SHIP COLLISION: REPAIR & REHABILITATION OF A CABLE STAYED BRIDGE

Sumitaka KURINO¹, Hiroshi KUDO², Masaru KUDO³ and Yuichi YAMAMOTO⁴

ABSTRACT

The Binh Bridge was officially opened in public in Vietnam in 2005. The bridge is a steel cable-stayed bridge with RC slab on 2 edge girders with 4 car lanes and 2 pedestrian & bike lanes. The bridge length is 1.3 km and the main span is 260 m. The bridge was, however damaged 5 years later. The bridge was collided by ships at the time of landing of the Typhoon Conson in 2010. The 3 cargo vessels were drifted due to strong winds and hit the bridge. The damages occurred. A steel girder was deformed and two cables were broken its plastic covers and wires were exposed. Traffic of the bridge had restricted then. Repair design was carried out in 2011, and works had done in 2012. Damaged parts of the girder was cut and welded by new parts. Damage girder was repaired using temporary supporting member called “Temporary By- Pass Truss”. Damaged two cables were replaced by new one using “Temporary Hanger System”. After completion of rehabilitation, the bridge has been in full re-opening in use in the end of 2012 and the final inspection on defect liability period was passed in 2014. The bridge is a cable stayed structure with RC and steel composite girder and its repair / rehabilitation work was a rare case and precious experience.

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Of A Cable Stayed Bridge

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The Binh Bridge was officially opened in public in Vietnam in 2005. The bridge is a steel cable-stayed bridge with RC slab on 2 edge girders with 4 car lanes and 2 pedestrian & bike lanes. The bridge length is 1.3 km and the main span is 260 m. The bridge was, however damaged 5 years later. The bridge was collided by ships at the time of landing of the Typhoon Conson in 2010. The 3 cargo vessels were drifted due to strong winds and hit the bridge. The damages occurred. A girder was deformed and two cables were broken its plastic covers and wires were exposed. Traffic of the bridge had restricted then. Repair design was carried out in 2011, and works had done in 2012. Damaged parts of the girder was cut and welded by new parts. Damage girder was repaired using temporary supporting member called “Temporary By-Pass Truss”. Damaged 2 cables were replaced by new one using “Temporary Hanger System”. After completion of rehabilitation, the bridge has been in full re-opening in use in the end of 2012 and the final inspection on defect liability period was passed in 2014. The bridge is a cable stayed structure with RC and steel composite girder and its repair / rehabilitation work was a rare case and precious experience.

Introduction

The Binh Bridge was opened at Hai Phong city in Viet Nam in 2005. The bridge is crossed over Cum River. The river is a big port just down stream side of the bridge and close to the sea. The bridge is a 17- span continuous steel bridge and the three spans at the center are supported by cables as cable stayed system. Span configuration is 50m +6@60m +100m +260m + 100 m +6@60m +50m =1,280m (Total length). Road width is 22.5m and it has 4 lanes for cars and 2 pedestrian ways. Deck system is Precast RC deck and its thickness is 260mm.

In July 17, 2010 at 22h00, Typhoon Conson landed in Hai Phong City. At that time three vessels which had anchored at Bach Dang shipyard, about 1 km far from the Binh bridge, broke anchor ropes and were drifted towards upstream side, and hit and crashed to the bridge and they were blocked at main span area (at locations near stay cable C23 to C28).

Five towboats were mobilized to rescue the ships, then two ships were pulled out to a nearby wharf on July 18. From the morning of July 19, rescue workers cut off the cabin on a stacked ship to loosen it from the bridge and finally the ship was pulled out on the same day.

Upper parts of ships attacked the girder and cables and it caused severe damages. However structure such as slabs, cross beams and anchorages of cable were not suffered much, therefore the bridge was escaped from collapse. Then the traffic was restricted only for small cars, motor bikes and pedestrians at the no- damage side.

After this incident, CHODAI and IHI group did initial check according to requests by the
bridge owner. Then later, CHODAI did FS design, detailed design in 2011, Construction Supervision in 2012 together with construction by IIA of IHI group.

Photo 1 Binh Bridge after completion

Photo 2 Collision of ships (July 17, 2010)

Photo 3 Stack of a ship (July 19, 2010)

Fig 1 Location of collided ships

Fig 2 Location of damage of the bridge
After Repair /Rehabilitation works in 2012, the bridge was full re-opening and has been in use since the end of 2012. The final inspection on defect liability period was passed in 2014.

**Damage of Ship Collision**
Damages were occurred on girder, cables, handrails and curb on slab etc (See Fig 1). Especially damage of girder and cables were needed special consideration.

**Damage of Girder**
The damaged part of steel girder was about 23m, from stay cable 27B to stay cable 30B.

![Photo 4 Damage of girder](image)

Main girder was deformed and partially buckled due to collision, the flange was buckled. Web plate was bended inward from C145 to location of cable 29B. At location of cable 28B, web plate was punched by cross girder. From C140 location of cable 30B, the paint was damaged at many parts.

**Damage of cables**
Two stay cable No 23B and 24B were damaged. The length of scratch portion is 2.0m and 7.6 m respectively. HDPE covers were peeled off and wires were exposed.

![Photo 5 Damaged cables](image)  
![Photo 6 Close-up of damage 24B](image)
Evaluation of the damage
Main girder: After the collision, main girder was seriously damaged. Web plate, flange, vertical stiffener and horizontal stiffener were seriously buckled and distorted exceeding the elastic limit of steel structure. It is necessary to replace all part of web plate, flange, vertical stiffener and horizontal stiffener.
Cable: Inside wires were affected by seawater. Therefore it was necessary to be replaced by new cables.
Cross girder: there was no damage, so the repair work was not necessary.
Deck slab, concrete curb: there was no crack on the deck slab. The damaged concrete curb had to be repaired. The repair work of damaged pieces of deck slab and concrete curb needed to be carried out at the same time.
Handrail: buckling and bending portions had to be replaced.

Concepts & Design
The bridge is a cable stayed and the damaged parts are supported by cables. Therefore it was necessary to check its repair procedure carefully. The girder support not only bending & shear force but also axial compression force. Also effects of construction live load and equipment should be checked.

To check the safety of repair works, a 2-D frame model was used for F/S design. Then a 3-D frame model was applied for D/Design. The damaged part of girder was modeled by two beams and upper beam was no- damage parts and bottom beam was cut parts and temporally reinforcement members. Among the damaged girder, there are two cables. This means cutting of girder would cause big bending of existing parts. Thorough these design, it was recognized that temporary reinforcement of guider was needed during cutting & attaching procedure of damaged parts of girder (See Fig 5).

A temporary reinforcement was designed as a truss envelope on damaged parts with triangular cross section called “Temporary By-Pass Truss” later.
Damaged two cables were decided to be replaced because of possibility of corrosion inside. Removal of a cable was checked in design and confirmed its safety.
Repair & Rehabilitation Works
According to the above mentioned designs, repair and rehabilitation works had done.
**Gider repair works**

Damaged part was located under cable supported area. Thus the temporary support system had to be assembled by compact parts to move through cables.

A truss system was adopted as temporary supporting member called “Temporary By-Pass Truss (TB Truss)”. The TB Truss was designed as triangular section to fix existing upper flange and to make an envelope along damaged parts. Both ends of TB Truss were welded tightly by anchor blocks to the existing girder.

Cutting area was revised according to examination at the site. Cutting line was designed with smooth as possible. This line was copied at site and brought to a factory to cutting new parts. Cutting was done rough cutting first, and then groove cut was carried out. New parts were temporally assembled at cut place and welded parts by parts.

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Fig 7 Cutting & attaching of girder and TB Truss

Photo 7 Installation of scaffolding

Photo 8 Cutting of damaged girder

Photo 9 TB Truss (After girder cutting)

Photo 10 Installation of new girder parts
Cable replacement works

Damaged 2 cables were located among healthy cables. Therefore replacements of new cables were using existing cable as support system not to damage other cables. The details of a method was developed by the Contractor and called “Temporary Hanger System (TH system)”. The TH system consists of roller-parts which were connected by wires to move on existing cable and to hang temporary hangers. Up side of wire was connected to a winch to move the system up and down along existing cable.

Removal of damaged cable was done by next procedure. Firstly the TH system was assembled/put on an upper side cable. Secondly temporary hangers were connected between the TH system and a damaged cable. Thirdly both ends of damaged cable were taken off from anchorages. Fourthly the up side of wire was released and the cable was moved towards the girder and cut it down to pieces.

Installation of a new cable was done by a next procedure. Firstly the HT system was put on girder by hanging from a wire. Secondly a new cable was pulled out from a cable unreeler. Thirdly both a new cable and the HT system were connected by hangers and pulled up towards tower top. Fourthly both ends of a new cable were anchored at anchorages at tower/girder sides.

Fig 8 Major equipment

Fig 9 Dismantlement of damaged cable

Photo 11 Dismantlement of a cable
Monitoring and Study

During the works, monitoring of stress of girder and the TB truss were carried out to confirm force transition from damaged girder to TB truss and TB truss to new girder parts. Measurement of cable tension and vertical alignment of deck were carried out too. Corrosion inspection inside cable was carried out at a girder side socket part. At the time of ship collision, damage cable was intruded by rain/sea water. Four days later after damage, the damaged parts were covered by plastic tape. A 7.6-m cover was damaged and exposed it wires. But it locates 5.8 m apart from the socket. Wire corrosion was checked 1.7 m length of cable parts from the socket. Among them a 1.5 m part was filled by poly-butadiene rubber. Results showed that there were almost new wires condition about 1.2 m from the socket except stripe white rust. And there were white rust with slight brown rust at other parts. Findings of rust inside cable after 2 years, means urgent waterproof measure should be taken when a cable will be damaged its cover.
Fig 11 Corrosion map inside of the cable 24B

Conclusions
The Binh Bridge was damaged due to collision of three ships at the landing of the Typhoon Conson in 2010. Two cables were broken their covers and a steel edge girder was buckled/distorted. Traffic of the bridge had restricted then.
- Thorough FS and Detailed design, it was recognized that reinforcement of girder was needed during cutting & attaching procedure of damaged parts of girder.
- Damage girder was repaired using temporary reinforcement member called “Temporary By-Pass Truss”. It was a truss envelope system on a damaged girder.
- Damaged 2 cables were replaced by new one using “Temporary Hanger System”. Two damaged cables among other health one were removed and replaced one by one.
- Inside inspection of cable was done near a socket and corrosion was found. This means urgent water proof measure of damaged cable is important issue of maintenance.

Acknowledgments
The works had successfully completed to meet a planned schedule, eight months, with cooperation of many people. Authors have to appreciate related people especially, CHODAI: Mr. K. Ishida(FD-PM), Mr. N. Son Tung (BE), Hai Phong Bridge Projects Management Department: D.Tuan Anh(GD, PM at the time), IIA: Mr. T. Tokuchi(DE), Mr. S. Kawabata(CE), Mr. T. Idani(DE). The works was funded as an urgent assistance by the Japan International Cooperation Agency (JICA) under ODA program.

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