Quarterly Progress 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): *Co-PIs and home institution(s)*
Reporting Period: 10/1/19~12/31/19
Submission Date: 12/31/19

Overview: (Please answer each question individually)

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. During the reporting period, we have been working on Tasks 1, 2, 3, 4, and 5 of the proposed research; **Task 1:** Preparation of laboratory concrete specimens with single and multiple cracking mechanisms. **Task 2:** Laboratory radar imaging of concrete specimens, **Task 3:** Preliminary field radar imaging of concrete bridges, **Task 4:** Development of an EM (electromagnetic) database, and **Task 5:** Data analysis and image interpretation. We have completed Tasks 1 and 2 and found that various parameters extracted from synthetic aperture radar (SAR) images can used to estimate the width, length, and depth of concrete cracks of a regular geometry. The findings developed from Tasks 1 and 2 will help us to complete the development of an EM database and to better characterize actual concrete cracks in the field.

Table 1: Task Progress

Task Number	Start Date	End Date	Percent Complete
Task 1:	1/1/19	6/30/19	100%
Task 2:	6/30/19	12/31/19	100%
Task 3:	6/30/19	6/30/20	70%
Task 4:	1/1/20	12/31/20	10%
Task 5:	1/1/20	12/31/20	10%

Table 2: Budget Progress

Entire Project Budget	Spend Amount	Spend Percentage to Date
$127,641.11	$75,584.67	60%

Table 3: Presentations at Conferences, Workshops, Seminars, and Other Events

Title	Event	Type	Location	Date(s)
Imaging of Concrete Materials and Structures using Synthetic Aperture Radar	International Seminar in Civil Engineering	Invited seminar talk	Department of Civil Engineering, National Cheng-Kung University, Tainan, Taiwan	12/19/19
Condition Assessment of Concrete Structures using Radar Imaging	School of Engineering Seminar	Invited seminar talk	Department of Civil Engineering, Chung Yuang University, Chungli, Taiwan	12/20/19

Table 4: Publications and Submitted Papers and Reports

Type	Title	Citation	Date	Status

Conference paper	Synthetic aperture radar imaging of concrete cracking	SPIE Smart Structures/NDE Conference	10/17/19	Submitted and accepted

Figure 1: Images of specimen CNI, CNC, CNCD and CNCW

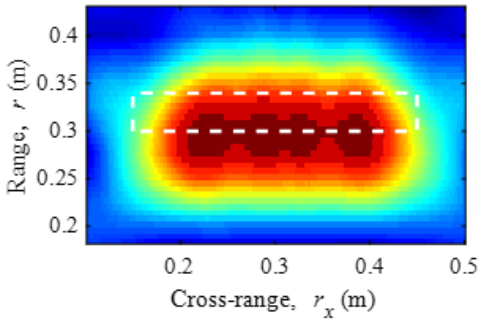


Figure 2a. SAR image of specimen CNI, Ψ_L= 1.2%

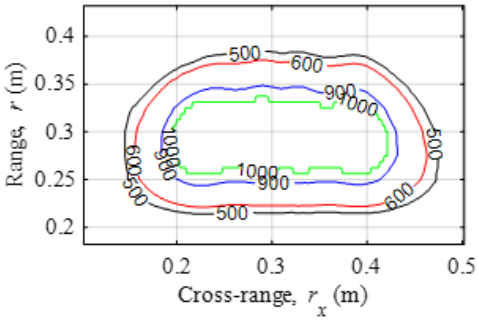


Figure 2b. Contour representation CNI, Ψ_L= 1.2%

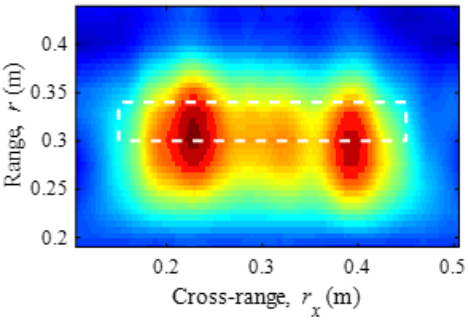


Figure 3a. SAR image of specimen CNCW, Ψ_L= 1.2%

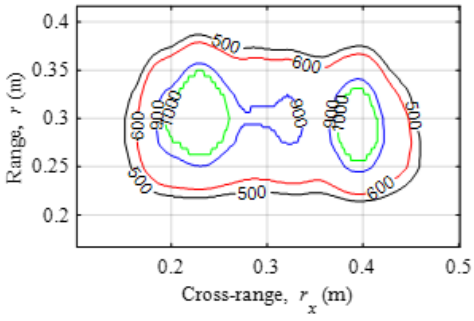
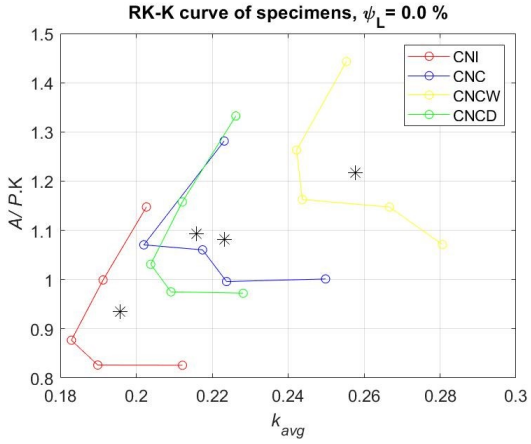


Figure 3b. Contour representation CNCW, Ψ_L= 1.2%

From Figures 2 and 3, we have found that the introduction of crack in concrete specimens splits the contour in SAR images of concrete specimens. The green contour representing the contour level of amplitude 1,000 and blue contour representing the contour level of amplitude 900 is continuous in the intact specimen, whereas in the cracked specimen it splits into two. We study the area(A), perimeter(P) and the average curvature (K_{avg}) to derive an empirical equation for finding crack width. A plot of $K_{avg}$and A/P.K at different contour levels is shown in Figure 3. Centre of each curve is calculated and plotted against crack width (W).



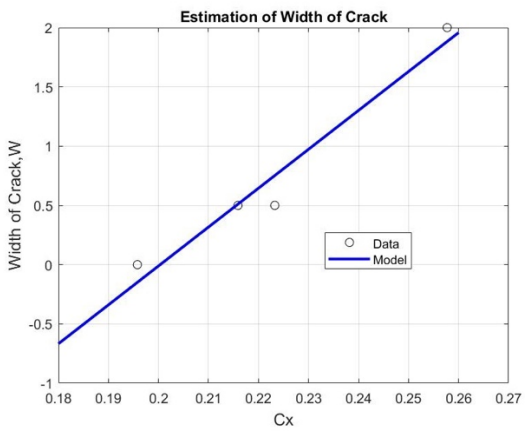


Figure 4a. Plot of k_{avg} vs A/P.K **Figure 4b. Plot of C_x vs Width of Crack**

Participants and Collaborators:

Table 5: Active Principal Investigators, faculty, administrators, and Management Team Members			
Individual Name	**Email Address**	**Department**	**Role in Research**
Tzuyang Yu	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 6: Student Participants during the reporting period				
Student Name	**Email Address**	**Class**	**Major**	**Role in research**
Ahmed Alzeyadi		Ph.D.	Civil and Environmental Engineering	Design and manufacturing of laboratory specimens, field radar imaging of structures, data analysis and signal processing
Sanjana Vinayaka		Ph.D.	Civil and Environmental Engineering	Manufacturing of laboratory specimens, field radar imaging of structures, data analysis and signal processing
Jade Man		Undergrad	Civil and Environmental Engineering	Manufacturing of laboratory specimens

Table 7: Student Graduates			
Student Name	**Role in Research**	**Degree**	**Graduation Date**
N/A			

Table 8: Research Project Collaborators during the reporting period						
Organization	**Location**	**Contribution to the Project**				
		Financial Support	**In-Kind Support**	**Facilities**	**Collaborative Research**	**Personnel Exchanges**
Massachusetts Department of	Boston, Massachusetts				X	X

Transportation (MassDOT)						
City of Lowell	Lowell, Massachusetts			X	X	X

Changes:

None.

Planned Activities:

In the next reporting period, we plan to continue working on following tasks.

Task 3: Preliminary field radar imaging of concrete bridges – Have started our first preliminary field inspection. Will continue working on this task.

Task 4: Development of EM database – Have started developing this EM (electromagnetic) database and will continue working on this task.

Task 5: Data analysis and image interpretation – Have started developing algorithms for analyzing and interpreting radar images for condition assessment. Will continue developing more algorithms.