NCHRP IDEA Sponsored Research Project

NDE Triggers for Early Age Preservation of Bridge Decks

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Infratek SOLUTIONS

Project Goals

- Produce an early-age, objective, and data-driven **vulnerability detection** and quantification system that prioritizes bridge decks for early preservation activities.

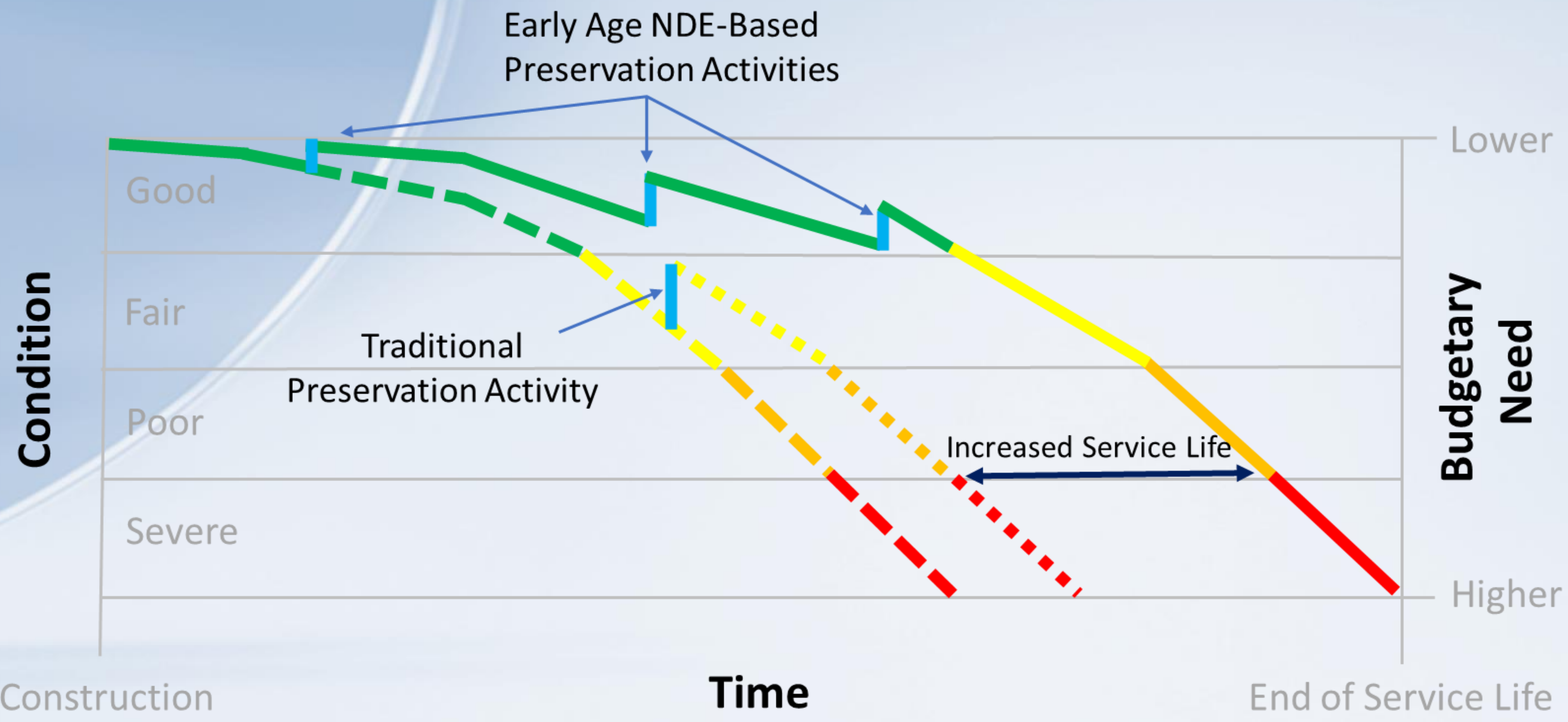
- Focus on the first few years of the bridge deck's life cycle, when problems are unlikely to be seen during inspections and are mostly simple and inexpensive to fix.
  - **Early preservation** activities can **be 10 to 15 times more cost-effective** than allowing a bridge to deteriorate to the point where extensive repairs or replacement are necessary (FHWA).

- **What is vulnerable?** Surface cracking and taking in moisture and chloride now or potentially in the near future)

- **Final Outcome:** End-to-end, data-driven and automated solution that begins with
  - Data collection
  - Ends with providing the vulnerability index for each bridge deck

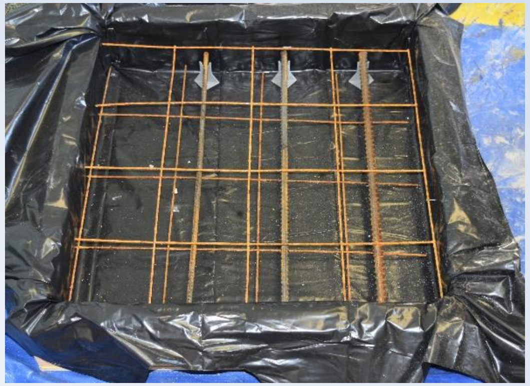
- **Field Applicable, Field Applicable, Field Applicable**
  - Automated data collection and data processing (no human taste or bias)
  - No lane closures or traffic disruption
  - Cost-effective and inexpensive

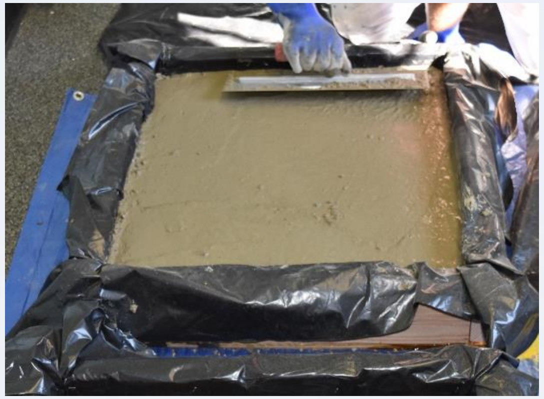
Project Goals

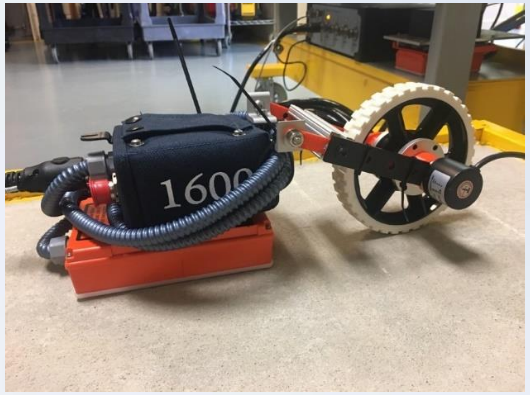


How ?

- Developed and finetuned the theory
  - Reviewed literature and field experience data (surface cracking, moisture ingress)
  - Examined multiple NDE technologies, methods, and theories with a focus on surface cracking and measuring ingress of moisture into the concrete bridge deck using Ground Penetrating Radar (GPR).
  - Ran lab tests to examine the theory (iterative process)

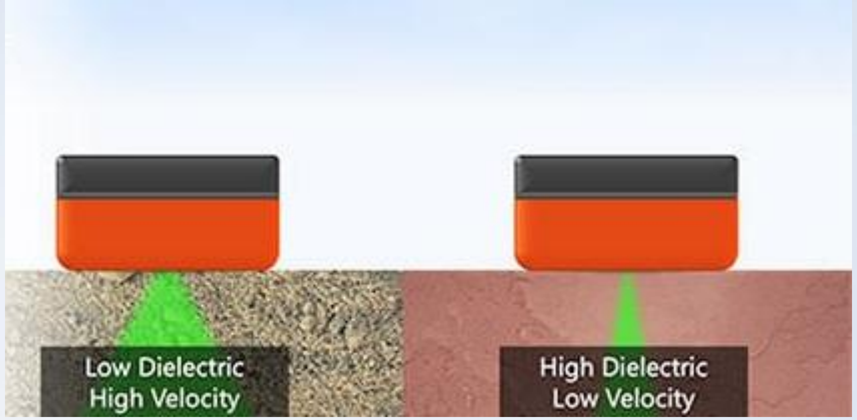






Factors to Measure

- **Concrete's Dielectric Constants**
  - The dielectric constant (also known as the relative permittivity) of concrete is a measure of the material's ability to store electrical energy in an electric field. It is a dimensionless quantity that indicates how much more electric field energy a material can store compared to a vacuum.
  - A higher dielectric constant in concrete signifies a higher moisture content and greater ionic mobility, both of which are conducive to the electrochemical reactions that cause corrosion of the rebar.



*Courtesy of GSSI

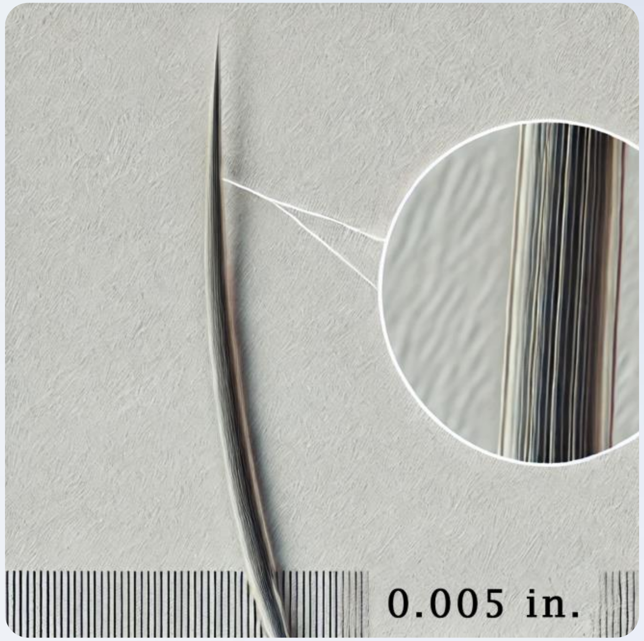
- **Surface Cracking**
  - Surface cracks (even hairline) in concrete facilitate corrosion of reinforcing steel, by creating a pathway for ingress of moisture, oxygen, and chloride ions, all of which start, contribute to, and accelerate the corrosion process

Methodology

- **Concrete's dielectric constants**
  - We establish the background dielectric constant for the entire deck.
  - We measure the percentage increase of each data point compared with the background.
  - The result is the areas of the deck that show elevated di-electric constant compared to other areas. (In equal conditions these areas facilitate a more corrosive environment than the other areas)

- **Surface cracking**
  - Cracks we are after are as small as 0.004" (0.1 mm)
    - Current thresholds
      - Hairline (0.005" or less)
      - Narrow (0.005" to 0.015")
      - Medium (>0.015" to 0.030")
      - Large (>0.030" to 0.040")
      - Wide (>0.040")

- Crack maps, crack density plots and tabulations are automatically generated.



Field Data Collection

- **Automated, fast data collection using sensors mounted on the DAQ vehicle traveling at (25 to 45 mph) – Delaware, Indiana, Iowa, Texas**
  - Use of Air-Launched GPR for dielectric constant estimation.
    - Rigid sensor calibration prior to data collection
      - Noise to Signal Ratio Test
      - Signal Stability Test
      - Long Term Signal Stability
      - Variations in Time Calibration Factor
      - End Reflection Test
      - Symmetry of Metal Plate Reflection
    - Automated as well as human-in-the-loop data processing.
  - Use of high-resolution cameras to take surface pictures (laser for surface illumination)
    - Trained Artificial Intelligence (AI) engine for crack mapping.
    - Automated as well as human-in-the-loop data processing.


Imaging System
GPR System
Laser Light
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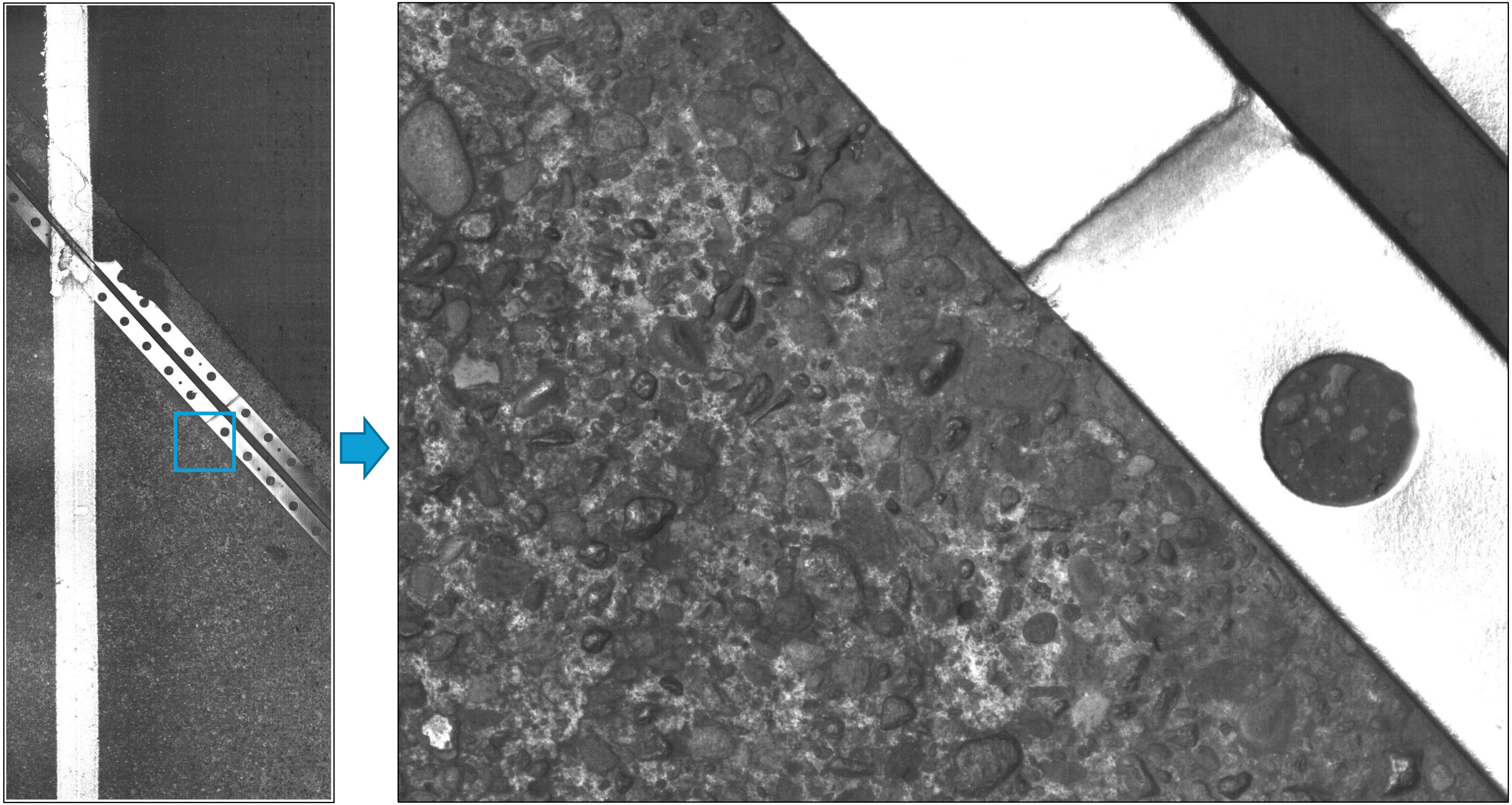
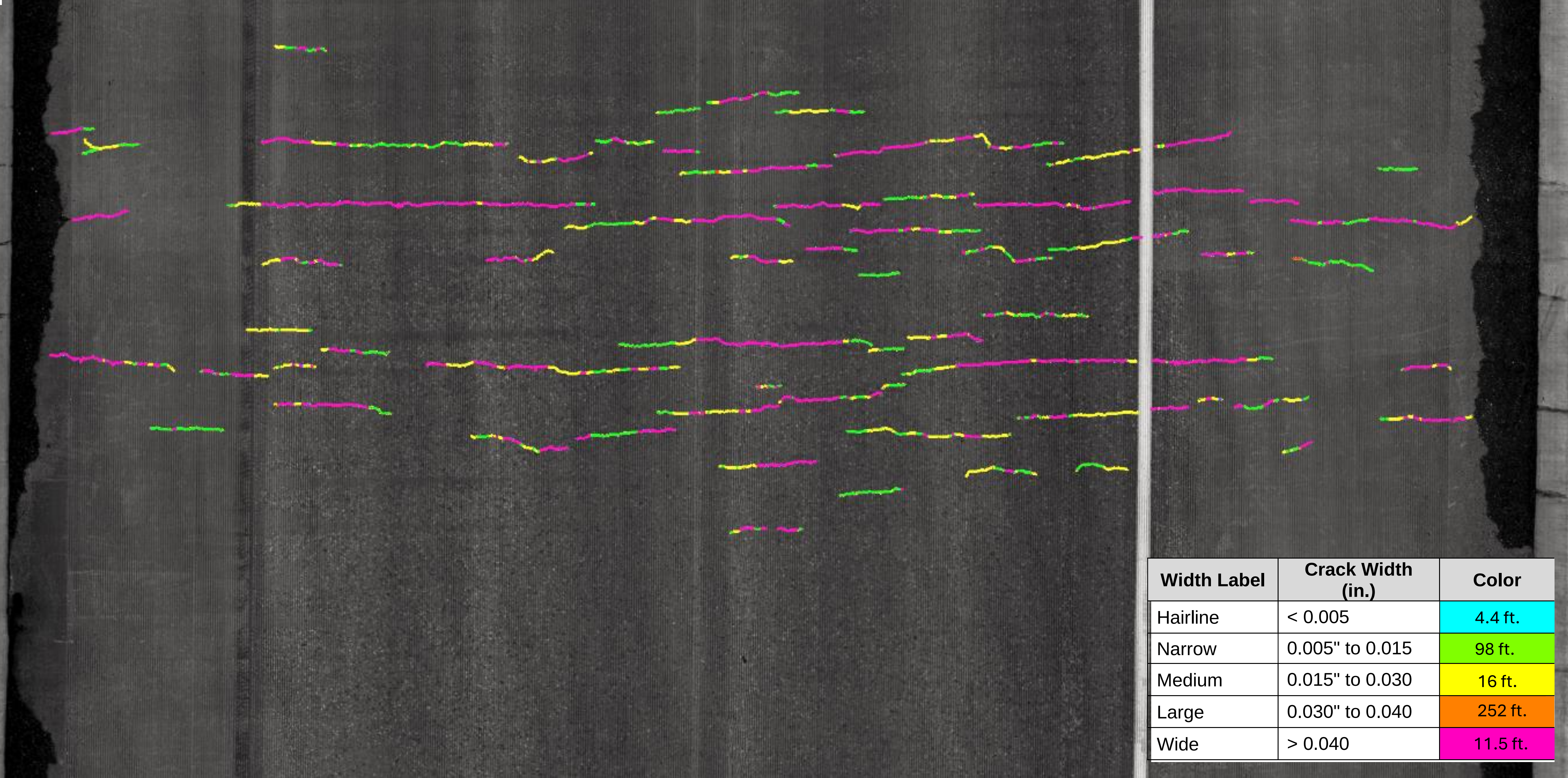
Metal Plate Calibration

Field Data Collection

#	State DOT Partner	Number of Bridge Decks	Date
1	Iowa DOT	8	Sep 2023
2	Indiana DOT	8	Nov 2023
3	Texas DOT	3	May 2024
4	Delaware DOT	4	May 2024

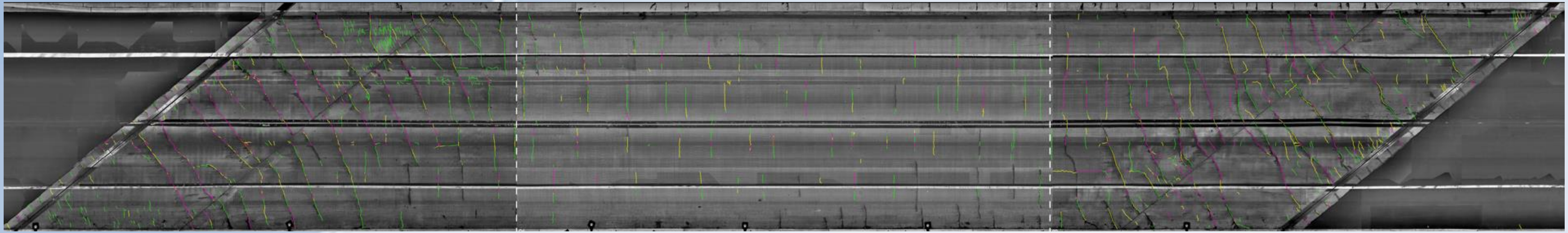


Sample Crack Mapping Results



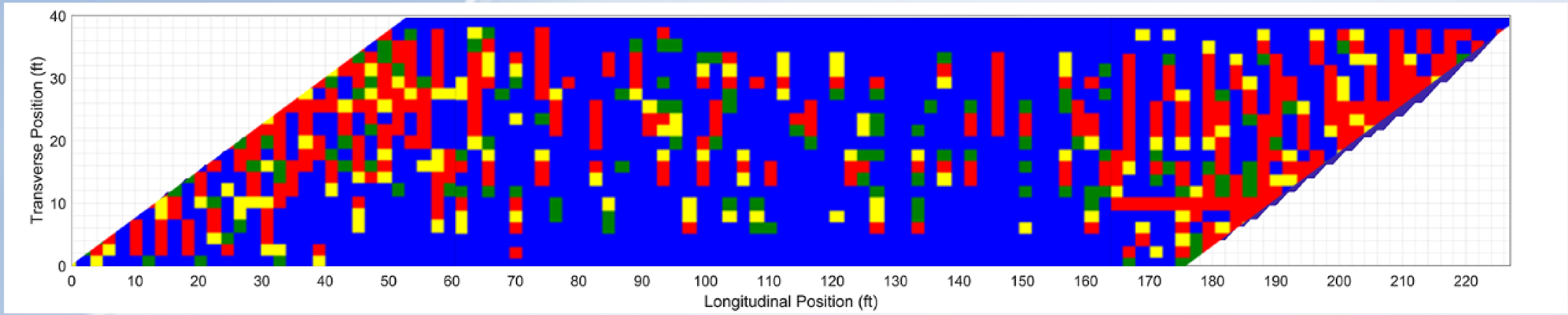
Width Label	Crack Width (in.)	Color
Hairline	< 0.005	4.4 ft.
Narrow	0.005" to 0.015	98 ft.
Medium	0.015" to 0.030	16 ft.
Large	0.030" to 0.040	252 ft.
Wide	> 0.040	11.5 ft.

DE Bridge ID: 1714 347 –Crack Mapping Plot

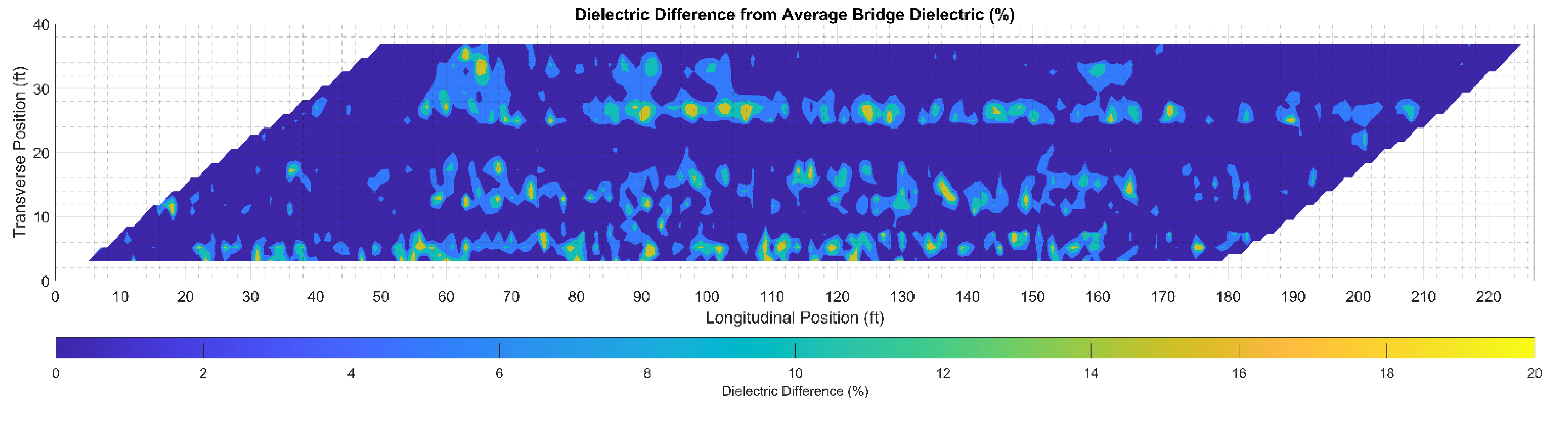


Width Label	Crack Width (in.)	Color
Hairline	< 0.005	
Narrow	0.005" to 0.015	
Medium	0.015" to 0.030	
Large	0.030" to 0.040	
Wide	> 0.040	

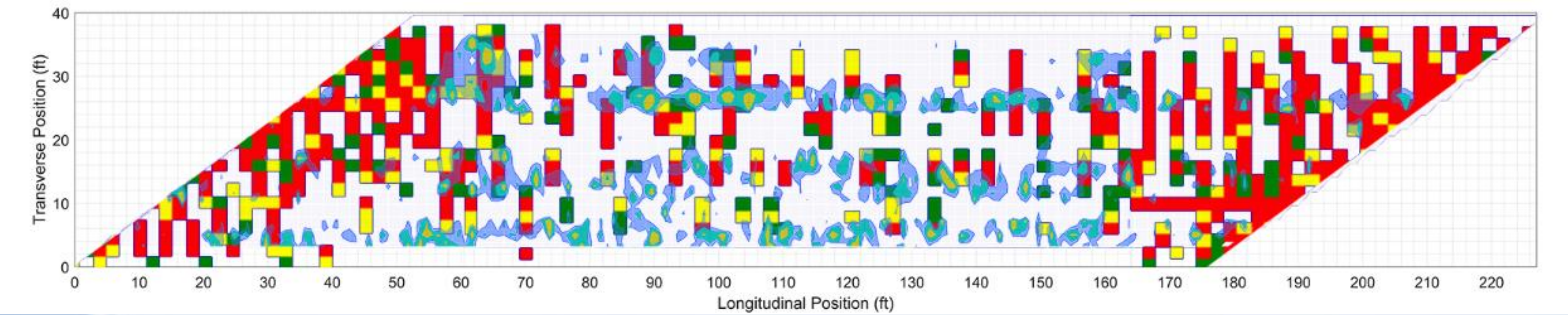
DE Bridge ID: 1714 347 – Crack Density Plot



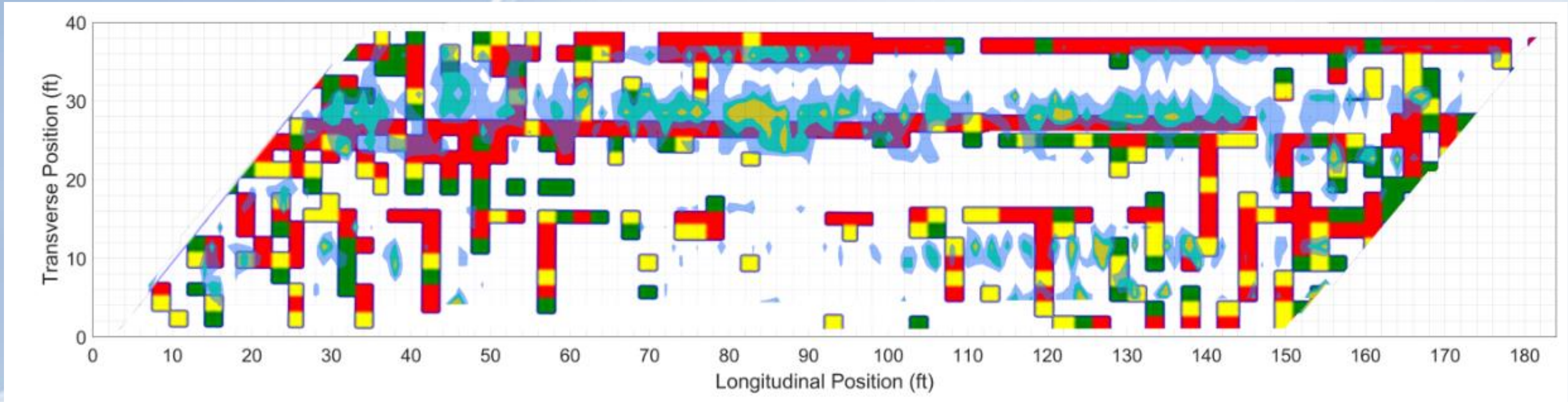
DE Bridge ID: 1714 347 – Dielectric Change Plot



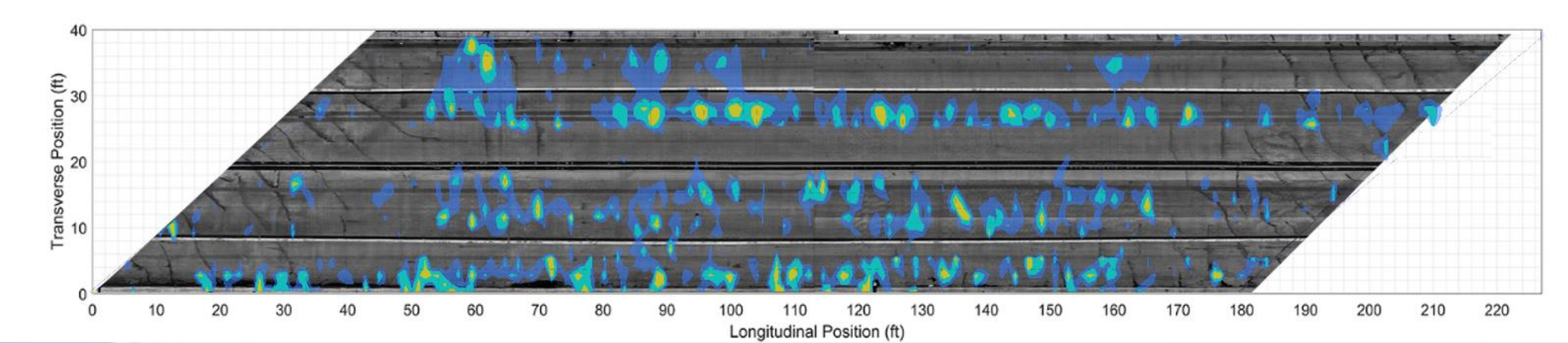
DE Bridge ID: 1714 347 – Dielectric Change Overlaid on Crack Density Plot



DE Bridge ID: 1714 A347 - Dielectric Change Overlaid on Crack Density Plot

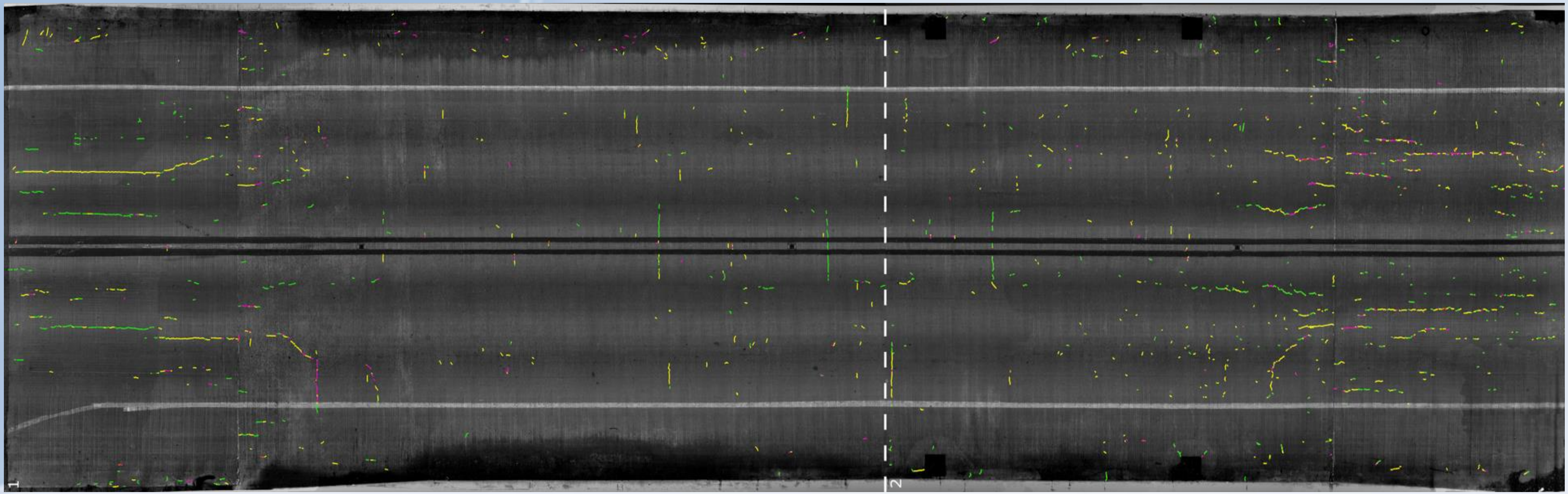


DE Bridge ID: 1714 347 – Crack Sealing Perspective



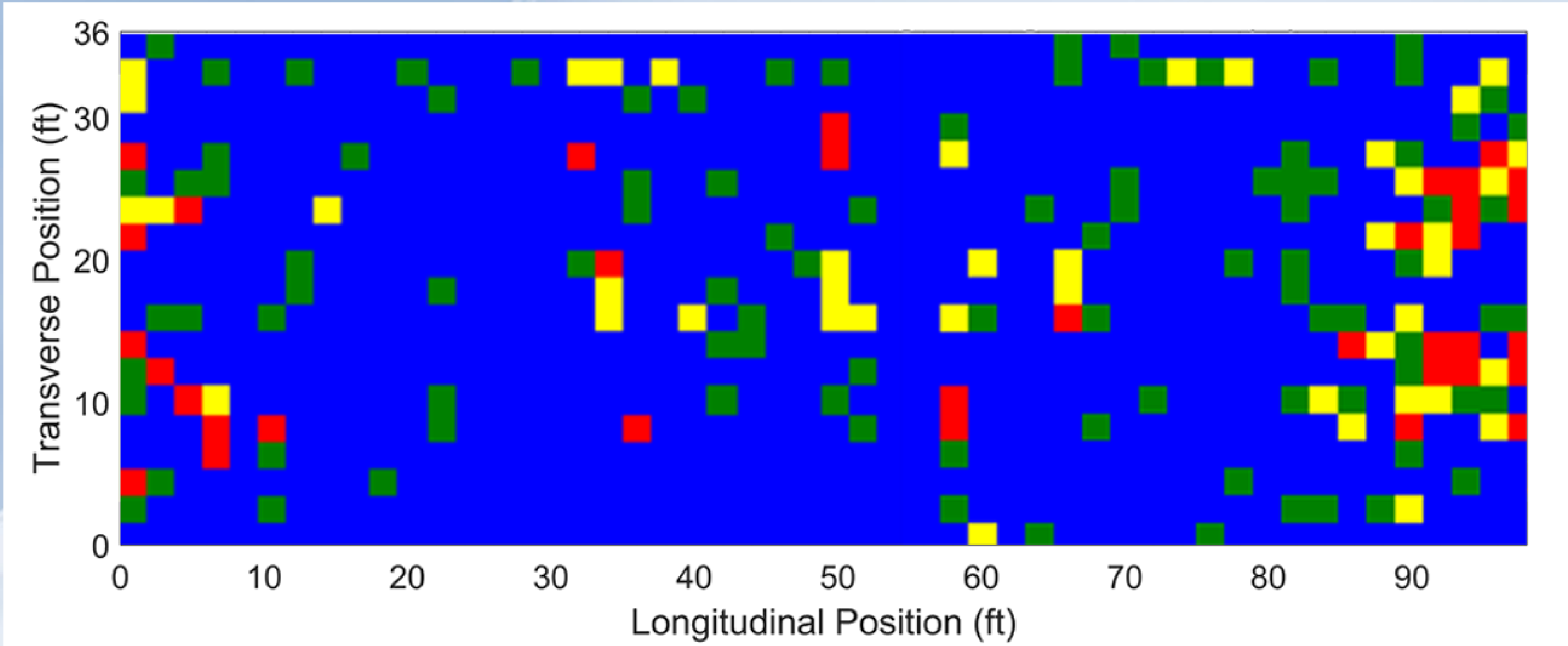
Areas with sealed cracks show lower changes in dielectric constant compared to the background.

IN Bridge ID: 17191 – Crack Mapping Plot

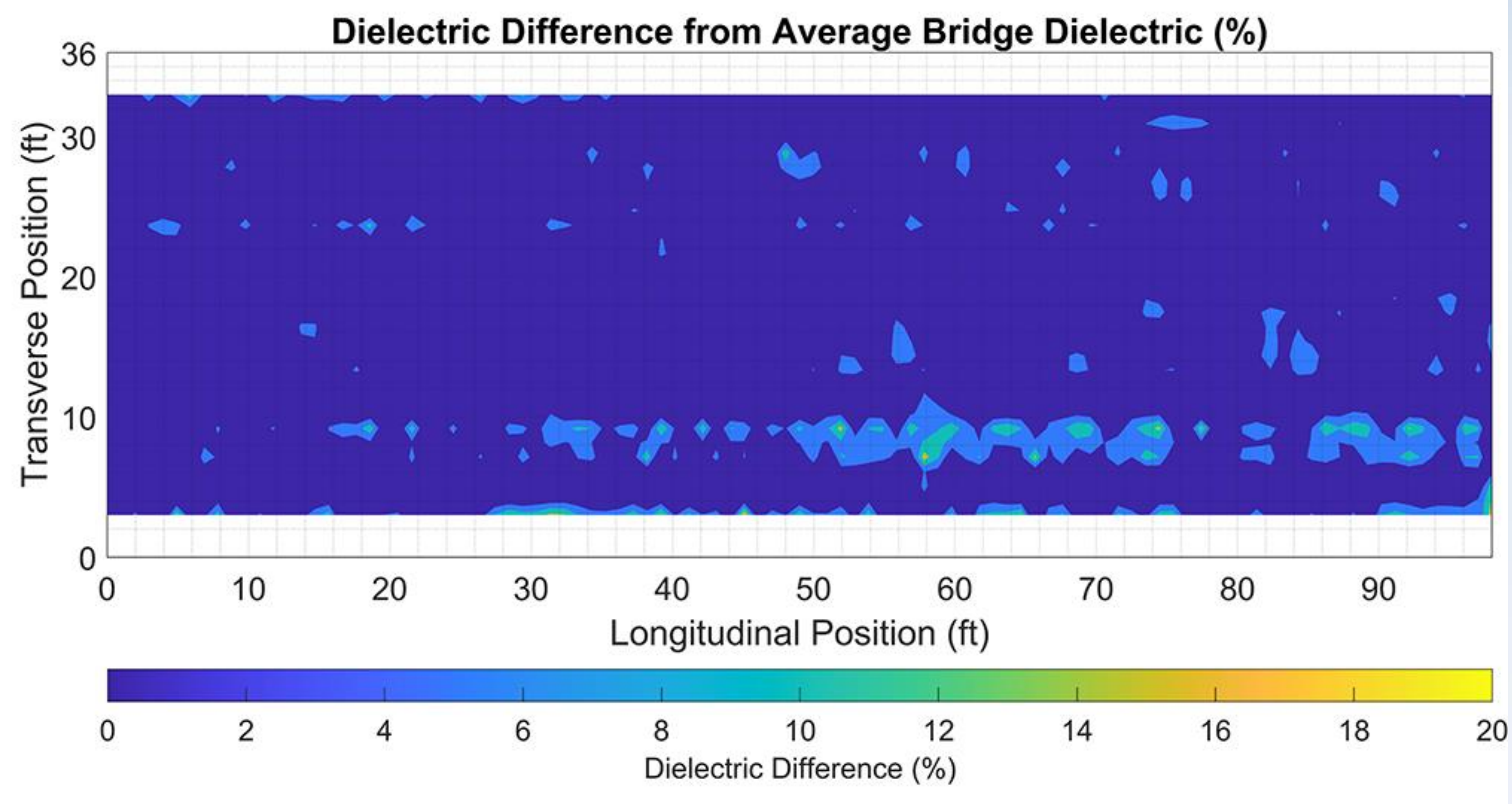


Width Label	Crack Width (in.)	Color
Hairline	< 0.005	
Narrow	0.005" to 0.015	
Medium	0.015" to 0.030	
Large	0.030" to 0.040	
Wide	> 0.040	

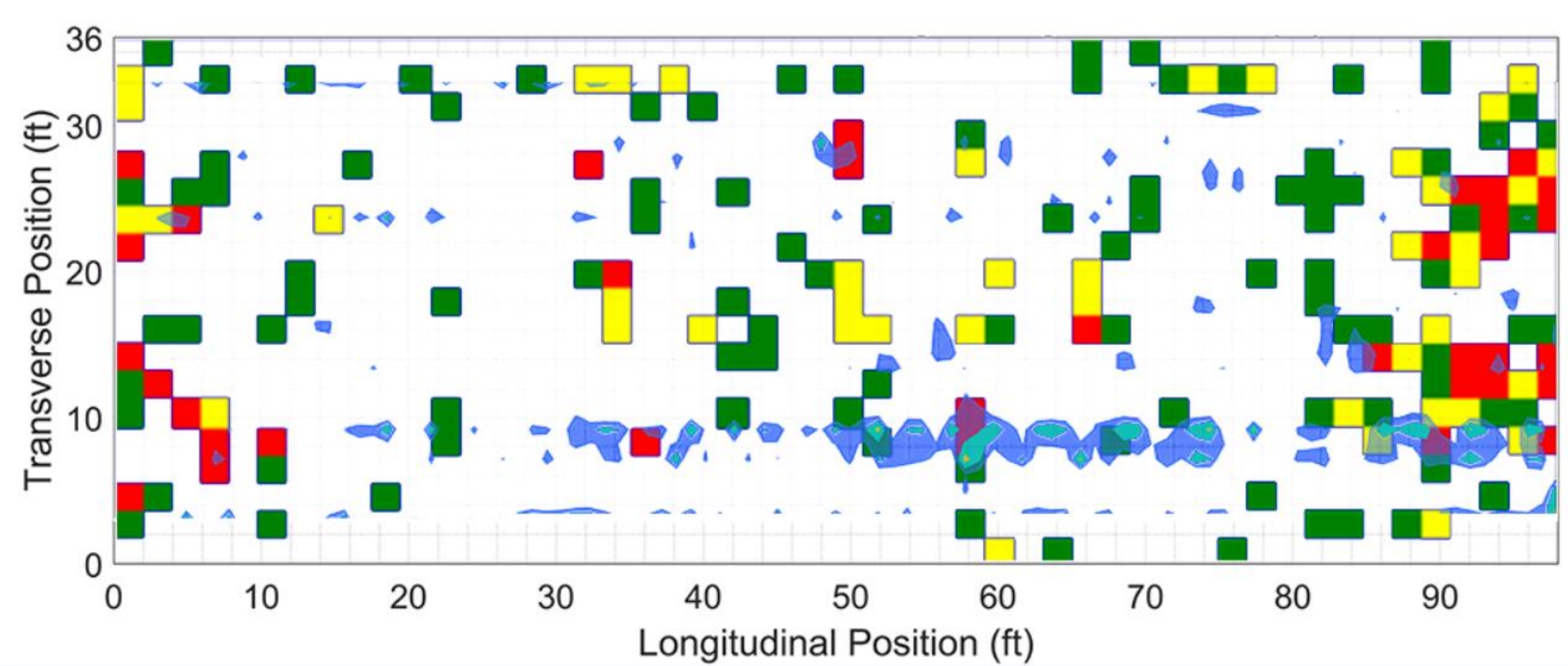
IN Bridge ID: 17191 - Crack Density Plot



IN Bridge ID: 17191 - Dielectric Change Plot



IN BRIDGE ID: 17191 - Dielectric Change Overlaid on Crack Density Plot



Vulnerability Factor

Density Label	Crack Density Range (ft/ft2)	Dielectric Increase Compared to Background	Assigned Weight in the formulation (W_x)
Low	<0.10	0% - 7%	0.125
Moderate	0.1 to 0.22	7%-14%	0.25
Severe	0.22 to 0.37	14%-21%	0.375
Very Severe	>0.37	>21%	0.5

With the above considerations, a proposed formula to calculate the vulnerability index is as follows:

$$VI = W_1 \text{ x } (CD_1 + DE_1) + W_2 \text{ x } (CD_2 + DE_2) + W_3 \text{ x } (CD_3 + DE_3) + W_4 \text{ x } (CD_4 + DE_4)$$

Where:

- VI is the Vulnerability Index.
- W_x is the assigned weight indicated in the table above.
- CD_x is the percentage of surface area corresponding to the respective crack density.
- DE_x is the percentage of surface area corresponding to the respective dielectric constant. increase

Vulnerability Factor

Bridge ID	Vulnerability Index
DE 1714347	0.352
DE 1714A347	0.352
IA 70950	0.295
IN 17191	0.294
IN 26211	0.290
IA 700945	0.282

*Calculated based on the proposed Vulnerability Index equation, actual conditions may vary.

Next Steps / Transfer to Practice

- More finetuning of the equation – establishing a minimum threshold for the “increase in dielectric constant”
- Continue to work with the state DOTs on the advisory panel to tie the vulnerability factors to bridge preservation practices
- Collect more data in the field with this perspective
- More data processing and analysis for refined equation and decision-making
- Create awareness (NDE Based –data driven- preservation strategies)

Special Thanks to Our Advisory Panel and State DOT Partners

Name	Affiliation
Bruce Johnson	Retired – Oregon State Bridge Engineer
Emily Parkany	VTrans
Gregg Freeman	Kwikbond Polymers - FHWA Bridge Preservation ETG
James Lacroix	VTrans
Jason Arndt	Delaware DOT
Joseph Stanisz	Iowa DOT
Michael Todsen	Iowa DOT
Philip Meinel	Wisconsin DOT

- Texas DOT – Steven Austin, Istiaque Hasan
- Indiana DOT – Anne Rearick, Prince Baah, Adam Post

Thank you!

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