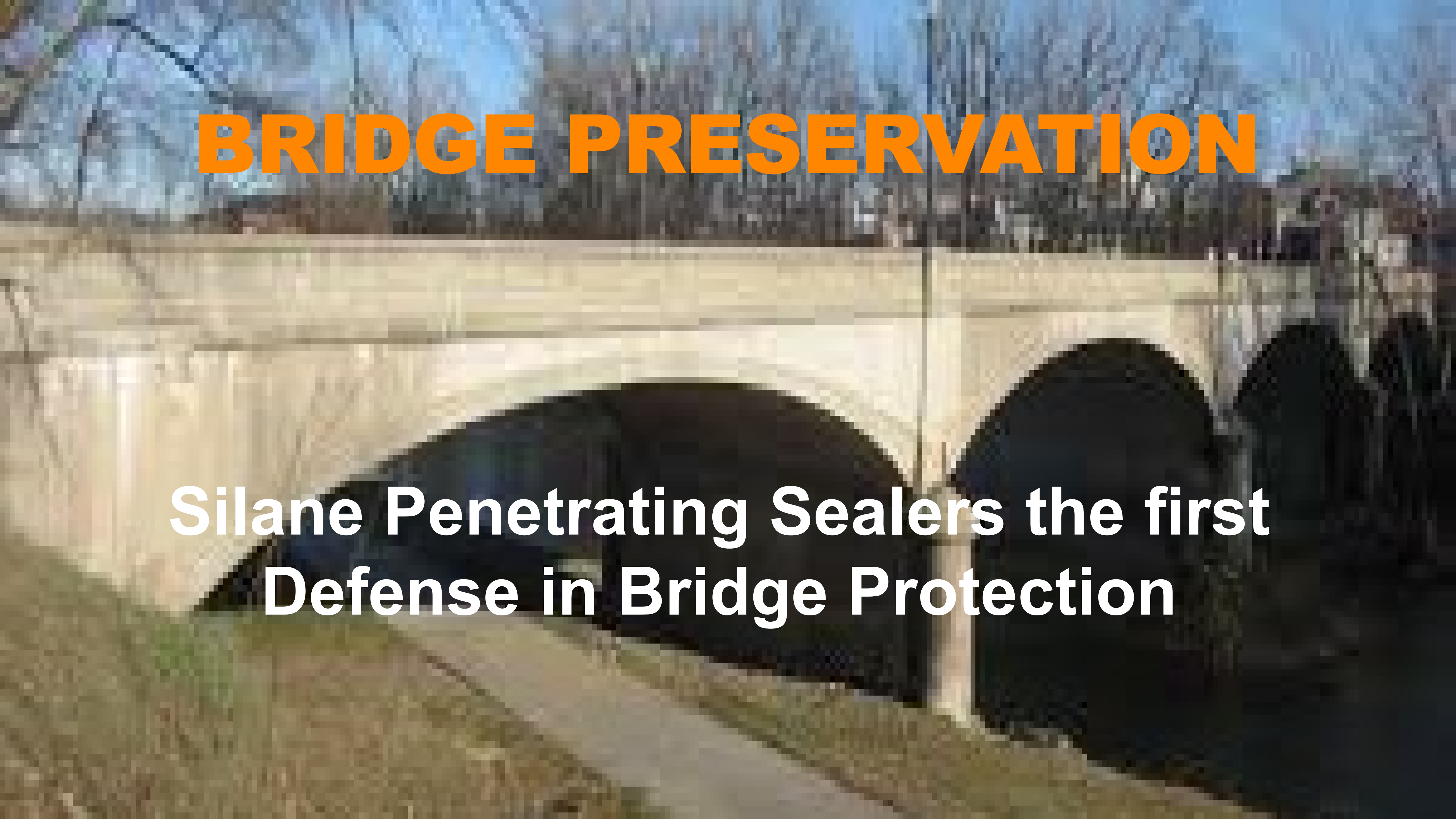
BRIDGE PRESERVATION



Silane Penetrating Sealers the first Defense in Bridge Protection

OUTLINE

PROBLEMS

WHAT ARE SILANES

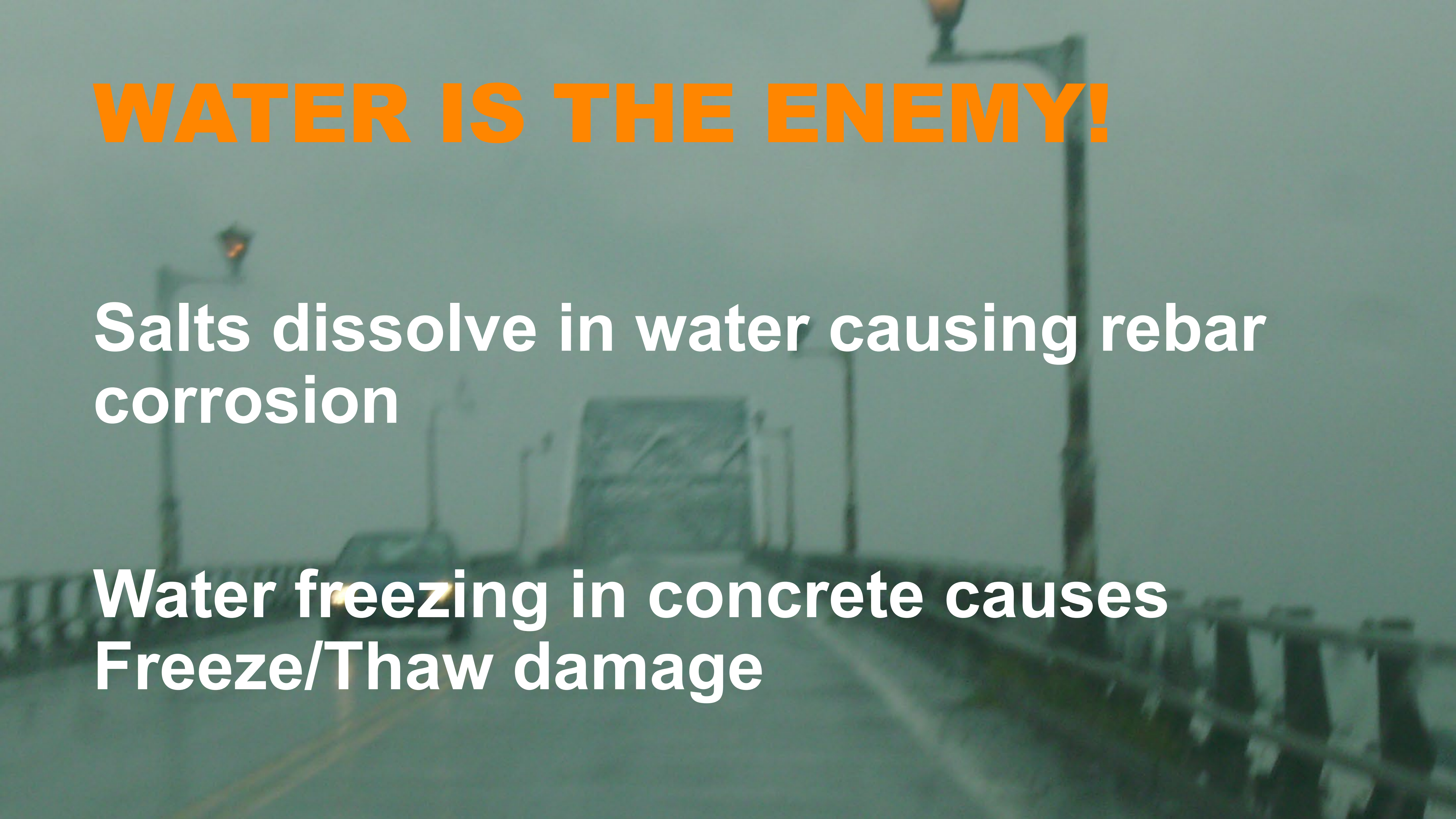
CORROSION INHIBITORS

TESTING

APPLICATION

WRITING SPECIFICATIONS

COST



WATER IS THE ENEMY!

Salts dissolve in water causing rebar corrosion

Water freezing in concrete causes Freeze/Thaw damage

SPALLING


SCALING


CRACKING

ALKALI SILICA REACTION (ASR)


REBAR CORROSION

WHY SILANES

Silanes Work

Silanes are easy to apply

Silanes are very cost effective

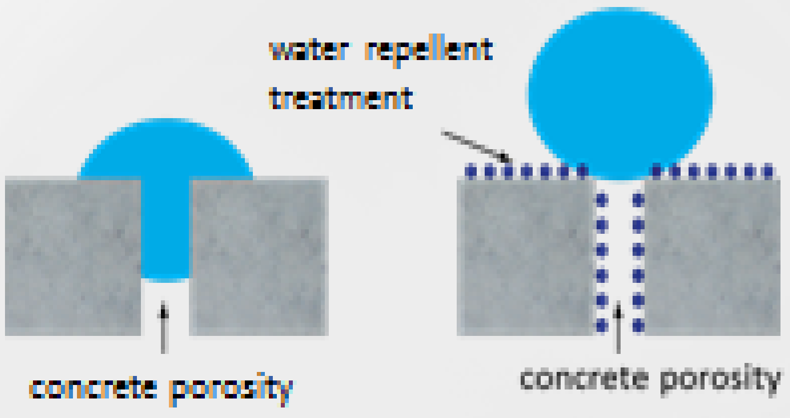
Silanes last for years

Silanes don’t change skid resistance

Silanes dry fast 30 minutes to 2 hours

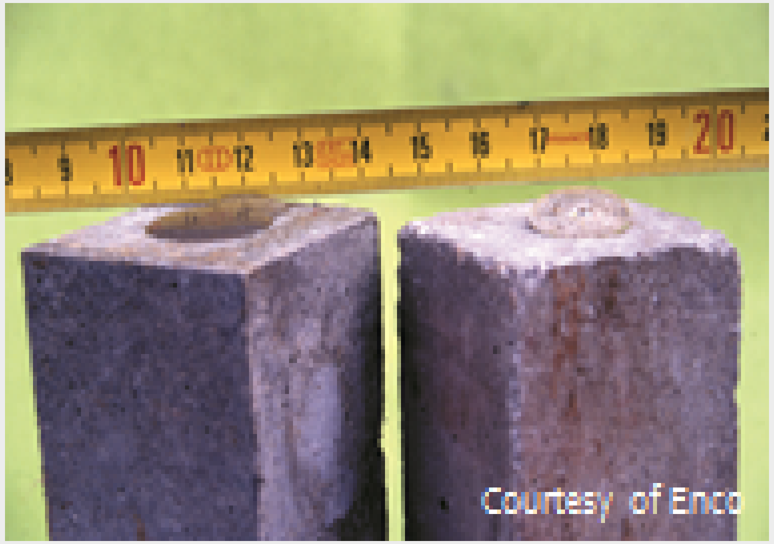
From Hydrophilic to Hydrophobic

Water repellents penetrate the surface pores and cracks, so that they are internally lined but not filled.



Reduction of concrete surface tension:

inter-molecular attraction of water molecules is much higher than the attraction of water into concrete



From hydrophilic (water-loving) to hydrophobic (water-hating) surface

ALKYLTRIALKOXYSILANE

Organo-functional reactive chemical

- **Isobutyl**
  - **Tri-methoxy**
  - **Tri-ethoxy**
- **Noctyl**
  - **Tri-methoxy**
  - **Tri-ethoxy**
- **Isooctyl**
  - **Tri-methoxy**
  - **Tri-ethoxy**

SOLVENT VS WATER

Solvent based Silanes

- Fast dry times
- Re-coatable
- VOC compliant
- Deeper Penetration

Water based silanes

- Lower VOC
- Slower dry times
- Use solvent based to recoat

SILANES DOT TESTED FOR OVER 30 YEARS

Oklahoma DOT	1986	Iowa DOT	1999
Texas DOT	1995	Wisconsin DOT	2005
Indiana DOT	1992	Missouri DOT	2007
Kansas DOT	1998	Illinois DOT	2009

CONTINUING UNIVERSITY STUDIES

Purdue University

Oklahoma State University

Michigan Tech

University of Leeds, UK

University of Delft, Netherlands

WJE CORROSION PROTECTION TESTS

1985   48 Week Salt Ponding test was performed

40% Silane applied at 125 sq ft per gallon

Ingress of Chloride Ions was reduced by 97-98%

Hydrophobic Concrete

Internal Electrical Resistance increased 2-3 times

Water Vapor Transmission

Zero Re-bar corrosion over the 48 week test!

PERFORMANCE TESTED

Test		Performance
ASTM C-672	Freeze Thaw Scaling	0 @ 50 cycles
ASTM C-642	Moisture Absorption	90% reduction
AASHTO T-259/T260	Chloride Penetration	90% reduction
NCHRP 244 series II	Absorption & Chloride Ion penetration	85% reduction
	Moisture vapor permeability 100%	
NCHRP 244 series IV	Accelerated Weathering	95% reduction

Treated Block

- 100% Silane
- 250sq ft. per gallon
- 3 hour time lapse
- **Zero water absorption.**

Untreated Block

- 3 hour time lapse
- **5 mL of water absorbed.**

OVERALL RESULT

91% reduction in water absorption.

Determining the Effective Service Life of Silane Treatments in Concrete Bridge Decks

Mehdi Khanzadeh Moradllo, Bryan Sudbrink, M. Tyler Ley

Department of Civil and Environmental Engineering, Oklahoma State University

ABSTRACT

Silane is a commonly used surface treatment to reduce water entry into concrete. Current ODOT specifications require 3.2 mm of silane on all in service bridge decks. Only limited work has been done to show the effective lifespan of silane sealers. This work uses 360 cores taken from 60 Oklahoma bridge decks treated with silane that have been in-service between 6 and 20 years. Optical staining techniques were used to image silane depth. These findings will be helpful to practitioners to determine the long-term performance of silane coatings.

SAMPLE ACQUISITION

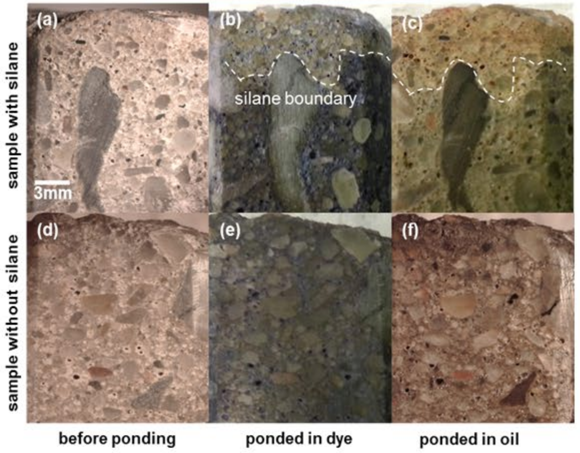
Cores that were approximately 18 mm in diameter by 25 mm in height were taken from the driving lane and shoulder of 60 bridge decks. Six cores were taken from each bridge for a total of 360 cores. This technique allowed two researchers to sample each bridge in about 1 h. Since the cores were small, this minimized damage and patching to the bridges.

Example of cores were taken from bridge decks

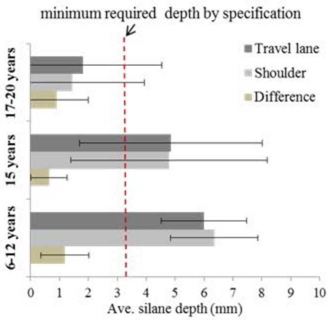
SAMPLE TESTING

- A cross section of each core was exposed by polishing with 120 grit sandpaper for 5 minutes.
- Each sample was inspected with two techniques to determine the presence of the silane.
- First, the core is ponded in blue dye for 30 minutes. The dye stains the concrete that is not treated with the silane.
- Next, the depth of the silane was measured at six different points by using a caliper and an optical microscope and an average was reported for each core.
- Next, the core was polished to remove the dye from the exposed surface and then ponded in mineral based cutting oil for 60 seconds. The oil will wet the surface of the concrete that does not contain the silane sealer.
- The depth is then measured as described previously with the optical microscope and calipers.
- These depths are compared to 3.2 mm as this is the minimum depth required at construction

TESTING PROCEDURE

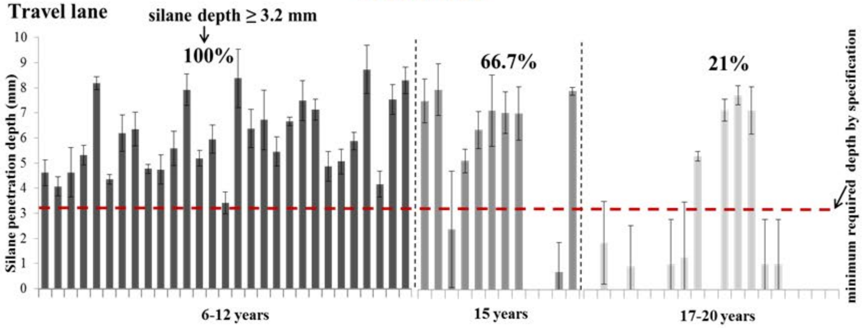


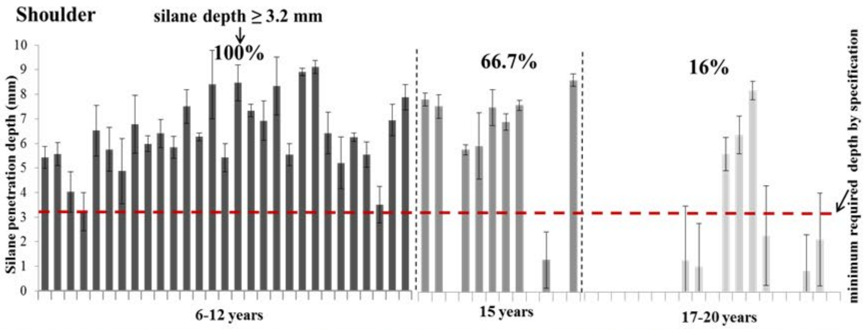
COMPARISON



Summary from all bridge decks

RESULTS

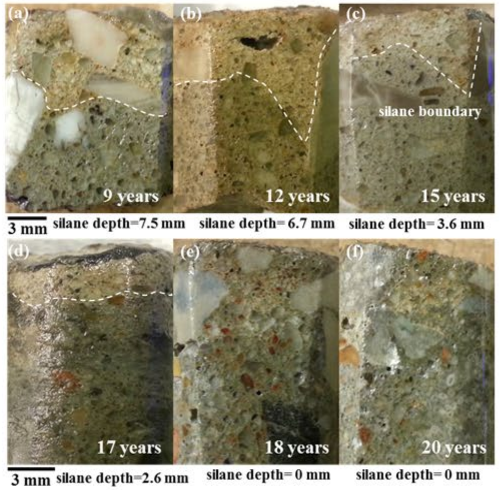




Average silane visual detection depth of samples from bridge decks in travel lane and shoulder

DETERIORATION MECHANISM

The silane deterioration seems to move from the bulk of the concrete towards the surface. One possible cause for the deterioration could be the attack of the silane by the alkaline pore solution of concrete.

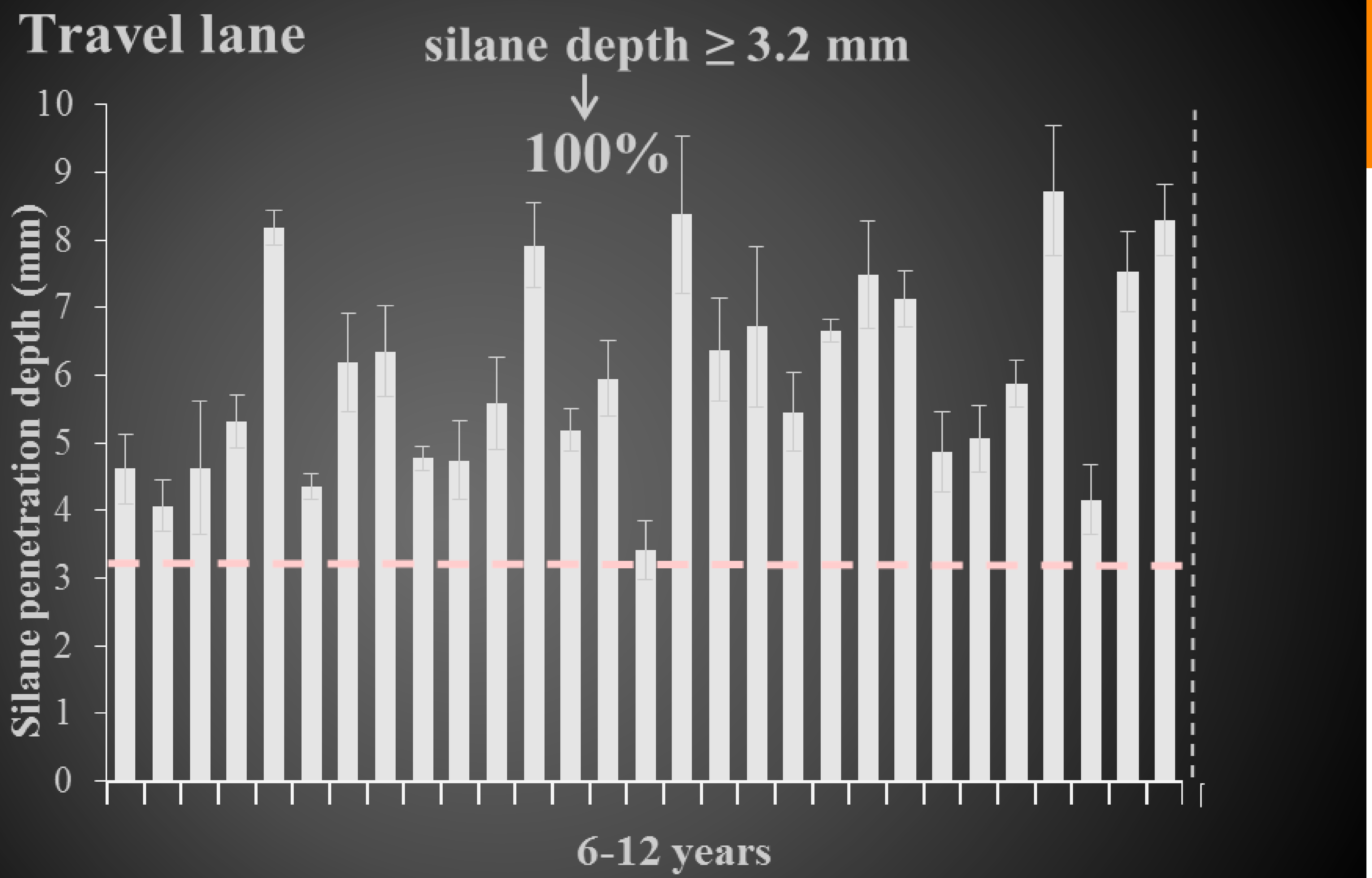


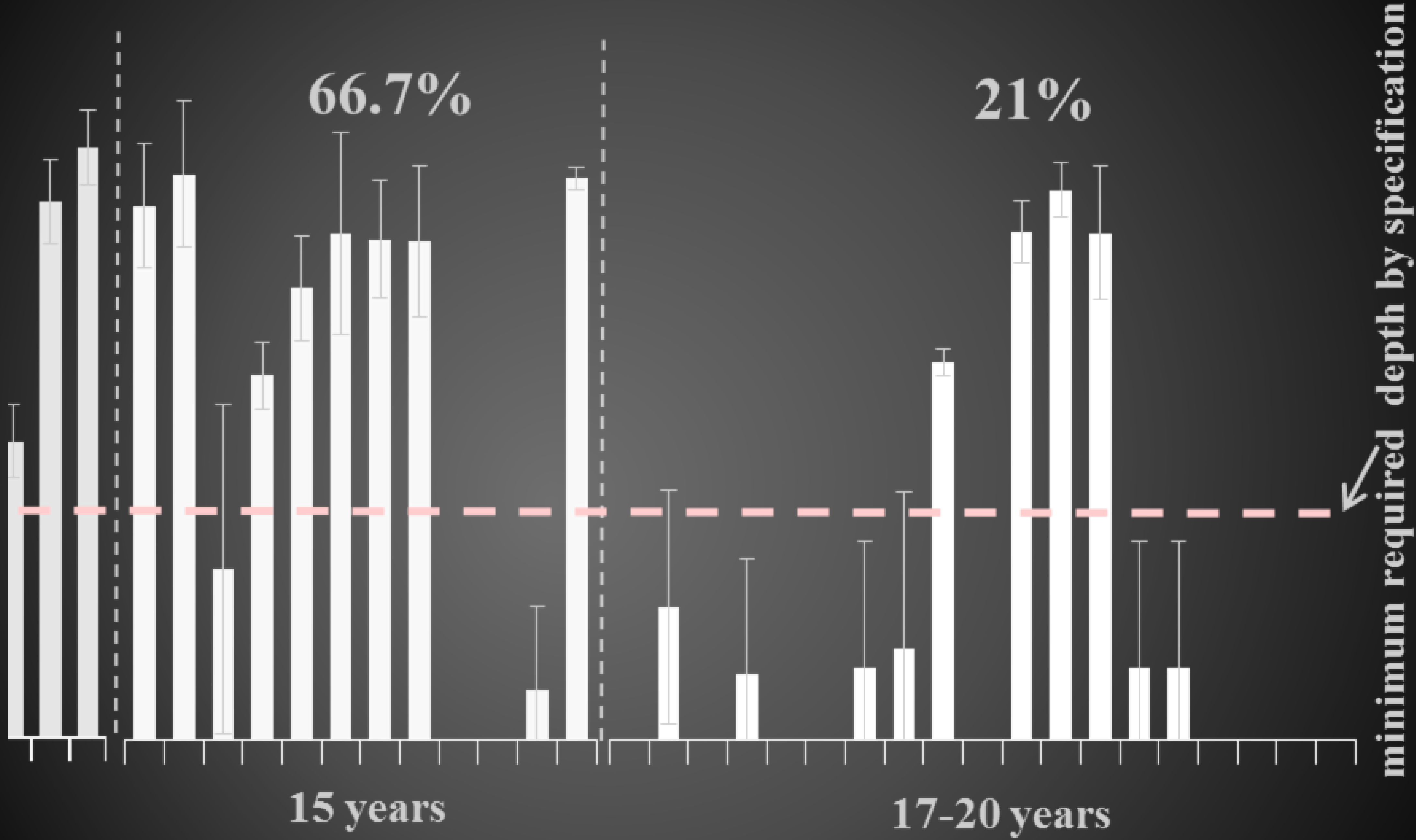
DISCUSSION AND CONCLUSIONS

- After 12 years of service, 100% of the bridge decks were found to have a silane layer greater than the minimum specified value of 3.2 mm
- After 15 years of service, only 68% and after 17 to 20 years only 16% of the bridges showed evidence of a silane layer greater than 3.2 mm in thickness
- The average depth of silane is decreasing with time.
- For bridges with 17 to 20 years of service, the average layer thickness reduced by 75%.
- Removal of the silane by abrasion was minimal over the first 20 years of service for the investigated bridges
- The deterioration by the alkaline pore solution appears to be a more important silane deterioration mechanism for these materials and exposure level

ACKNOWLEDGEMENT

The authors gratefully acknowledge the financial support from the Oklahoma Department of Transportation (ODOT). The authors would like to thank Mr. Jake Leflore, Mr. Colin Fleishacker, Mr. Chad Stevenson, and Mr. Jeffery Terronez for their assistance with conducting of the field experiments.

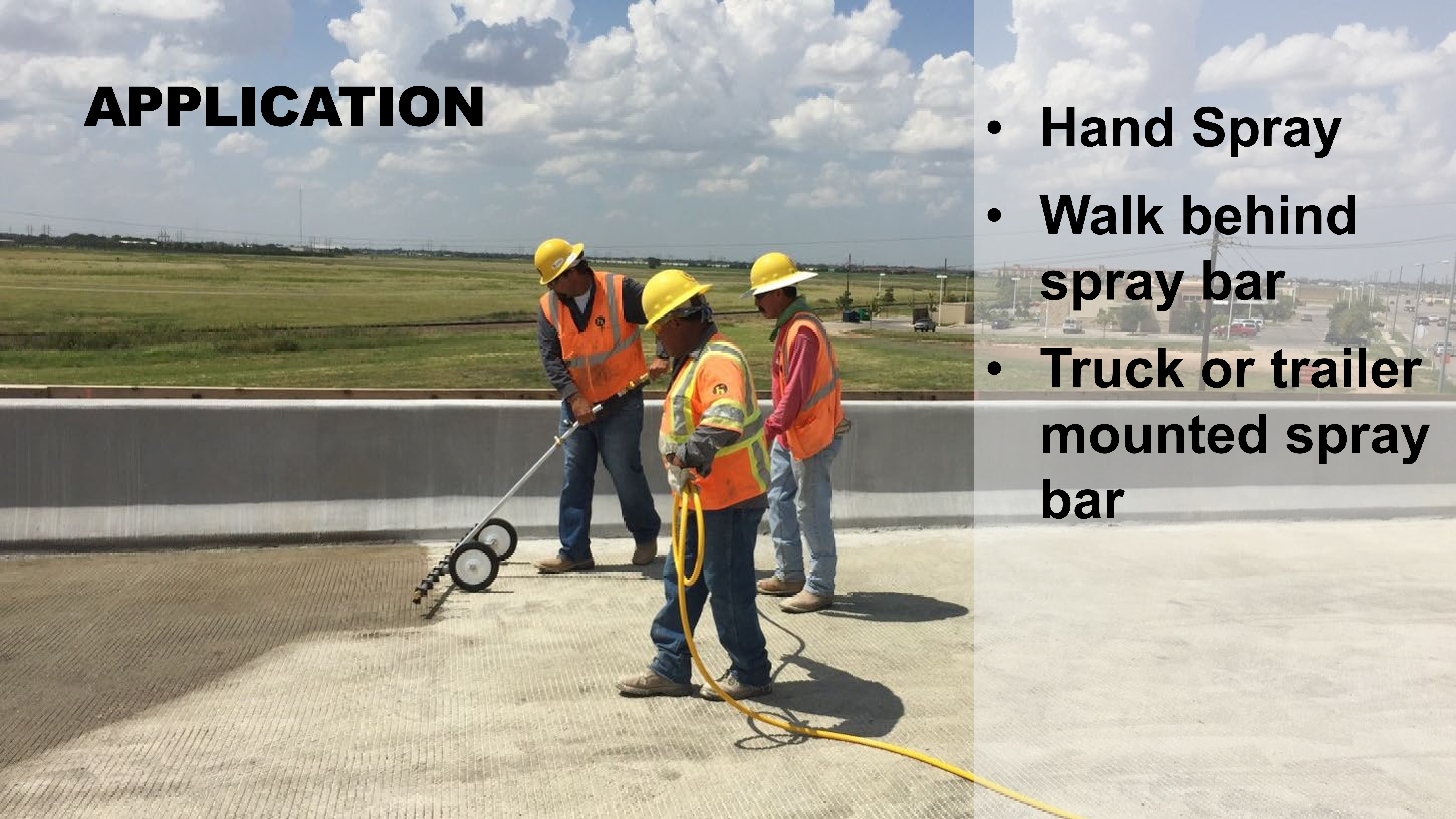

Travel lane
silane depth ≥ 3.2 mm
100%
Silane penetration depth (mm)
0
1
2
3
4
5
6
7
8
9
10
6-12 years


66.7%
21%
minimum required depth by specification
15 years
17-20 years


SURFACE PREPARATION
Sweeping
Power washing
Shot blasting


ROADWAY TECHNOLOGIES
405-567-3706
PRAGUE, OKLAHOMA

APPLICATION



- Hand Spray
- Walk behind spray bar
- Truck or trailer mounted spray bar


MONROE
330932 D

WRITING SPECIFICATIONS

Be consistent - application rates per % of Silane

- 20% @ 60 sq. ft. per gallon
- 40% @ 125 sq. ft. per gallon
- 100% @ 300 sq. ft. per gallon

Get what you pay for - Measure gallons used per bridge

Weather matters – 24 - 48 hours after a rain event

COSTS OF SILANES

20% Silanes

Apply at 60 square feet per gallon

11.61 grams of Silane per square foot

$15.00 per gallon

$0.25 per square foot

Retreat every 6-10 years

COSTS OF SILANES

40% Silanes

Apply at 125 square feet per gallon

11.14 grams of Silane per square foot

$20.00 per gallon

$0.16 per square foot

Retreat every 6-10 years

COST OF SILANES

100% Silanes

Apply at 300 square feet per gallon

11.61 grams of Silane per square foot

$35.00 per gallon

$0.12 per square foot

Retreat every 6-10 years

DO THE MATH

150 ft. X 38 ft. Bridge

5,700 square feet @ $140.00 per square foot

$800,000.00

5,700 square feet treated with Silane at 125 square feet per gallon

Requires 45.6 gallons of a 40% Silane

45.6 gallons of Silane at $20.00

$912.00 to protect an $800,000.00 Investment!

CONCLUSION

Silanes are a tested, studied and proven bridge protective treatment

Its never too late to start a Silane program

Silanes are cost effective

Silanes are easy for local crews to apply

Silanes have an extensive life span 6-12 years

NELSON TESTING LABORATORIES

May 10, 2018
ACT - SIL-ACT SIL-COR
NTL Project #16-1387

TEST RESULTS

FHWA-HRT-07-043 - Corrosion (continued)

Uncoated (Control)

Specimen X1

Duration	Test Date	Current (µA)	Total Corrosion (coulombs)
1 month	5/8/17	69.8	90.4
2 months	6/5/17	61.5	260.4
3 months	7/3/17	39.3	391.0
6 months	9/25/17	35.2	715.4
9 months	12/25/17	43.1	1,047.3
12 months	3/5/18	47.3	1,399.8

Specimen X2

Duration	Test Date	Current (µA)	Total Corrosion (coulombs)
1 month	5/8/17	29.5	38.4
2 months	6/5/17	37.2	124.7
3 months	7/3/17	30.4	212.3
6 months	9/25/17	35.8	482.4
9 months	12/25/17	31.0	714.2
12 months	3/5/18	32.3	958.3

Specimen X3

Duration	Test Date	Current (µA)	Total Corrosion (coulombs)
1 month	5/8/17	64.2	83.3
2 months	6/5/17	73.0	261.0
3 months	7/3/17	48.9	418.8
6 months	9/25/17	31.0	706.2
9 months	12/25/17	36.1	962.5
12 months	3/5/18	34.7	1,232.9

AVERAGE

Total Corrosion (TC) @ 1 month – **70.7 C**
Total Corrosion (TC) @ 2 months – **215.4 C**
Total Corrosion (TC) @ 3 months – **340.7 C**
Total Corrosion (TC) @ 6 months – **634.7 C**
Total Corrosion (TC) @ 9 months – **908.0 C**
Total Corrosion (TC) @ 12 months – **1,197.0 C**

NELSON TESTING LABORATORIES

TEST RESULTS (continued)

FHWA-HRT-07-043 - Corrosion (continued)

SIL-ACT SIL-COR

Specimen A1

Duration	Test Date	Current (µA)	Total Corrosion (coulombs)
1 month	5/8/17	0.1	0.1
2 months	6/5/17	0.1	0.4
3 months	7/3/17	0.1	0.6
6 months	9/25/17	0.1	1.9
9 months	12/25/17	0.1	2.1
12 months	3/5/18	0.0	2.1

Specimen A2

Duration	Test Date	Current (µA)	Total Corrosion (coulombs)
1 month	5/8/17	0.1	0.1
2 months	6/5/17	0.1	0.4
3 months	7/3/17	0.1	0.6
6 months	9/25/17	0.1	1.7
9 months	12/25/17	0.1	2.5
12 months	3/5/18	0.0	2.6

Specimen A3

Duration	Test Date	Current (µA)	Total Corrosion (coulombs)
1 month	5/8/17	0.2	0.3
2 months	6/5/17	0.2	0.8
3 months	7/3/17	0.2	1.3
6 months	9/25/17	0.1	2.7
9 months	12/25/17	0.1	3.5
12 months	3/5/18	0.1	3.8

AVERAGE

Total Corrosion (TC) @ 1 month – **0.2 C**
Total Corrosion (TC) @ 2 months – **0.5 C**
Total Corrosion (TC) @ 3 months – **0.9 C**
Total Corrosion (TC) @ 6 months – **2.1 C**
Total Corrosion (TC) @ 9 months – **2.7 C**
Total Corrosion (TC) @ 12 months – **2.8 C**

NELSON TESTING LABORATORIES

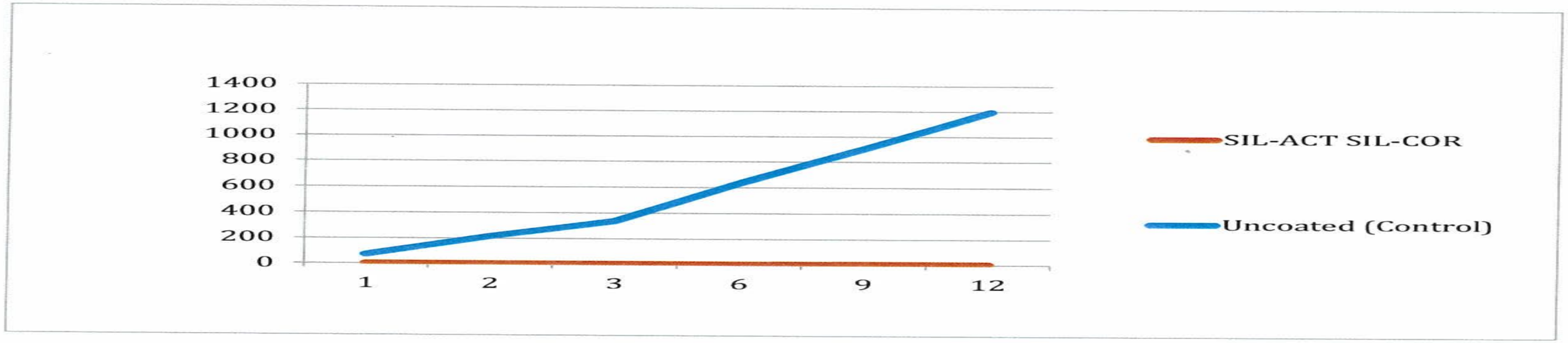
TEST RESULTS (continued)

FHWA-HRT-07-043 - Corrosion

	Control	SIL-ACT SIL-COR
Average Corrosion Results:		
Total Corrosion (coulombs)	1,197.0 C	2.8 C
Chloride content at top bar (%)	0.115%	0.051%
Area of top bar corrosion (%)	67%	<1%

Individual Corrosion Results:

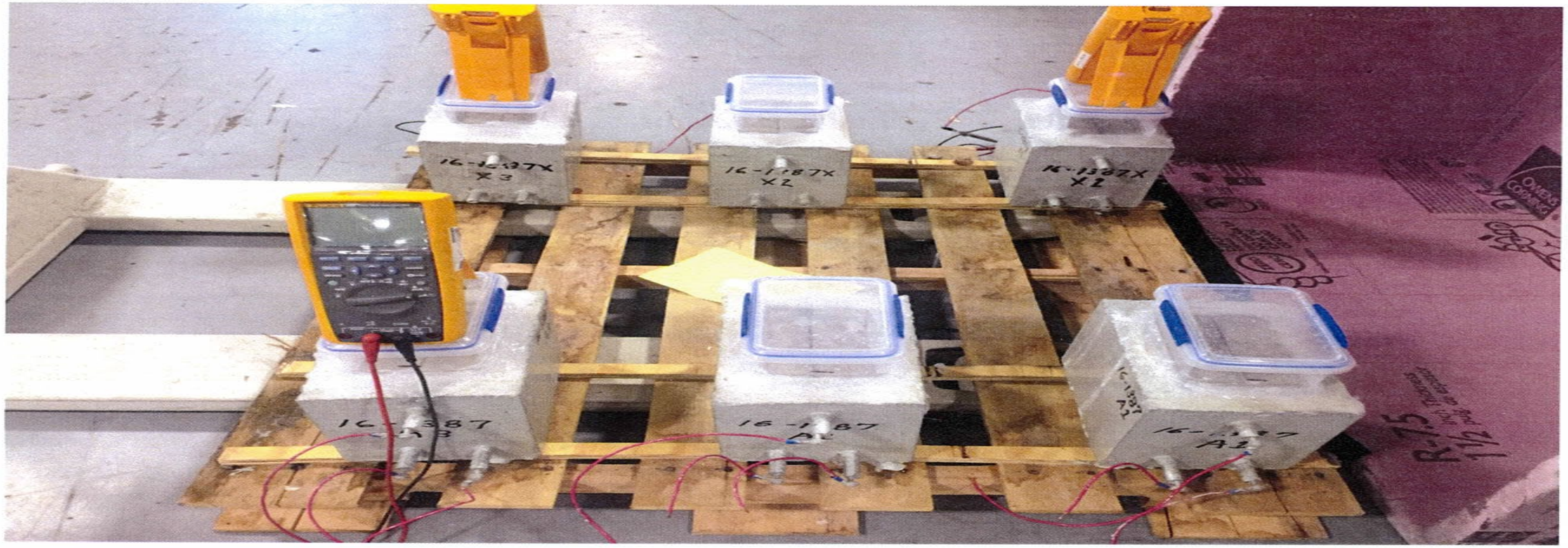
SIL-ACT SIL-COR (A1)	<1% corrosion visible on top bar after 12 month testing
SIL-ACT SIL-COR (A2)	<1% corrosion visible on top bar after 12 month testing
SIL-ACT SIL-COR (A3)	<1% corrosion visible on top bar after 12 month testing
Uncoated Control (X1)	50% corrosion visible on top bar after 12 month testing
Uncoated Control (X2)	60% corrosion visible on top bar after 12 month testing
Uncoated Control (X3)	90% corrosion visible on top bar after 12 month testing



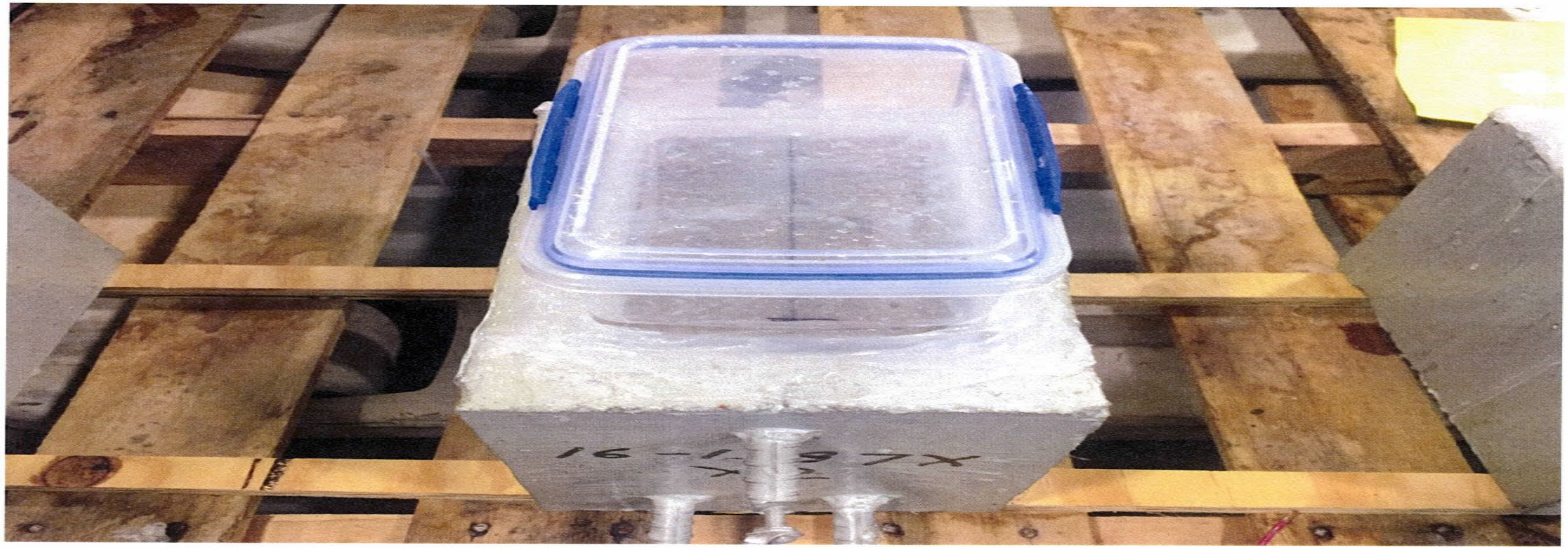
FHWA HRT-07-043 – Total Corrosion Comparison (coulombs vs. time, months)

NELSON TESTING LABORATORIES

Pictures – FHWA-HRT-07-043 Specimens

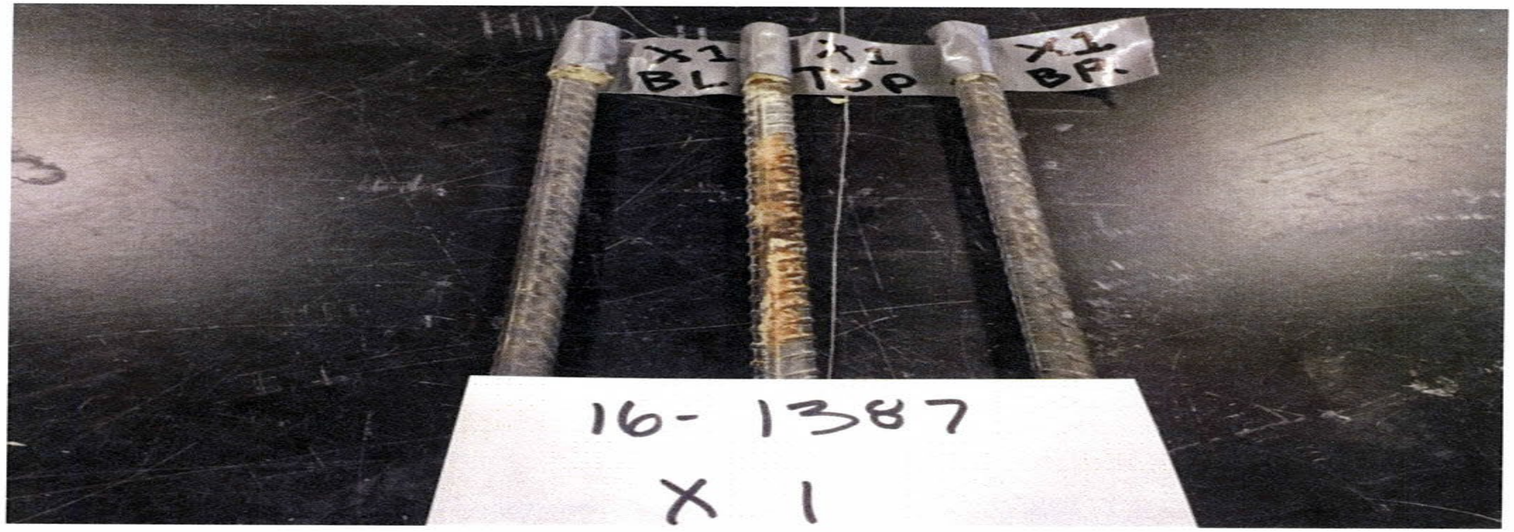


Pictures – FHWA-HRT-07-043 Specimens

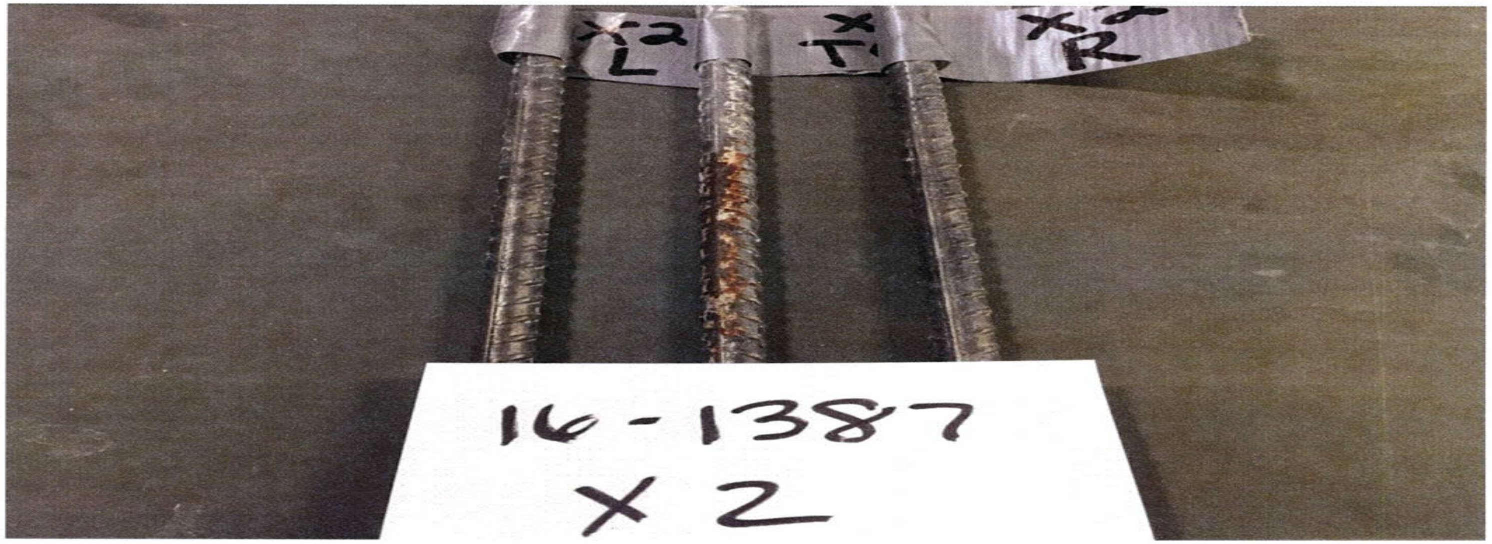


NELSON TESTING LABORATORIES

Pictures – FHWA-HRT-07-043 – After Testing – Control (X1)



Pictures – FHWA-HRT-07-043 – After Testing – Control (X2)



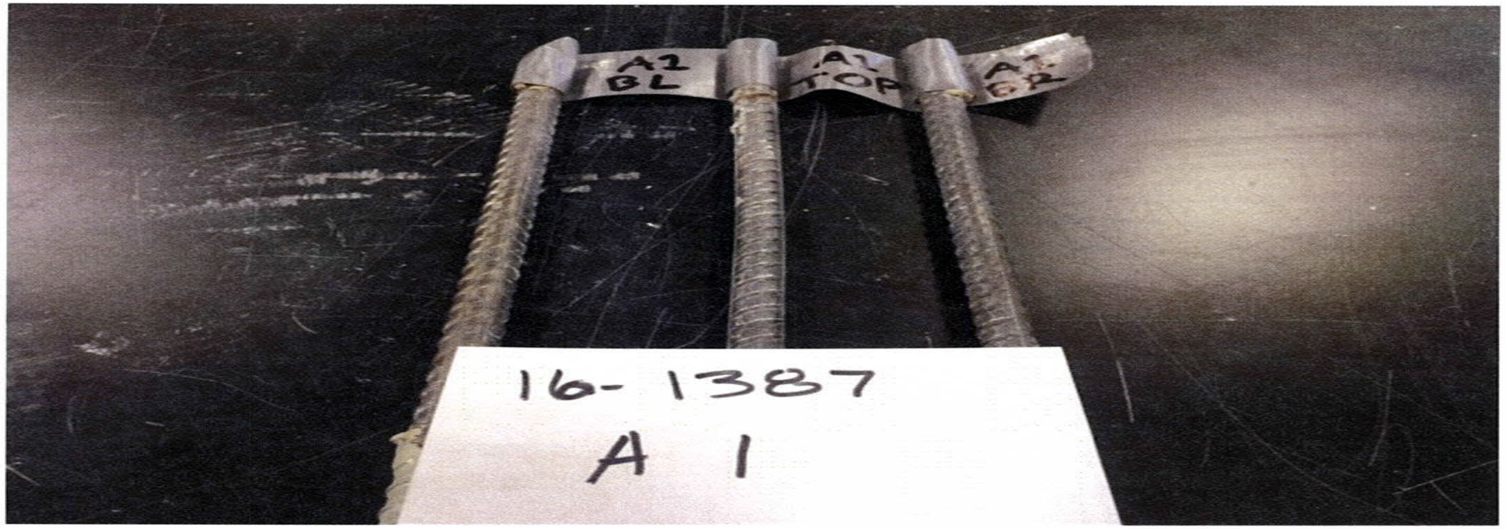
NELSON TESTING LABORATORIES

Pictures – FHWA-HRT-07-043 – After Testing – Control (X3)

NELSON TESTING LABORATORIES

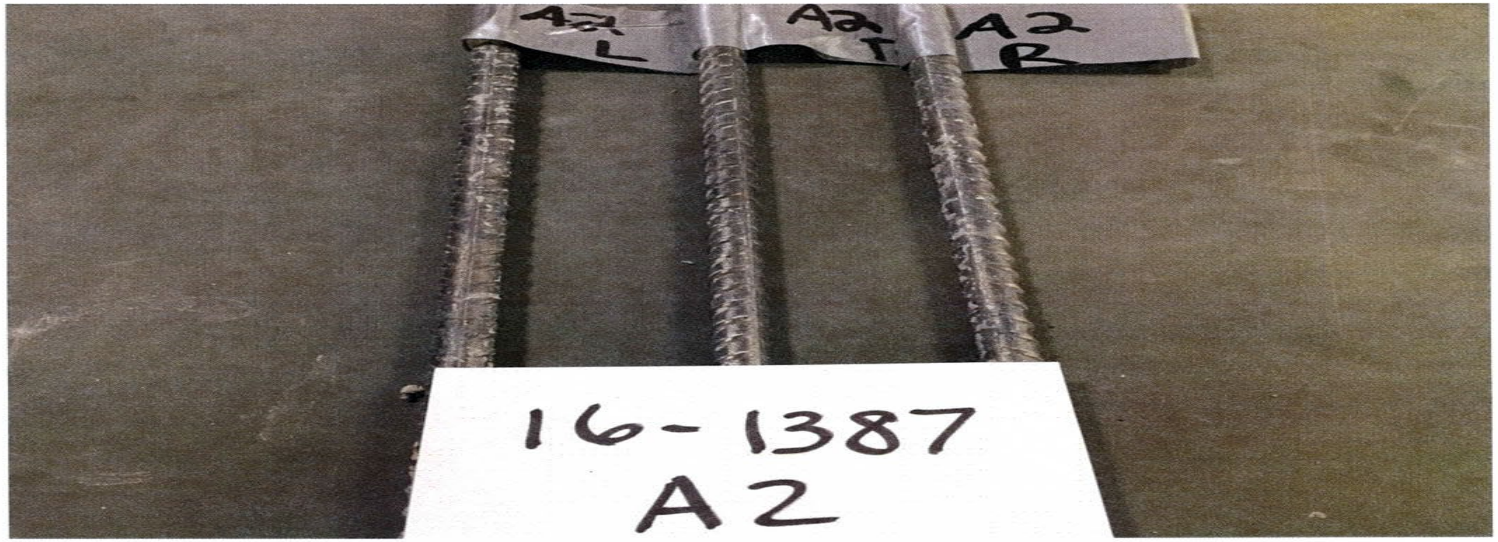
May 10, 2018
ACT - SIL-ACT SIL-COR
NTL Project #16-1387

Pictures – FHWA-HRT-07-043 – After Testing – Sil-Act CI (A1)

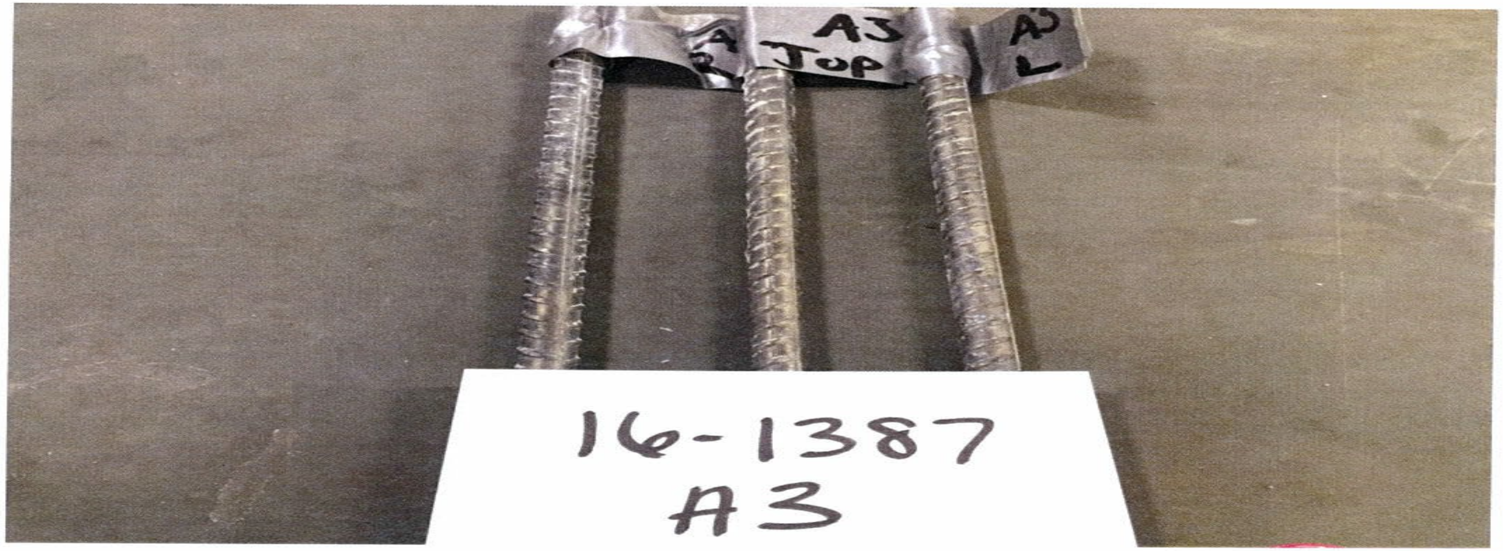


NELSON TESTING LABORATORIES

Pictures – FHWA-HRT-07-043 – After Testing – Sil-Act CI (A2)



Pictures – FHWA-HRT-07-043 – After Testing – Sil-Act CI (A3)



QUESTIONS?

Thank you

Tim Woolery
Advanced Chemical Technologies