Silver Jubilee Bridge Remediation

Widnes, Cheshire, UK

Submitted by Mott MacDonald, Ltd.

The Silver Jubilee Bridge is located in northwest England and crosses the River Mersey near Liverpool. Originally called the Runcorn-Widnes Bridge, it was renamed in 1977 to commemorate Queen Elizabeth II's Silver Jubilee. It was completed in the early 1960s as a replacement for an earlier transporter bridge and is now an English Heritage Grade II-listed structure. It forms part of the major highway route in northwest England, carrying over 90,000 vehicles per day on four lanes.

The extensive use of deicing salts in the winter months led to reinforcement corrosion in the bridge deck. A remediation strategy rather than reconstruction was developed to prevent any traffic disruptions and subsequent detrimental effects to the local economy. An innovative cathodic protection system was discovered, modified, and installed as a trial in 2008 and 2009 and, following successful results, the remaining suspended bridge deck was protected during the following 2 years.

DESCRIPTION OF STRUCTURE

The Silver Jubilee Bridge offers the only river crossing between the two Liverpool tunnels and bridge crossings in Warrington—20 miles (32 km) upstream. The bridge also crosses the Manchester Ship Canal, providing sufficient headroom for shipping. Any closure would result in a diversion of at least 40 miles (64 km), and even partial closures result in heavy congestion to the local road network.

Silver Jubilee Bridge with repair scaffolding in place

The original design carried a single lane in each direction plus a central shared passing lane. The bridge was initially designed to carry 9000 vehicles a day, but by the time it was opened in 1961, traffic had risen to 11,500 vehicles per day. Because of a steady increase in traffic, the bridge was widened during the late 1970s to carry two narrow lanes in each direction; currently, the bridge carries almost 100,000 vehicles daily.

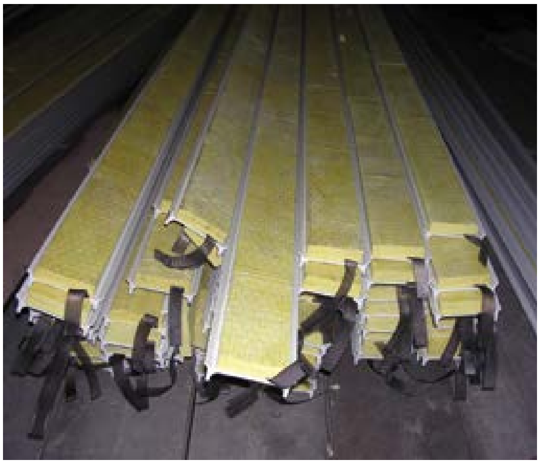
The central span of the bridge is an 1100 ft (330 m) long steel arch structure with two side spans that are each 250 ft (76 m). It is the largest bridge of its type in Europe and the proportions of the main span are approximately two-thirds the size of the Sydney Harbor Bridge in Australia. The deck is reinforced concrete supported on structural steelwork and is 8 in. (200 mm) thick. The original surfacing was hand-placed mastic asphalt, which provided some degree of waterproofing for over 40 years until a new waterproofing and surfacing system was installed in 2005.

The approach viaducts have four main beams supported by reinforced concrete piers. The ends of the beams were precast and the central spans were cast in place at the same time as the deck. The approach spans are a total of 1700 ft (522 m) in length.

CAUSE OF DETERIORATION

Since the mid-1960s, the highways in this part of England have been subjected to chloride-based deicing salts during the winter months. Chlorides have penetrated the concrete cover, and levels at the reinforcement commonly exceed 2% by mass of cement, which is more than sufficient to initiate and sustain corrosion.

The approach viaducts have joints over every third pier that degraded with time and allowed chloride-contaminated water to leak onto the substructure. Chloride contents of more than 2% by mass of cement have been identified in the concrete of the piers since the first investigations were performed 20 years ago.



Cathodic protection trays prior to installation

Installed cathodic protection "cassettes"

Underside of bridge where "cassettes" were installed

REPAIR HISTORY

Since 1993, a series of repair and maintenance strategies have been employed on the approach viaducts of the Silver Jubilee Bridge. These include patching repairs containing inhibitors, electro-osmosis moisture control systems, and numerous cathodic protection installations. Most of the areas protected on the viaducts were accessible from beneath the bridge, making the remediation and repair work relatively straightforward.

CHALLENGES AND RESTRICTIONS

Access to the main bridge deck is greatly restricted, as it is 130 ft (40 m) above the river and canal. Although the remedial systems previously employed for the approach viaducts were successful, they were not considered appropriate for the main deck soffit because of accessibility. Other factors affecting the suitability of any remediation technique are the thickness of the bridge deck (8 in. [20 mm]) and constant traffic vibration.

The deck contains approximately 1300 yd^3 (1000 m^3) of concrete. The embodied energy in the deck concrete is around 1.7 M kilowatt hours (6 Terajoules) and is equivalent to the energy produced by over 1200 barrels of oil. The diversion of traffic over the 40 mile (64 km) long alternative route would cause the release of an additional 1100 tons (1000 metric tons) of CO_2 per day based on 20% heavy good vehicles (HGVs) for the total 100,000 vehicles crossing the bridge per day. In addition, a disruption to the local economy and population valued at approximately $250,000 per hour would be realized if the bridge were closed.

CHOSEN REMEDIATION STRATEGY

A lightweight, prefabricated bolt-on "cassette" cathodic protection system was identified as the most suitable solution. The system was originally developed for use on harbor structures in Norway and consisted of mixed-metal oxide-coated titanium (MMOTi) ribbon anodes in a glass-fiber foam-filled fiber-reinforced polymer (FRP) tray that are mounted to the underside of the bridge deck using sleeved bolts.

In the original design, the foam is regularly wetted by the tide, providing the required electrolyte. The original system was modified for this bridge application by using calcium-nitrate-impregnated glass-fiber foam. The calcium nitrate is deliquescent and therefore able to maintain the electrolyte by absorbing moisture from the atmosphere rather than the tide.

To test its suitability, the cassettes were installed on a 200 ft (60 m) trial area on the soffit of the deck. The trial area was energized in October 2008 and protected over 600 yd^2 (520 m^2). The section was monitored over a period of 1 year and showed excellent results, demonstrating that the remaining suspended deck could be protected using this system.

INSTALLATION

The trial section was installed, taking advantage of scaffolding that was already erected for a major painting contract. However, the simplicity of installing the cassettes allowed for a consideration of a roped installation where alternative access was not readily available. This approach was used when the system was installed to the remaining 1700 ft (430 m) of the main suspended deck.

SPECIAL FEATURES OF THE PROJECT

Economic Benefits:

- Full closure due to major intrusive repair or replacement of the deck, causing a diversion of 40 miles (64 km), was avoided;
- Partial closure due to conventional cathodic protection installation, resulting in heavy congestions and diversion of 40 miles (64 km), was avoided;
- Disruption to the local economy worth an estimated \$250,000 per hour was avoided; and
- The costs for the installation were significantly reduced due to the use of roped access instead of scaffolding where possible.

Environmental/Sustainability Benefits:

- Deck replacement, causing an additional carbon footprint of 1.7 M kilowatt hours (6 Terajoules) (equivalent to the energy produced by 1200 barrels of oil), was avoided;
- The release of an estimated additional 1100 tons (1000 metric tons) of CO_2 per day as a result of diversions was avoided; and
- The cassette system allowed installation by roped access, avoiding extensive scaffolding with its associated cost, disruption, and health and safety considerations.

Impressed Current Cathodic Protection Cassette System:

- The installation of the cassette system was straightforward and its lightweight design makes for easier handling;
- The cassettes are tough and flexible and able to withstand the bridge environment, including vibration; and
- The system is suitable for installation above water courses.

Health and Safety:

- Working next to live traffic was avoided;
- Labor hours were significantly reduced;
- Working on scaffolding at potentially dangerous heights was avoided; and
- No extensive concrete removal and replacement were necessary.

The remediation of the main suspended deck span of the Silver Jubilee Bridge proved to be challenging due to its economic and structural restrictions. The development and adoption of the cassette system addressed all concerns, with no unforeseen problems encountered during its installation. Now developed and proven, this system has gone on to be used on other structures where access is restricted, and new applications are being considered and developed.

Side view of bridge

Night view of bridge

Silver Jubilee Bridge

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