Corrosion-induced Crack Detection of Reinforced Concrete Structures using a 1.6GHz GPR

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Introduction

The research problem we are trying to solve is the structural assessment of aging concrete bridges in New England, targeting concrete cracking and degradation. The research objective is to develop a remote radar sensor for the electromagnetic characterization of corroded reinforced concrete structures by studying concrete cover cracking and chloride-induced steel rebar corrosion. Fig. 1.a), d), and e) illustrate the progression of steel rebar corrosion in concrete structures, which happens in 4 stages.

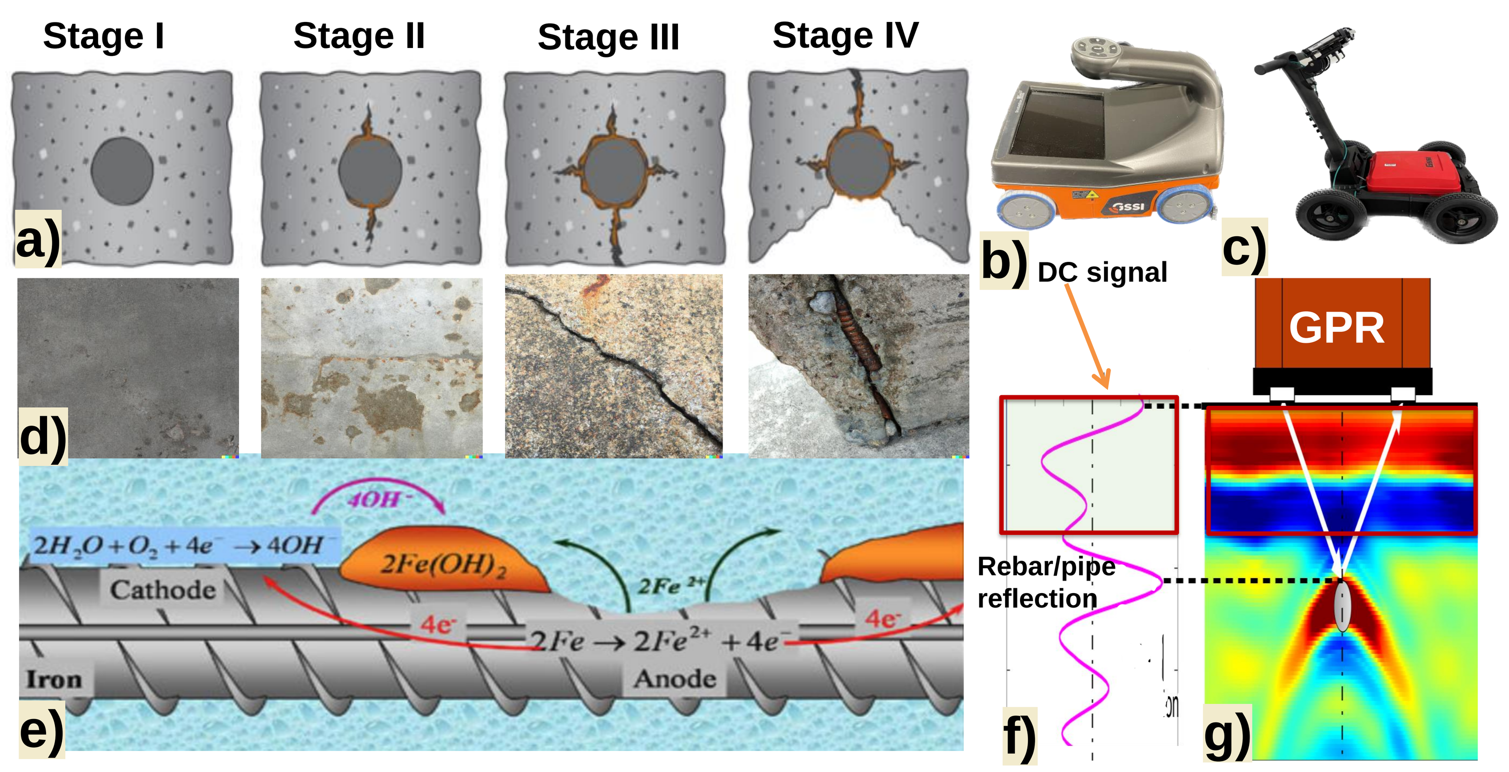

Fig. 1. a) Conceptual stages of corrosion; b) 1.6GHz GPR; c) 300/800 MHz GPR; d) Stages of corrosion on concrete surface; e); Electrochemical process of rebar corrosion; f); 1D A-scan curve; g): 2D B-scan image.

Specimens & their GPR Images

10 laboratory concrete panels (12x12x2 in^3) were cast with artificial cracks of various sizes (using polystyrene styrofoam) and inspected by a 1.6GHz GPR (GSSI StructureScan Mini) , (Fig. 1.b), as shown in Fig. 2. Our objective is to study the EM scattering pattern of cracks in B-scan images in laboratory specimens as well as real RC structures (e.g., highway bridges) for predicting crack characteristics such as crack depth.

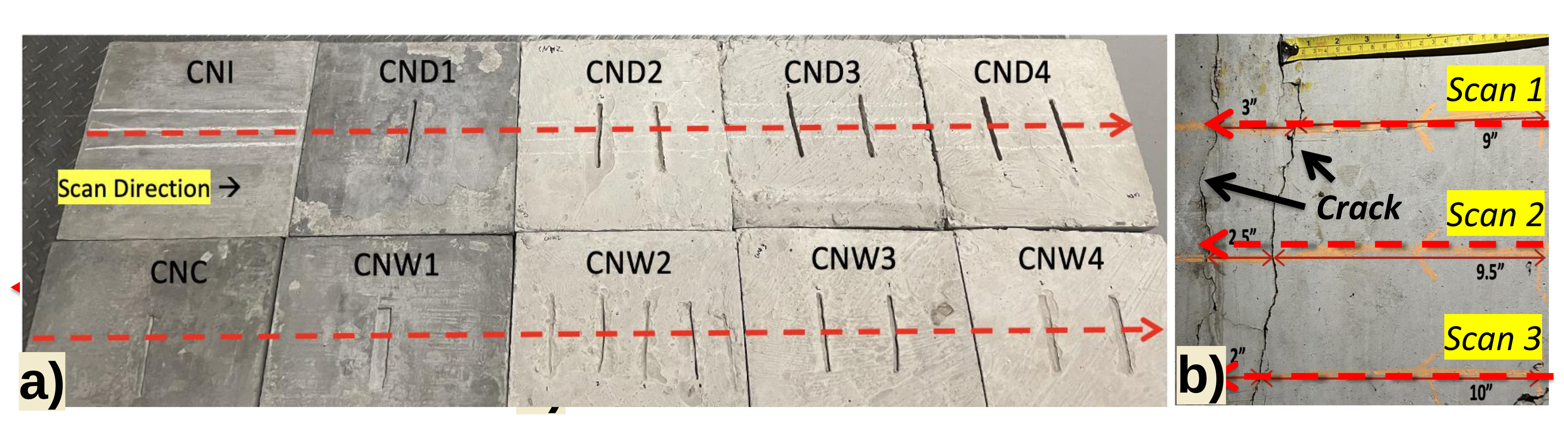

Fig. 2. a) 10 artificially-cracked concrete panels with GPR scan direction; b) UMass Lowell north campus parking lot concrete wall.

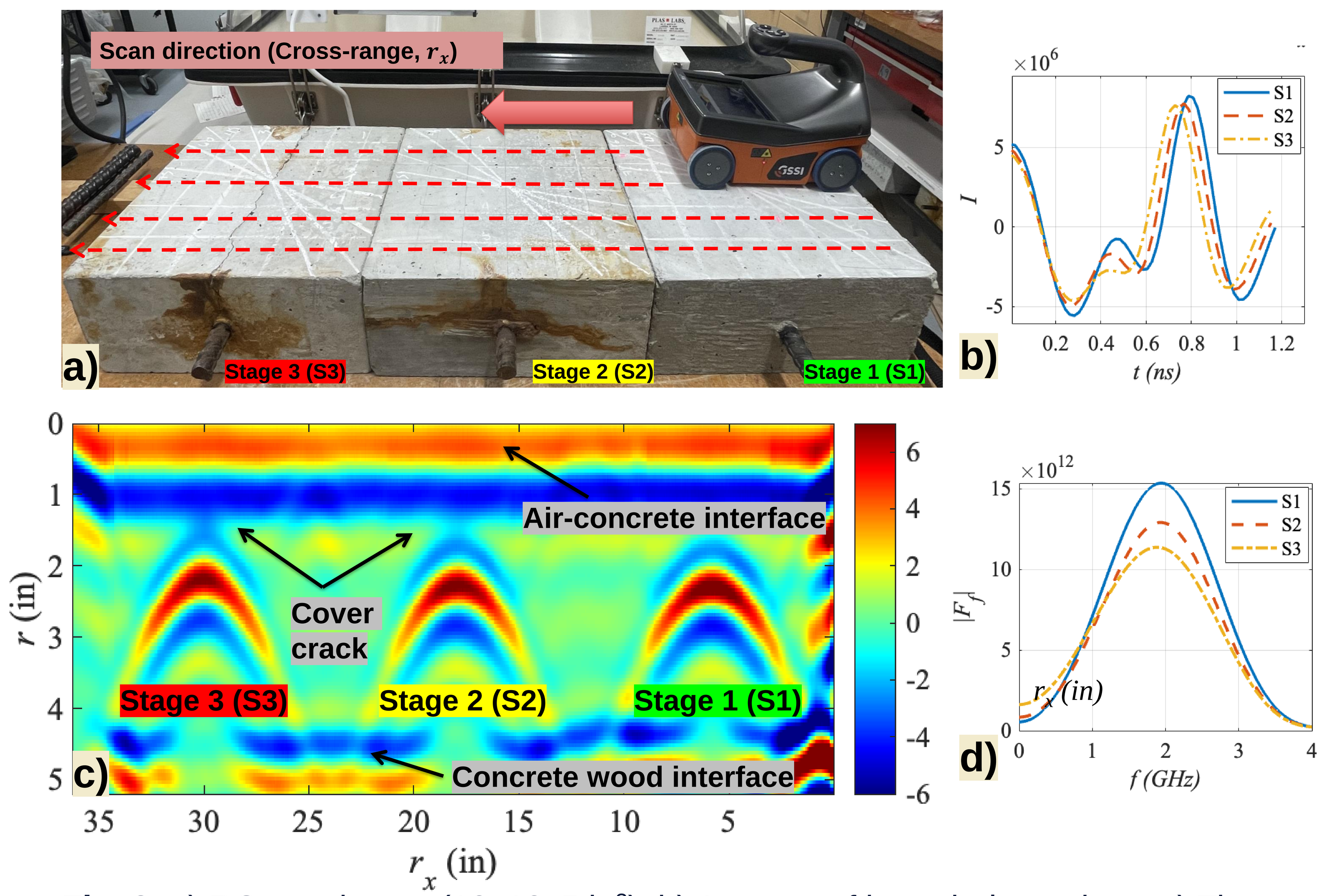

Fig. 3. a) RC specimens (12x12x5 in^3); b) A-scans of hyperbola vertices; c) Time-zero corrected B-scan image of the specimens; d) A-scans in frequency domain.

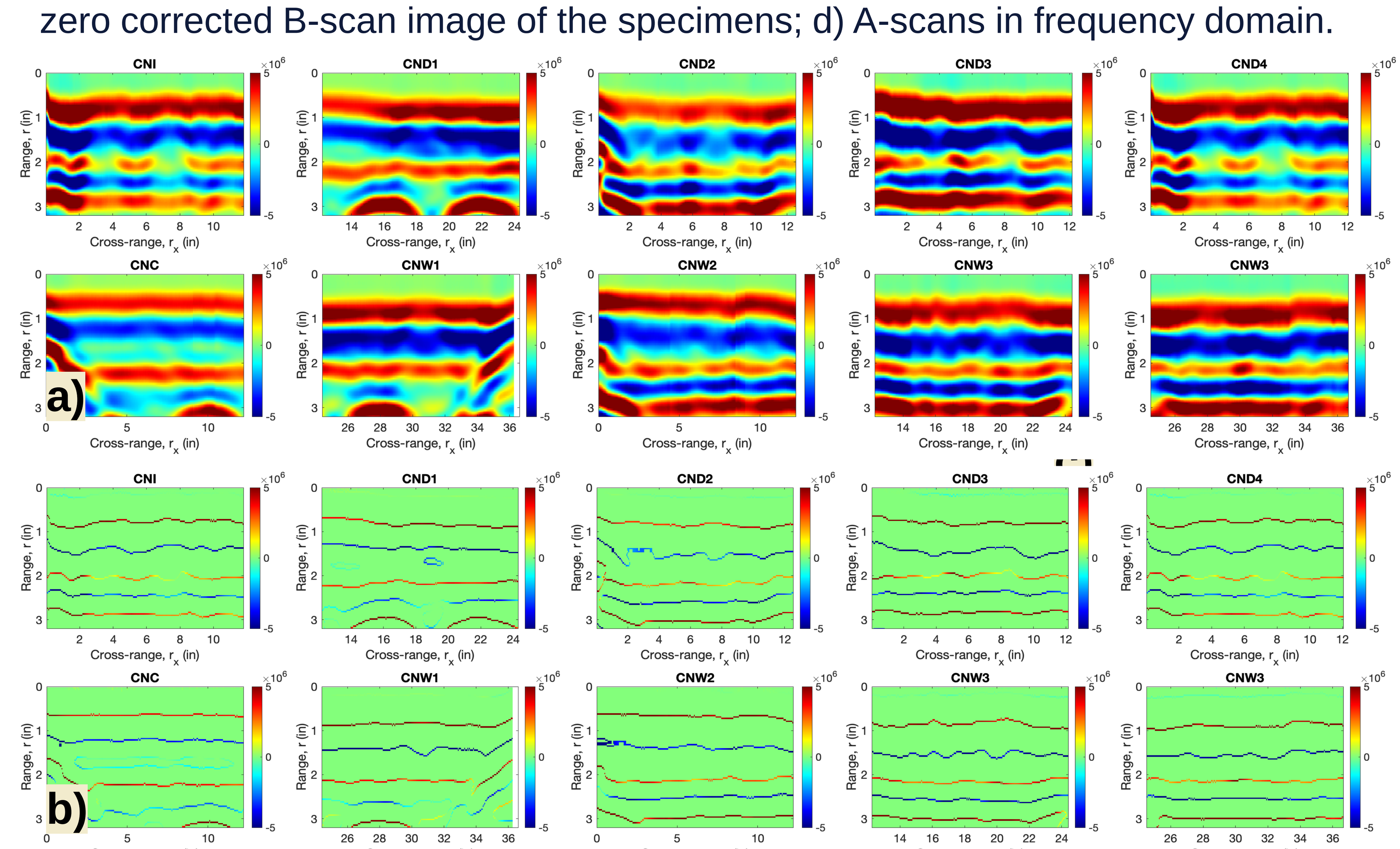

Fig. 4. a) B-scan images of CN specimens; b) Feature-extracted B-scan images to spot signal irregularities by mapping the local minima and maxima points.

In Fig. 3, we found that steel rebar corrosion results in: i) reduced GPR amplitude, ii) reduced travel time of GPR signals, and iii) Reduced frequency, due to the growth of small fissures around the cover, and surface roughness of corroded rebars due to rust layer formation. Our findings are in good agreement with other researchers (Sossa *et al.* (2019), Hubbard *et al.* (2003, Eisenmann *et al.* (2013), Hong *et al.* (2017)).

Fig. 5 illustrates the local mapping of the positive and negative reflections (i.e., edge boundaries, and local maxima and minima) in the direct-coupling (DC) signal. Cracks are detected as hyperbolic anomalies along the cross-range (r_x) axis.

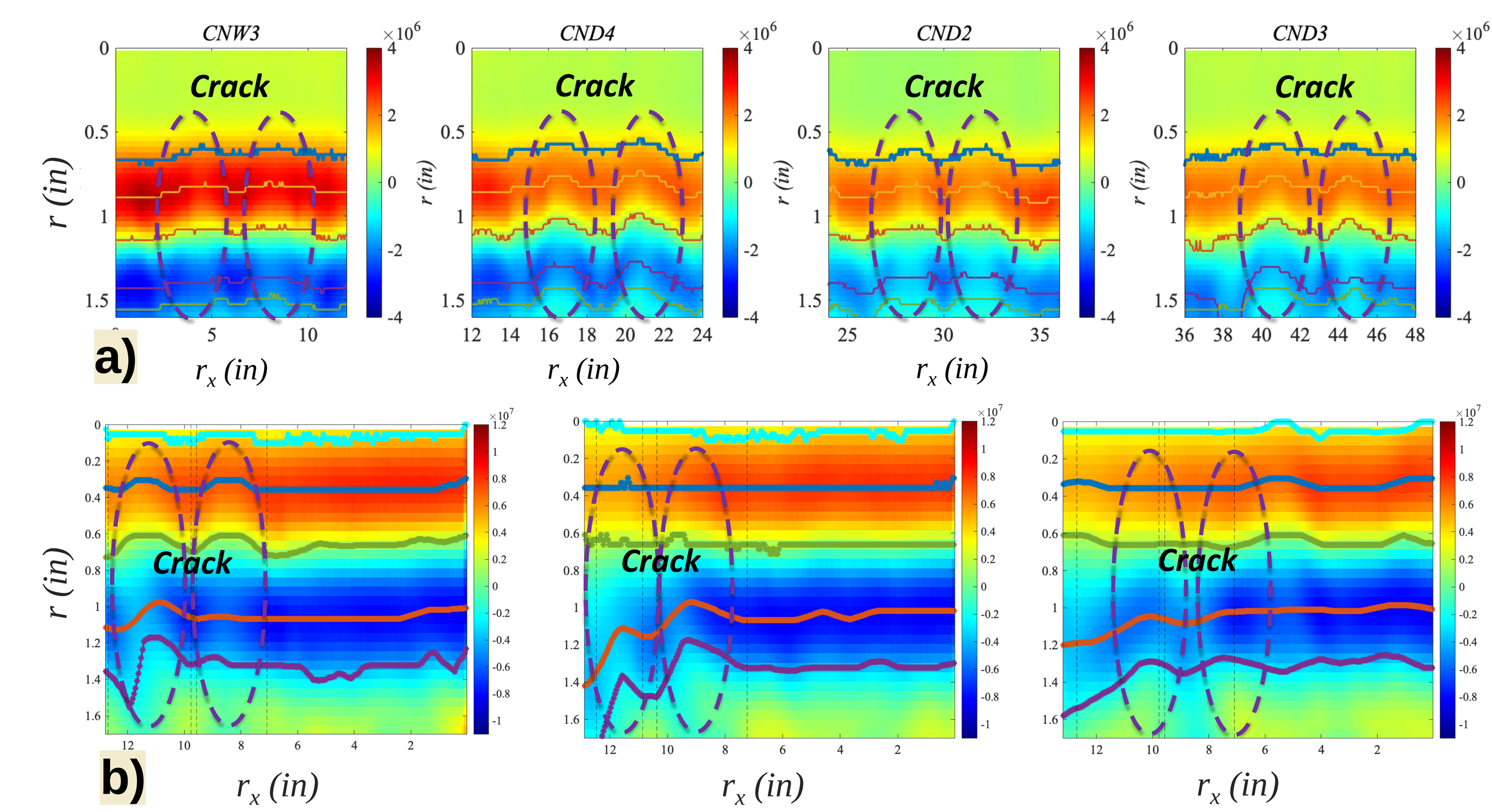

Fig. 5. a) DC signal mapping of a) Lab specimens; b) UML north campus parking lot (from left to right: scans 1, 2, and 3).

Findings & Conclusion

- 1.6GHz GPR can detect corrosion, corrosion-induced cover cracking, and the combination of corrosion and cracking, both in laboratory specimens and on field structures.
- EM waves are sensitive to the medium's dielectric properties, environmental noise, and are heavily impacted by the changes in moisture, thus making postprocessing analysis for meaningful physical quantifications challenging.
- GPR can be used as a supplementary NDT/E method for verification of other well-established methods such as HCP (for corrosion), and UPV (for cracking detection) while offering more resolution and fewer constraints in field implementation.
- Robustness of GPR (by controlling frequency for a resolution-penetration depth tradeoff) makes it a versatile NDT/E tool for assessing other Structural Health Monitoring (SHM) problems in Civil Engineering, such as transportation infrastructure.

Publications

- K. Raisi, N.N. Khun, and T. Yu (2022), SPIE, DOI: 10.1117/12.2613083
- K. Raisi, R. Batchu, and T. Yu (2023), SPIE, DOI: 10.1117/12.2657731
- R. Batchu, K. Raisi, and T. Yu (2023), SPIE, DOI: 10.1117/12.2658173
- T. Yu, K. Raisi, and R. Batchu (2023), SPIE, DOI: 10.1117/12.2657741
- N.N. Kulkarni, K. Raisi, N.A. Valente, J. Benoit, T. Yu, and A. Sabato, (2023), AIC, DOI: 10.1016/104784

Acknowledgements: Funding for this research is provided by the USDOT UTC TIDC at the UMaine under grant 69A3551847101. We thank Mr. Gregory Kirkoris (MassDOT) (Project Champion) ,Dr. David Cist (CSSI), and Mr. Ritham Batchu (UML) for their suggestions on our project activities.