Post Typhoon Morakot Disaster Railway Reconstruction

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Abstract

Typhoon Morakot hit Southern Taiwan on Aug. 8, 2009 with ultra-heavy rainfall (1402mm). Due to high tide, the flow of Lin Bian River was unable to flow out into sea and the water flow crossed over the sea dike. The flood caused many breaks along dike north of Lin Bian River and the northern gate of Lin Bian River Railroad Bridge (3 meters at both left and right side) and 2 piers and 3 openings were blown off, plus 120 meters of track base north of the bridge. The railway traffic was interrupted.

The restoration work of the rail road was divided into 3 parts:

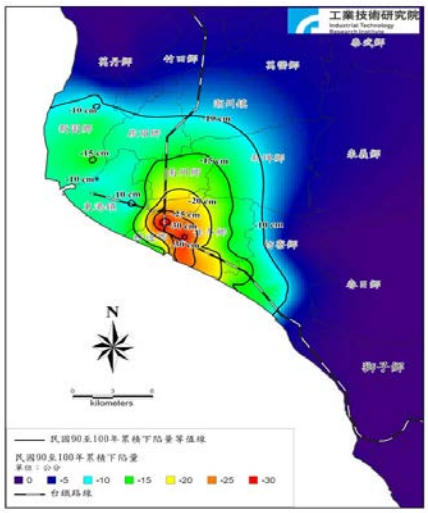
1) Feeder Bus Service: TRA set up feeder bus stations at Fangliao Railway Station and Nanzhou Railway Station to transport passengers northern bound and south bound with fixed schedule every day.
2) Restoration of Bridge Piers: This part include refilling of track base, restoration of piers, track work and electric works
   - Emergent survey on Aug. 9, 2009
   - Set up restoration budget and contracted out on Aug. 14, 2009 and commenced work on Aug. 15, 2009
   - Working period was set of 150 calendar days (Phase 1 120 days, with Dec. 30, 2009 targeted to resume the traffic and 30 calendar days for demolishing the temporary bridge
   - Restoration of Piers NO. 10, 11 and 12 and refilling of 120 meters track base
3) Stacking up of bridge piers: Following needs of the public and to boost the traffic safety, TRA commissioned CECI Engineering Consultants, Inc. Taiwan to stack up the existing bridge piers of Lin Bian River Bridge 2 meters during the outage period of the railroad.
   - On Sept. 3, 2009, CECI Engineering Consultants, Inc. Taiwan was commissioned to stack up 2 meters the piers
   - The emergent stacking work budget was established and the job was contracted out on Sept. 14, 2009 and the work commenced on Sept. 15, 2009.
   - Working period: 115 calendar days (Phase 1: 85 calendar days and Dec. 30, 2009 was targeted to resume the railway services and Phase 2: 30 days for demolishing temporary bridge
   - Added 2 meters high steel structure (total 21) on top of the piers and the RC pier was covered with steel clad and packed with concrete.

This project was completed on Dec. 30, 2009 with the hardworking of engineers and workers and the full line traffic was resumed to connect with South Link Line.

Keywords： Morakot、Lin-Bian River

1. INTRODUCTION

TRA Linbian River Bridge is located at K54+790 of Pintung Line. The bridge is 413 m long and is 1 km away from the estuary . It is a non-electrified single line 60-year old steel bridge. Linbian River is a typical silt-depositing river. In this area, there are dense aquaculture farms and they need fresh water supply and the water is supplied by pumping underground water and it led to the subsidence of land. According to statistical data, the land surface has been sunk for 3.76 meters since 1971. (Fig. 1)



(Fig. 1) Accumulated subsistence of land in Pintung Area between 2001 and 2011.

The river is curvy and sand and silt brought by heavy rainfall in the past years deposited at the estuary and formed a delta. With the subsidence of land along the river banks, the land at estuary is apparently higher than the land adjacent to the bank, according to site survey and the river becomes a peculiar phenomenon of “Suspended River”.

Linbian River Steel Bridge was built on 1948. The upper structural beam is made of I-shape Upper Deck of 1.375 m deep and 19.7 m long. The lower structure is

and the height of pier is 4.51 m high. The pier is made of concrete and is in the shape of semi-sphere in both sides facing the flow and back of the flow, and the perimeter is larger at the lower side and becomes slimmer progressively upward. Longitudinally the distance between supports is 0.75 m and the distance between piers is 19.81 m and there are 20 piers in total (Fig. 2 & 3)

(Fig. 2) Linbian River Bridge before Typhoon Morakot (1)

(Fig. 3) Linbian River Bridge before Typhoon Morakot (2)

Linbian River bed is deposited with sand and silt annually due to the change in environment and ecology and the dikes at south and north sides of the river have to be increased and they are already higher than the existing railway bridge. Taiwan Railway Administration (TRA) had been planning to rebuild the bridge and a joint survey was conducted in October 1995 and requested twice for rebuilding in May 1999 and March 2000 (at estimated budget of NT$2 billion at that time).

§ 4.00m 15m deep caisson foundation

However, due to short of fund, it was unable to rebuilt in time and the south and north dykes had to reserve gaps (1.2 m high and 6 m wide) for the rail traffic (Fig. 4). In order to prevent flooding through the gaps during high water level of tidal period or invasion of typhoon with heavy rainfall, TRA built water gates to both gaps in Aug. 1995 as an emergency measure, so that the traffic safety may be maintained. As to the reconstruction project, Railway Reconstruction Bureau has contracted the project to contractors in serial to build a new bridge at about 12 m downstream of the existing bridge for a dual track most update standard electrified railway. (Fig. 5)

(Fig. 4) Old Water Gate of Linbian River Bridge Dyke Gap

(Fig. 5) Bridge Pier of New Linbian River Bridge at the downstream side of old bridge.

The extraordinary disaster in southern Taiwan brought by invasion of Typhoon Morakot, other than the causes (rising river bed and subsidence of land), was mainly due to excessive rainfall. According to the statistics of Central Weather Bureau, the 3 days (7^{th}, 8^{th} and 9^{th} of August) the total precipitation hit historically high since measuring station was first set up in Taiwan and the accumulated rainfall in Chiayi, Tainan, Kaohsiung and Pintung was 2,500 mm and is almost equal to the accumulated average rainfall in one year in plain areas of Taiwan. In other words, in just 3 days, precipitation is equal to one full year. This is certainly in excess of the draining capacity of Linbian River. It was so heavy that there is not way for people to adjust to it and is the disaster Linbian Township had ever had.

2. DAMAGES

The heavy rainfall and huge flood brought by the Typhoon broke dikes of Linbian River and the town if literally submerged. The water level is as high as to the 2^{nd} floor muddy water is flowing everywhere (Fig. 6) bodies of livestock and debris rushed along the streets. It was sad and amazing scene. The height of deposited soil in Linbian Railway Station was almost as high as the platform. (Fig. 7)

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Due to the changes in the environment and terrain, the distance between surface of water flowing area and the bottom of Linbian River Railway Bridge was only 2 meter. With the instant heavy water flow, the cross section that allows for water to travel became insufficient, added with volume drifting wood (Fig. 8), furniture, bamboo rafts blocked by steel beam of the bridge. Under the giant thrust, the bridge was unable to sustain and 2 piers and 3 spans (P10, P11 & P12) were washed down (Fig. 9).

The upstream dike of north abutment was smashed for 30 meters and road base was flown away for 120 meters. In south side, the road base was covered by mud for 50 meters and the railway traffic was interrupted (Fig. 10).

(Fig. 8) Volume driftwood brought up from upstream

(Fig. 9) Washed off 2 piers and 3 spans (P10/11/12)

(Fig.10) Damages to north abutment 、Washed off Road Base.

3. POST-DISASTER EMERGENCY REPAIR

After the damages caused to Linbian River Railway Bridge, TRA set up Emergency Response Team on Aug. 10 to conduct site survey and mobilized all the engineers to draw up budgets and drawing for emergency repair. The job was awarded on Aug. 14, 2009 for the repair.

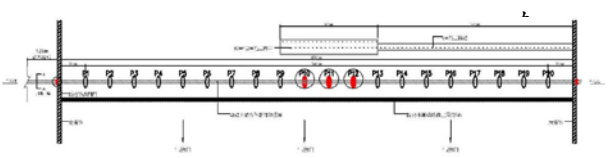
Since the repair period was still in high water period (May to December) and is in typhoon active period of summer and autumn, and in order to avoid further disaster of possible invasion of typhoon, TRA took the following emergency measures:

(1) Dismantle of Linbian River Railway Bridge Beams: After emergency joint survey of Aug. 27, to avoid added damages of any further invasion of typhoon, TRA removed all remaining 19 sets of steel beam of the bridge on

Sept. 7 to give increase space for water flow. (Fig. 11)

(Fig. 11) Bridge Steel Beams are totally lifted and moved away from site

(2) Restoration of Piers: This part included repair of damaged piers, refill of washed off road base, track laying and related electricity supply, electrical equipment and signal equipment. These jobs were awarded on August 13, 2009 and commenced the site construction. (Emergency joint survey was conducted on Aug. 9, 2009. Emergency Repair budget was established and contracted out on Aug. 14, 2009 and commenced on Aug. 15 with working period of 150 calendar days). The first phase 120 calendar days, aimed at resuming traffic on Dec. 30, 2009, and 30 calendar days for removing construction temporary bridge, restoration of pier No. 10, 11 and 12 and refilling of 120 meters road base (Fig. 12)



(Fig. 12) Sketch of location of pier restoration

(3) Raising Pier Height: Since the Linbian River Railway Bridge is lower than the dikes and the New Linbian River Railway Bridge, which is under construction and is scheduled to open to traffic by Dec. 2011 and there are still 2 high water period, and in order to increase the traveling section and eliminate break, the bridge is planned to raise up for 2 meters, after taking the slope restriction of railroad, the safety of pier structure and the traffic facilities of the surrounding area. The Project had price negotiation on Sept. 14, 2009 and commenced site construction. [On Sept. 3, 2009, Ceci Engineering Consultant, Inc. Taiwan was commissioned to design the 2-M pier height raising. The emergency raising budget was passed and job was contracted out on Sept. 14 with commencement on Sept. 15. The construction period was allowed for 115 calendar days (Phase 1 is 85 calendar days, with Dec. 30, 2009 targeted for opening to traffic; Phase 2: 30 days for dismantle of construction temporary bridge). A 2-M high formed steel structure is added to the top of each pier (total 20 sets); each pier is clad with steel plate and restrained with concrete. (Fig. 13)

(Fig. 13) Adding 2 M high formed steel structure on top of pier and the RC piers are clad with steel plate and constrained with concrete.

4. REVIEW OF RECONSTRUCTION

4.1 First Step

On Sept. 17, 2009, a meeting for Discussion of Linbian Railway Station Service Resumption schedule, Reconstruction of Linbian River Steel Bridge and Construction Interface Issues was convened together with Water Resources Agency of MOEA, Pintung County Government, Railway Reconstruction Bureau and CECI Taiwan. Parties to the meeting agreed to the following:

1) Height raising of Linbian River Railway Bridge is scheduled to complete by end of 2011;
2) Damaged railway bridge is scheduled to reopen to service before Dec. 31, 2009
3) The existing railway bridge shall be restored to 2-M higher as standard
4) The competent agency of dredging and clearing of Linbian River is Pintung County Government; however, considering the high water period that follows, TRA agreed to coordinate related units in removing of deposited soil within the range of 500 M upstream and downstream of existing railway bridge and mid-point of Tai 17 Highway bridge to the downstream 500- meter of the railway bridge.
5) The height-raising of current bridge, removal of deposited soil and the section for water flow under the bridge beam after the above shall satisfied the pass of expected 2011 flood volume.

4.2 Second Step

On Sept. 22, 2009, TRA again invited Reconstruction Promotion Council, Ministry of Transportation and Communication, Water Resources Agency, the 7th River Management Office, Pintung County Government, Railway Reconstruction Bureau, CECI Taiwan and Directorate General of Highway, plus Prof. Chao Wen-Chen of Department of Civil Engineering, Chiaotung University to further study the details that caused the flood, and parties to the meeting agreed to the following:

1) The rainfall on the day Typhoon Morakot hit Taiwan was indeed excessive and was in excess of 200-year frequency precipitation.
2) The S-curved flow of Linbian River offered different hitting angles and with the volume flood, along the river, from upstream to downstream, dikes were broken at many places. (Fig. 14)

(Fig. 14) Linbian River hitting angles.

3) The day was just the high water day that keeps the river water from draining out and forces the flood to pour on and over dikes.
4) The cleaning of soil deposit, CECI Taiwan was asked to plan based on 100-year flood peak level and present to TRA with river management office for detail discussion.

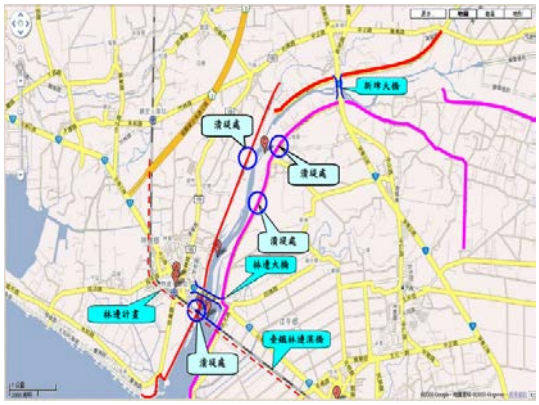
5. STUDY OF POSSIBLE FACTOR OF THE DISASTER

(1) Heavy transient rainfall: Up to at 9:00 am, Aug. 8, 2009 (from Aug. 7, 2009), the precipitation in Pintung area was already 2,000mm and the accumulated rainfall in the two days was almost the annual average rainfall of 2500mm. It would not be too exaggerating to say that the disaster would occur and would be in similar scale if the same rainfall dropped to any other place in Taiwan.

(2) The high water time of Aug. 7 was 21:00 pm which kept river water from draining into sea and the upstream was seen with several dike breaks. ◦

(3) The low water time period on Aug. 8 (03:00 – 05:00) was seen with the drag of low water washing the base of dike and vacated the content of dikes. This is proved by the time dike was found to have been smashed, 05:35 am.

(4) The lower part of the river water is characterized with S-shape flow and the attacking angles are curved and water flow rushes to and from. This is why the dikes were broken in many places both upstream and downstream and the break was not limited to the railway bridge. (Fig. 15)



(Fig. 15) Broken dikes along the river found after the disaster. (3 at upstream)

(5) Height of dikes at both ends of Railway Bridge: The dike at the north side of Linbian River is about 0.9 m higher than the south side. Based on the fact that no effluent found at south bank, there should not be any in north Bank .(Fig.16)

(Fig. 16) South side gate was intact after the disaster due to deposit and stacking of drifting articles brought by the flood.

(6) From the records of river bed prior to the typhoon, t he south side of the river had heavy deposit of soil and became dry land, and it obstruct water flow and when flood came, volume water was diverted to hit north side of the river bed and formed eddy current and washed off the foundation of dike.

(7) Concluding from the above, the main

course of the disaster should be attributed to the heavy precipitation exceeding the 100-year precipitating frequency based in the designs of dikes and river and is exasperated by the factors of soil deposit on river bed and curvy channels unfavorable to the water draining. The later factors in turn resulted in insufficient accommodating capacity of river channel. Also the high water kept river water from draining to sea and the dragging force caused the washing and caving of foundation of dike are other causes.

6. CONCLUSION

(1) Establish the concept of managing the bridge and river at the same time. River management agency and bridge management agency shall cooperate and coordinate with each other and shall set up a platform for communication, so that any issue can be dealt with jointly.

(2) Timing and criteria for blocking bridge shall not be based on the height of water flow as the only basis. Velocity and washing conditions shall also be taken into consideration when making judgment. Bridge control agencies are recommended to take a deeper thought.

(3) It is suggested that controlling agencies of bridges at the upstream and downstream shall have linked lateral reporting system to alert each other for avoiding occurrence of disaster.

(4) Water resources Agency shall take initiative action, based on the bridge management system as reported by various units, to calculate the requirements of t he river under control of the agency and shall ask the related unit to improve with deadlines, and all these shall have been tracked and supervised, and shall also provide support when there is difficulty encountered.

(5) River management agency shall initiatively provide the latest river management standard for the bridge control units to follow.

(6) As engineers of a public sector, it is obliged to keep people from threats and damages of natural disaster, and when it is occurred, all units involved shall cooperate with each other, instead of impeding each other as the later would keep the repair at the first time impossible and the time of restoration would be delayed.

(7) For the rivers found with issue, the resources controlling departments are recommended to provide resources to improve the situation to keep the people subject to the disaster away from the nightmare. This is particularly true in the era of global warming, climate change and frequent natural disaster, such as flood and earthquake, as they are unable to predict and an inch preparation is an inch protection.

(8) This cost of the emergency repair is totaled at NT$147,324,605 (Rebuilding of piers + bridge pier height increase = 62,086,612 +

85,237,993 = 147,324,605). Examined with the 2 high water period after resumption of traffic (2010 and 2011) the distance between bottom of the bridge and the surface of water flow of the river maintained at safety range and the expected effects are virtually achieved.

(9) Rebuilding or reinforcing aged bridges shall be maintained and before the rebuilding is underway, an early warning system shall be established.

(10) A life-cycle concept shall be introduced into design specification of bridge, in other words, the bridge shall be controlled in different manner in different stages of their life cycle, so that the bridges so built are operating under safety range and the public and user of the bridge may be warned and protected from the loss of life and property.

(11) Government unit shall establish Bridge Management Measure for the managing agency to follow and to report for super vision and appraisal.

7. AFTERWORD

The new Linbian River Bridge built by 'Railway Reconstruction Bureau was finally open to service on January 10, 2012 and the escalated railway of Linbian line is completed for service, the old Linbian River Railway Steel Bridge will be dismantled and it is scheduled to completed in April, 2012, before the high water period of 2012. The interruption of railway service of Pintung Line and South Link Line due to closing of water gate during period of heavy rainfall will become history (Fig. 17 & 18)

(Fig. 17) New Elevated Platform of Linbian Railway Station.

(Fig. 18) Train is switched to the elevated line.

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