ANODE PERFORMANCE IN SERVICE CASE STUDIES

P.A. Noyce[1], P.A.J. Gibbs[2]

[1]Electro Tech CP LLC, New York, USA, [2]Electro Tech CP Ltd, Dubai, UAE

NACE Saudi Arabia October 2011

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1. Titanium Mesh & Concrete Overlay
2. Sprayed Zinc & Discrete Probe Anodes

- CONCLUSIONS

Galvanic Systems
Key Points

- Primarily Used in USA
- Low Maintenance Requirements
- Various Systems Available
- Pre-Stressed Protection Simplification

Zinc Aluminium Indium Coating

- Completed in August 2003
- 320,000 Sq/ft
- 470 No. Pre-Stressed Beams
- 171 No. Pier Caps

San Luis Pass Galveston Texas USA

Zinc Aluminium Indium Coating

- Initial Current Density
  4.4mA/m² to 6.9mA/m²
- 7 Year Current Density
  0.49mA/m² to 1.27mA/m².
- Minor Defects
- CP Not Compromised
- No Corrosion Found

San Luis Pass Galveston Texas USA

Zinc Mesh Lifejacket & Metalized Zinc

Ketchikan, Alaska USA

- Completed in 2000
- Zinc Coating - Concrete Deck
- Zinc Mesh Lifejacket
  Pile Caps Splash Zone/Upper Tidal
- Zinc Bulk Anode
  Underwater Element of Piles

Sprayed Zinc & Lifejacket™

Typical Lifejacket™

Zinc Mesh Lifejacket & Metalized Zinc

Location	Average Current Density	
	mA/m^2	mA/ft^2
Bulk Anodes		
Conventional Reinforced Piles	23	2.2
Pre-stressed Piles	2.5	0.24
Lifejackets		
Conventional Reinforced Piles	1.4	0.13
Pre-stressed Piles	0.58	0.054
Pile Caps	1.6	0.15
Thermal Sprayed Zinc		
Precast Conventionally Reinforced Deck	1.0	0.097
CIP Conventional Deck	0.36	0.033
CIP Conventional Deck w/Prestressed Beams	0.43	0.040

Initial Current Densities 2000

Zinc Mesh Lifejacket & Metalized Zinc

- Successful CP
- Low Maintenance Cost
- New Phase II of Works 2010
- No Corrosion Evident

Pilaster Lifejacket™

Impressed Current Cathodic Protection Systems Key Points

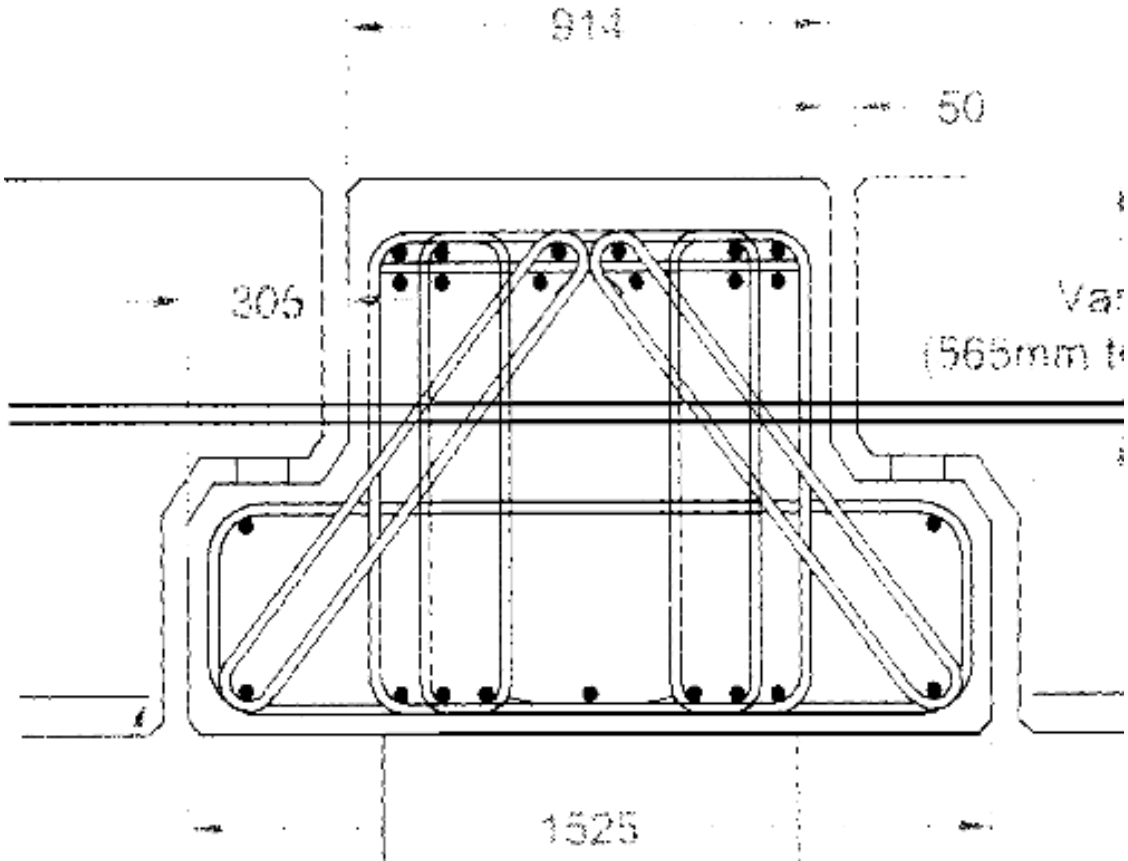
- Controllable Protection
- Monitoring System ALWAYS Installed
- Worldwide Acceptance
- Various Systems
- Long Term Durability

Titanium Mesh & Concrete Overlay

- January 2003
- High Chloride Levels 4.83% by weight of cement
- Three anode zones Crosshead, Lower Column, Upper Column
- Type 300 Ti Mesh Crosshead
- Type 150 Columns
- 24 Reference Electrodes

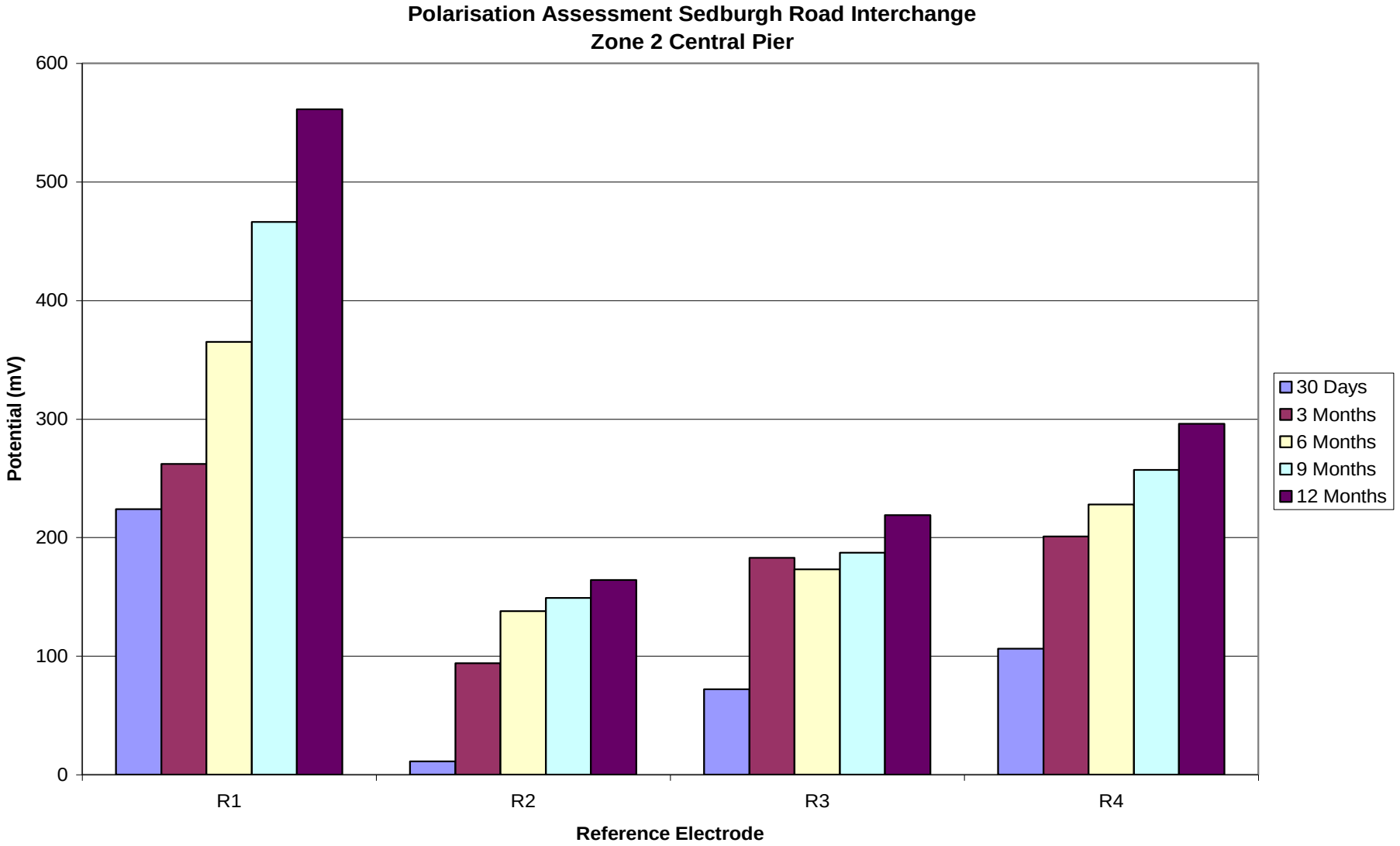
Sedbergh Road Interchange Bridge UK

Titanium Mesh & Concrete Overlay



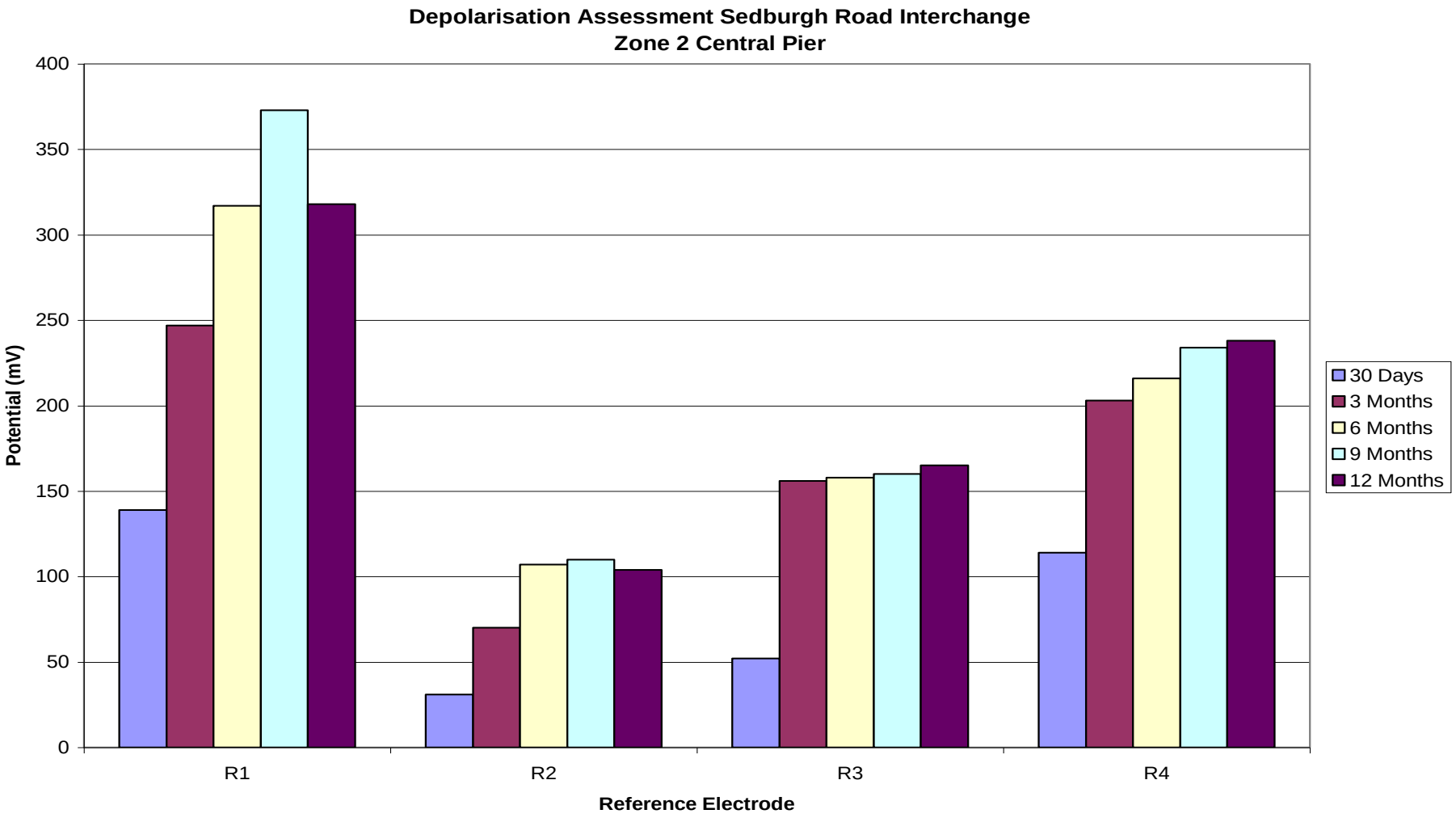
- Inverted “T” Construction
- Steel/Concrete Area Ratio 5:1
- Protection Designed for Full Depth

Titanium Mesh & Concrete Overlay



- R2 at 900mm Depth

Titanium Mesh & Concrete Overlay



- R2 at 900mm Depth

Titanium Mesh & Concrete Overlay

Seven Year Inspection of Anode System

- ✓ There are no reported defects in the anode system during the recent inspection carried out in 2010.
- ✓ Proven to be a very durable system based on design requirements and its atmospheric exposure

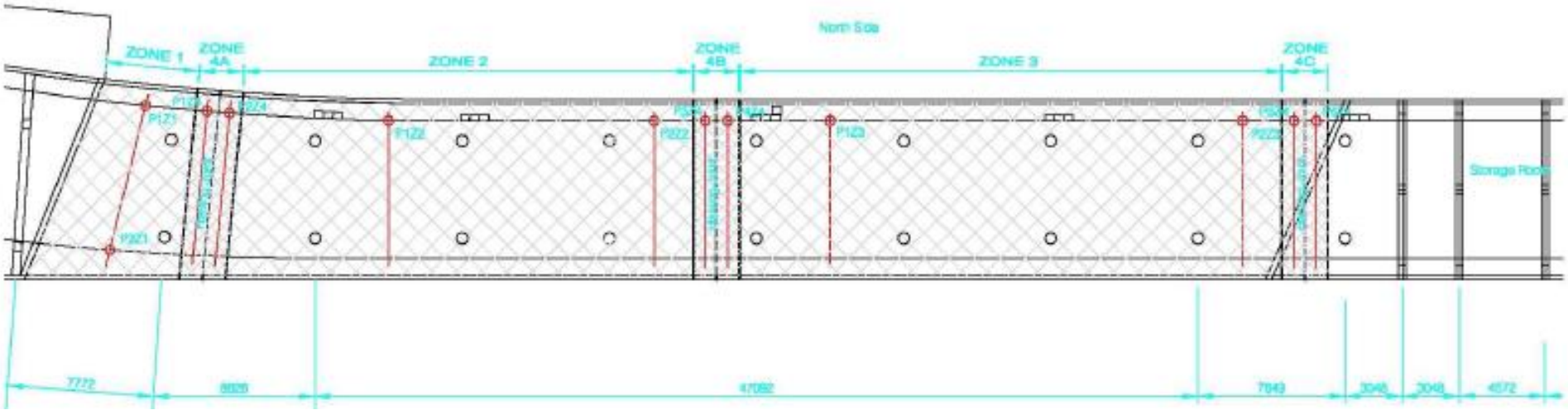
- ➢ Inverted “T” Construction
- ➢ Steel/Concrete Area Ratio 5:1
- ➢ Protection Designed for Full Depth
- ➢ Operating Current Densities High - Varied between 5.45mA/m² during the first year of operation and is now currently operating at 11.76mA/m²

Titanium Mesh & Concrete Overlay

Pier Approach Bournemouth UK

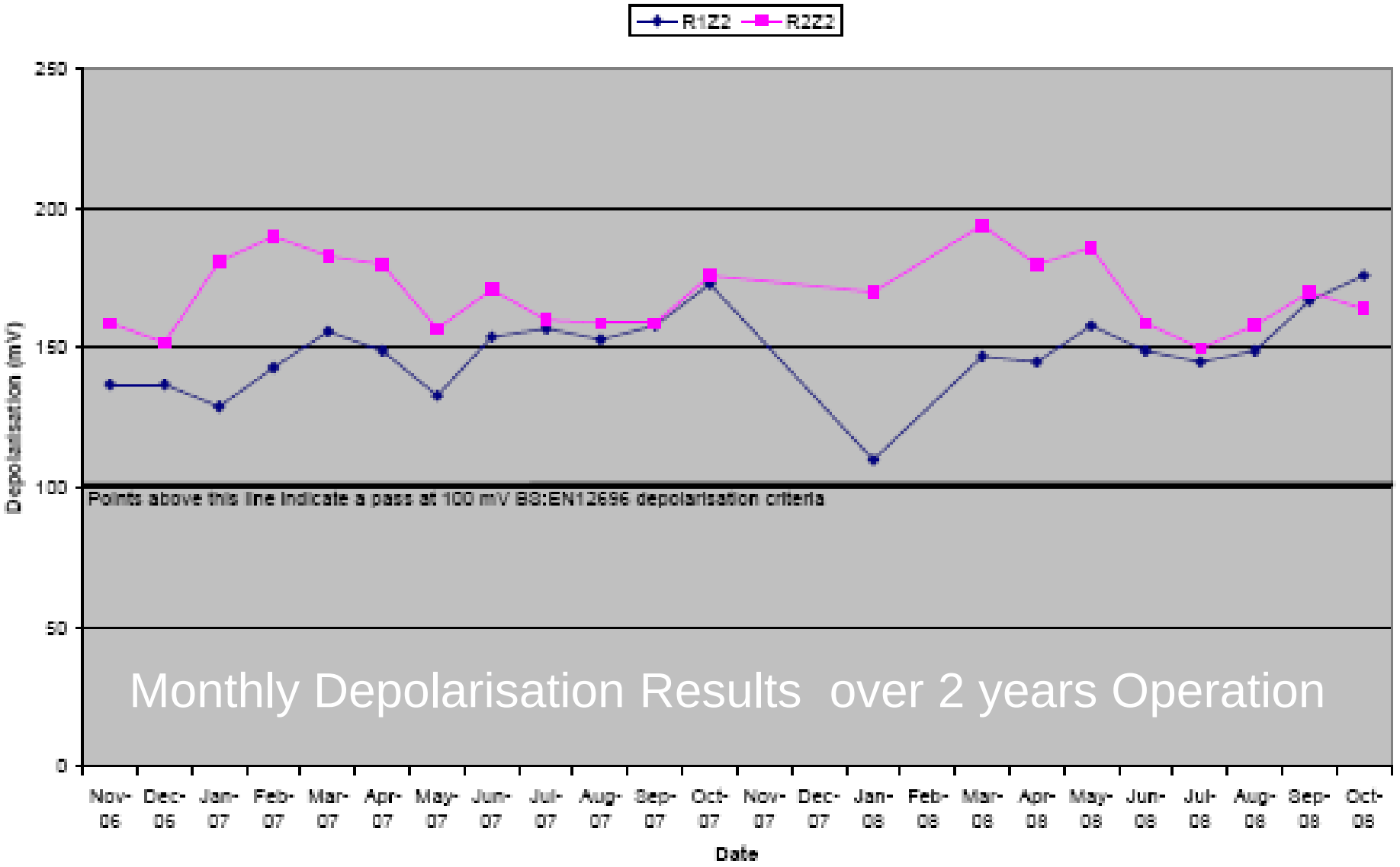
- December 2002
- Concrete Surface Area 616.7m²
- Four anode zones
- Anode Type LD25 Ti Mesh
- 8 Reference Electrode
- Marine Exposure

Titanium Mesh & Concrete Overlay



Zone Layout Across Construction Joints

Titanium Mesh & Concrete Overlay



Titanium Mesh & Concrete Overlay

Seven Year Surface Inspection of Overlay

- ✓ No defects in the anode system during the recent inspection carried out in 2010.
- ✓ Proven to be a very durable system based on design requirements and marine exposure

- ✓ Afforded adequate cathodic protection levels for the past 7 years.
- ✓ Current densities varied in the range of 1.45mA/m² during the first year of operation and are now currently operating at 13mA/m².

Sprayed Zinc & Discrete Probe Anode

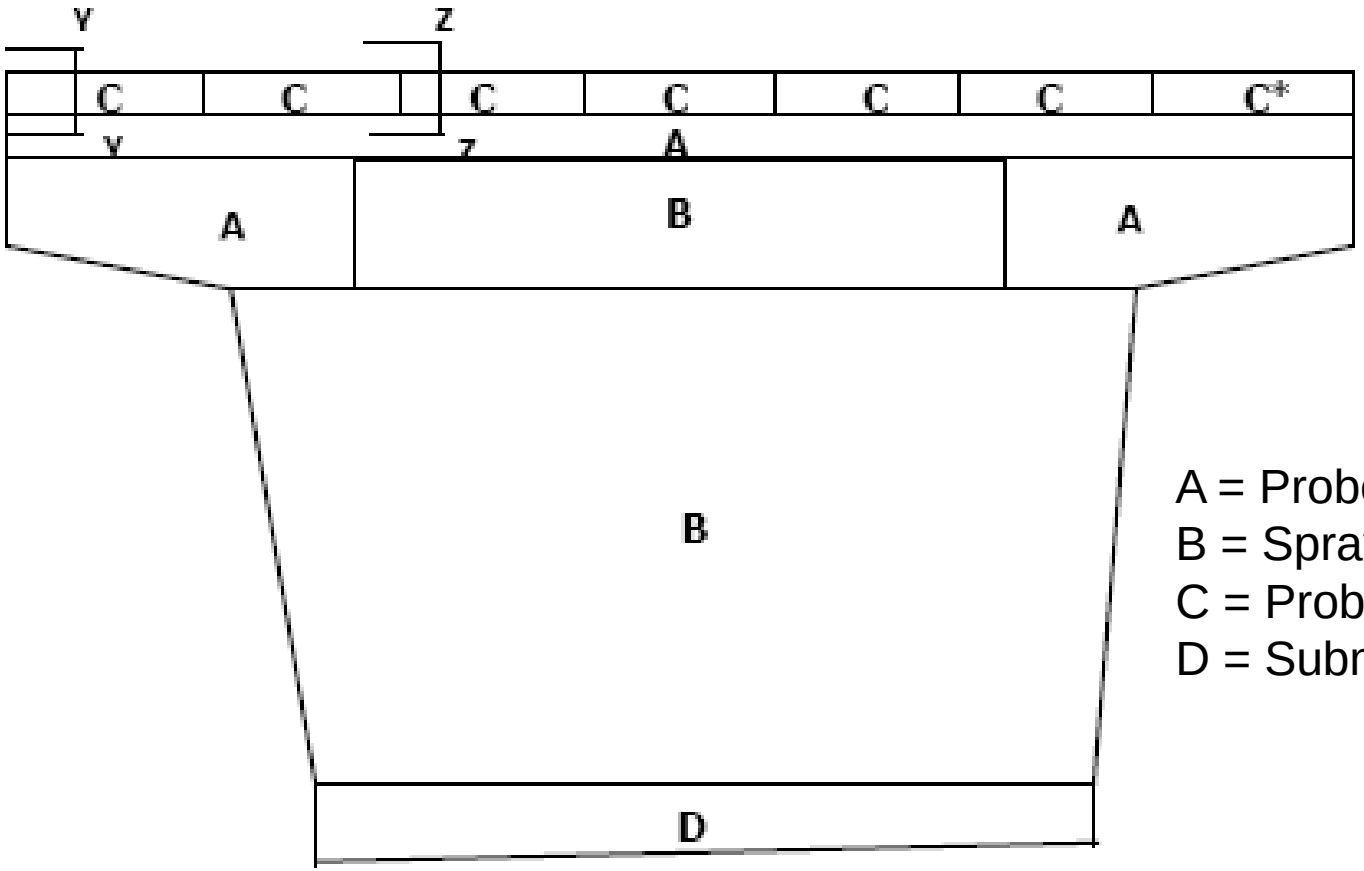
Golden Fleece Cumbria UK

- January 2003
- 4 Piers Protected
- 12 Anode Zones
- Various Anode Types
- 50 Reference Electrodes
- 32 Temperature & Humidity Sensors

Sprayed Zinc & Discrete Probe Anode

- CP Bearing Shelf/ Beam Ends by discrete anodes
  A.Bearing shelf Ebonex 18mm x 200mm, 86 number
  B.Beam Ends: Side Ebonex 18mm x 100mm, 100 number.
  C.Beam End and Soffit: Ebonex 18mm x 75mm, 32 number
- CP Central pier by sprayed zinc.
- CP to Diaphragm by discrete anodes.
  A.Ebonex Discrete anode 18mm x 100mm, 222 number
- Below ground section protected by tubular titanium ground bed anodes.
  A.Total of 6 anodes at 25mm diameter x 250mm long rated at 2A continuously for 20 years per anode.

Sprayed Zinc & Discrete Probe Anode



A = Probe Anodes
B = Sprayed Zinc
C = Probe Anodes
D = Submerged Anode

Anode Zone layout Golden Fleece

Sprayed Zinc & Discrete Probe Anode

- Sprayed zinc thickness of 400µm - 500µm.
- High purity zinc 99.9%
- Electric arc thermal spray.

- Constant current mode
- Current density of 5mA/m^2.
- Current density reduced since energising

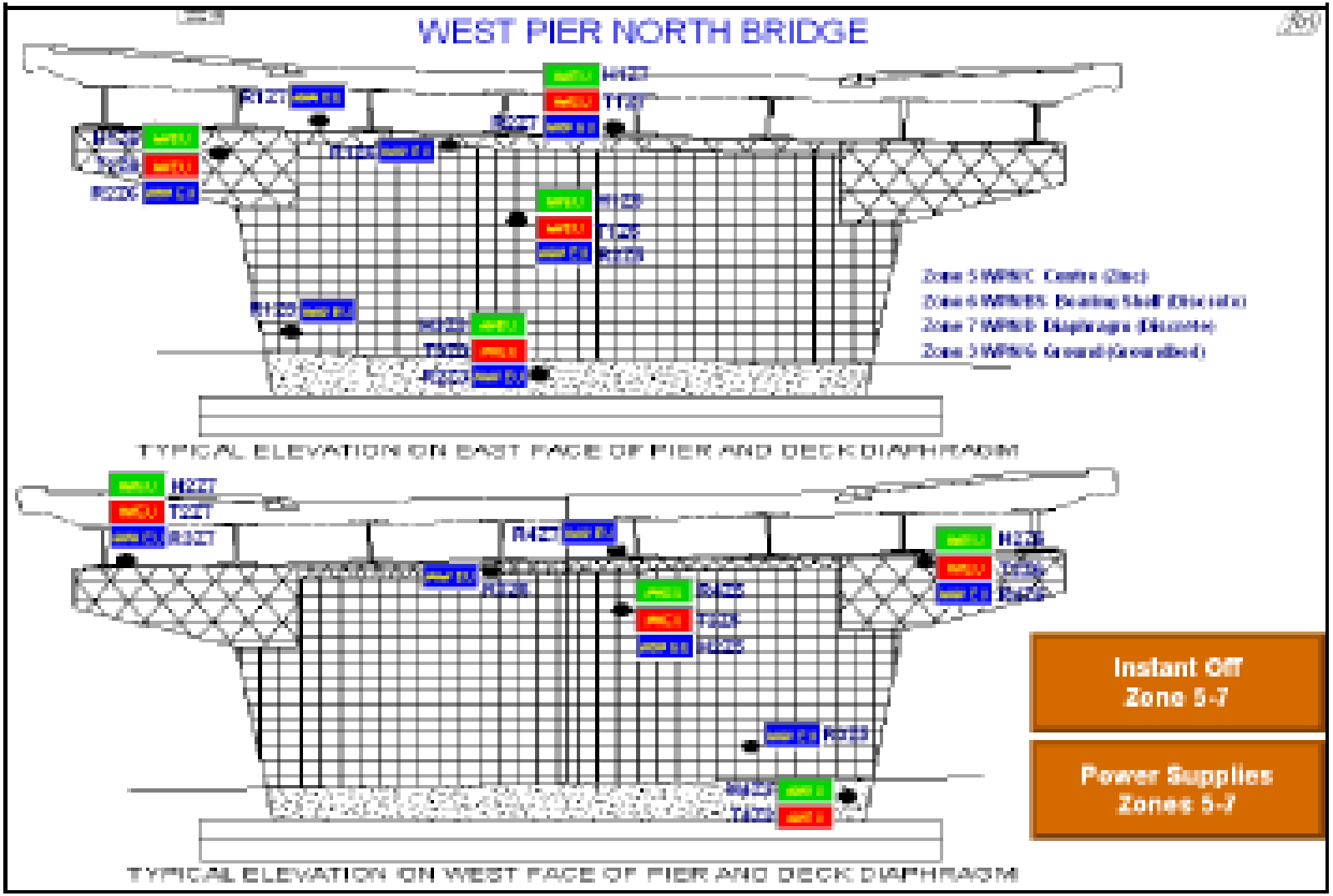
Sprayed Zinc & Discrete Probe Anode

Zinc		Discrete Anode	
Zone	mA/m^2	Zone	mA/m^2
1	1.53	2	3.51
5	4.76	4	0.97
8	0.75	6	3.11
10	0.54	7	2.31
		9	2.27
		11	3.91
		12	2.11

January 2010 Operating Current Density

- All Zones Requiring Lower Current Densities than at energising

Sprayed Zinc & Discrete Probe Anode



Screen Shot 1 Monitoring Probe Locations on West Pier North Bridge

Sprayed Zinc & Discrete Probe Anode

- Zinc De-bondment Found Caused by Low Resistivity Repair Material
- No Loss in Protection from De-bondment.
- No Noticeable Increase in De-bondment on Recent Inspection

- Probe Anode Extremely Effective
- Reduced Current Density Design Avoiding Acidification

Anode Failures
Key Points

Engineering Design Essential

Product Sale NOT Appropriate

Can Be Avoided

Sends Wrong Message for Electrochemical Repair Techniques

Anode Ribbon

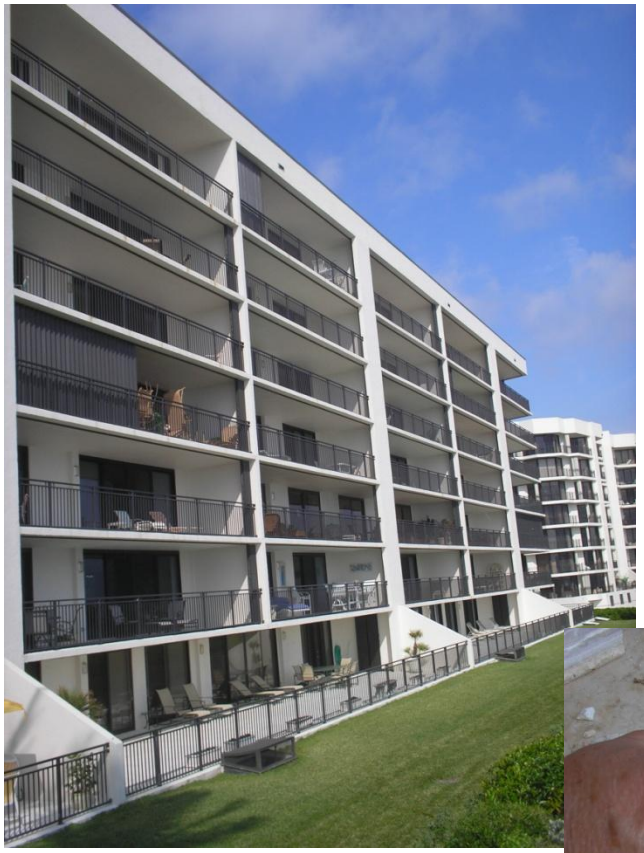
- Marine structure
- Tidal Range 20ft
- Anode Ribbon Design
- Column Pile Protection

Anode Ribbon

Anode Ribbon

- Multiple Failures
- Poor Installation
- Low Cover Anode Connection < 5mm
- Major Acidification Due to Current Dumping
- pH of < 5 at Connection points
- Cover > 40mm Connections Good

Surface Applied Zinc Sheet



- Coastal Structure
- Balcony Protection
- Chloride Problem
- Zinc Sheet Design
- Two Types of Covering Used. Tile & Deck Coating

Surface Applied Zinc Sheet

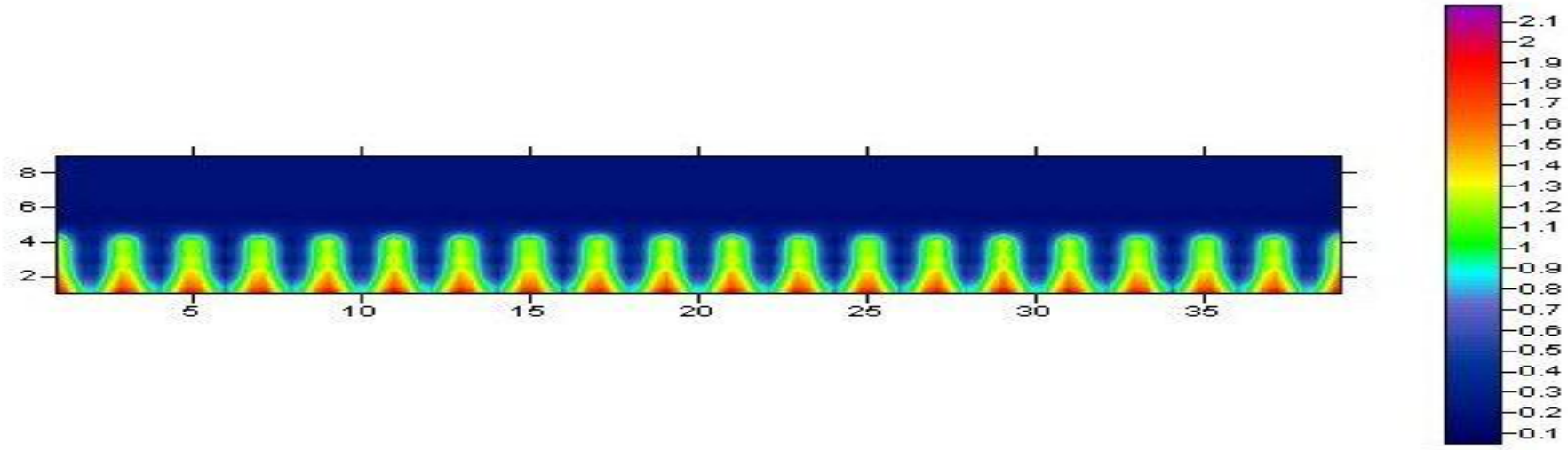
Deck Coating

- Failure on Both Surface Finishes

Ceramic Tile

Surface Applied Zinc Sheet

- Blistering of Surface Coating
- Jacking of Surface Tiling
- Non Breathable System
- Large Moisture Vapour could not escape
- Product Sale
- Little to No Engineering Carried Out
- Current Mapping Not Understood



CONCLUSIONS

- A series of critical items need to be addressed when utilising cathodic protection for corrosion related damage.
- Ensure that the anode is suitable for its environment.
- Its Capable of being installed correctly
- And Maintained in accordance with international standards

- Qualified Engineers are used for design
- Qualified Installation Contractors are Used
- Allow Sufficient Cost for qualified QA/QC during Works