Quarterly Progress and Performance Indicators Report:
Project Number and Title: 1.4 Electromagnetic Detection and Identification of Concrete Cracking in Highway Bridges
Research Area: Thrust 1: Transportation infrastructure monitoring and assessment for enhanced life
PI: Tzuyang Yu (UMass Lowell)
Co-PI(s): N/A
Reporting Period: 4/1/2022~6/30/2022
Submission Date: 7/6/2022

Overview:

The research problem we are trying to solve is the structural assessment of aging concrete bridges (reinforced and prestressed) in New England, targeting at concrete cracking and degradation. The overall research objective is to develop a remote radar sensor for the characterization of corroded reinforced concrete structures. In the reporting period of this project, we inspected one bridge abutment on the Lowell Connector (Lowell, MA) for concrete cracking and corrosion inspection (Task 3.2). The collected GPR B-scan images have also been added to the development of an electromagnetic (EM) database (Task 4).

Meeting the Overarching Goals of the Project:

- We have collected more GPR B-scan images of intact and corroded concrete bridge abutment from one bridge on the Lowell Connector in Lowell, MA to study combined effect of concrete cracking and steel rebar corrosion.
- For field GPR B-scan images of **cracked** concrete bridge abutment, we have collected B-scan images containing scattering pattern of real concrete cracks.

Accomplishments:

- We have expanded the EM database by adding GPR B-scan images of cracked concrete bridge abutments.

Task, Milestone, and Budget Progress:

Table 1: Task Progress

Task Number: Title	Start Date	End Date	% Complete
Task 1: Design and manufacturing of laboratory reinforced concrete specimens at various corrosion levels	10/01/20	09/30/21	100%
Task 2: Laboratory SAR imaging of corroded RC specimens and development of a robust baseline SAR/GPR image of concrete	10/01/21	09/31/22	90%
Task 3.1: Development of a compact, self-powered, light-weight SAR imaging sensor	10/01/21	05/31/22	100%
Task 3.2: Field inspection of corroded RC structures (Preliminary)	06/01/21	09/30/22	87%
Task 4: Development of EM database and correlation between SAR and GPR images	08/01/21	03/31/23	65%
Task 5: Data analysis and image interpretation	10/01/20	09/30/23	65%

Table 2: Milestone Progress			
Milestone #: Description	**Corresponding Deliverable**	**Start Date**	**End Date**
Milestone 1: Design of laboratory reinforced concrete (RC) specimens at various corrosion levels	Experimentation design matrix; manufactured RC specimens (10%); Quarterly report on 12/31/20	10/01/20	12/31/20
Milestone 2: Manufacturing of laboratory RC specimens at various corrosion levels / Laboratory SAR imaging of corroded RC specimens and development of a robust baseline SAR image of concrete / Development of a compact, self-powered, light-weight SAR imaging sensor	Manufactured RC specimens (20%); SAR images of RC specimens (5%); design of a compact SAR imaging sensor (10%); Quarterly report on 03/31/21	11/01/20	03/31/21
Milestone 3: Manufacturing of laboratory RC specimens at various corrosion levels / Laboratory SAR imaging of corroded RC specimens and development of a robust baseline SAR image of concrete / Field inspection of corroded RC structures (Preliminary)	Manufactured RC specimens (80%); SAR images of RC specimens (30%); Development of a compact SAR imaging sensor (100%); Preliminary SAR imaging of RC specimens in the field (5%); Quarterly report on 06/30/21	12/01/20	06/30/21
Milestone 4: Manufacturing of laboratory RC specimens at various corrosion levels / Laboratory SAR imaging of corroded RC specimens and development of a robust baseline SAR image of concrete / Field inspection of corroded RC structures (Preliminary)	Manufactured RC specimens (100%); SAR images of RC specimens (40%); Preliminary SAR imaging of RC specimens in the field (10%); Quarterly report on 09/30/21	12/01/20	09/30/21
Milestone 5: Laboratory SAR imaging of corroded RC specimens and development of a robust baseline SAR image of concrete / Field inspection of corroded RC structures (Preliminary)	SAR images of RC specimens (50%); Preliminary SAR imaging of RC specimens in the field (25%); Quarterly report on 12/31/21	12/01/20	12/31/21
Milestone 6: Laboratory SAR imaging of corroded RC specimens and development of a robust baseline SAR image of concrete / Field inspection of corroded RC structures (Preliminary)	SAR images of RC specimens (80%); Preliminary SAR imaging of RC specimens in the field (50%); Quarterly report on 03/31/22	12/01/20	03/31/22
Milestone 7: Laboratory SAR imaging of corroded RC specimens and development of a robust baseline SAR image of concrete / Field inspection of corroded RC structures (Preliminary)	SAR images of RC specimens (100%); Preliminary SAR imaging of RC specimens in the field (100%); Quarterly report on 09/30/22	12/01/20	09/30/22
Milestone 8: Field inspection of corroded RC structures	SAR imaging of RC specimens in the field (15%); Quarterly report on 12/31/22	10/01/22	12/31/22
Milestone 9: Field inspection of corroded RC structures	SAR imaging of RC specimens in the field (100%); Quarterly and Final reports on 09/30/23	10/01/22	09/30/23

Table 3: Budget Progress		
Project Budget	**Spend – Project to Date**	**% Project to Date (include the date)**
$330,495 (federal)	$258,628.04 (federal)	$78.25 (federal)

Is your Research Project Applied or Advanced?

☒ **Applied** (*The systematic study to gain knowledge or understanding necessary for determining the means by which a recognized and specific need may be met.)*

☐ **Advanced** *(An intermediate research effort between basic research and applied research. This study bridges basic (study to understand fundamental aspects of phenomena without specific applications in mind) and applied research and includes transformative change rather than incremental advances. The investigation into the use of basic research results to an area of application without a specific problem to resolve.)*

Education and Workforce Development:

1. Did you provide any workforce development or training opportunities to transportation professionals (already in the field)? If so, what was the training? When was it offered? How many people attended?
   N/A

2. Did you hold meetings with any transportation industry organizations or DOTs? If so, what was the meeting's purpose? When was it offered? How many people attended?
   N/A

3. Did you host/participant in any K-12 education outreach activities? If so, what was the activity? What was the target age/grade level of the participants? How many students/teachers attended? When was the activity held?
   N/A

Technology Transfer:

Table 4: Presentations at Conferences, Workshops, Seminars, and Other Events

Type	Title	Citation	Event & Intended Audience	Location	Date(s)
Conference presentation	Artificial crack depth determination of concrete specimens using ground penetrating radar and synthetic aperture radar	2022 ASCE Engineering Mechanics Institute (EMI) Annual Conference	ASCE annual conference / civil engineers, researchers, government officials	The Johns Hopkins University, Baltimore, MD	June 3, 2022

Table 5: Submitted/Accepted Publications, Technical Reports, Theses, Dissertations, Papers, and Reports

Type	Title	Citation	Date	Status
Peer-reviewed journal	Electromagnetic detection of concrete cracking by using synthetic aperture radar and ground penetrating radar	NDT&E International	June 30, 2022	Under revision

Answer the following questions (N/A if there is nothing to report):

1. Did you deploy any technology during the reporting period through pilot or demonstration studies as a result of this work? If so, what was the technology? When was it deployed?
   Yes, we applied an EM sensor (ground penetrating radar or GPR) on cracked concrete bridge abutment in the field on June 15, 2022.

2. Was any technology adopted by industry or transportation agencies as a result of this work? If so, what was the technology? When was is adopted? Who adopted the technology?
   Not yet.

3. Did findings from this research project result in changing industry or transportation agency practices, decision making, or policies? If so, what was the change? When was the change implemented? Who adopted the change?
   Not yet.

4. Were any licenses granted to industry as a result of findings from this work? If so, when? To whom was the license granted?
   N/A

5. Were any patent applications submitted as a result of findings from this research? If so, please provide a copy of the patent application with your report.
   N/A

6. Did industry organizations or DOTs provide cost-share (cash or in-kind) to your research during the reporting period? Who was the organization? Please provide an in-kind support invoice from the organization with your report (this is kept confidential and used for record keeping purposes only).
   N/A

In Figure 1, location of a GPR B-scan on the bridge abutment with crack #1 and the B-scan image are shown. We used a surface crack (#1) as an example target and the rest of the area on the bridge abutment as the background in this B-scan survey. In Fig. 1, eight steel rebars in the vertical direction are identified. In the vicinity of crack #1 near the surface level of the B-scan image, several irregular scattering signals are also clearly identified.

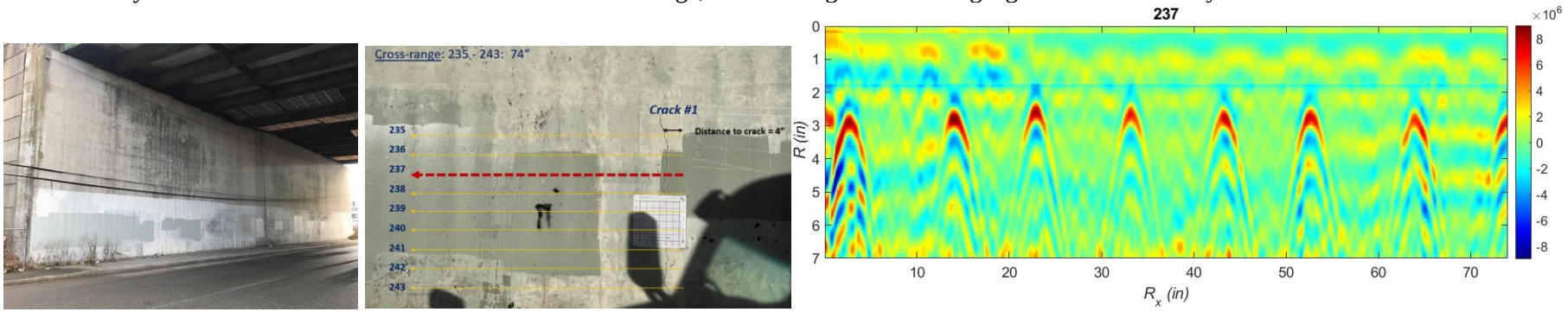

Fig. 1. Lowell connector bridge abutment (Lowell, MA) and its GPR B-scan image (scan 237) with extracted pattern

Outputs:

- New GPR B-scan image datasets have been included to our EM database for the nondestructive inspection and structural health monitoring of a highway bridge in Massachusetts.
- New image processing algorithm (written in Matlab) has been developed (and will be further improved) with the GPR B-scan images collected during this period of the project.

Outcomes:

- N/A

Impacts:

- N/A

Participants and Collaborators:

Table 6: Active Principal Investigators, faculty, administrators, and Management Team Members

Individual Name & Title	Dates involved	Email Address	Department	Role in Research
Tzuyang Yu	4/01/2022 ~ 6/30/2022	Tzuyang_Yu@UML.EDU	Civil and Environmental Engineering	Project principle investigator and Institutional Lead at UML; overseeing all projects and working on radar imaging and interpretation

Table 7: Student Participants during the reporting period

Student Name	Start Date	End Date	Advisor	Email Address	Level	Major	Funding Source	Role in research
Koosha Raisi	4/1/22	6/30/22	Prof. Yu		Ph.D.	Civil and Environmental Engineering	TIDC	Data processing and analysis
Nimun Nak Khun	4/1/22	6/30/22	Prof. Yu		M.S.	Civil and Environmental Engineering	TIDC	Laboratory radar imaging and data processing
Yaneliz Garcis Ruiz	4/1/22	6/30/22	Prof. Yu		B.S.	Civil and Environmental Engineering		Assistance in the preparation for bridge field tests
Farel Adelson	4/1/22	6/30/22	Prof. Yu		B.S.	Civil and Environmental Engineering		Assistance in the preparation for bridge field tests

Table 8: Students who Graduated During the Reporting Period			
Student Name	**Degree/Certificate Earned**	**Graduation/Certification Date**	**Did the student enter the transportation field or continue another degree at your university?**

Table 9: Industrial Internships			
Student Name	**Degree/Certificate Earned**	**Graduation/Certification Date**	**Did the student enter the transportation field or continue another degree at your university?**

Table 10: Research Project Collaborators during the reporting period						
Organization	**Location**	**Contribution to the Project**				
		Financial Support	**In-Kind Support**	**Facilities**	**Collaborative Research**	**Personnel Exchanges**
MassDOT	Boston, MA				X	X
City of Lowell	Lowell, MA				X	X
Geophysical Survey Systems, Inc. (GSSI)	Nashua, NH				X	X
City of Lowell	Lowell, MA				X	X

Table 11: Other Collaborators				
Collaborator Name and Title	**Contact Information**	**Organization and Department**	**Date(s) Involved**	**Contribution to Research**
David Cist		GSSI	3/16/22	Technical champion
Mark Jen		Kiewit Corporation	5/14/22	Technical champion

Table 12: Course List						
Course Code	**Course Title**	**Level**	**University**	**Professor**	**Semester**	**# of Students**
CIVE 5110	Inspection and Monitoring of Civil Infrastructure	Grad	UMass Lowell	Tzuyang Yu	Spring	17
ENGN 2070	Dynamics	Undergrad	UMass Lowell	Tzuyang Yu	Spring	37

Changes:
N/A

Planned Activities:

In the next reporting period, we plan to continue following research tasks with limited access to our laboratories.

- Task 3.2: Field inspection of corroded RC structures (Preliminary)
- Task 4: Development of EM database and correlation between SAR and GPR images
- Task 5: Data analysis and image interpretation