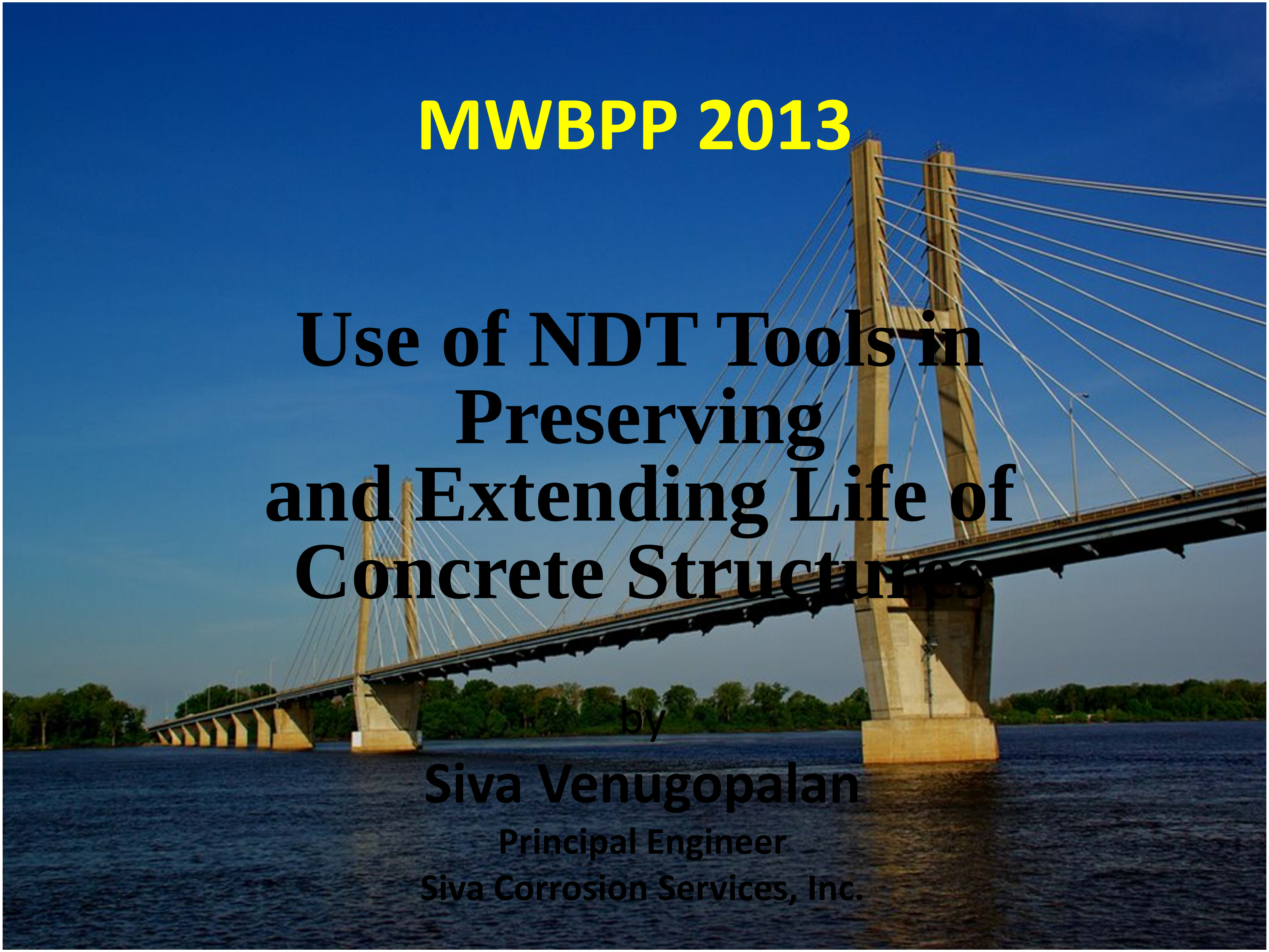


MWBPP 2013

Use of NDT Tools in Preserving and Extending Life of Concrete Structures

by

Siva Venugopalan

Principal Engineer

Siva Corrosion Services, Inc.

FHWA Preservation Guide

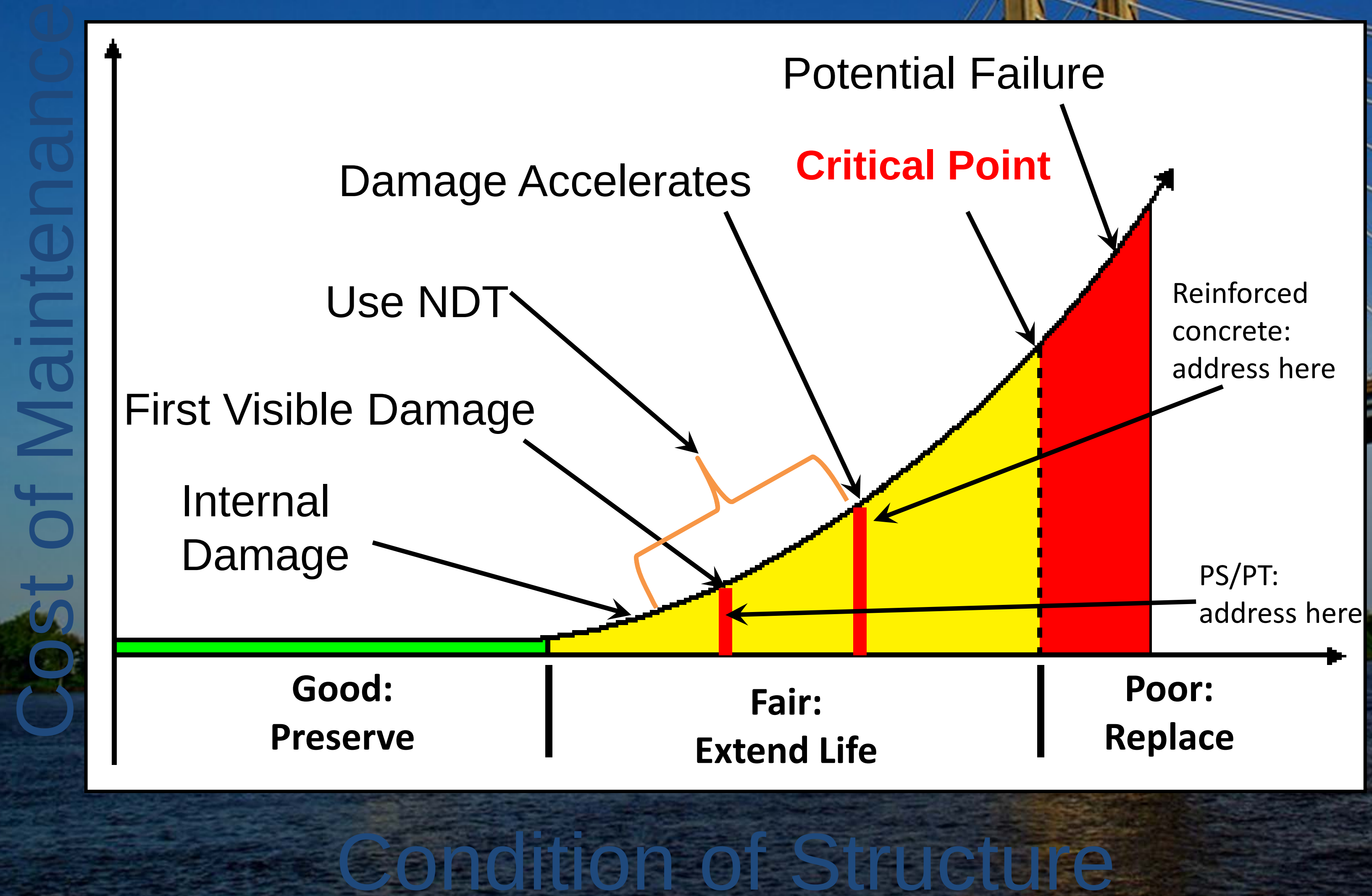
- Bridge preservation is defined as actions or strategies that **prevent, delay or reduce deterioration of bridges or bridge elements**, restore the function of existing bridges, **keep bridges in good condition and extend their life.** Preservation actions may be preventive or condition-driven. ***Source: FHWA Bridge Preservation Expert Task Group, May 2011.***

Bridge Preservation

- When a bridge experiences corrosion, we want to answer the questions:
  - What is the primary factor contributing to deterioration?
  - What is the current and future rate of deterioration?
  - Are there options to extend the service life by another 25 to 50 years?
- Develop a strategic inspection/evaluation plan to identify/quantify problems
- Average preservation cost : **75-80%** compared to replacement


Agenda
• Corrosion Deterioration & Cost
• Bridge Preservation using NDT
• Case Studies
➢Cable Stay Bridge
➢Deck Overlay Deterioration
• Conclusions

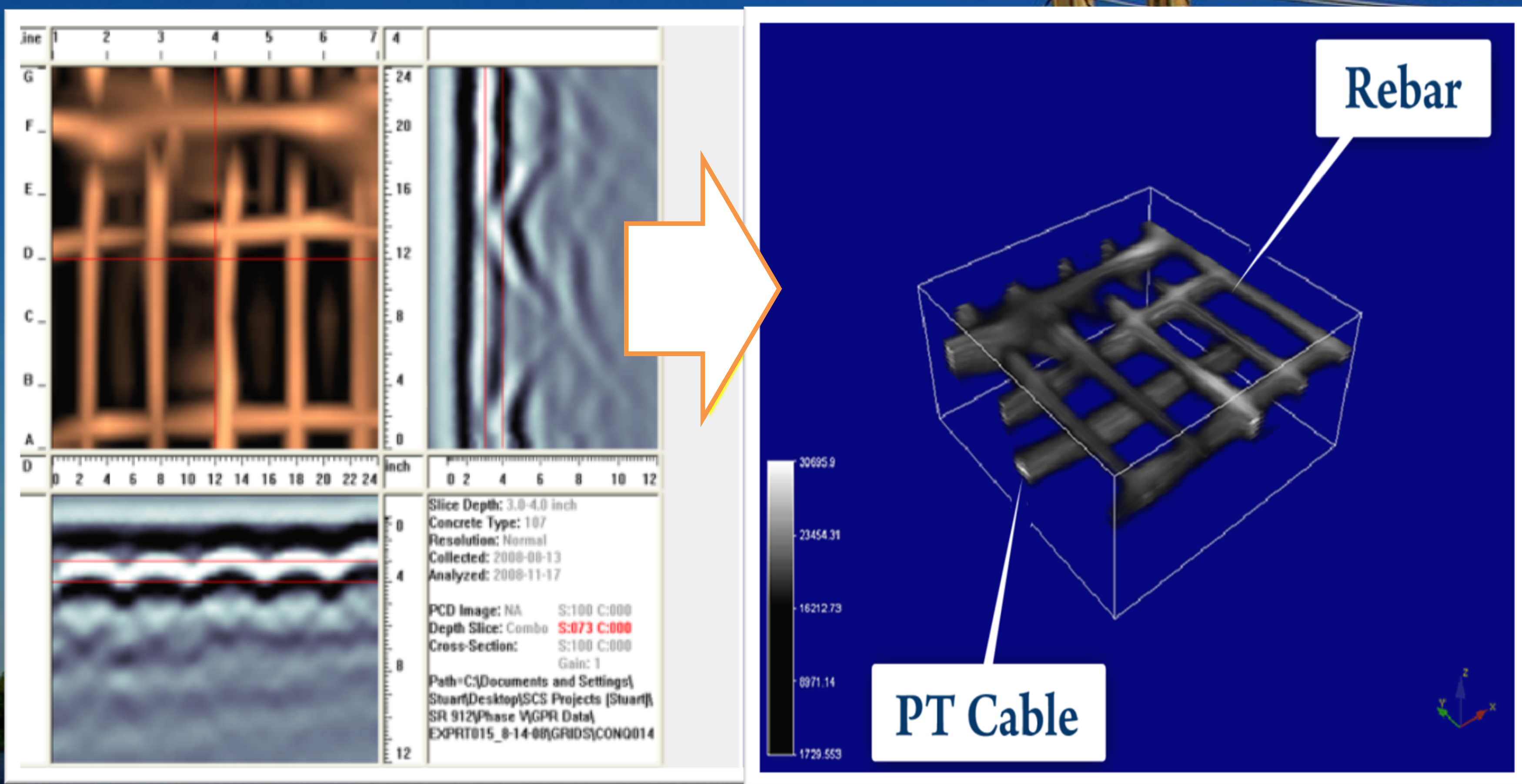
Corrosion Deterioration & Cost



Non-Destructive Testing (NDT)

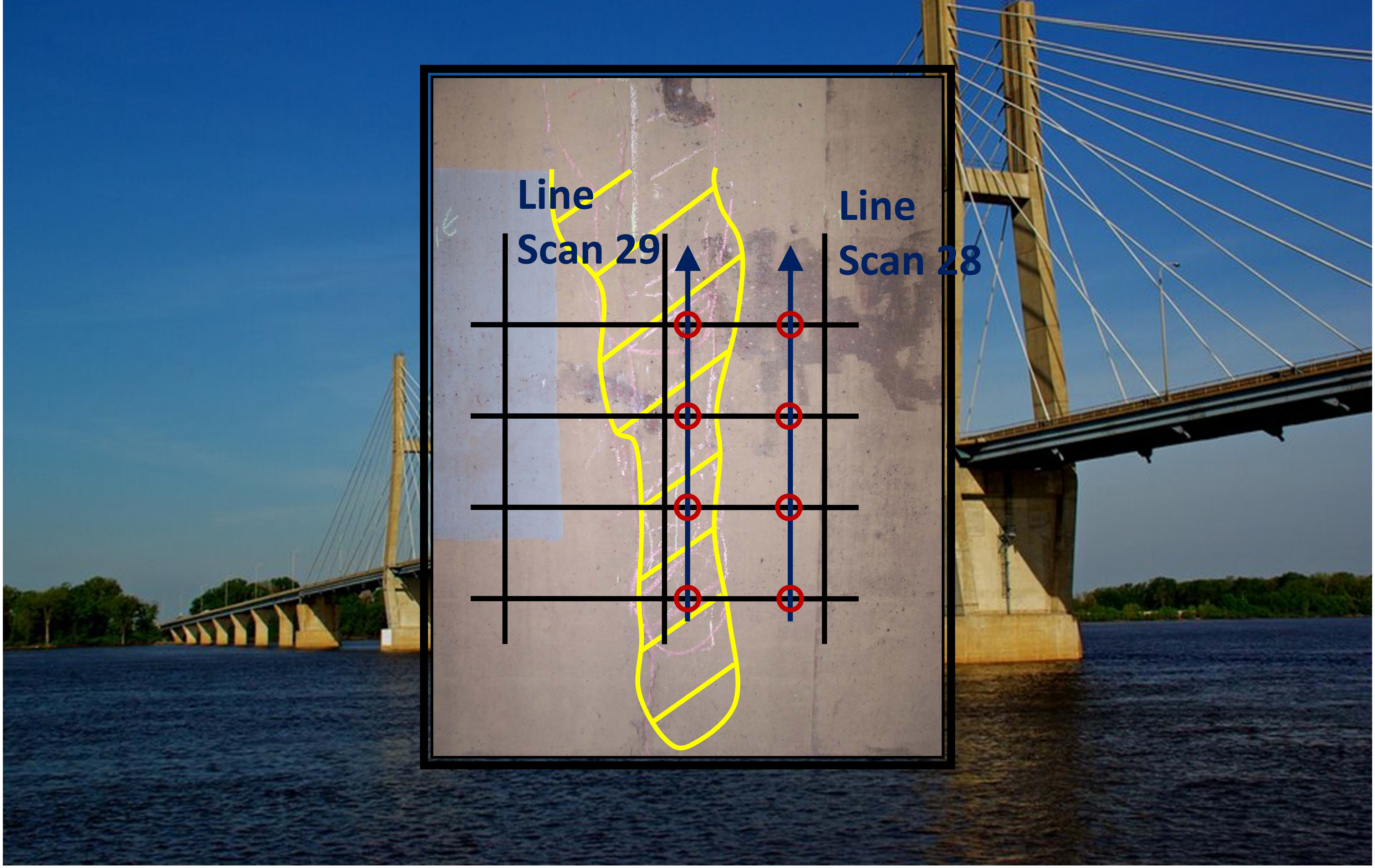
- Use NDT to identify hidden problems
- Minimize inspection time and damage to the structure
- Primary NDT tools:
  - Ground Penetrating Radar (GPR)
  - Infrared Thermography
  - Impact-Echo
  - Ultrasonic Tomography
  - Stat Test (Electrical Impedance Test for PT Strands and Rods)
  - Sensors
  - Service Life Estimates

Ground Penetrating Radar (GPR)

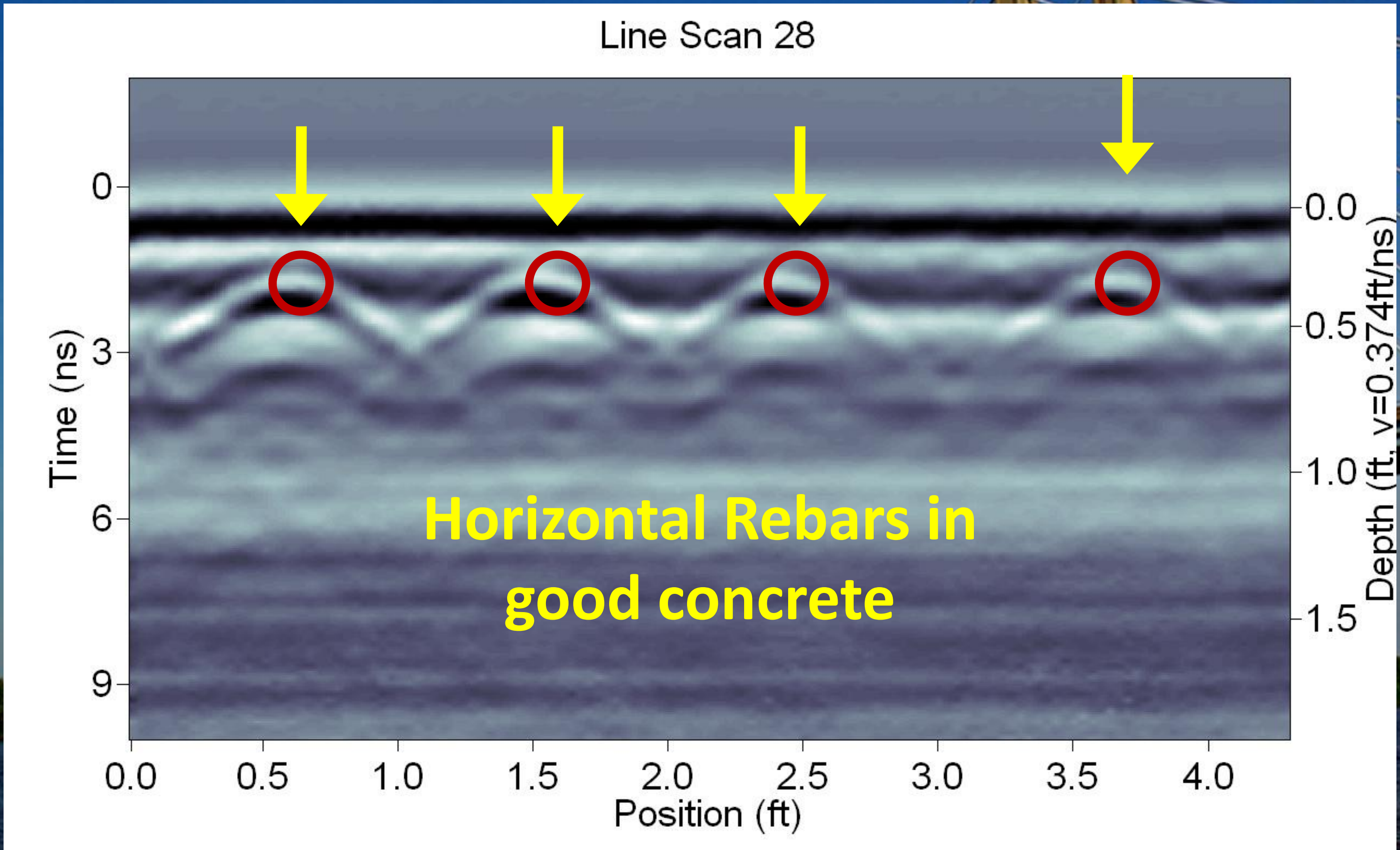


Delamination Survey

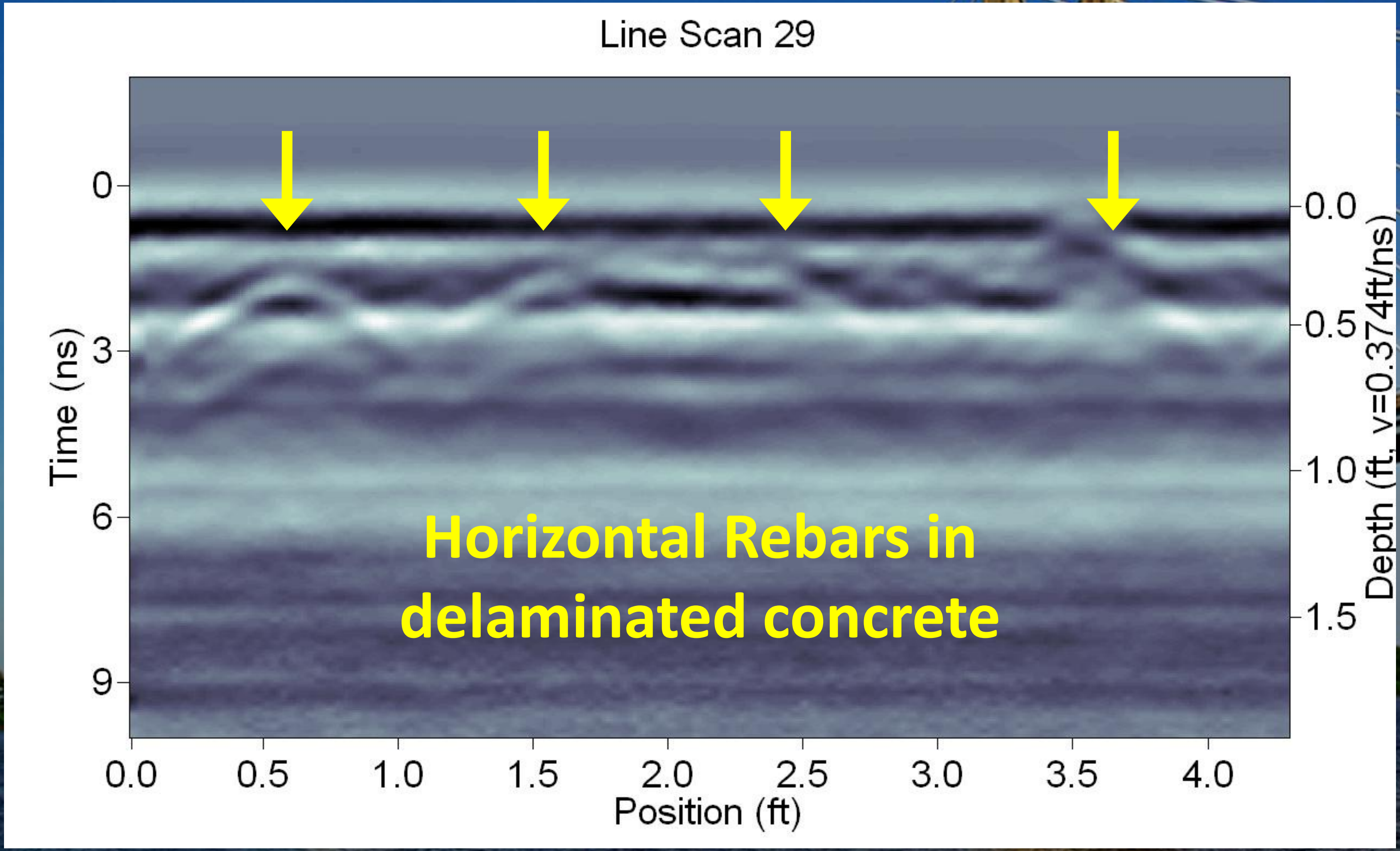
GPR Evaluation



GPR Evaluation



GPR Evaluation

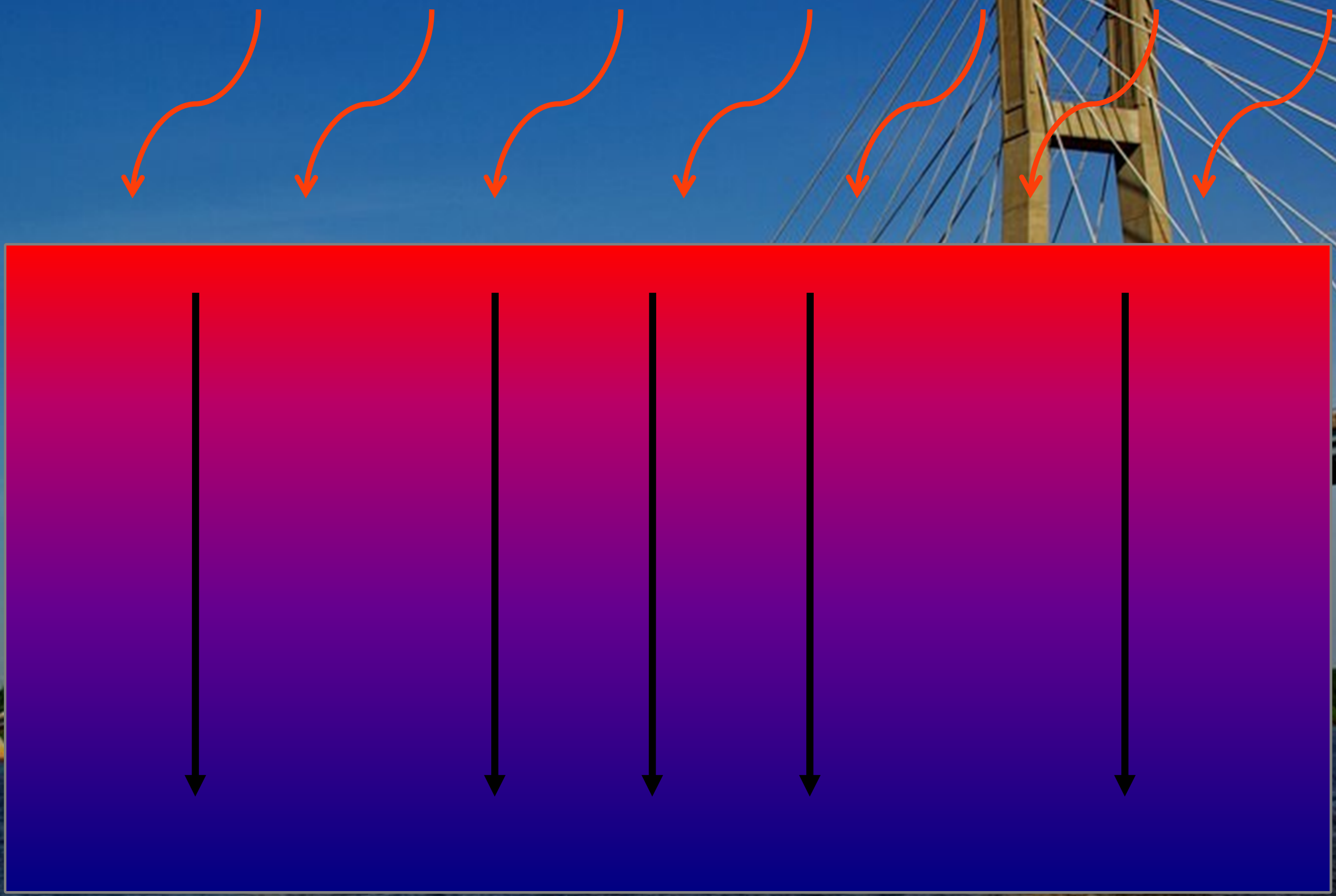


GPR at Traffic Speed

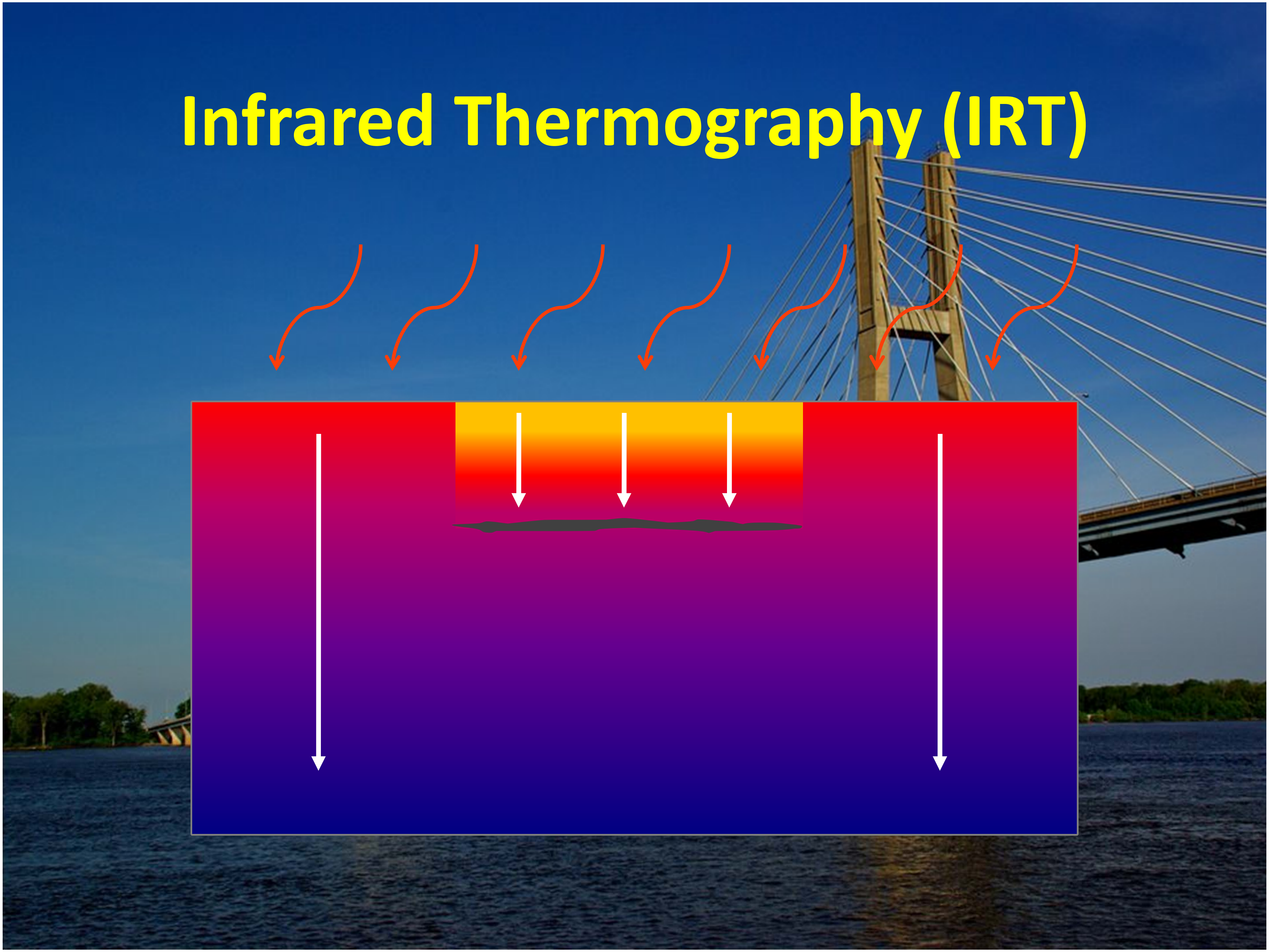
Application of GPR

- Inspect a deck/pavement without traffic control
- Examine for delamination/corrosion hot spots/pavement thickness
- Flag problem areas for further evaluation
- Inspect decks with overlays and membranes

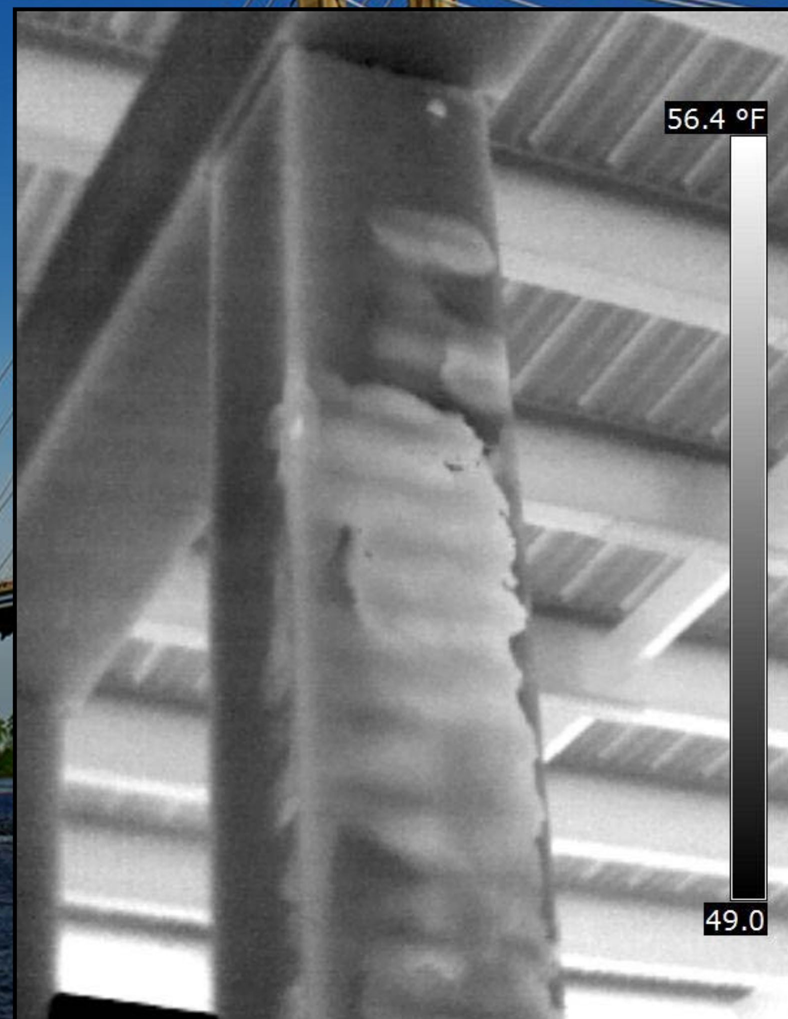
Infrared Thermography (IRT)



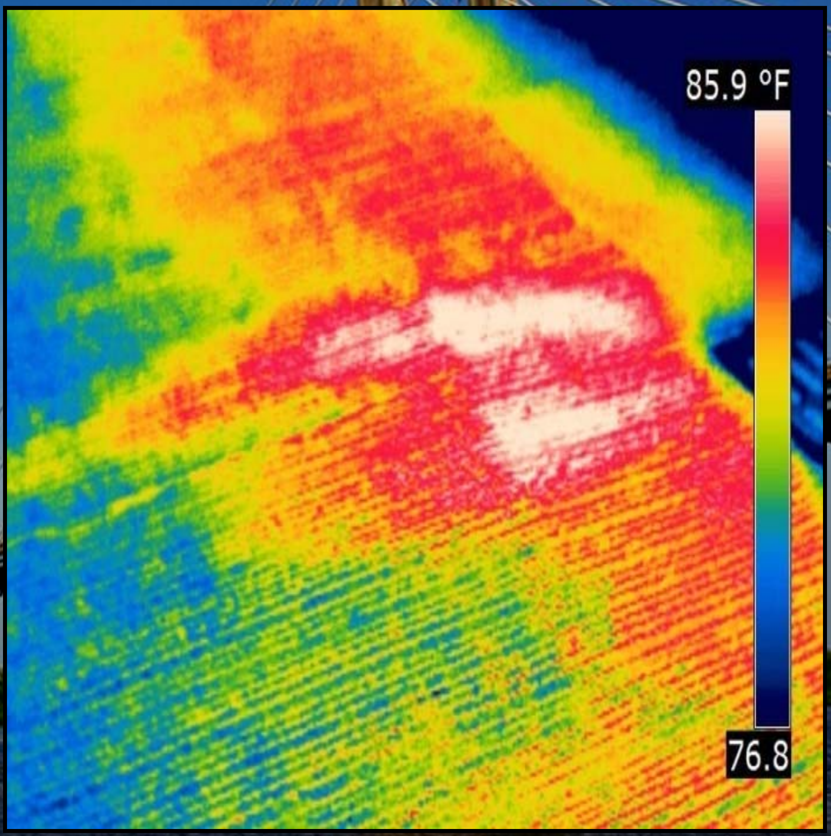
Infrared Thermography (IRT)



IRT Results



IRT Results

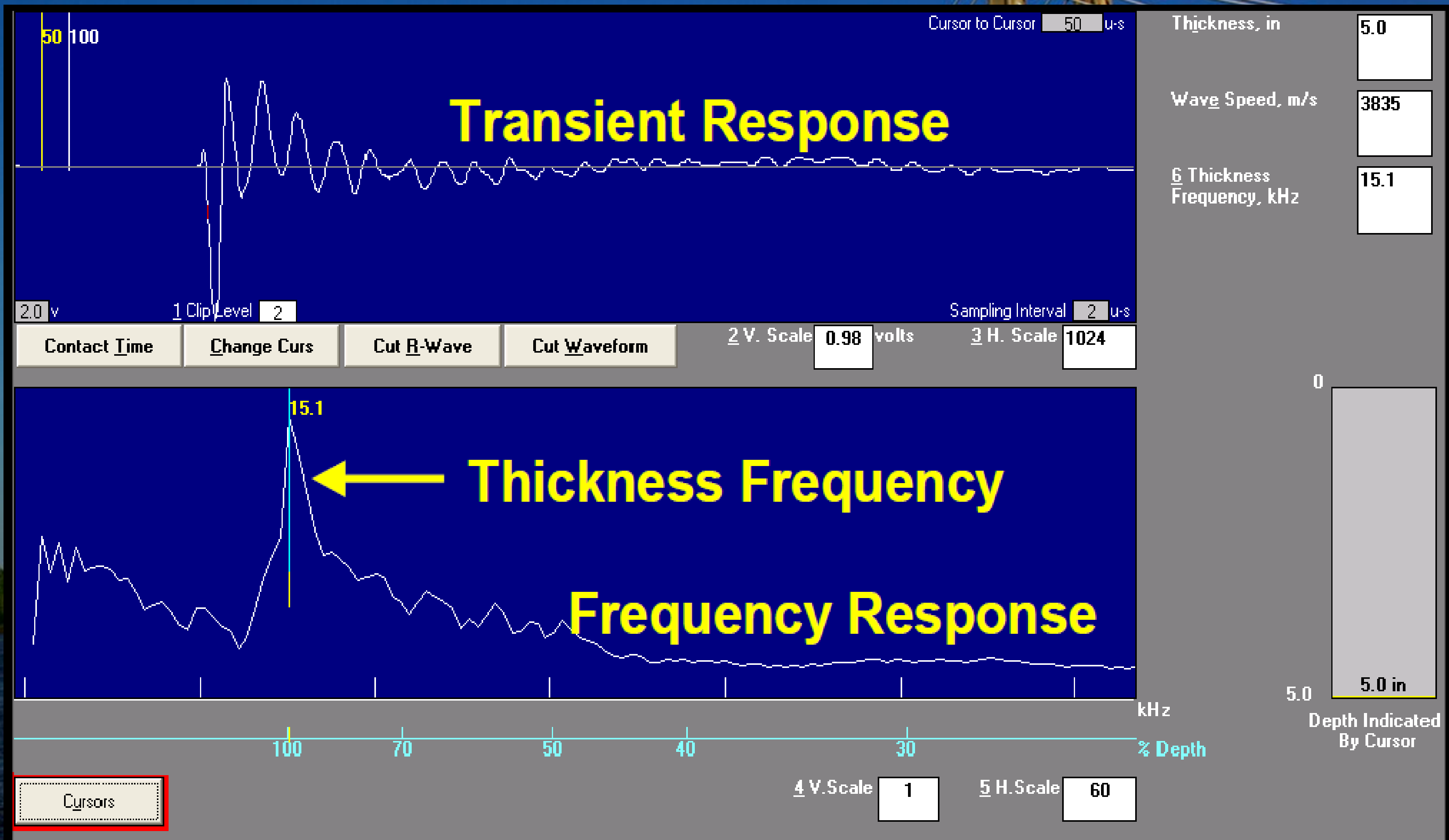


IRT Results

Impact Echo

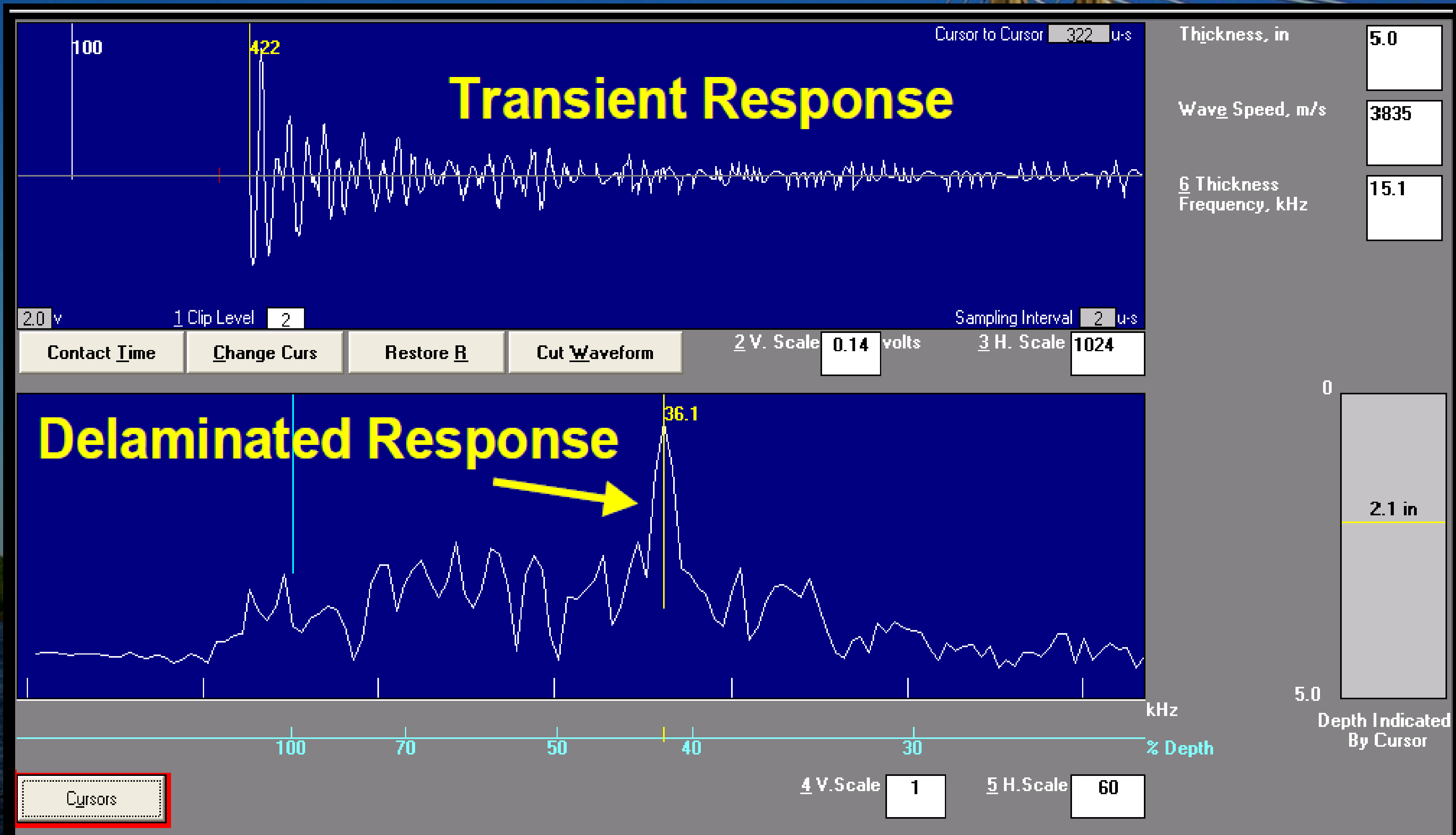
- Find flaws not detectable by GPR and provide more information about those flaws
- Well suited for structures with access constraints and multiple layers of materials (e.g. overlays)

IE Results



Cursor to Cursor 50 u-s
50 100
Transient Response
2.0 v
1 Clip Level 2
Sampling Interval 2 u-s
Thickness, in 5.0
Wave Speed, m/s 3835
6 Thickness Frequency, kHz 15.1
Contact Time
Change Curs
Cut R-Wave
Cut Waveform
2 V. Scale 0.98 volts
3 H. Scale 1024
15.1
Thickness Frequency
Frequency Response
kHz
100
70
50
40
30
% Depth
0
5.0
5.0 in
Depth Indicated By Cursor
Cursors
4 V.Scale 1
5 H.Scale 60

IE Results

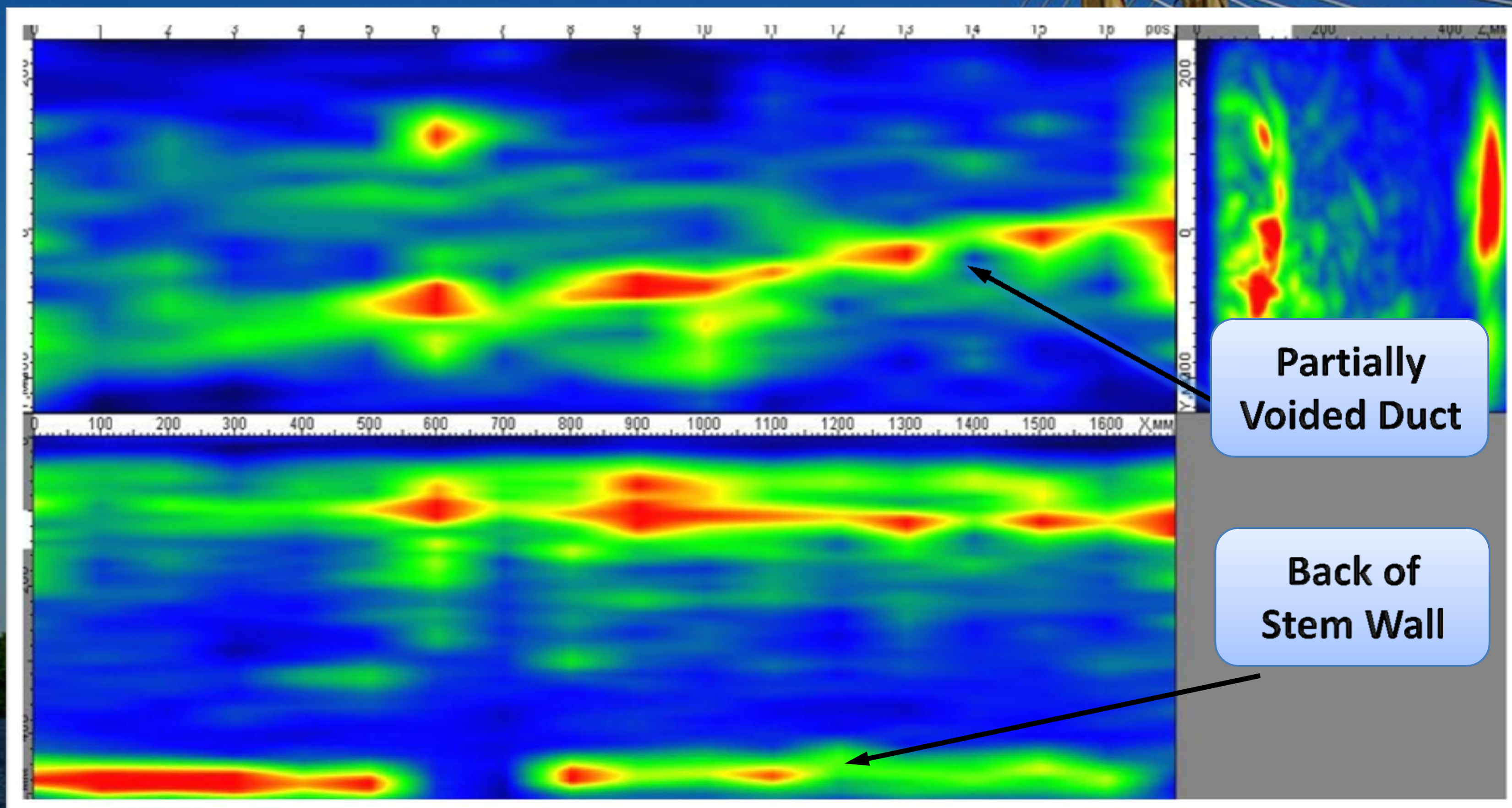


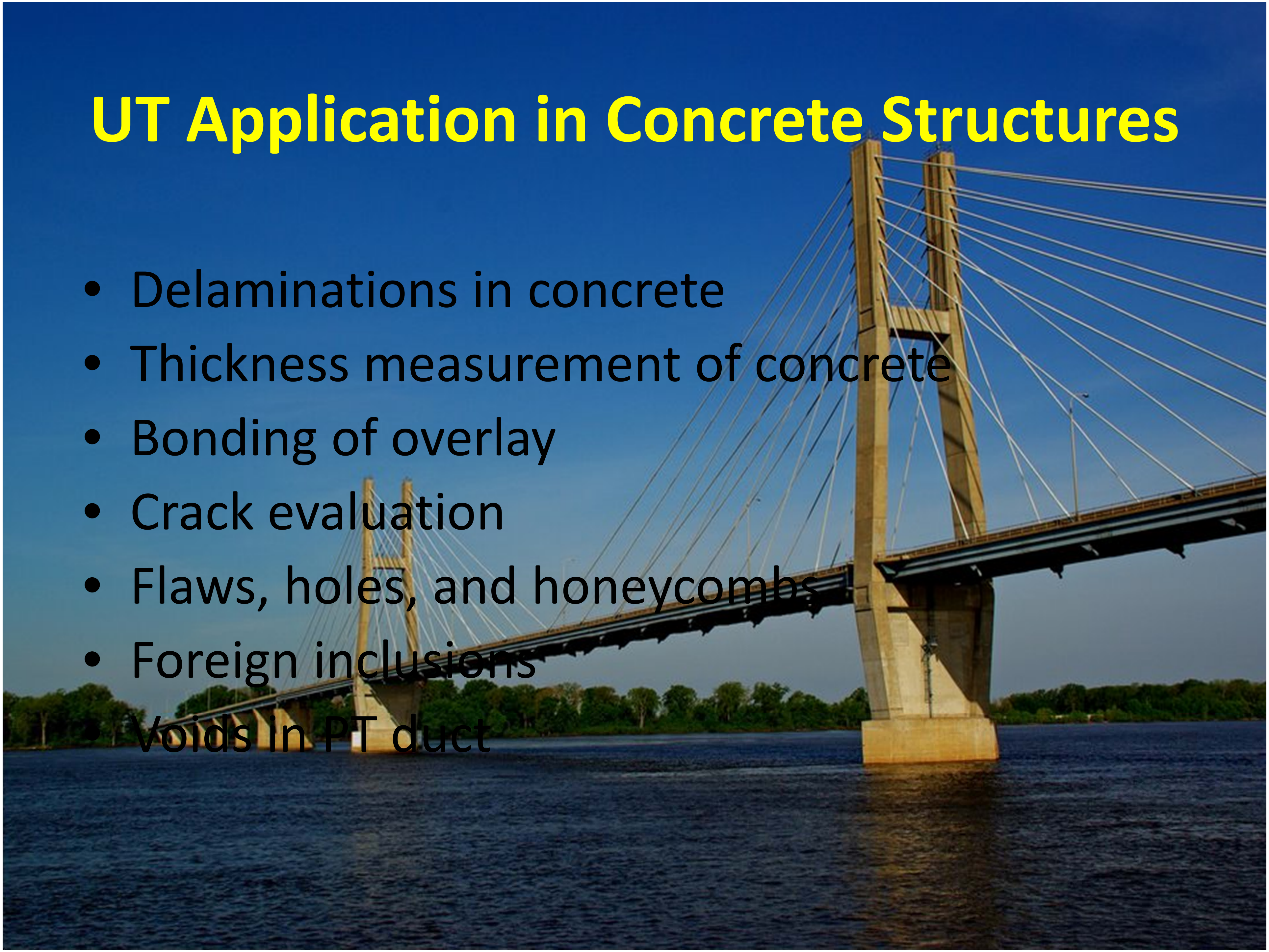
100
422
Cursor to Cursor 322 u-s
Transient Response
2.0 v
1 Clip Level 2
Sampling Interval 2 u-s
Contact Time
Change Curs
Restore R
Cut Waveform
2 V. Scale 0.14 volts
3 H. Scale 1024
Thickness, in 5.0
Wave Speed, m/s 3835
6 Thickness Frequency, kHz 15.1
Delaminated Response
36.1
kHz
100
70
50
40
30
% Depth
0
2.1 in
5.0
Depth Indicated By Cursor
Cursors
4 V.Scale 1
5 H.Scale 60

Ultrasonic Tomography (UT)

Ultrasonic Tomography

UT Results





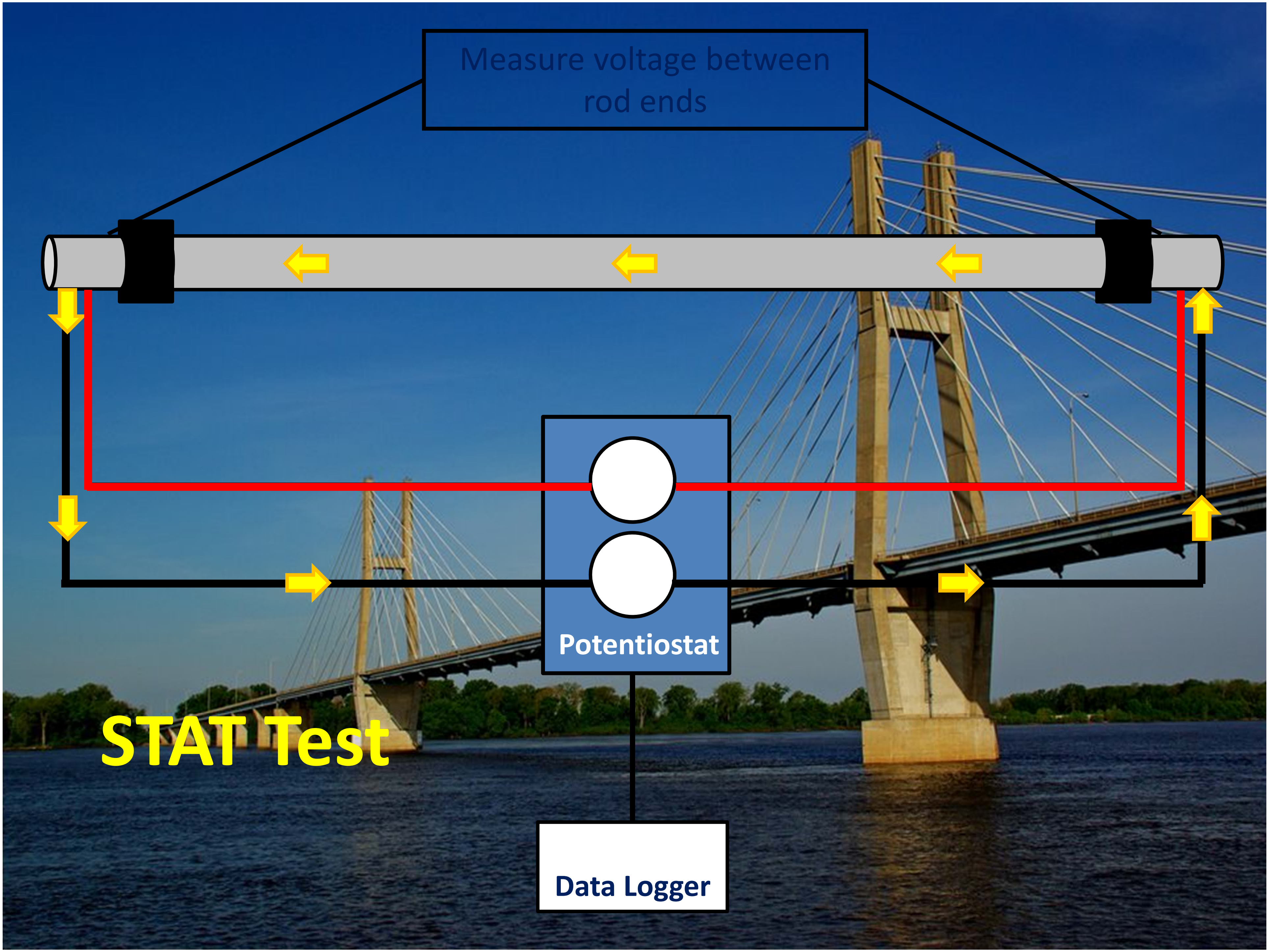
UT Application in Concrete Structures

- Delaminations in concrete
- Thickness measurement of concrete
- Bonding of overlay
- Crack evaluation
- Flaws, holes, and honeycombs
- Foreign inclusions
- Voids in PT duct

STAT Test

To identify:

- Severely corroded or broken strand in PT structures
- Severely corroded or broken PT rods
- Combination of STAT test results and statistical analysis to identify corroded strands/rods



Measure voltage between rod ends
Potentiostat
Data Logger
STAT Test

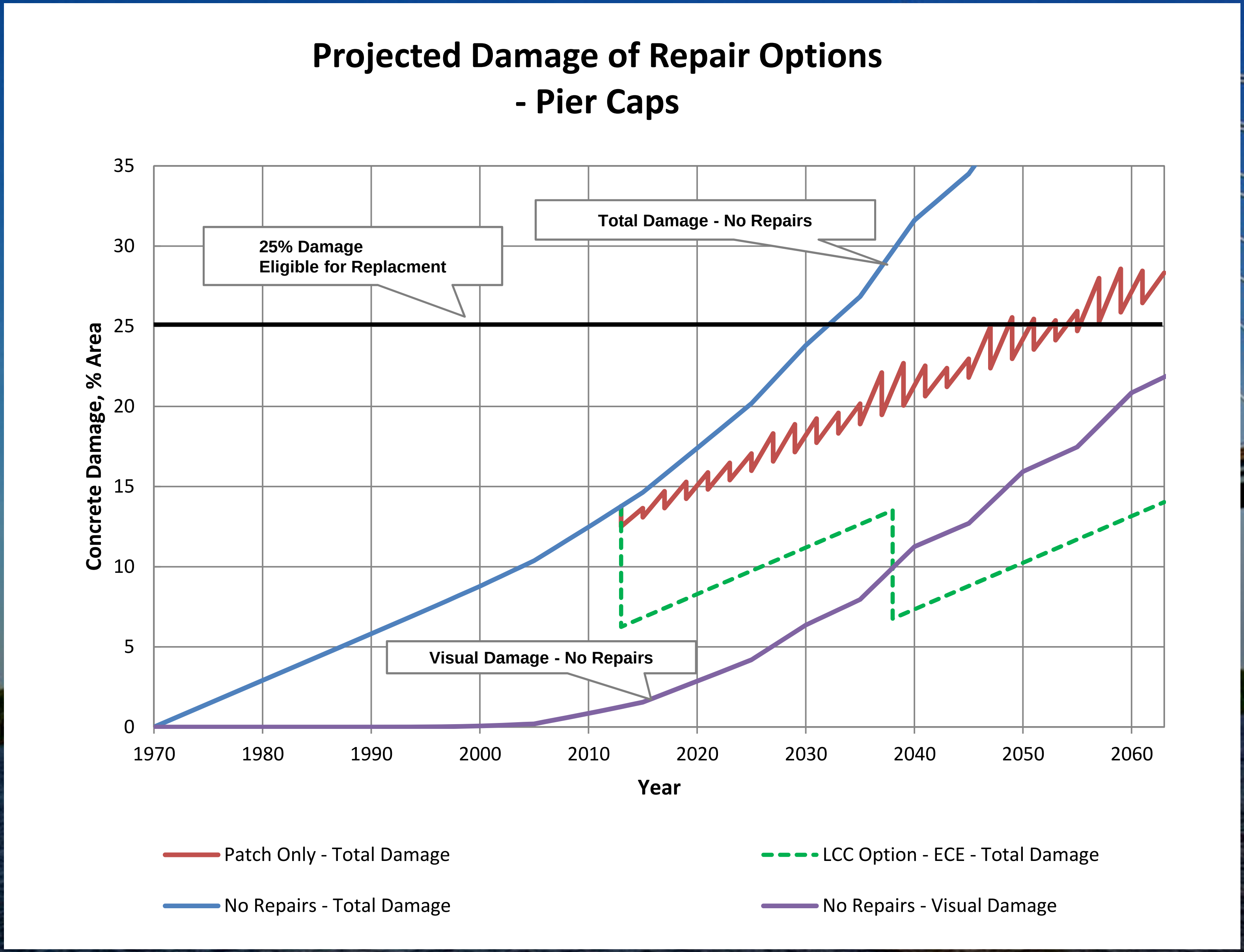
Service Life Estimate

- Applicable to new and existing infrastructure
- Calculate future concrete damage based on current existing condition
- Impact of protection solutions on the service life :
  - Sealers
  - Membranes
  - Thin and Rigid overlays
  - Coatings
  - High Performance Concrete
  - Corrosion Mitigation (GCP, ICCP, ECE)

Service Life Estimate

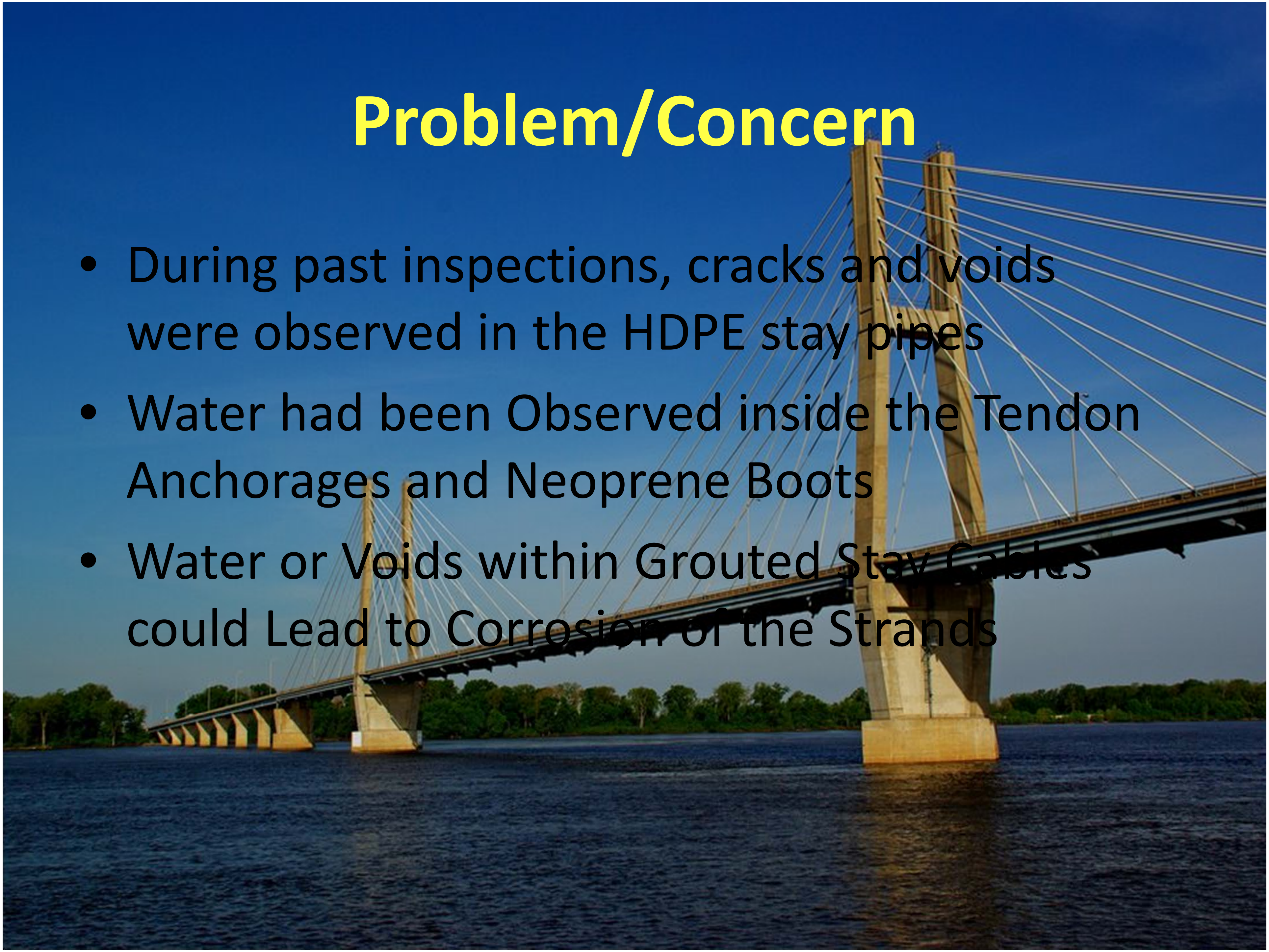
- Corrosion thresholds for different types of rebar
- Concrete mixtures properties
- Exposure conditions
- Comparisons of what-if scenarios
- Ion transport characteristics
- Effects of temperature

Service Life – For Mitigation Options



Case Study 1 : Cable Stay Bridge

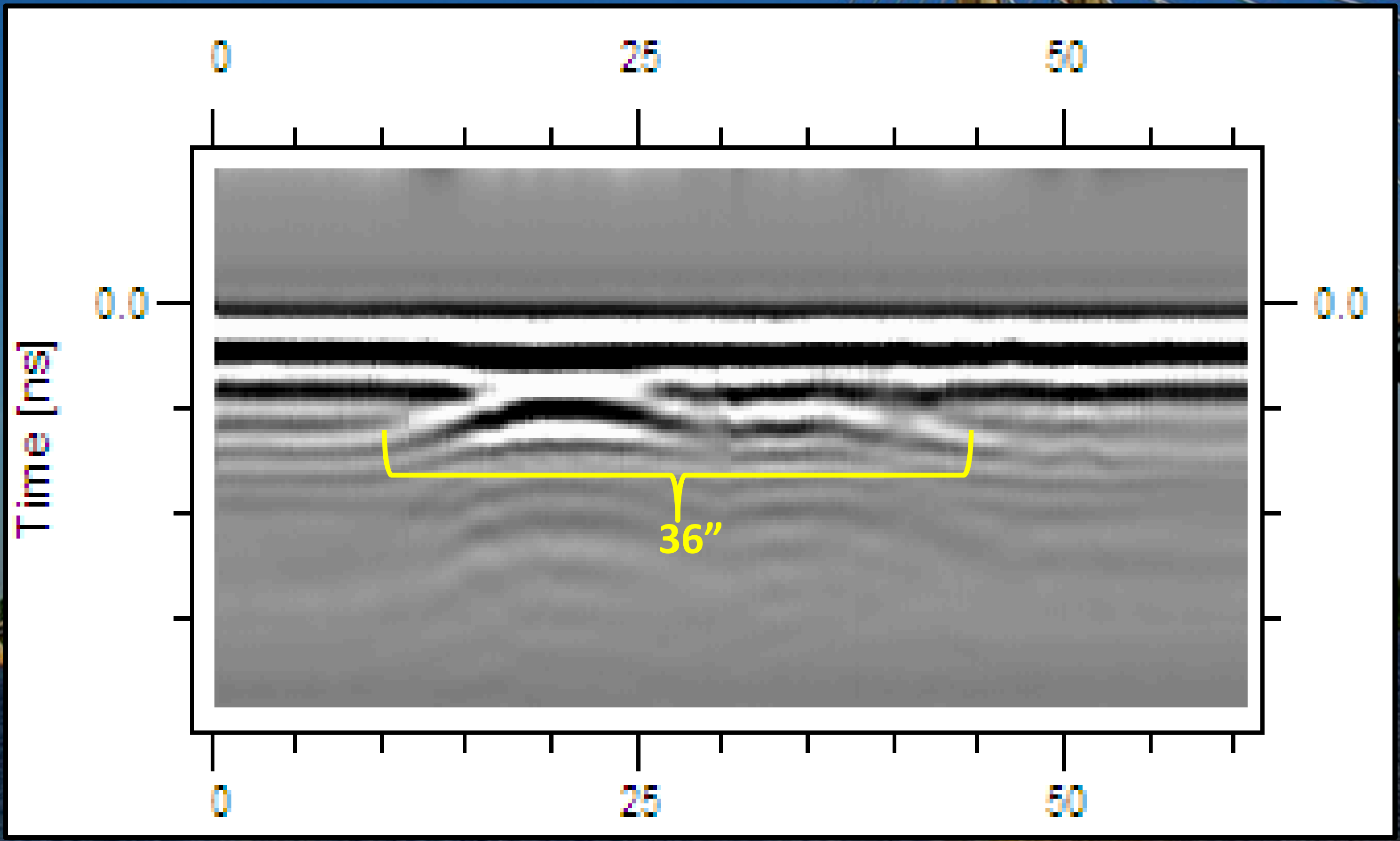
Problem/Concern



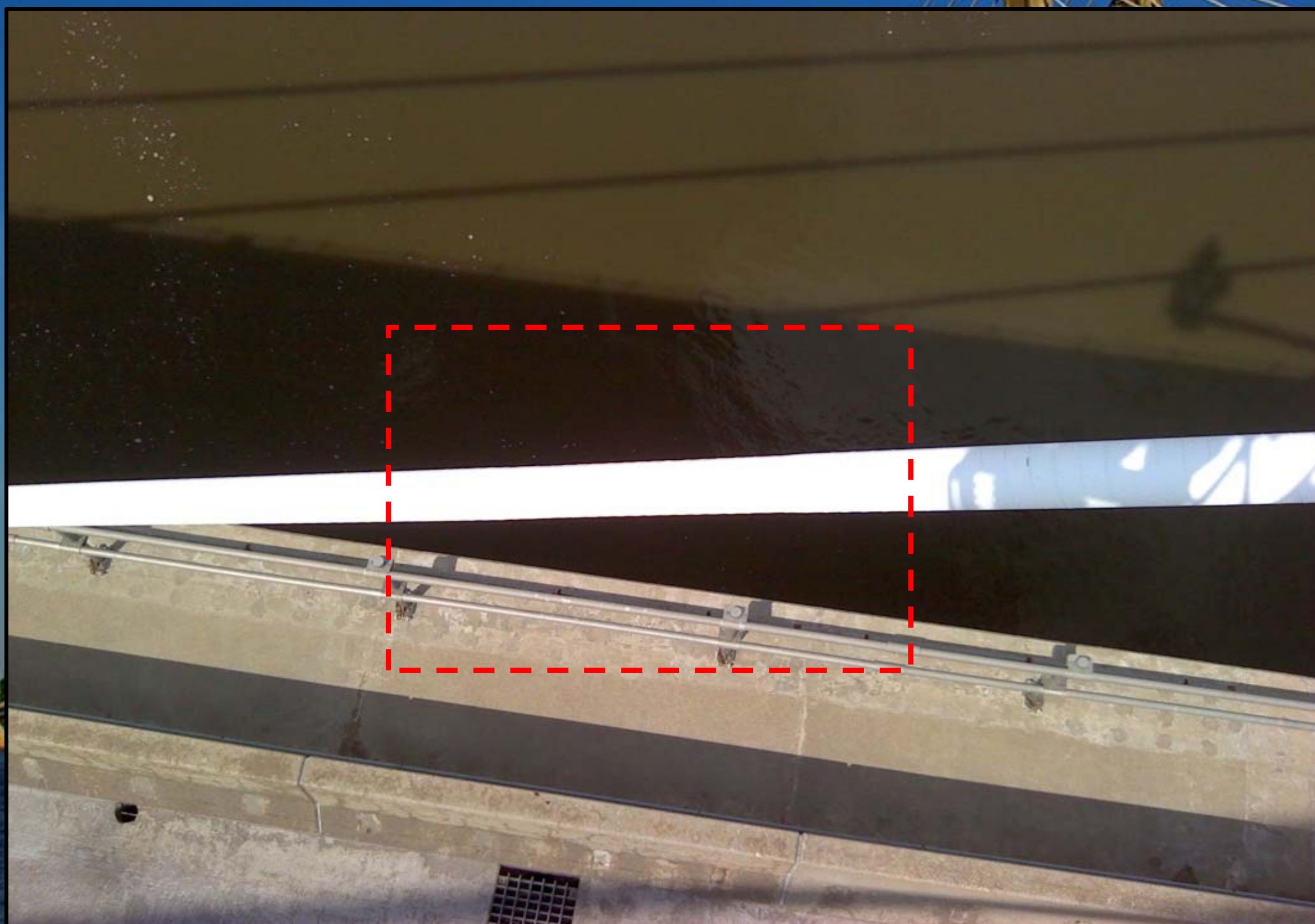
- During past inspections, cracks and voids were observed in the HDPE stay pipes
- Water had been Observed inside the Tendon Anchorages and Neoprene Boots
- Water or Voids within Grouted Stay Cables could Lead to Corrosion of the Strands

GPR & IR – Cable Stay Bridge

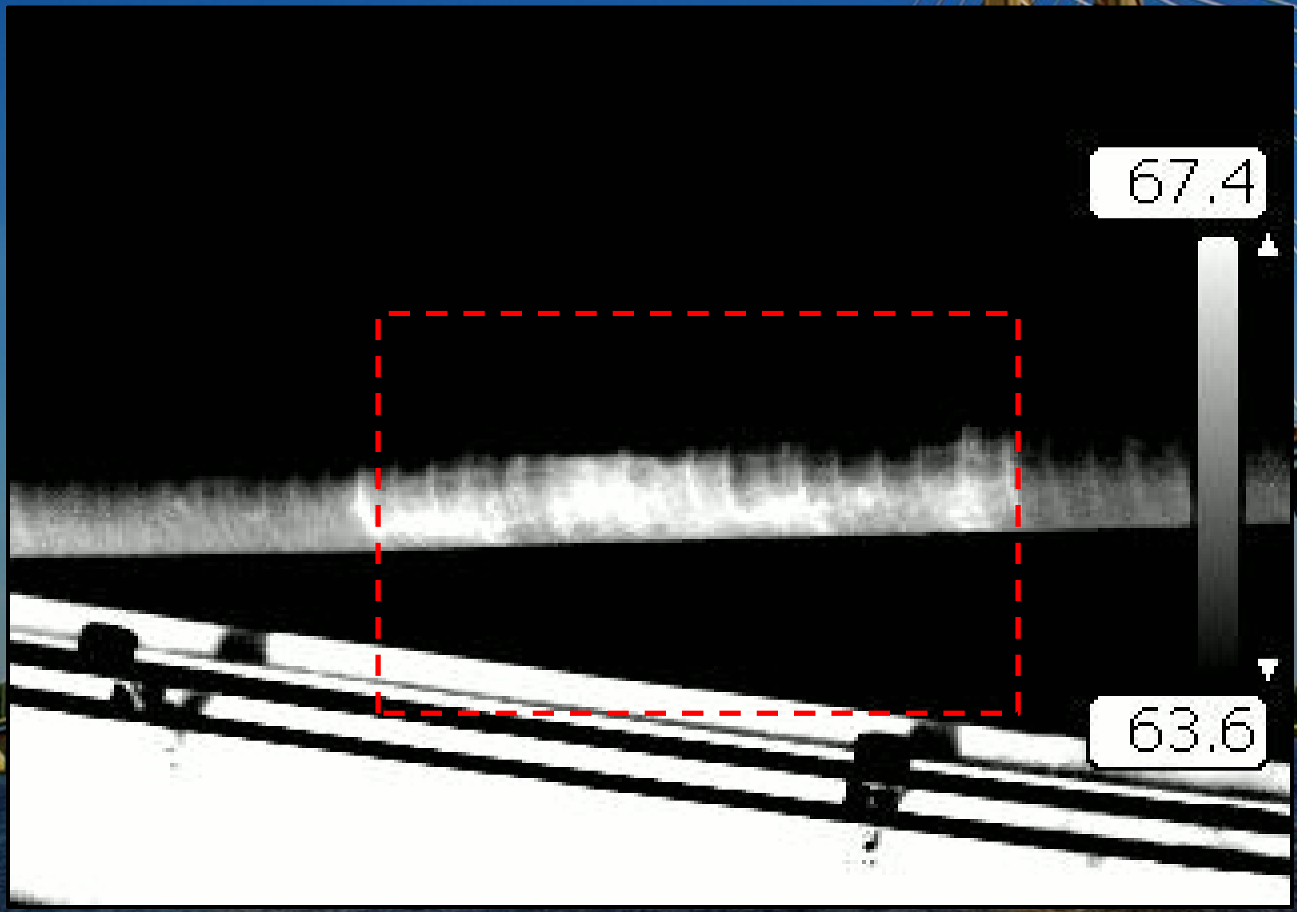
GPR & IR – Cable Stay Bridge



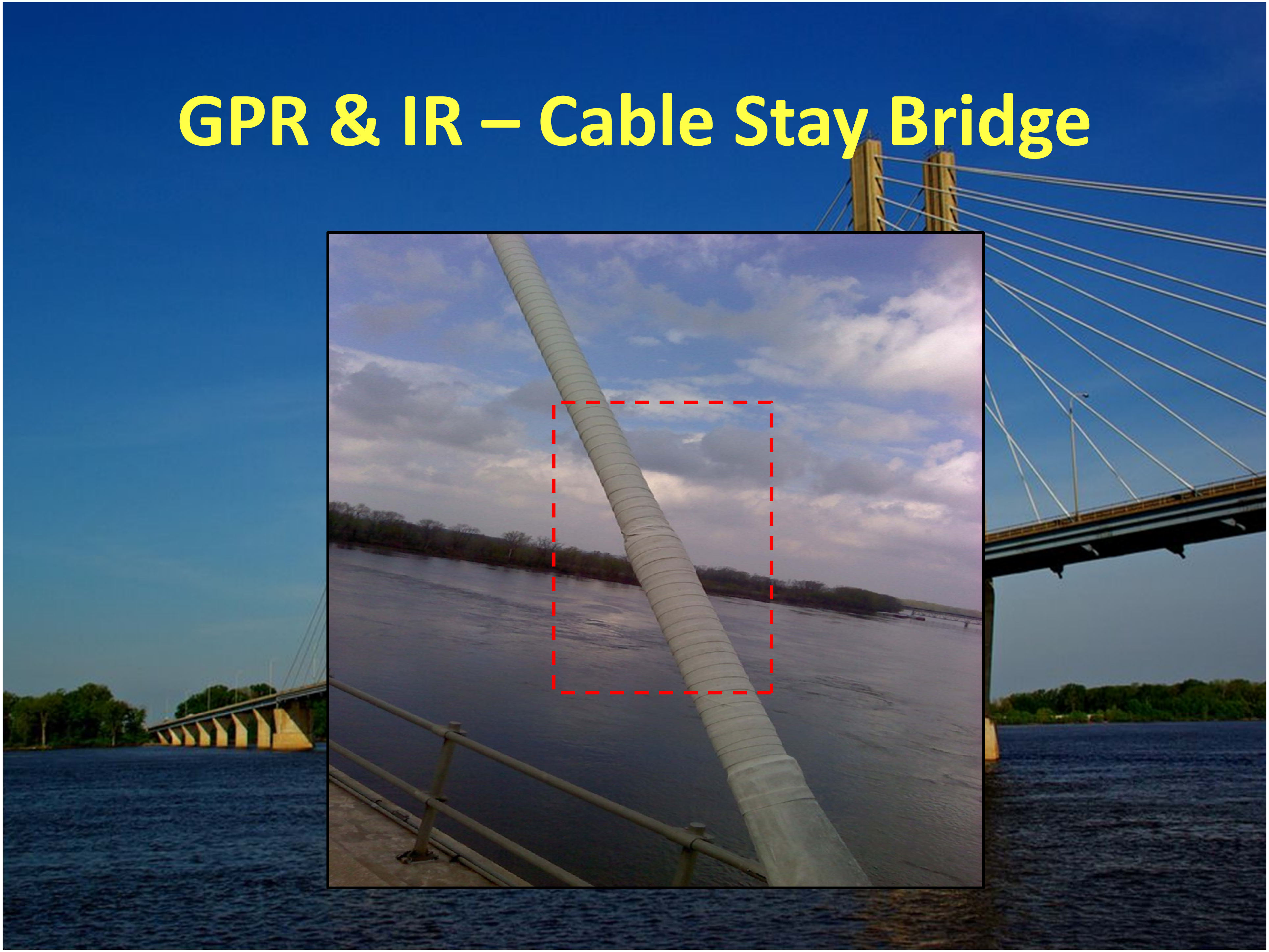
GPR & IR – Cable Stay Bridge



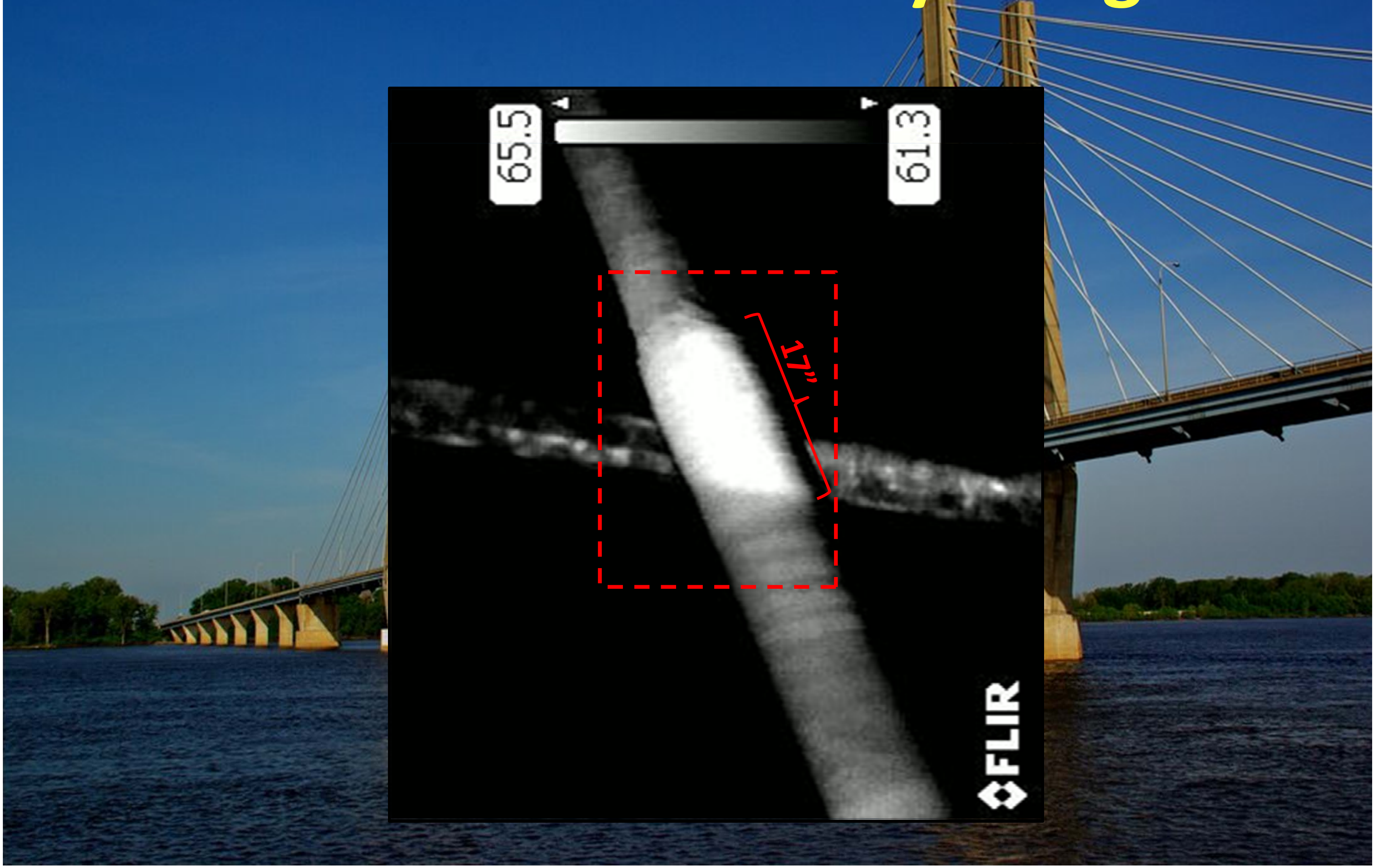
GPR & IR – Cable Stay Bridge



GPR & IR – Cable Stay Bridge



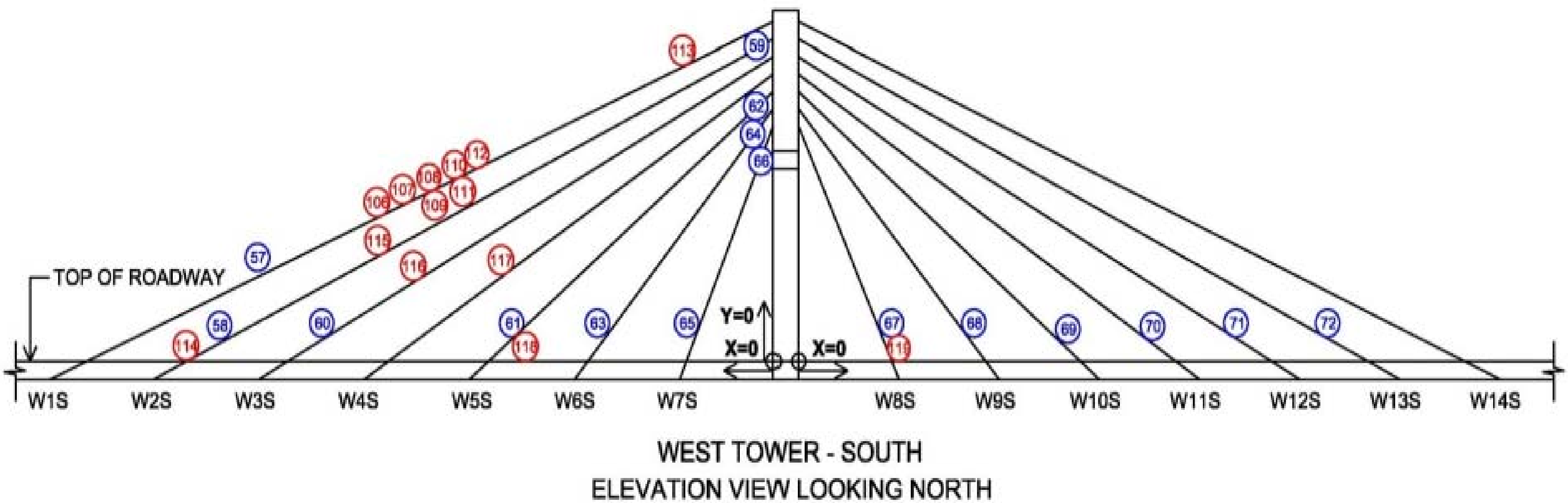
GPR & IR – Cable Stay Bridge



GPR & IR – Cable Stay Bridge

Elastomeric Cable Wrap System on PE Cables (not damaged by NDT)

Cable Stay Bridge – Deficiency Location



(#) ITEM # IN TABLE OF CABLE DEFICIENCIES - MARKED BY SCS PHASE I

(#) ITEM # IN TABLE OF CABLE DEFICIENCIES - MARKED BY SCS PHASE II

Cable Stay Bridge – Deficiency Table

A2 : CABLE DEFICIENCIES

SCS Project #: 10048-02 YEAR: 2012

ITEM #	CABLE	LOCATION	IMAGE	DEFICIENCY	PHASE
1	E1N	Top of lower PE pipe sleeve	N/A	19" void	I
2	E1N	20' above deck	2647	40" void; cracked pipe**	I
73	**E1N**	**20' above deck**	**1204240004**	**¼" void at top of cable; dry top half of one strand was visible; grout around void was cracked; no visible corrosion (Image 1)**	**II**
74	**E1N**	**87' above deck**	**100_3667**	**19" void (Image 2)**	**II**
3	E3N	Top of lower PE pipe sleeve	N/A	16" void	I
75	**E3N**	**69' above deck**	**100_3662**	**20" void (Image 3, 4)**	**II**
4	E4N	Top of lower PE pipe sleeve	N/A	11" void	I
5	E5N	Top of lower PE pipe sleeve	N/A	12" void	I
6	E6N	Top of lower PE pipe sleeve	N/A	13" void	I
76	E7N	Lower Boot	100_3650	Cut at bottom of boot; wet to the touch	II
7	E7N	Top of lower PE pipe sleeve	N/A	13" void	I
8	E7N	~40-50' above deck	SS 1	Butt weld	I
9	E8N	Top of lower PE pipe sleeve	N/A	16" void	I
77	**E8N**	**8' above deck**	**1205180030**	**3/8" gap between pipes; grout observed lower down in pipe sleeve (Image 5)**	**II**
10	E9N	Top of lower PE pipe sleeve	N/A	32" void	I
11	E10N	Top of lower PE pipe sleeve	N/A	19" void	I
78	E10N	8' above deck	1205180024	5/16" gap between pipes; grout observed lower down in pipe sleeve	II
79	E10N	15' above acoustic sensor along the top of the cable*	100_2920	Small cuts/bubbles in wrapping; water present in one cut (shortly after precipitation)	II
12	E11N	Top of lower PE pipe sleeve	N/A	23" void	I

In-Depth Inspection

In-Depth Inspection


Recommendation
Corrosion rate of strand due to rain water was low
Grout is of good quality
No observable water inside the cable or anchorage
Future deterioration is expected to be low

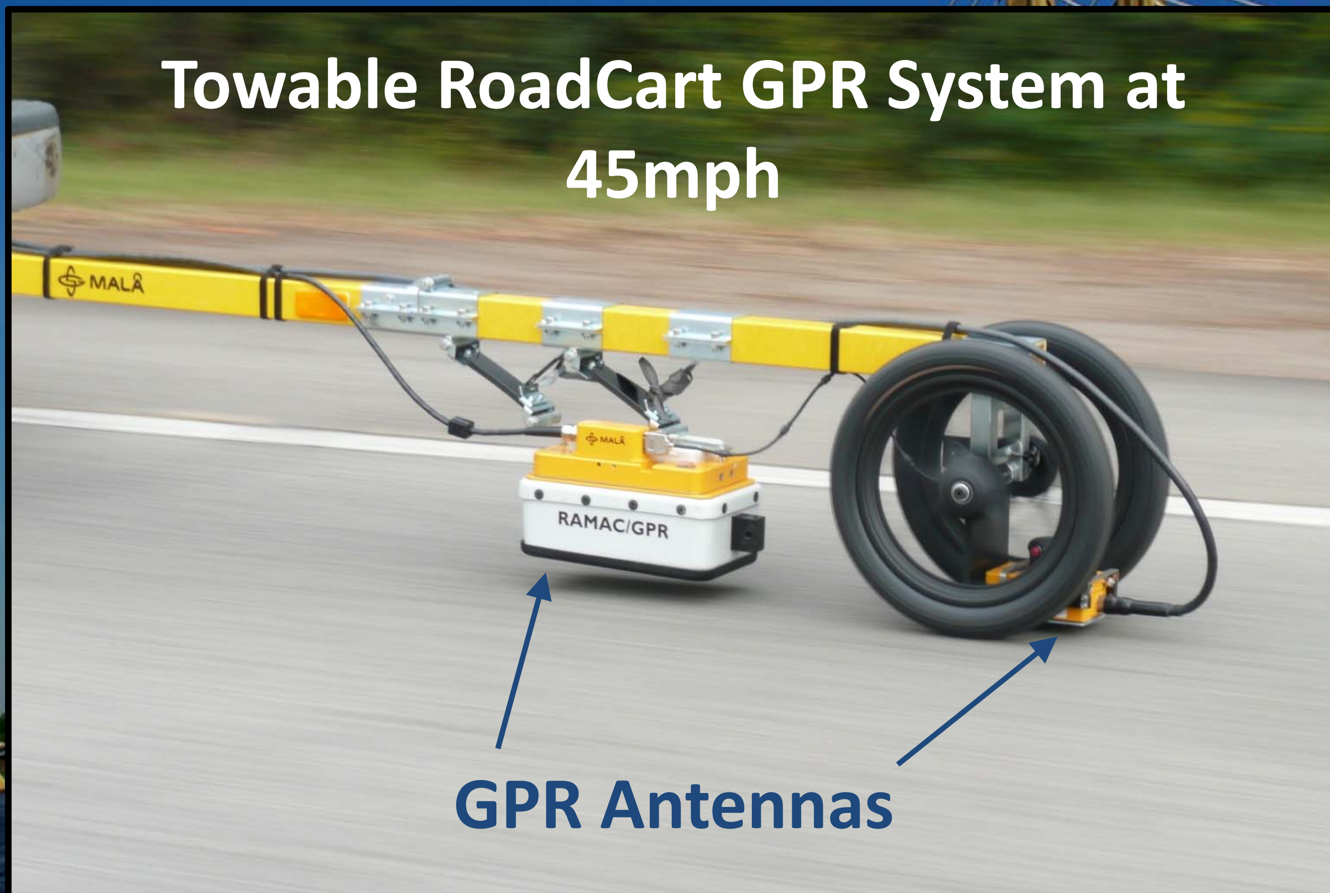

Case Study 2: Overlay Deterioration
Reinforced Concrete Deck
with LMC Overlay

Problem

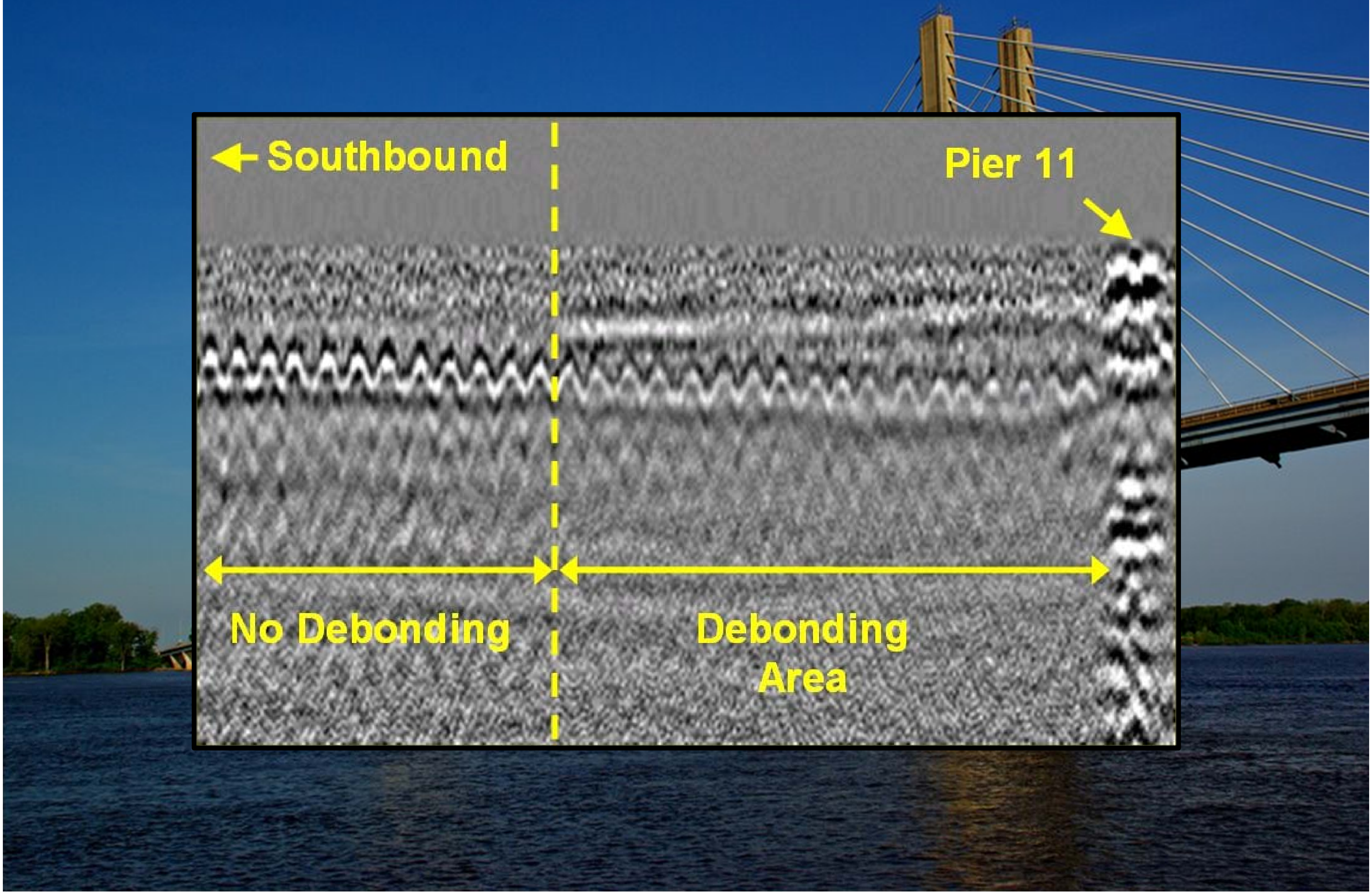
- A significant amount of the overlay had delaminated and spalled off
- The areas of spalls were growing over time
- Large portions of the overlay exhibited visible cracking
- Repairing spalls became very costly
- The cause of delamination was unknown

Problem

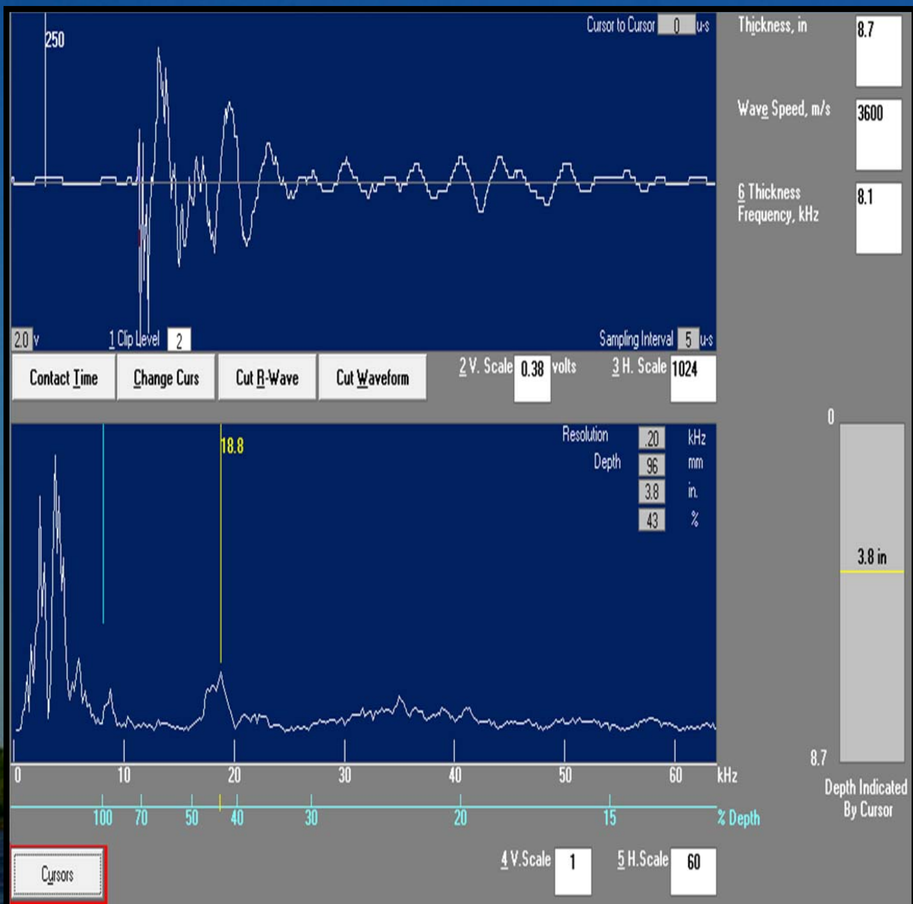
GPR at Highway Speed



GPR at Highway Speed



Impact Echo (IE)



Frequency Response of Debonded Overlay in Span 5

Extracted core confirming debonding

Recommendation

- Overlay will continue to debond
- SCS recommended removing and replacing the overlay

Conclusions

- Preservation program applied consistently over time is necessary to realize the benefits of preservation
- Using **right tools** at the **right time** for the **right structure** is essential for cost effective preservation program
- Quantifying instead of just identifying deterioration is necessary to schedule repairs or preservation activities
- If deterioration is left unaddressed, the repair can be very expensive

Conclusions

- Deterioration Is like cancer –typically hidden
- An appropriate combination of NDT/statistical/service life tools help us diagnose the problem correctly
- Correct diagnosis help design effective preservation/remediation
- Preservation is beneficial to environment and future generations


Questions?
Let us talk!