Reconstruction of Provincial Highway No. 13 Hou-Feng Bridge Damaged by Typhoon Sinlaku

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ABSTRACT: Typhoon Sinlaku brought a heavy rainfall on September 14, 2008. The P2 pie of Houfeng bridge was washed away by rushed Tachia Hsi river water. It caused part of the bridge deck collapsed and the traffic from Houli and Fengyuan was interrupted at once. In order to resume the traffic as soon as possible, Directorate General of Highways, MOTC planed a rehabilitation strategy which was including short-term rehabilitation scheme adopting temporary access road, intermediate rehabilitation scheme using temporary access bridge and long-term rehabilitation scheme building permanent bridge. The main purpose of the plan was to reduce the social cost and improve the traffic safety in typhoon season.

The bridge was under reconstruction when the disaster occurred. Because of the disaster, the original construction method using half-half construction in three stages keeping the traffic in service was intergraded to one construction stage since the bridge was collapsed. The construction time was shortened from 973 days to 540 days. The new Houfeng bridge was opened to traffic part by part. After 9 months, a 440 meters long 4 lines in two ways partial new bridge was completed for service. After 20 months, the whole bridge with 440 meters 10 lines in two ways was finished to fulfill the long-term rehabilitation goal.

KEYWORDS: Typhoon Sinlaku, reconstruction, temporary access road, temporary access bridge

1. INTRODUCTION

Provincial Highway No.13 STA.65K+629 Houfeng bridge serviced as an important traffic route in between Taichung County Houli and Fengyuan Towns for crossing the Tachia Hsi, Other than the railroad bridges and National Freeway bridges, Houfeng bridge was the only highway bridge that across the Tachia Hsi in the region more than 10 km of the upstream and downstream. At the same time, there was a ramp for the National Freeway No. 4 in the southern end of Houfeng bridge, therefore Houfeng bridge became the access route passing through the Tachia Hsi to National Freeway No. 4 in Houli area. (Figure 1.1).

Due to numbers of typhoon, heavily rainfall caused the riverbed eroded and continued to decline. Part of the caisson foundations of old Houfeng bridge were serious exposed, resulting in the structural safety problems.

Furthermore, the alignment of National Freeway No.4 intersection was not well designed and caused traffic jams. Adding a ramp was needed to improve the traffic flow. Together with new construction of the 10m width of the ramp and 41 meters width of main bridge was constructed and completed which was effectively improved the traffic situation and to promote local economic development.

Figute 1.1 Houfeng bridge location map

On September 12, 2008, during Typhoon Sinlaku invasion, it caused a serious disaster for Taiwan. From 12th 0:00am to15th 8:00pm, according to the Central Weather Bureau record, there were 1,600 mm rainfall in Taichung County which was ranked as No.1 in Taiwan. The foundation of P2 pier of Houfeng bridge was void for scouring at around 7 pm on September 14, resulted in a bridge deck collapse in north bound lane. And the traffic was disrupted (Photo 1.1). Directorate General of Highways, MOTC immediately built an emergency temporary access road on the downstream side of the bridge site about 100 meters away to reconnect the traffic cross the river. Later on, an emergency temporary access bridge was constructed for the traffic demand. (Figure

1.2 & 1.3)

Photo 1.2 Houfeng bridge collapsed in Typhoon Sinlaku

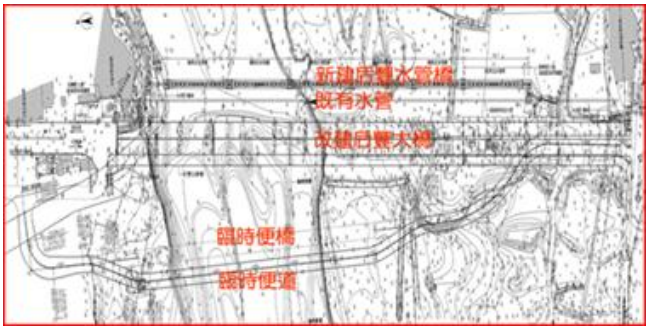

Figure 1.2 Plan view of the rehabilitation project

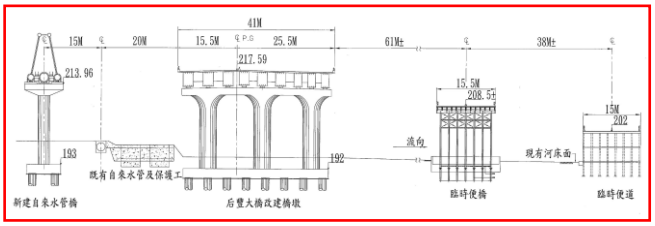

Figure 1.3 Cross section of the rehabilitation project

2. PLANNING AND DESIGN CONCEPT OF THE TEMPORARY ROAD ON THE FIRST STAGE

2.1 Goal of first stage

There was an emergency traffic reopening demand for Fengyuan and Houli, especially to reduce the detour time for motor user.

2.2 Considerations:

(1) Sufficient space for temporary access road and old main bridge in order to avoid the interaction effects of water erosion and reduce the interference with each other construction.

(2) Selection of convergent position, considering the length, right of way and traffic operation at intersection for temporary access road.

(3) Alignment of temporary access road and temporary access bridge road were considered together.

(4) Enough traffic lanes to maintain a smooth traffic flow.

(5) Adequate road elevation to maintain a certain demand of flood control section, and the cost of project was not too high.

(6) Proper flood control capacity of road foundation for the following flood season.

(7) The height difference was up to 8m for the convergence of the embankment and existing bridge, therefore there was a lot of earth filling volume.

(8) The materials were selected that they could be collected from the market in time, in order to build the temporary access road within 21 days after the construction begun.

2.3 Countermeasures

(1) Temporary access road and main bridge was located about 100m away in order to avoid mutual interference.

(2) On the northern end of bridge, the temporary access road was directed to the riverbed at abutment, across the deep channel of river and reconnected to the southern end of old bridge in order to keep traffic of National Freeway No.4 intersection running smoothly. There was no involving the private right of way, but the drawback was the high volume of earth filling.

(3) Temporary access bridge connected to the approach road of temporary access road on both sides. Alignment of temporary access road was pre-planned for temporary access bridge connection consideration.

(4) Two-way two-lane roadway was adopted. Total lane width was 15m, and limited to 10 tons or less vehicular traffic to ensure the safety.

(5) The flood cross-section across the deep trench was planned 140m wide. Both sides of the approach road used the containers filled with earth to improve its anti-flood capacity. The first layer of temporary access road had 300cms flow capacity as the warning value. It was estimated about 2 hours for flood level arisen from the first layer to the second layer for the closure. The total flow capacity was approximate 650cms, and the return period was less than 1 year.

(6) Considering the temporary access road was constructed in flood season, H-shaped steel was adopted for its quick drilling into the gravel riverbed for road foundation.

(7) Steel container filled with riverbed material combined with steel wire strengthening was used for over high embankment to overcome the earth filling construction problem for the existing bridge connection. Moreover, it could effectively shorten the construction time.

(8) Cast-in-place reinforced concrete box culvert did not match the construction schedule requirements, so the main

components were using steel pipe and the market available RCP pipe. (Photo 2.1)

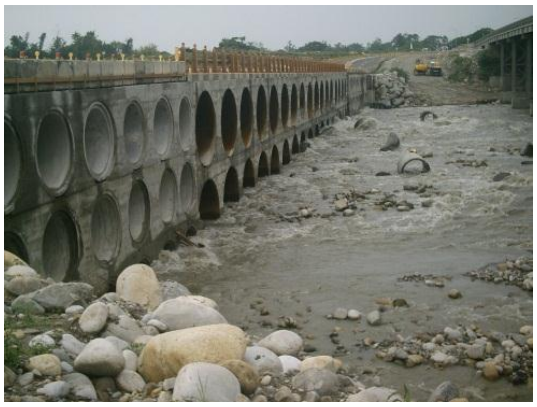

Photo 2.1 Temporary access road built by steel pipe and RCP pipe

The old Houfeng bridge was interrupted on September 14, 2008, and the temporary access road started to construct on October 5. At the same year, the traffic was reopened on October 26. It took only 21 days to complete a 700 meters long and 15 meters wide, two-way four-lane temporary access road. (Photo 2.2)

Photo 2.2 Completed temporary access road

3. PLANNING AND DESIGN CONCEPT OF THE TEMPORARY ACCESS BRIDGE ON THE SECOND STAGE

3.1 Goal of second stage

To improve the cross section of temporary access road for flood consideration and to reduce the social costs and risks of the bridge closure in the flood season.

3.2 Considerations

(1) Keeping an adequate distance between temporary access bridge, temporary access road and old main bridge during construction to avoid interaction of the river water.

(2) Temporary access bridge should have a proper cross-section and elevation for flood passing.

(3) Basic needs of flood resistant for foundation

(4) Bridge girders, bridge elements and bridge deck should be rapid constructed.

3.3 Countermeasures

(1) Temporary access bridge was 61 meters away from the main bridge, 38 meters away from the temporary access road. Temporary access road was functioned as riverbed protection work to protect the temporary access bridge.

(2) 300 m temporary access bridge across the main river, the elevation of bridge deck was suitable for up to 100-year flood return period to fulfill the flood control needs.

(3) Considering the duration factor, is still adopted to quickly enter the gravel riverbed H-shaped steel as the basis for flood.

(4) Simple construction, fast multi-span simply supported steel I girder bridge, and waved steel sheet with RC bridge deck system were used.

Temporary access bridge made in steel was started to constructed on October 15, 1997 and was completed by December 20 of the same year. It took only 66 days to

construct the 300 meters long and 15.5 meters wide, two-way four-lane steel bridge for 15 tons of heavy vehicle traffic. (Photo 3.1)

Photo 3.1 Completed temporary access bridge

4. PLANNING AND DESIGN CONCEPT OF MAIN BRIDGE RECONSTRUCTION

4.1 Purpose of bridge reconstruction

(1) Houfeng bridge crossed the Tachia Hsi, the foundations of old bridge were severely eroded. Long-span bridge with deep foundation was adopted for flood damage prevention and, lifecycle extension.

(2) This project is important provincial highway bridge connection between Fengyuan, after the completion of the deck a total of 10 lanes, open environment, good ride comfort, and effectively eased the solution of the country, four intersection congestion situation.

(3) Chelungpu fault and Tuntszchau fault are active faults, away from this project site about 3 to 4 km, continuous beam, seismic design and seismic isolation bearing, were adopted the effective seismic protection.

4.2 Considerations

(1) Modifying the length of bridge to pass the main river channel, and the new bridge should be able to sufficient control the flood.

(2) Enlarging the bridge span length to reduce water blocking and using deep foundations to have adequate anti-flood capacity.

(3) Using half-half construction method to shorten the construction time.

(4) Fulfilling the seismic demand.

(5) Improving the traffic condition at National Freeway No.4 junction.

(6) Establishing the reconstruction strategy after bridge collapsed.

4.3 Countermeasures

(1) The original plan was only 280m long reconstruction, P1~P6 pier, in the main river channel. However through a detailed hydraulic analysis, the original plan was not able to meet the needs of the flood control section. It was finally approved the alteration of 440m long reconstruction, P1~P10 pier, and additional ramp, P11~A2, in PCI girder. (Figure 4.1, 4.2)

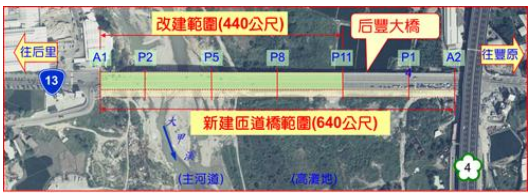

Figure 4.1 Plan view of Hou-Feng Bridge

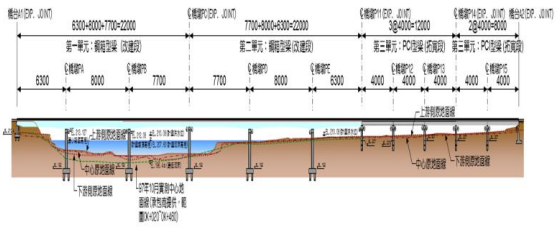

Figure 4.2 Elevation of Houfeng bridge

(2) Larger span of 80m was adopted for new bridge, the number of piers was reduced from 10 piers to 5 piers. The hydraulic analysis showed the maximum scouring depth might be up to 25 meters; therefore, 200cmø cast-in-place with full casing pile was designed for pier foundation.

(3) Varied depth steel box girder bridge constructed in 3 stages was designed to shorten the construction time. Since the superstructure could be fabricated while the substructure was under construction

(4) In the seismic design, Houfeng bridge not only met the seismic design specification, but also used high damping rubber bearing (HDRB). (Photo 4.1) By using the HDRB the seismic force can be distributed to all the piers to reduce the impact of seismic forces on a bridge. Elasticmeric bearing support has three advantages: (a) the seismic force acting on each pier was reduced, so that bridges can be multi-span continuous; (b) under earthquake, the elasticmeric bearing can appropriately extend vibration period to reduce the seismic force; (c) by adjusting the horizontal stiffness of elasticmeric bearing, the level of force for each pier could be also adjusted. Moreover, the usage of high damping rubber bearing has three more advantages: (a) the normal horizontal force from elongation or shortening can be reduced; (b) less vibration caused by normal applied load (live load, wind load, etc.); (c) considerable energy absorption (damping) function can reduce the seismic force, effectively reduce the number of piles, the size of the pile cap, project costs, construction time and the scouring.

Photo 4.1 High damping rubber bearing

(5) In accordance with the traffic analysis, if Houfeng bridge could have a right turn ramp onto National Freeway No.4, the congestion situation of the southern end of the bridge could be effectively relieve. Therefore an additional 10 meters wide ramp bridge was designed.

(6) The original three-stage half-half construction procedure was adjusted for one stage of construction to shorten the construction time by the design consulting firm. Directorate General of Highways, MOTC wished to complete the upstream side of the bridge before the next flood season to provide reliable local transportation system. Therefore Directorate General of Highways, MOTC actively coordinated the contractor to complete the upstream side of the bridge at the first stage. The design consulting firm was handling the design changes. The downstream side of the bridge as well as the widening part of the bridge was completed at the second stage.

The main bridge construction was started on October 20, 2008. By all the effort, the first stage traffic was opened on

June 29, 2009. Only eight months of construction, 440 meters long, 15.5 meters wide, two-way four-lane steel box girder bridge was built and opened to service for all kind of vehicles.(Photo 4.2) The second stage was completed on July 23, 2001 for the remaining 440 meters long, 15.5 meters wide, four-lane steel bridge and 640 meters long, 10 meters wide, two-lane ramp. (Photo 4.3)

Photo 4.2 Serviced Houfeng ridge at first stage

Photo 4.3 Completed Houfeng bridge

5 Conclusion

Due to the limitations of topographic conditions of collapsed Houfeng bridge and Tachia Hsi and geological characteristics, flood season concern as well as government policy, temporary access road and temporary access bridge were planned and designed to reopen the traffic as soon as possible. However the planning and design process experienced a certain difficulty, it could be summarized and served as a teaching lesson for future similar situation.

- Limited planning and design time for temporary access road

September 14, 1997, after the bridge collapse, traffic disruption, Directorate General of Highways, MOTC assessed that the downstream side bridge was not able to be repaired. It was immediately proceed the planning of temporary access road. All the tasks, planning, design, review, approval bidding were done within only 14 calendar days, even the holiday was still work to modify the contract documents and review the design. Temporary access road construction started the same year on October 5, and opened to traffic on October 26. It took only 14 days for 700 meters long, 15 meters wide, two-way four-lane temporary access road to be constructed. Feasible type of temporary access road and construction method should be studied and prepared in advance, so that the authorities could make a quick decision in the disaster condition.

- High initial cost for temporary access bridge

15m long H-section steel piles were used for the temporary access road foundation to have sufficient anti-erosion capability. Steel pipe culvert and RCP pipe were adopted for easy construction and flood passing requirement. Although H-section steel piles and steel pipe culvert could be recycled, the initial cost was still high. For the flood concern, the diameter of existing RCP pipe

in the market was not enough for flood control, but the cost of steel pipe culvert was high. More detailed considerations and planning were needed to casting large diameter RC pipe in a short period of time. Due to the construction schedule and work site geological condition, a hard layer of gravel, relatively high cost H-section steel piles were adopted. However, in other geological considerations, cheaper PC piles could be used to reduce the costs.

- The detour road at both ends of the embankment was not built in pile foundation. Containers were adopted for the reinforcement, and they were not able to prevent the flush-away by the flood. (Photo 5.1) However, there was no better method to avoid the problem for this section of detour road.

Photo 5.1 Container embankment

- The temporary steel bridge was difficult to overcome the erosion problem, therefore the bridge closure was inevitable

Since the flow of Tachia Hsi was so fast, H-section steel pile foundation was continued to be hollowed (Photo 5.2). Based on safety concern, during the typhoon the temporary steel bridge was needed to be closed. The advantages of temporary steel bridge were no requirement to repair the road embankment sections, both sides of the road embankment sections were easily washed away after typhoon. The staff was under a tremendous pressure for bridge closure and tried to repair the road within a few days.

Photo 5.2 Temporary steel bridge with H-section steel pile

- The reasons for building temporary access road and temporary access bridge in different stages were mainly because of the heavy traffic and inconvenient detour. The authorities had estimated the social costs of one-day closured to about NT 4.83 million. The initial cost of adding a temporary access road was less than half of the social costs. Furthermore, it was priceless for the Government to resume traffic earlier and to show the executive ability in order to get the deep affirmation by the residents.

- The temporary access bridge was evaluated to attach water pipe temporarily when the upstream water pipe destroyed, to ensure that water usage in Taichung.

- It was required for design firm and construction supervision units in close consulting with the contractor. The inter-unit

communication, supervision units and contractors with decision-making authority personnel active involvement, even on-site supervision’s morale promoting, all about were the important factors for the project completion in each stage.

- The foundation of temporary access road was utilized as a submerged dam to protect the foundation of new Houfeng bridge and Houfeng water-pipe bridge in the future. This could enhance the value of temporary access road.