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Repair and Protection of Oldbury Viaduct: the Largest Concrete Repair Project Ever in the United Kingdom

BIRMINGHAM, WEST MIDLANDS, UNITED KINGDOM

SUBMITTED BY VECTOR CORROSION TECHNOLOGIES

Fig. 1: Overhead view of M5 Oldbury Viaduct

INTRODUCTION

At 2 miles (3.2 km) long, the Oldbury Viaduct is a major artery in the West Midlands, UK, carrying 120,000 vehicles per day (Fig. 1). There are 165 sections in the viaduct that are separated by expansion joints. After years of exposure to de-icing salts, the structure had experienced deterioration and needed major repairs. To preserve and extend its service life, a major renewal scheme was developed that included hydrodemolition, concrete repair, expansion joint replacement, cathodic protection and waterproofing. Two types of cathodic protection were employed; the substructure was protected with impressed current cathodic protection and galvanic anodes were used in the concrete deck and expansion joint repairs. After the concrete repairs had been completed, a waterproofing membrane was applied and overlaid with asphalt. Ultimately, over 3.3 million lb (1.5 million kg) of repair materials were used, and the project was dubbed the largest concrete repair project ever completed in the United Kingdom.

The decision to repair Oldbury Viaduct was based on its condition and to avoid large-scale projects occurring at the same time around the 'Birmingham Box' (M5/M42/M6) over the coming years. The work was part of the government's long-term Road Investment Strategy to build a modern and resilient road network. By maintaining this key corridor around Birmingham, the government is supporting economic growth locally and across the West Midlands.

HISTORY

In the late '60s and early '70s, the motorway network started to rapidly expand. Part of that expansion meant linking the M6 motorway from the Catthorpe Interchange on the M1 in Leicestershire to Cumbria and beyond. The route of the M6 had to go straight through the industrial heartland of Birmingham and the West Midlands. To overcome many of the difficulties on this project, the engineers decided to elevate miles of the motorway (Fig. 2). This first phase of work, called Gravelly Hill Interchange, later became more commonly known as the Midland Links or Spaghetti Junction. The same engineering strategy was continued when the M5 was constructed linking Birmingham to Exeter in Devon. Oldbury Viaduct was the start of the M5 near Junction 1 in West Bromwich. Subsequently, the M42 was constructed with a circle of motorways called the Birmingham Box around Birmingham that is comparable to the M25 around London.

An inherent problem in the elevated sections of the motorway was that the expansion joints were directly over the bents (Fig. 3). Not uncommon, these joints leaked and allowed de-icing salts to percolate through and pond on top of the support beams. High chlorides were identified at the surface of the steel within 4 years of construction, and there were over 1,800 bents in total, supporting 13 miles (21 km) of viaduct. A comprehensive investigation was started into the extent of the problem using survey techniques that included concrete cover measurements, carbonation depths, and chloride levels and depths of penetration. In addition, half-cell corrosion potential mapping was carried out on an unprecedented scale. This information was then used to model the rate that corrosion would progress and at what point the bents would be compromised, allowing the client to know where to begin the repair. To an amateur, it might seem logical to start the rehabilitation at one end of the motorway and work along the rest of it; however, the half-cell results showed that some bents could to be left alone for many years without repair. Where there was a requirement for major repair, demolition and rebuild were considered; but even if this had been achievable, the potential disruption to the motorway network was unthinkable. A temporary solution was to install plastic guttering under the joints to divert the saline water away.

The severity of the problems started to draw in some of the finest corrosion experts in the world. Gravelly Hill Interchange became a mecca for cathodic protection trials. It is rare to find a UK-based corrosion engineer for concrete structures who has not at some point worked on the Midland Links. It became a hotbed of training. Everyday best practices were learned that had not yet been established.

PROJECT CHALLENGES

The challenges of completing the project were substantial, one of them being tasked with gaining enough survey information and historical data to develop the most appropriate strategy. Some of the most knowledgeable experts in the industry were asked to contribute to that strategy and ensure that all options were considered, and the best engineering solutions selected.

Fig. 2: Elevated construction of M5 viaduct works near Oldbury

Fig. 3: Elevated sections of the motorway with expansion joints over the bents

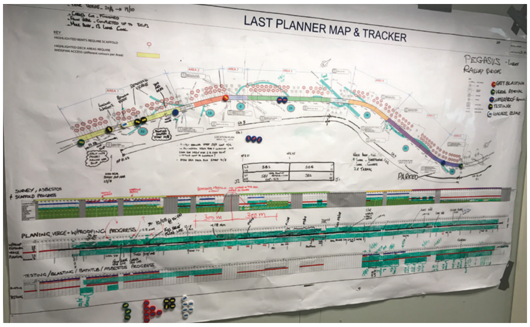

Fig. 4: Planner map for 2-year repair program


Fig. 5: Hydrodemolition of the concrete

A section of the motorway was restricted for 2 years creating a plethora of social media comment; managing public expectations and opinions in a sensitive manner was a major challenge. Listening to the concerns of other affected parties was critical—for example HS2, Network Rail, managers of the 'Birmingham Box', Canal Trust, Environment Agency, Severn Trent Water, National Grid, and other utility companies.

Fig. 6: Concrete repairs and installation of cathodic protection on the underside of the viaduct

Fig. 7: Saw-cutting edges for concrete repair

Fig. 8: Welding in new reinforcement steel

Other challenges included:

- Constant communication with individuals and businesses situated beside or under the motorway in this highly built up area;
- Managing access, managing load transfer related to concrete removal, and controlling water from hydrodemolition;
- Completing the work safely;
- The expectation of the owner to keep the motorway accessible 24/7 while completing the work; and
- Coordinating multiple suppliers and contractors to support the site in a consistent ongoing basis.

PROJECT SCOPE

The work process started with planing off the existing surfacing and removing the failed waterproofing system (Fig. 4). A third party then tested the deck to identify where concrete repairs were needed. Hammer testing identified where the concrete had delaminated, and half-cell testing pinpointed other areas of potentially corroding steel. Once the areas requiring repair were identified, the concrete that needed repairing was saw cut before proceeding with hydrodemolition.

Hydrodemolition was a crucial part of the work (Fig. 5). A 9.8 ft x 9.8 ft (3 m x 3 m) enclosure was created and surrounded with two layers of debris netting to contain flying fragments of concrete. Removing concrete with water brings safety benefits as the operators do not experience hand-arm vibration injuries and it eliminates the associated problems with silica dust. It also helps to wash away chlorides and importantly does not create vibration and microcracking in the same way percussion tools do. The water can travel at speeds of up to 1,000 mph (1,600 km/h). Due to the volume of work, the three largest hydrodemolition companies in the country at that time were all contracted to keep the project on schedule. Potable water was supplied from a complex 4 in (100 mm) pipe network on the viaduct deck. Each individual hydrodemolition team used 88 cf (2.5 m^3) of water per hour.

Additional concrete repairs and impressed current cathodic protection were installed on the underside of the viaduct requiring one of Europe's largest scaffold plans (Fig. 6). The scaffold also supported the network of pipes and drains required for the wastewater filtration settlement tanks. The tanks capture sediment and bubble CO_2 through the water to achieve a pH level approved by the Environment Agency, allowing it to be discharged into the adjacent rivers and canals.

The project required over 400 miles (640 km) of scaffolding with enough boards to cover seven football fields and enough staircases to reach the top of Ben Nevis in Scotland, the highest mountain in the British Isles and Snowdon, the highest mountain in Wales. The importance and commitment to the cost of using stairs instead of ladders was because of the significant reduction in accidents.

Once the hydrodemolition was completed, each area was prepared for concrete repair (Fig. 7) and severely corroded reinforcement steel was replaced and welded into position (Fig. 8). At that point, alkali-activated embedded galvanic anodes (Fig. 9) were tied to the steel around the periphery of all repair areas to prevent incipient anode formation.

Experience has shown that repairs to chloride contaminated concrete can cause corrosion cells to propagate around the repair area in the adjacent existing concrete (Fig. 10). The steel corrodes and expands causing disruption to the waterproofing membrane, and even though it is buried beneath the tarmac (bituminous surface), it is no longer watertight. Once the water gets in, the weight from the wheels of thousands of vehicles starts a hydraulic pumping pressure to create more damage and substrate weakness. From that deterioration, a pothole in the tarmac starts to grow. Once the pothole is large enough, traffic management must be put in place to carry out what is essentially a holding repair.

Considering the major investment in extending the life of Oldbury Viaduct, the risk of incipient anode formation needed to be addressed. On the substructure, impressed current cathodic protection was utilized. On the deck, embedded galvanic anodes were installed in the repair areas. The original 1990s development of embedded galvanic anodes that took place in the United Kingdom not far from this location had become a useful tool for Highways England to address localized corrosion risk. The zinc core of the anode is surrounded with a highly alkaline covering that keeps the zinc active but is not corrosive to reinforcing steel. The embedded anodes were tied directly to the exposed reinforcing steel at the interface between new and old concrete at a spacing of 18 in (450 mm).

The repairs incorporating the sacrificial anodes were replenished with a high performance, free-flowing micro-concrete conforming to the requirements of Highways England Specification for Highways Works and EN1504-3[1] Structural and Non-Structural Concrete Class 29F. Due to the scale of the repairs, large 1100 lb (500 kg) bags of repair material were used instead of the standard 55 lb (25 kg) bags. This eliminated manual handling as the bags were lifted using telehandlers and an opening on the bottom allowed for the material to be discharged directly into large pan mixers.

CONCLUSION

As repair work was required to be carried out throughout winter months, heated enclosures were constructed over the areas to be repaired. The work was carried out while keeping the motorway open. The southbound carriageway was repaired first, with a contraflow system set up on the northbound carriageway, then once the southbound carriageway was finished, traffic switched to the northbound carriageway. On the southbound carriageway, more than 6,000 substantial repairs were completed, and overall 12,000 additional repairs than planned.

REFERENCES

1. DIN EN1504-3, *Products and systems for the protection and repair of concrete structures—Definitions, requirements, quality control and evaluation of conformity, Part 3: Structural and non-structural repair,* European Standards, 2005.

Fig. 9: Installation of embedded galvanic anodes

Fig. 10: Example of incipient anode formation

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