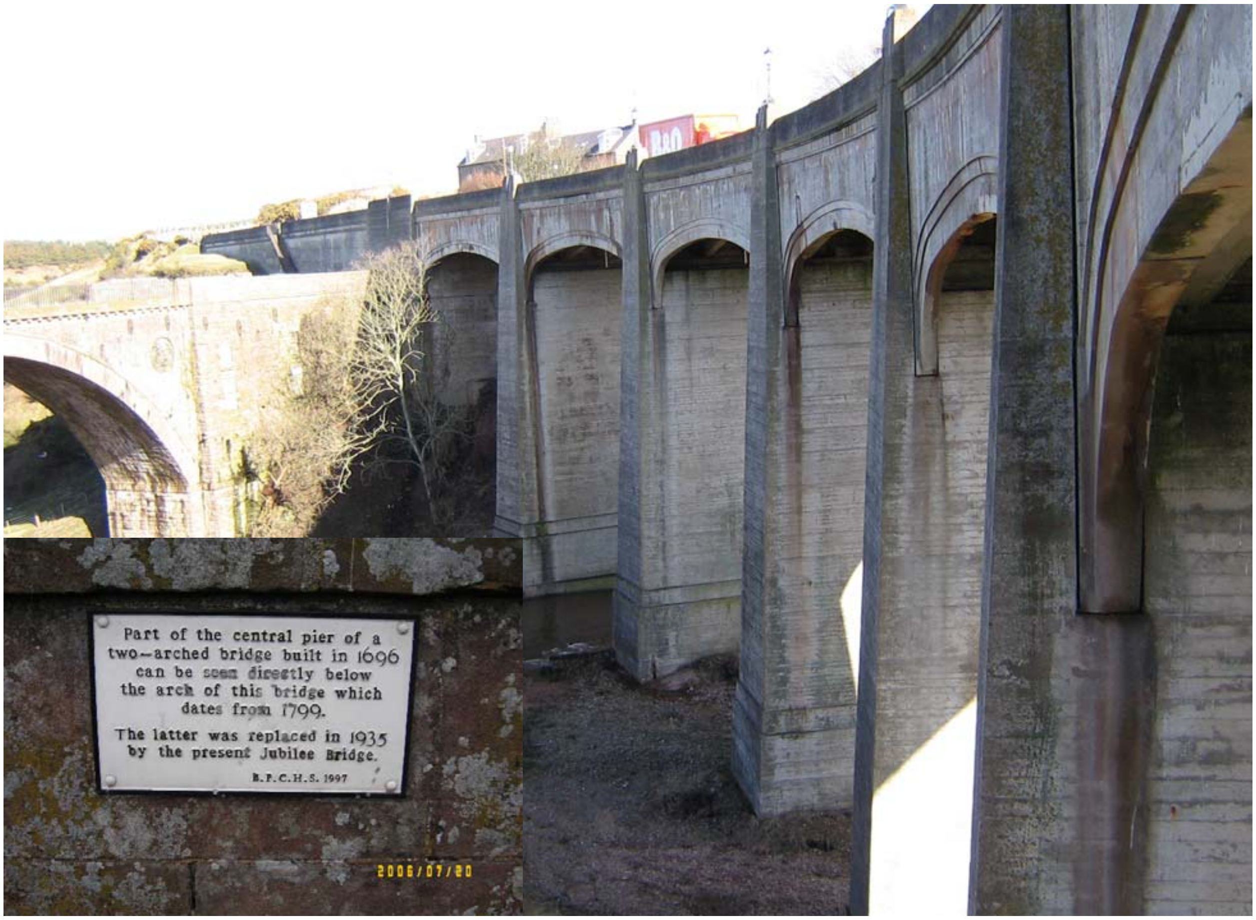
Restoration of Bervie Jubilee Bridge



Abstract

One of Aberdeenshire's historic landmarks has been restored to its former splendour following a ca. $2 million repair project was completed in 2009 after a 12-month restoration period.

It is the third bridge to be built on the site with the first constructed in 1697 and the second in 1799 and marked the 25th (silver jubilee) anniversary of the reign of King George V in 1935.

The now 76-year-old Grade II listed bridge had been suffering from the effects of corrosion to the bridge’s suspended and cantilever reinforced concrete support beams and half-joint elements.

Cracks were beginning to become evident in the concrete cover and through leakage from within the half-joints that carried deicing salts from the road above and weathering effects to the underside of the bridge. If not remedied, the condition was threatening to cause serious structural problems. A comprehensive repair programme was necessitated, which involved repair of the beam soffits and joints.

In addition to traditional concrete repair methods, the application of impressed current cathodic protection has ensured that the bridge will remain free of corrosion problems into its future.

Corrosion management systems are being integral to the operation of the bridge as well as providing proof of performance of the ICCP systems to Bervie Jubilee Bridge they represented an extension to the existing Client infrastructure management facility in place since a sister bridge at Dinnet was repaired and protected in 2005.

Restoration and Corrosion Management of an Historic Bridge in Scotland

Historical Context

Bervie Jubilee Bridge is a key arterial road structure carrying the A92 from Aberdeen in the North through the historic town of Inverbervie to Dundee in the South.

Inverbervie (normally shortened to Bervie locally) has been occupied by Man since the Middle and New Stone Ages. It was already an established fishing settlement in 1341 when King David II rewarded the small hamlet with Royal Burgh status following the hospitality shown to the King and Queen Joanna by the town when their ship ran aground on their way back from 9 years of exile in France.

The first bridge was built in 1697 (no longer standing) before being replaced in 1799 by the second bridge (see Plate 2) over the Bervie Water that transported textiles from the thriving industrial settlement following the establishment of the first flax mill in 1788. The second bridge is still used for pedestrian access from the A92 to the town's residential area.

Plate 2: View of second bridge construction dating to 1799 running perpendicular to the Bervie Jubilee Bridge built in 1935.

Problems that Prompted Repair

The bridge is a seven span reinforced concrete bridge constructed with 3 suspended spans between cantilevered piers (see Plate 3) located by the North Sea near Aberdeen.

Plate 3: General view of suspended slab held in position with cantilevered beams cast insitu from 100ft high piers

The worst problems were focused on the soffits of the beams arising from the venturi effects of the circulating marine environment under the bridge and through the leakage of chloride-entrained water through the half joints (see Plates 4 and 5 below).

The nature of the corrosion problems were typical for chloride accelerated attack typified by the pitting of the surface of the reinforcement steel closest to the point of ingress of the environment.

Plate 4: Worst case expansion joint condition found during inspection

Plate 5: View of support beam disrepair of soffits and arrises

The Client undertook a major underbridge Principal Inspection visual survey marking all repairs necessary to be done (an extract is shown in Plate 6) and concluded that if the corrosion was left unchecked then this would lead eventually to a reduction in strength and the contravening of European legislation for full vehicle loading that in turn would have a debilitating effect on local trade and to the economy of the area in general.

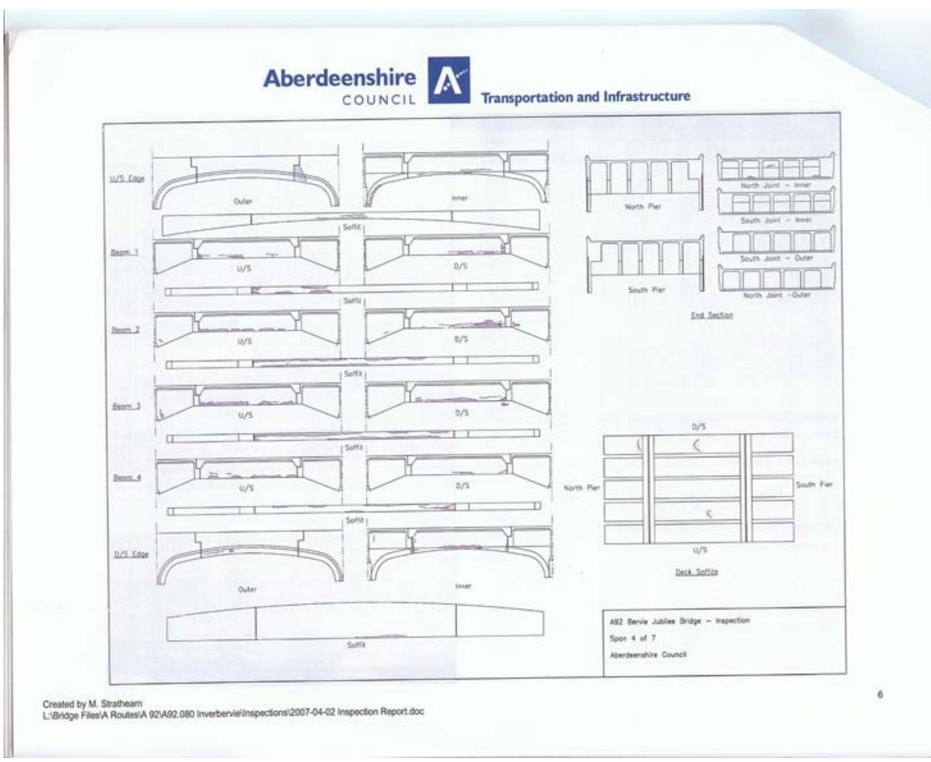


Plate 6: Extract from Principal Inspection of bridge support beams

Phase 1 restoration scheme was completed in Fall 2003 and involved concrete repairs to the deck, replacement of leaking expansion joints and application of a deck waterproofing system, including the reinstatement of the carriageway and footpaths.

The Phase 2 restoration scheme addressed the issues of the repair and protection of the lower section of the main supporting beams and half-joints and work began in August 2008.

Restoration Method

The situation of the bridge made access a major issue given that the bridge had to stay open at all times to allow normal traffic and trade to continue for the town, local businesses were operational below the bridge so accessibility had to remain in place and the height of the bridge over water made access to the underside of the bridge challenging.

The contractor was therefore required to provide traffic management to access the top of the bridge for the workforce to operate from a raised platform built into extensive scaffolding constructed the full height of the piers.

Plate 7: Extensive scaffolding was needed to access the underside of the bridge.

Plate 8: Overbridge access was used by the workforce to access the underbridge scaffolding and perform the works.

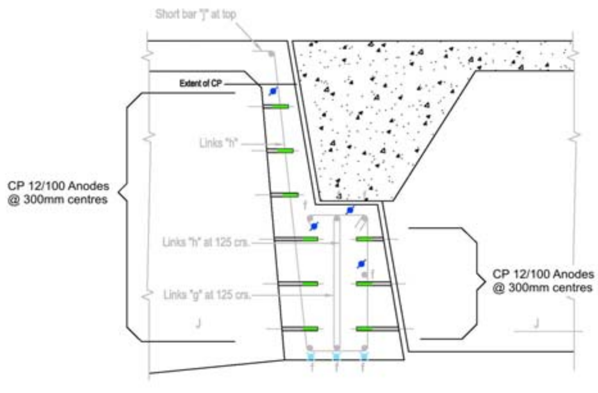
The concrete repairs were undertaken in compliance with the EN 1504 standard for repair and protection of reinforced concrete structures that mirrors practices within the Concrete Repair Guide. Concrete removal was achieved generally by hydrodemolition of delaminated concrete only. Plate 9 below demonstrates the extensive repair needed to repair the damage to the half-joints of the bridge.

Plate 9: Repair to the expansion joints varied in complexity with this joint compared to the initial damage depicted in Plate 4.

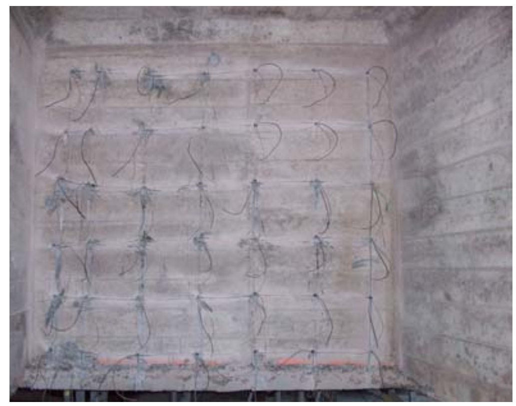
The complex steel configurations through depth coupled to the wish to maintain a simple production schedule meant that the ICCP design had to choose a single anode type that could provide sufficient output current without the need for extensive and environmentally-unfriendly surface preparation of the concrete.

This lead to the specific choice of the fluted or star-shaped conductive ceramic anode that provided the necessary higher currents needed to protect the 3-dimensional steel densities whilst minimizing the diameter of the drill hole. All anodes were installed as ½ inch diameter with a standardized 4 inch length to provide the necessary current output with variable depth of drilling to target shallow and deep steel configurations.

Plates 10 and 11 show cross-sectional details of anode positions within the half joints and compares this with a photograph of the installed anodes.



Half Joint (cantilever)



The final installation saw over 8,500 anodes drilled in and are controlled in 20 zones with separate control of the beams and the half-joints. These zones are networked together internally to minimize the amount of cable to the project and managed from a single communication point to the North of the bridge.

The performance is managed using remote internet access to data and control functions and is issued to the Owner on an annual basis whilst providing on-call access to performance throughout the year.

Initial Performance since Restoration was completed

Cathodic protection performance complies fully with the principles of both the NACE SP0290:2007 standard practice and European EN 12696:2000 standard relating with the use of ICCP in reinforced concrete.

Performance is summarized below over the initial first year of operation for one position at R2.2 in Zone 2 for Span 1. There are 80 ICCP standard monitoring locations investigating instantaneous-OFF potentials weekly, potential decay measurements monthly for the bridge as well as specific remote corrosion rate assessment. Power outputs are assessed on a daily basis and as well as being recorded for archive purposes also act as an alert for any power outages that may occur.

This example performance is typical of data achieved on the project and is displayed in terms of potential decay (continuous achievement of greater than 100mV after 4hrs and 150mV after 24hrs). Moreover an assessment is made of change from the original pre-energized condition (base) to the condition existing at each stage annually following the potential decay test.

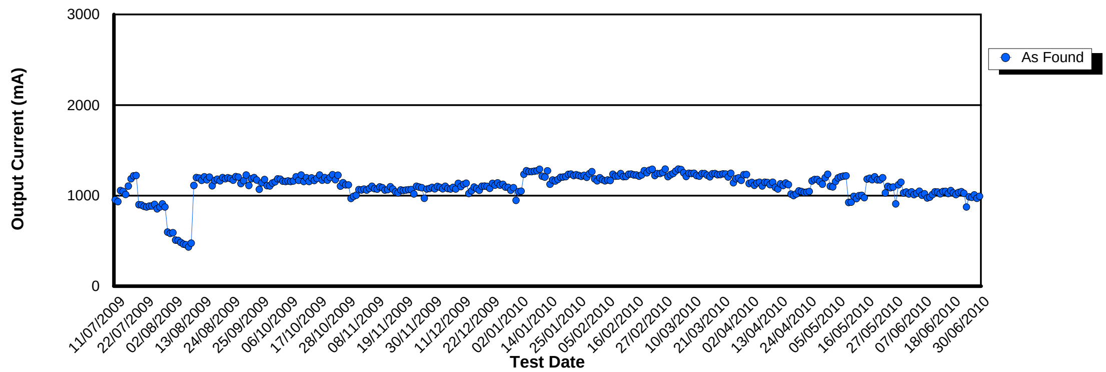
This is a measure that relates directly back to existing ASTM C876:99 standard and allows assessment of measured electrochemical change at the level of reinforcement steel in the absence of ICCP current and cross-checks the corrosion rate reduction data.

All ICCP zones achieved the required polarization on energization in July 2009.

The ICCP system is currently under a rolling yearly monitoring and maintenance contract through the specialist cathodic protection sub-contractor directly to the Owner as part of the warranty.

Note in this zone that the power is supplied in constant voltage mode and the output current varies with environmental demand.

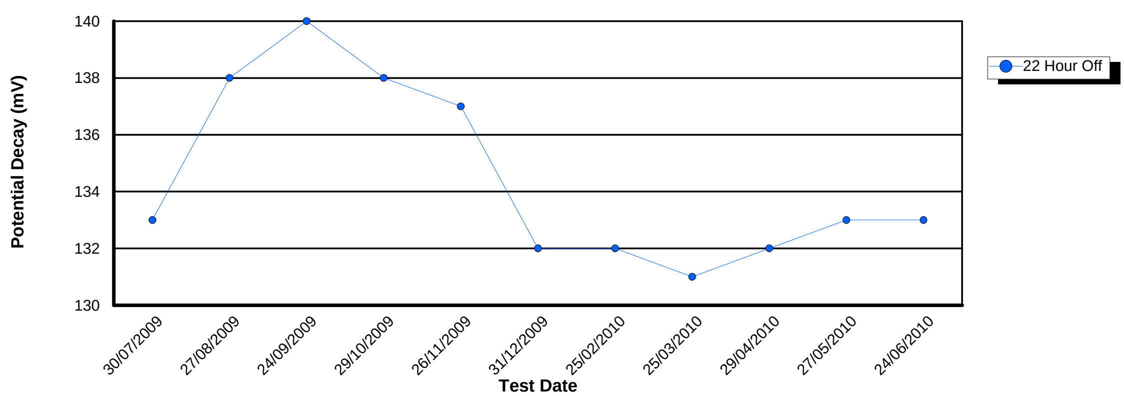
Daily As Found Currents

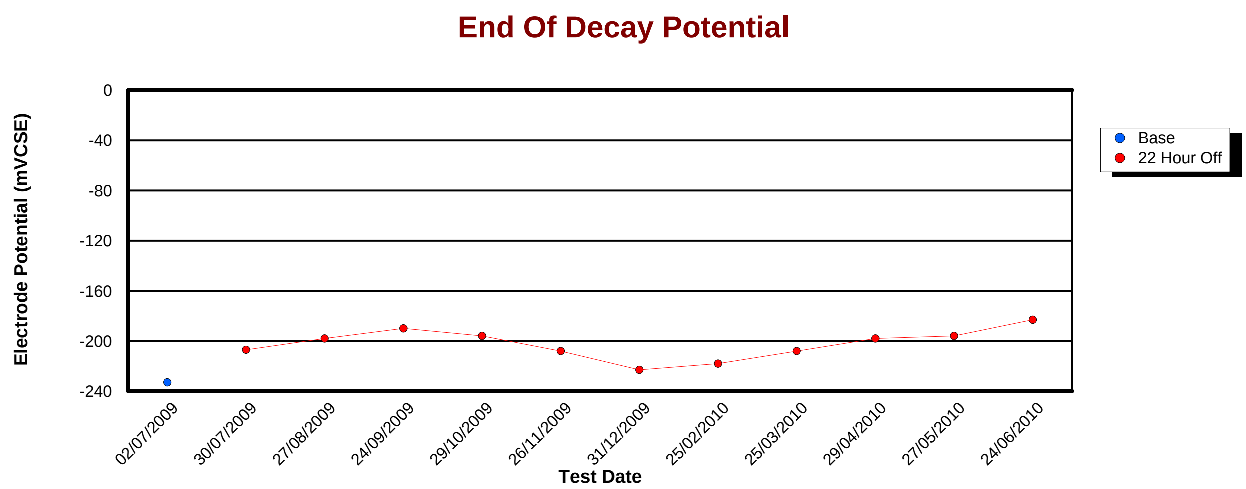


The current supplied has been consistently less than 50% of capacity for year 1 when the demand is at its highest and providing consistent protection.

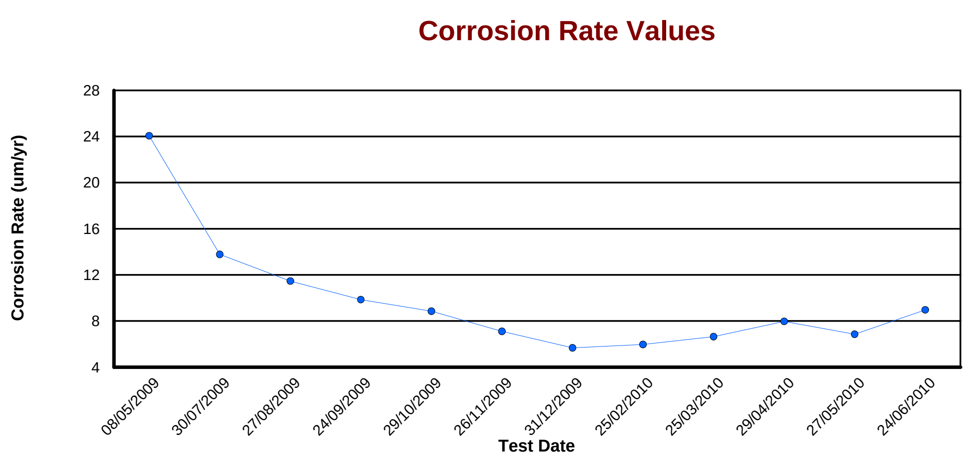
The data demonstrates a consistent achievement of 100mV potential decay and a shift of end of decay potential towards a less active potential (-237mVCSE towards -185mVCSE) that would represent a move from medium to low risk if left unenergized. This situation is not repeated in all locations as the ability to repassivate the steel will vary over the structure.

Electrode Potential Decay





The data demonstrate that the standards are being met with corrosion rate also reducing.



Special Features of the Project

State-of-the-Art Methods

- Anode system choice to comply with 25+ year warranty requirements and aesthetic appearance.
- Management system that can be remotely monitored and controlled over the Internet for immediate and proactive operation and reporting.
- Expansion of infrastructure reporting and operation of multiple historic bridges.

- The specialist design and evaluation team completed the comprehensive and necessary steps to determine the root cause, quantify the components and specifically locate them to meet the Owner’s requirements.

Aesthetics

- Compliance with all the requirements of the national conservation authority (Historic Scotland).

- Despite the requirement to be intrusive during the repair of the concrete and the installation of the ICCP drilled in anodes the bridge looks largely untouched following completion.

Summary and Conclusions

The dovetailing of good reinforced concrete repair practices with the long-term benefits of corrosion mitigation and management are exemplified in this project.

A difficult to access and key strategic local structure was repaired and protected whilst meeting all the requirements within the guidelines and standards for the repair methodology, environmental and conservation regulations to engineer a truly sustainable solution for this historic structure.

Without the combined expertise of the Owner’s design team and the specialisms of the Contractor, their corrosion protection sub-contractor and the innovations of the anode supplier then the establishment of these types of cost-effective solutions may never have been possible.

Plate 12: View of the completed Bervie Jubilee Bridge from North to South into the Royal Burgh of Inverbervie.