile Mattress as Fig2-5, ACEFormer™ is made of high-strength synthetic fabric. Two layers of woven fabric are sewn to form a tube-like structure. ACEFormer™ has various advantages, such as: high permeability, high strength, simple installation, easy to move and so on. ACEFormer™ can be filled

up with concrete at low pumping pressure and installed based on in-situ terrain to form a slope-protection or shoreline protection structure.

Fig 2-4 ACETube®

Fig 2-5 ACEFormer™

3. DESCRIPTION OF CASE STUDY

Zhuoshui River is a central canal river, located in central Taiwan. It is the longest river in Taiwan, its total length is 186.6 kilometers, flow volume is 24,000 cubic meter per second, and the drainage area reaches 3,156.90 sqm. As to its terrain, in-situ site is sandy soil and the origin is in the east in the central mountains so the eastern part is higher than the western, so is the river gradient. The length of shoreline-protection is 150 meters.

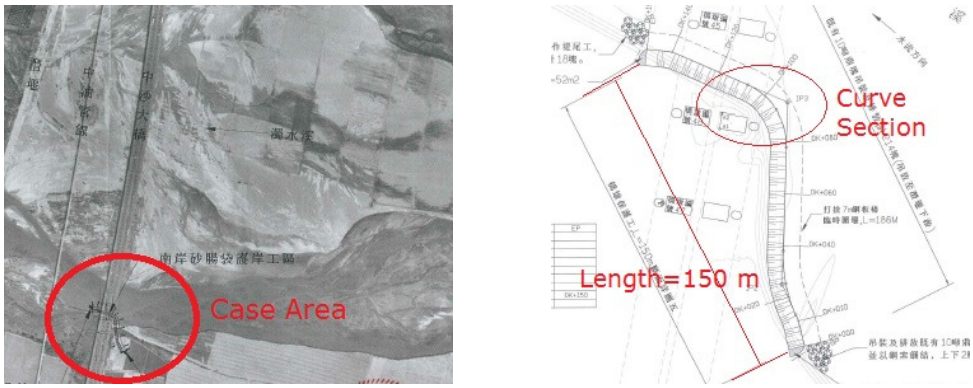

Fig. 3-1 Case Area

Before construction, the bridge abutments were built in the high beach which was directly eroded by water flow (Fig3-2). However, the beach was being eroded for a long time because there was no protection structure for the abutments. Erosion made the beach line closer and closer to the embankment. It not only affected resident safety, but also caused damage to the crops. The traditional method with gabions was adopted for the shoreline protection. In the beginning gabion-protection did work. However, long-term erosion by typhoons and flood in the downstream of Zhuoshui river lead to the high beach groundsill collapse, and consequently it produced a bridge scour around abutments and caused embankment instability. Just as Fig3-3 shows, it did cause gabions deformed due to scour, and the structure was damaged as well.

Fig. 3-2 Erosion by Flood

Fig. 3-3 Gabion Failure

4. DESIGN CONCEPT

4.1 Structure stability with ACETube®

According to in-situ terrain, analysis was made by GeoCops software to design ACETube® with circumference 8.6m and parameters were assumed based on properties of in-situ filling materials. Filling height of each ACETube® can reach 1.4m as Fig.4-1 shows. 4 layers of ACETube® must be stacked to reach required height 5.6m. Between layers in-situ gravel was paved evenly, and then covered with a layer of geotextile. Stacked ACETube® make not only the filling materials compact, but also structure stable.

ACETube® can be used for Near Natural River Construction. This case is located in a meander. Therefore construction was completed in a bend of the sinuous Zhuoshui river. It caused many difficulties under construction. More anchors were required for fixing ACETube®. Besides, pumping velocity might change according to practical conditions. As Fig. 4-2 shows, after filling, ACETube® forms a near natural bend with the local terrain.

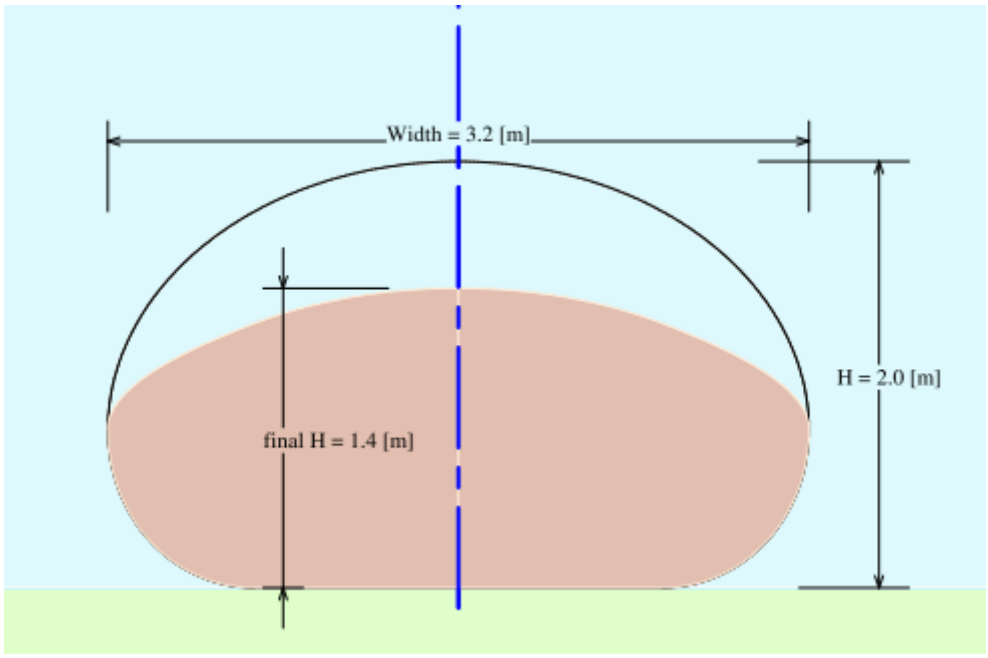

Fig. 4-1 Analysis Result (by GeoCops)

Fig. 4-2 Construction (Curve Section)

4.2 Paved with ACEFormer™ as a protective layer

After ACETube® had been filled, then ACEFormer™ would be paved on them. The paving method shows as Fig.4-3. On the top of the structure, ACEFormer™ needs fixed with anchors that were buried in 60 cm deep ditches. The top of ACEFormer™ should be installed under the foundation not less than 2m from erosion. One of ACEFormer™ Properties is permeability. Besides, after filled with concrete, the outside forms as a protective coat as an armor layer from damages of driftwood. The most important thing is that ACEFormer™ not only can protect groundsill of the bridge abutments, but also promote safety of the structure. Filling material of ACEFormer™ is concrete mortar which can strengthen impact resistance from outside collision damage. After construction, as Fig.4-4 shows. The structure obviously can prevent from flood erosion. As a result, it also makes sediments more effectively on the riverbed. The additional value is to make river improvement easier.

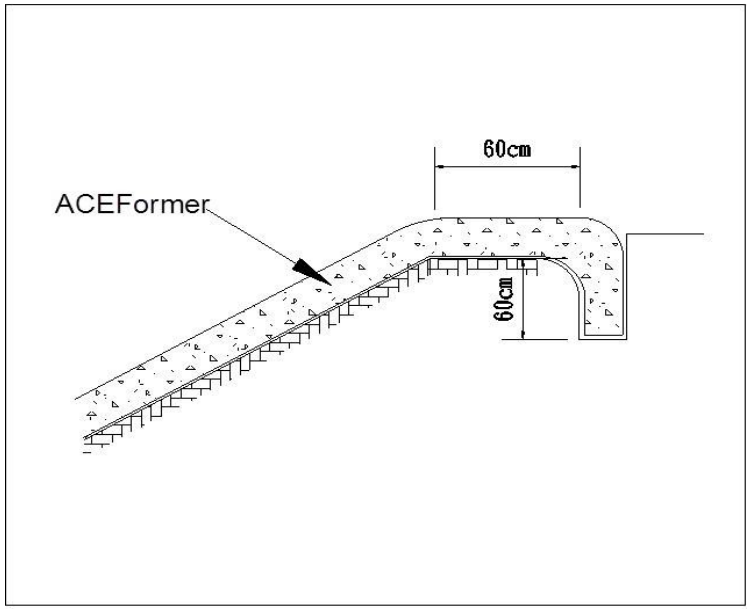

Fig. 4-3 ACEFomer™ Anchor

Fig. 4-4 After Construction by ACEFormer™

5. CONCLUSION

All in all, the combination of these two materials provided more reliable protection to the pier foundations and the embankments and, as a result, greatly and effectively improved the structural safety of the bridge. The foundation improvement is part of the project started from 2012 to this day. The authorities budget for riverbank protection and maintenance every year with the purpose of ensuring the safety of neighboring residents and drivers.

Both ACETube® and ACEFormer™ have been used since the very beginning of the project because of their eco-friendliness and cost-effectiveness. Structures made of these innovative flexible geotextile materials make better use of in-situ sand and soils than those made of concrete. It, on the one hand, greatly reduces greenhouse gas emissions as well as substantially increases environmental sustainability and, on the other hand, allows construction to go on even with limited budget.

Meanwhile, the flexibility of these materials makes them adaptable to different kinds of landforms and site conditions. It not only makes construction much easier, but also helps the structures co-exist with the environment as Fig5-1. Even typhoons that bring disastrous floods were not able to cause any damage to them.

Besides, the completed structures are good for aggradation. It shows erosion is under control. On the fertile newly-formed land even luxuriantly grows vegetation that makes the site blend with the surroundings.

Fig. 5-1 Currently Landscape

REFERENCES

Federal Highway Administration (1989). Design of Riprap Revetment, Hydraulic Engineering Circular No. 11.

National Freeway Bureau (2000), The Study of Zhuoshui River Scour Monitoring.
Taiwan Construction Research Institute.

Federal Highway Administration (2001). Evaluating Scour at Bridges (Fourth Edition), Hydraulic Engineering Circular No. 18.

Dov Leshchinsky and Ora Leshchinsky (1995). Geosynthetics confined pressurized slurry (GeoCoPS); supplement Notes for Version 1.0, US Army Corps of Engineers. and Nicolon Corporation US.

Ministry of Transportation and Communications (2011). Design Code of Bridge Protection.

Shelly Wu, Amy Tang, Lili Yang(2012). Geotextile Tubes in Groyne Structure Repair and Riverbank Protection. GeoAmericas 2012, Lima, Peru.