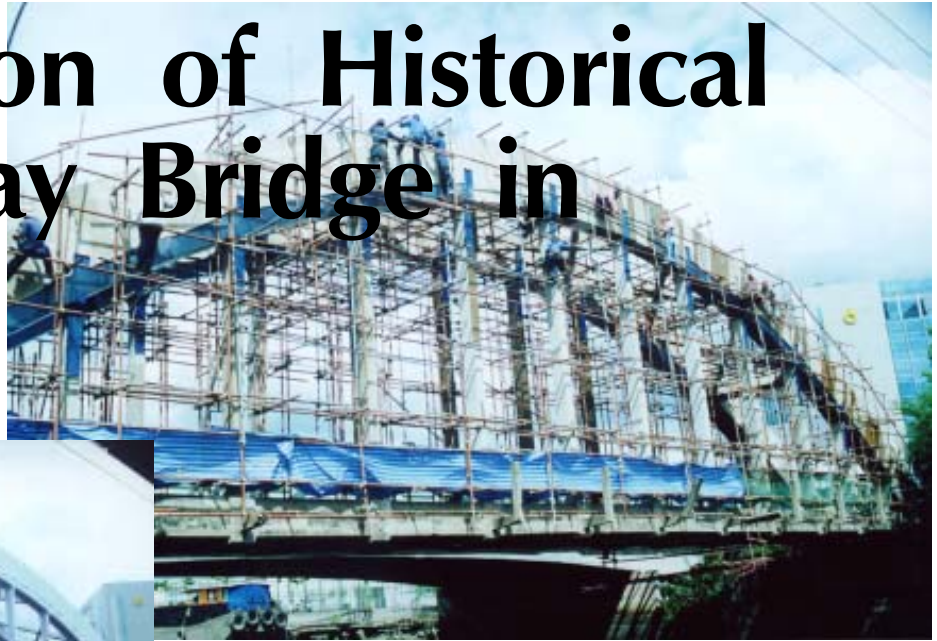


Rehabilitation of Historical Arch Railway Bridge in Bangkok



2000 Award of
Excellence Winner,
Transportation Category

This historic structure is a reinforced concrete railway bridge which was built about fifty years ago. It is a State Railway Arch Bridge and is registered in the “Arch Bridge Preservation Register” with the Department of Fine Arts of Thailand. The primary use of the bridge is to facilitate the transportation of crude oil from the harbor to the local oil refinery.

The State Railway decided to repair the structure due to reinforcing steel corrosion and the numerous cracks that were found on the arches, beams, hanger columns, and underneath the slab. Overloading of the bridge beyond its capacity and its long period of service were determined to have contributed to its deterioration. They also wished to increase the bridge’s load carrying capacity. The project was awarded to B.T. Interholding Co. Ltd., Bangkok, Thailand, who began the work in May 1999 and finished it in August 1999.

Structural Characteristics

The bridge has a free span length of 40 meters (130 ft.) and a width of 4.6 meters (15 ft.), and consists of reinforced concrete arches on both sides. The two arches are connected with reinforced concrete crossbeams, with the railroad track laid on a slab hung from concrete-encased hanger columns. The railway track lies on top of wooden ties on a bed of crushed rocks supported by the concrete slab and

beams. Under current conditions, the weight of a fully-loaded freight train is approximately about 15 tons per axle.

During the condition investigation of the bridge, reinforcing corrosion, concrete spalling, and numerous cracks were found in the arches, hanger columns, beams, and slabs. These conditions were determined to have been caused by the excessive loading that the bridge had to carry. The moisture in the air and concrete carbonation had also contributed to the weakening of the structure.

The Register mandated that any repair work had to conform to architectural preservation standards. To increase its load-carrying capacity, the State Railway elected to strengthen the bridge by the use of carbon-fiber composites.

Inspection/Evaluation Methods

When a visual inspection was carried out, it was estimated that 15% of the superstructure was damaged. Cracks were clearly visible in 25 different areas. After opening up the concrete surface for inspection, it was estimated that approximately 5 to 25% of the total structural strength of the reinforcing steel had already been lost due to corrosion.

Four groups of samples were collected for concrete compressive strength tests, and a strength of 150 Kg/cm² (2150psi) was determined as a result. An ultrasonic pulse technique was also used for

checking and the bridge was found to be in fairly good condition and amenable to strengthening. Test results also determined that the concrete had a Ph value of about 12.

To use carbon fiber for strengthening of the flexural and shear strength of the superstructure, a series of 30 pull-off tests were done to determine the viability of using that technique. The average failure stress in the substrate layer was found to be 25 Kg/cm² (350 psi). This was determined to be sufficient.

Before strengthening, an LVDT instrument had been installed to check for slab deflection and a baseline established by use of a locomotive for loading. After strengthening, the deflection was reduced by about 26 to 30%.

Strain gauges were attached at the outer surface of the composites. Strain was measured while the locomotive was passing by. The obtained results were determined to be satisfactory.

Repair System Selection

Using a finite element method for investigation of superstructure under the new standard loading, it was found that the reinforcing steel would not be able to resist the induced tensile stress. Carbon-fiber composites were selected to strengthen the superstructure due to their light weight, their ability to resist all types of environmental corrosion, and their ability to maintain the architectural and structural characteristics of the existing structure.

Carbon-fiber sheets were used for increasing flexural strength and shear strength at major areas of the structure, and glass fiber sheets were used to wrap around the superstructure to prevent corrosion.

The arches were strengthened to increase flexural and shear strength. The crossbeams were strengthened to increase flexural strength. The hanger columns were strengthened to increase confinement and axial force capacity, and the slabs were strengthened to increase flexural strength.

Site Preparation

The project requirements dictated that the work must be done without closing the bridge to railway traffic. This meant that the scaffolding and equipment had to be set up without interfering with the freight train which ran every 30 to 90 minutes and also without interfering with the barges running under the bridge at all times of the day. With the width of the bridge at only 4 meters (15 ft.), this left only one meter (three feet) on each side to set up.

Scaffolding was set up on both sides of the bridge. A movable platform was installed underneath the bridge under difficult circumstances, with limited space between the bottom of bridge and the top of the barges that passed by.

The bridge is situated in landscape that limits visual distance and thus safety precautions were very

important during the repair work. Radio communications were used between conductor of the freight train and the construction crew, and a fire truck stood near the site at all times because of the volatile nature of the crude oil that the train was carrying.

Concrete Repair Work

The sequence of the concrete repair work was as follows:

1. Old concrete was saw cut and the deteriorated concrete was removed.
2. A pneumatic needle scaler was used to remove corrosion from the affected steel.
3. The entire structure was sandblasted.
4. A bonding agent was applied, followed by a cementitious anti-corrosion coating and patching with repair mortar.
5. Narrow cracks were repaired by use of low-viscosity epoxy injection. Major crack areas were stitched with carbon-fiber composites.



Composite Strengthening

Proper preparation of the concrete surfaces before the installation of carbon-fiber sheets was very important to the success of the operation. Surface preparation of concrete consisted of sandblasting of the entire surface after all required concrete repair procedures were completed. To complete the carbon fiber installation:

1. Epoxy putty was applied for leveling and smoothing the surface.
2. An epoxy primer was applied to improve the bond strength to the system.
3. Fiber sheets were installed with an epoxy adhesive to strengthen the superstructure.
4. A latex coating mixed with cementitious materials was applied over the carbon fiber to add UV protection. The repair work was completed with an application of a colored and textured finish.
5. Pull-off tests were repeated. It was found that the fiber sheet had bonded very well with the concrete surface, and no bond failures were found.



Unforeseen Conditions

Heavy rainfall continued for many weeks while the project was under way. This made surface preparation and other work more difficult. All surfaces had to be dry before the installation of the fiber sheet could proceed.

The crushed rock on top of the slab had to be removed before the slab could be repaired. As soon as possible after the repair work was finished, the rock had to be replaced and the track reset and leveled. These processes were time-consuming and were made more difficult because of the frequent passage of the freight trains.

Also, when the crushed rock was removed, more corrosion was found than had been anticipated, and oil stains had spread throughout many areas. This caused surface preparation work to be more difficult.

Summary

This was the first project in bridge repair and strengthening in Thailand in which a composite material was used to strengthen a concrete structure. As a national heritage bridge, it was important to maintain the architectural appearance, while performing repairs that would extend the life of the

bridge for many years. This was accomplished through the use of carbon-fiber reinforcement, which was proven by load testing to have been successful.

Adding to the challenge of the restoration of so important a structure was the limited space in which to work, with freight trains

frequently passing on the deck of the bridge and barges passing below. Working space on the underside became even tighter at high tide!

Completing the work in the limited time period of only four months under these conditions was a major accomplishment, and one in which all the participants can take great pride.

Rehabilitation of Historical Arch Railway Bridge in Bangkok

Owner

State Railway of Thailand
Bangkok, Thailand

Project Engineer/Designer

Nontri Co. Ltd.
Praves, Bangkok, Thailand

Repair Contractor

B.T. Interholding Co. Ltd.
Bangkok, Thailand

Material Supplier

Thai Master Builders Co. Ltd.
Bangkok, Thailand