
## Inception

- LPG Trestle, Ju'Aymah, Saudi Arabia
- Trestle constructed in 1980
- Precast concrete cylinder piles

## LPG Trestle, Ju'Aymah, Saudi Arabia

- Routine inspection in 1983 (3 years after construction) revealed severe marine borer attack
- 616 piles affected

## LPG Trestle, Ju'Aymah, Saudi Arabia

- The owner required that the repair method…
- Would eradicate the existing borers
- Would repair the damage done by the borers
- Would not be susceptible to future borer attack
- Would stay in place and continue to provide protection for 20+ years without any maintenance

## LPG Trestle, Ju'Aymah, Saudi Arabia

- The 616 piles were encapsulated using the advanced pile encapsulation technique in 1984

## Repairing Marine Structures

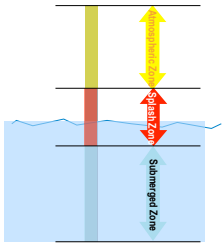
- Marine Structures
  - Submerged Piles
  - Submerged Piers
  - Seawalls
  - Dams / raceways
  - Offshore Platform Supports

## The Need for Repair and Protection

- Marine Environment
  - Highly Corrosive Environment
  - Susceptible to Rot
  - Attack from Marine Organisms
  - Damage from Scour and Abrasion

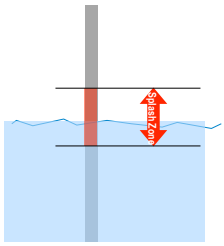
## Repairs to Marine Structures

- Repair Zones
  - Atmospheric Zone
  - Splash Zone
  - Submerged Zone




## Repairs to Marine Structures

- Splash Zone
  - Wetting & Drying Cycles
  - Available Oxygen
  - Heavy Wear & Abrasion

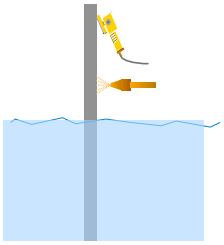


## Repairs to Marine Structures

- Repair Challenges
  - Durability of Materials for Repair / Protection
  - Adequate Performance of Materials for Repair / Protection
  - Proper Placement of Materials for Repair / Protection

## The Encapsulation Process

- Step 1
  - Surface preparation
  - Remove marine growth
  - Clean rust and scale
  - Profile substrate



## The Encapsulation Process

- Step 1
  - Sandblasting
  - Pneumatic Rotary Grinder

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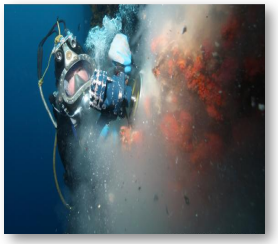
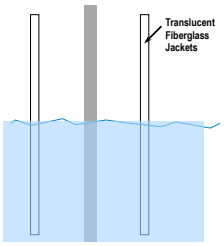


## The Encapsulation Process

» Step 2
- Fiberglass Jackets Placed Around Structure
- Leaving 3/8" to 1/2" Annulus between Jacket and Structure
- Seams are sealed with epoxy




## Purpose Designed FRP Jackets

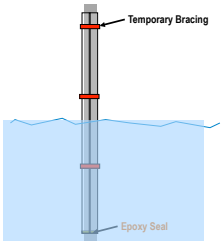
» Step 2
- Appropriately sized FRP Jackets Delivered to Site
- Polymer Stand-offs
- Seam adhesive applied on deck

## Purpose Designed FRP Jackets

- Step 2
  - Jackets set in place around pile

## The Encapsulation Process

- Step 3
  - Seams are riveted in place
  - Temporary bracing is installed
  - Bottom of Jacket is sealed w/ epoxy coated backer rod

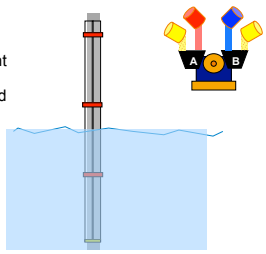



## Encapsulation Purpose Designed FRP Jackets

- Step 3
  - Temporary bracing installed

## The Encapsulation Process

- Step 4
- Each component of a two-component marine grade epoxy is mixed with sand

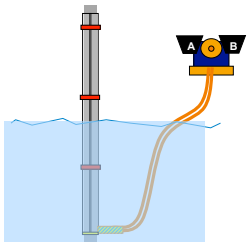



## Epoxy Grout Infill Properly Placed

- Step 4
  - Plural component grout plant
  - Part A & Part B mixed with sand in each hopper

## The Process

- Step 5
  - Grout plant is attached to injection port in fiberglass jacket
  - Dual-umbilical hose w/ static mixer at injection site



## Epoxy Grout Infill Properly Placed

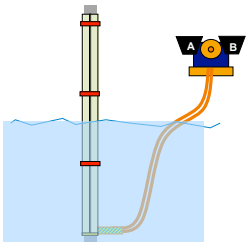
- Step 5
  - Downstream mixer

## Epoxy Grout Infill Properly Placed

- Step 5
  - Fluid sand-filled epoxy grout is dispensed out of the mixer

## The Encapsulation Process

- Step 6
  - Epoxy grout is pumped into annulus
  - Water in the annulus is displaced and expunged out of the top of the jacket



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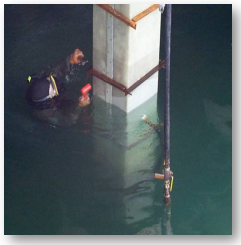


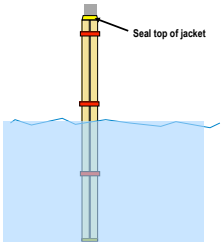
- Step 6
- Grout is pumped into the annulus
- Water is displaced above grout
- Grout progress is monitored

## Epoxy Grout Infill Properly Placed

- Step 6
- Water is expunged out of the top of the jacket

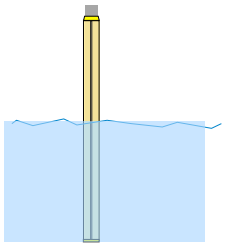
## The Encapsulation Process

- Step 7
- Top of jacket is sealed with epoxy
- Bracing is removed

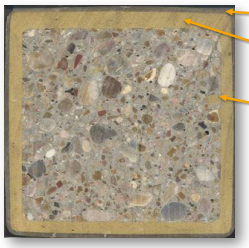


## The Encapsulation Process

- Encapsulation is complete!



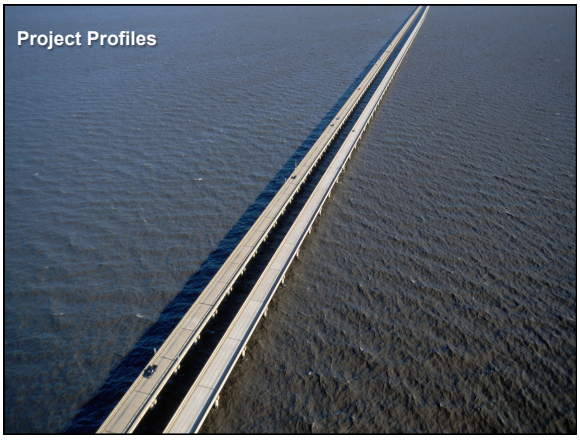
## Complete Encapsulation



- FRP Jacket
- Epoxy Grout Infill
- Complete Coverage of Grout
- Well Bonded to the Pile

## Complete Encapsulation

- Epoxy Grout is pumped under pressure
- Grout penetrates into cracks and voids in the substrate




## Lake Pontchartrain Causeway, New Orleans, Louisiana

- Pile Encapsulation
  - Started in 1988
  - 26 mile long bridge
  - 54” diameter concrete cylinder piles

## Lake Pontchartrain Causeway, New Orleans, Louisiana

- Pile Encapsulation
  - Encapsulations soon after completion in 1989

## Lake Pontchartrain Causeway, New Orleans, Louisiana

Pile Encapsulation

- Encapsulations in 2002

## Lake Pontchartrain Causeway, New Orleans, Louisiana

- Bond testing 13-year old encapsulations

## Lake Pontchartrain Causeway, New Orleans, Louisiana

- Encapsulations in 2017

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## Lake Pontchartrain Causeway, New Orleans, Louisiana

## Rappahannock River Bridge, Tappahannock, Virginia

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- 1993
- RC Piers Showing Corrosion and Spalling
- Encapsulations all Above Water

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- 1993
- RC Piers Showing Corrosion and Spalling
- Encapsulations all Above Water

## Rappahannock River Bridge, Tappahannock, Virginia

- Jackets placed over spalled areas
- No patching was done

## Rappahannock River Bridge, Tappahannock, Virginia

- Completed Encapsulation

## BG&E Facility, Baltimore, Maryland

- Badly deteriorated H-Piles

## BG&E Facility, Baltimore, Maryland

- Encapsulate 44 “H” Piles
- Completed in 1993

## BG&E Facility, Baltimore, Maryland

- Corroded steel section replaced with new structural steel
- Steel channels bolted and spliced onto existing piles

## BG&E Facility, Baltimore, Maryland

- Jackets sized to H-Pile Profile

## BG&E Facility, Baltimore, Maryland

- Encapsulations in place

## Warren Road Bridge, Baltimore, Maryland

## Warren Road Bridge, Baltimore, Maryland

Deteriorated piers
- Large concrete pier

## Warren Road Bridge, Baltimore, Maryland

Pier Encapsulation:
- Large concrete pier
- Jacket Fabrication

## Warren Road Bridge, Baltimore, Maryland

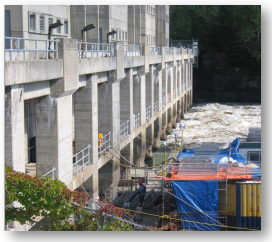
- Large concrete pier

## Des Joachims Hydroelectric Dam
## Deep River, Ontario, Canada

- Tailrace Structure
  - Sits on the Ottawa River between Ontario and Quebec
  - 200-km Upstream from Ottawa, ON
  - 8 power generation units

## Challenges

- Tailrace Structure
  - Structure built in 1940's
  - Damage to tailrace from scour and abrasion



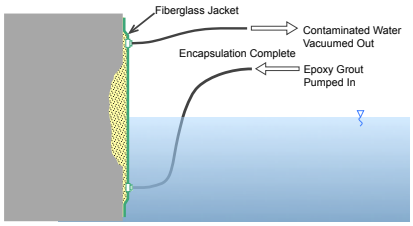
## Challenges

- Damage to Piers
  - Loss of section
  - 12" to 18" of section loss in some instances
  - Reinforcing steel exposed

## Challenges

- Repair Procedure
  - Restore loss of section
  - Protect against future abrasion damage
  - Protect the downstream ecosystem
  - Minimize dam shutdown time to less than 10-days

## Concept




## Implementation

- FRP Panels
  - Face of peirs encapsulated using FRP panels
  - Thicker than usual panels (1/4") were used due to severity of scour and abrasion
  - Panels hoisted into place

## Implementation

- Panels Installed
  - Panels are anchored into the face of the wall at appx 12”o.c. EW
  - Stiffeners are placed to resist grouting pressure

## Implementation

- Grouting Operation
  - Grout pumped into annular space
  - Expunged water and excess grout reclaimed by vacuum pumps installed on upper ports
  - Contaminated water disposed of separately to minimize environmental impact

## Des Joachims Hydroelectic Dam Deep River, Ontario, Canada

- Encapsulation in Place
  - Completed without dewatering
  - Only 7-days of shutdown time for the generators

## Testing

- Core Samples
  - Excellent bond to backwall
  - Good grout consolidation
  - No cracking in grout from exotherm

## Conclusion

- Before…

## Conclusion

- …and After

**Des Joachims Hydroelectric Dam**
**Deep River, Ontario, Canada**

- …and In Service

**Gandy Bridge**
**Tampa Bay, FL USA**

**Gandy Bridge**
**Tampa Bay, FL USA**

## Gandy Bridge
## Tampa Bay, FL USA

2010

- Condition Survey
- First Encapsulated in 1987

## LPG Trestle,
## Ju'Aymah, Saudi Arabia

**33 years later…**

The repair and protection via Advanced Pile Encapsulation remains in place and continues to provided protection without any maintenance

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