Quarterly Progress and Performance Indicators Report:
Project Number and Title: 3.19 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): Jianqiang Wei (UMass Lowell)
Reporting Period: 7/1/2022~9/31/2022
Submission Date: 9/31/2022

Overview:

The research problem we are trying to solve is the detection and monitoring of aging civil infrastructure components and systems in New England by using visual information and subsurface images in a virtual reality (VR) environment for data visualization and machine learning (ML) for data interpretation. The overall research objective is to study the detection and monitoring problem of aging civil infrastructure components and systems in New England by using visual information and subsurface images in a virtual reality (VR) environment for data visualization and machine learning (ML) for data interpretation. In the reporting period of this project, we have selected a reinforced concrete (RC) highway bridge for high-frequency nondestructive testing (NDT) inspection (Task 1) and started collecting high frequency NDT data (Task 2) and manufacturing laboratory concrete specimens for material aging study (Task 4).

Meeting the Overarching Goals of the Project:

- We have identified a RC highway bridge (I-495, Chelmsford, MA) for high frequency NDT inspection.

Accomplishments:

- We have designed and manufactured laboratory concrete specimens for material aging study.

Task, Milestone, and Budget Progress:

Table 1: Task Progress

Task Number: Title	Start Date	End Date	% Complete
Task 1: Selection of candidate transportation infrastructure systems for high-frequency NDT inspection	6/1/22	6/31/22	100%
Task 2: Collection of high inspection frequency NDT sensor data from transportation infrastructure systems	6/15/22	5/31/23	5%
Task 3: Laboratory and field investigation of material aging with sensor data	7/1/22	5/31/23	10%
Task 4: Manufacturing of concrete specimens with simulated material aging problems	7/1/22	5/31/23	10%
Task 5: Training and development of ML/AI models with NDT sensor data	11/1/22	5/31/23	0%
Task 6: Development of predictive models for material aging and structural deterioration	6/1/22	5/31/23	15%
Task 7: Meetings, Documentation, dissemination, and reporting	6/1/22	5/31/23	15%

Table 2: Milestone Progress

Milestone #: Description	Corresponding Deliverable	Start Date	End Date

Milestone 1: Selection of candidate structures for high inspection frequency NDT inspection	Selection of candidate highway bridges in Massachusetts (100%); Quarterly report (9/31/22)	6/1/22	6/31/22
Milestone 2: Development of preliminary NDT sensor data for ML/AI modeling	Collection of NDT sensor data using GPR (5%); Quarterly report (12/31/22)	6/1/22	12/31/22
Milestone 3: Development of baseline model for each new bridge	Development of data processing algorithms for baseline calculation (10%); Quarterly report (12/31/22)	6/1/22	11/1/22
Milestone 4: Development of graphic user interface tool for each bridge	Development of data interpretation model in a VR environment (0%); Quarterly report (12/31/22)	11/1/22	12/31/22
Milestone 5: Development of annual monitoring dataset	Development of annual dataset comprising of visual and NDT inspection information in a VR environment (0%); Quarterly report (3/31/23)	1/1/23	8/31/23
Milestone 6: Development of structural performance curve for each bridge	Development of ML models for processing NDT data to generate structural performance curve of the monitored bridge (0%); Quarterly report (3/31/23)	4/1/23	5/31/23

Table 3: Budget Progress

Project Budget	Spend – Project to Date	% Project to Date (include the date)
$199,256 (federal)	$18,483.33 (federal)	9.27% (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	Hydration of sustainable cementitious composite with internal conditioning by functionalized montmorillonite	Dayou Luo, Jianqiang Wei, Hydration of sustainable cementitious composite with internal conditioning by functionalized montmorillonite, Engineering Mechanics Institute Conference, Baltimore, MD	Engineering Mechanics Institute Conference 2022	Baltimore, MD	June 01, 2022
Conference	Exploring the Role of Magnesium Nitrate in Modifying Properties of Alkali-Silica Reaction Gels	Arkabrata Sinha, Jianqiang Wei, Exploring the Role of Magnesium Nitrate in Modifying Properties of Alkali-Silica Reaction Gels, Engineering Mechanics Institute Conference, Baltimore, MD	Engineering Mechanics Institute Conference 2022	Baltimore, MD	June 01, 2022
Conference	Multi-Scale Characterization of Alkali-Silica Reaction Gels Modified with Magnesium Nitrate	Jianqiang Wei, Arkabrata Sinha, Dayou Luo, Multi-Scale Characterization of Alkali-Silica Reaction Gels Modified with Magnesium Nitrate, 16th International Symposium on Functionally Graded Materials, Hartford, CT	16th International Symposium on Functionally Graded Materials	Hartford, CT	August 07, 2022

Table 5: Submitted/Accepted Publications, Technical Reports, Theses, Dissertations, Papers, and Reports				
Type	**Title**	**Citation**	**Date**	**Status**
Peer-reviewed journal	Mitigating alkali-silica reaction through metakaolin-based internal conditioning: New insights into	Dayou Luo, Arkabrata Sinha, Madhab Adhikari, Jianqiang Wei*, Mitigating alkali-silica reaction through metakaolin-based internal conditioning: New insights into property evolution and	September 2022	Accepted

	property evolution and mitigation mechanism	mitigation mechanism, Cement and Concrete Research, 2022, 159, 106888, https://doi.org/10.1016/j.cemconres.2022.106888		

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 a RC highway bridge for high frequency NDT data collection.

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).
   No.

Figure 1 shows our visit to I-495 highway bridge on September 29, 2022 for collecting GPR and visual data of corroded bridge pier columns. A 1.6GHz GPR (StructureScan, GSSI) system was used in collecting all B-scan images. A digital camera (Canon Mark II) was also used in collecting digital images for building the VR model of the bridge. On the other hand, raw materials for regular and high-performance concrete, such as cement, sand, gravel, and chemical admixtures have been collected in Co-PI Wei's laboratory. Supplementary cementitious materials, including silica fume, fly ashes, and metakaolin have been prepared. To investigate the alkali-silica reaction (ASR) of concrete, reactive fine aggregates collected from El Paso, TX have been delivered to the lab. Two types of specimens, including 2-inch by 2-inch by 2-inch cubes (Figure 1a) and 1-inch by 2.25-inch by 11-inch beams (Figure 1b), have been cast for compressive and flexural strength tests. 1-inch by 1-inch by 10-inch mortar bars (Figure 1c) have been cast for ASR expansion tests. The hydration behavior of the cement binders was monitored to determine the hydration kinetics and activation energy of the hydration reactions. X-ray diffractometer (XRD), dynamic vapor sorption analyzer, and thermogravimetric analyzer have been calibrated for the analysis of cement hydration products.

Figure 1. (a) GPR inspection of corroded RC bridge pier column (Koosha and Nak); (b) Visual inspection of RC bridge pier column (PI Yu)

Figure 2. (a) cubes for compressive strength test, (b) beams for flexural strength test, and (c) mortar bars for ASR expansion test.

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:

- We presented our radar imaging study at the 2022 SPIE Smart Structure/NDE Symposium (Long Beach, CA, March 6~10, 2022) to in-person and online attendees from around the world, through two conference presentations. We have received many questions regarding the use of GPR for concrete characterization.

Impacts:

- Through our conference presentation at the 2022 SPIE Smart Structure/NDE Symposium, we have promoted the use of EM sensors for concrete bridge inspection and monitoring to an audience comprising of faculty, undergraduate and graduate students, bridge engineers, and sensor vendors, and government officials.

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	10/01/2021~ 12/31/2021	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	7/1/22	9/30/22	Prof. Yu		Ph.D.	Civil and Environmental Engineering	TIDC	Data processing and analysis
Nimun Nak Khun	7/1/22	8/31/22	Prof. Yu		M.S.	Civil and Environmental Engineering		Laboratory radar imaging and data processing

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?**
Nimun Nak Khun	Master's in Civil Engineering	8/31/2022	Yes

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
Eco Material Technologies	Oxford, MA		X		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		Michael Baker Engineering, Inc.	1/20/22	Technical champion

Table 12: Course List

Course Code	Course Title	Level	University	Professor	Semester	# of Students

Changes:
N/A

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

- Task 1: Selection of candidate transportation infrastructure systems for high-frequency NDT inspection
- Task 2: Collection of high inspection frequency NDT sensor data from transportation infrastructure systems
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