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Structural Strengthening Using Composite Materials

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Presentation Overview

- Who is CS|NRI?
- Overview of composites and their application in submerged environments
- How composites work?
- Case studies
- The design and implementation process

Company Overview

- CS|NRI is the leading provider of high-performance repair, rehabilitation, and construction products for global critical infrastructure
- Relentless focus on safety, innovation, and stewardship of customer assets and the environment.
- Solutions driven, manufacturing firm and ASME, ISO and ACI compliant composite materials firm
- State-of-the-art, ISO 9001-certified manufacturing and R&D facilities across the world
- Best-in-class design, engineering, testing, and training services to ensure proper installation and optimal performance

REFINERIES & CHEMICAL PROCESSING FACILITIES

PIPELINE DISTRIBUTION & TRANSMISSION COMPANIES

LARGE SCALE CIVIL - CONCRETE & STEEL STRUCTURAL STRENGTHENING

OFFSHORE PLATFORMS & FPSO

In-house Resin Formulation & Manufacturing

- **Extensive in-house testing services to verify key physical properties:**
  - **Tensile properties**
  - **Fiber and resin compatibility**
  - **Glass transition temperature of the material**
  - **Chemical compatibility**
  - **Adhesion to surfaces**
- **Fiber Manufacturing Capabilities**
  - **11 needle looms**
  - **1 multi axial stitch bond knitting machine**

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COMPOSITE OVERVIEW

Composites: What are they?

- Combination of fabric and resin that form an extremely strong monolithic material
- Designed to share the loads & stresses with the host substrate

Fiber Reinforcement

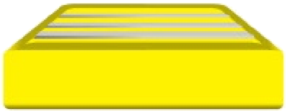
(carbon, glass, or synthetic)

- High tensile strength
- High stiffness
- Low density

+

Polymeric Binding Matrix

(epoxy, vinyl ester, urethane)



- Good shear properties
- Low density

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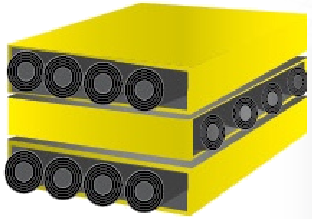
Composite



- High tensile strength
- High stiffness
- Good shear properties
- Low density

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Why chose composite repairs

- To extend the service life of a structure.
- To eliminate downtime - can be applied while structure is in service
- They are a cost-effective alternative to replacement
- Can be used to repair, confine or strengthen structures.
- Can be engineered to proper design guides

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Types of composite strengthening materials


NSM Plates


Pultruded Plates


Wet lay-up systems


FRP Bars


FRCM

Types of Composite Strengthening Materials for Underwater Piles

Field vs Pre Saturated Wet Layup Systems

Standard Epoxy Systems

Field vs Pre Saturated Wet Layup Systems

Factory-Saturated System

STEPS ELIMINATED WITH PRE-SATURATED SYSTEMS

- Provide saturating resin
- Mix epoxy saturant
- Set up saturator
- Saturate fabric (saturator or table/rollers)
- Clean up saturator and tools
- Dispose of resin pails

NO FIELD SATURATION REQUIRED

Damp Application/ Underwater Product

- **Most of the strengthening applications are done in dry environment.**

- **NRI offers a variety of products that can be used in damp or submerged environments in order to minimize down time and overtime charges**

HOW DO COMPOSITES WORK?

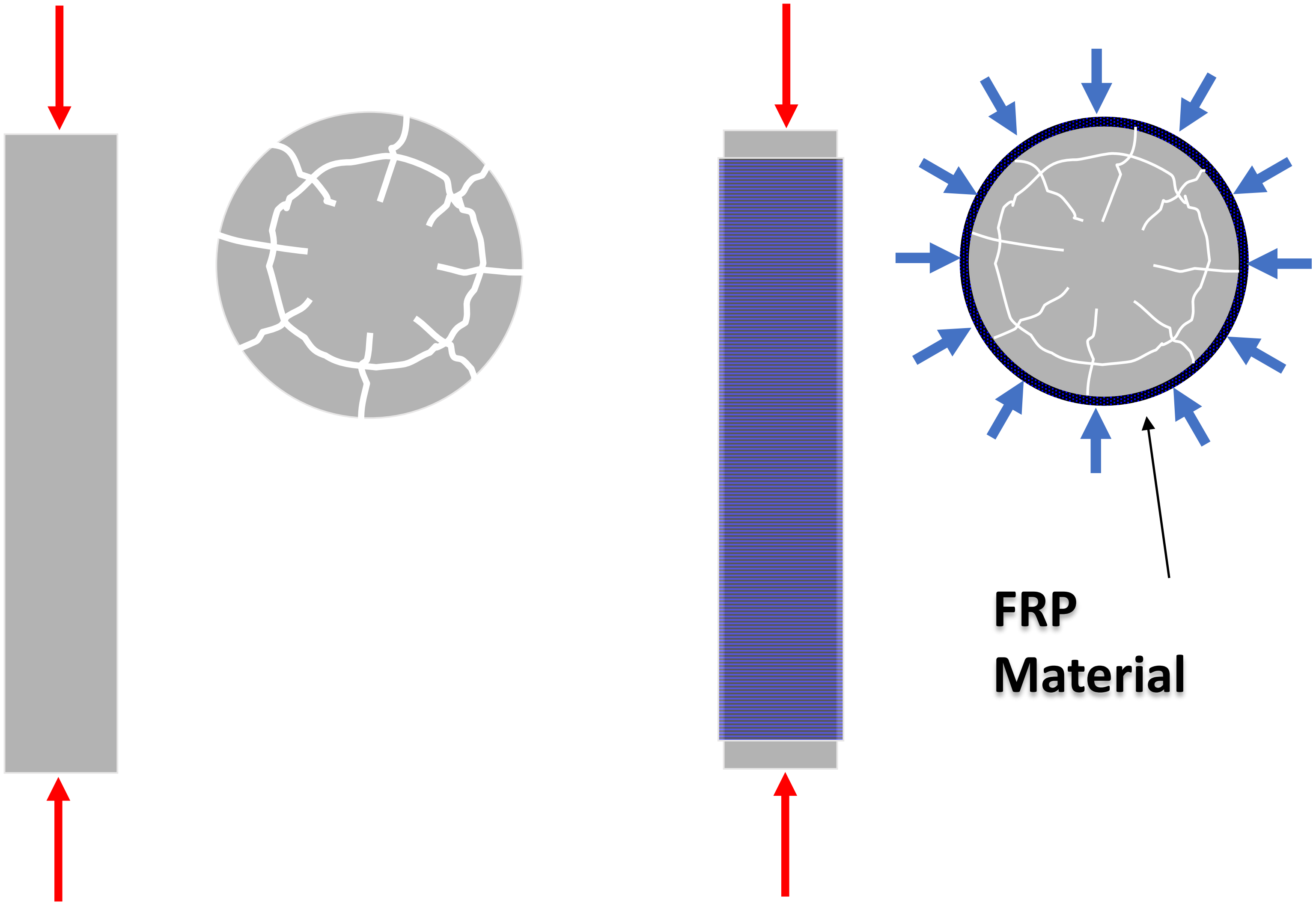
Confinement

Reinforcement is accomplished by utilizing tensile strength of composite system

Column Wrapping

- Increase in both axial and flexural strength
- Commonly used for seismic retrofitting
- Most efficient reinforcement in circular columns

Confinement

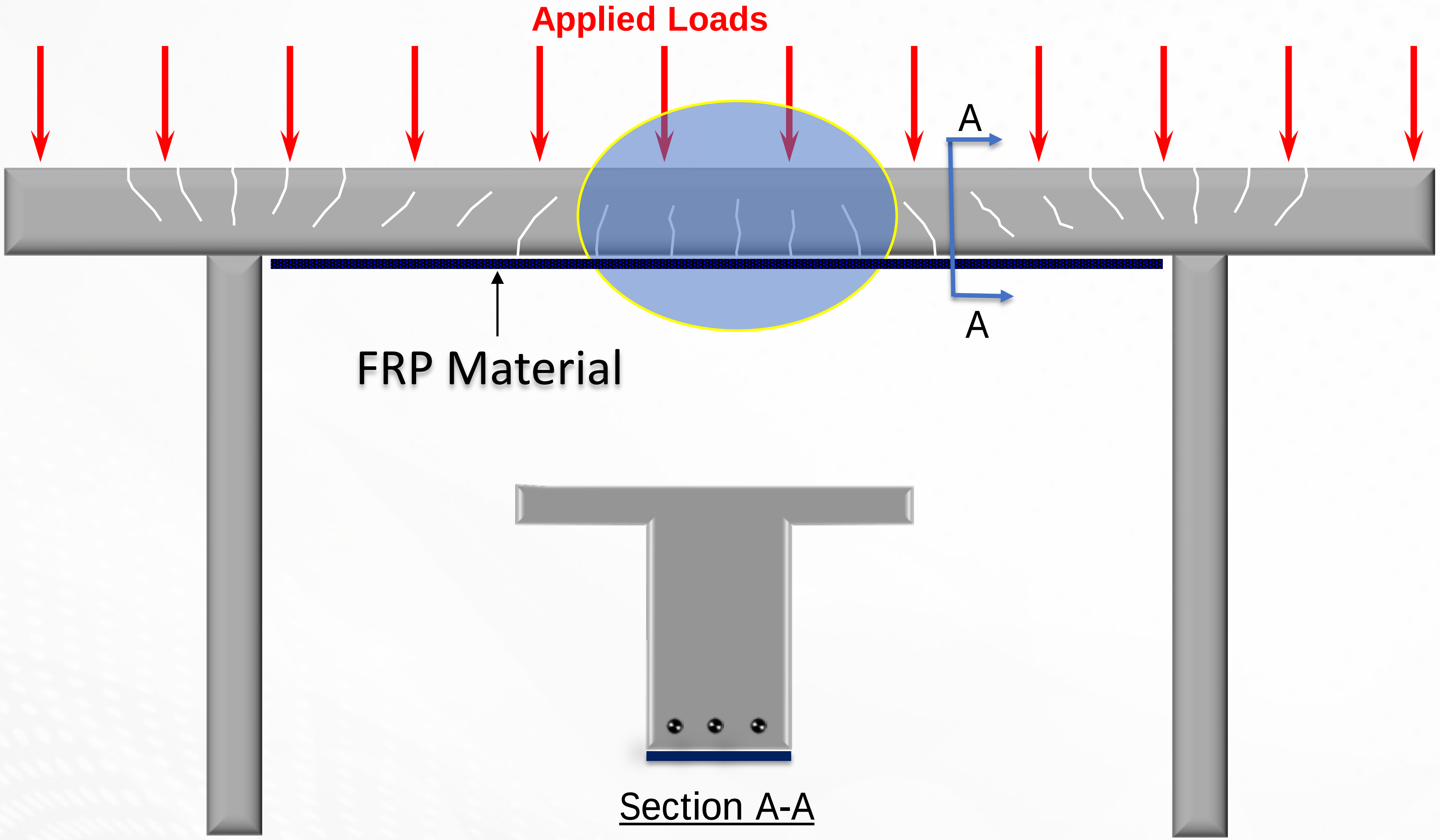


Flexural Strengthening

Reinforcement is accomplished by utilizing tensile strength of composite system

- FRPs can strengthen reinforced and pre-stressed members
- Beams, slabs, walls, etc.
- Increases in bending capacity is a function of FRP stiffness and thickness

Flexural Strengthening

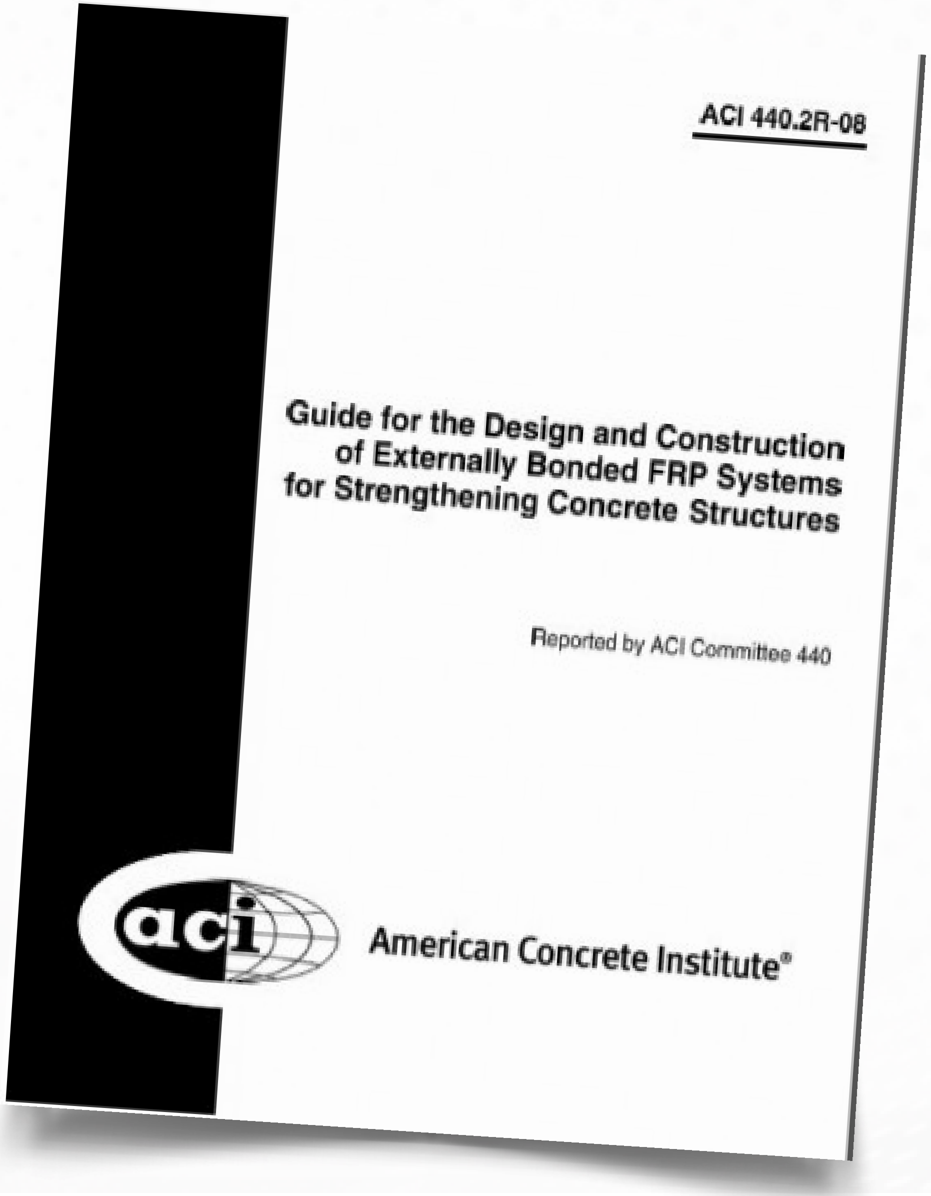


Standards and Design Guides

- **Reinforced concrete design Guides available**

  ACI 440.2R-08

  ISO 14484



Steel and Timber Strengthening

- No governing standard – conservative approach
  - Published guidelines
  - Research papers (Empirical)
  - Engineering first principles
- Iterative process with client
  - Safety factors

CNR – Advisory Committee on Technical Recommendations for Construction

NATIONAL RESEARCH COUNCIL

ADVISORY COMMITTEE
ON TECHNICAL RECOMMENDATIONS FOR CONSTRUCTION

Guidelines for the Design and Construction of Externally Bonded FRP Systems for Strengthening Existing Structures

Metallic structures

Preliminary study

CNR-DT 202/2005

Steel Details		
Depth	2	mm
Yield Strength	235	MPa
Young's Modulus	200	GPa
Yield Strain	1.18E-03	

Composite		
No. of layers	2	
Depth	1.10	mm
Compressive Strength	320	MPa
Tensile Strength	894	MPa
Flexural Modulus	71.6	GPa
Factored Flexural Modulus	47.7	GPa
Compressive Yield Strain	6.70E-03	
Tensile Yield Strain	1.87E-02	
REP thickness	5	mm
Factored REP thickness	3.33	mm

Deck Geometry		
Total Depth	6.43	mm
Width	1	m
Span	1.17	m

Safety factors	
Lifetime (years)	10
Lifetime SF	1.30
REP thickness SF	1.5
Composite material SF	1.5
Live load SF	1
Dead load SF	1

Load		
Unfactored Live load	1.9	kN/m^2
Factored Live load	2.85	kN/m^2
Self weight	0.15	kN/m^2
Additional Dead Load	0	kN/m^2

USE OF COMPOSITES IN STRUCTURAL STRENGTHENING

Application – Reinforced Concrete

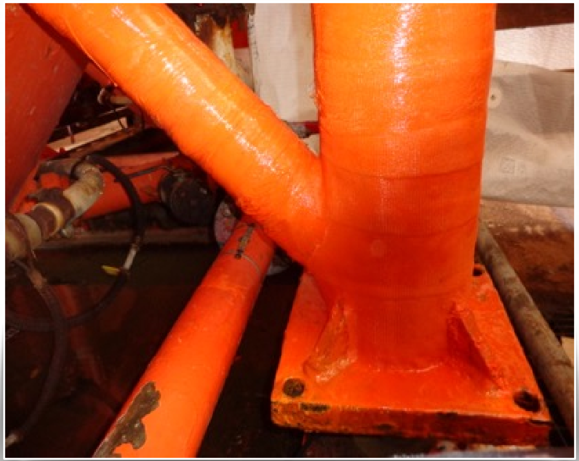
- Structural strengthening due to: loss of strength, change of use, design error
- Beams, columns, slabs, walls, pipe supports, pilings, concrete tanks.
- Above and underwater applications

Application – Wood/Timber Piles

- Wood power poles
- Marine pile strengthening and protection
- Soil to air interface protection against rotting

Application – Steel Substrate

- Corrosion protection and strengthening
- Decks, caissons, hollow sections, and non-critical structural members (columns, beams, truss members)
- Above and underwater applications

CASE STUDIES

APM Terminal, Peru

- A large shipping terminal in Lima Peru is experiencing deterioration due to aging, weathering, and extensive use of the terminal for large ships
- Approximately 300 pre-stressed reinforced concrete pilings.
- Underwater inspection different levels of damage, including loss of concrete and exposed steel pre-stressing wires.
    A. Severely damaged piles with >40% capacity loss
    B. Highly corroded, spalled piles
    C. Cracked and corroded stained piles
    D. Minorly cracked piles

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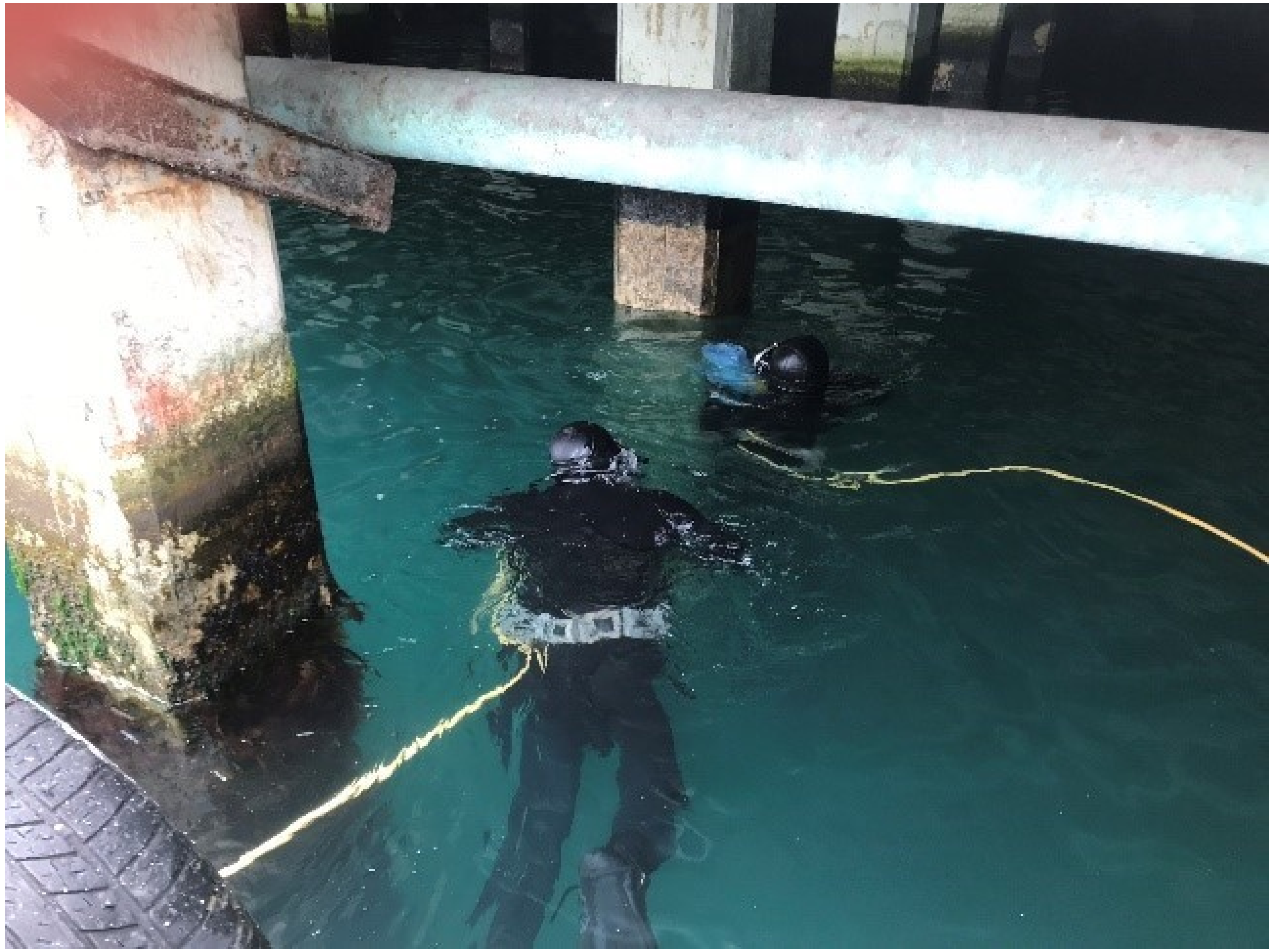
APM Terminal Trial Project

- Syntho-Shore provided a simpler solution for strengthening and protection of the shipping terminal's underwater piles.
- Syntho-shore is the first test-proven, underwater product in the market
- Selected for a trial project to wrap 2 pilings
- Installed successfully, in less than one hour, by divers who had not previously worked with the product.
- Project has advanced and the owner will wrap over 1,300m in pile length with Syntho-Shore product by September 2019.



Vale, Brazil Project

- 1mile (1.67 km) bridge with more than 147 underwater piles, maintained by Vale in São Luís (MA), Brazil
- Existing piles are reinforced concrete, with steel jackets around them
- The original steel jackets were designed to be sacrificial
- A need to increase the capacity of the bridge has resulted in the necessity for the steel jackets to perform as structural elements
- Syntho Shield was selected due to:
    - minimal surface prep requirements,
    - speed of installation,
    - excellent impact and corrosion prevention
    - low mobilization costs

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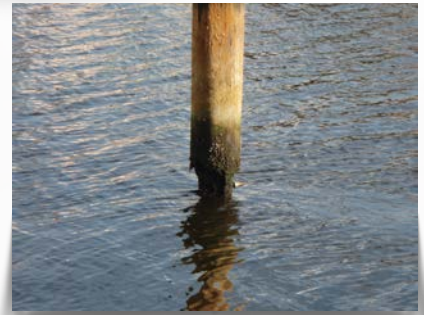
12” OD Timber Piling Repair, USA

- 12” OD wood piling experienced severe damage due to marine bore attack on the splash-zone area
- Foreign matter and marine growth were removed using a high-pressure water blast.
- A high density polyethylene (PE) jacket was used to create a form in which hydraulic cement was injected to restore the shape of the piling.
- The piling was encapsulated with four layers of Syntho-Glass®24 to provide structural integrity and mechanical protection.
- The application was completed by positioning and nailing a PE jacket to provide UV protection as well as a bumper to protect boats from scratches.



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14” OD Wooden Power Pole Rehabilitation, USA

- Soil-to-air interface rotting occurring in 14”OD wooden power poles in a Louisiana chemical plant.
- Unexpected power loss due to a pole failure could result significant financial loss for the facility.
- NRI recommended Syntho-Glass 24 and a UV protective coating at the soil line
- Eight layers where applied to five poles requiring integrity restoration.
- Four layers were applied to five poles requiring preventative maintenance.

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Wood Piling Submersion Project

- Based on AWPA E5-15
  - Used to determine efficacy of “treatment” against naturally occurring wood-destroying agents
  - Exposure to be at a minimum of two locations with different degrees of marine bore attack
- Total of 8 treated and untreated pilings submerged
  - Intracoastal waterway
    - 4 pilings – 2 treated, 2 untreated
  - Salt-water canal waterway
    - 4 pilings – 2 treated, 2 untreated

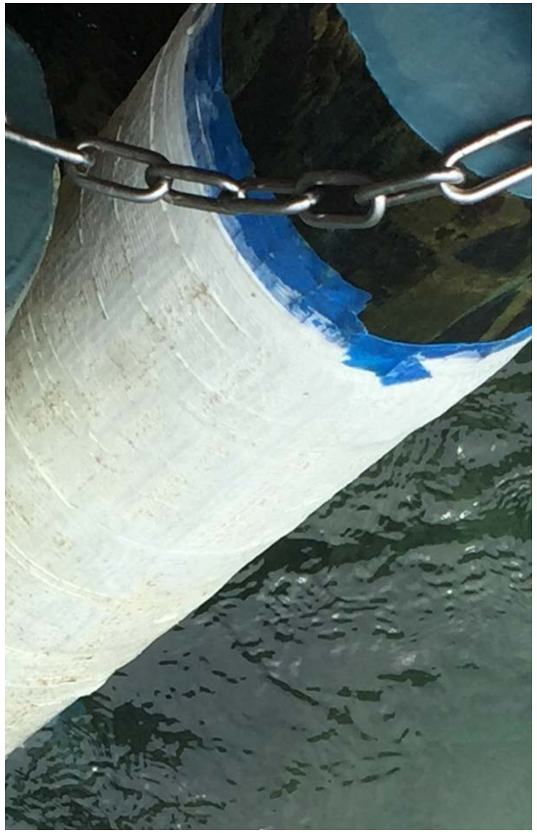
Rating	Description
10	No attack
9.5	Suspicion of attack
9	Slight attack, up to 3% of any cross-sectional area affected
8	Moderate attack, 3-10% of any cross-sectional area affected
7	Moderate/severe attack, 10-30% of any cross-sectional area affected
6	Severe attack, 30-50% of any cross-sectional area affected
4	Very severe attack, 50-75% of any cross-sectional area affected
0	Failure

1 month after submersion

Intracoastal Waterway

Untreated

Treated



Saltwater-Canal Waterway

Untreated

Treated

2 Year After Submersion – Canal Water

2 Year After Submersion – Canal Water

2 Year After Submersion – Intercoastal

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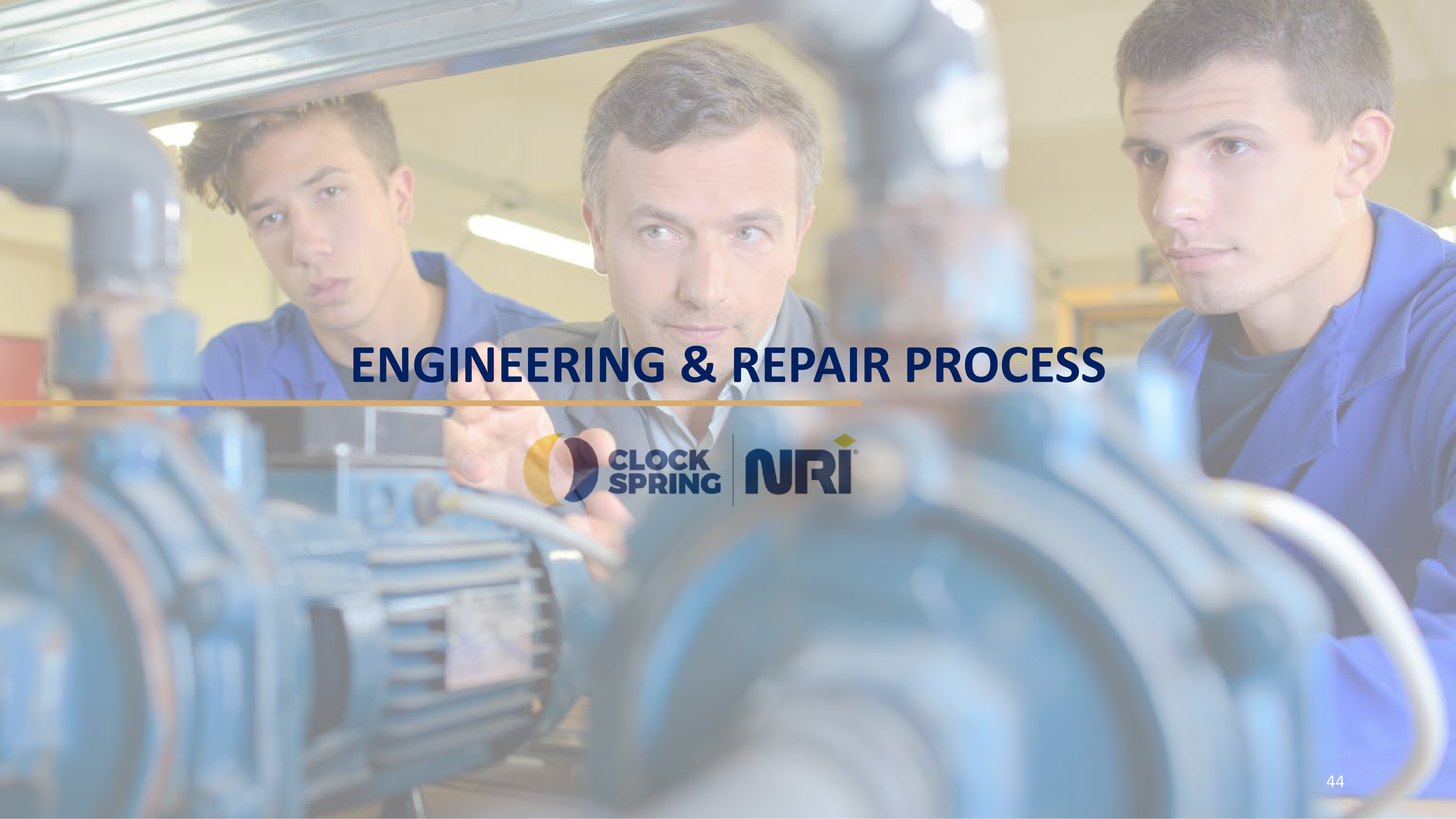
2 Year After Submersion – Intracoastal



ENGINEERING & REPAIR PROCESS

Engineering & Repair Process

End User Inquiry

EAF Completion

Technical Feasibility Review

Calculations Performed

Proposal Developed & Sent

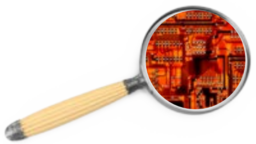
Installation

QC Inspection

Responsible Party:

- Operator
- Manufacturer
- Contractor

CONTROLLED PROCESS: NRI



Technical Feasibility Review

- Does the proposed scenario fall within the scope of an Engineered Composite Repair (ECR) system's capabilities?

Calculations Performed

- ECR material selection, repair thickness, and length calculated based on ASME and/or ISO standards.
- A report is provided detailing the prod

Customized Design Specification Delivered

- A report is provided detailing the product, repair calculations, installation specifications, Critical Hold and QC documentation.

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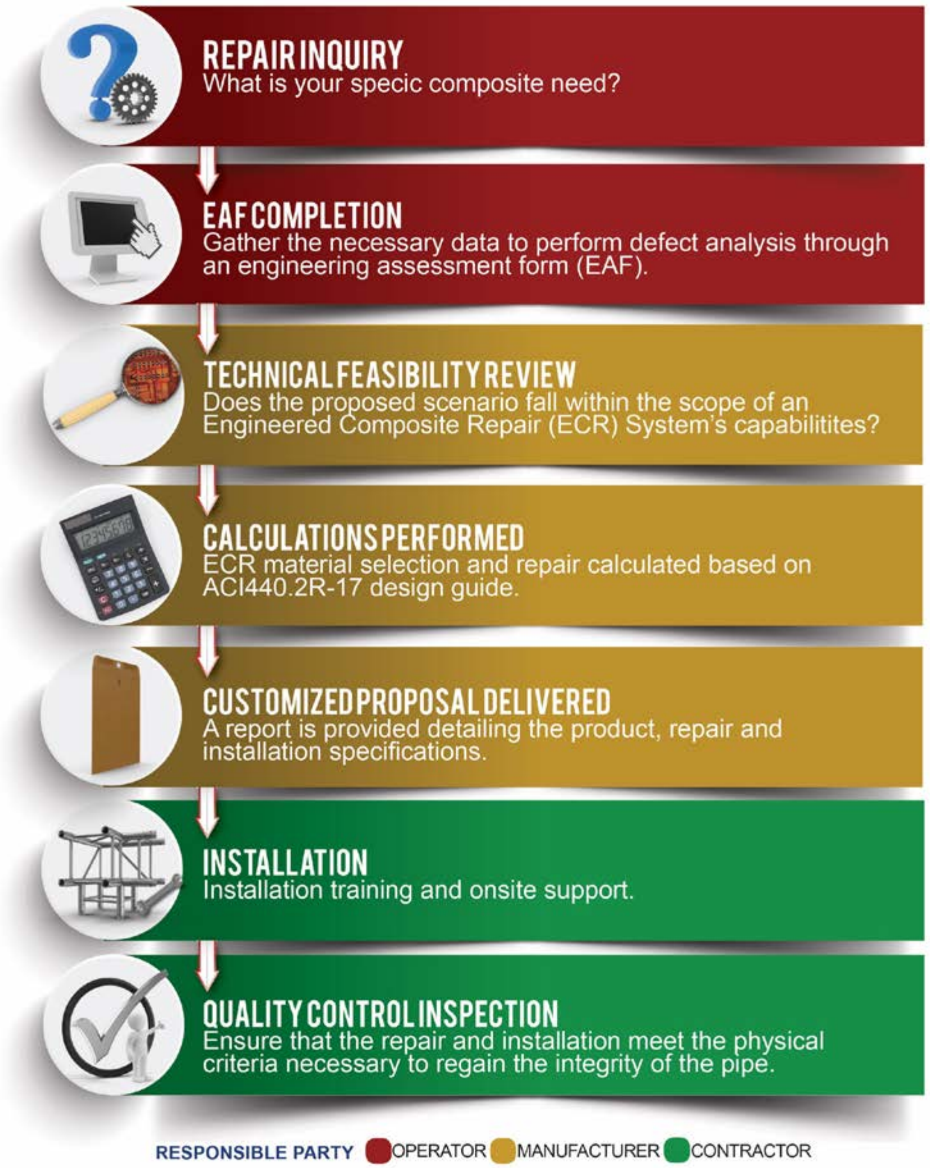
CONTROLLED PROCESS: Contractor

Installation

- Responsible for supplying NRI qualified, trained craftsman
- Following repair procedure, surface preparation requirements and critical holds

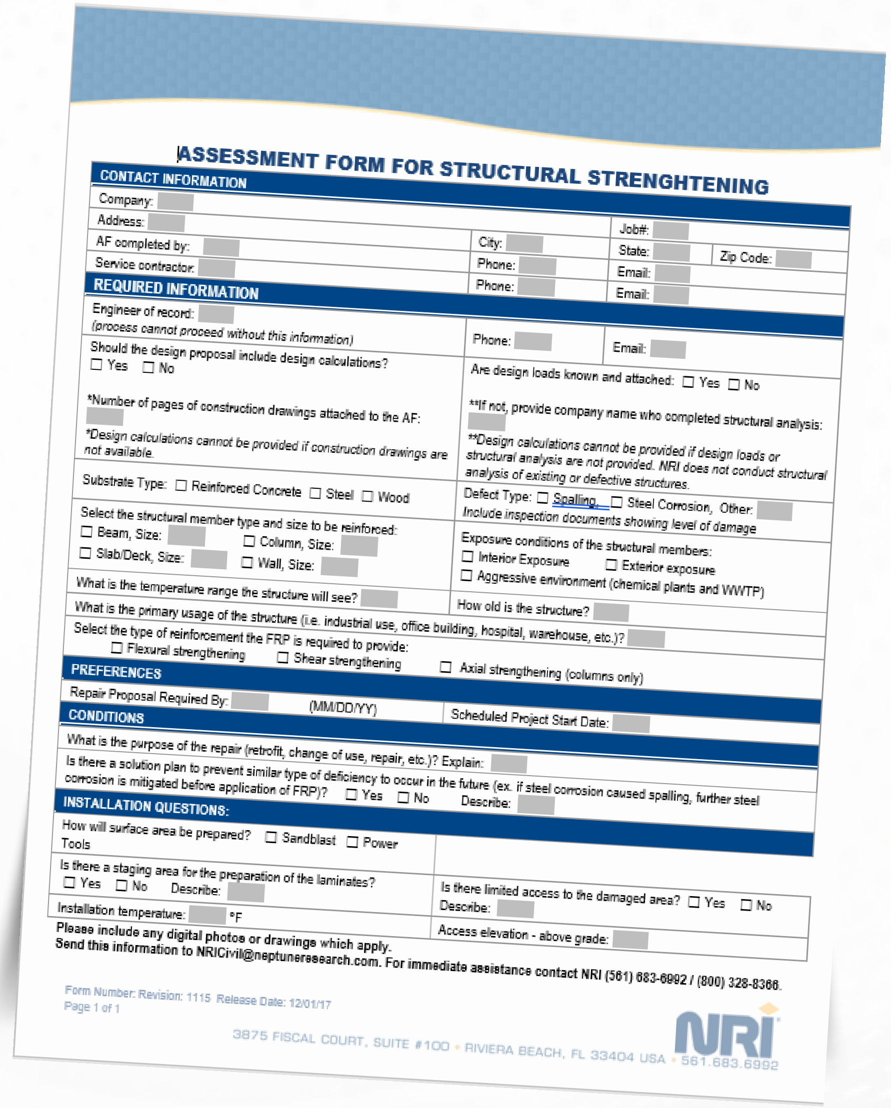
Quality Control

- All pre & post job inspections are complete, documented and submitted to the asset owner by the qualified, lead craftsman



Assessment Form For Structural Strengthening

- **Checklist to be able to perform design calculations**
  - Contact information of the engineer of record (i.e. client’s engineer)
  - Construction drawings (Ex. as-built drawings, structure layout, internal rebar layout, deck support structure, etc)
  - Loading requirements and/or structural deficiency analysis of structure
  - NDT inspection documentation/inspection reports
  - Highlighted area requiring repair
  - Exposure conditions of the structure
  - Accessibility
  - Purpose of the repair



ASSESSMENT FORM FOR STRUCTURAL STRENGHTENING

CONTACT INFORMATION

Company:
Address: | Job#:
AF completed by: | City: | State: | Zip Code:
Service contractor: | Phone: | Email:
| Phone: | Email:

REQUIRED INFORMATION

Engineer of record:
(process cannot proceed without this information) | Phone: | Email:
Should the design proposal include design calculations?
☐ Yes ☐ No
*Number of pages of construction drawings attached to the AF:
*Design calculations cannot be provided if construction drawings are not available.
Are design loads known and attached: ☐ Yes ☐ No
**If not, provide company name who completed structural analysis:
**Design calculations cannot be provided if design loads or structural analysis are not provided. NRI does not conduct structural analysis of existing or defective structures.
Substrate Type: ☐ Reinforced Concrete ☐ Steel ☐ Wood
Defect Type: ☐ Spalling, ☐ Steel Corrosion, Other:
Include inspection documents showing level of damage
Select the structural member type and size to be reinforced:
☐ Beam, Size: ☐ Column, Size:
☐ Slab/Deck, Size: ☐ Wall, Size:
Exposure conditions of the structural members:
☐ Interior Exposure ☐ Exterior exposure
☐ Aggressive environment (chemical plants and WWTP)
What is the temperature range the structure will see?
How old is the structure?
What is the primary usage of the structure (i.e. industrial use, office building, hospital, warehouse, etc.)?
Select the type of reinforcement the FRP is required to provide:
☐ Flexural strengthening ☐ Shear strengthening ☐ Axial strengthening (columns only)

PREFERENCES

Repair Proposal Required By: (MM/DD/YY) | Scheduled Project Start Date:

CONDITIONS

What is the purpose of the repair (retrofit, change of use, repair, etc.)? Explain:
Is there a solution plan to prevent similar type of deficiency to occur in the future (ex. if steel corrosion caused spalling, further steel corrosion is mitigated before application of FRP)? ☐ Yes ☐ No Describe:

INSTALLATION QUESTIONS:

How will surface area be prepared? ☐ Sandblast ☐ Power Tools
Is there a staging area for the preparation of the laminates?
☐ Yes ☐ No Describe:
Is there limited access to the damaged area? ☐ Yes ☐ No
Describe:
Installation temperature: °F
Access elevation - above grade:

Please include any digital photos or drawings which apply.
Send this information to NRICivil@neptuneresearch.com. For immediate assistance contact NRI (561) 683-6992 / (800) 328-8366.

Form Number: Revision: 1115 Release Date: 12/01/17
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Training and On-site Support

What we do…

- **Ensure project integrity by providing practical training that qualifies composite installers and inspectors**
- **Qualify installers to meet the exact skill requirements required for the project**
- **Provide composite inspection and design courses for contractors and engineers**
- **Provide onsite support for quality assurance for any size project**


Classroom & Exam


Practical


Field Support

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NEXT STEPS

Do you have a project that you would like to walk through the AF process?

Do you know another department who could use some help?


Thank You!