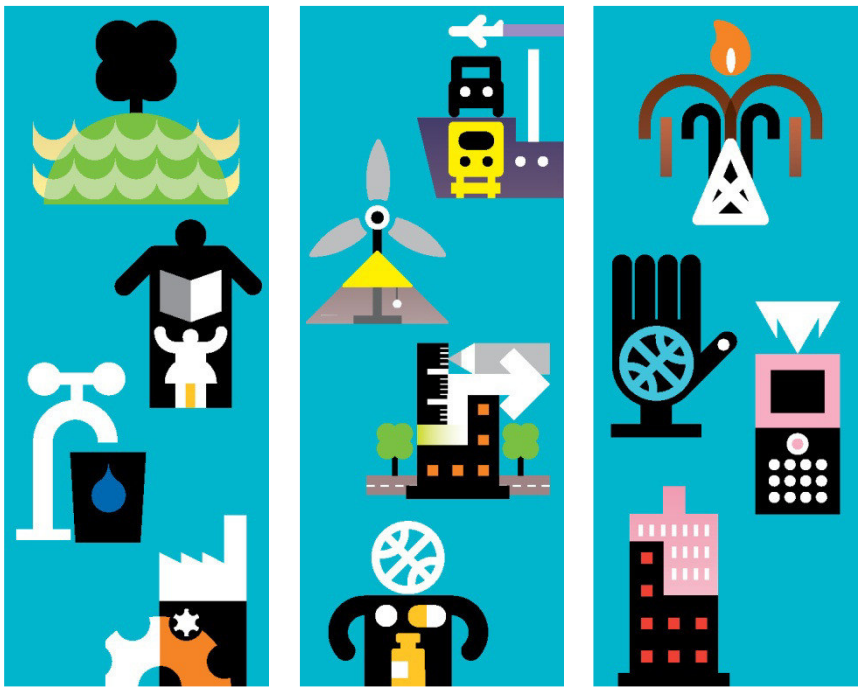

A91 New Bridge Guardbridge

Concrete Repairs & Cathodic Protection Design

July 2015

Fife Council

Mott MacDonald

A91 New Bridge Guardbridge

Concrete Repairs & Cathodic Protection Design

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Fife Council

Transportation and Environmental Services
Bankhead Central
Bankhead Park
Glenrothes
KY7 6GH

Mott MacDonald, Spring Bank House, 33 Stamford Street, Altrincham, WA14 1ES United Kingdom
T +44 (0)11 926 4000 **F** +44 (0)161 926 4100 **W** www.mottmac.com

Issue and revision record

Revision	Date	Originator	Checker	Approver	Description	Standard
A	July 2015	[Redacted]			First Issue	

Contents

Executive Summary

New Bridge at Guardbrige shows areas of spalled concrete and exposed corroding reinforcement.

Following an inspection carried out in February 2015 by Amey, Mott MacDonald Ltd recommended that concrete repairs be carried out and an impressed current cathodic protection (CP) system be installed to mitigate further deterioration of the bridge.

This document presents the detailed design of the CP system and the specification for concrete repairs.

1 Introduction

New Bridge at Guardbridge carries the A91 over the river Eden and is located within the village of Guardbridge, Scotland.

The structure consists of five reinforced concrete arch spans. The three central spans are 34.4m, 36.6m and 34.4m long. The two end spans measure approximately 15m and are buried by sediment deposits.

A principal inspection of the bridge was carried out between the 12th and the 14th February 2013 by Halcrow Group Limited. The investigation included a visual inspection, a delamination survey and a covermeter survey. The findings of the investigation are presented in the report *"Principal Inspections Group 6, A91-70B New Bridge, Guardbridge"* produced by Halcrow and dated 5th March 2013.

The report concluded the following:

- The spans have numerous examples of exposed rebar and spalled or delaminated concrete. This has likely been exacerbated by the seepage occurring through joints at the west and east spans.
- The arch soffits were found to have low cover throughout (minimum 5mm, average 20mm). This will be a contributing factor to the high number of defects found at these areas.
- The remainder of the structure is largely in good condition with only minor patching repairs needed at the carriageway and minimal repairs required at the parapets and elevations.

Following the Halcrow survey, the half joint sealant and asphaltic plugs of the carriageway were replaced and a new waterproofing system was implemented to the bridge deck.

Mott MacDonald was appointed to provide technical support for the second stage of the repairs. These were to comprise concrete investigations and repair specifications including cathodic protection design, if required.

Following a review of the available documentation and a site visit carried out by our Rudi Merola and Michael Laing on the 3rd December 2014 a testing program was proposed. This is presented in the "*A91 New Bridge Guardbridge – Testing Schedule"* report produced by Mott MacDonald and dated December 2014.

The recommended testing included the following inspection methods:

- Delamination survey;
- Reinforcement electrical continuity;
- Chloride content;
- Cement content;
- Carbonation depth;
- Breakout.

The testing was carried out between the 2nd and the 6th February 2015 by Amey Civil Engineering Laboratory. The test results are presented in the report "*Concrete testing, A91 New Bridge, Guardbridge"* produced by Amey and dated March 2015.

The analysis of the test results was undertaken by Mott MacDonald and is presented in the report *"A91 New Bridge, Guardbridge, Testing Analysis"* dated May 2015.

The primary cause of degradation was established to be chloride contamination together with the low cover to the reinforcement.

A repair strategy in line with BS EN 1504 was proposed. This includes concrete repairs and the installation of an impressed current cathodic protection (CP) system.

2 Standards

The specified cathodic protection system has been designed in accordance with the following national and international codes of practice and standards:

- ISO 12696: 2012 Cathodic protection of steel in concrete;
- NACE RP0290-2000 Impressed Current Cathodic Protection of Reinforcing Steel in Atmospherically Exposed Concrete Structures;
- Highways Agency Document BA83/02 Cathodic Protection for Use in Reinforced Concrete Highway Structures;
- Manufacturer's guidance notes and recommendations.
- The electrical components shall be installed in accordance with the Institute of Electrical Engineers' wiring regulations and carried out by an appropriately qualified NICEIC contractor.

3 Design Parameters

3.1 Design Current Density

The following design current densities were selected:

- For atmospherically exposed reinforced concrete: 15mA/m^2;
- For immersed reinforced concrete: 10mA/m^2;
- For buried reinforced concrete: 5mA/m^2.

3.2 Area to be Protected

The areas to be protected are the four piers of the bridge and the soffit slab of Spans 2, 3 and 4, see drawing in Appendix C.

The ribs of the free spans treated with shotcrete are not included in the CP system.

The buried elements of Span 1 and Span 2 have been included in the CP system protecting the piers.

3.3 Anode System

3.3.1 Soffit Slab

The system will utilise Elgard 210 mixed metal oxide coated titanium mesh embedded within a 25 mm thick cementitious overlay. Elgard 200 ribbon anodes will be installed along the perimeter of each anode zone.

The CP system for the soffit slab is divided into 8 zones as illustrated on the drawing in Appendix C

Details of the anode system can be found in Appendix C.

The datasheets for the anode system used are contained in Appendix E.

3.3.2 Piers

The system will comprise tubular cannistered anodes. These are 0.5m long, 16mm diameter mixed metal oxide coated titanium anodes from BAC (ref ISO 1.6-50 MT). The anodes are pre-packaged in 0.8m long, 0.3m diameter canisters filled with carbonaceous material.

The CP system for the piers is divided into 4 zones as illustrated on the drawing in Appendix C.

The datasheets for the anode system used are contained in Appendix E.

3.4 DC Connections to Steelwork

Connections to the reinforcement shall be made as shown on the drawing in Appendix C.

3.5 Monitoring System

3.5.1 Soffit Slab

To permit the system to be monitored in the future each zone within the soffit slab will incorporate 4 No. LD15 Ag/AgCl/0.5M KCl reference electrodes supplied by Castle Electrodes Ltd.

The datasheet of the LD15 reference electrode is presented in Appenxix F.

3.5.2 Piers

Each Pier will be monitored with 2 No. LD15 Ag/AgCl/0.5M KCl reference electrodes cast in 6 inch concrete cubes, see detail on the drawing presented in Appendix C.

3.6 Power Supplies

The power and monitoring equipment shall have an appropriate track record for cathodic protection of similar structures. 5 No DurAcenter 4+8 units from Cathodic Protection International will be required and 1 No. associated master control unit.

4 Design Summary

The detailed calculations are contained within Appendix B, with drawing included in Appendix C.

The design is summarised in the following Sections.

The quantity of the anodes quoted does not include a deliberate contingency and are based on the dimensions identified on the drawings. They do not include for any wastage or for laps required for jointing of anodes. Actual dimensions need to be confirmed on site.

The system is split into 12 No. zones.

4.1 Zone 1

This includes: Pier 1, Span 1 and Pier 2.

2 No. tubular anodes;

2 No. reference electrodes, labelled “1,a” and “1,b”;

3 No. DC negatives;

1 No. monitoring negative;

Approximate output 3A @10mA/m^2.

4.2 Zone 2

This includes: Span2-west end.

136m^2 of Elgard 210 Anode Mesh and 45m of Elgard 200 Anode Ribbon installed along the perimeter of the anode zone.

4 No. reference electrodes, labelled “2,a” to “2,d”;

2 No. DC positives;

2 No. DC negatives;

1 No. monitoring negative;

Approximate output 1.7A @15mA/m^2.

4.3 Zone 3

This includes: Span 2 - free span.

126m^2 of Elgard 210 Anode Mesh and 68m of Elgard 200 Anode Ribbon installed along the perimeter of the anode zone.

4 No. reference electrodes, labelled “3,a” to “3,d”;

4 No. DC positives;

4 No. DC negatives;

2 No. monitoring negatives;

Approximate output 1.7A @15mA/m^2.

4.4 Zone 4

This includes: Span2-east end.

136m^2 of Elgard 210 Anode Mesh and 45m of Elgard 200 Anode Ribbon installed along the perimeter of the anode zone.

4 No. reference electrodes, labelled “3,a” to “3,d”;

2 No. DC positives;

2 No. DC negatives;

1 No. monitoring negative;

Approximate output 1.7A @15mA/m^2.

4.5 Zone 5

This includes: Pier 3.

2 No. tubular anodes;

2 No. reference electrodes, labelled “5,a” and “5,b”;

3 No. DC negatives;

1 No. monitoring negative;

Approximate output 2.4A @10mA/m^2.

4.6 Zone 6

This includes: Span3-west end.

226m^2 of Elgard 210 Anode Mesh and 60m of Elgard 200 Anode Ribbon installed along the perimeter of the anode zone.

4 No. reference electrodes, labelled “6,a” to “6,d”;

2 No. DC positives;

2 No. DC negatives;

1 No. monitoring negative;

Approximate output 2.8A @15mA/m^2.

4.7 Zone 7

This includes: Span3-east end.

226m^2 of Elgard 210 Anode Mesh and 60m of Elgard 200 Anode Ribbon installed along the perimeter of the anode zone.

4 No. reference electrodes, labelled “7,a” to “7,d”;

2 No. DC positives;

2 No. DC negatives;

1 No. monitoring negative;

Approximate output 2.8A @15mA/m^2.

4.8 Zone 8

This includes: Pier 4.

2 No. tubular anodes;

2 No. reference electrodes, labelled “8,a” and “8,b”;

3 No. DC negatives;

1 No. monitoring negative;

Approximate output 2.4A @10mA/m^2.

4.1 Zone 9

This includes: Span4-west end.

136m^2 of Elgard 210 Anode Mesh and 45m of Elgard 200 Anode Ribbon installed along the perimeter of the anode zone;

4 No. reference electrodes, labelled “4,a” to “4,d”;

2 No. DC positives;

2 No. DC negatives;

1 No. monitoring negative;

Approximate output 1.7A @15mA/m^2.

4.2 Zone 10

This includes: Span 4 - free span.

126m^2 of Elgard 210 Anode Mesh and 68m of Elgard 200 Anode Ribbon installed along the perimeter of the anode zone;

4 No. reference electrodes, labelled “10,a” to “10,d”;

4 No. DC positives;

4 No. DC negatives;

2 No. monitoring negatives;

Approximate output 1.7A @15mA/m^2.

4.3 Zone 11

This includes: Span4-east end.

136m^2 of Elgard 210 Anode Mesh and 45m of Elgard 200 Anode Ribbon installed along the perimeter of the anode zone;

4 No. reference electrodes, labelled “11,a” to “11,d”;

2 No. DC positives;

2 No. DC negatives;

1 No. monitoring negative;

Approximate output 1.7A @15mA/m^2.

4.4 Zone 12

This includes: Pier 5, Span 5 and Pier 6.

2 No. tubular anodes;

2 No. reference electrodes, labelled “12,a” and “12,b”;

3 No. DC negatives;

1 No. monitoring negative;

Approximate output 3.0A @10mA/m^2.

5 Installation

5.1 Anode System

5.1.1 Soffit Slab

The MMO mesh anode shall be totally encapsulated within a 25mm cementitious overlay.

Prior to the application of the MMO mesh the concrete surface shall be prepared in order to achieve an adequate adhesion of the cementitious overlay as described in Section 12. A Covermeter survey shall also be carried out in order to identify low cover that poses a risk of anode to steel short circuits.

The mesh shall be pinned directly to the prepared concrete surface. Proprietary anode fixings shall be provided by the anode supplier and driven into holes drilled into the concrete in appropriate places. The fixings shall be non-metallic to prevent accidental electrical contact with, or close approach to, the reinforcement.

Connections at 250mm c/c shall be made to the conductor bar by spot welding.

Connections at 250mm c/c shall be made to the ribbon anodes along the perimeter of the anode zone by spot welding.

Application of the overlay shall follow established good practice as published by the Sprayed Concrete Association, see Section 12. The spraying technique shall ensure complete encapsulation of the mesh without underlying voids. The applied overlay shall not be trowelled.

5.1.2 Piers

Each of the tubular anodes shall be installed either:

- In a 300mm diameter hole backfilled with local fill material and with the top of the anode 1m below the riverbed, or
- In a 1300 x 400 x 1000 mm trench backfilled with local fill material, see drawing in Appendix C.

The anode shall be positioned at 3m from the pier.

The anode cable shall be routed on the soffit slab to the junction box as shown in drawing in Appendix C. Cables from the tubular anodes shall be run to the overlaid areas in conduit then embedded in the overlay.

Similarly, cables from the DC negatives and monitoring negatives shall be run to the overlaid areas in conduit then embedded in the overlay.

5.2 Reference Electrodes

5.2.1 Soffit Slab

In each zone there will be 4 embeddable Ag/AgCl/0.5M KCl reference electrodes.

The reference electrodes shall be installed in accordance with the Manufacturer's instructions. The general procedure is as follows:

- Pre-soak the reference electrodes in accordance with the Manufacturer's recommendations. Record the identification number and potential measured in accordance with the Manufacturer's instructions.
- Mark out the location of the electrodes with reference to the drawing presented in Appendix C. Record the location on a sketch, including the reference identification.
- Ascertain the location of the steelwork using a covermeter.
- Remove dust and debris from the reference electrode fixing holes.
- Wet the hole and insert a small amount of R3 repair mortar.
- After removing the protective end cap from the reference electrode insert into hole and grout into position ensuring the tip remains firmly embedded in the R3 mortar.
- Run the cables to the junction box.
- Ensure the reference electrode cables are individually labelled at the junction box and correctly terminated.

5.2.2 Piers

Each Pier will be monitored with 2 No. Ag/AgCl/0.5M KCl reference electrodes cast in 150mm concrete cubes. These are to be installed in the riverbed at an approximate depth of 500mm at the locations shown on the drawing presented in Appendix C. Cables from these reference electrodes will be run to the overlaid areas in conduit then embedded in the overlay.

5.3 Cables

All single core cables from anodes, reference electrodes, DC negatives and monitoring connections shall be XLPE/PVC(Cu) to BS6004 with minimum cross section areas of 2.5mm^2.

The cables shall terminate in a non-metallic junction box mounted in locations shown on the drawings. The exact location of junction boxes shall be agreed in conjunction with the Designer on site.

The cable connections between the junction box and the combined power supply unit and monitoring enclosure shall be made in multi-core copper XLPE/PVC/SWA/PVC Copper cable with a minimum cross sectional area of 1.5mm^2 per core.

Cable splicing shall only be undertaken in exceptional circumstances and by using an approved splicing procedure. Cable splicing shall not be performed without the prior approval of the Designer. Within chases, no bunching of cables shall be permitted which may interfere with successful reinstatement.

All cabling shall be installed according to the relevant codes and standards. Installation and commissioning of all main power and AC distribution electrical wiring and systems shall only be undertaken by NICEIC approved contractors. The installed cables shall be rated to carry a capacity at least 50% in excess of the designed current.

All cables not embedded shall be placed in cable conduit or provided with other means of support and protection. Conduit shall conform to BS4607. Conduit shall be manufactured from PVC-u or similar material. Conduit for the cathodic protection system shall be clearly and indelibly marked “CATHODIC PROTECTION” every 5.0m.

Entries/exits of all cables from conduit shall be through appropriate junction boxes with cable gland entries. All entries and junction boxes shall be protected to IP65 as specified in BS EN 60529:1992. All Junction boxes shall have impact resistance to IK08.

All cable labelling is as per the drawings. Each label will be with the relevant zone number. For example:

- 1,a is reference electrode “a” in zone 1;
- 1,m is the monitoring connection in zone 1;
- +1 is the anode connection for zone 1;
- -1 is the steel connection for zone 1;

5.4 Junction Boxes

Non-metallic junction boxes shall be used.

Where possible junction boxes shall be situated in protected positions and away from locations where they may be inundated by water, mechanical damage, UV degradation or vandalism.

The exact location of junction boxes shall be agreed in conjunction with the Design Engineer on site.

Junction boxes shall be protected to IP65 as specified in BS EN 60529:1992 and shall have impact resistance to IK08 as specified in BS EN 62262:2002.

The junction boxes shall be fixed using non-metallic fixings in such a manner that the IP protection rating is not compromised or any buried components are not damaged.

Junction boxes shall be labelled clearly and shall have unique identification.

5.5 Power and Monitoring Enclosures

The power supply units shall be durAcenter 4+8 units from Cathodic Protection International. The client is to provide an appropriate AC feed for this.

Five power supply units will be utilised. Location of the units shall be agreed in conjunction with the Design Engineer on site. It is currently envisaged that two units will be installed at the north-east end of the bridge and thee units will be installed at the north-west end of the bridge together with the main monitoring unit.

The three units at the north-west end of the bridge will power zones 1 to 7.

The two units at the north-east end of the bridge will power zones 8 to 12.

The main control unit shall be sited at the north-west end of the bridge.

The monitoring unit shall be housed in a stainless steel enclosure to IP65/IK08 and fitted with a padlock and tamper-proof fixings

The enclosure shall have doors and/or swing sections to provide access to all internal components and wiring. Conduit and cable entries shall be made on site, following the enclosure installation.

All the housings containing electrical equipment shall be clearly and securely marked with ‘Danger - contains live electrical equipment’, or similar.

Appropriately sized fuses shall be located within the AC supply panel.

The rectifier system shall be furnished with a separately housed disconnect switch. For 240 V AC service, it shall be a double pole single throw, fused safety disconnect switch.

The electrical components shall be installed in accordance with the Institute of Electrical Engineers’ wiring regulations and carried out by an appropriately qualified NICEIC contractor.

The main rectifier enclosure supplied shall include two sets of the following documentation:

- Operation and maintenance manual.
- Wiring schematic showing the connections from the rectifier to the structure, anodes and reference cells.

6 Testing and Monitoring Prior to Commissioning

All test results shall be certificated and supplied to the Designer.

6.1 Continuity Testing

The Contractor shall check that the steel reinforcement within each zone is electrically continuous using the potential difference method or a DC resistance meter with a short circuit current of minimum 200mA. The Designer shall be given 7 days notice to allow witnessing of tests. This shall include but not be limited to:

- Steel continuity within each element encompassed by the cathodic protection system;
- Electrical continuity of any other metallic elements;
- Isolated steel reinforcement shall be identified by any one of the following results:

    a) An absolute potential difference greater than 1 mV.

    b) A resistance reading greater than 1.0 Ω or a negative resistance reading.

    c) Resistance readings that change by more than 1.0 ohm when the instrument leads are reversed.

    d) An unstable resistance reading that changes more than 1.0 Ω in 15 seconds.

6.2 Continuity Bonding

All metallic objects embedded in the concrete, buried in the riverbed or adjacent to the areas to be cathodically protected (within 1m of the anode boundary) shall be tested for electrical continuity and treated appropriately using one of the following methods:

- Electrically connected to the steelwork;
- Isolated from the surrounding concrete; or
- Tested for interaction to determine whether the element would receive significant stray current when the system is polarised.

Interaction testing shall take the form of a one hour polarisation followed by a fifteen minute potential decay, with potentials monitored every minute using an appropriate reference electrode.

Details for electrical isolation or continuity bonding shall be assessed on the various merits of each case. Where cable is used to provide electrical connections to other metallic elements it shall be colour coded black.

Any discontinuous structural steel shall be made fully electrically continuous in an appropriate manner.

To ensure that all bonded steel is electrically continuous, the new maximum steel to steel resistance shall not be greater than 1 ohm, and this shall be demonstrated in each case and recorded.

It is understood that there are two metallic pipes adjacent the bridge. Interaction testing shall be carried out to determine whether the pipes would receive significant stray current when the system is polarised.

6.3 Reference Electrodes

Reference electrodes shall be checked for stability on receipt from the Manufacturer and prior to installation. The results of these checks shall be recorded. Any reference electrode whose potential varies by more than 5mV in one hour will be rejected.

The following measurements shall be made and recorded in accordance with the quality plan and shall include the following for the cathodic protection system:

- The steel potentials at the reference electrodes shall be measured and recorded. The potentials shall be measured at two instrument input impedance values of 10 MΩ, and 1000 MΩ. If the potentials measured at the two input impedance values differ by more than 20 mV at any reference electrode, an investigation to confirm the integrity of the reference electrode will be carried out and/or remedial measures required.

- The steel potential with respect to the anode system shall be measured and recorded. Values between -20mV and +20mV shall be investigated to confirm the absence of any anode - steel short and/or the remedial measures required.

- Measurements to prove any electronic data logging and data transmitting facility installed as part of the performance monitoring system is functioning correctly and is accurate.

7 Energising the System and Commissioning

7.1 Pre-commissioning

The Contractor shall give at least seven days notice to Mott MacDonald that the system is available for commissioning. Commissioning testing will be undertaken by Mott MacDonald in accordance with the procedures identified in BS EN ISO 12696. Prior to this procedure being carried out the Contractor shall confirm the following:

- AC supply to the power unit is installed and certificated;
- All DC wiring is installed, labelled and terminated correctly in the power supply and resistor box;
- Anodes are electrically isolated from the steelwork;
- Reference electrodes are providing stable readings.

Prior to energisation the following tests shall be undertaken:

- Potential difference check to confirm anode to cathode not continuous;
- Reference electrode – steel natural potential measurements;
- Anode – cathode discontinuity resistance test.

All pre commissioning tests will be conducted manually by Mott MacDonald at the control panel unit.

The Contractor shall attend site to investigate and rectify any defects identified.

For the purposes of pre-commissioning, continuity shall be considered to exist between two points when the measured resistance is less than 1 Ω. Anode to cathode discontinuity shall be demonstrated by a potential difference greater than 20mV.

7.2 Commissioning

The cathodic protection system and all its component parts shall be subjected to a complete visual inspection confirming that all components and cables are installed properly, labelled where appropriate and protected from environmental, human or animal damage.

The system shall not be energized until all cementitious materials have been adequately cured and the electrical circuits and equipment have

been inspected, tested and certified with an NICEIC certificate, in accordance with BS 7671, and found to be satisfactory and capable of being energised with complete safety.

The cathodic protection system shall be energized initially at low current (between 10% to 20% of maximum design current capacity). Measurements shall be made and recorded in accordance with the quality plan and shall include the following:

- The steel potentials at the embedded reference electrodes.
- The output voltage and current values of all D.C. power supplies providing current to the cathodic protection system.
- Confirmation that the polarity of all values indicate that the steel potential is shifted in the negative direction. Positive steel potential shifts shall be investigated to determine any requirements for additional testing and/or remedial works required.

8 Performance Monitoring

The performance of the CP system shall be assessed in accordance with BS EN 12696: 2012 by Mott MacDonald.

A summary of the pertinent test criteria is given below. When conducting these tests the full document shall be referred to.

Testing and monitoring shall be conducted after 3, 6 and 12 months for the first year and either 6 or 12 monthly thereafter.

8.1 Criteria

No instant off steel/concrete potential shall be more negative than -1100mV with respect to Ag/AgCl/0.5M KCl.

2. Representative points on the steel shall meet one of the following criteria.

i) An instant off potential (measured between 0.1 and 1s after switching the D.C. circuit open) more negative than -720mV with respect to Ag/AgCl/0.5M KCl.

ii) A potential decay over a maximum of 24 h of at least 100mV from instant off.

iii) A potential decay over a period greater than 24 h of at least 150mV subject to stable reference electrode potentials.

9 Documentation

The Contractor shall maintain written records for all tests undertaken during installation. These shall be provided to the Designer.

Within 1 month of the date of the completion of the works, the Contractor shall provide the Designer with draft documentation comprising the records and certificates specified above in the form of a volume entitled "Installation Report" (which shall also include as-built drawings). The Contractor shall finalise the documentation and supply three copies to the Designer within 28 days of receipt of the Designer's comments.

The Installation Report shall have all necessary information within one volume. It shall include and describe in detail the following:

- Materials - a full list of all materials used in the Works including datasheets and names and addresses of suppliers;
- Test results - details of all test methods and results including short circuit and polarity checks, continuity and steel potentials;
- As-built drawings - showing for each Zone the exact locations of any repairs, location of anode and all electrical installations including cables and connections.
- Factory test certificates for:
  - Control panel unit;
  - Anodes;
  - Reference electrodes;
- Declaration of conformity for equipment/cables/materials;
- Equipment Operation & Maintenance Manual;
- System Operation & Maintenance Manual.

10 Concrete Repair Specifications

10.1 Standards

BS EN 1504 shall be applied to all elements of concrete repair. All products shall be used in accordance with the Manufacturer's recommendations. CE marked repair products shall be used where available unless a significant benefit can be demonstrated with an appropriate track record.

10.2 Extent of Repair

An estimate of the extent of the repairs is presented in the report "A91 New Bridge, Guardbridge, Testing Analysis" produced by Mott MacDonald and dated May 20415. The following procedure shall be followed to determine the actual extent of the repairs:

The number and extent of defects requiring repair shall be identified by a thorough visual inspection and delamination survey on site. The Client's Representative shall be given seven days notification (in writing) prior to this survey taking place to allow attendance.

The Contractor shall submit sketches showing the locations and approximate surface area of spalled and delaminated concrete to the Client's Representative for assessment.

For all repairs, the inspections and measurements of repair locations, including areas and depths shall be carried out jointly by the Contractor and the Client's Representative. The limits of any repair shall be recorded and agreed with the Client's Representative on site, and shall be subject to modification as work proceeds according to the conditions found. This applies both to surface perimeters, depths, widths and lengths.

10.3 Surface Cleaning of Concrete

Prior to starting any preparation work, the areas around repairs shall be cleaned to remove all dirt and other contaminants, previous coatings, laitance, paint, algae, moss, lichens, plant growth etc. Following this operation the area shall be kept free of contamination to the satisfaction of the Client's Representative. The surface of the newly exposed concrete shall be cleaned of all dust and grit using a mains pressure water jet, properly filtered oil free airline or other approved method, and any loose aggregate shall be collected and removed.

The Contractor shall propose a method of cleaning to the approval of the Client's Representative that will not cause any damage to sound concrete.

At all times during cleaning operations full protection shall be provided to the general public and property located within close proximity to the Works.

10.4 Remedial Repair of Delaminated and Spalled Concrete

Concrete repairs shall be carried out in accordance with BS EN 1504 principle 3.

10.5 Preparation for Removal of Concrete

Proposed methods of removal of damaged concrete shall be to the approval of the Client's Representative. Such methods shall include light handheld pneumatic/electric percussive tools and hydrodemolition (see Section 11). No breaking equipment shall be used without the prior approval of the Client's Representative to ensure that removal of any concrete does not disturb or damage the reinforcement.

10.6 Removal of Concrete

All defective concrete shall be collected and removed and a sound substrate shall be achieved over the full extent of the repair. Such a substrate shall have a regular 5mm surface profile to provide a good bond for repair. This shall be checked using a stainless steel profile comb which shall be provided by, and used by the Contractor, at the instruction of the Client's Representative. This surface finish shall be extended to all repair perimeters. The maximum depth of repair shall be as agreed with the Client's Representative.

For each repair, an agreed method shall be used to remove the concrete which will not result in overbreak beyond the designated area of the repair.

For each repair area, a perimeter to the repair shall be marked and broken out perpendicular to the face of the concrete, to a depth of not less than 15mm or to within 10mm of the reinforcement, whichever is the lesser. Prior to carrying out any breakouts the Contractor shall ascertain the depth of the reinforcement along the line of the break out by means of a cover meter. Care shall be taken to prevent overbreak

beyond the line of the cut. The limits of any repair shall be broken as a series of straight lines at right angles to the surface.

Where reinforcement is exposed during concrete removal then the substrate shall be taken to a minimum of 25mm behind the bars and no greater than the maximum depth of repair specified by the Client's Representative. Where reinforcement is not exposed during concrete removal specified by the Client's Representative, then the substrate shall be prepared without further breaking out.

Where an unacceptable level of corrosion to reinforcement is found within any designated repair area, or is suspected of existing beyond this area, further concrete shall be removed where necessary, as directed by the Client's Representative, until a continuous length of not less than 100mm of reinforcing bar of acceptable condition is exposed. The extent and sequence of removal of the additional concrete shall be as instructed by the Client's Representative.

10.7 Preparation of Reinforcement

Exposed reinforcement shall remain in position, subject to there being no mechanical damage, or loss of section. Exposed reinforcement shall be cleaned to achieve a suitable surface finish in accordance with the repair material Manufacturer's instructions. Special care shall be taken to clean out any pits which have developed on the surface of the bars.

Where loss of section as a result of corrosion (in excess of 10%) is found to have occurred on exposed reinforcement, the Contractor shall, as directed by the Client's Representative, install an additional length of steel alongside the damaged bar. The Contractor may be required to remove the damaged bar if it prevents the installation of new bars, or it is considered by the Client's Representative as being likely to cause unacceptable damage to the repaired area at a later stage in the remaining life of the structure. Where directed by the Client's Representative, the Contractor shall replace such bars with bars of an equivalent size and type. Reinforcement shall be removed by disc-cutting or other method approved by the Client's Representative.

At the direction of the Client's Representative, replacement bars shall be lapped at the appropriate lengths.

The reinforcement primer, if required, shall be as recommended by the Manufacturer of the proprietary repair system and shall be applied in accordance with the Manufacturer's instructions.

10.8 Reinstatement with Repair Materials

Before the application of any repair material, the Contractor shall ensure adequacy of the prepared surface for repair, by obtaining approval from the Client's Representative.

Reinstatement is to be undertaken using a certificated R4 repair mortar with a declared carbonation resistance that passes the requirements of BS EN 13295.

The proprietary material shall be supplied by a Manufacturer who either:

(a) Holds a current BSI Certificate of Registration as a BSI Registered Firm of Assessed Capability in accordance with BS EN ISO 9000; or
(b) Operates quality assurance procedures of a similar standard to (a) above and which meet the approval of the Client's Representative.

Only one type of repair concrete shall be used for a particular type of structural repair throughout the Works. Once proposed by the Contractor, and approved by the Client's Representative for inclusion in the Works, the source and type of the repair mortar (which may include a concrete primer) and its mix proportions for any specific application shall not be varied. The repair material shall be pre-packaged. The Contractor shall provide details of product type, Manufacturer and method of placing. The selected and approved system shall be fully compatible with the existing concrete and any subsequently applied CP system.

The repair material shall be applied by a contractor experienced in the use of the proposed system, and in accordance with the Manufacturer's recommendations. The Client's Representative shall be furnished with details of the material for his approval. This shall include details of placing methodology including batching and mixing, primers, placing technique, curing and any temporary works needed.

All material shall be used within the pot-life as specified by the Manufacturer.

All repair materials shall be mixed in the proportions and manner recommended by the Manufacturer. Part mixing shall not be permitted unless otherwise specified.

No additional water, admixtures or other materials shall be added without the written permission of the Client's Representative.

All areas to be repaired shall be protected from contamination from any source.

Immediately prior to reinstatement all dust, debris and loose material shall be removed from the repair area. The substrate shall be thoroughly wetted down for a minimum of 2 hours (unless otherwise agreed with the Client's Representative) and any surplus water allowed to drain to leave a saturated, but surface dry substrate.

Where a primer or bonding agent is specified by the repair material Manufacturer, it shall be thoroughly worked into all hollows and crevices in the prepared surface and around the reinforcement as required.

Unless otherwise specified by the Manufacturer the repair mortar shall be applied to the primer or bonding agent "wet on wet". Where the primer or bonding agent is allowed to completely dry out, except as permitted by the Manufacturer, the substrate shall be re-prepared by complete removal of the dried primer.

The repair material shall not be applied thicker than the maximum thicknesses approved by the Manufacturer. Each layer shall be completely bonded to the preceding layer and worked around all reinforcing bars.

Successive layers shall be applied as soon as the preceding layer has become sufficiently stiff to support the weight of the additional build up layer, but still adequate to provide bonding. If at any time during the application of the material the surface dries out completely then the surface shall be prepared according to the Manufacturer's recommendations.

Immediately after placing, the concrete must be allowed to cure in accordance to good practice, in particularly dry or windy conditions additional precautions must be taken. The methods of protection used

shall be in accordance with the Manufacturer's instructions and subject to the approval of the Client's Representative.

The curing membrane to be used shall be as recommended by the Manufacturer of the proprietary repair system and shall be applied in accordance with the Manufacturer's instructions.

10.9 Finish to Concrete

In areas not to be overlaid with sprayed concrete, trowel concrete repairs shall be placed flush to the surrounding concrete, to provide a close textured, accurate and level finish which matches the appearance of the surrounding concrete.

11 Removal by Hydrodemolition (High Pressure Water Jetting)

11.1 General

Defective concrete may be removed with the controlled use of hydrodemolition or high pressure water jetting techniques.

The work shall be undertaken by a reputable sub-Contractor who is a member of the Water Jetting Association and who has had previous experience of similar concrete cutting operations.

The name and particulars of the proposed sub-Contractor and the water pressures to be adopted shall be submitted at return of tenders for approval.

In areas where concrete surface contamination may interfere with preparation for concrete removal, then prior to starting any preparation work, the areas around repairs shall be cleaned to remove all dirt and other contaminants, previous coatings, latency, paint, algae, moss, lichens, plant growth etc.

The method of surface cleaning shall be high pressure water employing a properly filtered oil free airline.

At all times, the cleaning operations shall be directed away from all other persons. Where this is not practicable, tenting shall be provided to contain the operation. The drainage in the area of the cleaning shall be kept free of silt and debris, which may lead to a build up of water.

11.2 Phases of Water Jetting Works

Prior to any concrete removal the "as found" condition, shall be determined with respect to the quantity of concrete that has already been removed. The quantity shall be agreed with the Client's Representative prior to any concrete removal being undertaken.

The water jetting works shall nominally be undertaken in three phases. Prior to commencing the first phase of the works a hammer rap survey shall be undertaken and the extent of apparently delaminated and cracked areas marked and confirmed for removal during the first phase of the water jetting works.

11.3 Phase 1

Phase 1 shall involve removal of loose or obviously cracked or delaminated material and may be undertaken using water jetting. Removal of such material by other approved mechanical means shall be at no additional cost.

On completion of this phase, to the satisfaction of the Client's Representative, the surfaces shall be left to dry for 24 hours. Any debris from the water jetting process shall be removed by grit and air blasting to allow an inspection of the surfaces prior to commencement of Phase 2 of the water jetting works.

The Contractor should note that delaminated concrete may require careful removal to avoid large sections of concrete from falling in an uncontrolled manner.

11.4 Phase 2

The Contractor shall mark up in conjunction with the Client's Representative, areas for further preparation as part of Phase 2. These areas shall include:-

- Areas for surface preparation prior to anode placement and overlay application.
- Areas of cracking or delamination not found by the initial hammer rap survey.
- Areas containing metallic mesh.
- Other areas as defined by the Client's Representative on site.

Phase 2 of the water jetting shall commence following approval of the Client's Representative. This phase of work shall only be undertaken using water jetting. Following completion of this phase to the satisfaction of the Client's Representative, the surfaces shall be left to dry for 24 hours. Any debris from the water jetting process shall be removed by grit and air blasting to allow an inspection of the surfaces prior to commencement of Phase 3 of the water jetting works.

11.5 Phase 3

The Contractor shall mark up in conjunction with the Client's Representative, areas for further preparation as part of Phase 3. These areas shall include:-

- Further areas of cracking or delamination.

- Further areas containing metallic mesh or similar.
- Other areas as defined by the Client's Representative on site.

Phase 3 of the water jetting shall commence following approval of the Client's Representative. Following completion of this phase, to the satisfaction of the Client's Representative, the surfaces shall be left to dry for 24 hours and any debris from the water jetting process removed by grit and air blasting to allow an inspection of the surfaces. The quantity of material removed shall be agreed with the Client's Representative.

11.6 Safety of Operation for High Pressure Water Jetting (HPWJ)

The Contractor shall demonstrate his competence in the operation of HPWJ. Experience in similar schemes shall be presented to the Client's Representative for his approval. The Contractor shall be a member of the Water Jetting Association. All working practices and equipment shall be in accordance with the "Code of Practice for the use of High Pressure Water Jetting Equipment" as published by the Water Jetting Association, PO Box 59451, London, SE2 8AL.

11.7 Safety of Operation for High Pressure Water Jetting - Special Protection

Enclosures are to be provided to give complete protection to all persons in the vicinity from flying debris and effects of the water jet. Full details of the enclosure are to be with the Contractor's Tender. The proposed enclosure must provide controlled access to the supervisory staff for frequent inspection and monitoring.

All hoses are to be adequately protected from external damage and to protect personnel and the public from the effect of any puncturing.

11.8 Contractor's Supervisory Staff

The Contractor shall provide supervision at all times during water jetting operations, by suitably experienced personnel familiar with the techniques and constraints of High Pressure Water Jetting, in particular its use at the pressures proposed in relation to concrete removal.

11.9 Method Statement for Concrete Removal

With his tender the Contractor shall submit a method statement giving:

- Details of the proposed cutting operation for High Pressure Water Jetting indicating the areas, direction and orientation of the cutting, together with measures to be taken to control the rate of concrete removal.
- Details of the type and performance and location of the pump equipment for High Pressure Water Jetting, together with nozzle type, diameter, approximate power output of the jet and estimated operating reaction force.

11.10 Water Supply

The Contractor shall locate and obtain a supply of water of a volume and purity suitable for use in the water jetting operations.

11.11 Health and Safety Executive

Methods are to be acceptable to the Health and Safety Executive who must be informed of the specific location and timing of the works at least 7 days in advance of the proposed commencement of water jetting.

11.12 Control of Debris

The Contractor shall construct silting dams and take all other measures necessary to prevent debris entering public and private water courses. During concrete removal debris shall be removed daily.

12 Provisions for Sprayed Concrete

12.1 Materials

The repair material shall be dry or wet sprayed concrete with a proven track record of use in concrete repair applications. The choice between the wet or dry spray application shall depend upon the repair depths experienced and available curing times.

The repair materials shall have a proven track record for use in cathodic protection systems, demonstrating similar resistivity values to the parent concrete, unless by prior approval by the Client's Representative.

Full details of the proposed materials shall be submitted to the Client's Representative for formal approval, or rejection, during the tender period. Examples where such materials have been used in similar circumstances shall also be presented. The Manufacturer's recommendations for the application of wet and dry sprayed products shall be sought. Method statements shall be produced for approval prior to application of sprayed products. Tenders based on materials which have not been formally approved by the Client's Representative will be unconditionally rejected.

12.2 Testing of Sprayed Concrete Material

Independent of the works area and prior to the application of sprayed concrete, 3 No. trial panels shall be prepared within pre-formed shutters.

The first two shall comprise a 1000mm x 1000mm x 100mm thick test panel that shall be sprayed at the time of the first application of sprayed concrete work. The test panels shall be cured in similar conditions to those existing in the repair and overlay areas. 3 No. 100mm diameter cores shall be removed from the central 350mm x 350mm of each panel and tested for compressive strength in accordance with BS EN 12504-1:2000 to determine at what age 30N/mm^2 is achieved (i.e. cores shall be extracted at 7, 14 and 28 day intervals). The results of this test shall be documented and passed to the Client's Representative for approval.

The third shall comprise a 600mm x 600mm x 25mm thick test panel that shall be sprayed on the structure at the time of the first application of sprayed concrete work. The test panel shall be cured in similar conditions to those existing in the repair and overlay areas.

After completion of each overlaid area 2 No. in-situ pull-off tests shall be undertaken on 50mm diameter cores drilled through the overlay material and into the concrete, taking care not to core through any reinforcement, cabling or reference cells. The bond strength between the overlay material and the substrate shall exceed 1N/mm^2. The Contractor shall fill the core holes after completion of testing with a hand placed mortar approved by the Client's Representative. The pull-off test cores shall be passed to the Client's Representative following completion of testing.

12.3 Safety of Operations

The Contractor shall take all necessary measures to provide adequate protection to safeguard adjoining structure elements, services and vehicles from noise, dust, rebound, water run-off, abrasive materials, falling debris and other hazards to the satisfaction of the Client's Representative. All debris and water shall be removed by the Contractor in such a way as to prevent damage, fouling or blockage to existing public or private drainage systems.

The expansion joint shall be temporarily sealed (from the soffit) to prevent any ingress of water.

All personnel working in or near the spraying operations shall be provided with appropriate clothing, face masks and safety goggles.

Where concrete spraying is taking place, lighting of not less than 500 lux minimum measured illuminance shall be provided in areas of inadequate natural light.

Delivery hoses shall not be left unprotected across the path of any vehicular traffic.

Blocked hoses shall not be blown clear unless the free end is securely held or tied down such that the affected material can be cleared safely.

12.4 Transportation of Materials

All transportation of the repair and overlay materials to the point of application shall be such as to prevent contamination or segregation of the overlay material or loss of fine constituent materials.

12.5 Batching and Mixing of any Wet Sprayed Material

All material shall be used within the pot-life as specified by the Manufacturer.

All materials shall be mixed in the proportions and manner recommended by the Manufacturer.

No additional water, admixtures or other materials shall be added without the written permission of the Client's Representative.

The overlay material shall be sprayed into its final position in as short a time as possible after mixing (or opening of container/bag).

12.6 Air Supply

The Contractor shall ensure that the air compressor intended to be employed is of sufficient capacity to maintain continuity of placing. The compressor shall maintain a supply of clean dry air adequate to maintain sufficient nozzle velocity for all parts of the work while simultaneously operating a blow pipe for clearing away rebound. The Contractor shall be fully responsible for proving the adequacy of the equipment.

12.7 Water Supply

Water for mixing shall be clean and free from harmful matter and in accordance with BS EN 10008:2002.

The water pressure at the discharge nozzle shall be sufficiently greater than the operating air pressure to ensure that the water is intimately mixed with the other materials. The Contractor shall arrange their own water supply. The water pressure shall be uniformly steady and non-pulsating.

12.8 Experience

The material shall be applied by an experienced Contractor in accordance with the Manufacturer's recommendations. All sprayed concrete shall be applied in accordance with the Sprayed Concrete Association Code of Good Practice.

The foreman, nozzle man and delivery equipment operator shall show evidence before employment of having completed satisfactory work in similar capacities elsewhere. The nozzle man and delivery equipment operator shall hold a current "Certificate of Competence in Sprayed Concrete" as issued by the Sprayed Concrete Association, Kingsley House, Ganders Business Park, Kingsley, Bordon, Hampshire, GU35 9LU. Evidence of this shall be provided upon request.

12.9 Preparation of Surfaces

The existing concrete at the perimeters of any concrete repair or overlay areas shall either be disc cut or groove cut by precision water jetting to a depth of 5mm, the cut shall be square to the finished surface of the concrete. Care shall be taken to avoid damaging any reinforcement or embedded metal fixings and the like. Concrete removal shall not undermine the perimeter cut.

All concrete surfaces to be repaired or overlaid (including the cut edge) shall be of a rough texture appropriate for a good bond for repair i.e. with a 5mm surface profile. All loosely adhering materials shall be removed.

Immediately prior to placement of any concrete repair or overlay material, the entire area to be repaired or overlaid shall first be grit blasted and then cleaned thoroughly by brushing and washing with clean water to remove loose particles and dirt. The area shall then be blasted with oil free compressed air (pressure to exceed 100 lb/sq.in.) and wetted, sufficiently to keep the substrate continuously saturated for a minimum of 2 hours unless agreed with the Client's Representative. Immediately prior to spraying the substrate shall be allowed to become surface dry.

Any prepared surface shall be maintained free from subsequent contamination.

12.10 Application of Sprayed Concrete

All plant and tools used for the mixing, transportation and spraying of repair materials shall be kept clean and free from accumulated deposits of repair material.

The delivery system and discharge nozzle shall be capable of delivering a conical discharge stream of uniform appearance throughout.

Distortion of this stream, or any non-uniform appearance shall be remedied by immediate examination of the nozzle and any malfunction rectified by replacement of defective parts before further work is carried out.

The delivery equipment shall be thoroughly cleaned at the end of each shift. Equipment parts shall be regularly inspected and replaced as required.

The concrete repair in each anode zone shall each be placed in a separate continuous operation. The sprayed concrete shall be built up by making several passes of the nozzle over the work area. The sprayed concrete shall emerge from the nozzle in a steady uninterrupted flow. Should the flow become intermittent for any reason, the nozzle man shall direct it away from the work until it again becomes constant. The distance of the nozzle from the work shall be between 0.5 and 1.5 metres, such as to give best results for the conditions. As a general rule it shall be held perpendicular to the application surface. However, when shooting through reinforcing bars and or the anode mesh the nozzle shall be held closer and at a slight angle from the perpendicular in order to permit better encasement and facilitate removal of rebound.

The repair material shall be applied up to the maximum thickness approved by the Manufacturer in a single layer application. Where necessary, subsequent layers shall be applied, with each layer being fully bonded to the preceding layer. The sprayed materials shall be thoroughly worked around all exposed reinforcing bars.

Successive layers shall be applied as soon as the preceding layer has become sufficiently stiff to support the weight of the additional build up layer, but still adequate to provide bonding. If at any time during the application of the material the surface dries out completely then the surface shall be prepared according to the Manufacturer's recommendations.

12.11 Rebound

Under no circumstances shall rebound be worked back into the construction by the nozzle man. If it does not fall clear of the work it must be removed. Rebound which has been removed shall not be included in later batches.

Cleanliness is essential and rebound spray or particles of materials from the work shall not be permitted to escape beyond the working area.

All rebound shall be removed by a suitable method.

The delivery equipment including hoses, connections and valves must at all times be maintained in first class condition to ensure that there is no leakage whatsoever from the plant.

Details of the screening necessary to avoid contamination from the sprayed concrete process and the means of disposal of the rebound material from the working areas shall be provided with the tender.

12.12 Repair of Defective Areas

Sprayed concrete repair shall be fully bonded to the substrate.

On completion of each sprayed concrete application the completed repairs, any intermediate surfaces formed due to failure to complete an area in a continuous operation and surfaces of the finished overlay shall first be allowed to take their initial set. All laitance, loose material and rebound shall then be removed and the surfaces will be thoroughly inspected and sounded with a hammer by the Client's Representative's Representative. Cracked, hollow and delaminated areas, sags or other defects shall be cut out to be replaced separately or, where approved by the Client's Representative, with the succeeding layer. In the case of repair to the overlay any consequential repairs to the embedded anode system shall be approved and carried out to the satisfaction of the Client's Representative.

All defects shall be made good at the Contractor's own expense.

12.13 Spraying Concrete in Cold Weather

Temperatures shall be monitored daily and the work programmed accordingly.

Unless otherwise approved by the Manufacturer of the repair system, ambient temperatures and the temperature of the concrete substrate shall not be lower than 5ºC and rising at the time of placing. Long duration of low temperatures may require artificial heating to be employed. Newly placed sprayed concrete shall be protected by

covering with suitable insulating material for a period of at least 72 hours if the temperature is expected to fall below 5ºC.

Adequate measures, to the Client's Representative's approval, shall be taken to ensure that the mixing water is sufficiently warm to ensure that the temperature of the freshly placed sprayed concrete shall be not less than 5ºC. The water temperature shall not exceed 60ºC.

12.14 Tolerances, Surface Finish and Formwork

The finished, 'as sprayed' concrete overlay shall provide a nominal cover of at least 25mm to the surface mounted anode. The surface shall be cut + flush finished so that it does not deviate from the required profile by more than 10mm over a 3 metre gauge length, or have any abrupt irregularities.

The Contractor shall include with his tender details of the type and method of overlay placement.

12.15 Curing

The placed repair material shall be fully cured by spraying a single coat of degradable, spray apply curing compound as recommended by the Manufacturer. This curing coat shall be applied to the 'as sprayed' concrete within one hour of its placement. As an alternative, polyethylene sheeting may be used, but this shall be adequately secured and shall fully encompass the area to be cured whilst providing a good seal at the area boundaries. The curing coat/sheeting shall be left in place for a minimum of 14 days.

Appendices

Appendix A. CP Contractor Specialist

A.1 Cathodic Protection

A.1.1 Experience of Personnel

The Contractor responsible for the installation of the cathodic protection system shall have personnel with demonstrable experience at an appropriate level of at least 3 projects in the installation of impressed current cathodic protection systems.

A.1.2 General

The Contractor shall be responsible for providing an Impressed Current Cathodic Protection system as shown on the drawings. The system shall be split into separately controllable zones. The cathodic protection system shall be installed in accordance with the following standards:

- BS EN 12696:2012 Cathodic Protection of Steel in Concrete.
- Statutory Acts
- BS 7671-Part 1: Requirements for Electrical Installations – the IEE Wiring Regulations. Seventeenth Edition
- Guidance Notes to BS 7671 published by the IEE
- Manufacturer's guidance notes and recommendations.

Appendix B. CP Design Calculations

Pier 1

Top Slab	**Longitudinal Reinforcement**		
	Bar "f" diameter	inch	0.75
	Bar "f" diameter	mm	19.05
	Bar "f" surface area (1 m length)	mm^2/m	59845.6
	Bar "f" lengh	m	20.70
	Bar "f" surface area (actual length)	mm^2	1238803.403
	Bar "f" surface area (actual length)	m^2	1.2388
	No of bars "f"	-	12
	Total bar "f" surface area	m^2	14.87
	Area of reinforcement	**m^2**	**14.87**
Main Elevation			
	Vertical Reinforcement		
	Bar "d" diameter	inch	0.875
	Bar "d" diameter	mm	22.225
	Bar "d" surface area (1 m length)	mm^2/m	69819.8
	Bar "d" lengh	m	5.25
	Bar "d" surface area (actual length)	mm^2	366721.7145
	Bar "d" surface area (actual length)	m^2	0.3667
	No of bars "d"	-	60
	Total bar "d" surface area	m^2	22.00
	Bar "c" diameter	inch	0.875
	Bar "c" diameter	mm	22.225
	Bar "c" surface area (1 m length)	mm^2/m	69819.8
	Bar "c" lengh	m	2.40
	Bar "c" surface area (actual length)	mm^2	167567.61
	Bar "c" surface area (actual length)	m^2	0.1676
	No of bars "c"	-	60
	Total bar "c" surface area	m^2	10.05
	Horizontal Reinforcement		
	Bar "f" diameter	inch	0.75
	Bar "f" diameter	mm	19.05
	Bar "f" surface area (1 m length)	mm^2/m	59845.6
	Bar "f" lengh	m	20.70
	Bar "f" surface area (actual length)	mm^2	1238803.403
	Bar "f" surface area (actual length)	m^2	1.239
	No of bars "f"	-	7
	Total bar "f" surface area	m^2	8.67
	Area of reinforcement	**m^2**	**40.73**
Side Elevation			
	Vertical Reinforcement		
	Bar "e" diameter	inch	0.875
	Bar "e" diameter	mm	22.225
	Bar "e" surface area (1 m length)	mm^2/m	69819.8
	Bar "e" lengh	m	5.25
	Bar "e" surface area (actual length)	mm^2	366721.7145
	Bar "e" surface area (actual length)	m^2	0.367
	No of bars "e"	-	3
	Total bar "e" surface area	m^2	1.10

	Bar "c" diameter	inch	0.875
	Bar "c" diameter	mm	22.225
	Bar "c" surface area (1 m length)	mm^2/m	69819.8
	Bar "c" lengh	m	2.40
	Bar "c" surface area (actual length)	mm^2	167567.61
	Bar "c" surface area (actual length)	m^2	0.168
	No of bars "c"	-	3
	Total bar "c"	m^2	0.50
	Horizontal Reinforcement		
	Bar "g" diameter	inch	0.75
	Bar "g" diameter	mm	19.05
	Bar "g" surface area (1 m length)	mm^2/m	59845.6
	Bar "g" lengh	m	4.05
	Bar "g" surface area (actual length)	mm^2	242518.2081
	Bar "g" surface area (actual length)	m^2	0.243
	No of bars "g"	-	7
	Total bar "g" surface area	m^2	1.70
	Area of reinforcement	**m^2**	**3.30**
Base			
	Base - Longitudinal Reinforcement		
	Bar "b" diameter	inch	0.75
	Bar "b" diameter	mm	19.05
	Bar "b" surface area (1 m length)	mm^2/m	59845.6
	Bar "b" lengh	m	20.70
	Bar "b" surface area (actual length)	mm^2	1238803.403
	Bar "b" surface area (actual length)	m^2	1.239
	No of bars "b"	-	7
	Total bar "b" surface area	m^2	8.67
	Base - Transverse Reinforcement		
	Bar "a" diameter	inch	0.75
	Bar "a" diameter	mm	19.05
	Bar "a" surface area (1 m length)	mm^2/m	59845.6
	Bar "a" lengh	m	2.85
	Bar "a" surface area (actual length)	mm^2	170703.5181
	Bar "a" surface area (actual length)	m^2	0.1707
	No of bars "a"	-	62
	Total bar "a" surface area	m^2	10.58
	Area of reinforcement within base	**m^2**	**19.26**
Total			
	Total area of reinforcement	**m^2**	**122.2**
	Design current density in soil	mA/m^2	5
	Total current demand in soil	mA	610.90
	Total design current demand	mA	672.0
	Total design current demand	**A**	**0.67**

Pier 2

Top Slab

Longitudinal Reinforcement

Bar "j/k/g" diameter	inch	1.125
Bar "j" diameter	mm	28.575
Bar "j" surface area (1 m length)	mm^2/m	89768.4
Bar "j" lengh	m	16.66
Bar "j" surface area (actual length)	mm^2	1495289.568
Bar "j" surface area (actual length)	m^2	1.4953
No of bars "j"	-	10
Total bar "j" surface area	m^2	14.95

Transverse Reinforcement

Bar "m" diameter	inch	1.125
Bar "m" diameter	mm	28.575
Bar "m" surface area (1 m length)	mm^2/m	89768.4
Bar "m" lengh	m	5.40
Bar "m" surface area (actual length)	mm^2	484749.1575
Bar "m" surface area (actual length)	m^2	0.4847
No of bars "m"	-	35
Total bar "m" surface area	m^2	16.97

Hinge

Bar "o/p" diameter	inch	0.75
Bar "o" diameter	mm	19.05
Bar "o" surface area (1 m length)	mm^2/m	59845.6
Bar "o" lengh	m	14.40
Bar "o" surface area (actual length)	mm^2	861776.28
Bar "o" surface area (actual length)	m^2	0.862
No of bars "o"	-	2
Total bar "o" surface area	m^2	1.72

Bar "q" diameter	inch	0.5
Bar "q" diameter	mm	12.7
Bar "q" surface area (1 m length)	mm^2/m	39897.1
Bar "q" lengh	m	14.40
Bar "q" surface area (actual length)	mm^2	574517.52
Bar "q" surface area (actual length)	m^2	0.575
No of bars "q"	-	3
Total bar "q" surface area	m^2	1.72

Bar "n" diameter	inch	0.5
Bar "n" diameter	mm	12.7
Bar "n" surface area (1 m length)	mm^2/m	39897.1
Bar "n" lengh	m	1.43
Bar "n" surface area (actual length)	mm^2	56996.92563
Bar "n" surface area (actual length)	m^2	0.0570
No of bars "n"	-	65
Total bar "n" surface area	m^2	3.70

Inside Walls

Bar "l" diameter	inch	1.125
Bar "l" diameter	mm	28.575
Bar "l" surface area (1 m length)	mm^2/m	89768.4
Bar "l" lengh	m	2.10
Bar "l" surface area (actual length)	mm^2	188513.5613
Bar "l" surface area (actual length)	m^2	0.1885
No of bars "l"	-	8
Total bar "l" surface area	m^2	1.51

Bar "f" diameter	inch	1.125
Bar "f" diameter	mm	28.575
Bar "f" surface area (1 m length)	mm^2/m	89768.4
Bar "f" lengh	m	2.85
Bar "f" surface area (actual length)	mm^2	256055.2772
Bar "f" surface area (actual length)	m^2	0.2561
No of bars "f"	-	4
Total bar "f" surface area	m^2	1.02
Features		
Bar "s" diameter	inch	0.5
Bar "s" diameter	mm	12.7
Bar "s" surface area (1 m length)	mm^2/m	39897.1
Bar "s" lengh	m	2.10
Bar "s" surface area (actual length)	mm^2	83783.805
Bar "s" surface area (actual length)	m^2	0.0838
No of bars "s"	-	6
Total bar "s" surface area	m^2	0.50
Bar "t" diameter	inch	0.5
Bar "t" diameter	mm	12.7
Bar "t" surface area (1 m length)	mm^2/m	39897.1
Bar "t" lengh	m	1.50
Bar "t" surface area (actual length)	mm^2	59845.575
Bar "t" surface area (actual length)	m^2	0.060
No of bars "t"	-	6
Total bar "t" surface area	m^2	0.36
Bar "u" diameter	inch	0.5
Bar "u" diameter	mm	12.7
Bar "u" surface area (1 m length)	mm^2/m	39897.1
Bar "u" lengh	m	1.58
Bar "u" surface area (actual length)	mm^2	62885.73021
Bar "u" surface area (actual length)	m^2	0.063
No of bars "u"	-	6
Total bar "u" surface area	m^2	0.38
Bar "w" diameter	inch	0.375
Bar "w" diameter	mm	9.525
Bar "w" surface area (1 m length)	mm^2/m	29922.8
Bar "w" lengh	m	1.73
Bar "w" surface area (actual length)	mm^2	51724.53047
Bar "w" surface area (actual length)	m^2	0.052
No of bars "w"	-	7
Total bar "w" surface area	m^2	0.36
Area of reinforcement (submerged)	**m^2**	**44.81**

Main Elevation

Vertical Reinforcement		
Bar "f" diameter	inch	0.75
Bar "f" diameter	mm	19.05
Bar "f" surface area (1 m length)	mm^2/m	59845.6
Bar "f" lengh	m	5.25
Bar "f" surface area (actual length)	mm^2	314332.8981
Bar "f" surface area (actual length)	m^2	0.3143
No of bars "f"	-	44
Total bar "f" surface area	m^2	13.83

Bar "c" diameter	inch	0.75
Bar "c" diameter	mm	19.05
Bar "c" surface area (1 m length)	mm^2/m	59845.6
Bar "c" lengh	m	1.50
Bar "c" surface area (actual length)	mm^2	89768.3625
Bar "c" surface area (actual length)	m^2	0.0898
No of bars "c"	-	44
Total bar "c" surface area	m^2	3.95
Horizontal Reinforcement		
Bar "k/l" diameter	inch	0.625
Bar "k" diameter	mm	15.875
Bar "k" surface area (1 m length)	mm^2/m	49871.3
Bar "k" lengh	m	17.10
Bar "k" surface area (actual length)	mm^2	852799.4438
Bar "k" surface area (actual length)	m^2	0.853
No of bars "k"	-	5
Total bar "k" surface area	m^2	4.26
Area of reinforcement (considered submerged)	**m^2**	**22.04**

Side Elevation

Vertical Reinforcement		
Bar "f" diameter	inch	0.75
Bar "f" diameter	mm	19.05
Bar "f" surface area (1 m length)	mm^2/m	59845.6
Bar "f" lengh	m	5.25
Bar "f" surface area (actual length)	mm^2	314332.8981
Bar "f" surface area (actual length)	m^2	0.3143
No of bars "f"	-	8
Total bar "f" surface area	m^2	2.51
Bar "d" diameter	inch	0.75
Bar "d" diameter	mm	19.05
Bar "d" surface area (1 m length)	mm^2/m	59845.6
Bar "d" lengh	m	1.50
Bar "d" surface area (actual length)	mm^2	89768.3625
Bar "d" surface area (actual length)	m^2	0.090
No of bars "d"	-	8
Total bar "d"	m^2	0.72
Horizontal Reinforcement		
Bar "p" diameter	inch	0.625
Bar "p" diameter	mm	15.875
Bar "p" surface area (1 m length)	mm^2/m	49871.3
Bar "p" lengh	m	4.50
Bar "p" surface area (actual length)	mm^2	224420.9063
Bar "p" surface area (actual length)	m^2	0.224
No of bars "p"	-	7
Total bar "p" surface area	m^2	1.57
Area of reinforcement (considered submerged)	**m^2**	**4.80**

Base

Base - Longitudinal Reinforcement		
Bar "b" diameter	inch	0.75
Bar "b" diameter	mm	19.05
Bar "b" surface area (1 m length)	mm^2/m	59845.6
Bar "b" lengh	m	17.56
Bar "b" surface area (actual length)	mm^2	1050720.729
Bar "b" surface area (actual length)	m^2	1.051
No of bars "b"	-	13
Total bar "b" surface area	m^2	13.66
Base - Transverse Reinforcement		
Bar "a" diameter	inch	0.875
Bar "a" diameter	mm	22.225
Bar "a" surface area (1 m length)	mm^2/m	69819.8
Bar "a" lengh	m	4.65
Bar "a" surface area (actual length)	mm^2	324829.812
Bar "a" surface area (actual length)	m^2	0.325
No of bars "a"	-	52
Total bar "a" surface area	m^2	16.89
Area of reinforcement (buried)	**m^2**	**30.55**

Total

Total area of reinforcement in water (elevation + top slab)	**m^2**	**98.5**
Total area of reinforcement in soil (base)	**m^2**	**30.6**
Design current density in water	mA/m^2	10
Design current density in soil	mA/m^2	5
Current demand in water	mA	985.02
Current demand in soil	mA	152.75
Total design Current demand	mA	1251.6
Total design Current demand	**A**	**1.25**

Pier 4 (Pier 3 similar)

Steel area per m^2 for Pier 2	***Pier 2***		
	Elevation		
	Perimeter of Pier 2	m	33
	Higth of Pier 2	m	4.15
	Elevation area	m^2	136.95
	Area of reinforcement	m^2	53.70
	Area of reinforcement per m^2	m^2/m^2	0.39
	Base		
	Base area	m^2	65
	Area of reinforcement	m^2	30.55
	Area of reinforcement per m^2	m^2/m^2	0.47
	Top slab		
	Top slab area	m^2	40.6
	Area reinforcement	m^2	44.81
	Area of reinforcement per m^2	m^2/m^2	1.10
Current demand for Pier 4	***Pier 4***		
	Elevation		
	Area of reinforcement per m^2 (assumed to be same as Pier 2)	m^2/m^2	0.39
	Perimeter of Pier 2	m	42
	Higth of Pier 2	m	7.2
	Elevation area	m^2	302.4
	Area of reinforcement	m^2	118.57
	Base		
	Area of reinforcement per m^2 (assumed to be same as Pier 2)	m^2/m^2	0.47
	Base area	m^2	93
	Area of reinforcement per m^2	m^2	43.71
	Top slab		
	Area of reinforcement per m^2 (assumed to be same as Pier 2)	m^2/m^2	1.10
	Top slab area	m^2	52
	Area of reinforcement per m^2	m^2	57.39
	Total area of reinforcement in water (elevation + top slab)	**m^2**	**175.95**
	Total area of reinforcement in soil (base)	**m^2**	**43.7**
	Design current density in water	mA/m^2	10
	Design current density in soil	mA/m^2	5
	Current demand in water	mA	1935.49
	Current demand in soil	mA	240.41
	Total current demand	mA	2175.9
	Total design current demand	mA	2393.5
	Total design current demand	**A**	**2.39**

Span 3

Slab	Slab width	m	13.182
	Span arch length	m	34.2
	Longitudinal Reinforcement		
	Bar diameter	inch	0.5
	Bar diameter	mm	12.7
	Bar surface area (1 m length)	mm^2/m	39897.1
	Bar spacing	inch	12
	Bar spacing	mm	304.8
	No of bars per m of soffit slab	-	4.0
	Reinforcement area per m^2 of soffit slab	mm^2/m	159588.2
	Reinforcement area per m^2 of soffit slab	m^2/m	0.1596
	Transverse Reinforcement		
	Bar diameter	inch	0.5
	Bar diameter	mm	12.7
	Bar surface area (1 m length)	mm^2/m	39897.1
	Bar spacing	inch	9
	Bar spacing	mm	228.6
	No of bars per m of soffit slab	-	5.0
	Reinforcement area per m^2 of soffit slab	mm^2/m^2	199485.3
	Reinforcement area per m^2 of soffit slab	m^2/m^2	0.1995
	Area of reinforcement per m^2 of slab	**m^2/m^2**	**0.36**
Ribs A & G	**Links**		
	bar "n1" diameter	inch	0.375
	Bar diameter	mm	9.525
	Bar length	mm	900
	Bar surface area (actual length)	mm^2	26930.5
	Bar spacing	inch	12
	Bar spacing	mm	304.8
	No of bars per m of rib	-	4.0
	Reinforcement area per m of rib	mm^2/m	107722.0
	Reinforcement area per m of rib	m^2/m	0.1077
	bar "j14" diameter	inch	0.375
	Bar diameter	mm	9.525
	Bar length	mm	228.6
	Bar surface area (actual length)	mm^2	6840.3
	Bar spacing	inch	12
	Bar spacing	mm	304.8
	No of bars per m of soffit slab	-	8.0
	Reinforcement area per m of rib	mm^2/m	54722.8
	Reinforcement area per m of rib	m^2/m	0.0547
	Lonfitudinal Reinforcement		
	Bars "c/b"diameter	inch	1.5
	Bar diameter	mm	38.1
	Bar surface area (1 m length)	mm^2/m	119691.2
	Bar spacing	inch	-
	Bar spacing	mm	-
	No of bars per m of soffit slab	-	4.0
	Reinforcement area per m of rib	mm^2/m	478764.6
	Reinforcement area per m of rib	m^2/m	0.4788

	Bars "m7" diameter	inch	0.75
	Bar diameter	mm	19.05
	Bar surface area (1 m length)	mm^2/m	59845.6
	Bar spacing	inch	-
	Bar spacing	mm	-
	No of bars per m of soffit slab	-	1.0
	Reinforcement area per m of rib	mm^2/m	59845.6
	Reinforcement area per m of rib	m^2/m	0.0598
	Total reinforcement area per m of rib	m^2/m	0.7011
	Number of ribs (Ribs B, C, D, E and F assumed to be as reinforced as Ribs A and G)	-	7
	Area of reinforcement per m^2 of slab	**m^2/m^2**	**0.37**
Cross bracing Beams	**Links**		
	bar "d/e" diameter	inch	0.5
	Bar diameter	mm	12.7
	Bar length	mm	279.4
	Bar surface area (actual length)	mm^2	11147.2
	Bar spacing	inch	8
	Bar spacing	mm	203.2
	No of bars per m of rib	-	10.0
	Reinforcement area per m of beam	mm^2/m	111472.4
	Reinforcement area per m of beam	m^2/m	0.1115
	Lonfitudinal Reinforcement		
	Bars "az"diameter	inch	1
	Bar diameter	mm	25.4
	Bar surface area (1 m length)	mm^2/m	79794.1
	Bar spacing	inch	-
	Bar spacing	mm	-
	No of bars per m of soffit slab	-	4.0
	Reinforcement area per m of beam	mm^2/m	319176.4
	Reinforcement area per m of beam	m^2/m	0.3192
	Total reinforcement area per m of rib	m^2/m	0.4306
	Number of cross bracing beams	-	3
	Area of reinforcement per m^2 of slab	**m^2/m^2**	**0.04**
Total	**Total reinforcement area per m^2 of soffit slab**	**m^2/m^2**	**0.77**
	Design current density	mA/m^2	15
	Current demand per m^2 of soffit slab	mA/m^2	11.54
	Slab width	m	13.182
	Span Arch length	m	34.2
	Span 3 area	m^2	451
	Total current Demand	mA	5201.1
	Total design current demand	mA	5721.2
	Total design current demand	**A**	**5.7**

Cantiliver of Spans 2 and Span 4

	Slab width	m	13.182
	Span Arch length	m	10.32
(assumed same as Span 3)	**Total reinforcement area per m^2 of soffit slab**	**m^2/m^2**	0.77
	Design current density	mA/m^2	15
	Current demand per m^2 of soffit slab	mA/m^2	11.54
	Span 2/ cantiliver area	m^2	136
	Total current demand	mA	1569.46
	Total design current demand	mA	1726.4
	Tatal design current demand per each cantiliver	**A**	**1.73**

Centre Span - West Span - East Span

Slab - Soffit	Soffit width to be CPd	m	4.064
	Arch span length	m	11.32
	Longitudinal Reinforcement		
	Bar diameter	inch	0.5
	Bar diameter	mm	12.7
	Bar surface area (1 m length)	mm^2/m	39897.1
	Bar spacing	inch	12
	Bar spacing	mm	304.8
	No of bars per m of soffit slab	-	4.0
	Reinforcement area per m^2 of soffit slab	mm^2/m	159588.2
	Reinforcement area per m^2 of soffit slab	m^2/m	0.1596
	Transverse Reinforcement		
	Bar diameter	inch	0.5
	Bar diameter	mm	12.7
	Bar surface area (1 m length)	mm^2/m	39897.1
	Bar spacing	inch	9
	Bar spacing	mm	228.6
	No of bars per m of soffit slab	-	5.0
	Reinforcement area per m^2 of soffit slab	mm^2/m^2	199485.3
	Reinforcement area per m^2 of soffit slab	m^2/m^2	0.2
	Area of reinforcement per m^2 of soffit slab		**0.3591**
Ribs A & G	**Links**		
	bar "f1" diameter	inch	0.375
	Bar diameter	mm	9.525
	Bar length	mm	900
	Bar surface area (actual length)	mm^2	26930.5
	Bar spacing	inch	12
	Bar spacing	mm	304.8
	No of bars per m of rib	-	4.0
	Reinforcement area per m of rib	mm^2/m	107722.0
	Reinforcement area per m of rib	m^2/m	0.1077
	bar "d3" diameter	inch	0.375
	Bar diameter	mm	9.525
	Bar length	mm	228.6
	Bar surface area (actual length)	mm^2	6840.3
	Bar spacing	inch	12
	Bar spacing	mm	304.8
	No of bars per m of soffit slab	-	8.0
	Reinforcement area per m of rib	mm^2/m	54722.8
	Reinforcement area per m of rib	m^2/m	0.0547
	Lonfitudinal Reinforcement		
	Bars "a"diameter	inch	1.5
	Bar diameter	mm	38.1
	Bar surface area (1 m length)	mm^2/m	119691.2
	Bar spacing	inch	-
	Bar spacing	mm	-
	No of bars per m of soffit slab	-	4.0
	Reinforcement area per m of rib	mm^2/m	478764.6
	Reinforcement area per m of rib	m^2/m	0.4788

	Bars "e1" diameter	inch	0.625
	Bar diameter	mm	15.875
	Bar surface area (1 m length)	mm^2/m	49871.3
	Bar spacing	inch	-
	Bar spacing	mm	-
	No of bars per m of soffit slab	-	1.0
	Reinforcement area per m of rib	mm^2/m	49871.3
	Reinforcement area per m of rib	m^2/m	0.0499
	Total reinforcement area per m of rib	m^2/m	0.6911
	Number of ribs (Ribs B and F assumed to be as reinforced as Ribs A and G)	-	2
	Area of reinforcement per m^2 of slab	**m^2/m^2**	**0.68**
Cross bracing Beams	**Links**		
	bar "d/e" diameter	inch	0.5
	Bar diameter	mm	12.7
	Bar length	mm	279.4
	Bar surface area (actual length)	mm^2	11147.2
	Bar spacing	inch	8
	Bar spacing	mm	203.2
	No of bars per m of rib	-	10.0
	Reinforcement area per m of beam	mm^2/m	111472.4
	Reinforcement area per m of beam	m^2/m	0.1115
	Lonfitudinal Reinforcement		
	Bars "az"diameter	inch	1
	Bar diameter	mm	25.4
	Bar surface area (1 m length)	mm^2/m	79794.1
	Bar spacing	inch	-
	Bar spacing	mm	-
	No of bars per m of soffit slab	-	4.0
	Reinforcement area per m of beam	mm^2/m	319176.4
	Reinforcement area per m of beam	m^2/m	0.3192
	Total reinforcement area per m of rib	m^2/m	0.4306
	Number of cross bracing beams	-	3
	Area of reinforcement per m^2 of slab	**m^2/m**	**0.11**
Total - soffit	**Total reinforcement area per m^2 of soffit slab**	**m^2/m^2**	**1.15**
	Design current density	mA/m^2	15
	Current demand per m^2 of soffit slab	mA/m^2	17.30
	Area - soffit	m^2	46.0
	Current demand for soffit slab	mA	795.92
	Design current demand for soffit slab	mA	875.52
	Span 2/ Free span ribs Area Current demand-soffit A		**0.88**

Slab - deck	Deck width to be CPd	m	4.6
	Arch span length	m	11.32
	Longitudinal Reinforcement		
	Bar diameter	inch	0.75
	Bar diameter	mm	19.05
	Bar surface area (1 m length)	mm^2/m	59845.6
	Bar spacing	inch	6
	Bar spacing	mm	152.4
	No of bars per m of slab deck	-	7.0
	Reinforcement area per m^2 of slab deck	mm^2/m	418919.0
	Reinforcement area per m^2 of slab deck	m^2/m	0.4189
	Transverse Reinforcement		
	Bar diameter	inch	0.75
	Bar diameter	mm	19.05
	Bar surface area (1 m length)	mm^2/m	59845.6
	Bar spacing	inch	12
	Bar spacing	mm	304.8
	No of bars per m of slab deck	-	4.0
	Reinforcement area per m^2 of slab deck	mm^2/m^2	239382.3
	Reinforcement area per m^2 of slab deck	m^2/m^2	0.2394
	Total reinforcement area per m^2 of slab deck	**m^2/m^2**	**0.66**
	Design current density	mA/m^2	15
	Current demand per m^2 of slab deck	**mA/m^2**	**9.87**
	Design current demand per m^2 of slab deck	**mA/m^2**	10.86
	Area - slab deck	m^2	52.1
	Current demand	**A**	**0.57**

Elevation of Rib B/F	Elevation to be CPd	m	1.22
	Arch span length	m	11.32
	Links		
	bar "f1" diameter	inch	0.375
	Bar diameter	mm	9.525
	Bar length	mm	2201.6
	Bar surface area (actual length)	mm^2	65878.0
	Bar spacing	inch	9
	Bar spacing	mm	228.6
	No of bars per m	-	5.0
	Reinforcement area per m	mm^2/m	329390.0
	Reinforcement area per m	m^2/m	0.3294
	longitudinal Reinforcement		
	Bar " k1"diameter	inch	0.6
	Bar diameter	mm	15.24
	Bar surface area (1 m length)	mm^2/m	47876.5
	No of bars	-	2.0
	Reinforcement area per m	mm^2/m	95752.9
	Reinforcement area per m	m^2/m	0.0958
	Links + longitudinal reinforcement area per m	m^2/m	0.43
	Lengh of rib	m	11.33
	Total links + longitudinal reinforcement area	**m^2**	**4.82**
	bar "a2" diameter	inch	1.25
	Bar diameter	mm	31.75
	Bar length	mm	9900
	Bar surface area (actual length)	mm^2	987452.0
	No of bars	-	1.0
	Reinforcement area	m^2	0.987
	bar "b2" diameter	inch	1.125
	Bar diameter	mm	28.575
	Bar length	mm	13276.2
	Bar surface area (actual length)	mm^2	1191782.7
	No of bars	-	1.0
	Reinforcement area	m^2	1.2
	bar "c1" diameter	inch	1.125
	Bar diameter	mm	28.575
	Bar length	mm	5852.4
	Bar surface area (actual length)	mm^2	525360.4
	No of bars	-	1.0
	Reinforcement area	m^2	0.5
	Total reinf. area of elevation	**m^2**	**15.04**
Total	Design current density	mA/m^2	15
	Current demand	mA	225.64
	Design current demand	mA	248.21
	Span 2/ Free span ribs Area Current demand	A	0.25
	Total current demand of half free span	**A**	**1.69**

Span 1 (Span 5 similar)

Soffit Slab

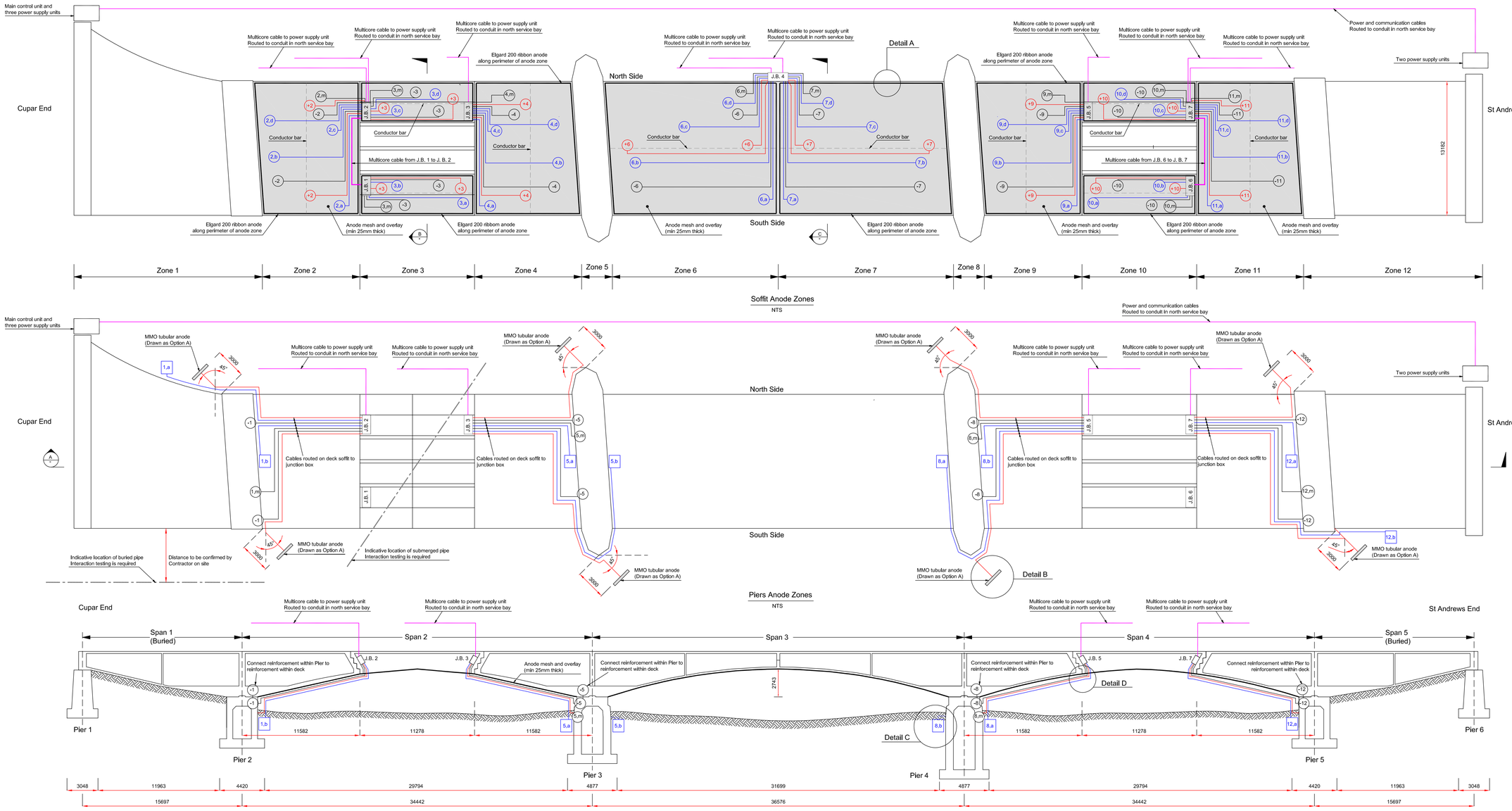
	Soffit area	m^2	209
Assumed to be as per Span 3	Total reinforcement area per m^2 of soffit slab	m^2/m^2	0.77
	Total area of reinforcement within soffit slab	**m^2**	**160**

Elevations

Links		
Bar "L4" diameter	inch	0.375
Bar diameter	mm	9.525
Bar surface area (1 m length)	mm^2/m	29922.8
Bar spacing	inch	6
Bar spacing	mm	152.4
No of bars per m of elevation	-	7.0
Reinforcement area per m^2 of elev	mm^2/m	209459.5
Reinforcement area per m2 of elev	m^2/m	0.2095
bar "n1" diameter	inch	0.375
Bar diameter	mm	9.525
Bar length	mm	381
Bar surface area (actual length)	mm^2	11400.6
Bar spacing	inch	9
Bar spacing	mm	228.6
No of bars per m of soffit slab	-	10.0
Reinforcement area per m^2 of elev	mm^2/m^2	114005.8
Reinforcement area per m^2 of elev	m^2/m^2	0.1140
Bar ""c,d,e,f"" diameter	inch	1.5
Bar diameter	mm	38.1
Bar surface area (1 m length)	mm^2/m	119691.2
Bar spacing	inch	30
Bar spacing	mm	762
No of bars per m of elevation	-	2.0
Reinforcement area per m^2 of elev	mm^2/m	239382.3
Reinforcement area per m2 of elev	m^2/m	0.2394
Longitudinal		
Bar "m" diameter	inch	0.375
Bar diameter	mm	9.525
Bar surface area (1 m length)	mm^2/m	29922.8
Bar spacing	inch	15
Bar spacing	mm	381
No of bars per m of elevation	-	3.0
Reinforcement area per m^2 of elev	mm^2/m	89768.4
Reinforcement area per m2 of elev	m^2/m	0.0898
Area of elevation	m^2	43.4
Total reinforcement area per m^2 of elevation	m^2/m^2	0.65
Total area of reinforcement within each elev.	**m^2**	**28**

Total reinforcement area	**m^2**	**217**
Design current density	mA/m^2	5
Current demand	mA	1085
Current demand	**A**	**1.09**

Appendix C. CP Drawings



Soffit Anode Zones

NTS

Piers Anode Zones

NTS

Cabling: Zones 1 to 5

Junction Box	Single Core Cables in from Structure	Cable Lable	Cables in as Multicore From Adjacent Junction Box	Cores out as Multicore	Notes
J.B. 1	Ref 3,a Ref 3,b 2 No. DC positives from zone 3 2 No. DC negatives from zone 3 1 No. Monitoring from zone 3	Ref 3,a Ref 3,b +3 -3 3,m	None	Ref 3,a Ref 3,b 1 No. DC positive from zone 3 1 No. DC negative from zone 3 1 No. Monitoring from zone 3	DC positives to zone commoned DC negatives to zone commoned
J.B. 2	Ref 1,a Ref 1,b 2 No. DC positives from zone 1 2 No. DC negatives from zone 1 Monitoring from zone 1 Ref 2,a Ref 2,b Ref 2,c Ref 2,d 2 No. DC positives from zone 2 2 No. DC negatives from zone 2 1 No. Monitoring from zone 2 Ref 3,c Ref 3,d 2 No. DC positives from zone 3 2 No. DC negatives from zone 3 1 No. Monitoring from zone 3	Ref 1,a Ref 1,b +1 -1 1,m Ref 2,a Ref 2,b Ref 2,c Ref 2,d +2 -2 2,m Ref 3,c Ref 3,d +3 -3 3,m		Ref 1,a Ref 1,b 2 No. DC positives from zone 1 2 No. DC negatives from zone 1 Monitoring from zone 1 Ref 2,a Ref 2,b Ref 2,c Ref 2,d 1 No. DC positive from zone 2 1 No. DC negative from zone 2 1 No. Monitoring from zone 2 Ref 3,c Ref 3,d 1 No. DC positive from zone 3 1 No. DC negative from zone 3 1 No. Monitoring from zone 3 Ref 3,a Ref 3,b	 DC positives to zone commoned DC negatives to zone commoned DC positives to zone commoned DC negatives to zone commoned
J.B. 3	Ref 4,a Ref 4,b Ref 4,c Ref 4,d 2 No. DC positives from zone 4 2 No. DC negatives from zone 4 Monitoring from zone 4 Ref 5,a Ref 5,b 2 No. DC positives from zone 5 2 No. DC negatives from zone 5 1 No. Monitoring from zone 5	Ref 4,a Ref 4,b Ref 4,c Ref 4,d +4 -4 4,m Ref 5,a Ref 5,b +5 -5 5,m	None	Ref 4,a Ref 4,b Ref 4,c Ref 4,d 1 No. DC positive from zone 4 1 No. DC negative from zone 4 Monitoring from zone 4 Ref 5,a Ref 5,b 2 No. DC positives from zone 5 2 No. DC negatives from zone 5 1 No. Monitoring from zone 5	 DC positives to zone commoned DC negatives to zone commoned

Cabling: Zones 6 to 7

Junction Box	Single Core Cables in from Structure	Cable Lable	Cables in as Multicore From Adjacent Junction Box	Cores out as Multicore	Notes
J.B. 4	Ref 6,a Ref 6,b Ref 6,c Ref 6,d 2 No. DC positives from zone 6 2 No. DC negatives from zone 6 1 No. Monitoring from zone 6 Ref 7,a Ref 7,b Ref 7,c Ref 7,d 2 No. DC positives from zone 7 2 No. DC negatives from zone 7 1 No. Monitoring from zone 7	Ref 6,a Ref 6,b Ref 6,c Ref 6,d +6 -6 6,m Ref 7,a Ref 7,b Ref 7,c Ref 7,d +7 -7 7,m	None	Ref 6,a Ref 6,b Ref 6,c Ref 6,d 1 No. DC positive from zone 6 1 No. DC negative from zone 6 1 No. Monitoring from zone 6 Ref 7,a Ref 7,b Ref 7,c Ref 7,d 1 No. DC positive from zone 7 1 No. DC negative from zone 7 1 No. Monitoring from zone 7	 DC positives to zone commoned DC negatives to zone commoned

Cabling: Zones 8 to 12

Junction Box	Single Core Cables in from Structure	Cable Lable	Cables in as Multicore From Adjacent Junction Box	Cores out as Multicore	Notes
J.B. 5	Ref 8,a Ref 8,b 2 No. DC positives from zone 8 2 No. DC negatives from zone 8 Monitoring from zone 8 Ref 9,a Ref 9,b Ref 9,c Ref 9,d 2 No. DC positives from zone 9 2 No. DC negatives from zone 9 1 No. Monitoring from zone 9	Ref 8,a Ref 8,b +8 -8 8,m Ref 9,a Ref 9,b Ref 9,c Ref 9,d +9 -9 9,m	None	Ref 8,a Ref 8,b 2 No. DC positives from zone 8 2 No. DC negatives from zone 8 Monitoring from zone 8 Ref 9,a Ref 9,b Ref 9,c Ref 9,d 1 No. DC positive from zone 9 1 No. DC negative from zone 9 1 No. Monitoring from zone 9	 DC positives tc zone commoned DC negatives to zone commoned
J.B. 6	Ref 10,a Ref 10,b 2 No. DC positives from zone 10 2 No. DC negatives from zone 10 1 No. Monitoring from zone 10	Ref 10,a Ref 10,b +10 -10 10,m	None	Ref 10,a Ref 10,b 1 No. DC positive from zone 10 1 No. DC negative from zone 10 1 No. Monitoring from zone 10	 DC positives tc zone commoned DC negatives to zone commoned
J.B. 7	Ref 10,c Ref 10,d 2 No. DC positives from zone 10 2 No. DC negatives from zone 10 1 No. Monitoring from zone 10 Ref 11,a Ref 11,b Ref 11,c Ref 11,d 2 No. DC positives from zone 11 2 No. DC negatives from zone 11 1 No. Monitoring from zone 11 Ref 12,a Ref 12,b 2 No. DC positives from zone 12 2 No. DC negatives from zone 12 1 No. Monitoring from zone 12	Ref 10,c Ref 10,d +10 -10 10,m Ref 11,a Ref 11,b Ref 11,c Ref 11,d +11 -11 11,m Ref 12,a Ref 12,b +12 -12 12,m		Ref 10,c Ref 10,d 1 No. DC positive from zone 10 1 No. DC negative from zone 10 1 No. Monitoring from zone 10 Ref 10,a Ref 10,b Ref 11,a Ref 11,b Ref 11,c Ref 11,d 1 No. DC positive from zone 11 1 No. DC negative from zone 11 Monitoring from zone 11 Ref 12,a Ref 12,b 2 No. DC positives from zone 12 2 No. DC negatives from zone 12 1 No. Monitoring from zone 12	 DC positives tc zone commoned DC negatives to zone commoned DC positives tc zone commoned DC negatives to zone commoned

Notes

1. Dimensions in millimetres unless noted otherwise.
2. All dimensions to be confirmed on site.
3. Electrical continuity shall assessed on site. Where limited continuity is found additional investigations and remediation shall be carried out on site by the Contractor in areas to be agreed with the Designer.
4. Exact location of reference electrodes shall be agreed on site.
5. Junction boxes shall be IP65/IK08.
6. Exact location of junction boxes, power supply units and main control enclosure shall be agreed on site.
7. All single core cables from anodes,reference electrodes, DC negatives and monitoring connections shall be XLPE/PVC(Cu) to BS6004 with minimum CSA 2.5mm².
8. All multicore cables shall be Cu/XLPE/PVC/SWA/PVC to BS6004 with minimum CSA 1.5mm².
   Multicore cables for the soffit anode zones shall labeled as follows:
   - Core 1: DC positive cable;
   - Core 2: DC negative cable;
   - Core 3: Monitoring negative cable;
   - Core 4: Reference electrode "a" cable;
   - Core 5: Reference electrode "b" cable;
   - Core 6: Reference electrode "c" cable;
   - Core 7: Reference electrode "d" cable.

   Multicore cables for the piers anode zones shall be labeled as follows:
   - Core 1: DC positive cable;
   - Core 2: DC positive cable;
   - Core 3: DC negative cable;
   - Core 4: DC negative cable;
   - Core 5: Monitoring negative cable;
   - Core 6: Reference electrode "a" cable;
   - Core 7: Reference electrode "b" cable.
9. All multicore cables shall be routed to conduit in the north service bay.
10. Conduit shall be manufactured from PVC-u or similar material and shall conform to BS 4607.
11. Conduit shall be indelibly marked "CATHODIC PROTECTION" every 5m.

Key to symbols

- +2 — DC Positive - Location to be agreed on site.
- -2 — DC Negative - Location to be agreed on site.
- 2,m — Monitoring Negative - Location to be agreed on site.
- 2,a — Reference Electrode - Location to be agreed on site.
- Elgard 200 ribbon anode.
- J. B. 1 — Junction box
- Anode mesh and overlay
- 1,a — Reference electrode buried in the seabed - See Detail C

Reference drawings

Rev	Date	Drawn	Description	Ch'k'd	App'd
P1	June 2015	RM	First Issue	CA	PL

Mott MacDonald
Spring Bank House
33 Stamford Street
Altrincham, WA14 1ES
United Kingdom
T +44 (0)161 926 4000
F +44 (0)161 926 4100
W www.mottmac.com

Client: Fife Council

Title: New Bridge Guardbridge Cathodic Protection

Designed	R Merola		Eng check	C Atkins	
Drawn	R Merola		Coordination	C Atkins	
Dwg check	C Atkins		Approved	P Lambert	

Scale at A0: As Shown
Status: PRE
Rev: P1

Drawing Number: MMD-349042-0001

Appendix D. Estimated Quantities

The quantities listed in Table D.1 do not include a deliberate contingency and are based on the dimensions identified on the drawings. Actual quantities need to be confirmed on site.

Table D.1: Estimated quantities

Zone	Mesh and overlay (m^2)	Ribbon Anode (m)	Tubular anode	Ref Electr.	DC+	DC-	Monitoring	Conductor bar (m)
1	N/A	N/A	2	2[(a)]	2	3	1	N/A
2	136	45	N/A	4	2	2	1	13
3	126	68	N/A	4	4	4	2	2 bars of 11m
4	136	45	N/A	4	2	2	1	13
5	N/A	N/A	2	2[(a)]	2	3	1	N/A
6	226	60	N/A	4	2	2	1	16.5
7	226	60	N/A	4	2	2	1	16.5
8	N/A	N/A	2	2[(a)]	2	3	1	N/A
9	136	45	N/A	4	2	2	1	13
10	126	68	N/A	4	4	4	2	2 bars of 11m
11	136	45	N/A	4	2	2	1	13
12	N/A	N/A	2	2	2	3	1	N/A
Total	**1248**	**436**	**8**	**40**	**28**	**32**	**14**	**129**

[(a)]Cast in 150mm concrete cube

- 7 No Junction boxes;
- 5 No. Power supply Units;
- 1 Main Control Unit;
- 110 m of conduit.

Appendix E. Anode System Datasheets

MIXED METAL OXIDE ELGARD 210 ANODE MESH

REVISION 1

ELGARD™ Anode mesh is composed of a precious metal oxide catalyst sintered to an expanded Titanium mesh substrate. The Anode Mesh is used as a key component in the Cathodic Protection of Reinforced Concrete Structures.

MATERIAL SPECIFICATIONS

ANODE PERFORMANCE	
Current rating @ 110 mA/m^2 (10 mA/ft^2)	24.4 mA/m^2 (2.22 mA/ft^2)
Expected life (NACE Standard TM02944-94)	75 Years
Catalyst	Iridium Based Mixed Metal Oxide
Maximum anode concrete interface current density :	
FHWA limit	110 mA/m^2 (10 mA/ft^2)
Short-term limit	220 mA/m^2 (20 mA/ft^2)
NOMINAL DIMENSIONS	
Width of roll	1.22 m (4 ft)
Length of roll	76 m (250 ft)
Area per roll	92.9 m^2 (1000 ft^2)
Actual anode surface per unit area of concrete	0.22 m^2/m^2 (0.22 ft^2/ft^2)
Expanded thickness	1.981 mm (0.078")
Diamond dimensions	34 x 76 x 0.89 mm (1.33 " x 3.0 " x 0.035 ")
Shipping weight per coil	33kg (73 lbs)
SUBSTRATE	
Composition	Titanium, Grade 1 per ASTM B265
Coefficient of thermal expansion	8.7 x 10^{-5}/˚K (0.0000048/in/in/˚K)
Thermal conductivity @ 20˚C	15.6W/ m^2 - ˚K (9.0BTU/hr/ft^2/˚F/ft)
Electrical resistivity	0.000056 Ohm-cm (0.000022 Ohm-in)
Modulus of elasticity	105 GPa (14,900,000 PSI) minimum
Tensile strength	245 MPa (35,000 PSI) minimum
Yield strength	175 MPa (25,000 PSI) minimum
Elongation	24% minimum
ELECTRICAL PROPERTIES	
Anode mesh resistance lengthwise	0.046 Ohm/m (0.014 Ohm/ft)
Current distributor resistance lengthwise	0.049 Ohm/m (0.015 Ohm/ft)
Resistance widthwise c/w current distributor	0.016 Ohm/m (0.005 Ohm/ft)

Venture Way, Grantham, Lincs NG31 7XS UK. Tel: +44 (0)1476 590666 Fax: +44 (0)1476 570605
Email: cpc@cathodic.co.uk Website: www.cathodic.co.uk
Registered Office: Minalloy House, Regent Street, Sheffield S1 3NJ, UK VAT No. 116 8408 71, Reg'd in England No. 478098

MIXED METAL OXIDE
ELGARD 200 RIBBON MESH

REVISION 1

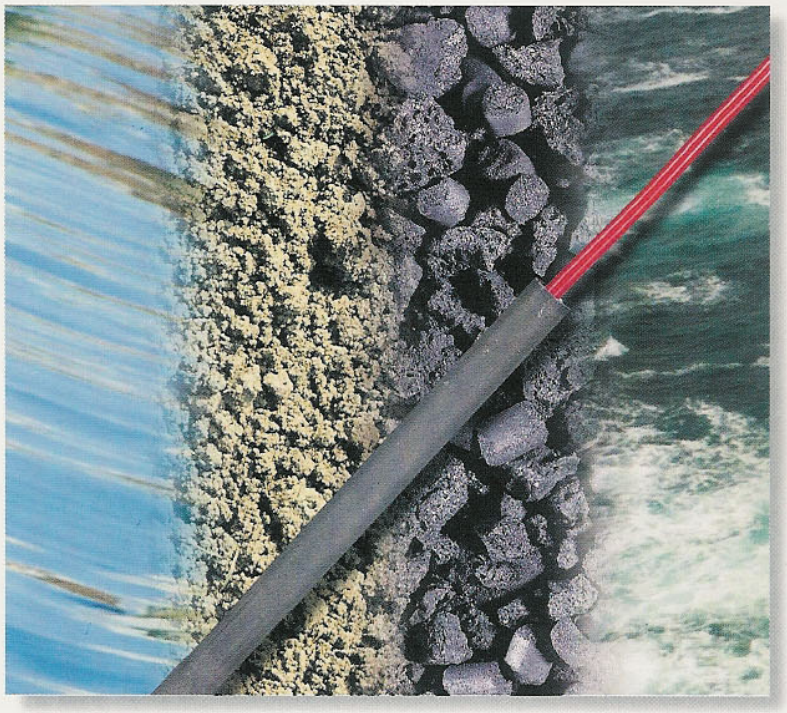
ELGARD™ Anode ribbon mesh is composed of a precious metal oxide catalyst sintered to an expanded Titanium mesh substrate. The Anode Ribbon Mesh is used as a key component in the Cathodic Protection of Reinforced Concrete Structures.

MATERIAL SPECIFICATIONS

ANODE PERFORMANCE	
Current rating @ 110 mA/m^2 (10 mA/ft^2)	7.0 mA/m (2.13 mA/ft)
Expected life (NACE Standard TM02944-94)	75 Years
Catalyst	Iridium Based Mixed Metal Oxide
Maximum anode concrete interface current density	
FHWA limit	110 mA/m^2 (10 mA/ft^2)
Short-term limit	220 mA/m^2 (20 mA/ft^2)
NOMINAL DIMENSIONS	
Width	25 mm (0.8 ")
Coil length	76 m (250 ft)
Actual anode surface per unit length of anode	0.062 m^2/m (0.203 ft^2/ft)
Expanded thickness	1.30 mm (0.051 ")
Diamond dimensions	2.5 x 4.6 x 0.6 mm (0.10 " x 0.18 " x 0.025 ")
Shipping weight per coil	3.6 kg (7.9 lbs)
SUBSTRATE	
Composition	Titanium, Grade 1 per ASTM B265
Coefficient of thermal expansion	8.7 x 10^{-5}/°K (0.0000048/in/in/°K)
Thermal conductivity @ 20°C	15.6W/ m^2 - °K (9.0BTU/hr/ft^2/°F/ft)
Electrical resistivity	0.000056 Ohm-cm (0.000022 Ohm-in)
Modulus of elasticity	105 GPa (14,900,000 PSI) minimum
Tensile strength	245 MPa (35,000 PSI) minimum
Yield strength	175 MPa (25,000 PSI) minimum
Elongation	24% minimum
CURRENT DISTRIBUTOR	
Width	12.70 mm (0.5 ")
Thickness	0.90 mm (0.035 ")
Coil length	76 m (250 ft)
Shipping weight per coil	3.9 kg (8.6 lbs)
ELECTRICAL PROPERTIES	
Anode ribbon mesh resistance lengthwise	0.20 Ohm/m (0.061 Ohm/ft)
Current distributor resistance lengthwise	0.049 Ohm/m (0.015 Ohm/ft)

Venture Way, Grantham, Lincs NG31 7XS UK. Tel: +44 (0)1476 590666 Fax: +44 (0)1476 570605
Email: cpc@cathodic.co.uk Website: www.cathodic.co.uk
Registered Office: Minalloy House, Regent Street, Sheffield S1 3NJ, UK VAT No. 116 8408 71, Reg'd in England No. 478098

BAC®
CORROSION CONTROL



MIXED METAL OXIDE ANODES
HIGH PERFORMANCE
ISOMMO

ENGINEERED FOR LIFE

Where Safety, Long Life and Protection of the Environment is essential

A high performance anode specifically designed for harsh environments and areas where conventional installations and replacements would be economically prohibitive.

The mixed metal oxide coating is a crystalline electrically conductive coating that activates and enables a titanium substrate to function as an anode.

Whether operating in fresh water, seawater, soil or mud, ISOMMO mixed metal oxide coatings are extremely stable even in very low pH environments.

The unique ISOMMO crimp cable connection and high specification components means that the ISOMMO anode is extremely durable and unlike other impressed current anodes, will not be affected by the presence of chlorine.

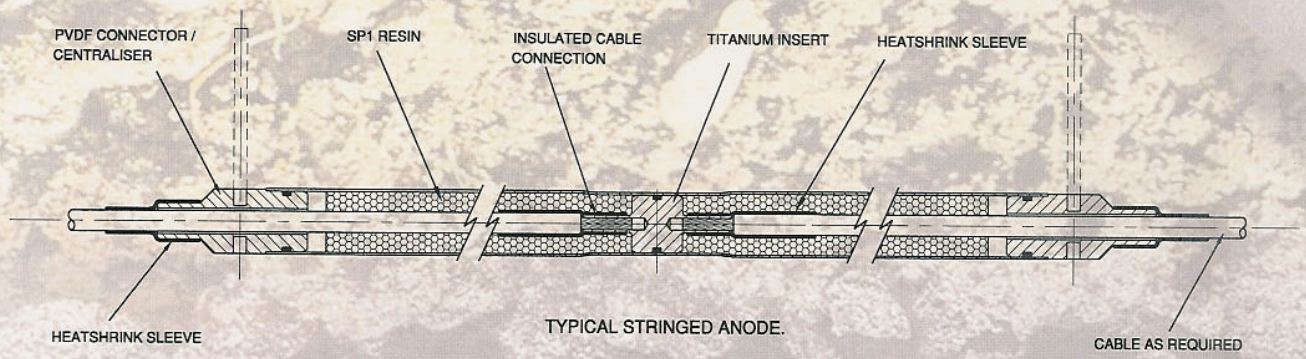
TYPICAL APPLICATIONS:

Impressed Current Cathodic Protection Installations.

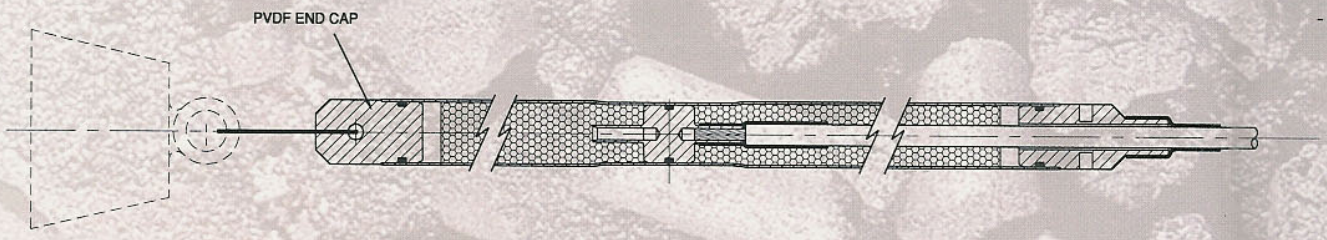
- Oil & Water Well Casings
- Sheet Piling and Marine Jetties
- Internal Storage tanks
- Pipelines

Environments:

- Desert Deep Boreholes
- Sea Water
- Brackish Water
- Fresh Water
- Mud



TYPICAL STRINGED ANODE.



SINGLE / END ANODE ASSEMBLY.

Features:

- High Current Output
- Multi Anode Strings
- Lightweight
- Strong
- High Specification Cable Components
- Unique Cable Connection
- Chloride Resistant Components

Benefits:

- Low Cost per Amp
- Low Installation Costs
- Easy Handling
- Low Maintenance
- Reduced Power Requirement

Standard ISOMMO Titanium Tubes
2.5cm, 1.9cm & 1.6cm

Titanium centre connection insert

TUBULAR ANODE Specifications

Anode Type	Environment	Length cm (inches)	Diameter cm (inches)	Surface Area M^2 (ft^2)	Assembled Weight Kg (lbs)	Maximum Current output Amps
ISO 2.5-50 FW ISO 2.5-50 SW ISO 2.5-50 MT	coke breeze/fresh water seawater mud/brackish water	50 (19.7)	2.5 (1)	0.039 (0.42)	0.560 (1.23)	4 25 4
ISO 2.5-100 FW ISO 2.5-100 SW ISO 2.5-100 MT	coke breeze/fresh water seawater mud/brackish water	100 (39.4)	2.5 (1)	0.079 (0.84)	1.100 (2.43)	8 50 8
ISO 1.9-50 FW ISO 1.9-50 SW ISO 1.9-50 MT	coke breeze/fresh water seawater mud/brackish water	50 (19.7)	1.9 (0.75)	0.030 (0.32)	0.400 (0.852)	3 19 3
ISO 1.9-100 FW ISO 1.9-100 SW ISO 1.9-100 MT	coke breeze/fresh water seawater mud/brackish water	100 (39.4)	1.9 (0.75)	0.060 (0.64)	0.770 (1.70)	6 38 6
ISO 1.6-50 FW ISO 1.6-50 SW ISO 1.6-50 MT	coke breeze/fresh water seawater mud/brackish water	50 (19.7)	1.6 (0.63)	0.025 (0.27)	0.370 (0.816)	2.5 15 2.5
ISO 1.6-100 FW ISO 1.6-100 SW ISO 1.6-100 MT	coke breeze/fresh water seawater mud/brackish water	100 (39.4)	1.6 (0.63)	0.050 (0.54)	0.710 (1.57)	5 30 5

Data based on temperature range:

soil/coke breeze/fresh water:	5°C - 50°C	(40°F-122°F)	20 year life
seawater	10°C -50°C	(50°F-122°F)	15 year life
mud/brackish water	5°C - 50°C	(40°F-122°F)	20 year life

Current output should be halved when operating outside the above temperature ranges.

CABLE SELECTION

- Cable selection is an extremely important factor when designing a cathodic protection groundbed.
- BAC recommend XLPE/PVC sheathed cable for general applications in soil, mud, fresh & brackish water and sea water.
- Where high current capacities are required, such as marine applications then the EPR/CSPE sheathed cable is best suited.
- For specialist applications such as deepwell groundbeds and where chlorides are liable to be present, BAC recommend a 1.8mm thick single sheathed PVDF type cable.

CABLE SPECIFICATION

Insulation	Size mm^2 (AWG)	Kg/m (lbs/ft)	*Volt Drop mV/Amp/Metre	Application
XLPE/PVC	10mm^2 (#8) 16mm^2 (#6)	0.13 (0.09) 0.18 (0.12)	2.05 1.3	soil, mud fresh & brackish water, sea water
EPR/CSPE	25mm^2 (#4) 50mm^2 (#1/0)	0.67 (0.46) 0.90 (0.61)	0.85 0.46	high current marine, sea water
PVDF	10mm^2 (#8) 16mm^2 (#6)	0.13 (0.09) 0.18 (0.12)	2.05 1.3	high chlorine environment

Other types and sizes of cable are available on request.
* Ambient at 30°c

ANODE ELEMENTS

- BAC ISOMMO titanium tubular anodes are coated with a mixed metal oxide that has an extremely low consumption rate measured in milligrams per year. Unlike other types of anodes the consumption rate of ISOMMO anodes is negligible with dimensions of the anode element remaining virtually unchanged during the operational service life of the anode. As a result the power required to impress current will remain the same.

ANODE ASSEMBLY

- Single and multi anode assemblies are available in both single lead and ring main type, double lead configurations.

CENTRE CABLE CRIMP CONNECTION

- BAC has developed an extremely strong and electrically low resistance centre crimp connection, which ensures the lowest possible electrical resistance between the cable and anode substrate. In strength tests the cable will always break first without any effect on the crimp connection.

Typical Anode to Cable insert strength (Tensile)

2.5cm Diameter:	1200kg
1.9cm Diameter:	1200kg
1.6cm Diameter:	1200kg

COMPONENTS

- All ISOMMO anodes use PVDF end caps and sleeving to ensure maximum protection in the most hostile of environments. As a further safe guard the centre connection is sealed with an extremely high performance 2 pack epoxy resin.

TESTING & INSPECTION

- Each anode assembly is rigorously tested and inspected from design to packaging.

All phases of material selection, MMO coating, testing and assembly are scrutinised under BAC ISO 9001 procedures.

BAC®

CORROSION CONTROL

ISOMMO ACCESSORIES

CENTRALISERS AND END WEIGHTS

- Ensure that the anode(s) remain central when installed in restricted vertical bore holes. Centralisers are fitted into the PVDF tube seals and do not restrict the active length of the anode(s) element. Standard sizes Range between 150mm (6") to 300mm (12").

  End Weights are supplied as standard for multiple anode strings.

WELL CASING AND CHAMBERS

- BAC supply a range of non metallic well casing material, both solid and perforated for deepwell groundbeds. BAC manufacture above ground chambers for deepwell groundbed installations including all necessary connection and control boxes.

VENT PIPES

- For removal of gases generated in down hole installations BAC supply the appropriate continuous and perforated vent pipe systems suitable for any design.

CONTACT BACKFILL

- For both horizontal and vertical installations BAC supply carbonaceous earth contact backfill for any design. All backfill supplied for ISOMMO anode installations is the superior Petroleum Calcined Coke.

HOW TO ORDER ISOMMO

- When ordering BAC ISOMMO anodes please specify the following:

- Anode type: i.e. ISO2.5-100SW
- Number of anodes per String
- Preferred cable type and size i.e. PVDF 10mm^2
- Spacing between anodes on string, from anode centre to anode centre.
- Number of cable tails i.e. single or double
- Cable tail length (from top anode for vertical installations)
- Total anode string length.
- Required current output.

BAC Corrosion Control Ltd
Stafford Park 11
Telford
TF3 3AY
United Kingdom
Tel: +44 (0) 1952 290321
Fax: +44 (0) 1952 290325
Email: bac@bacgroup.com

Visit our website at ***www.bacgroup.com***

Certificate No. 2000/3071

NACE INTERNATIONAL
Informing the world on Corrosion Control

INSTITUTE OF CORROSION

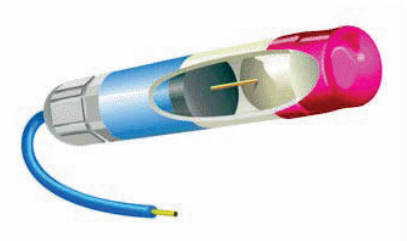
MEMBER OF THE MIDROC GROUP

Appendix F. LD15 Reference Electrode Datasheet

CASTLE ELECTRODES

PHONE: +44 (0) 208 144 6688
MOBILE: +44 (0) 752 545 2382
EMAIL: mail@castle-electrodes.com
WEB: www.castle-electrodes.com

LD15 Reference Electrode Datasheet



- Reference Electrode: Silver / Silver Chloride
- Model: LD15

General Description

The LD15 is a long life silver/silver chloride reference electrode with a stable reference potential specifically for permanent installation in reinforced concrete structures. The essential components are silver metal, silver chloride, soluble silver ions and chloride ions.

$$Ag, AgC1(s), C1^-, Ag^+$$

A sparingly soluble salt, silver chloride, is in equilibrium with a saturated solution of this salt which precipitates in the course of electrolysis. The reversible electrode reaction consists of silver ions going into solution and then combining with the chloride ions to form silver chloride. Thus its potential is determined by the following reactions:

$$Ag \leftrightarrow Ag^+ e^-$$

$$Ag^+ + C1^- \leftrightarrow AgC1(s)$$

$$Ag^+ C1^- \leftrightarrow AgC1(s) + e^-$$

The potential is dependent on temperature and the concentration of chloride ions in accordance with the following equation:

$$E=E_0 - (RT/F)1n[C1^-]$$

Where E_0, **R**, **F** and **T** are the standard potential, gas constant, Faraday Constant and temperature respectively. The reaction has been proved to obey these equations in solutions with pH's of between 0 and 13.5. The potential is however very sensitive to traces of bromide ions which make it more negative.

The electrode element has been prepared by electrolytic precipitation of silver chloride onto silver metal. This has then been embedded in a mortar containing a known concentration of chloride ions and an anti-drying agent. The housing consists of a white nylon barrel, white nylon inserts, and a cable gland rated at IP68.

Specification

Element Type:

`Ag, AgCI(s), CI-, Ag+`
Typical 1.2g silver per electrode

Potential:

-15Mv +/-10Mv versus the Saturated Calomel Electrode (SCE)

230Mv +/-10mV versus the Standard Hydrogen Electrode (SHE)

Drift:

less 3mV in 24 hours.
Typically less than +/-10mV expected in 20 years
Note: The potential drift is subject to temperature, Donnan potential and liquid junction potential changes within the surrounding environment which may mask any changes produced by the electrode itself.

Internal Resistance:

Less than 2kOhms

Polarisation Characteristics (determined galvanostatically in sodium hydroxide solution)

2mV potential shift after the application of 0.1µA for 30 seconds.
12mV potential shift after the application of 1µA for 30 seconds.

Dimensions:

75 mm long x 15mm diameter
Cable gland 20mm long x 15mm diameter.

Housing:

White Nylon Barrel
White Nylon Inserts
Cable Gland IP68

Cable:

Supplied to order

Expected life:

More than 30 years at a leakage current of 1µA will result in the loss of 0.7 grams of silver. The functional life of the electrode will most likely to be determined by the life of the associated cables.

Other Features:

Large Measuring Interface (>175mm^2)
Anti Drying agent