Bi-Monthly 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: 4/1/2019~5/31/2019
Date: 5/31/2019

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. During the reporting period, we have been working on Task 1 and Task 2 of the proposed research; **Task 1**: Preparation of laboratory concrete specimens with single and multiple cracking mechanisms (6 months), and **Task 2**: Laboratory radar imaging of concrete specimens (6 months). These two tasks will provide us the data (radar images) to understand how single crack on concrete specimens can be characterized and quantified by radar images, such that ultimately, we can use field-collected radar images to quantify cracks on real concrete bridges and to achieve the following **project goals**.

a. Develop a data driven field inspection procedure for concrete cracking on concrete bridges
b. Develop a radar signature database of concrete cracking at various levels such that bridge engineers can use it for efficient assessment of concrete cracking in the field.

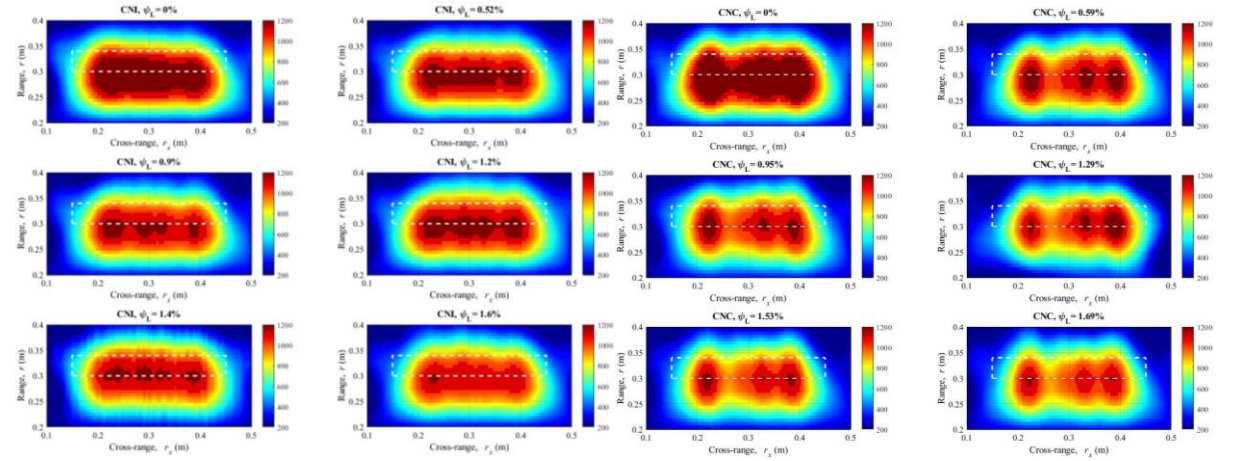
In the past two months, we have accomplished 30% of Task 1 and 30% of Task 2 by developing synthetic aperture radar (SAR) image based inspection procedure for quantifying an artificial surface crack on concrete panels. Table 1. The SAR images of concrete panels at various moisture levels are shown in Figure 1. These SAR images were collected as part of the effort to develop a radar signature database of concrete cracking, as described in Task 2.

In order to develop a data driven field inspection procedure for concrete cracking on concrete bridges (Task 1), **inspection parameters** must be identified/defined by using SAR images. In this project, we have identified the following inspection parameters for bridge engineers to use in the field, including i) distribution of SAR amplitudes (1D and 2D) and ii) critical contour area (A_c) of SAR images. From our study, the following findings have been drawn.

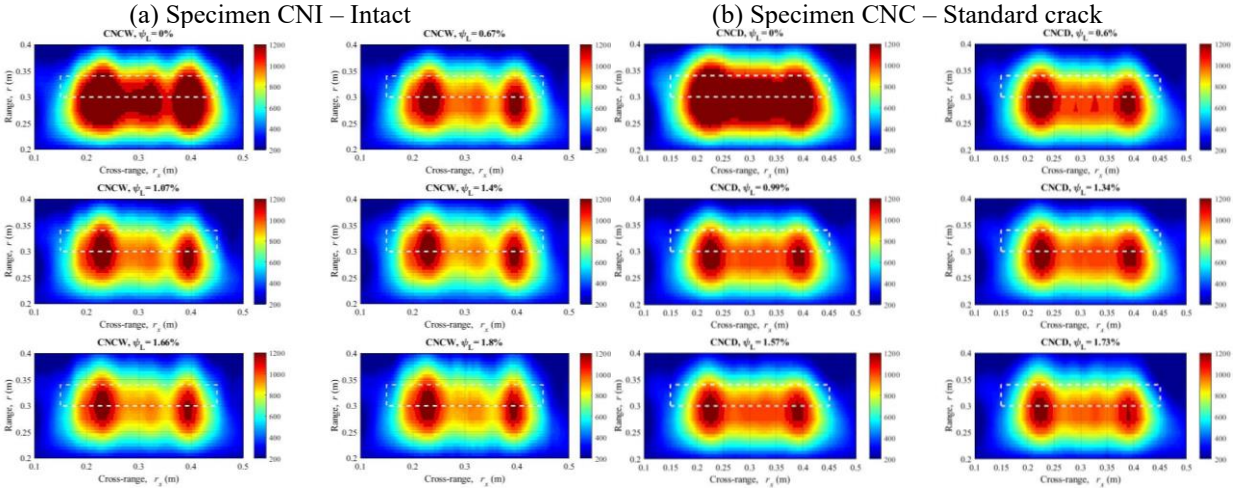
- Distribution of SAR amplitudes can be quantified by the K-R-I transform for crack detection. The K-R-I curves of SAR images allows bridge engineers to directly compare two SAR images without constraints on image resolution and image orientation (typical issues in the baseline approach). Figure 2 exemplifies the K-R-I transform of four SAR images of specimens CNI, CNC, CNCW, and CNCD.
- Critical contour area (A_c) can be used to estimate crack depth if crack length and width are measured from the surface. The background information (e.g., moisture content) in SAR images of concrete panels also needs to be developed such that an empirical model between critical contour area and moisture content is established.

Table 1. Intact and damaged concrete panels

Specimen	Crack Dimensions			Note
	Length (cm)	Width (cm)	Depth (cm)	
CNI	0	0	0	Intact concrete panel
CNC	10	0.5	0.5	With a 0.1m-by-0.005m-by-0.005m crack
CNCW	10	2	0.5	With a 0.1m-by-0.005m-by-0.02m crack
CNCD	10	0.5	1.5	With a 0.1m-by-0.015m-by-0.005m crack

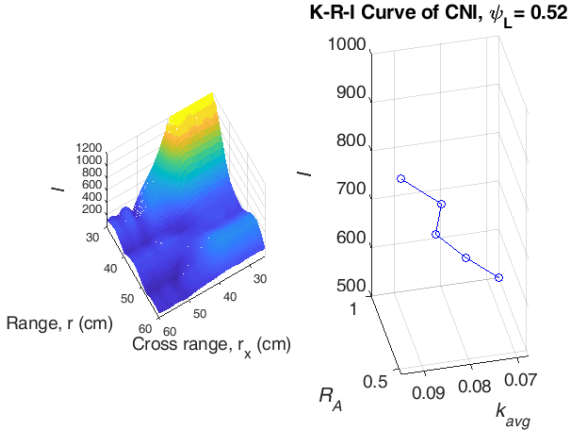


(a) Specimen CNI – Intact (b) Specimen CNC – Standard crack

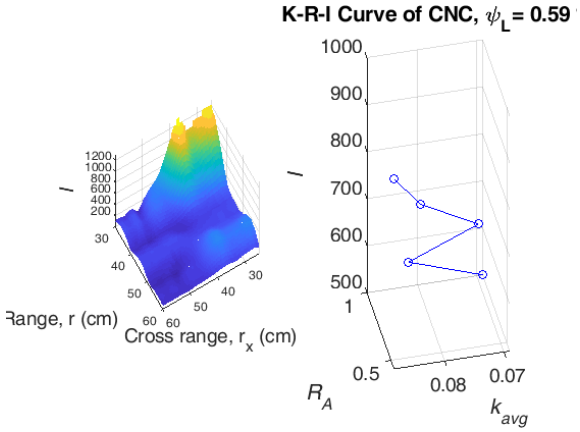


(c) Specimen CNCW – Crack with increased width (d) Specimen CNCD – Crack with increased depth

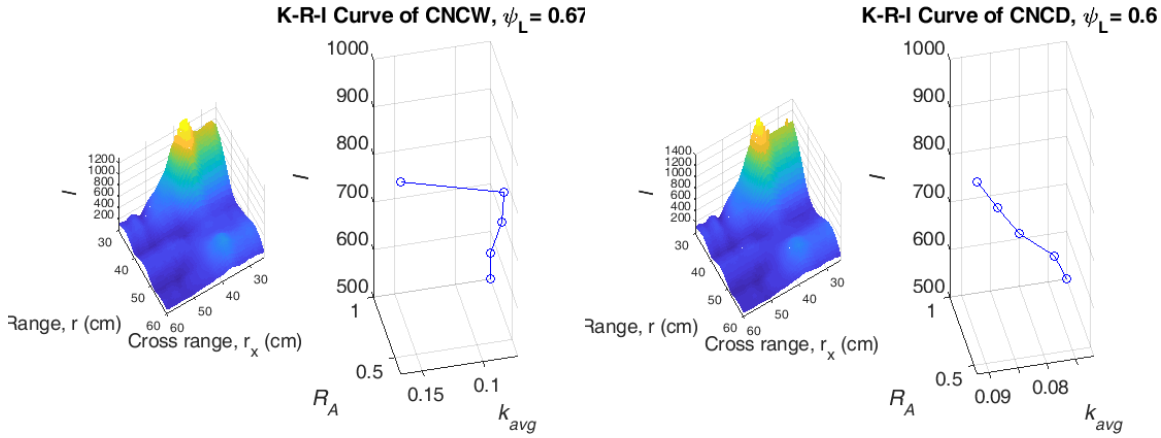
Figure 1. SAR images of intact and damaged concrete panels at various moisture levels



(a) Specimen CNI – Intact



(b) Specimen CNC – Standard crack



(c) Specimen CNCW – Crack with increased width (d) Specimen CNCD – Crack with increased depth

Figure 2. K-R-I transforms of SAR images of intact and damaged concrete panels

Regarding **training/professional development**, there are graduate and three undergraduate research assistants working on this research. Regarding the **dissemination** of research results during the reporting period, we have submitted two journal manuscripts to *NDT&E International* and *Construction and Building Materials*. We also have updated our project websites by providing interview videos with faculty researchers for each project (https://www.uml.edu/Research/tidc/projects/), Equipment and Facilities information (https://www.uml.edu/Research/tidc/Equipment-Facilities.aspx), Research Activities (https://www.uml.edu/Research/tidc/Activities.aspx), Collaborators (https://www.uml.edu/Research/tidc/Collaborators.aspx), and Publications (https://www.uml.edu/Research/tidc/Publications.aspx)

Participants and Collaborators:

During the reporting period, the following participants have worked on the project; Dr. Tzuyang Yu (Associate Prof., Civil & Environmental Eng./CEE, project management), Mr. Ahmed Alzeyadi (full-time graduate RA, doctoral candidate, CEE), Mr. Harsh Gandhi (part-time graduate RA, Master's student, CEE), Ms. Sanjana Vinayaka (part-time graduate RA, doctoral student, CEE), Mr. Ruben Diaz, Jr. (part-time undergraduate RA, Bachelor's student, CEE), Ms. Jade Man (part-time undergraduate RA, Bachelor's student, CEE), and Mr. Benjamin Roth (part-time undergraduate RA, Bachelor's student, Mechanical Engineering). Collaboration with the MassDOT and the City of Lowell – We are continuing our collaborations with the MassDOT (Mr. A. Bardow) and the City of Lowell (Ms. C. Clancy, Mr. J. Assenza).

Changes:

At this stage of the project, we do not anticipate any problems or delays in our project. We also do not plan any changes to be made to our original research plan.

Planned Activities:

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

Task 1: Preparation of laboratory concrete specimens with single and multiple cracking mechanisms – To be completed in the next four months.

Task 2: Laboratory radar imaging of concrete specimens – To be completed in the next four months.

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.

We also plan to attend the 2019 QNDE (Quantitative Non-Destructive Evaluation) Symposium in Portland, OR during July 14~18, 2019 to disseminate our research findings.