Figures 1 and 2 above: Concrete repair operations to soffit of bridge.

A55 Cliff Gardens Bridge, Old Colwyn, Colwyn Bay

"Due to the level of damage and the extent of chloride ion contamination from contact with the seawater, the only long-term remedial solution would be to install an impressed current cathodic protection system."

Figure 3: Trial CP area using thermal arc spray material.

Cliff Gardens Bridge at Old Colwyn, north Wales is a reinforced concrete structure supporting the main A55 trunk road over local residential estate roads. The structure, built in the early 1980s, is in a marine environment immediately adjacent to the promenade at Old Colwyn and is managed by Conwy County Borough Council acting as agent for the North Wales Trunk Road Agency.

Terry Davies, Quadriga Concepts

Damage to the reinforced concrete, arising from corrosion of the embedded steel reinforcement, has been recorded over time and, following completion of an in-depth condition survey during 2008, the suspicion was confirmed that the airborne salts from the marine environment had played a major role in the initiation and progression of corrosion. This process has led to spalling and delamination of concrete at various locations around the structure where concrete has either separated from the body of the structure and fallen to the ground or has delaminated within the body of the structure; this delamination takes the form of internal radial cracking around a point where the greatest stresses are exerted and will ultimately lead to spalling. These damage patterns have been shown to have arisen from the internal stresses placed upon the concrete by the expansive nature of the corrosion process.

The concrete repairs on the structure were carried out in a traditional manner using cementitious materials applied by both cast and hand-placed techniques depending upon the extent, type and location of the damage. Removal of damaged and defective material was carried out using hydro-demolition and the wastewater was filtered, dosed with carbon dioxide and checked for water quality prior to being discharged into the adjacent watercourse. The exposed steel reinforcement was cleaned and primed immediately before application of the repair materials. The cast-on material was used in the case of a particularly large repair to the retaining wall adjacent to the Afon Colwyn. Elsewhere, hand-placed repairs were used due to the intricate nature of the repairs where existing profiles were exactly recreated.

Due to the level of damage and the extent of chloride ion contamination from contact with the seawater, it was obvious that the only long-term remedial solution to the damage to the retaining wall, adjacent to the Afon Colwyn, would be to install an impressed current cathodic protection system. A ribbon anode system has been installed in this part of the structure, embedded in either repaired areas or chases cut into the wall itself.

The patterns of damage to the main bridge structure itself presented a more complex problem, in that the correlation between chloride ion contamination, other recorded defects and levels of damage were not entirely consistent. While the marine environment itself was a consistent factor in providing an answer to the origin of the chloride contamination, the effects of that contamination were found to be entirely inconsistent, resulting in a measure of uncertainty in relation to the immediate development of the most appropriate, permanent solution to the various problems that were found.

In line with the strategic approach to repair and maintenance of structures taken by the client, it was decided that more information was required in relation to the state of corrosion in the structure over time and, based on the assumption that some form of electrochemical remedial solution may be required, trials of different systems were undertaken to establish the most efficacious method of providing long-term protection.

To examine the state of corrosion, a permanent monitoring system using linear polarisation resistance probes together with a series of embedded half cells and a permanent low-voltage power supply was designed and installed and, using that equipment, information will be gathered over time to enable value engineering judgements to be made. This type of permanent monitoring has been used by members of staff at Quadriga in development of remedial solutions on a regular basis since the late 1980s.

With regard to the type of electrochemical system that may, over time, be shown to be necessary, various factors were taken into account in selecting the most likely potential systems to use in the long-term trials. These factors

were predominantly associated with the construction of the bridge itself, the nature of damage and its causes and the environment. The ability of the system to be flexible in extent of installation and future extension to meet varying environmental factors was also a serious consideration in the selection process.

Trials, using both impressed current and galvanic cathodic protection systems, have been installed in each of three separate areas on the structure. The intention of the trials is two-fold: first to confirm the beneficial effects of the systems on the structure over time; and second, to determine the more effective of the two systems in providing long-term protection. Both of the systems have been selected from an array of various methods as being the most likely to provide best technical and economic performance over time.

The design of the impressed current trial is based upon the use of an expanded titanium mesh ribbon with a current rating of 5.28mA/m, set in chases in the concrete with a conductor bar spot-welded to the ribbon to act as the primary feed for the system.

The galvanic cathodic protection trial is a revolutionary method that uses a wire comprised of an alloy of aluminium, zinc and indium. This material is designed as a sacrificial anode, which is spray-applied onto the surface of the concrete using a thermal arc system. To complete the circuit, an electrical connection is made between the steel reinforcement and the applied anode using a bolted connection to the steel and a zinc plate at the surface. This system has had extensive successful use in the USA and on a number of particularly large projects in the UK.

The extensive concrete repairs, together with the design and installation of electrochemical works (permanent monitoring and cathodic protection trials), were carried out by Quadriga Concepts which was working in close association with both the client and framework contractor, Daniel Contractors (UK). ■

Figure 4 above left: Concrete repair operations to retaining wall within Afon Colwyn.

Figure 5 above: General arrangement of site.

Figure 6 left: Prepared steel within repair area to abutment.

Figures 7 and 8 left: Concrete repair operations to figured abutments.