



Pack Rust Identification and Mitigation Strategies for Steel Bridges

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3 Major Tasks

- Literature review.
- Reviewing existing mitigation strategies and repair procedures for selected DOTs.
- Pack rust in Indiana Bridges.



Task 1

Literature Review

Pack Rust or Crevice corrosion

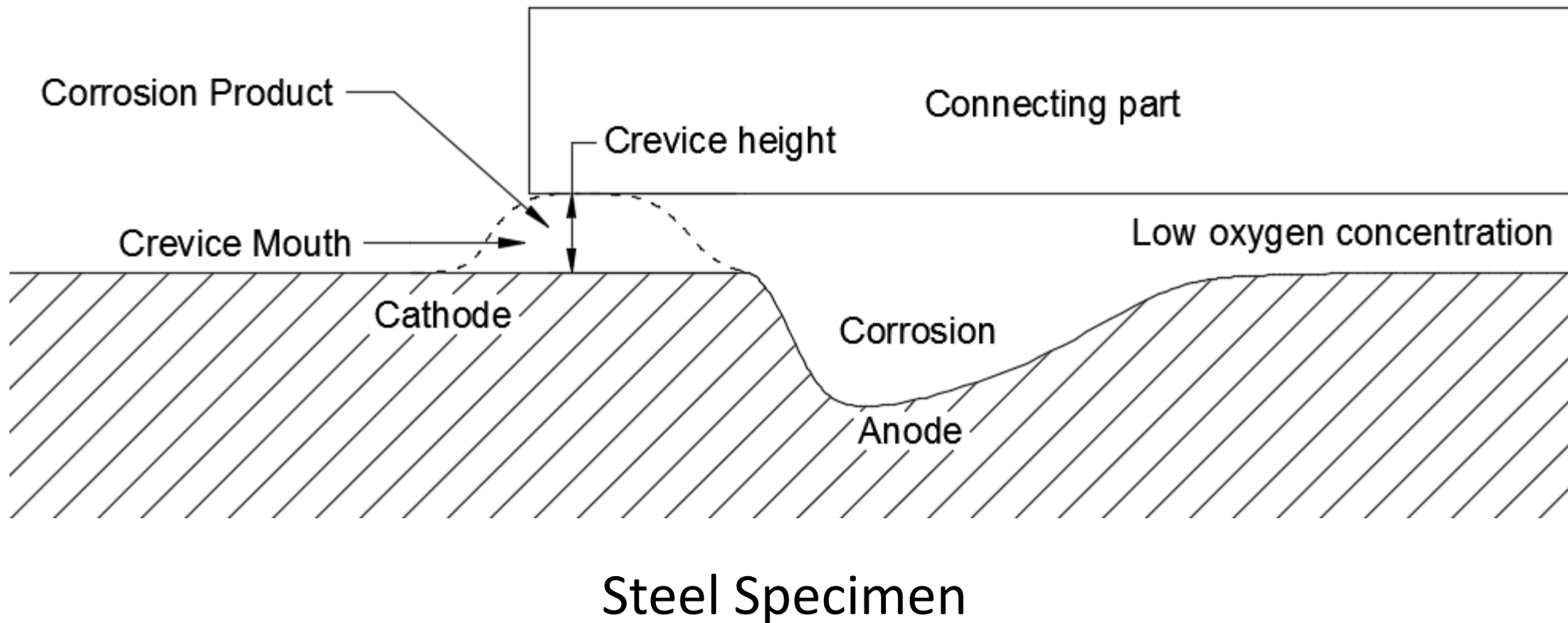
- Localized attack on metal surface.
- Crevice formed between two joining surfaces.
 - Metal – Metal
 - Metal – Non-metal

Initiation Process

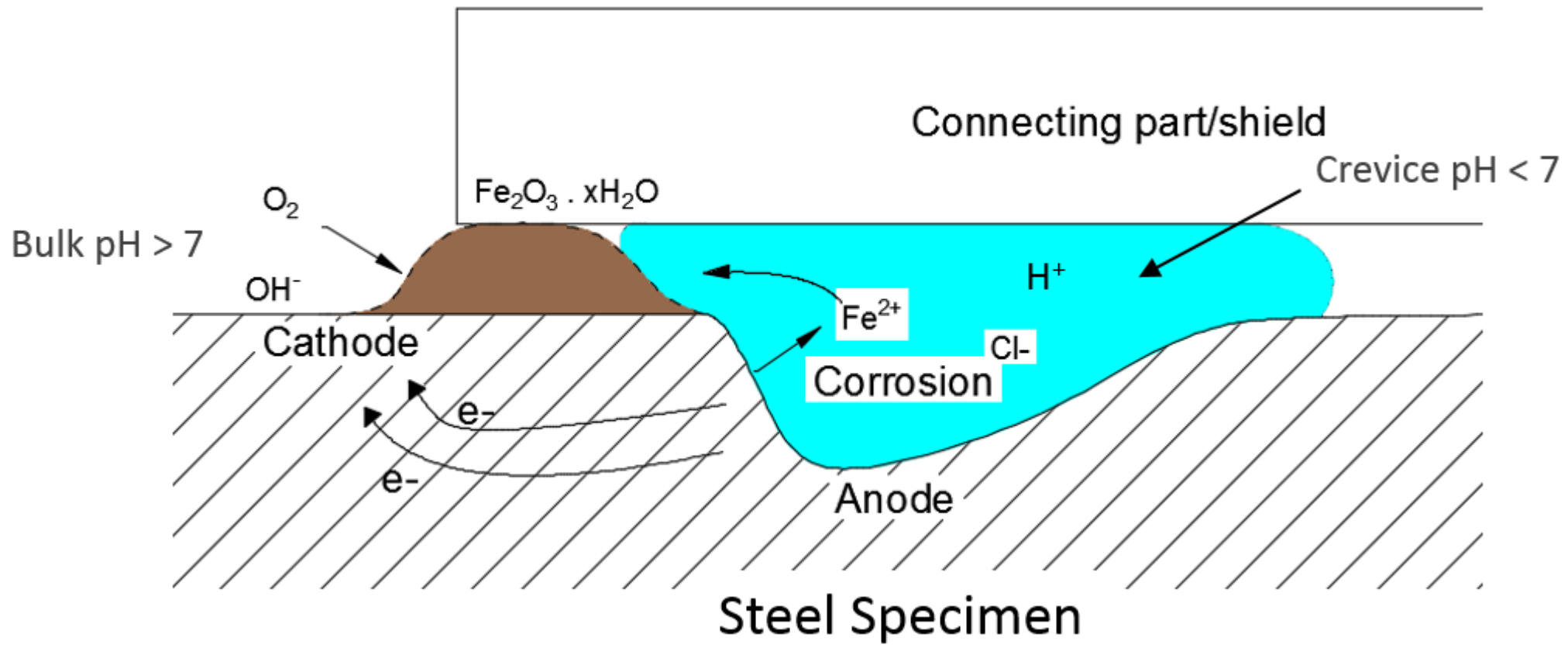
- Crevice corrosion initiation process
 - Differential oxygen concentration needed
 - Aqueous solution(water), pathway for ions to flow
 - Process accelerated
 - $[\text{Cl}^-]$ present
 - pH acidic present

Mechanism

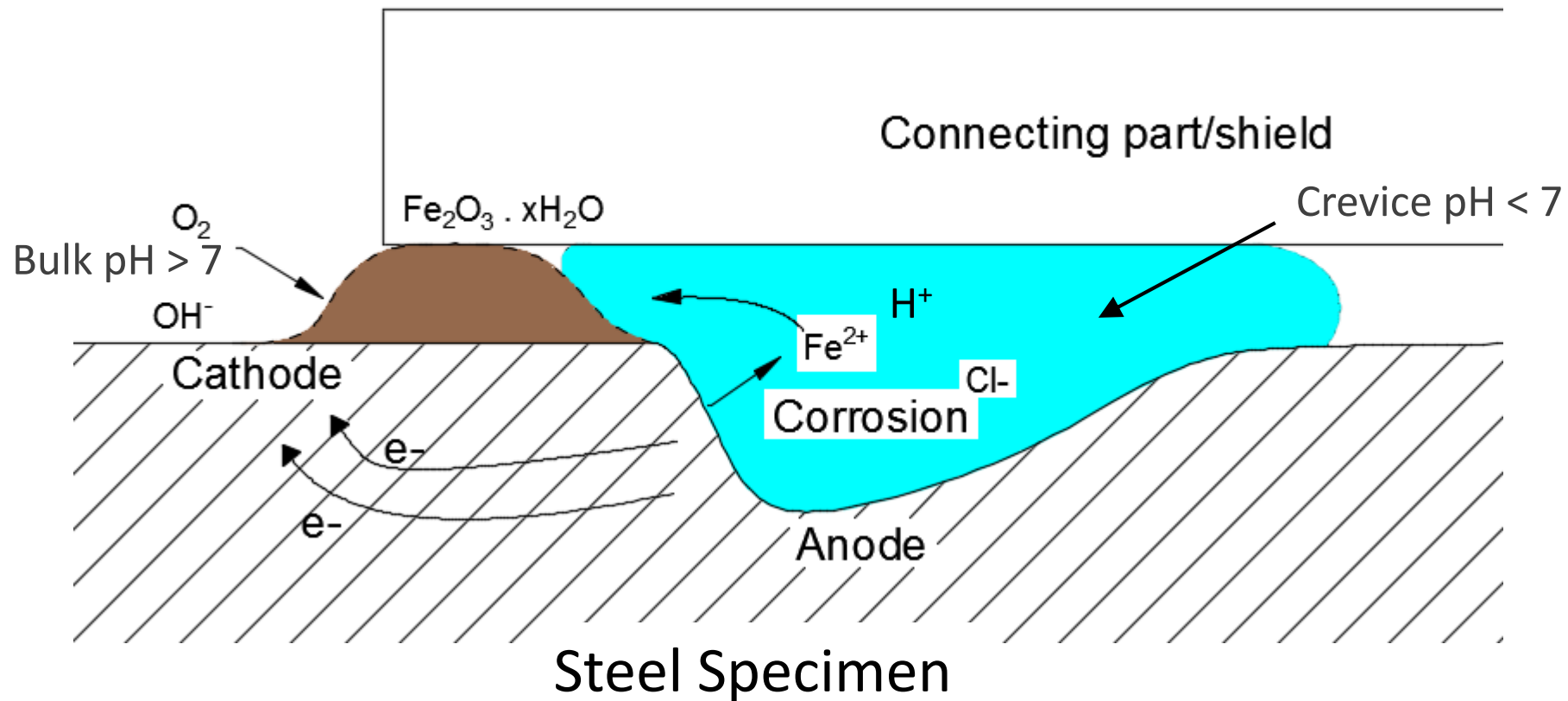
- Formation of differential oxygen concentration cell.



Mechanism



- Inhibitors like chromium decreases the corrosion rate.
- Severe corrosion takes place near the mouth of the crevice.





Attributes of crevice corrosion

- Crevice height
 - Ranging from 0.1 mm to 3 mm.
 - Large enough to allow entry of electrolyte (water)
 - small enough to not allow electrolyte to flow out.



- Rust build-up eventually seals the crevice and the corrosion process stops. (U.R.Evans, researcher in corrosion science)

On contrary

- Sealing the crevice without neutralizing the active corrosion product can cause accelerated corrosion. (Roads and Bridges, Sept, 2003)



Task 2

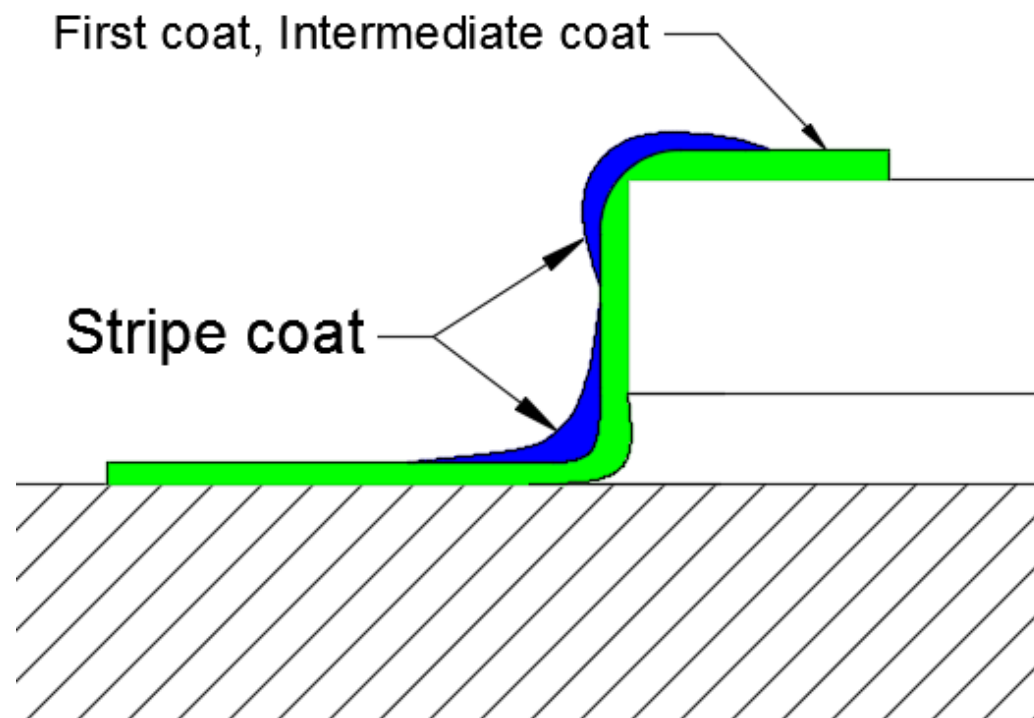
Mitigation strategies and repair procedures
of selected DOTs



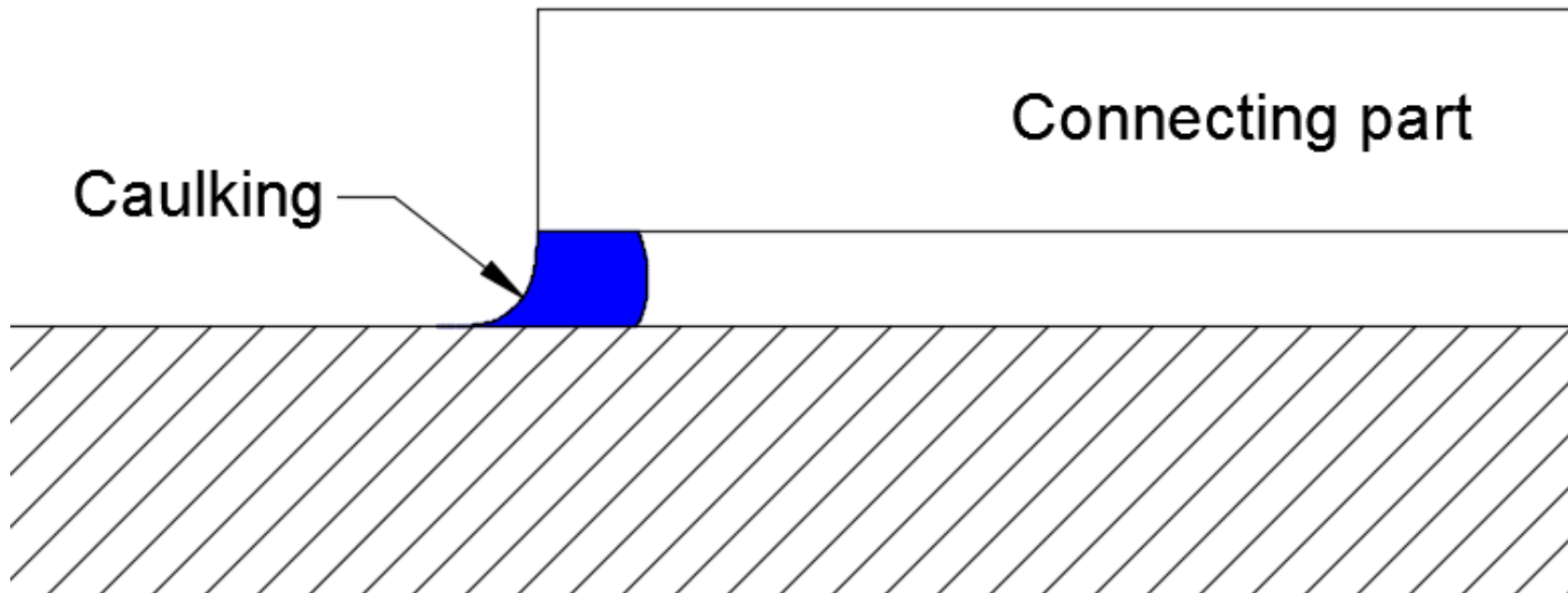
Mitigation and repair strategies

- Stripe coat
- Caulking
- Penetrating sealer
- Backer rod

Stripe coat

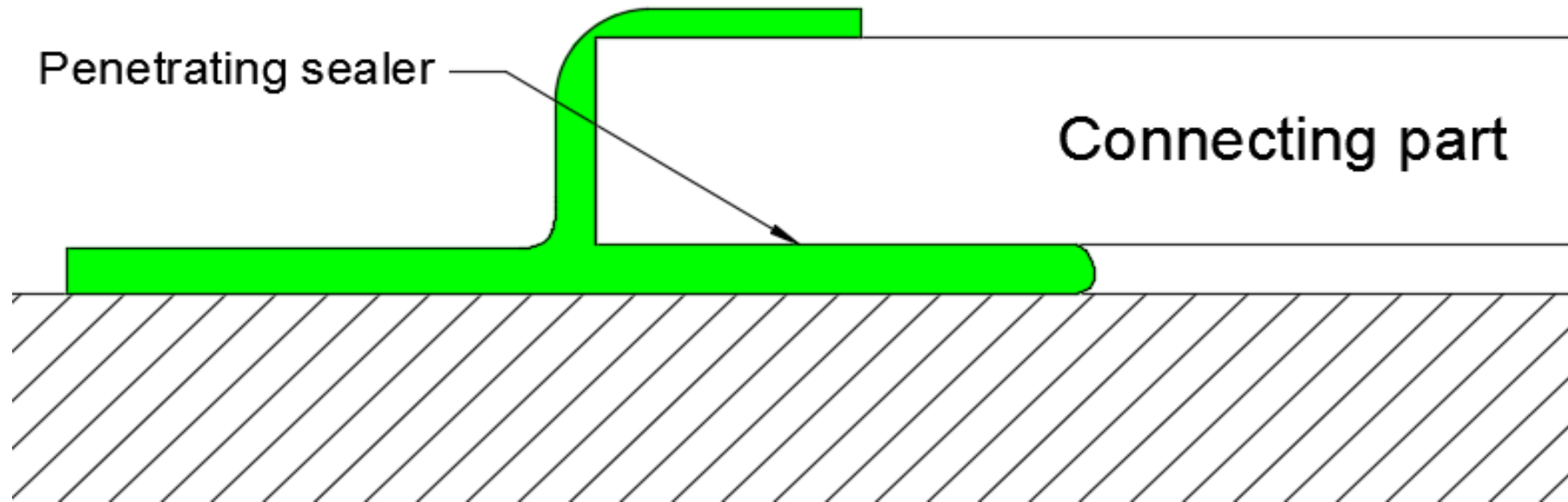


Caulking

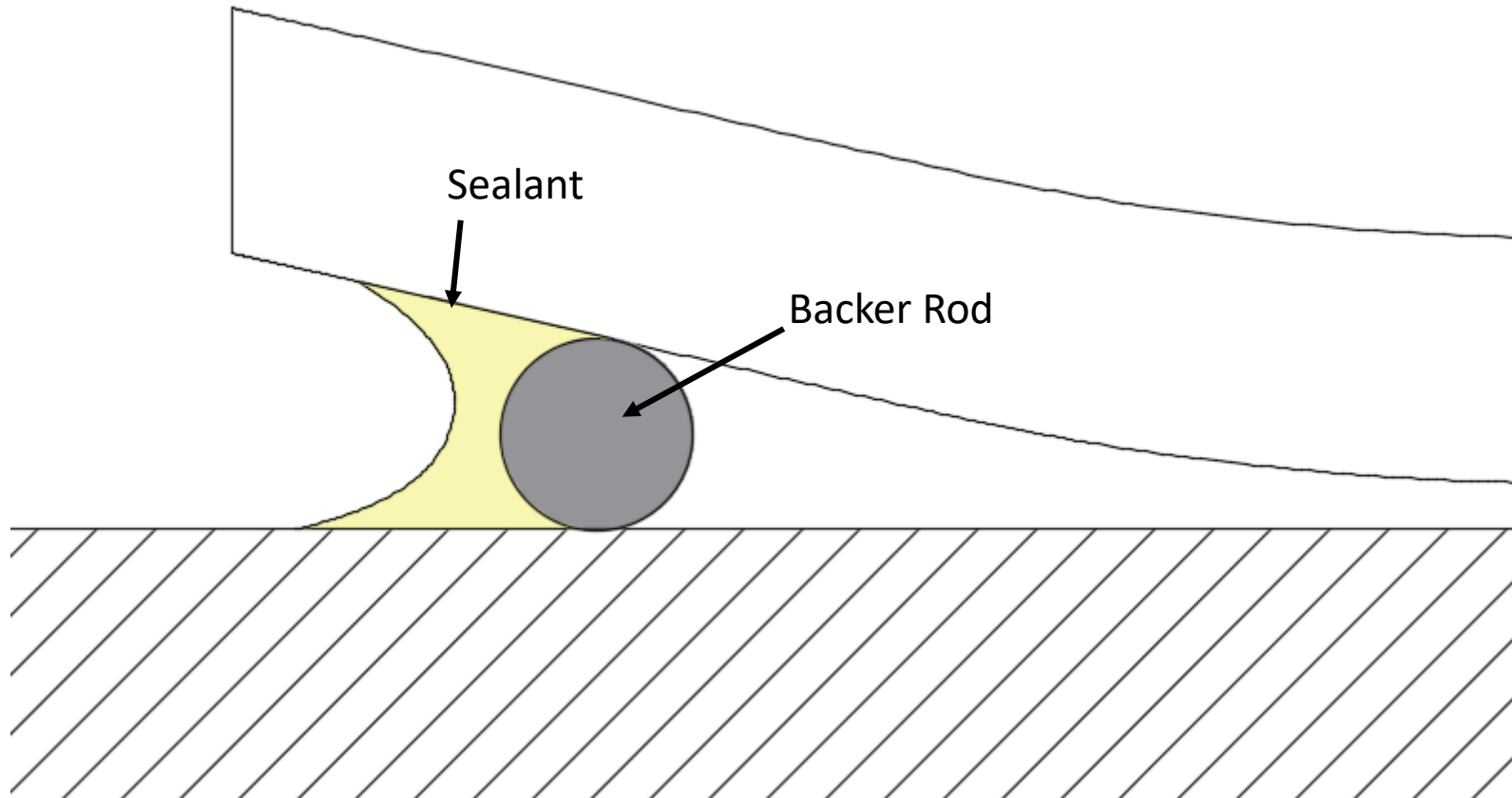


Penetrating sealer

- Has viscosity to penetrate into the crevice.
- Ability to neutralize the corrosive environment inside the crevice.



Backer rod and sealant





State Dept. of Transportation

Stripe coat (21 states)	Caulking (10 states)	Penetrating sealers (5 states)	Backer rod (2 states)
Alabama, California, Delaware, Florida, Georgia, Illinois, Indiana, Iowa, Maryland, Massachusetts, Minnesota, New Jersey, New York, North Carolina, North Dakota, Ohio, Oregon, South Dakota, Virginia, West Virginia, Wisconsin	California, Delaware, Florida, Iowa, Maryland, Missouri, Ohio, Oregon, Washington, West Virginia	Washington, Missouri, Iowa, Illinois, Delaware	Oregon, Washington



Repair Procedure

Oregon

- Remove pack rust by mechanical cleaning, and heating water-saturated pack rust to a minimum of 250 °F and a maximum of 400 °F, or
- Using 35,000 psi ultra-high pressure water jet.



Missouri

- Calcium sulfonate rust penetrating sealer
- Suitable for any steel structure that has developed pack rusting in overlapping steel plates, joints or at bolted areas.
- Applied in accordance with SSPC-PA1.



Missouri Continued.

- Can be applied to
 - bearings,
 - overlapping steel plates,
 - pin connections,
 - pin and hanger connections and
 - locations where
 - rust bleeding,
 - pack rust,
 - layered rust occurs.



Washington

Pack rust of 1/16 inch or greater.

- Clean to a depth of ½ of the gap width, maximum of ¼ inch.
- Cleaned gap treated with rust penetrating sealer.
- Apply Caulk to form watertight seal.

If gap greater than ¼ inch

- Gap should be filled with foam backer rod material.
- Apply sealant over the backer rod.



Task 3

Pack Rust in Indiana Bridges



Pack Rust in Indiana Bridges

- Gathered relevant pack rust information from Bridge inspection reports.



Typical Members Affected by Pack Rust

- Bearings (Rocker, some cases Elastomeric)
- Splice connections
- Hinge-pin connection
- Gusset plate and other connections
- Beam cover plates
- End diaphragms



Bearings



Pack Rust

Pack Rust





Pack Rust



Pack Rust

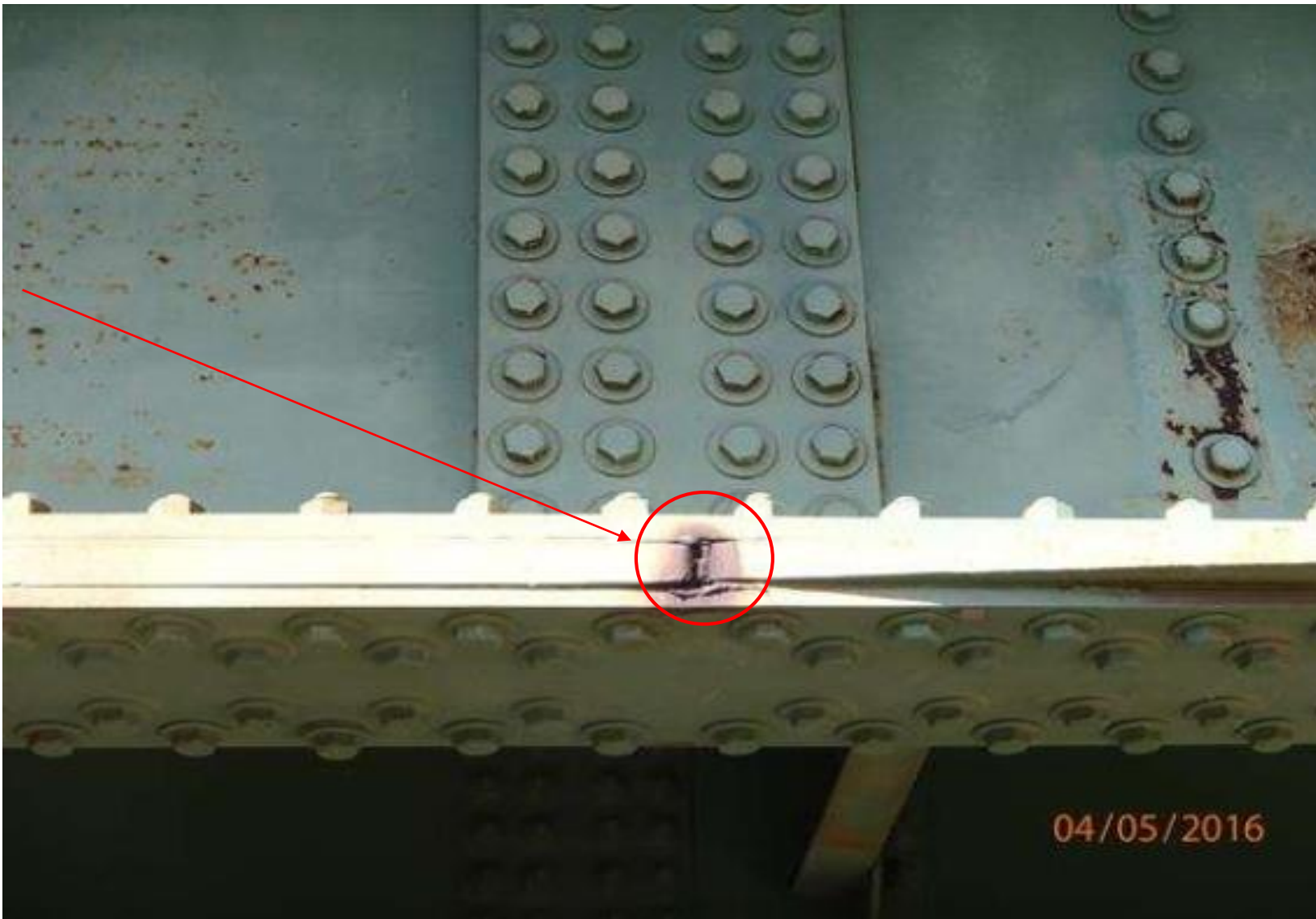


Splice plates

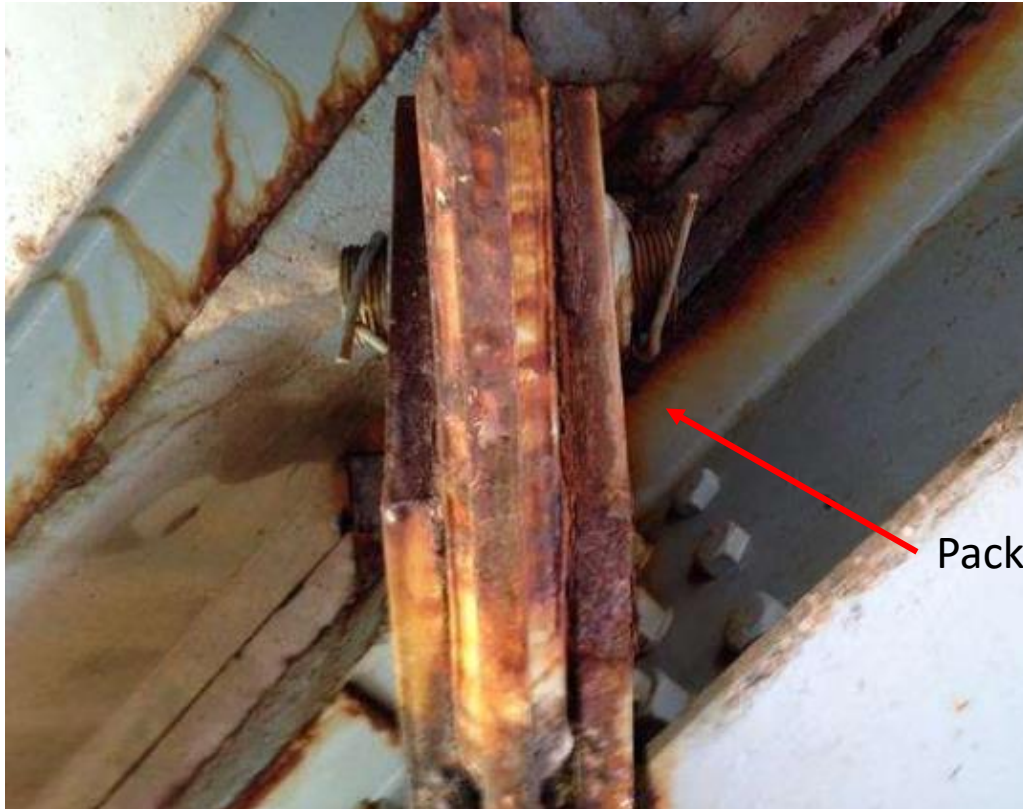


Pack rust

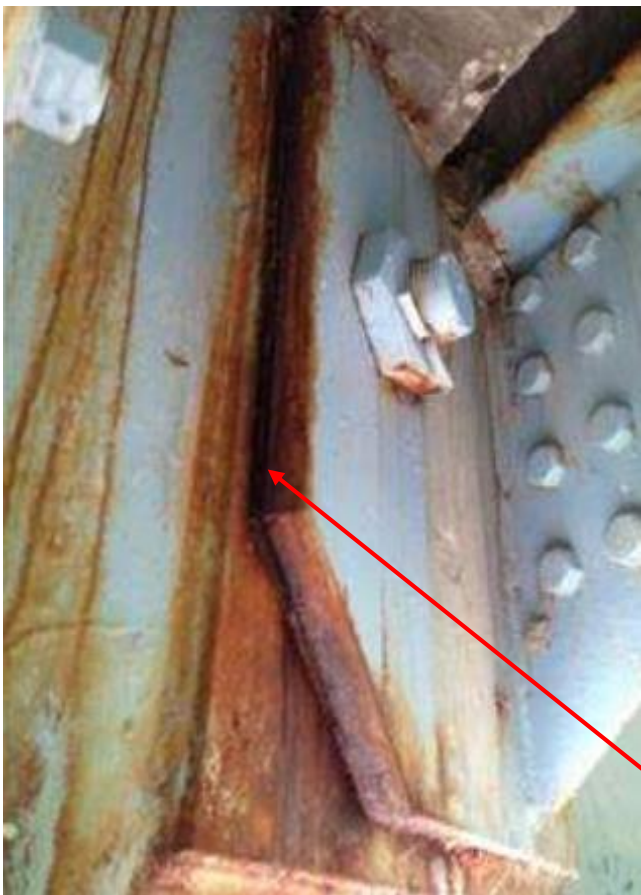
Pack rust



Hinge-pin connection



Pack Rust



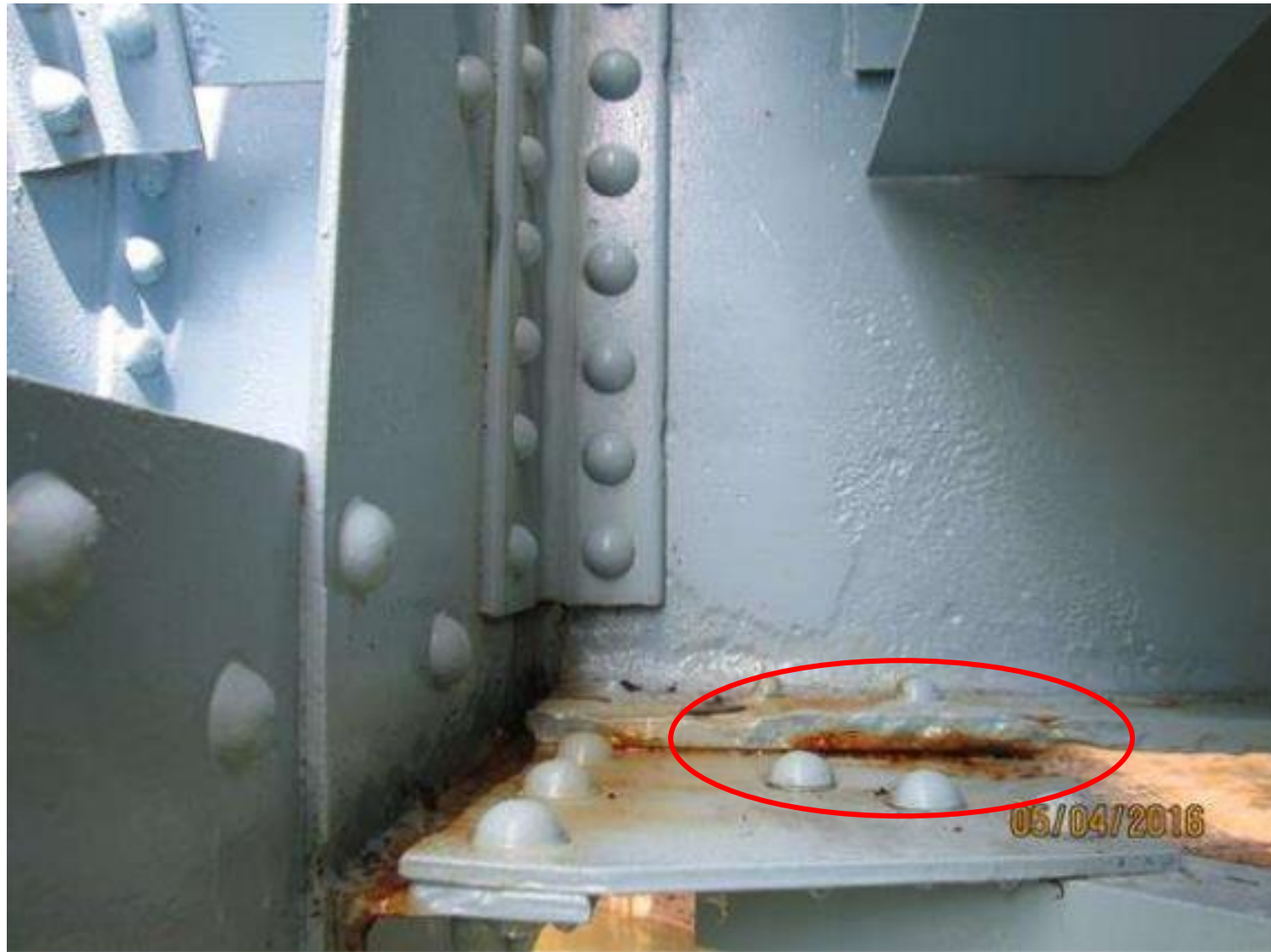
Pack rust

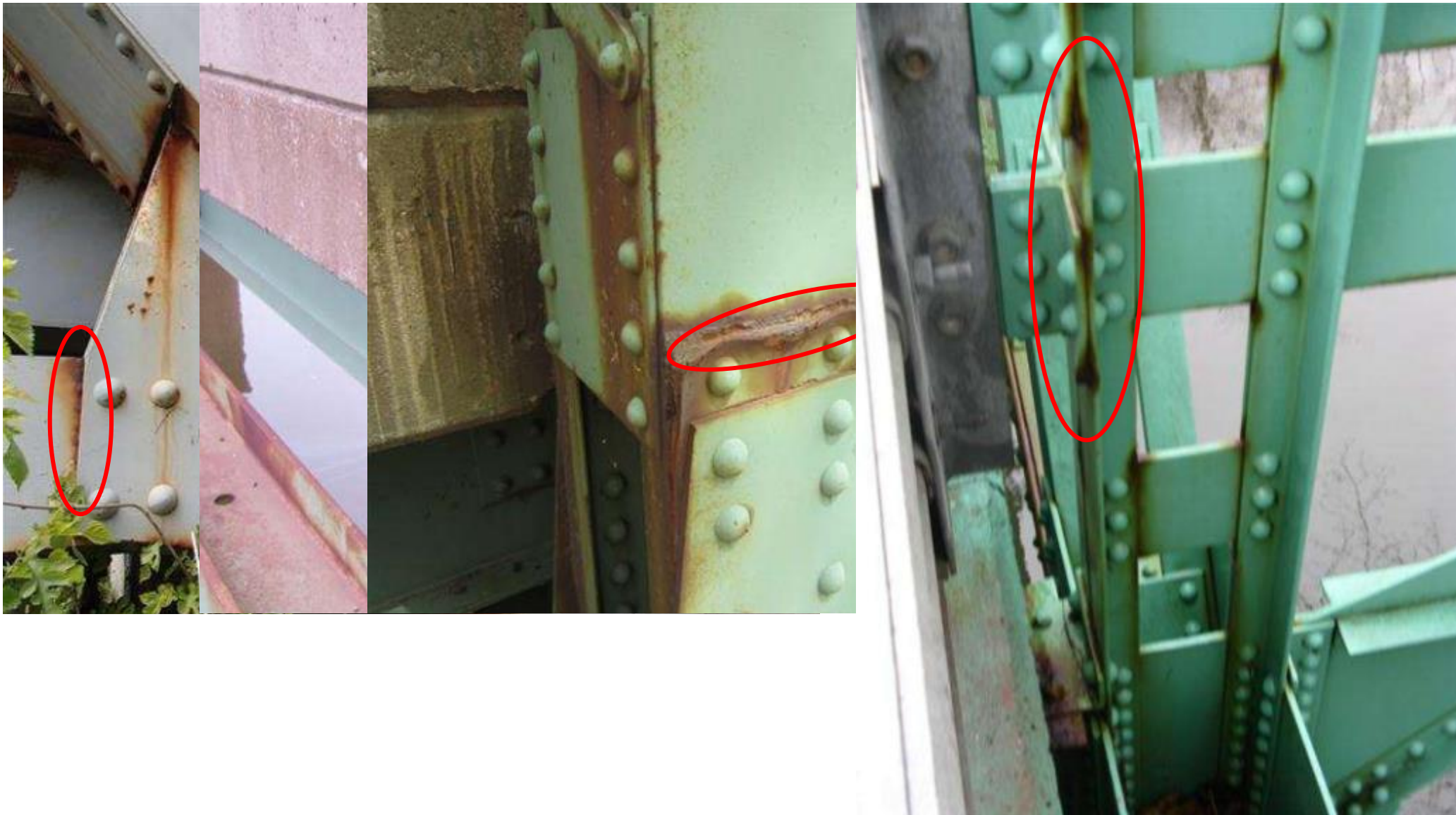


Gusset plates, battens and angles

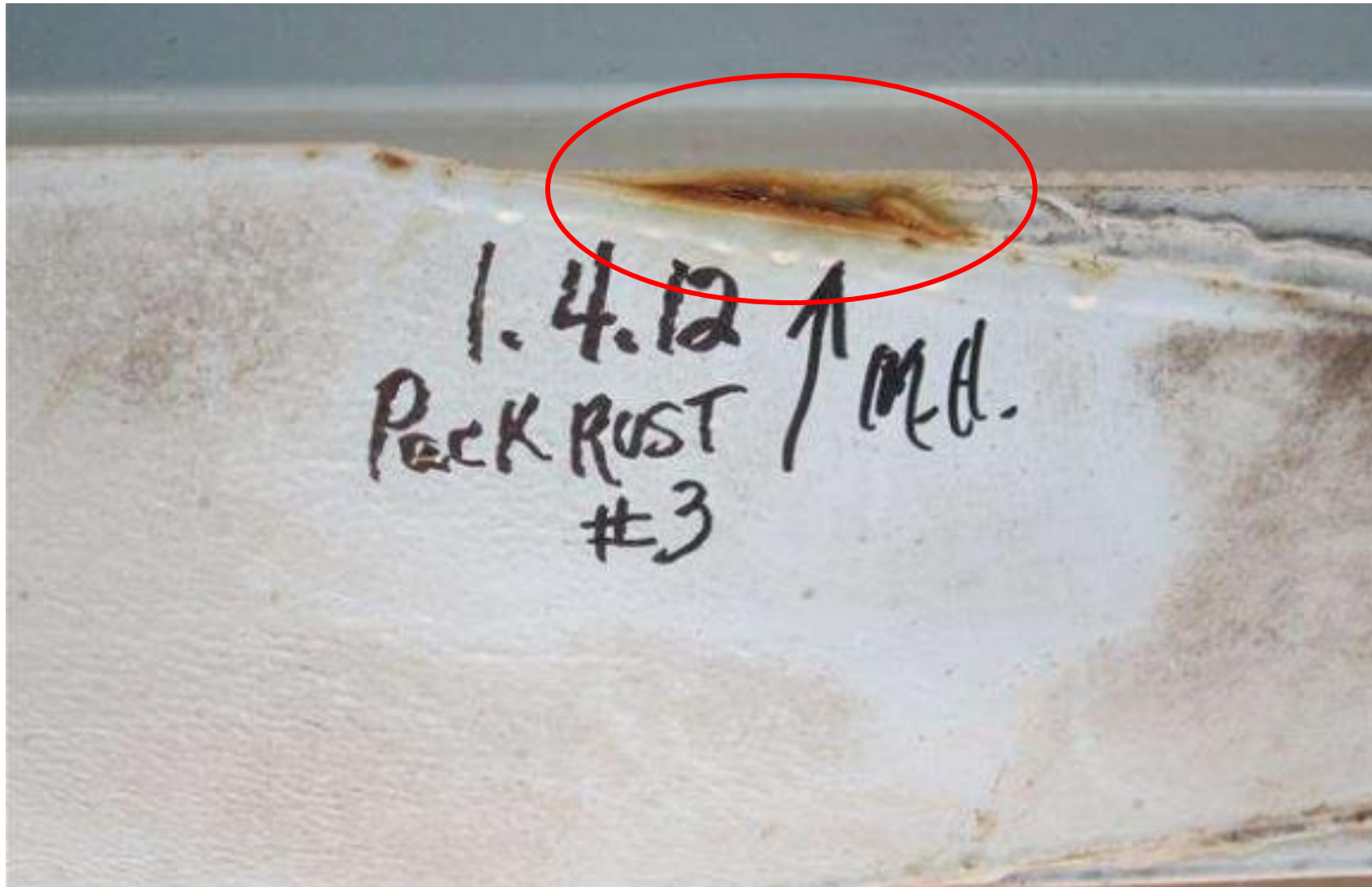


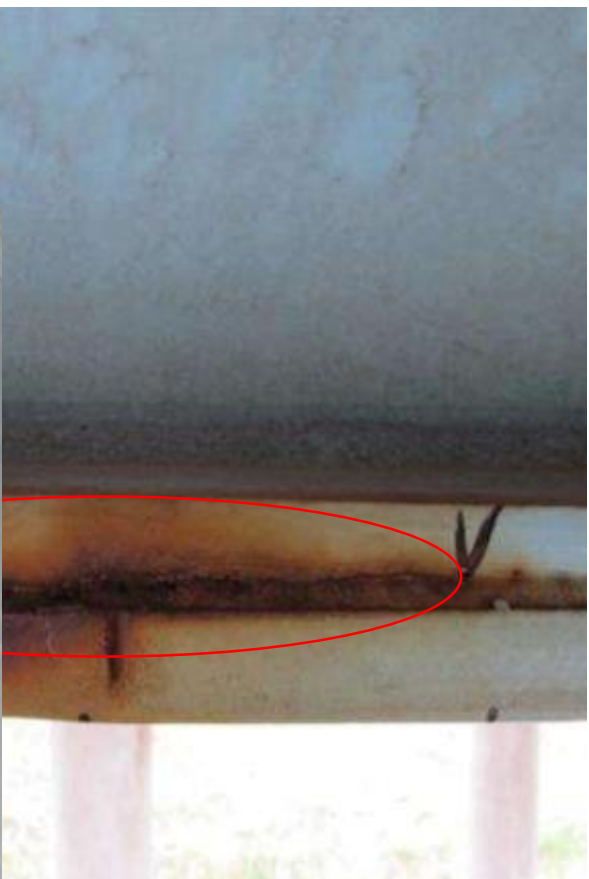




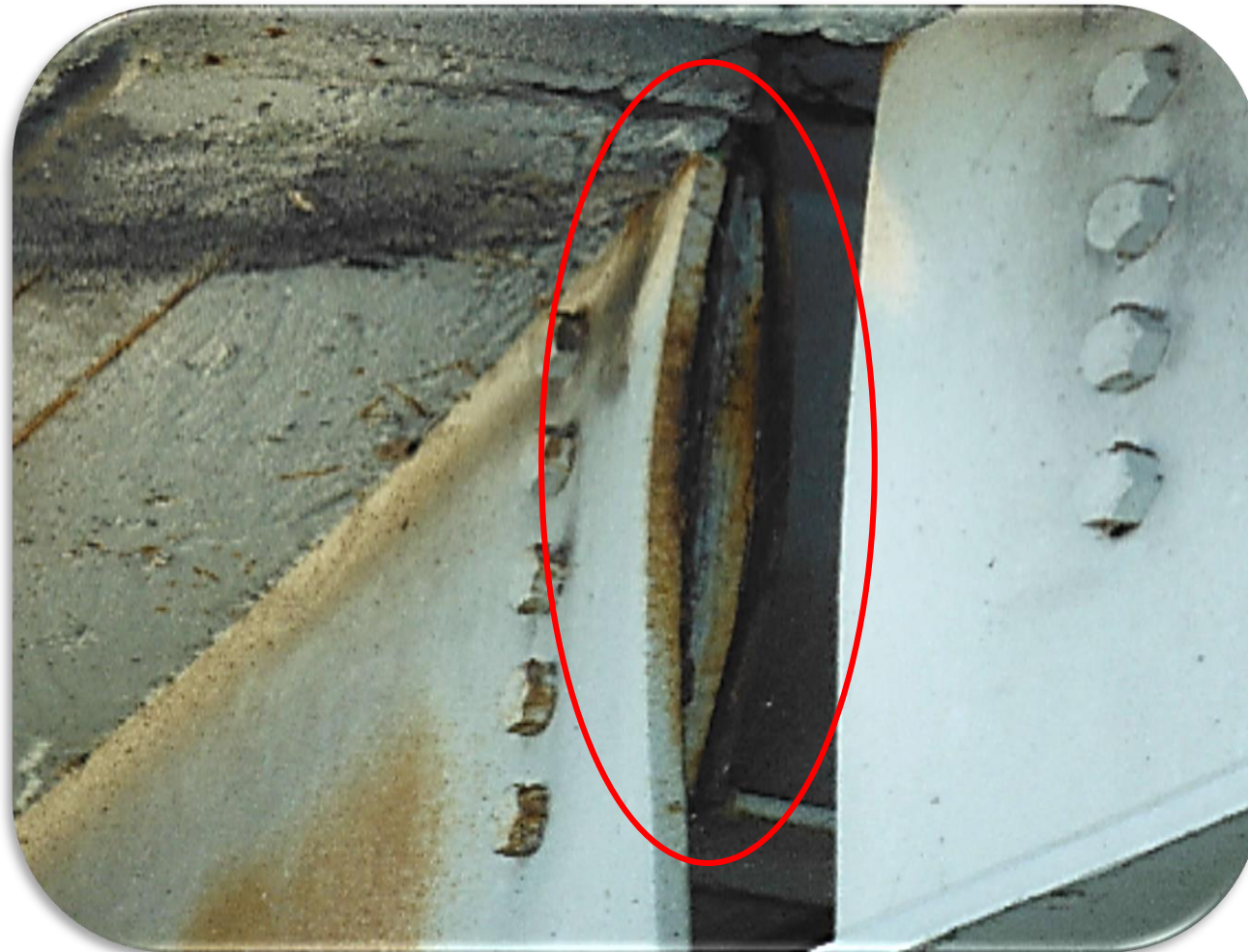


Cover plates





Diaphragms



Cross bracings connections



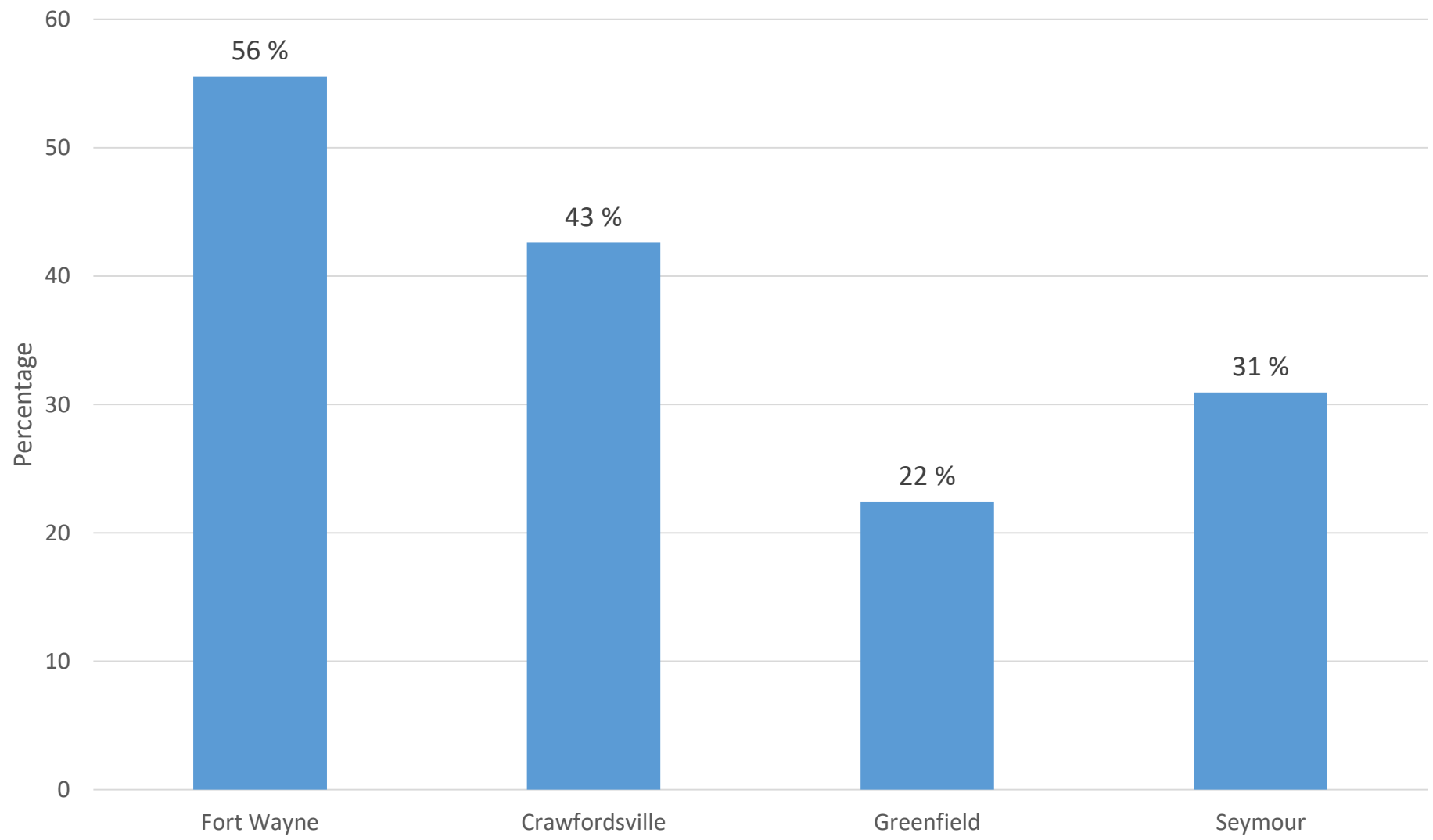


Statistical Analysis on Data Collected

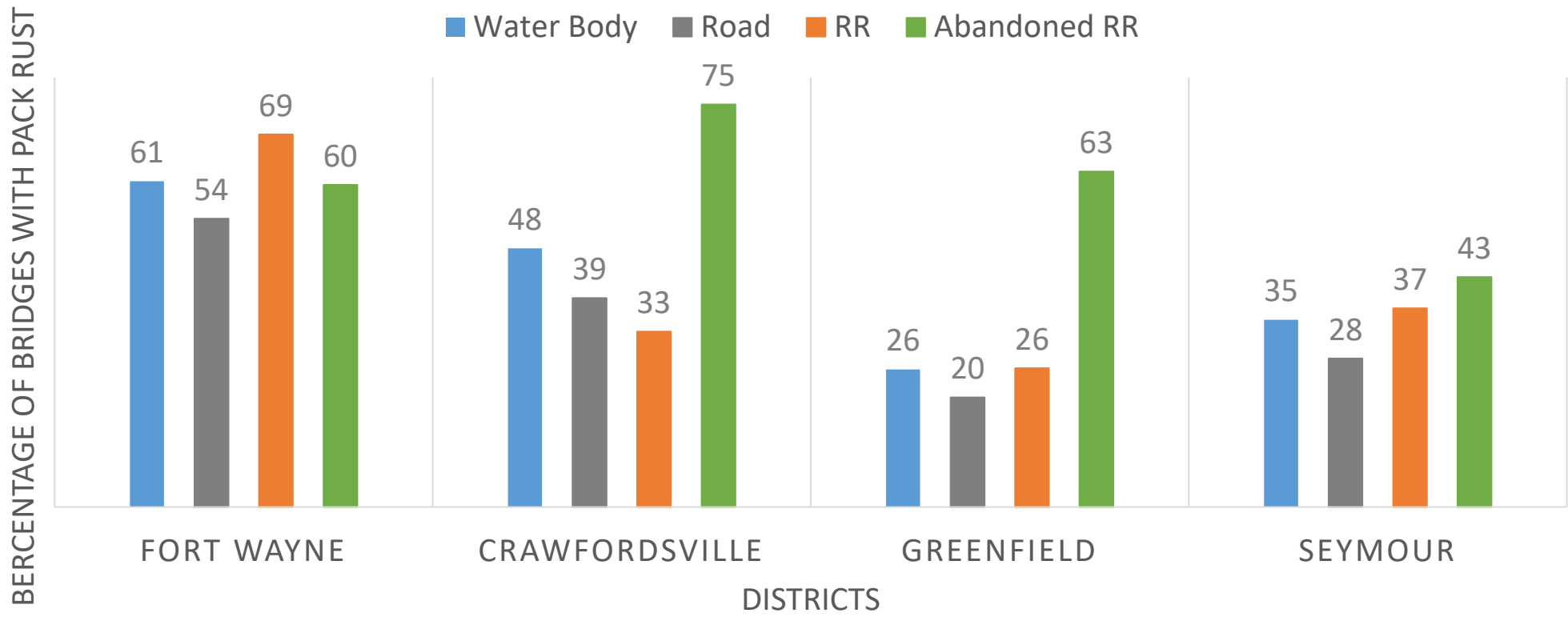
- Total state owned steel bridges in 4 districts inspected – 1235
- No. of bridges with some form of pack rust – 422



Percentage of Bridges with Pack Rust

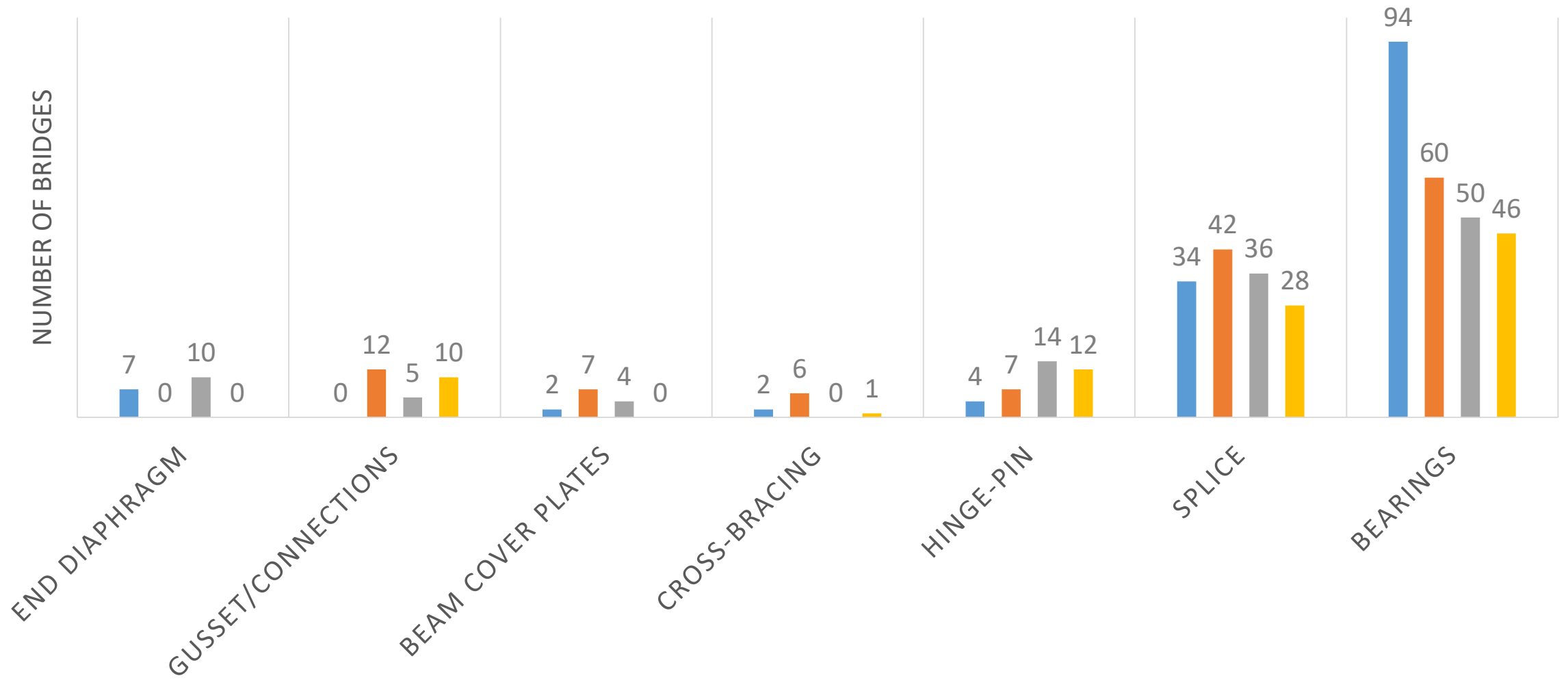


PERCENTAGE OF BRIDGES WITH PACK RUST BASED ON FEATURE INTERSECTED



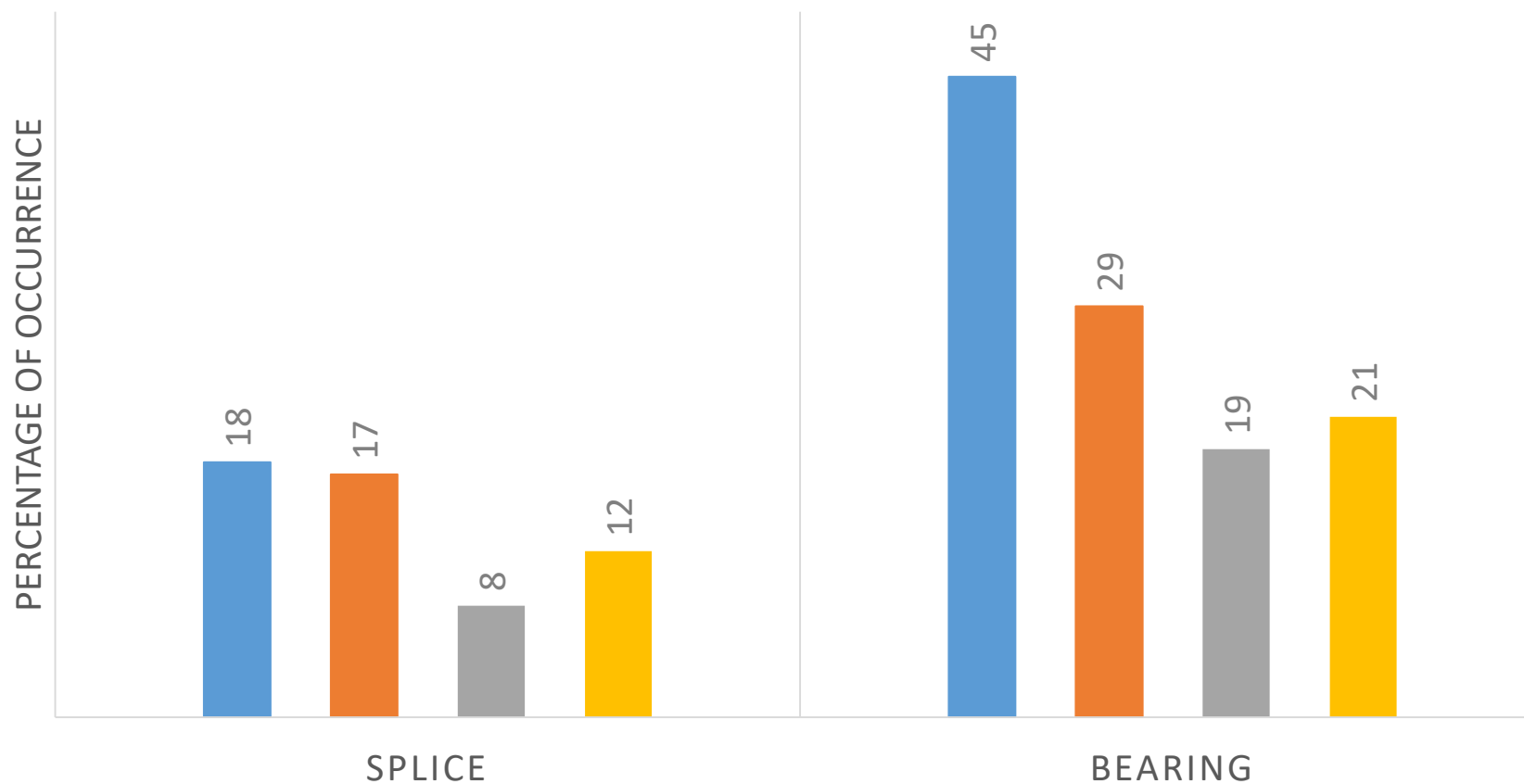
MEMBER WISE COUNT

■ Fort Wayne
 ■ Crawfordsville
 ■ Greenfield
 ■ Seymour



COMPARISON OF PERCENTAGE OCCURRENCE OF PACK RUST

■ Fort Wayne ■ Crawfordsville ■ Greenfield ■ Seymour





District wise Salt usage

	(lane-miles)	salt (tons)	(tons/lane-miles)
Fort Wayne	4,652	47000	10.1
Crawfordsville	4,699	44000	9.4
Greenfield	4,500	60000	13.3
Seymour	4,693	41500	8.8



Splice plate pack rust in detail

Severity rating for pack rust in splices



Rating 1

Severe PR - $> \frac{3}{4}$ inch bowing of splices or bolt failure





Rating 2

Moderate to severe PR - $\frac{1}{4}$ to $\frac{3}{4}$ inch
bowing of the splice plates



Rating 3

Moderate PR – Visible bowing of the
splice plates $< \frac{1}{4}$ inch of PR



Rating 4

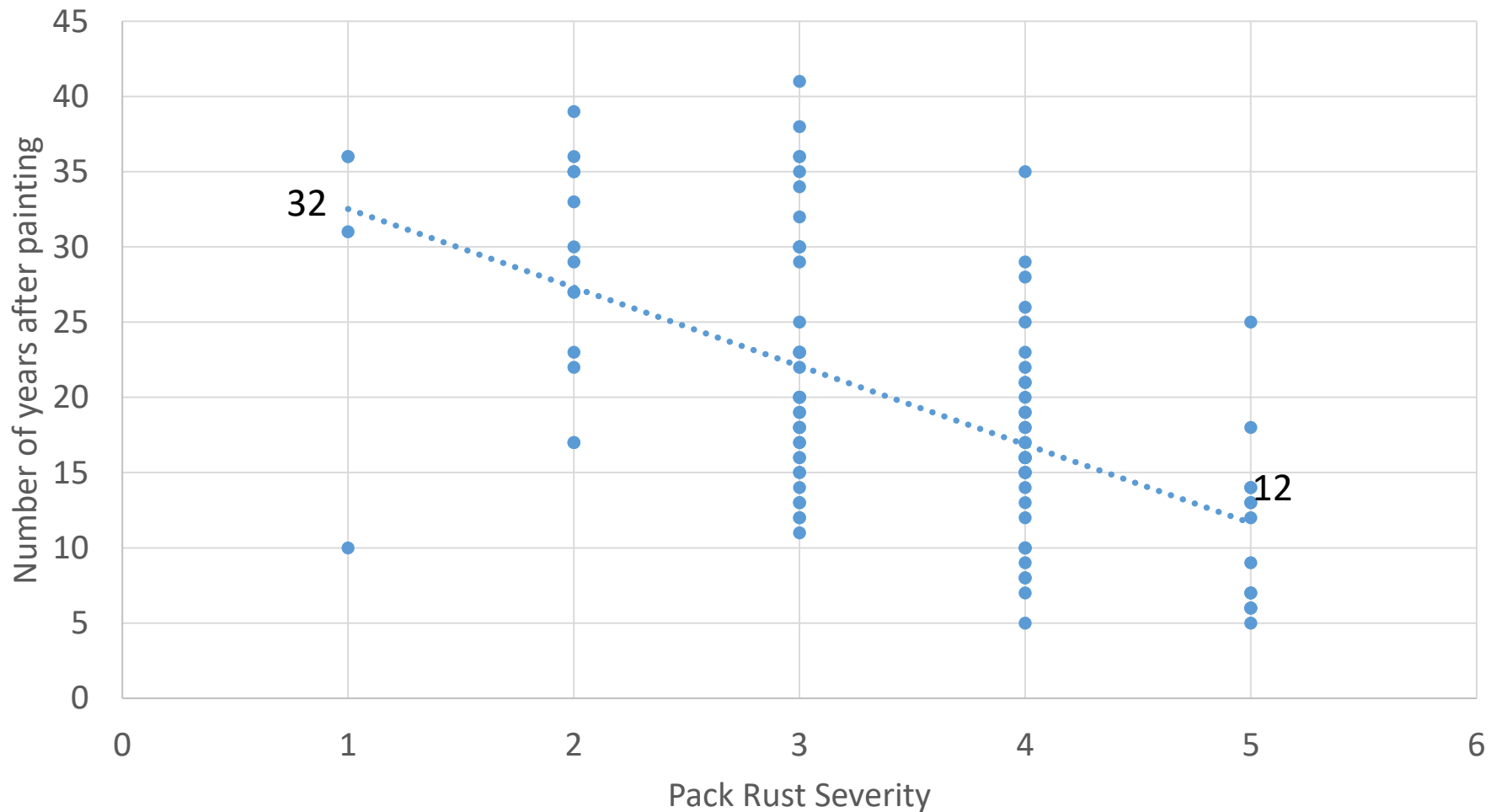
Minor to moderate PR - Visible corrosion @ middle of splice Connection.



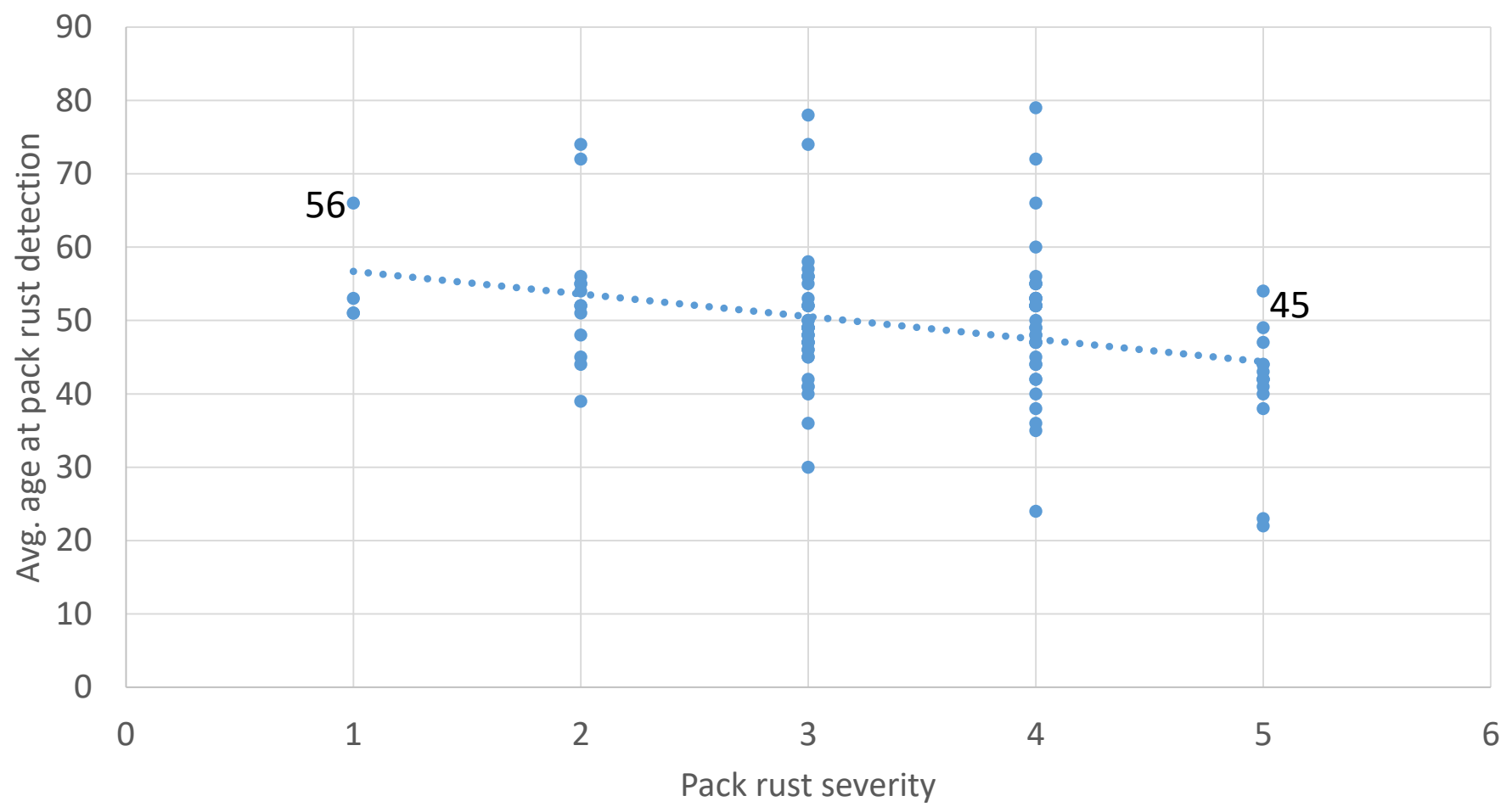
Rating 5

Minor PR - Rust bleeding @ middle of splice Connection.

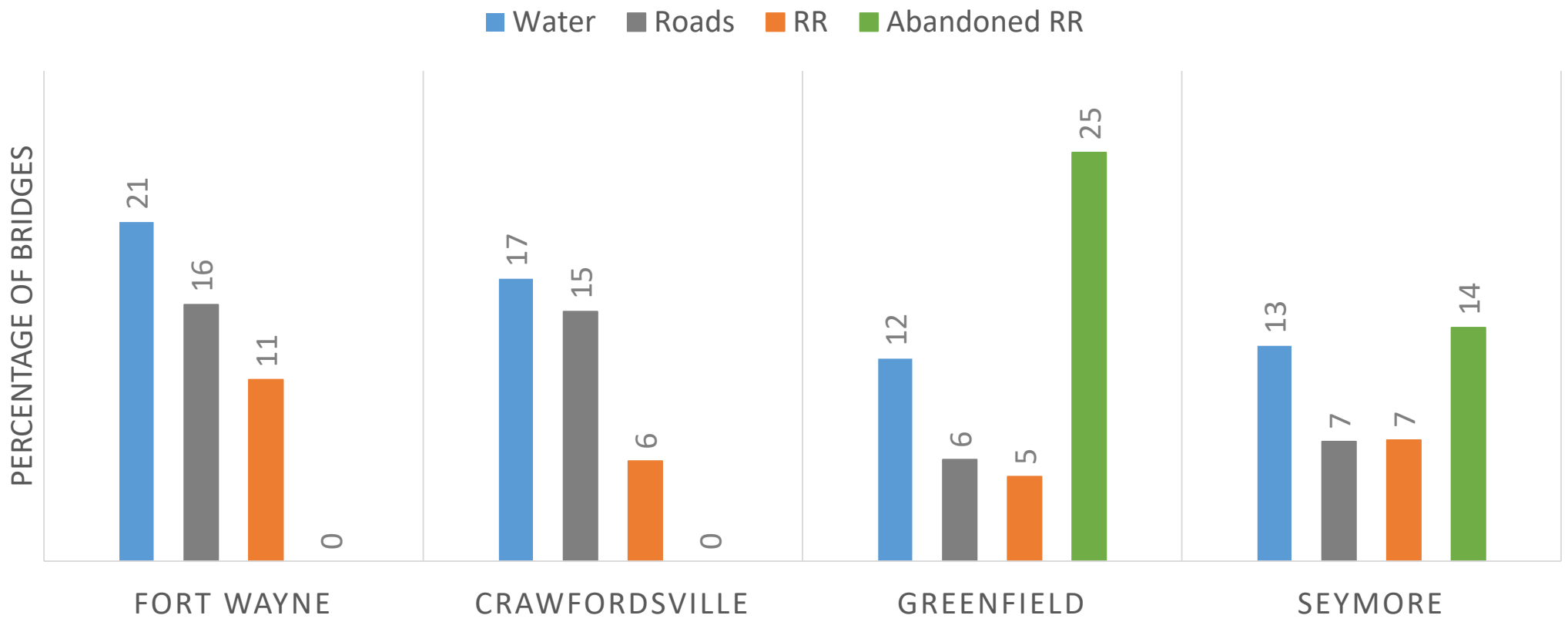
YEARS AFTER PAINTING VS. PACK RUST SEVERITY IN SPLICES (4DISTRICTS)



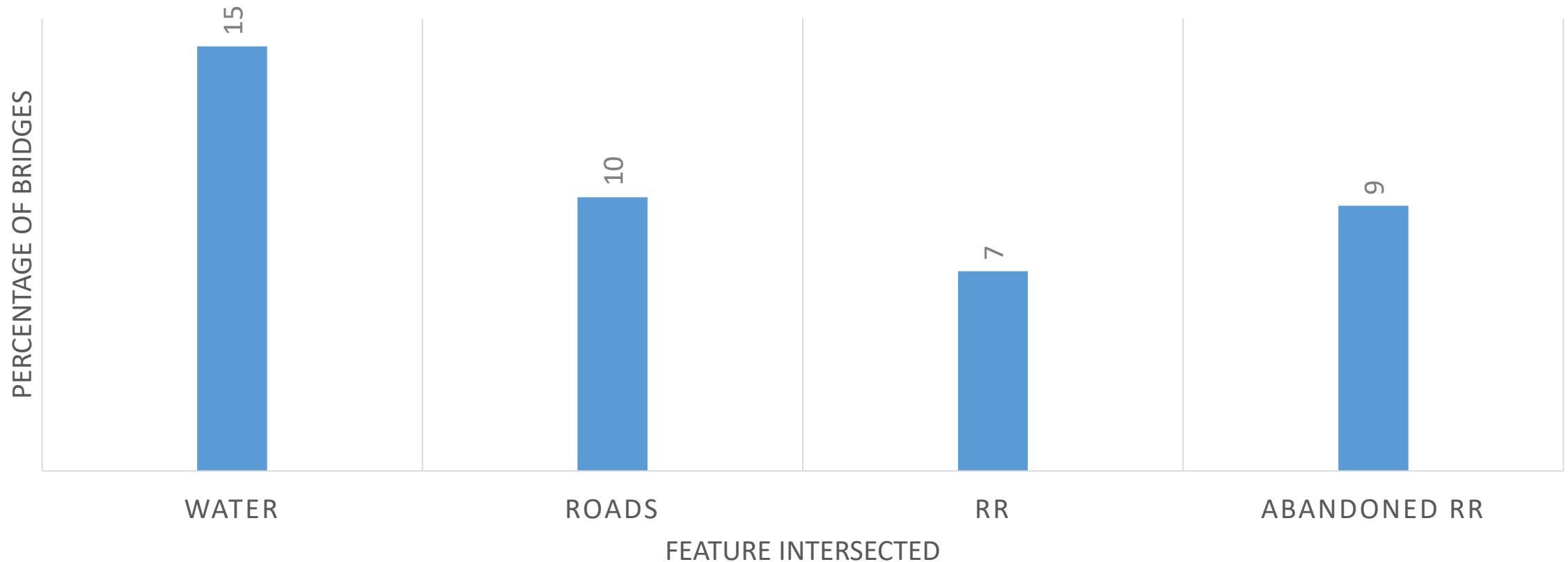
AGE AFTER BUILT VS. PACK RUST SEVERITY IN SPLICES (4DISTRICTS)



PERCENTAGE OF BRIDGES WITH PACK RUST IN SPLICES OVER FEATURE INTERSECTED DISTRICT BREAKUP

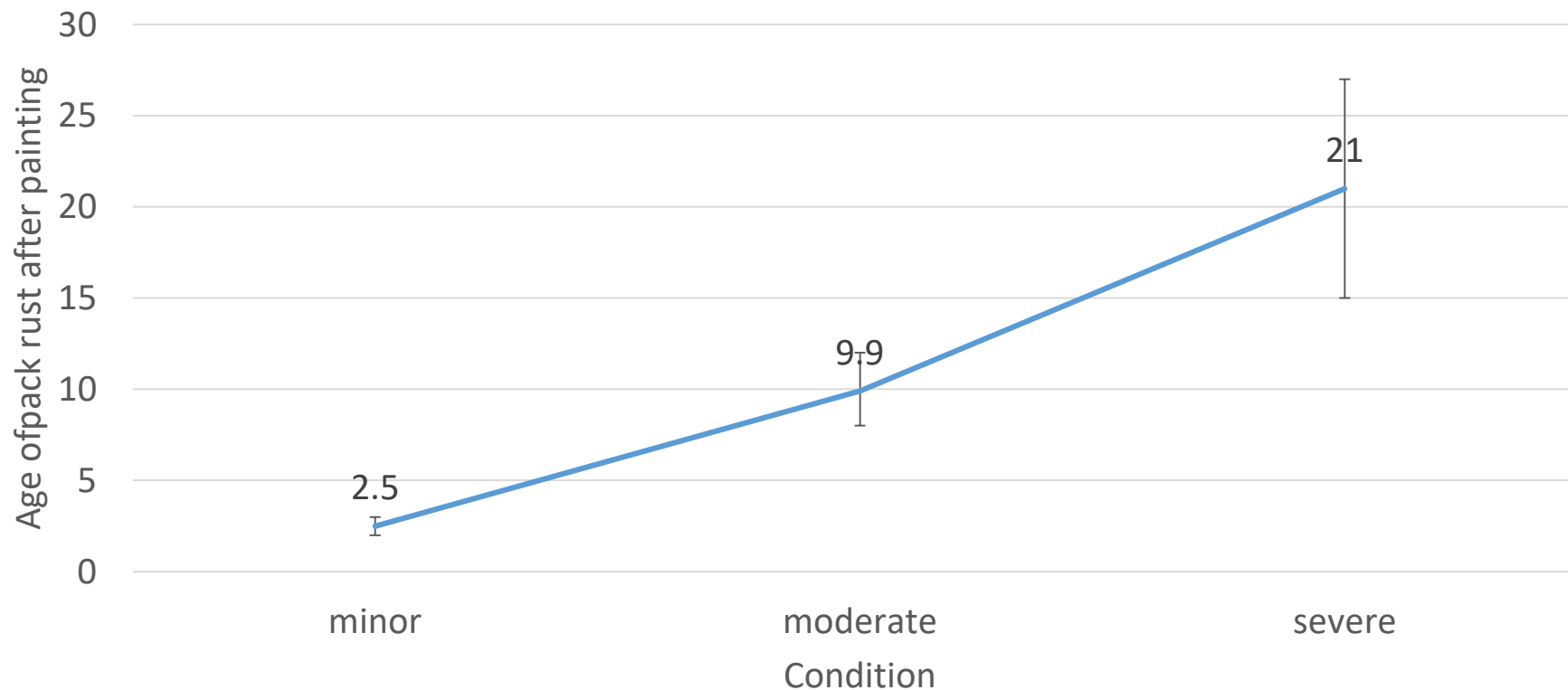


PERCENTAGE OF BRIDGES WITH PACK RUST IN SPLICES OVER FEATURE INTERSECTED



Trends for Cover Plates

Cover plate condition vs age after painting





Conclusions

- Pack rust frequently occurs in Indiana bridges
- Most common locations
 - Bearings(top and bottom)
 - Splice plates (joints)
 - Hinge-pin connections
 - Gusset plates
 - Lower chords of truss
- No correlation between pack rust occurrence and salt usage.



Conclusions

- Common mitigation and repair methods
 - Stripe coat
 - Caulking
 - Penetrating sealer (Promising mitigation and repair method)



Future Tasks

- Investigate remaining 2 districts of Indiana.
- Investigate strength degradation due to pack rust.
- Review repair strategies for Indiana.



Questions ?