Provincial Highway No.17 Shuangyuan Bridge Reconstruction Project

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ABSTRACT: On August 8, 2009, Typhoon Morakot invaded Taiwan, historical volume of rainfall dropped on southern Taiwan, amazing single-day rainfall over 1,000 mm and the cumulative rainfall of 2,500 mm or more, creating a new record of rainfall in Taiwan. During Typhoon Morakot attacking, it caused Taiwan's largest flood in last 100 years, half of the island was submerged in water, resulting in a number of bridges were washed away, and countless railway and highway were disconnected, many mountain villages were destroyed overnight. Loss of life, property and agriculture is extremely miserable. There are over 600 people killed in this tragedy. The total losses and damage of agricultural products and civilian infrastructure are estimated up to 16.4 billion NT dollars. This event is historically called as "Eighty-eight Flood". Because of large accumulated rainfall on Kaoping Hsi upstream, Provincial Highway No.17 Shuangyuan Bridge, located at the downstream of Kaoping Hsi, was collapsed around 2:00 AM on August 9. The flow rate was up to 34,000 cubic meters per second, which was over 200 years flood return period of Kaoping Hsi. In addition, due to the impact of flowing wood, Shuangyuan Bridge on Kaohsiung side was washed away about 460 meters overnight (northbound P1 ~ P14 and southbound P1 ~ P16). Although the bridge management unit closed the bridge immediately, still ten people in six cars were killed in this bridge collapsing accident.

KEYWORDS: Typhoon Morakot, Shuangyuan Bridge, Reconstruction

1. INTRODUCTION

Shuangyuan Bridge is situated in the junction of Kaohsiung City Linyuan District and Pingtung County Sinyuan Township. The total length of the bridge is 2082.8 m. The upstream side of the original bridge was built in 1974, while as the downstream side of the bridge was extended in 1981. After the completion, Shuangyuan Bridge was the main traffic route for southern part of Kaohsiung and Pingtung areas, and also serviced as the economic artery for the coastal town of Pingtung area. Therefore, the bridge rehabilitation or reconstruction was urgent and could not be delayed. The Ministry of Transportation and Communications (MOTC) instructed Directorate General of Highways to start the reconstruction work before the end of 2009. Within a short time, the budget for reconstruction and rehabilitation project was established; the design, supervision and contracting tasks were done. The Directorate General of Highways, MOTC collaborated with the design team to overcome various difficulties and to complete the detail design in 2.5 months. The reconstruction project was successful for bidding on December 22, 2009, which let reconstruction works start before the end of 2009 in order to fulfill the deadline of the mission. The main bridge reconstruction work was conducted day and night, around the clock. The first phase, northbound line, was completed and opened to traffic on September 4,

2011. Premier Wu participated the opening ceremony, and announced that the whole bridge should be completed on December 25, 2011.(Figure 1) Via the hard working among Directorate General of Highways and other relevant unit teams, the southbound line was completed on December 23, 2011. And it was opened to traffic on next day December 24, fulfilled the mission within the time limit. During the reconstruction and rehabilitation period, there were different comments and opinions. The central and local governments had different point of views, too. The planning and design process were not very smooth at beginning. Even President Ma was unlikely to solve the odds, and gave a special instruction to MOTC to communicate with two county governments and elected representatives to decide the bridge configuration. The construction of temporary bridge should be decided through an expert assessment. This paper will introduce not only the planning and design contents for entire rehabilitation and reconstruction works, but also explain the rebuild team how to resolve various disputes within a limited time, the program's decision-making principles to achieve the mission. The spiritual and practical experience of the entire reconstruction works can be shared as an example for a similar disaster in the future, so that future disaster prevention and reconstruction management can follow such experience.

Figure 1 New Shuangyuan Bridge opens for service

2. CAUSE OF BRIDGE COLLAPSING AND BRIDGE MANAGEMENT SYSTEM DISPUTE

Shuangyuan Bridge has been built for more than 30 years. From the completion to the time of bridge collapse, there were a lot of efforts for the maintenance of the bridge. The bridge was situated near seaport, the maintenance record of the prestressed concrete girder superstructure started from 1991. After the Typhoon Toraji in 2001, the more serious of the river bed decline, exposing pile foundations in the deep water canal, coupled with the beam salt water damage became a growing problem. So the reconstruction of Shuangyuan Bridge superstructure and reinforcement of bridge foundation protection were taken in place and completed in June 2003. The project was named "Provincial Highway No.17 Shuangyuan Bridge local girder bridge panel removal of reconstruction and bridge piers basis of facilities based project." This task was mainly for the superstructure demolition and reconstruction of total 31 spans, substructure of the piers, P5~P14, P22~P25, and P30. The downstream addition of four 90cm ∮ cast-in-place with full casing RC piles in 50m was designed for strength reinforcement.

After studies by scholars and experts of the reason that Shuangyuan Bridge collapsed, there is still the complexity of the possible reasons. Professor Lin reasoned that the Typhoon Morakot brought on flooding beyond the bridge’s of the original flood tolerant design amount, the bridge had reached the unstable phase extent which rendered collapse. However, this bridge had been reinforced and the bridge erosion assessment in years after the retrofitting. The inspection records of bridge were not indicated that there were any safety problems. The safety of the bridge was concerned O.K, and had

not been characterized as the old provincial highway dangerous bridges. But still, during Typhoon Morakot overnight invasion the bridge was washed away up to 450 meters by the torrent without warning. The society and the Investigation Bureau were requested that the current warming system for bridge collapsing needed to be reviewed, since there were repeatedly bridge collapsing events occurred without warning and caused heavy casualties of road users. Whether the system and method was only a mere formality, or the contents met the actual needs, required further study and improvement.

3. PLANNING AND DESIGN OF THE SHUANGYUAN BRIDGE

3.1 Design problems and countermeasures

There was problem for the scheduling of surveying and geological investigation. The contract of project was signed on October 16, 2009. The design work should be completed in 62 days and the design schedule was tight. However the surveying task should take 30 days to finish and boring log drilling work was required 80 calendar days to complete. So the design could only first be amended in accordance with the new measured data. The final design work was justified according to the later on completed boring log data and survey information. It was specified in the contract and allowed the design change in order to complete the project on schedule. The design consulting firm was fully cooperated. With the mobilization and coordination, the design firm shortened design time to 42 days to complete the detailed design results on November 27, 2009. When bridges were destroyed, the remains of the old bridge may affect the pier location and construction. The design firm used sonar especially to measure riverbed depth, scour depth and siltation situation as the basis information for foundation elevation and the length of the pile. Ground-penetrating radar detection was used to detect the riverbed in order to find out the probable location of collapsed old bridge structures as the reference for route planning.

3.2 Planning and design

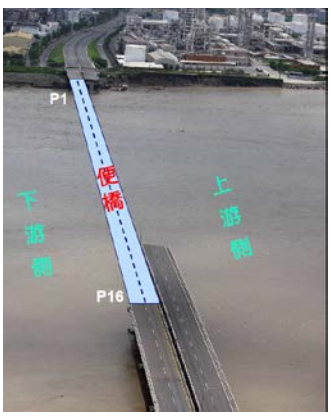
The content of the project is to build a new bridge on the upstream side of the original bridge which can fulfill the requirements of flood control. Fast construction method, large span bridge, good aesthetic configuration, and high safety priorities are set up for the project. The main bridge is 2,178 meters long and approach roads are 340 meters on, Kaohsiung side, 382 meters on Pingtung side, the total length of the project is 2,900 meters. The design of main bridge adopts long span arrangement and main span length is 96 to 120 meters, The number of piers are reduced from 67 piers for the old bridge to 19 piers for new bridge, which increasing the cross-section of water passing o improve the flood control capacity. The main design schemes are summarized as follows.

(1) route alignment

The advantages and disadvantages of different alignments are as follows:

On downstream side: conflict to the broken bridge wreckage, alignment is poor, standard of service is lower.

Using part of the original bridge site: less demand for land, there is the danger of conflict with the old bridge wreckage, special consideration is needed for adjacent construction, construction period is long, and the span arrangement is limited



by the old bridge foundations.

On upstream side: away from the old bridge wreckage and temporary bridge, easier for the construction, alignment is good to enhance service quality, short construction time; the bridge span arrangement is flexible.

A comparative assessment and evaluation of the options had been carried out, and decision was made to build new bridge at the upstream side of the old bridge. The two rehabilitation schemes are compared in Table 1. The Client selected option one for the final design scheme.

Option One: upstream side, completely deviates from the old bridge to locate the new bridge, as shown in Figure 2.

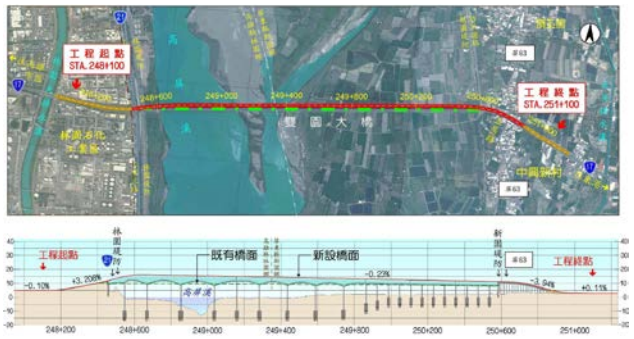


Figure 2 Option one layout, full offset from old bridge

Option Two: upstream side, partially deviates from the old bridge to locate the new bridge, as shown in Figure 3.

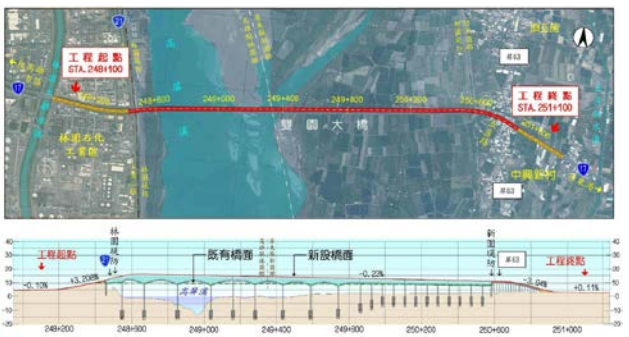


Figure 3 Option two layout, partial offset from old bridge

Table 1 Route Option Evaluation

Items	Option 1 (full offset)	Option 2 (partial offset)
Alignment	Curve radius: Kaohsiung Linyuan end, R=600m and R=900m. Pingtung Xing end, R=500m.	Curve radius: Kaohsiung Linyuan end, R=950m. Pingtung Xing end, R=400m.
Widen for insufficient sight distance	1.Vd=80km/hr : Pingtung Xingyuan side R=500m to Kaohsiung, inner shoulder need to widen 1m. 2. Vd=70km/hr : Pingtung Xingyuan side R=500m to Kaohsiung, inner shoulder no need to widen.	1.Vd=80km/hr : Pingtung Xingyuan side R=400m to Kaohsiung, inner shoulder need to widen 2m. 2. Vd=60km/hr : Pingtung Xingyuan side R=400m to Kaohsiung, inner shoulder no need to widen.
New road of right (including river land)	New road of right approximate 54,665 m^2, no need for change of urban plan, Pingtung Xingyuan side uses more land.	New road of right approximate 44,660m^2, no need for change of urban plan, Pingtung Xingyuan side uses less land.
Construction Difficult	Upstream side for new bridge, fully offset from old bridge, easy to construct	Overlapping part of old bridge, difficult to construct
Construction Time	Short	Long

(2) Design scheme of main bridge

The project had to be completed before the deadline. Since the deep trench region across the bridge is about 1,200m. It is impossible to avoid flood season during construction. The superstructure and substructure should be built at the same time to shorten the construction time. For increased span length and lightweight, reducing the number of piers and the number of foundation piles, the steel box girder is selected. The main bridge section is 26m in width, and bridge height is about 16m. There are two steel box for superstructure, the girder depth of 2.6 ~ 4.2m. Orthotropic steel deck and Guss asphalt concrete pavement are used. The span arrangement is 105 +2@120 +96 +3(96+2@120+96) + 105 +2@120 +96 = 2,178m, and the substructure is 200cm § cast-in-place with full casing RC piles. The cross section is shown in Figure 4.

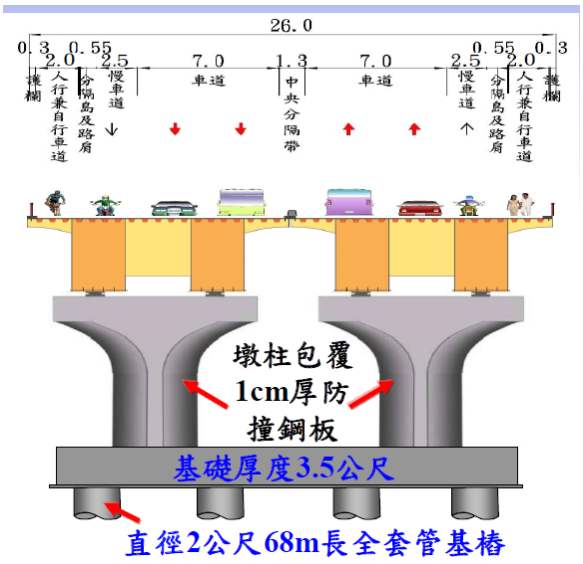


Figure 4 Cross section of main bridge

(3) Design scheme of approach bridge

The span arrangement of approach bridge is (26+30) + 2(3@31) = 242m. Due to the existing bridge span arrangement and girder depth limit, the prestressed hollow plate girder bridge is adopted for superstructure (ground staging method), with girder depth of 1.2m. And the substructure is 150cm ϕ cast-in-place with full casing RC pile. The cross section is shown in detail in Figure 5.

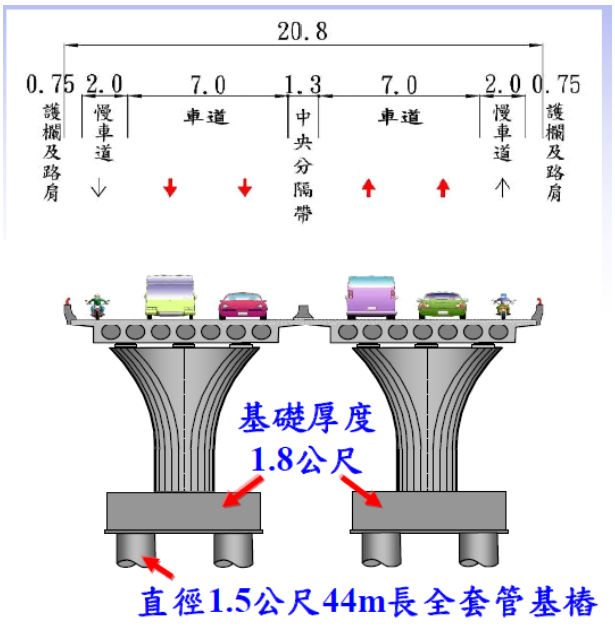


Figure 5 Cross section of approach bridge

4. PROJECT CONTRACTS STRATEGY AND SCHEDULE

The MOTC had set to start the construction in 2009 and to complete the project in two years. (i.e. by the end of 2011). Therefore, the design process was fairly tight, and the construction had to start in advance even the drilling data had not yet been completed. The authority that was in charge of reconstruction decided to break the traditional design process, a basic design results were used for contracting. The design firm carried out the design in accordance with the existing information. The boring log data was available only after the construction and used for detail design check, later on, using the checking result for changes of design. All these were put into the tender notes, so that in the construction process the contractor had to deal with all the design changes.

This project is considered the traffic operation with the temporary steel bridge while dismantling the old bridge; therefore, the construction is divided into three stages. First stage, there are 480 calendar days to complete the northbound bridge, and diver the traffic of temporary bridge to the new completed bridge. Second stage, there are 250 calendar days after the completion of first stage, all the design works have to finish (except the third stage work). There are 30 calendar days after the completion of the second stage for third stage. The contractor should complete the as-built drawings and the final accounts document, and submit to the Client.

5. SUPERVISION AND CONSTRUCTION

The contract of Shuangyuan Bridge reconstruction sets a deadline for project completion, so the tight

deadline becomes the greatest challenges of this project. The new bridge is designed to cross the Kaoping Hsi. During the early phase of construction, there are up to six pile drilling machines on job site in the non-flood season. Large-span steel box and orthotropic steel deck for superstructure are adopted. The total weight of steel is about 34,800 T. All the steel is manufactured within one year. The average monthly required amount was about 3,000 T, which is almost a full production capacity for a single factory. Therefore, the steel factory turned down other orders, and put into the production line only for this project. There is a total of about 5,000 GUSS asphalt concrete used in the project. The construction scheduling was on raining summer season, there were frequent typhoons and rainfall. Due to the characteristics of materials and construction methods, once the job site experienced rainfall, all the work had to stop; in addition, extra few days are needed to carry out site finishing and dry. So as to ensure that the project be completed on schedule, the Contractor grasped every clear gap of no rain and work in full effort in order to complete the pavement work.

There were five typhoons in 2010 and 2011 during the reconstruction process. The worst one was Typhoon Fanapi on September 19, 2010, while the invasion of typhoon brought severely damaged along with heavy rains, resulting in rising Kaoping Hsi water. The constructions of temporary bridge between P2 ~ P4 piers and some steel sheet pile were destroyed. The restoration work of the construction site is time-consuming, and the part destroyed steel sheet pile is buried beneath the riverbed, resulting in delays in the construction operations. Fortunately, the owner, design firm and supervision units took many efforts to work with the contractor. After consultation with the contractor, the contractor was willing to invest more resources of manpower and construction machinery, and worked day and night. After about three months, the construction schedule was gradually caught up.

Since the new bridge is across the Kaoping Hsi, P1 ~ P12 pier are situated in the water channel and water flow is more rushed. Therefore the construction is very difficult. Pier P1 is most difficult to construct. The pier is conflict with new embankment built by the Seventh River Management Offic. The Client, design consulting firm, and construction supervision unit are constantly discussed with the Seventh River Management Office. Let the foundation of pier P1 construct first, then the embankment. And the gap of P1 foundation can be utilized for flood control with certain structural reinforcement. During the process, both parties maintained close consultation and communication.

6. CONCLUSIONS

Characteristics of this project are using large-span steel girder to cross Kaoping Hsi, and artistic lights and railings are designed, to integration into the beautiful local water and geographical landscape. The LED color projection lights will illuminate Shuangyuan Bridge at night, dotted with some different style, this new Shuangyuan Bridge landscape in the future will become a new landmark of Kaohsiung and Pingtung coastal areas.

Since the schedule of this project is tight, and construction is not easy, all the units have put their efforts around the clock. The 2,900 meter long Shuangyuan Bridge was opened to traffic in two years after the start of construction. The reopening of Shuangyuan Bridge is not only an effective solution

to Pingtung and Kaohsiung traffic inconvenience, but also is helpful for the passage of the residents of Kaohsiung and Pingtung areas. And the social perception is tremendous enhanced. Moreover, a safe passers-line is provided and society cost is saved. In the construction process, the execution ability of the work team is well confirmed by all levels of senior officers and gets good social comments. The design team is awarded a medal of "The mission is accomplished and the performance is outstanding" by MOTC. The experiences of reconstruction work are worth sharing, and can be available in the future. It can service as a useful reference for future disaster prevention and reconstruction management.

Figure 6 Shuangyuan Bridge opening ceremony