TXDOT PROJECT NO. 0-7193

DEVELOP ASSESSMENT AND MITIGATION GUIDANCE FOR ANCILLARY HIGHWAY STRUCTURES WITH EXISTING CRACKS

TASIG Meeting

RESEARCH TEAM

UT Austin – Junghoon Sohn, Shouchen Zhang (PhD Student), Dr. Mojtaba Aliasghar, Dr. Aidan Bjelland, Dr. Todd Helwig, Dr. Matthew Hebdon, Dr. Salvatore Salamone

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AUGUST 14, 2025

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Research Team (RT) – UT Austin

- Research Supervisors – Co-PIs: Todd Helwig, Matthew Hebdon, and Salvatore Salamone
- Graduate Research Assistants (GRAs and Post-Doctoral Researchers):
  - Junghoon Sohn and Shouchen Zhang (PhD Candidate)
  - Post-Doctoral Researchers: Mojtaba Aliasghar and Aidan Bjelland

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Research Team (RT) – Texas A&M

- Research Supervisors – Co-PIs: Stefan Hurlebaus, Peter Keating, Kinsey Skillen, and Arash Rockey
- Graduate Research Assistants (GRAs):
  - HanGil Kim (PhD Candidate)

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Presentation Outline

- Introduction and Background – Junghoon
- Field Assessment – Junghoon
- Lab Test Setup – Junghoon
- Current Results
  - UT – Shouchen
  - Texas A&M – Hangil
- Conclusion and Future work – Hangil

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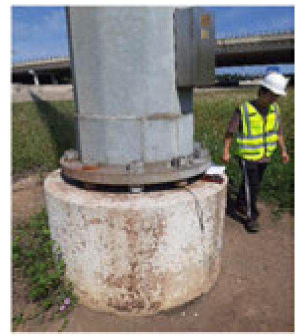
Introduction

- Ancillary structures experience repetitive fatigue loading
- Early detection is critical to prevent failure and reduce cost

Traffic Signal Structure
(TSS)

Cantilever Overhead Sign Structures
(COSS)



High Mast Illumination Pole
(HMIP)

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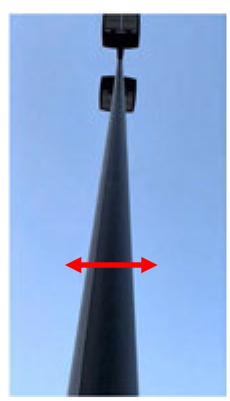
Fatigue Sources by Structure Type

- TSS/COSS: Vibration from mast arm (wind/galloping)
- HMIP: Wind-induced vortex shedding

Mast arm vibration (TSS/COSS)



Wind-induced vortex shedding (similar to HMIP)

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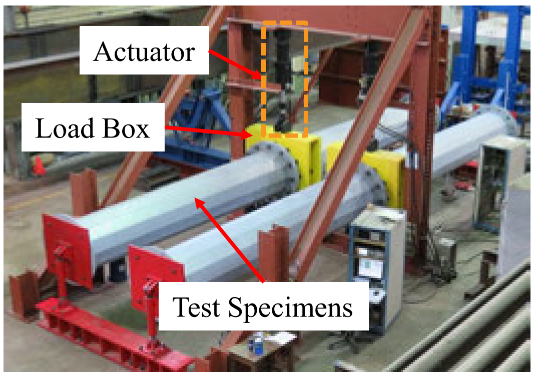
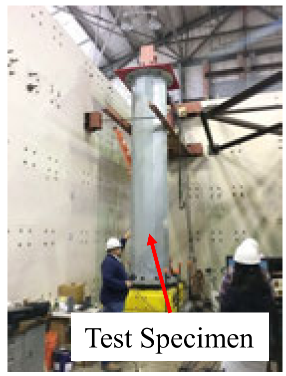
Lab Testing Background

- Lab Test (Pool – 2010, Balivanis – 2013, Morovat et. al, 2018)
- Crack started at weld toe between baseplate and pole



Horizontal test setup



Vertical test setup

Test Results

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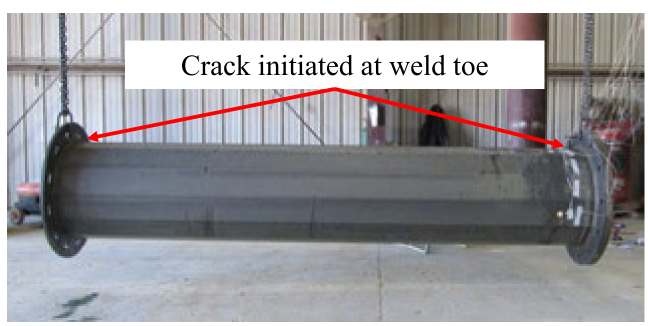
Galvanizing-Induced Cracking

- Galvanizing monitoring (Kleineck – 2011)
- Thermal stress during galvanizing can cause galvanizing crack
- Cracks typically start at weld toe due to stress concentration


Thermal stress during galvanizing



Typical location of galvanizing crack

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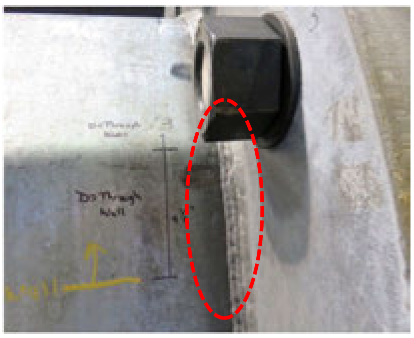
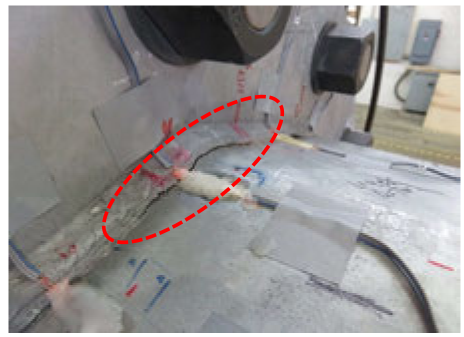
Challenge of Visual Inspection

- Cracks often remain invisible in early stages
- NDT (Non-Destructive Testing) is essential for early detection


Cracks not visible to eye


Visible significant crack

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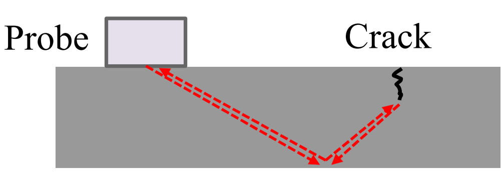
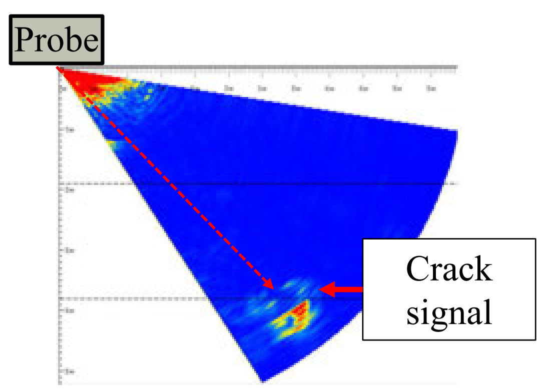
Challenge of Visual Inspection

- PAUT (Phased Array Ultrasonic Testing)
- Enables visualization of crack location and size



Crack monitoring using PAUT



PAUT result image

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Crack Repair Method Overview

- Identify and fully remove the crack through grinding
- Restore the grinded area by rewelding the section

Crack identification

Crack removal (grinding)

Repair by rewelding

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Research Objectives

- Field assessment using PAUT various jurisdictions of Texas
- Lab testing of repair strategies
- Provide practical recommendations
  - Monitoring
  - Repairing
  - Potential Component Replacement

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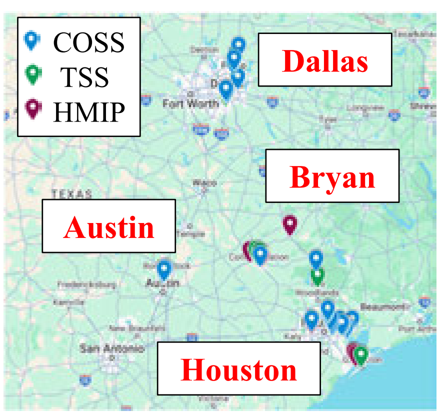
Field Assessment Scope

- 120 poles across Austin, Bryan, Dallas, Houston
- 40 each: COSS/ TSS/ HMIP



Structural Type	No. of inspected poles				
	Austin	Bryan	Dallas	Houston	Total
COSS	10	2	12	18	40
TSS	10	10	10	10	40
HMIP	10	10	10	10	40
Total					120

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Field Assessment Procedure

- Measured dimensions and PAUT were used to detect cracks
- PAUT was effective in identifying weld toe cracks

Field assessment


Dimension Measurement


PAUT crack detection

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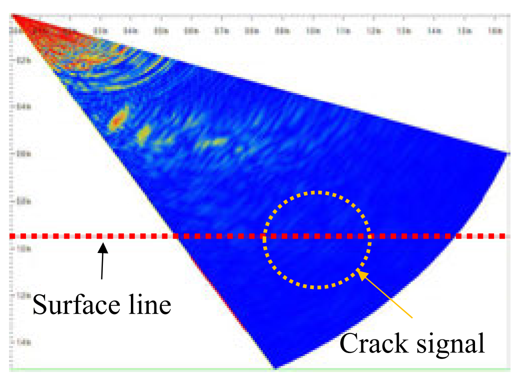
Field Assessment Procedure

- Measured dimensions and PAUT were used to detect cracks
- PAUT was effective in identifying weld toe cracks


PAUT during field assessment



PAUT result

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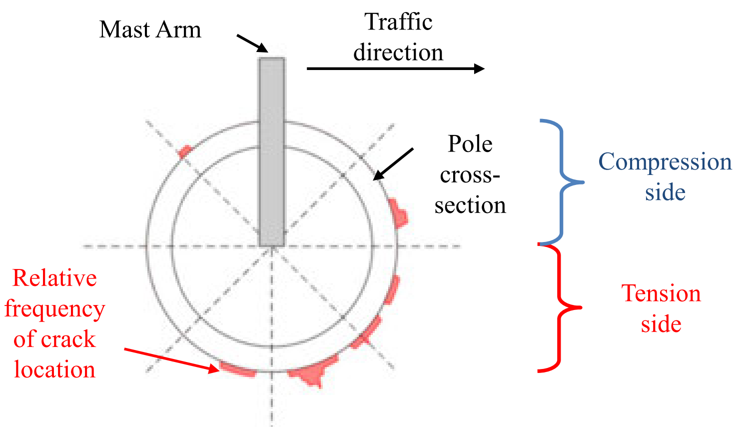
COSS Field Results

- Cracks primarily on tension side (opposite mast arm)



Field crack distribution from 40 COSS specimens

Common crack location of COSS

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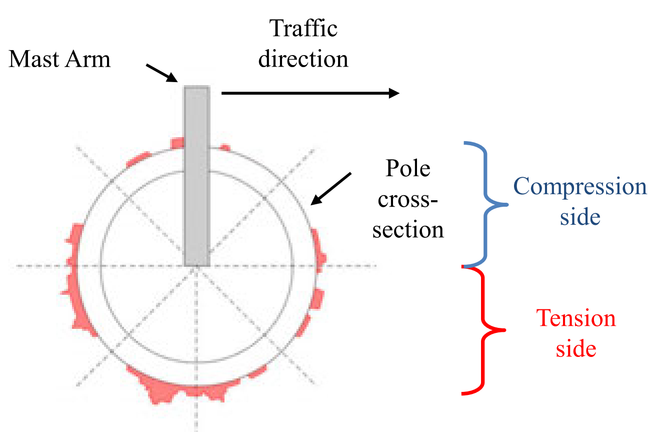
TSS Field Results

- Cracks more scattered, but concentrated on tension side



Field crack distribution from 40 TSS specimens

Common crack location of TSS

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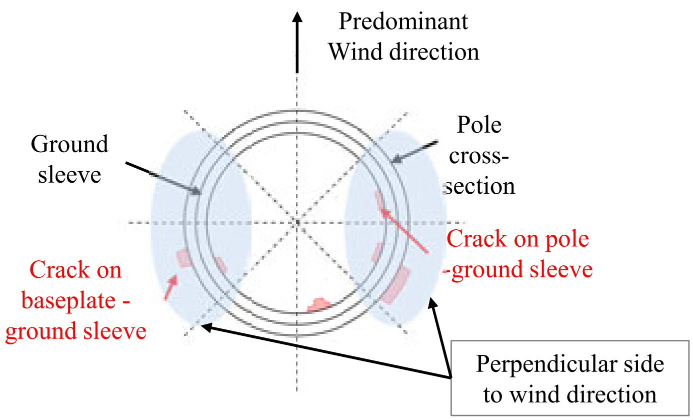
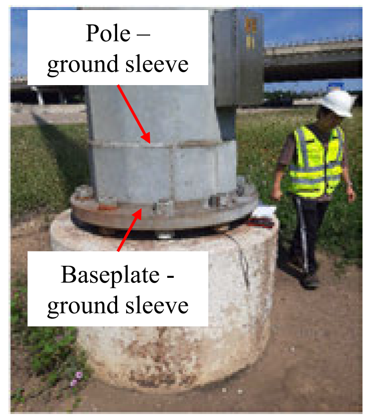
HMIP Field Results

- Cracks primarily perpendicular to wind (vortex shedding)



Field crack distribution from 40 HMIP specimens



Common crack location of HMIP

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Field Assessment Findings

- TSS & COSS: Cracks mainly located on the tensile side
- HMIP: Cracks typically occur perpendicular to the predominant wind direction
- Crack-prone locations should be regularly monitored based on structure type

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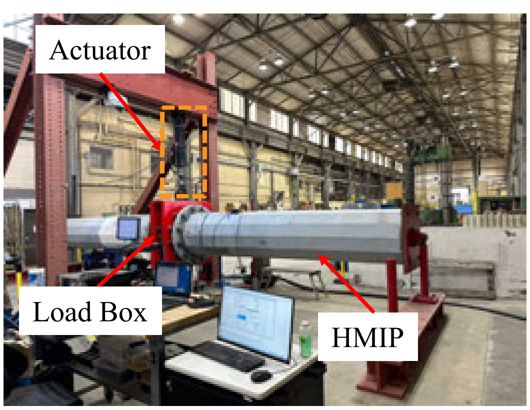
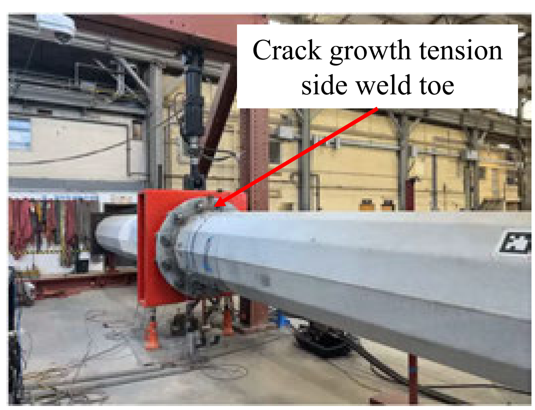
Lab Test setup

- UT: testing HMIP, COSS / A&M: testing TSS
- Actuator applies cyclic load through load box – upward only





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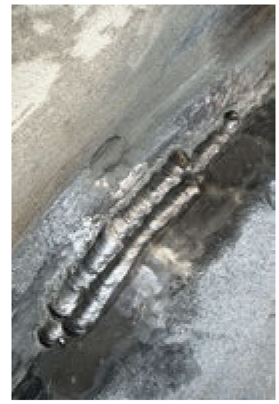
Lab Monitoring & Repair

- Periodic PAUT scans monitor crack growth
- Repair triggered when crack exceeds length or depth threshold

Crack monitoring (PAUT)

Ground area before rewelding

Rewelding in progress



Post-repair weld

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Pre-Rewelding Strategy

- Option 1: Grind groove to remove crack
- Option 2: No groove, allow weld to penetrate crack

Crack removed prior to rewelding

Crack left in place prior to rewelding

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Post-Rewelding Strategy

- Option 1: Leave weld as-is
- Option 2: Shallow weld toe grinding (<1mm depth)
- Option 3: Full surface sanding to remove surface irregularities

As-welded surface

Weld toe after shallow grinding

Smoothed surface after sanding

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HMIP Test

- Specimens were taken from in-service HMIPs in Houston.
- Total length: 14 ft 4 in
- Wall thickness: 0.45 in


HMIP specimens transported from Houston to UT Austin

HMIP test setup

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HMIP Test

Geometry	12-sided
Diameter of base plate	49 in.
Wall thickness	0.45 in.

HMIP test setup

Lab test setup				Field assessments (TXDOT Project 0-6829)		
Stress range	Controlling amplitude	Frequency		Effective stress range	Amplitude at 14'-4"	Cycles per day
7 ksi	0.19 in	1.25 Hz		0.6 ksi	0.01 in	26,500

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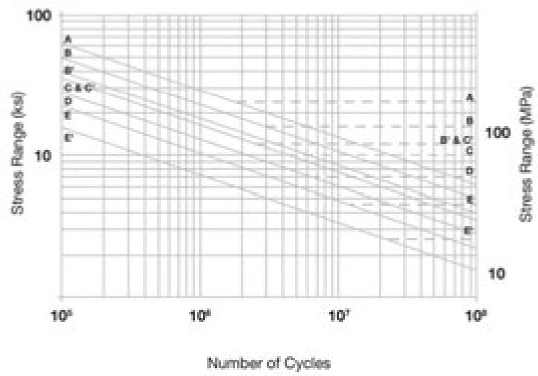
Conversion of Laboratory Data to Time Estimates in Field

S-N curve: $$\frac{N_{lab}}{N_{Field}} = \frac{S^3_{R_{field}}}{S^3_{R_{lab}}} \quad (1)$$

$$\Rightarrow N_{Field} = N_{lab} \cdot \left(\frac{S_{R_{lab}}}{S_{R_{field}}}\right)^3 \quad (2)$$

Lab test		Field (Project 0-6829)	
Stress range	Inspection interval	Effective stress range	Cycles per day
7 ksi	10,000	0.6 ksi	26,500



AASHTO Structural Supports Spec.: C11.9.3-1: Stress range vs. number of cycles

Applying 7 ksi to the HMIP in the lab for 10,000 cycles (2.5 hrs) is equivalent to approximately 1.6 years of natural wind loading in Austin.

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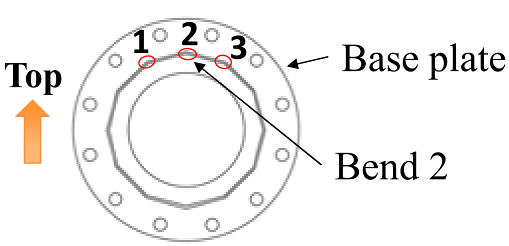
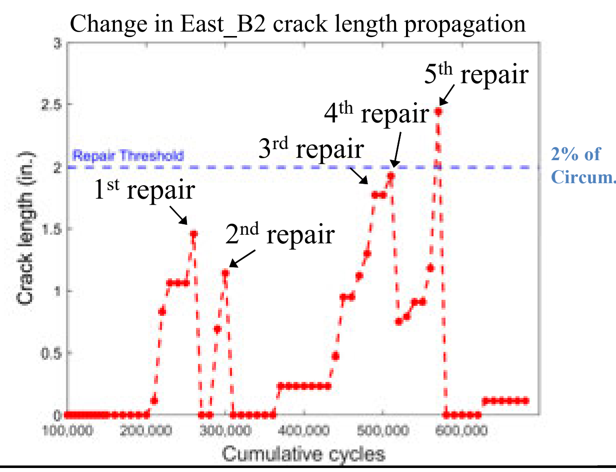
HMIP Test Results



East HMIP

A crack first appeared ➡ 210,000 cycles (approx. 34 yrs)

Welding repairs ➡ 5 times



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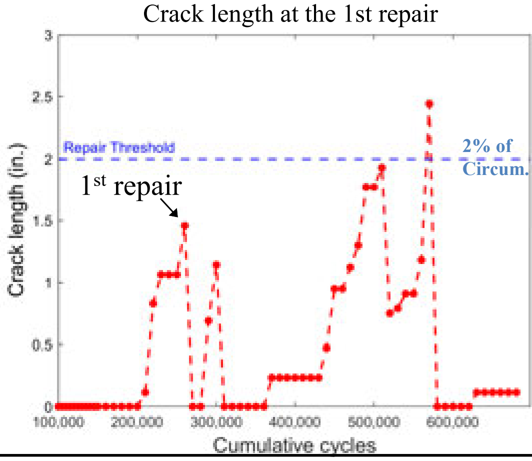
HMIP Test Results

The 1st repair was performed → 50,000 cycles (~8 yrs) after cracking

Crack depth → 0.1 in.

Crack length at the 1st repair



Crack location (a) after grinding

(b) after 1st weld repair

- The crack reappeared <u>20,000 cycles (~3 yrs)</u> after the first repair and grew rapidly.
- The new crack occurred <u>between the two weld passes</u>.

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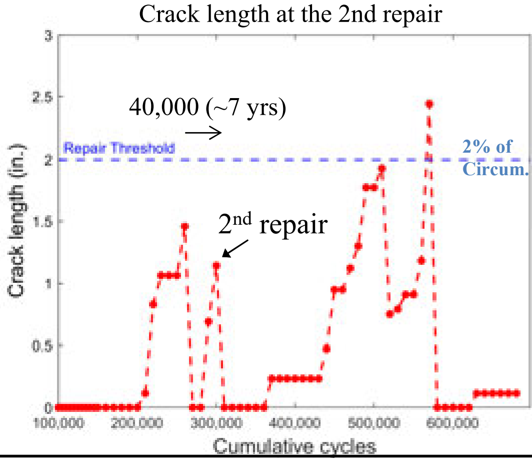
HMIP Test Results

The 2nd repair was performed → 40,000 cycles (~7 yrs) after the 1st

Crack depth → 0.05 in.

Crack length at the 2nd repair



Crack location (a) after grinding

(b) after 2nd weld repair

- Two fill welds were placed on the bottom and three cover passes to help <u>distribute potential stress concentrations</u>.
- After the 2nd repair, the crack did not reappear until <u>60,000 additional cycles (~10 yrs)</u>.

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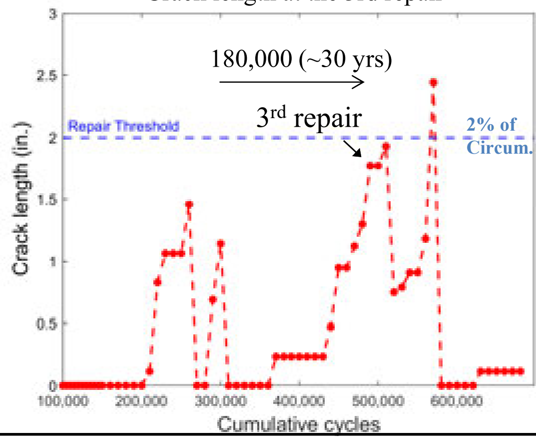
HMIP Test Results

- Repairs at 480k (3rd) and 510k (4th) cycles, performed within a short interval.

Crack length at the 3rd repair



Crack location (a) after grinding

(b) after 3rd weld repair

Repair	Groove grind
3	N

- After the 3rd repair, PAUT showed that the crack tip remained and quickly penetrated the weld, becoming visible on the surface.

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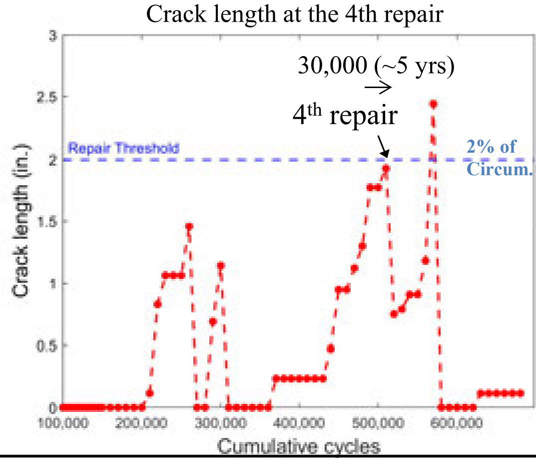
HMIP Test Results

- Repairs at 480k (3rd) and 510k (4th) cycles, performed within a short interval (~5 yrs).

Crack length at the 4th repair



Crack location after 4th weld repair

Repair	Groove grind	Post-repair sanding
3	N	N
4	Y	Y

- The 4th repair removed the crack, followed by surface sanding after welding to reduce stress concentration.

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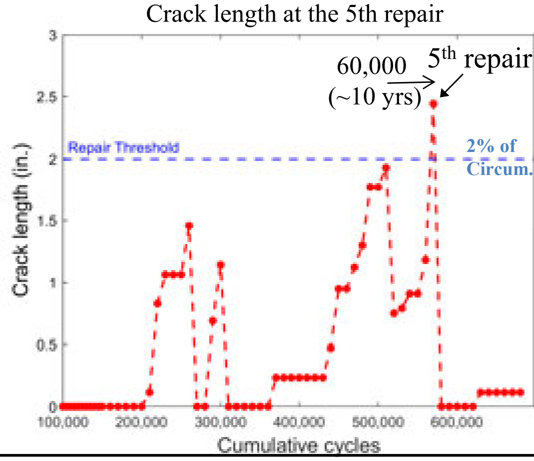
HMIP Test Results

The 5th repair was performed → 60,000 cycles (~10 yrs) after the 4th

Crack depth → 0.3125 in.

Crack length at the 5th repair



Crack location after 5th weld repair

Repair	Groove grind	Post-repair sanding
5	Y	Y

- The 5th repair involved a total of nine weld passes.

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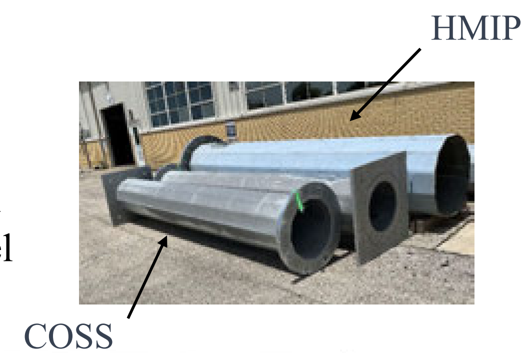
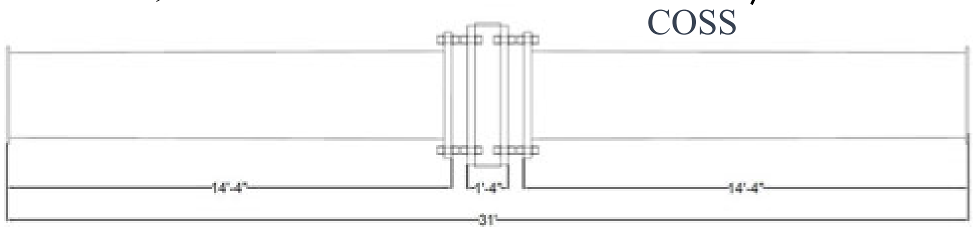
Ongoing Research on HMIP and COSS

- Testing and repairs of the HMIP are ongoing.
- The two COSS specimens to be tested were fabricated by Structural and Steel Products, Inc.





COSS test setup

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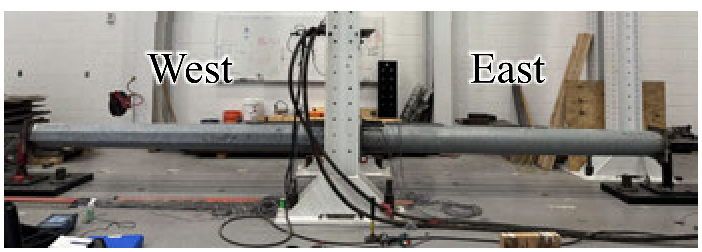
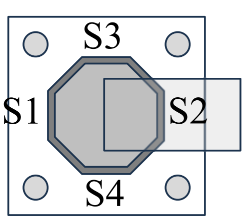
TSS Test Results



Location	West	East
Geometry	8-sided	Round
Diameter	12.0 in.	12.5 in.
Thickness	0.255 in.	0.181 in.



Setup	Stress Range	Loading Stress	Frequency
Side 1 (S1)	15 ksi	2 – 17 ksi	1 Hz
Sides 2–4 (S2–S4)	10 ksi	2 – 12 ksi	1.25 Hz

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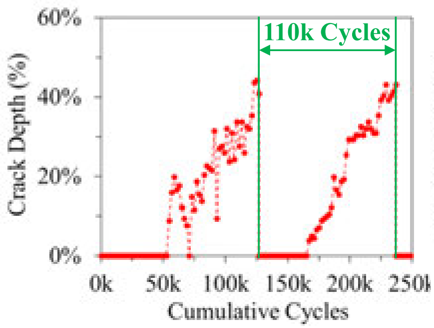
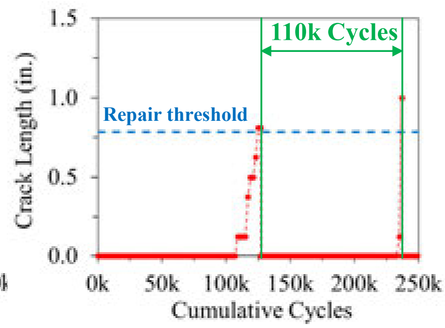
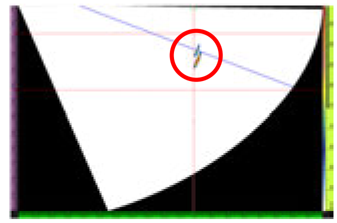
TSS Test Results

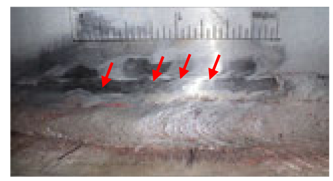
- Inspection interval: 2,000 cycles
- Inspection method: Visual inspection, PAUT
- Repair threshold: 2% circumference







PAUT result (S-Scan)



Crack configuration

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TSS Test Results

- Repair procedure

Dye penetration test

Grinding and grooving

Welding

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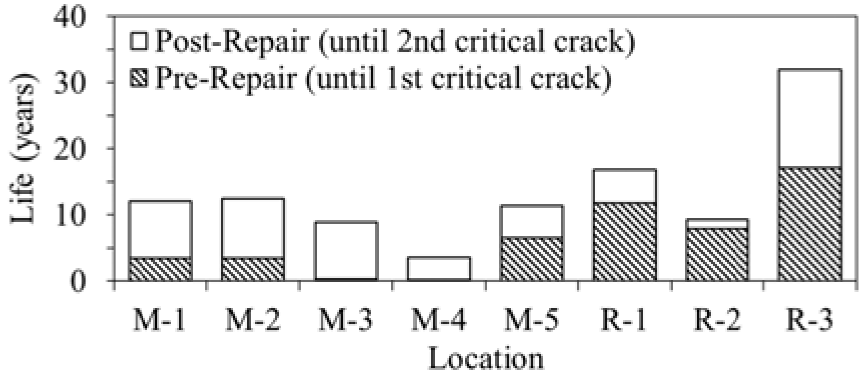
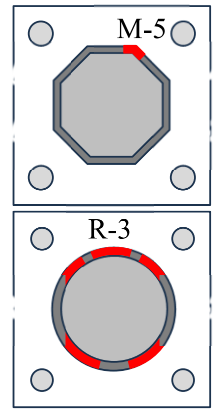
TSS Test Results

- Field pole (previously in service)
- Extended life after repair





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TSS Test Results

2 Round Specimens – Fabricated by Valmont Industries

- Test plan: Fabricated round poles
- Outer diameter: 21 in.
- Wall thickness: 0.313 in.

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Experimental Test Findings

- (Multi-Sided Pole) Fatigue crack initiates from bend
- Repairs → Extended fatigue life
- (TSS) Fatigue performance: Round Pole > Multi-sided pole

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Conclusions

- TSS, COSS: Fatigue crack commonly occurs on the tension side (constant bending moment from mast arm dead load)
- HMIP: Fatigue crack commonly occurs perpendicular to the predominant wind direction (wind-induced vortex shedding)
- Multi-sided poles: Fatigue crack initiates from the bend
- Repair: Extend fatigue life of the pole

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Future Work

- Complete experimental tests (TSS, COSS, HMIP)
- Develop certification methods for inspection personnel
- Finalize guidance on crack mitigation, repair, or replacement
  - Identify effective repair methods (e.g., grooving before, grinding after repair) and optimal repair timing (Crack depth and length)

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Thank you!

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