

CONCRETE DAMAGE REPAIRS OF EXISTING MARINE TERMINALS

BERNARDO WAISMAN, P.E.

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TOPICS

- ❖ TYPES OF CONCRETE DAMAGE
- ❖ REINFORCING STEEL CORROSION DAMAGE
- ❖ REPAIR METHODS AND MATERIALS
- ❖ TYPICAL REPAIR COSTS
- ❖ RECOMMENDATIONS FOR NEW TERMINALS
- ❖ LESSONS LEARNED

TYPES OF CONCRETE DAMAGE

- ❖ **REINFORCING STEEL CORROSION**
Causes cracking, closed spalls, open spalls & delamination
- ❖ **STRUCTURAL DAMAGE**
Caused by large object impact, abnormal accidental berthing or seismic loads
- ❖ **DENTING & PITTING**
Caused by floating debris, abrasion and concrete age
- ❖ **SLOPE PROTECTION CRACKING**
Caused by saturated soil movement and undermining of concrete slab

TYPES OF CONCRETE DAMAGE



Concrete Beam with Cracks & Rust Stains



Concrete Beam with Open Spall & Exposed Corroded Rebar

TYPES OF CONCRETE DAMAGE



Concrete Beam with Open Soffit Spall & Exposed Corroded Rebar



Concrete Beam with Corner Open Spall & Exposed Corroded Rebar

TYPES OF CONCRETE DAMAGE



Concrete Beam with Cracks & Open Spall



Utility Vault with Soffit & Wall Damage Being Repaired

TYPES OF CONCRETE DAMAGE



Concrete Column with Open Spall & Corroded Rebar



Concrete Column with Open/Closed Spall & Corroded Rebar

TYPES OF CONCRETE DAMAGE



Reinforced Concrete Pile with Vertical Crack



Prestressed Concrete Pile with Vertical Crack & Rust Stains

TYPES OF CONCRETE DAMAGE



Prestressed Concrete Pile with Horizontal Structural Crack



Reinforced Concrete Pile with Breakage from Object Impact

TYPES OF CONCRETE DAMAGE



Prestressed Concrete Pile with Pitting



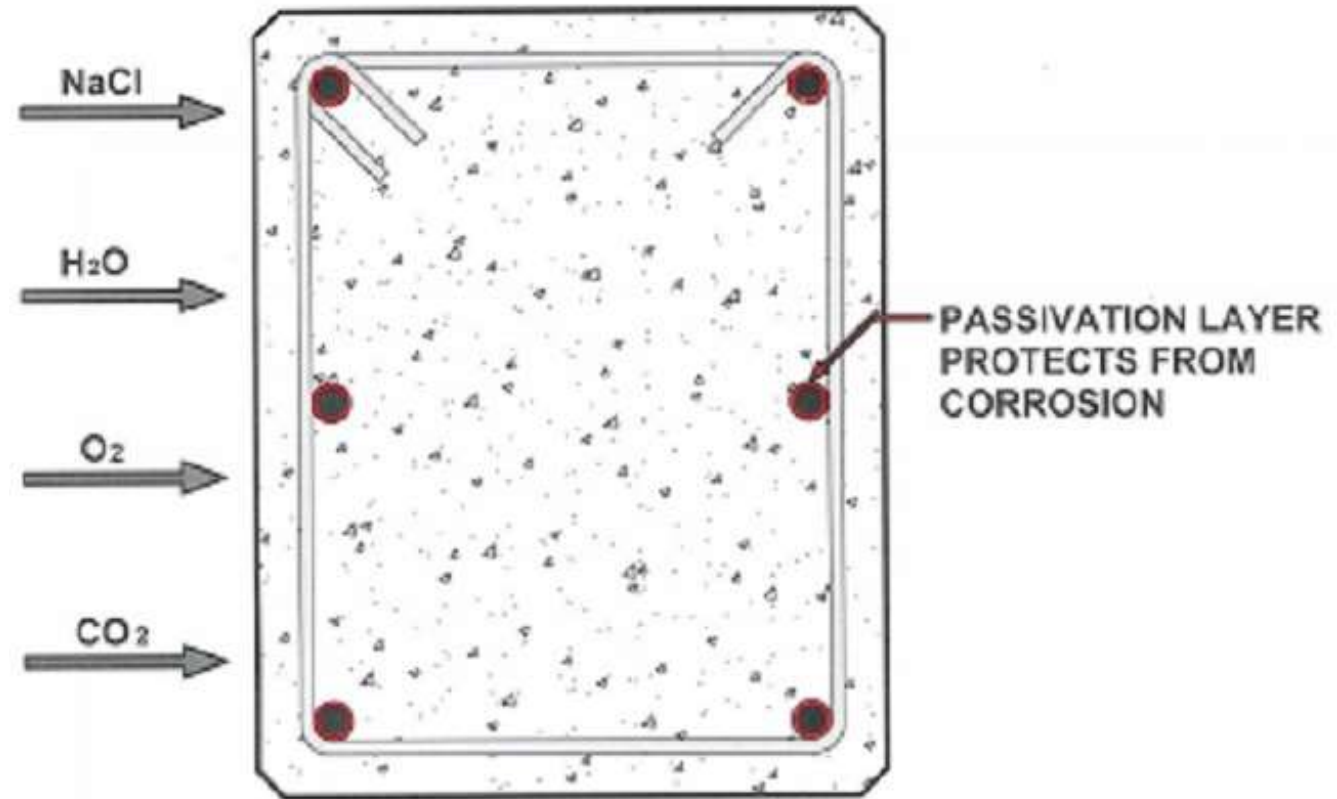
Slope Protection Cracks

REINFORCING STEEL CORROSION DAMAGE

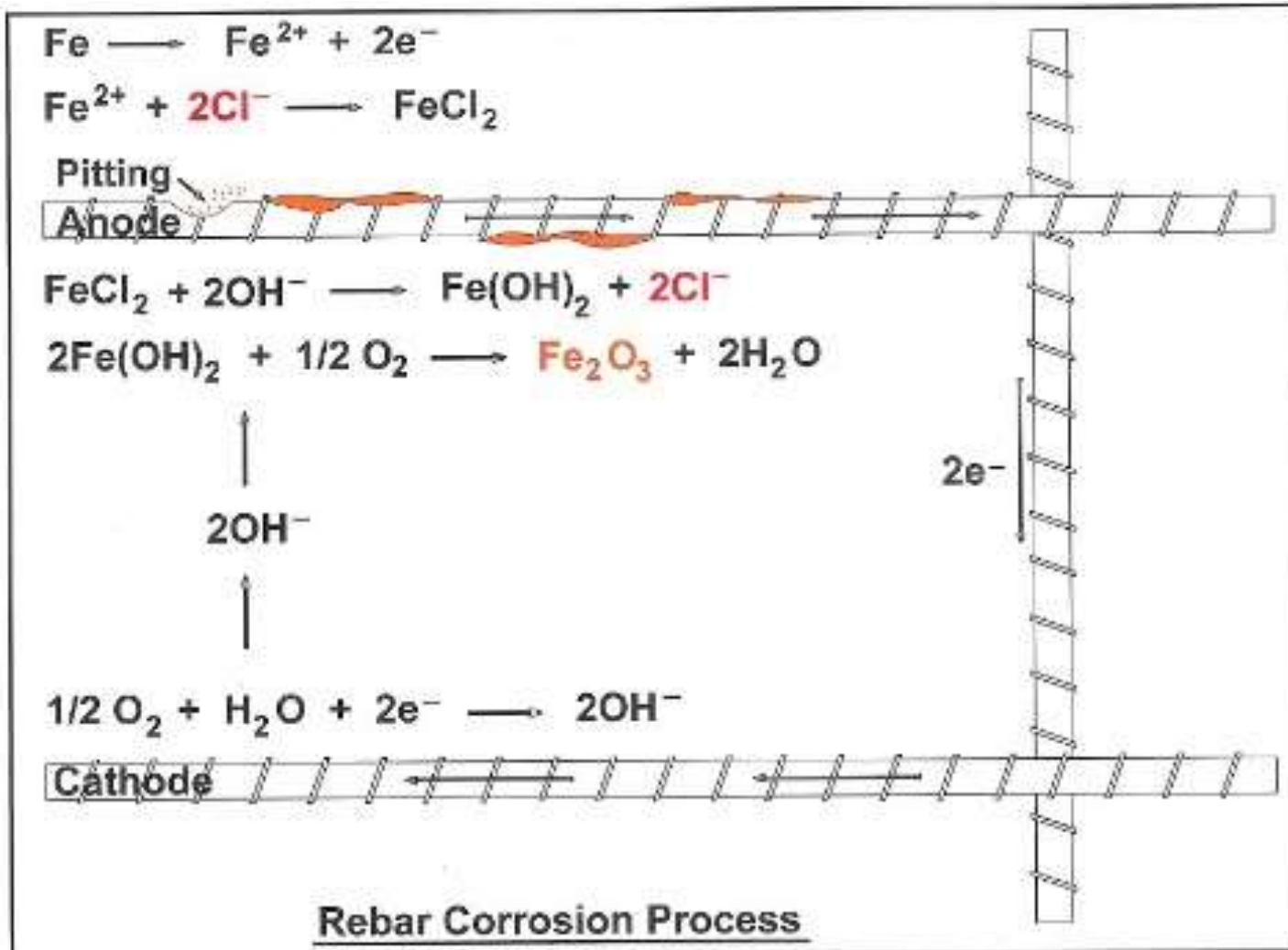
PASSIVATION LAYER

The high alkalinity provided by fresh concrete results in the formation of the passivation layer on the surface of the reinforcing. This is a thin film of rust that protects the steel from further corrosion.

Chloride ions present in the marine environment penetrate the concrete cover and break down the passivation layer, initiating the progressive corrosion process.



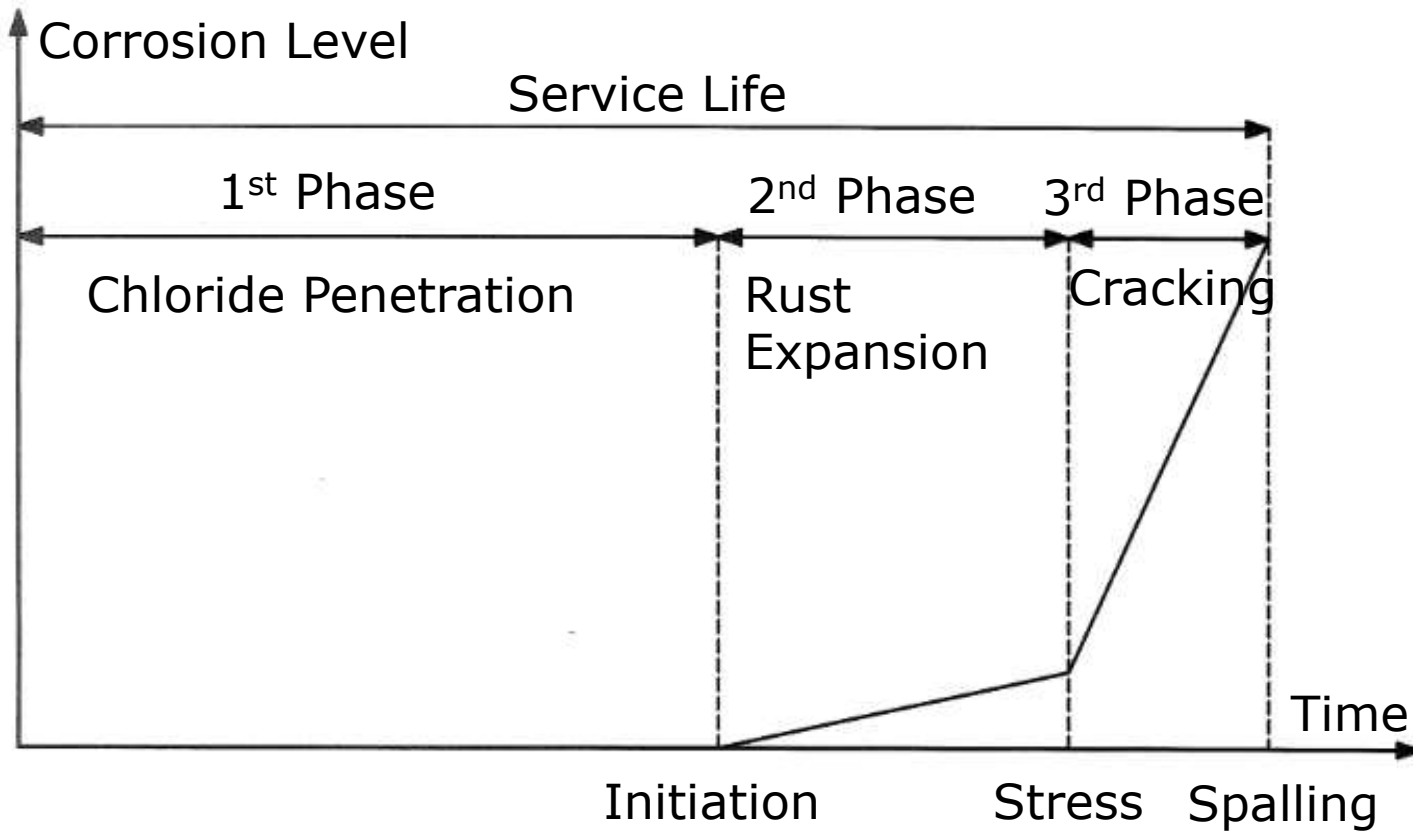
REINFORCING STEEL CORROSION DAMAGE



Effect of Concrete Alkalinity on Corrosion

- ❖ Fresh concrete provides a high-alkalinity environment ($\text{pH} > 12$) that protects the reinforcing from corrosion.
- ❖ The intrusion of chloride reduces the alkalinity of the concrete. Corrosion may occur when the pH reaches a value of 9 or less.

REINFORCING STEEL CORROSION DAMAGE



Beam Corroded Rebars

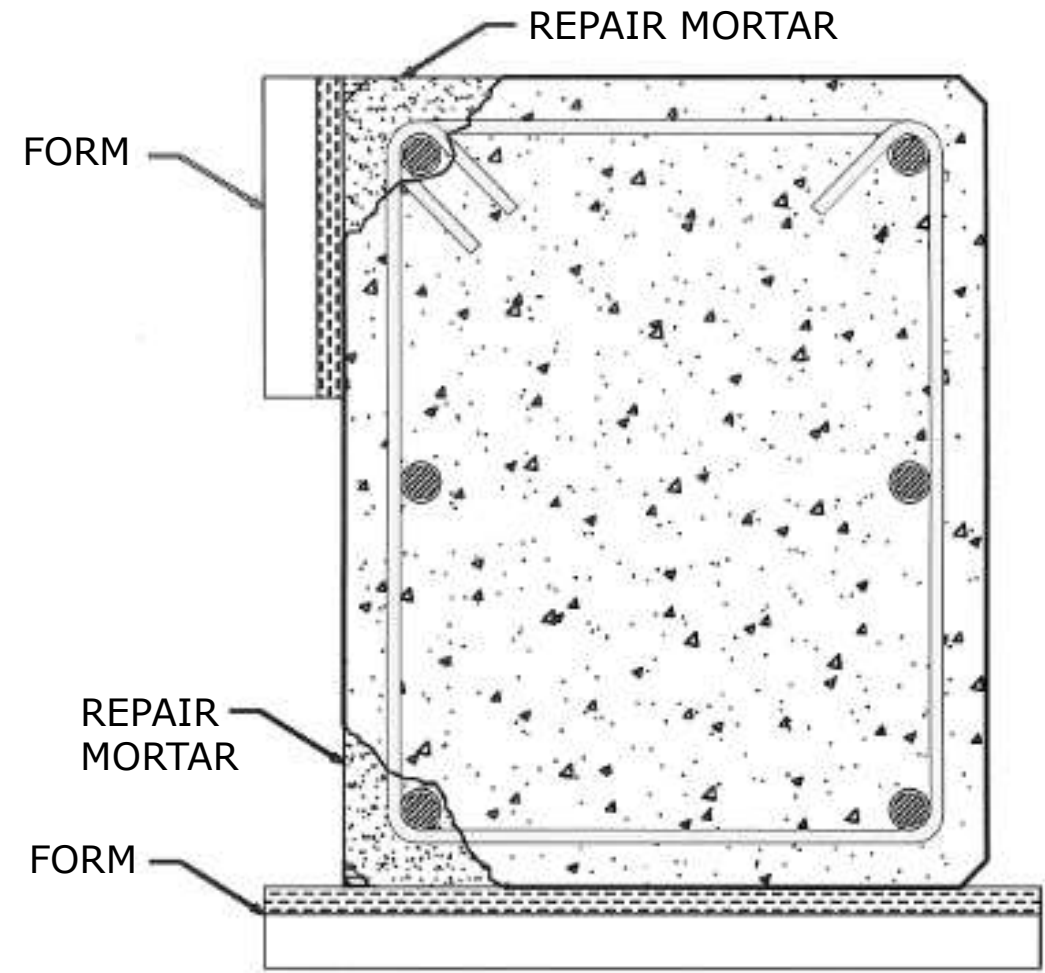
Rebar Corrosion Progression

REPAIR METHODS AND MATERIALS

REPAIR PROCEDURE

1. CHIP-OFF LOOSE CONCRETE AND CLEAN SURFACE OF ALL BOND INHIBITING MATERIALS.
2. GRIND PERIMETER OF REPAIR AREA TO 1/2" MINIMUM DEPTH TO AVOID FEATHERED EDGES.
3. CLEAN REBARS MECHANICALLY TO REMOVE ALL RUST. REPLACE CORRODED REBAR WITH MORE THAN 30% SECTION LOSS.
4. USING A STIFF BRUSH APPLY SIKA ARMATEC 110 EPOCEM CORROSION INHIBITING & BONDING AGENT AT 20 MILS MINIMUM THICKNESS COVERING ALL EXPOSED STEEL AND ALLOW TO DRY. APPLY A SECOND COAT AT 20 MILS MINIMUM THICKNESS AND ALLOW TO DRY.
5. PRE-WET SURFACE TO SATURATED SURFACE DRY.
6. PREPARE AREA WITH SIKA ARMATEC 110 EPOCEM.
7. PLACE REPAIR MATERIAL SIKAREPAIR 223, OR SIKATOP 123 PLUS.
8. CURING WITH WET BURLAP AND POLYETHYLENE SHEETING.

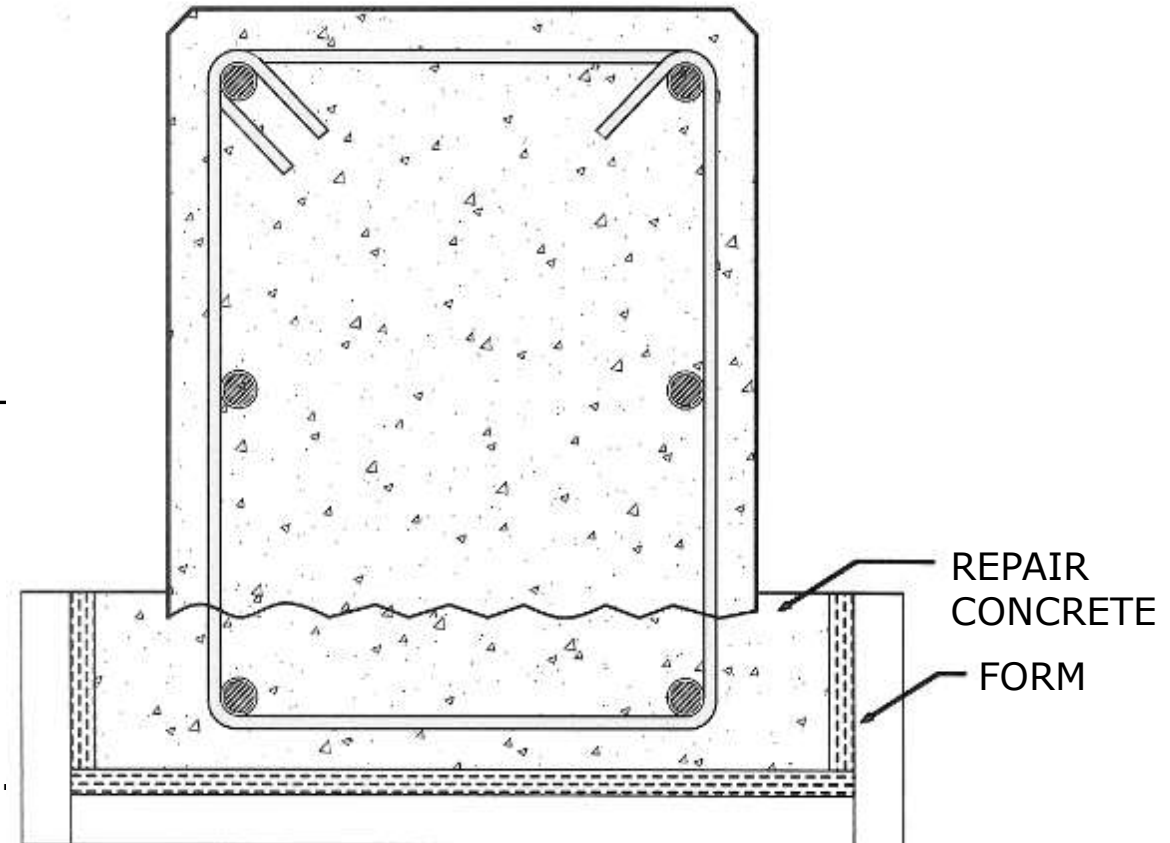
Beam Corner Repair



REPAIR METHODS AND MATERIALS

REPAIR PROCEDURE

1. DEMOLISH BEAM SOFFIT ALONG DAMAGED AREA.
2. CLEAN EXPOSED SURFACE OF LOOSE CONCRETE AND ALL BOND INHIBITING MATERIALS.
3. CLEAN REBARS MECHANICALLY TO REMOVE ALL RUST. REPLACE CORRODED REBAR WITH MORE THAN 30% SECTION LOSS.
4. USING A STIFF BRUSH APPLY SIKA ARMATEC 110 EPOCEM CORROSION INHIBITING & BONDING AGENT AT 20 MILS MINIMUM THICKNESS COVERING ALL EXPOSED STEEL AND ALLOW TO DRY. APPLY A SECOND COAT AT 20 MILS MINIMUM THICKNESS AND ALLOW TO DRY.
5. SET FORM. PRE-WET SURFACE TO SATURATED SURFACE DRY.
6. PLACE 5,000 PSI, 3/8" MAXIMUM AGGREGATE SIZE CONCRETE INTO FORM, VIBRATE FORM WHILE POURING.
7. CURING WITH WET BURLAP OR CURING COMPOUND.

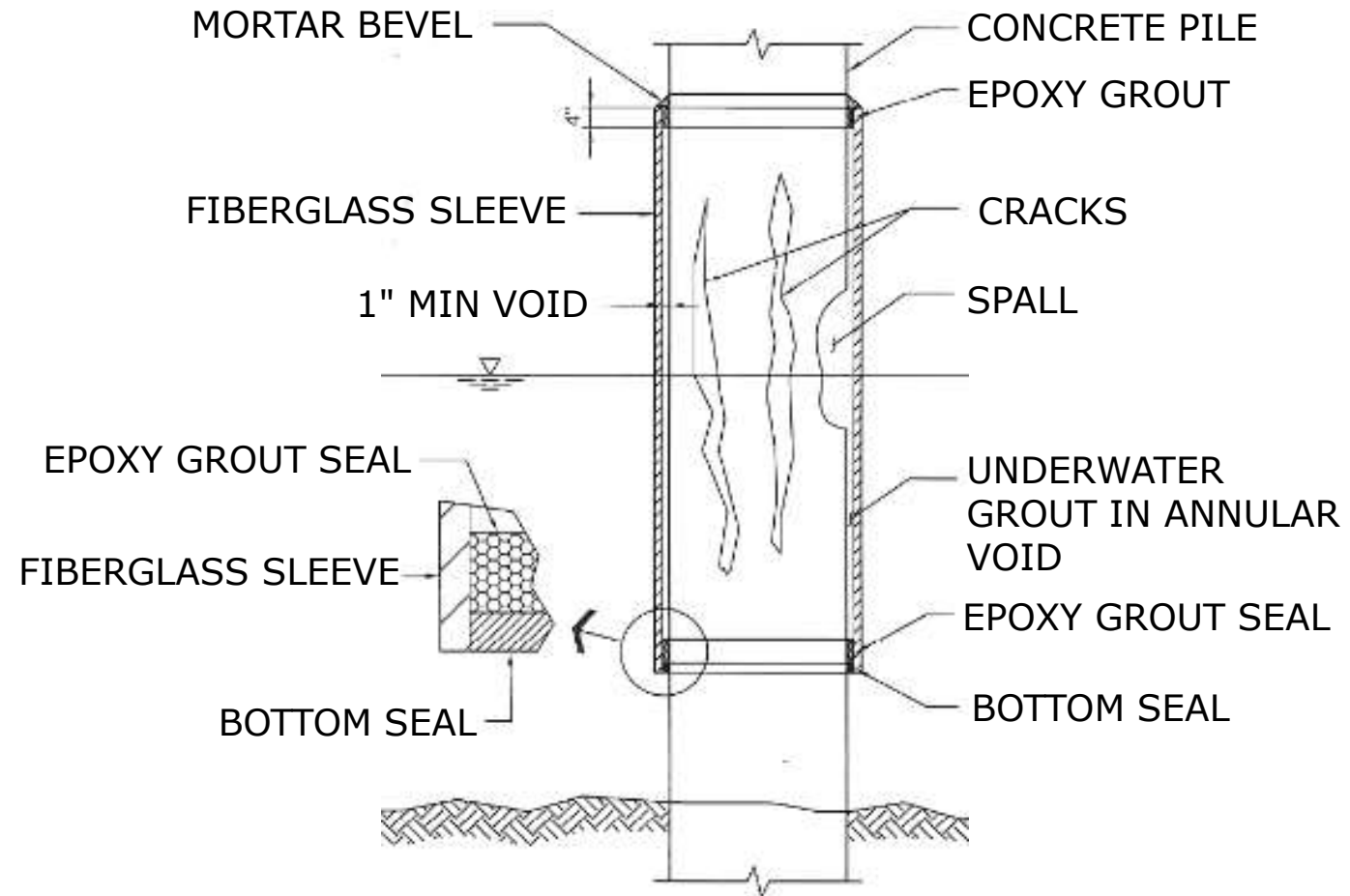


Beam Full Soffit Repair

REPAIR METHODS AND MATERIALS

REPAIR PROCEDURE

1. MECHANICALLY REMOVE GREASE, RUST, MARINE GROWTH, UNSOUND CONCRETE, AND OTHER BOND INHIBITING MATERIALS.
2. PLACE FX-70-1 COMPRESSIVE SEALING STRIP AT BOTTOM.
3. POSITION FX-70 FIBERGLASS SLEEVE.
4. MIX AND PUMP FX-70-6MP EPOXY GROUT INTO BOTTOM 6" OF ANNULAR VOID AND ALLOW TO CURE.
5. MIX AND PUMP FX-225 UNDERWATER GROUT UP TO 4" FROM TOP OF SLEEVE.
6. MIX AND POUR FX-70-6MP EPOXY GROUT INTO TOP 4" OF SLEEVE.
7. CONSTRUCT A BEVEL AT TOP OF GROUT USING FX-763 TROWEL GRADE EPOXY MORTAR.



Pile Grouted Sleeve Repair

REPAIR METHODS AND MATERIALS

REPAIR PROCEDURE

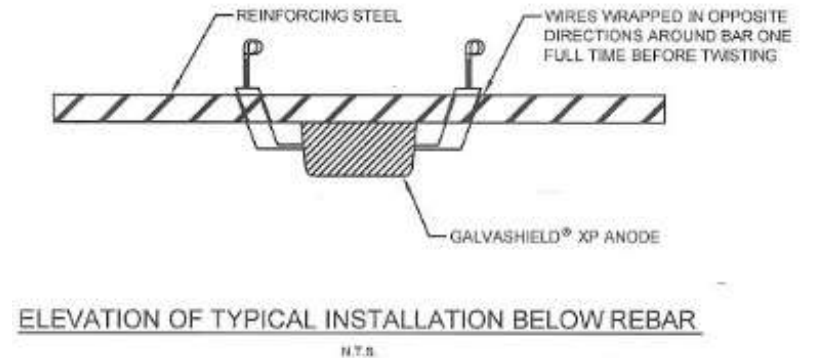
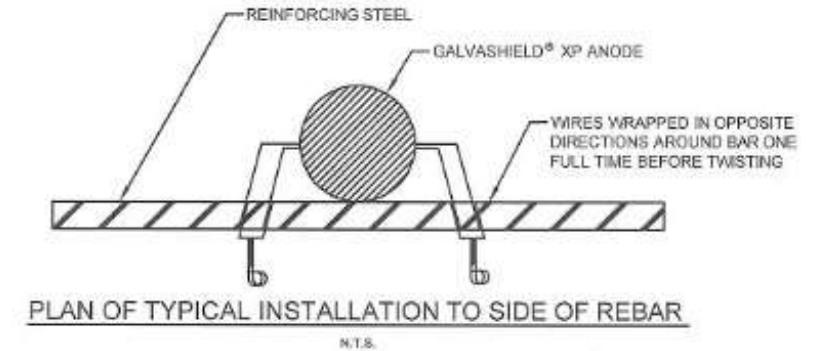
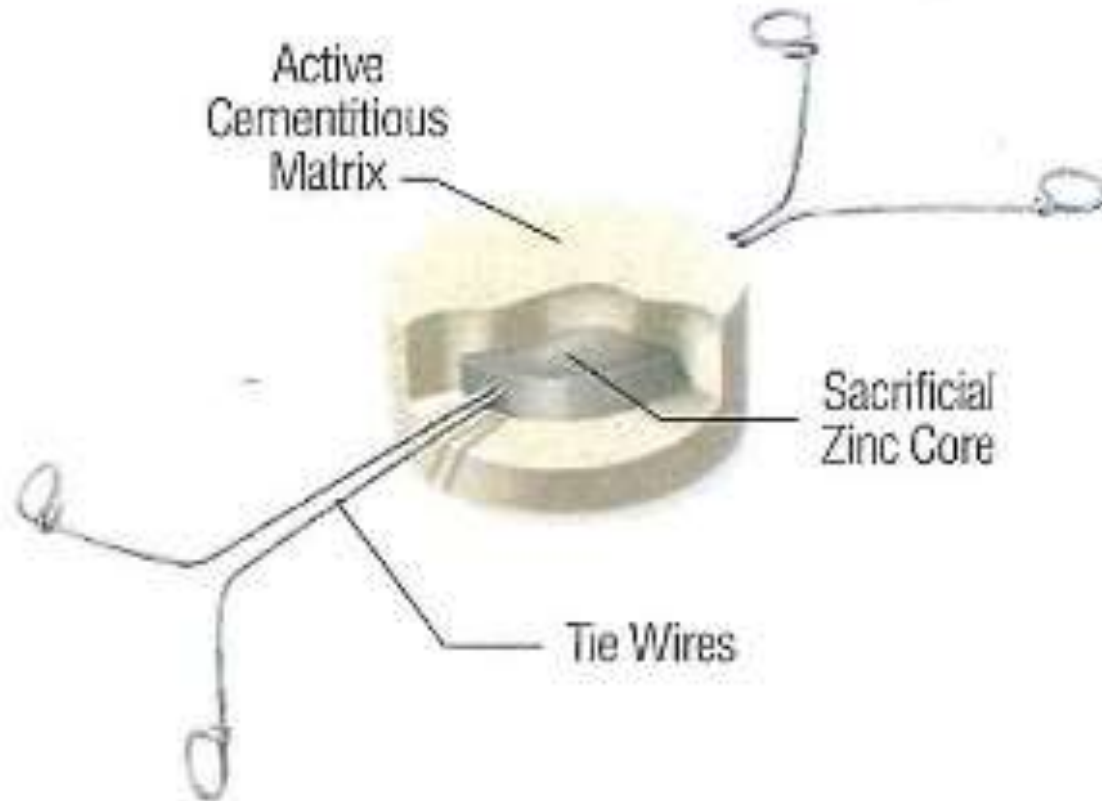
1. CLEAN CRACK VACUUMING OR BLOWING WITH COMPRESSED AIR.
2. MAKE "V" GROOVE AROUND PERIMETER WITH 1/4" MINIMUM WIDTH.
3. DRILL AND INSTALL INJECTION ENTRY AND VENTING PORTS WITH SIKADUR 31 OR SIKADUR 33 ADHESIVE.
4. SEAL CRACK WITH SIKADUR 31 HIGH-MODULUS EPOXY GEL ADHESIVE OR SIKADUR 33 HIGH-MODULUS EPOXY PASTE ADHESIVE. ALLOW TO CURE.
5. FILL CRACK INJECTING SIKADUR 35 HIGH-MODULUS, LOW VISCOSITY, EPOXY ADHESIVE. MAXIMUM INJECTION PRESSURE 40 PSI. ALLOW TO CURE.
6. CUT-OFF ENTRY AND VENTING PORTS.



Pile Epoxy Injection Repair

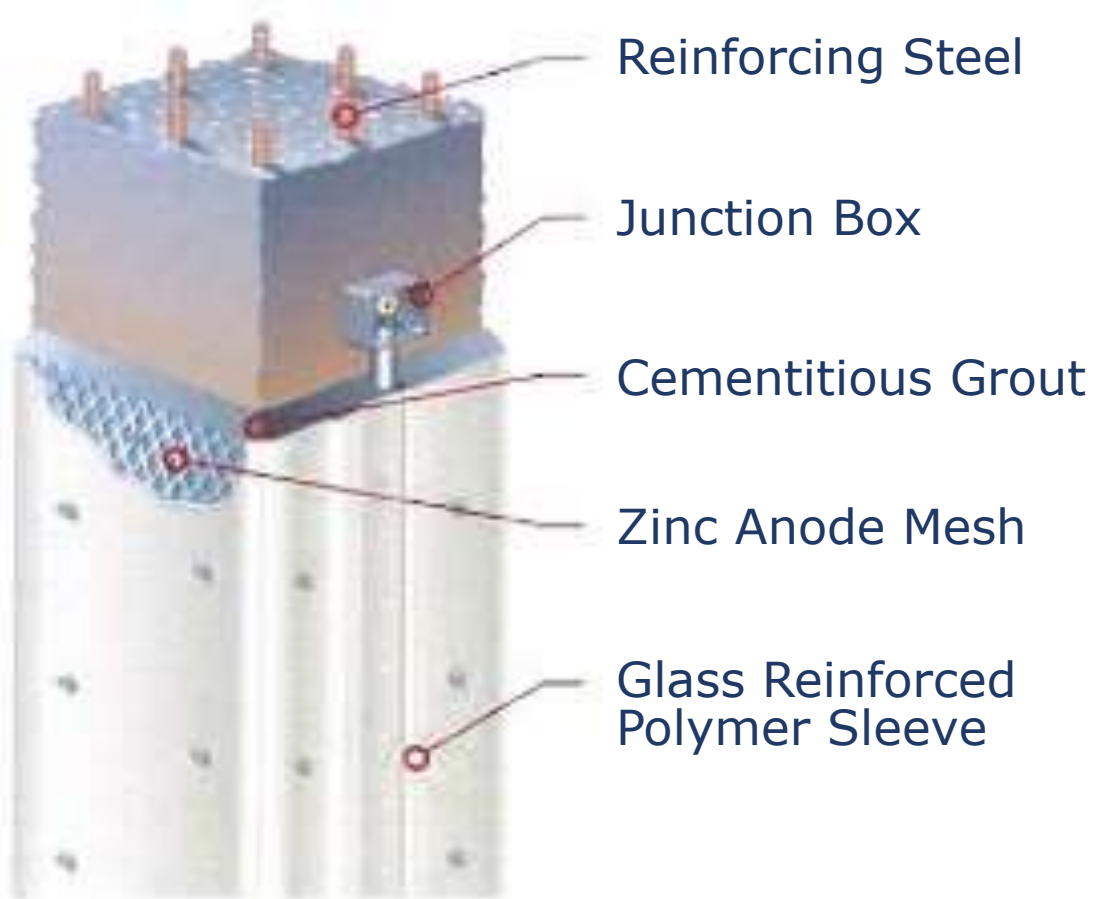
REPAIR METHODS AND MATERIALS

Sika Galvashield XP Anode



Sacrificial Anode Protection

REPAIR METHODS AND MATERIALS



Concrete Pile Galvanic Protection

REPAIR METHODS AND MATERIALS



Beam Full Soffit Repair



Beam and Column Repair

Completed Repairs

REPAIR METHODS AND MATERIALS



Pile Grouted Sleeve Repair



Pile Epoxy Injection Repair

Completed Repairs

REPAIR METHODS AND MATERIALS



Pile Epoxy Injection Repair



Utility Vault Repair

Completed Repairs

TYPICAL REPAIRS COST

Concrete repairs of marine terminals are expensive. Following is a list of the main reasons:

- ❖ Use of heavy marine equipment like crane barges, material barges and tugs.
- ❖ Skilled and experienced labor is required.
- ❖ Work over water is more difficult and time consuming. Debris containment is required to prevent it from falling into the ocean.
- ❖ Strict security and safety measures required by government, operators and contractors increase labor time.
- ❖ High repair quantities escalation factor that may vary from 1.25 to 2.50, depending on the condition of the damaged concrete.
- ❖ Occasional crew and equipment standby time due to weather conditions and vessel schedule changes.

TYPICAL REPAIRS COST

Typical concrete repairs unit cost:

- ❖ Beam one corner repair \$1,500/LF
- ❖ Beam full soffit repair \$2,500 - \$3,000/LF
- ❖ Column repair \$2,500 - \$3,000/LF
- ❖ Pile grouted sleeve repair \$4,000/LF
- ❖ Pile epoxy injection repair \$200/LF + \$3,000 per location if scaffolding required

RECOMMENDATIONS FOR NEW TERMINALS

- ❖ Specify 5,000 psi, 9 sack cement, low water-cement ratio ($w/c = 0.35$) concrete for superstructure. Substitute part of cement with pozzolans. Include in concrete mix water-reducing, corrosion-inhibiting admixtures. Prestressed concrete piles have shown good performance in marine terminals.
- ❖ Consider increasing the minimum concrete cover prescribed in American Concrete Institute ACI-318. This will reduce the intrusion of corrosion producing elements and increase the service life of the structure.
- ❖ Consider using sacrificial anode protection. Manufacturers claim it can retard the initiation of the rebar corrosion process by 10 to 15 years.

RECOMMENDATIONS FOR NEW TERMINALS

- ❖ Design the lowest beam with the soffit elevation above the maximum predicted water elevation for the service life of the structure.

Example:

Soffit elevation = MHHW + 0.6 x significant wave height (Hs) + sea level rise (SLR) + 2'

= 6.2' + 0.6 x 4' + 1.9' + 2' = +12.5' (MLLW datum).

- ❖ Implement a comprehensive construction quality control program. Use the assistance of the engineer of record to resolve unpredicted issues encountered during construction.
- ❖ Good communication between the owner, engineering consultants, regulatory agencies, and contractors is essential for the successful development and completion of the project.

LESSONS LEARNED

- ❖ During field inspections of concrete marine structures, it is beneficial to spend extra time on the observation and recording of the damage. What seems very obvious at the time of observing the damage, it becomes not so obvious days or weeks later when processing the field notes and preparing the inspection drawings. The extra time spent in the field will save time and effort during the following phases of the repair project.
- ❖ During the planning, bidding, and execution of the concrete repairs project, consideration should be given to the repair quantities escalation. The escalation factor may vary from 1.25 to 2.50, depending on the condition of the damaged concrete.