Clifton Suspension Bridge - Cathodic Protection Case Study

Protection of Original Embedded Ironwork

Clifton Suspension Bridge, Bristol, spans the River Avon Gorge. The original designs for the bridge were produced by Isambard Kingdom Brunel, although these were revised after his death and the bridge was finally opened in 1864. Both wrought and cast iron was used in the bridge's construction, the bridge deck being supported by roughly 160 vertical iron rods. Wrought iron was used in the construction of the bridge's two supporting towers: iron cramps are used to 'tie' the stonework together and holding-down bolts used to secure the cast iron tower parapets.

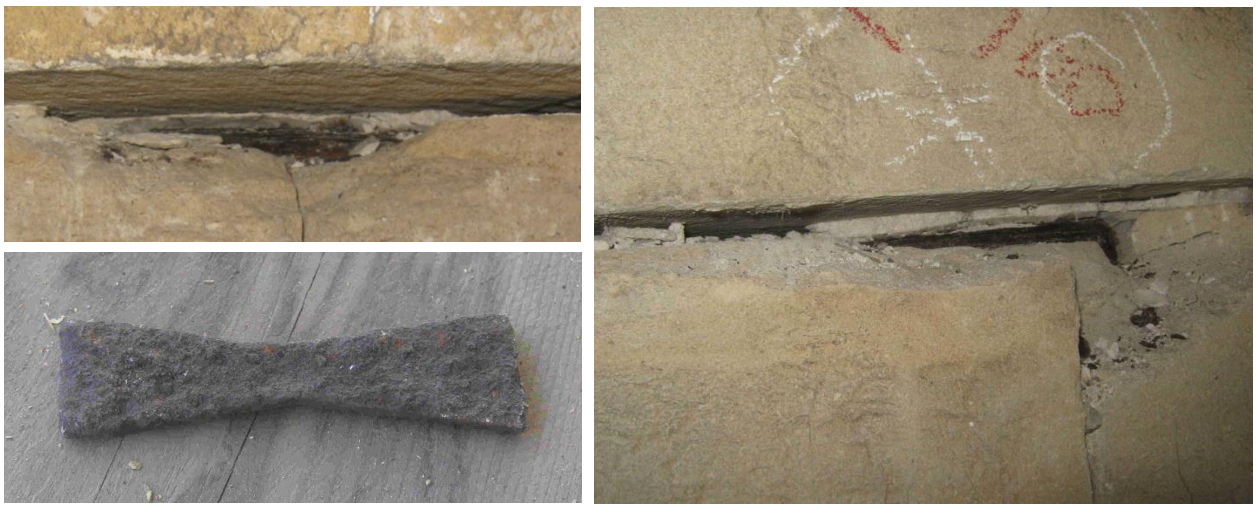
Clifton Suspension Bridge – Based on Designs by Isambard Kingdom Brunel

In 2015, Rowan Technologies was awarded a contract to install a CP system to inhibit further corrosion of the iron cramps and holding down bolts embedded in the stonework at the top of the two towers. Corrosion by-products are many times the volume of the original iron and it was these by-products that were causing both cracking and lifting of the stonework. Conservation policy requires that, as far as possible, the original structural materials be retained and cathodic protection was chosen to help prevent further damage caused by the original iron fittings.

Both Lifting of Stonework (Left) and Cracking (Right) are the Result of Corroding Embedded Ironwork

Ironwork Assessment

An initial survey of the ironwork involved a combination of different investigative techniques to identify and quantify the iron components within the stonework. Cramps were found to be of two kinds: so-called 'fishtail' and 'dog' cramps.



Fishtail (Left) and Dog Cramps (Right)

A total of 28 holding-down bolts were also identified, these held in place the two cast iron tower parapets, below:

The Cast Iron Parapets Sit Atop of Each Tower

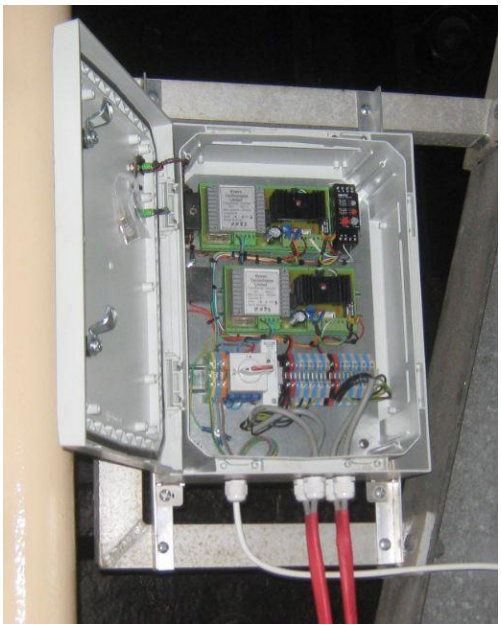
Installation of CP Hardware

The ICCP zones were designed using a system of mixed-metal oxide coated titanium ribbon anodes to protect the embedded iron components. The positive anode ribbon was installed as rings around the piers. The ribbon was inserted into opened-up joints which were subsequently repointed in using a cement/lime mortar. The completed piers were finished off with a shelter coating.

For the negative side of the circuit, 4mm self-tapping screws were used to fix a ring tag (and wire) to each individual section of wrought iron. Insulated copper wire was used to 'daisy chain' the individual sections of iron together.

'Keyhole Surgery' is used to make Electrical Connections (Left). Anode Mesh Installation (Right)

To monitor the performance of the ICCP systems, reference electrodes were embedded close to the ironwork. Silver/silver chloride reference electrodes were used for areas where there was substantial damage to the masonry (i.e. lifting) allowing these larger reference electrodes to be inserted. Pseudo reference electrodes were used for undamaged areas as their small size allows them to be readily inserted close to the embedded iron.



The CP electronics enclosures were installed at the top of each tower in close proximity to the CP zones (Right). The internal power supplies are adjusted manually and LEDs provide a convenient indicator of system status. The enclosures also contain additional circuitry that allows routine system performance monitoring.

Discussion

The installed system is designed to provide many years of reliable service with minimal maintenance. Techniques used in this installation are also used in many other similar installations undertaken by Rowan Technologies over the last 15-20 years.

Rowan Technologies, November 2016.