

# **Corrosion Potential Monitoring for Polymer Composite Wrapping and Galvanic CP System for Reinforced Concrete Marine Piles**

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# Report Documentation Page

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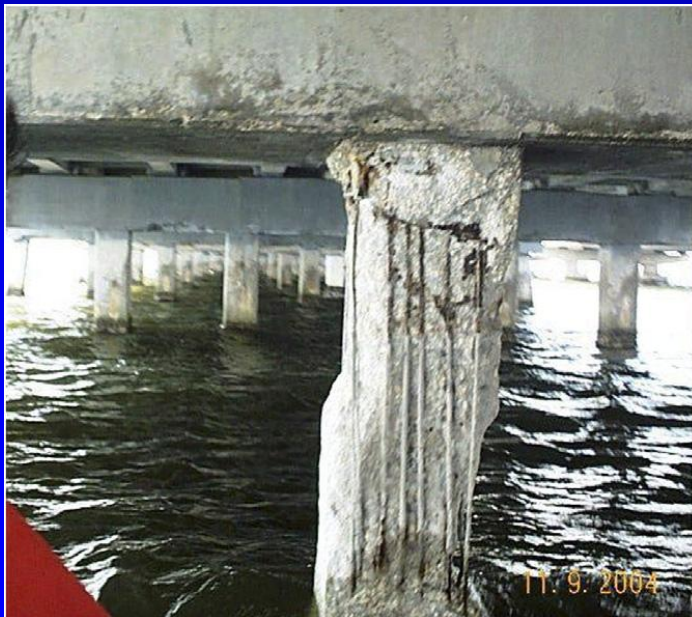
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## Project Sponsors

# DoD Corrosion Prevention and Control

- Office of Under Secretary of Defense, Office of Corrosion Policy and Oversight
- Deputy Assistant Secretary of the Army Acquisition Policy and Logistics
- Assistant Chief of Staff for Installation Management
- Headquarters, U.S. Army Installation Management Command

# DoD Corrosion Problem



- Piers and wharves
  - Critical facilities
  - \$14.5M maintenance costs
  - Reinforced concrete piles
- Aged and deteriorated
  - Rebar corrosion
  - Spalling concrete

# Repair Options



- Patching
- Polymeric composite wraps
- Pre-fabricated composite shell with CP

# Objective

- Demonstrate and implement innovative technology that provides corrosion protection and impact resistance to reinforced concrete piles in marine environments
- FRP Composite wrap with galvanic CP protection

Demonstration Site

# Kawaihae Harbor Dolphin Piers



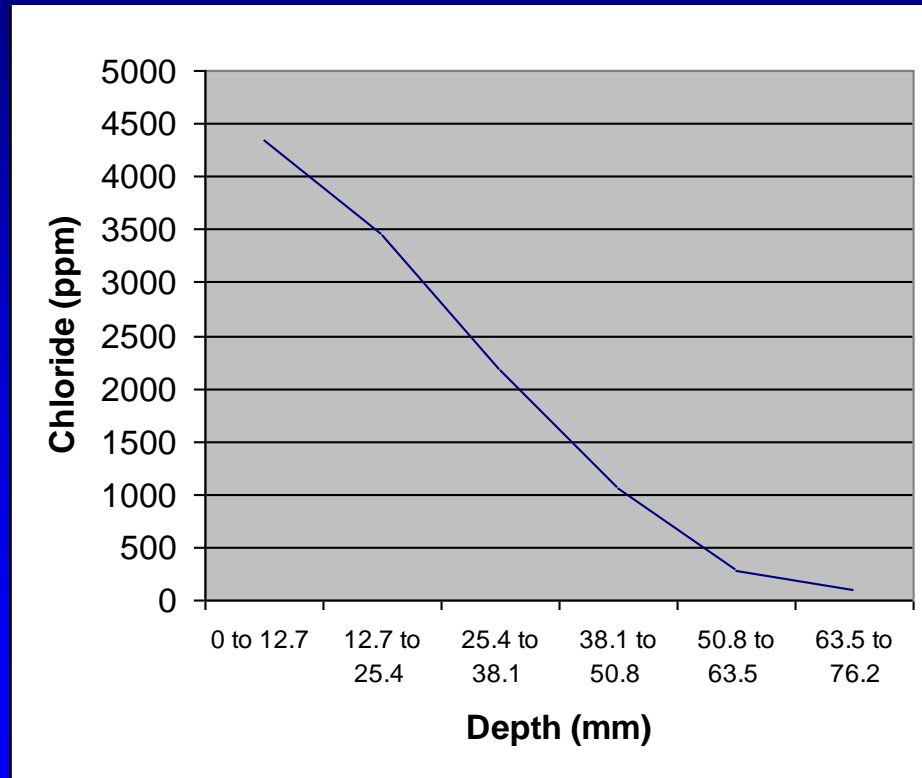
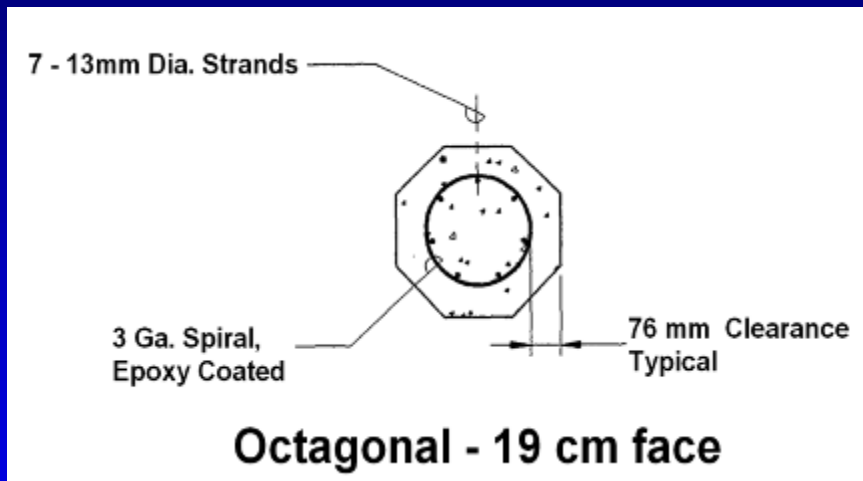
Demonstration Site

# Kawaihae Harbor Dolphin Piers





# Pre-Cast Steel Reinforced Concrete Piles



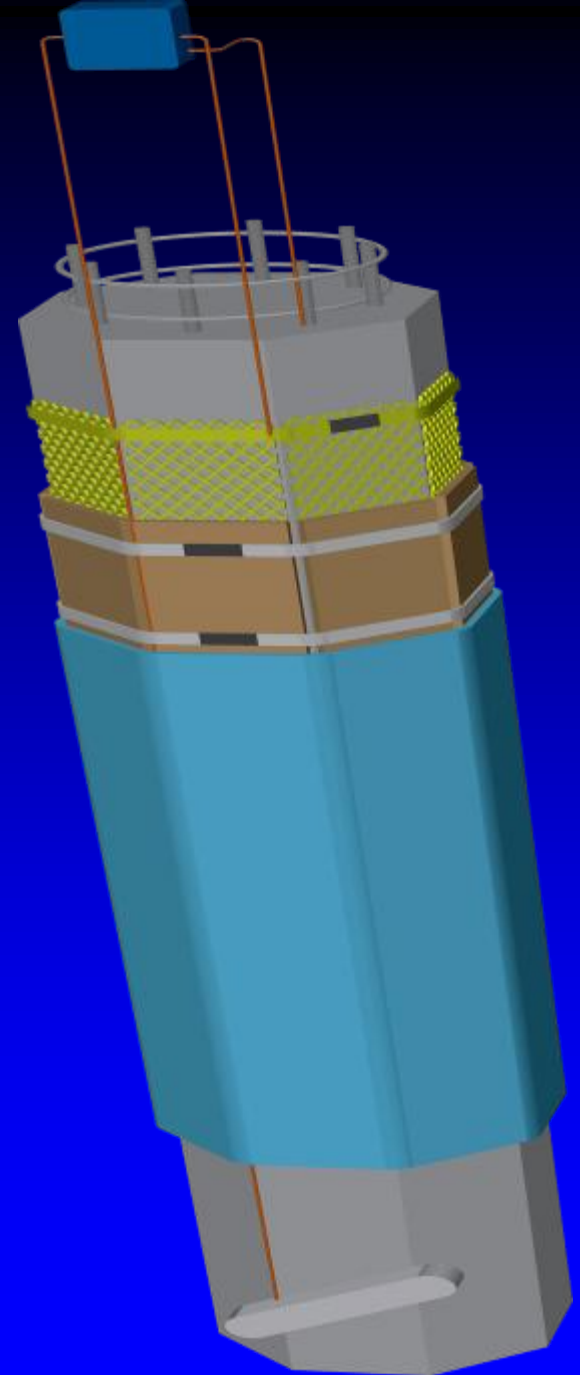
# Demonstration Metrics

- FRP composite pile wrapping
  - Field applied, commercially available
  - Underwater installation
  - Splash zone application (*2.4 meters*)
  - Impact and abrasion resistance
- Galvanic cathodic protection system
  - Integrated anode within wrapped section
- Corrosion potential monitoring

# System Design

- Expanded mesh zinc anode
- Composite board compression panels
- Woven glass fiber wrap

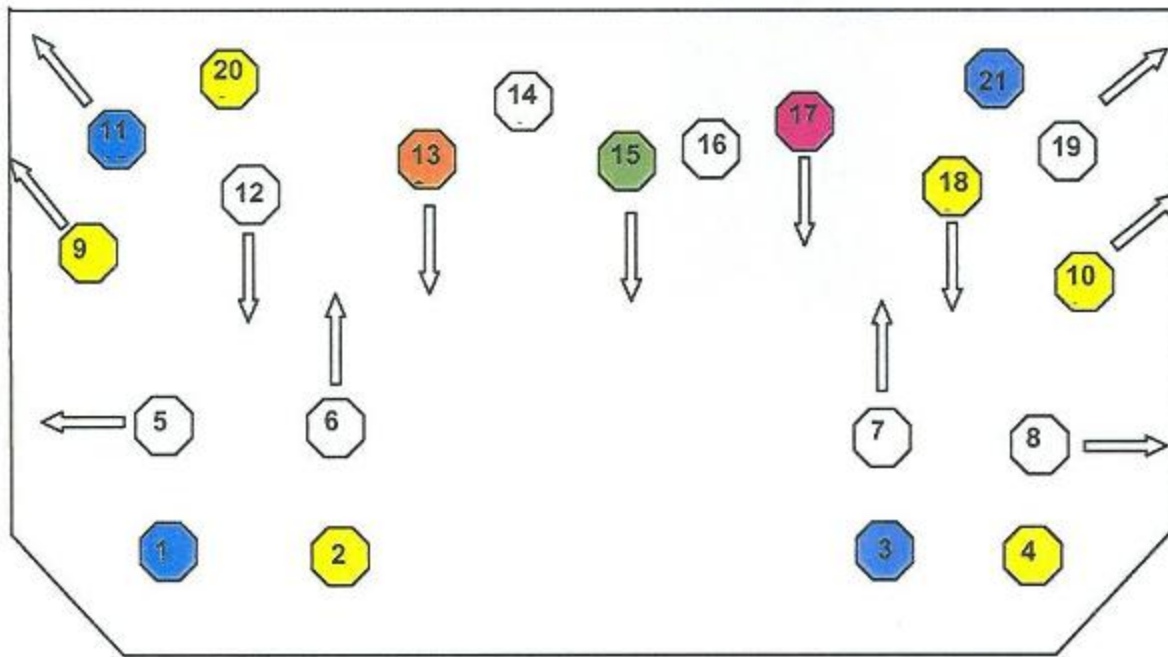
Nominal Thickness	0.685 mm
Tensile Strength	$32.8 \times 10^4$ kN/m <sup>2</sup>
Tensile Load, per ply	580 kg
Comp. Strength	$17.2 \times 10^4$ kN/m <sup>2</sup>
- Bulk zinc anode



# Corrosion Monitoring System

- Silver/silver chloride reference electrodes
  - Three locations per pile
  - Cables protected with PVC conduit
- Remote Monitoring Unit (RMU)
  - Onboard software & data storage backup
  - Instant off, depolarisation measurements
  - PV-powered data transmission
- Shore-side Main Control Unit (MCU)
  - Radio transmission from RMU
  - Data storage
  - Land line accessibility



# Dolphin #2 Piles



## Monitored Piles

-  No wrap, No CP
-  Wrap, No CP
-  Wrap, bulk CP only
-  Wrap, full CP

## Piles with No Monitoring

-  Wrap, full CP
-  No work

# System Installation

- Work restricted to low tide
- Interruptions
  - planned
  - Unplanned
- Dive Crew Coordination



# Shore Side Preparation

## Zinc Mesh Anode / Compression Panels / Electrode Calibration



# System Installation

## Bulk Zinc Anode Attachment and Surface Cleaning





# System Installation Setup



System Installation

# Electrical Continuity & Steel Connections



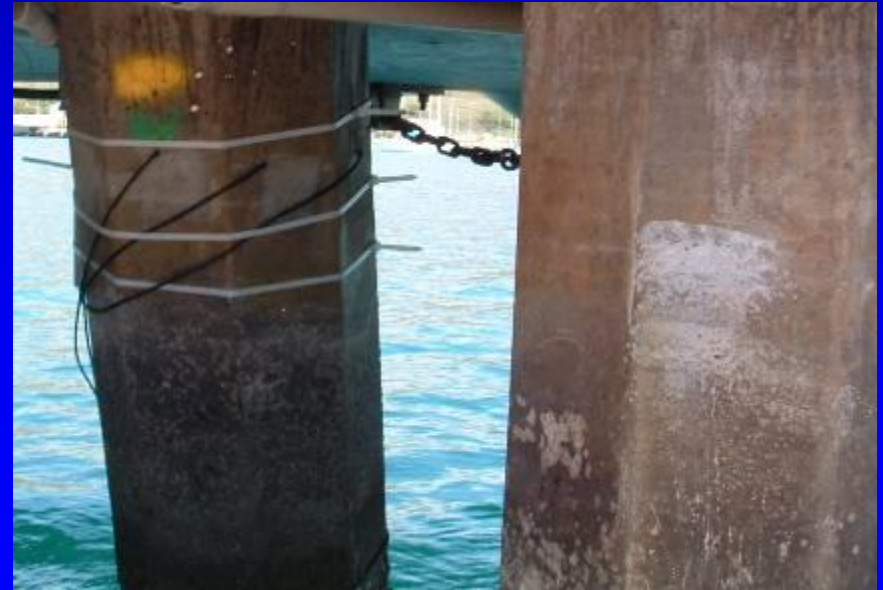
# System Installation

## Electrical Continuity & Steel Connections



System Installation

# Patching & Securement of Cables



System Installation

# Zinc Mesh Anode & Compression Panels



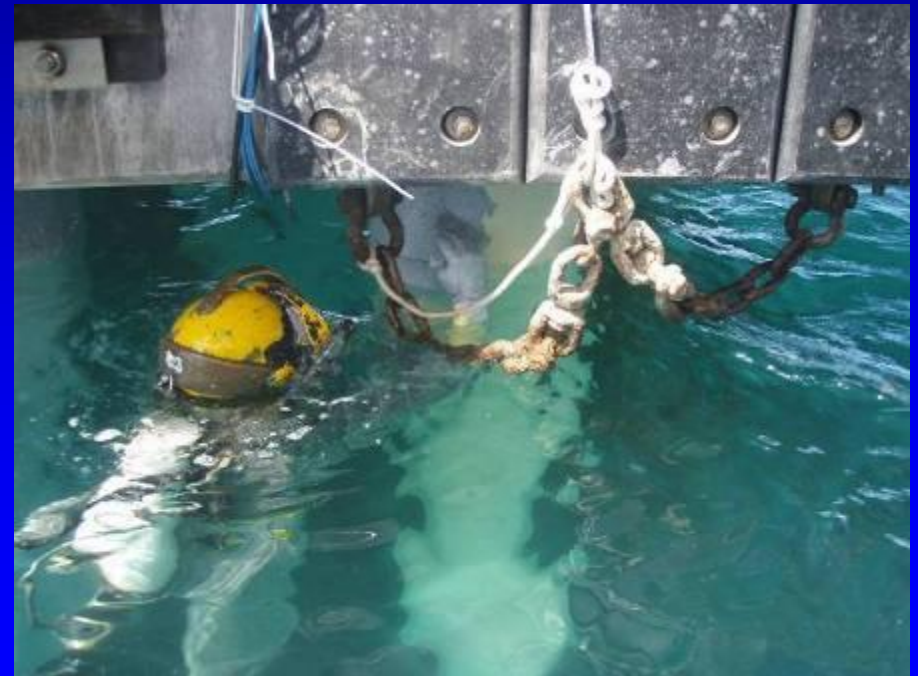
System Installation

# Zinc Mesh Anode & Compression Panels



# System Installation

## Composite Wrap



# System Installation **Composite Wrap**





System Installation

# Electrical Wiring and Monitoring System



## System Installation

# Electrical Wiring and Monitoring System



System Installation

# Electrical Wiring and Monitoring System



## System Installation

# Commissioning & Performance Monitoring

- Baseline readings of reference electrodes
- Reporting of monthly corrosivity potential data
- 6, 9, 12 and 15 month inspection of RMU / MCU components
- Four-Year evaluation

# Dolphin #3

## Time Zero – Baseline Data

Pile #18: Wrap with integrated CP and bulk CP			
On Potentials	Ref. Cell #1 (v)	Ref. Cell #2 (v)	Ref. Cell #3 (v)
Instant On	-0.562	-0.752	-0.433
Native Potentials	-0.407	-0.444	-0.137
Current Output			
System	0.562 amps		
Bulk Anode	0.534 amps		
Mesh Anode	0.270 amps		

Pile #14 - Wrap with no CP			
On Potentials	Ref. Cell #1 (v)	Ref. Cell #2 (v)	Ref. Cell #3 (v)
Instant On	n/a	n/a	n/a
Native Potentials	-0.385	-0.508	-0.503
Current Output			
System	n/a		
Bulk Anode	n/a		
Mesh Anode	n/a		

Pile #17: Wrap with bulk CP			
On Potentials	Ref. Cell #1 (v)	Ref. Cell #2 (v)	Ref. Cell #3 (v)
Instant On	-0.349	-0.794	-0.787
Native Potentials	-0.317	-0.366	-0.370
Current Output			
System	0.505 amps		
Bulk Anode	n/a		
Mesh Anode	n/a		

Pile #16 - Control, no wrap and no CP			
On Potentials	Ref. Cell #1 (v)	Ref. Cell #2 (v)	Ref. Cell #3 (v)
Instant On	n/a	n/a	n/a
Native Potentials	-0.629	-0.629	-0.431
Current Output			
System	n/a		
Bulk Anode	n/a		
Mesh Anode	n/a		

# Dolphin #3

## 1 Month Data

Pile #18: Wrap with integrated CP and bulk CP			
On Potentials	Ref. Cell #1 (v)	Ref. Cell #2 (v)	Ref. Cell #3 (v)
On	-0.678	-0.878	-0.815
Instant Off	-0.665	-0.820	-0.761
IR	0.013	0.058	0.054
Native Potentials	-0.407	-0.444	-0.137
Polarisation	0.258	0.376	0.624
Current Output			
System	n/a		
Bulk Anode	0.103 amps		
Mesh Anode	0.077 amps		

Pile #14 - Wrap with no CP			
On Potentials	Ref. Cell #1 (v)	Ref. Cell #2 (v)	Ref. Cell #3 (v)
On	-0.412	-0.484	-0.478
Instant Off	n/a	n/a	n/a
IR	n/a	n/a	n/a
Native Potentials	-0.385	-0.508	-0.503
Polarisation	n/a	n/a	n/a
Current Output			
System	n/a		
Bulk Anode	n/a		
Mesh Anode	n/a		

Pile #17: Wrap with bulk CP			
On Potentials	Ref. Cell #1 (v)	Ref. Cell #2 (v)	Ref. Cell #3 (v)
On	-0.638	-0.917	-0.905
Instant Off	-0.637	-0.909	-0.900
IR	0.001	0.008	0.005
Native Potentials	-0.317	-0.366	-0.370
Polarisation	0.320	0.543	0.530
Current Output			
System	n/a		
Bulk Anode	0.110 amps		
Mesh Anode	n/a		

Pile #16 - Control, no wrap and no CP			
On Potentials	Ref. Cell #1 (v)	Ref. Cell #2 (v)	Ref. Cell #3 (v)
On	-0.395	-0.480	-0.478
Instant Off	n/a	n/a	n/a
IR	n/a	n/a	n/a
Native Potentials	-0.629	-0.629	-0.431
Polarisation	n/a	n/a	n/a
Current Output			
System	n/a		
Bulk Anode	n/a		
Mesh Anode	n/a		

# Conclusions

- An innovative polymer composite pile wrapping system with integrated CP was demonstrated on two structures
- Initial data collection indicates proper operation of CP system
- Data acquisition has posed some preliminary problems. System currently undergoing upgrade

**Corrosion Potential Monitoring for Polymer  
Composite Wrapping and Galvanic CP  
System for Reinforced Concrete Marine Piles**

**Questions ?**