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: 10/01/2020~12/31/2020
Date: 12/28/2020

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	8/31/21	60% (stalled)
Task 4	9/1/19	9/30/20	85%
Task 5	1/1/20	9/30/20	85%

Table 2: Budget Progress

Entire Project Budget	Spend Amount	Spend Percentage to Date
$269,791.11	$229,322 (*estimated*)	85% (*estimated*)

In our last quarterly report, we carried out a quantitative analysis on detecting and quantifying artificial cracks in concrete using GPR and SAR images. Due to the worsening situation of covid-19 in Massachusetts and an increasing health concern among our undergraduate and graduate students, our field test tasks have been delayed. Our progress on the project has been mainly on data analysis.

Crack detection of a reinforced concrete (RC) beam specimen using SAR images

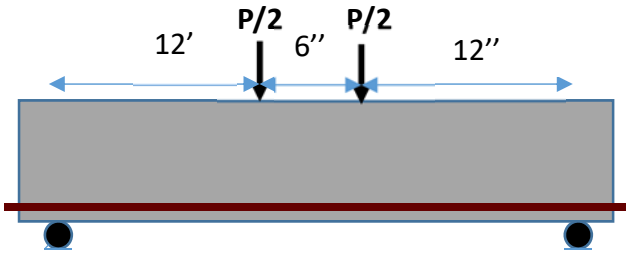


Fig. 1 a) Pictorial representation of 4 - point bending test to generate cracks

Fig. 1 b) Picture of 4- point bending

Fig. 1 c) Cracks generated

Figure 1 shows a RC beam created as a calibration specimen, whose detail information was reported in our last quarterly report. We scanned the RC beam with our SAR imaging sensor at different ranges (15cm, 30cm, and 45cm) inside an anechoic chamber at UMass Lowell, as shown in Fig. 2. In Figure 2, a major electromagnetic reflection (specular returns) from the surface and subsurface of the RC beam is imaged by SAR algorithm into a spatial distribution of SAR amplitudes. In Fig. 2, the presence of a subsurface crack in RC will lead to a reduced SAR scattering response centering in the vicinity of 40-cm (0.4-m) for all ranges. It is clear that such a reduced SAR scattering response is associated with a spatial pattern in the range—cross-range SAR images (Fig. 2). This spatial pattern may be used to estimate crack volume in the future. To better quantify crack location, we calculated

the average SAR amplitudes along the cross-range of the specular response and obtained the cross-range SAR curves in Figure. 3.

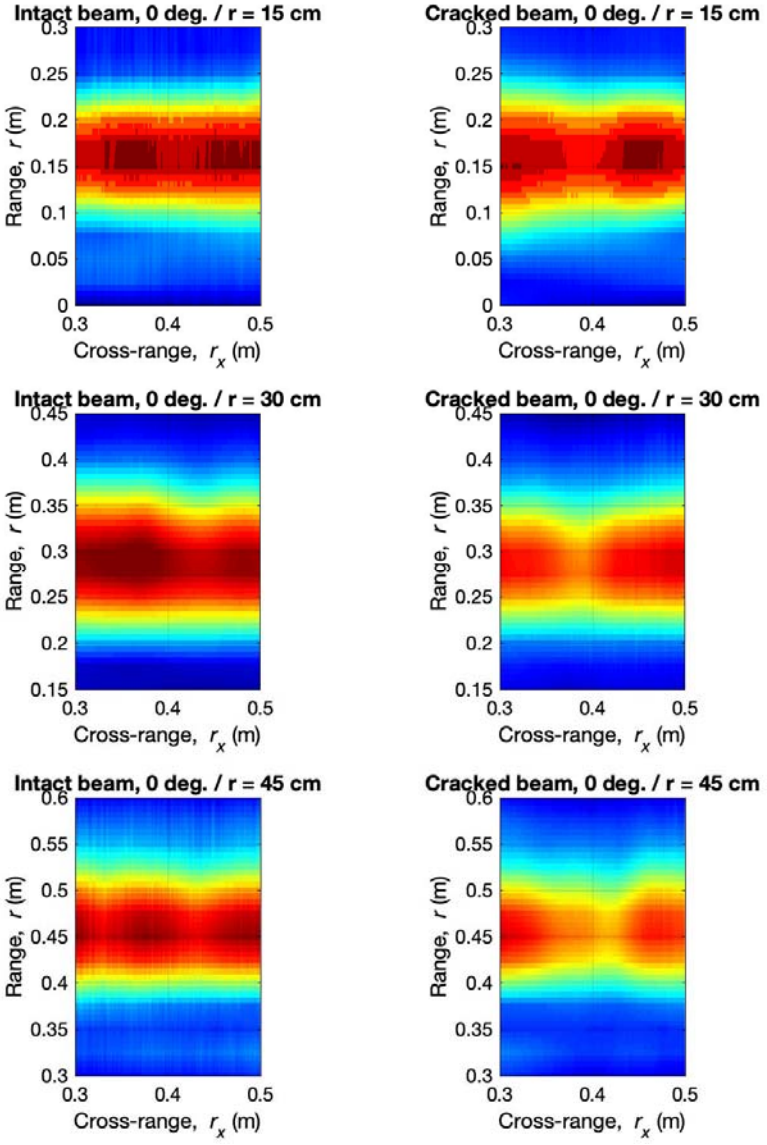
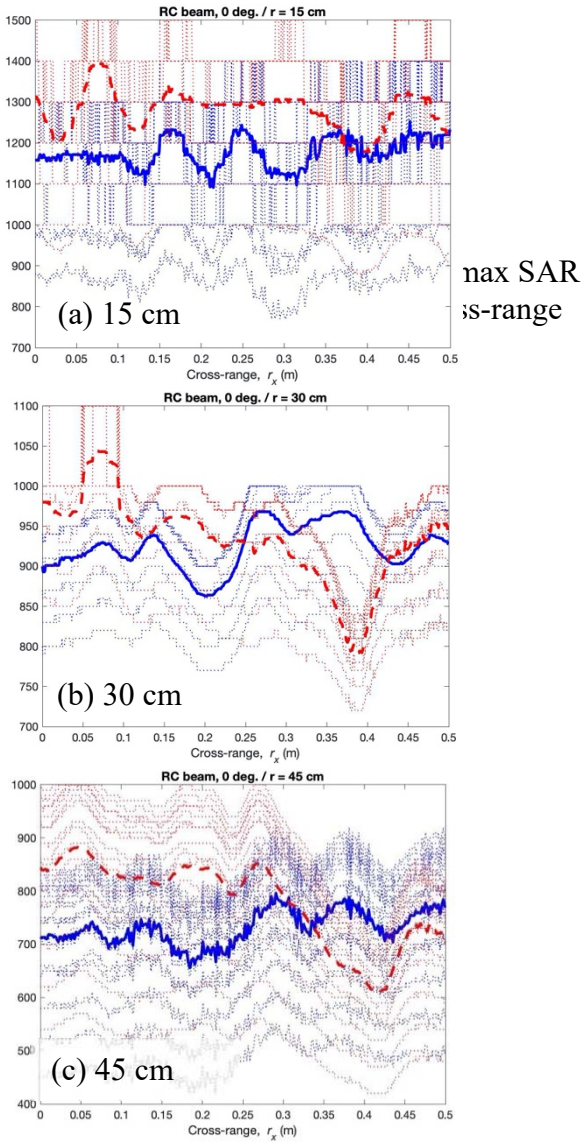


Fig. 2. SAR images at different ranges



nax SAR
ss-range

Fig. 3. Maximum SAR amplitudes

In Figure 3, blue solid SAR curves represent the averege specular response of an intact RC beam and red dashed SAR curves the average specular respoinse of a cracked RC beam, at three different ranges. While the SAR amplitude of cracked RC beam (red dashed curves) in average is greater than the one of intact RC beam (blue solid curves), it becomes smaller than the one of intact RC beam in the vicinty of the crack location. This difference can be categoried into the two aspects; cross-range location and amplitude change. In Figure 3 (a), the cross-range location where such SAR amplitude reduction occurs is 0.35~0.4 m for 15-cm range. It becomes 0.25~0.42 m for 30-cm range and 0.34~0.5 m for 40-cm range. However, in terms of SAR amplitude reduction, it shows 40 at 15-cm range, 170 at 30-cm range, and 120 at 45-cm range.

Table 3: Presentations at Conferences, Workshops, Seminars, and Other Events				
Title	**Event**	**Type**	**Location**	**Date(s)**

Table 4: Publications and Submitted Papers and Reports

Type	Title	Citation	Date	Status
Journal	Remote electromagnetic detection of concrete cracking by using synthetic aperture radar imaging	NDT&E International		To be submitted in January 2021

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
Abdulla Aljeboure		M.S.	Civil and Environmental Engineering	Laboratory radar imaging of specimens, data analysis and signal processing
Nashire Pelatra		B.S.	Civil and Environmental Engineering	Assistance in the preparation for bridge field tests
Ronan Bates		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

Maine DOT	Hampden, Maine			X	X	X

Changes:

1) Since last quarter, our laboratory tests were limited by i) access time (Phase 3 access), ii) social distancing (6 feet) and iii) the maximum number of students in each laboratory (SO130 and FA104). With team's health being our topic priority, we took extra care when performing any experimental work (indoor or outdoor). We would postpone or cancel scheduled laboratory or field test whenever there is a team member not feeling completely healthy in order to avoid the spreading of the pandemic on campus.
2) Owing to the delay due to covid-19, we had submitted a no-cost extension request on Dec. 4, 2020 to continue our research until September 30, 2021. It has been approved on Dec. 8, 2020 by the TIDC.
3) Doctoral student Sanjana Vinayaka will not continue her role on the project, due to personal health issue. A new member (Abdulla Aljeboure, Master's graduate) will join the team as doctoral student in next quarter.
4) We will collaborate with MaineDOT and UMaine in the Hampden Bridge monitoring project in the upcoming field test (Dec. 30~31, 2020).

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