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): N/A
Reporting Period: 07/01/2020~09/30/2020
Date: 09/29/2020

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. Table 1 provides our progress on individual tasks. Table 2 reports our budget progress.

Table 1: Task Progress			
Task Number	**Start Date**	**End Date**	**Percent Complete**
Task 3	9/1/19	6/31/20	60% (stalled)
Task 4	9/1/19	12/31/20	80%
Task 5	1/1/20	12/31/20	80%

Table 2: Budget Progress		
Entire Project Budget	**Spend Amount**	**Spend Percentage to Date**
$269,791.11	$215,833 (TBD)	80% (TBD)

In our last quarterly report, we carried out a quantitative analysis on detecting and quantifying artificial cracks in concrete using GPR and SAR images. Our major findings are summarized in the following:

1. Subsurface moisture content in concrete is an important factor affecting the crack detectability in concrete. Moisture content must be estimated and compensated when using GPR and SAR images for crack detection.
2. Presence of an artificial crack in concrete will reduce the amplitudes in GPR and SAR images of concrete.
3. Presence of an artificial crack in concrete generates different patterns in GPR and SAR images. A hyperbolic pattern is found in GPR B-scan images of concrete, while a semi-sinusoidal pattern is found in SAR images of concrete.

Crack detection of a reinforced concrete beam specimen under four-point bending

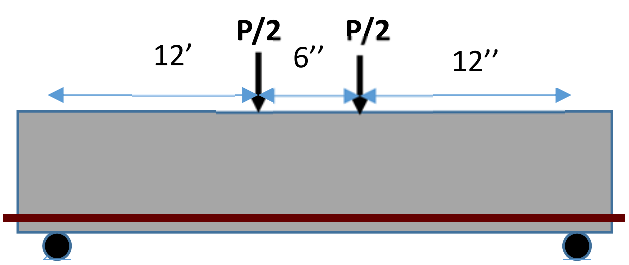

Fig. 1 a) Pictorial representation of 4 - point bending test to generate cracks

Fig. 1 b) Picture of 4- point bending

Fig. 1 c) Cracks generated

A four-point bending test was carried out to generate flexural cracks on a 36''x 6''x6'' reinforced concrete (RC) beam specimen as shown in Fig. 1. **Fig.1a)** and **Fig. 1b)** show our experimental set up. **Fig. 1c)** shows few flexural cracks observed on the surface of concrete. SAR images were collected on the same RC beam inside an anechoic chamber, before and after cracking. Experimental setup and the SAR images collected at the range of 45-cm in range-cross-range domain are shown in **Fig. 2a)**, **Fig. 2b), and Fig. 2c),** respectively.

Fig. 2a) Laboratory SAR imaging

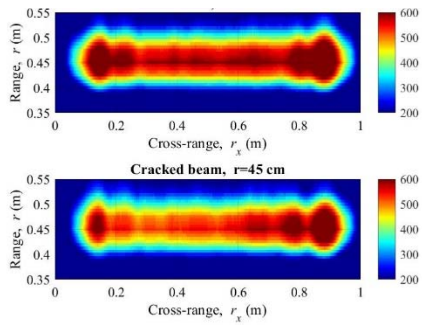

Fig. 2b) SAR image of Intact and cracked beam

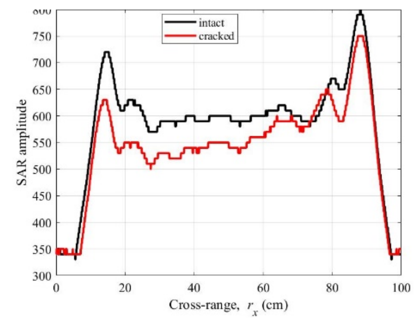

Fig. 2c) Variation of max SAR amplitude along cross-range

From **Fig. 2b)**, it was observed that there is an overall amplitude reduction in the SAR image of cracked RC beam when compared to the SAR image of intact RC beam. This can be attributed to loss in moisture since the SAR image of cracked RC beam was collected six hours after the SAR image of intact RC beam was collected. Assuming that the moisture loss in concrete is uniform throughout the RC beam, compensation of moisture change was applied to the SAR image of cracked RC beam and shown in **Fig. 3a**) with contours at an SAR amplitude of 540. Fig. 3b) compares two SAR curves of intact and cracked RC beams, and **Fig. 3c)** compares the SAR contours intact and cracked RC beams.

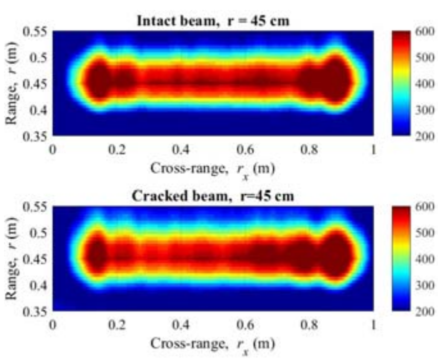

Fig. 3a) SAR image of Intact and cracked beam after moisture compensation

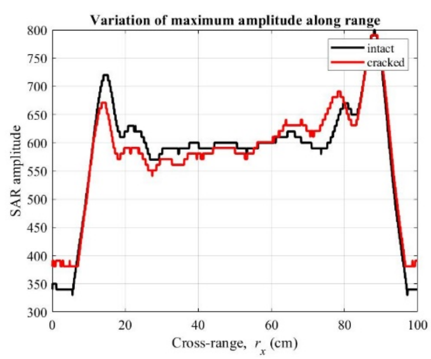

Fig. 3b) Variation of max SAR amplitude along cross-range after moisture compensation

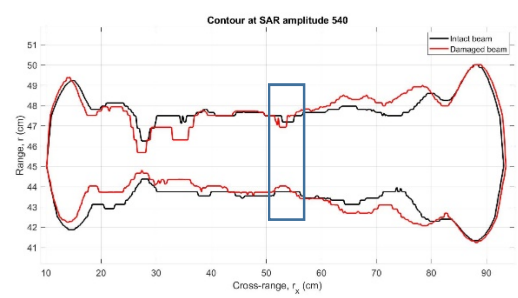

Fig. 3c) Contour at SAR amplitude of 540

Table 3: Presentations at Conferences, Workshops, Seminars, and Other Events				
Title	**Event**	**Type**	**Location**	**Date(s)**
Remote Radar Inspection of Concrete Bridges for Moisture Characterization and Crack Depth Detection	2020 VTrans Research and Innovation Symposium	Conference	Online	Sep. 9, 2020

Table 4: Publications and Submitted Papers and Reports

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Type	Title	Citation	Date	Status

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**
Sanjana Vinayaka		Ph.D.	Civil and Environmental Engineering	Manufacturing of laboratory specimens, field radar imaging of structures, data analysis and signal processing
Ronan Bates		B.S.	Civil and Environmental Engineering	Assistance in the preparation for bridge field tests
Nashire Pelatra		B.S.	Civil and Environmental Engineering	Assistance in the preparation for bridge field tests

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

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

Changes:

Due to the significant impact of covid-19 pandemic in Massachusetts, we have been prohibited from accessing our research facility, equipment, and specimens since March 6, 2020. Since July 6, 2020, we have been granted limited access to our research laboratories (Monday to Friday, 7:00 AM to 1:00 PM), which has hindered our capabilities to conduct planned laboratory experimental task (Task 3). Due to covid-19, additional internal approval process at UML also has limited our options to perform field tests. Until September 29, 2020, we are taking the following safety measures in the laboratory and for field tests.

1. Reduced population density on campus with social distancing – As required by the University, we have to reduce the number of students allowed in our laboratory to 50%. Students working in the laboratory must wear personal protection equipment (PPE) including face masks and face shields all the time, while maintaining a six-foot social distance.
2. Transportation requirement – When commuting to bridge sites, we have to reduce the number of passengers in each vehicle from five to two (one driver and one passenger). All other regular safety measures such as wearing face masks still apply during transportation.

On the other hand, we will continue our research meetings that have been converted to a virtual platform since last quarter. We will use the virtual meeting platform for our educational and outreach activities, as well as meeting with state DOTs.

Planned Activities:

In the next reporting period, we plan to continue following research tasks with limited access to our laboratories.
Task 3: Preliminary field radar imaging of concrete bridges –
Task 4: Development of EM database
Task 5: Data analysis and image interpretation