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
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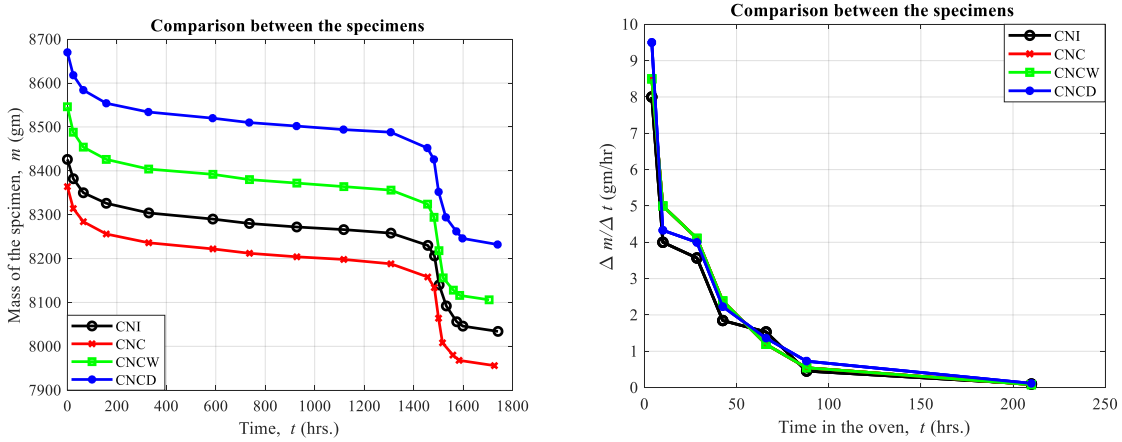
Co-PI(s): N/A
Reporting Period: 6/1/2019 ~ 7/31/2019
Date: 7/31/2019

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 Tasks 2, 3, 4, and 5 of the proposed research; **Task 2**: Laboratory radar imaging of concrete specimens (6 months), **Task 3**: Preliminary field radar imaging of concrete bridges, **Task 4**: Development of EM database, and **Task 5**: Data analysis and image interpretation. In this bi-monthly report, we will report our progress on analyzing and modeling our radar images (reported in our last bi-monthly report on 05/31/19) of concrete specimens CNI, CNC, CNCW, and CNCD. These two tasks will help us 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.

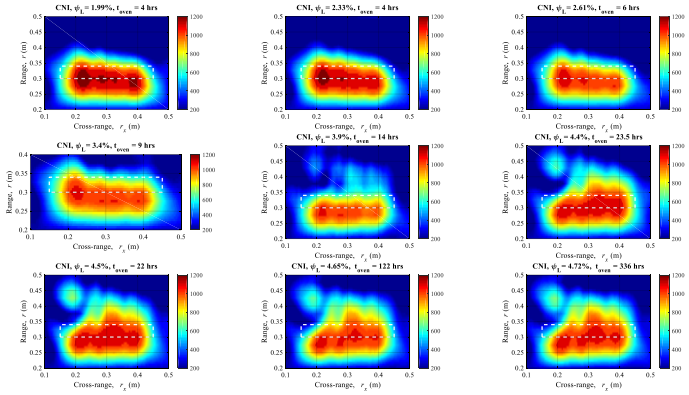
In the past two months, we have accomplished 100% of Task 1, 40% of Task 2, 30% of Task 3, 20% of Task 4, and 20% of Task 5 by developing synthetic aperture radar (SAR) image-based data analysis and image interpretation procedures for concrete panels with and without a surface crack. In order to model the background signal in all SAR images, we monitored the moisture variation in each concrete specimen for approximately three months (73 days) in two conditions; room-drying and oven-drying. Figure 1 (a) shows the three-month moisture variations of all four concrete specimens. In Figure 1 (a), the first nonlinear decay of moisture variation (from the 0^{th} hr to the 1450^{th} hr) shows the room-drying moisture measurements, while the second nonlinear decay of moisture variation (from the 1450^{th} hr to the end). Time rate of change for moisture loss was also calculated for all concrete panels and shown in Figure 1 (b). We found that the rate of moisture loss is positively affected by the surface area of concrete panels. The relationship of rate of moisture loss for all concrete panels is specimen CNCD (surface area = 2,311.5 cm^2) > specimen CNCW (surface area = 2,292 cm^2) > specimen CNC (surface area = 2,290 cm^2) > specimen CNI (surface area = 2,280 cm^2), as we expected.



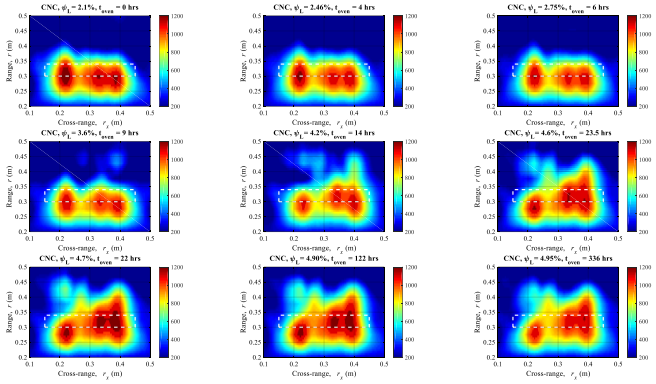
(a) Moisture measurements (b) Rate of moisture loss

Figure 1. Time-dependent variations of moisture level in all four concrete specimens for approximately three months

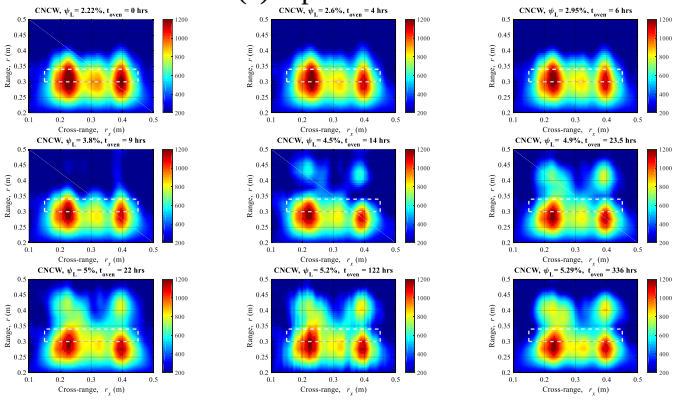
After room-drying, we oven-dried all concrete panels in order to obtain absolute moisture content (oven-dried weight) of concrete panels. The radar image database for oven-dried concrete panels is reported in Figure 2. In Figure 2, we found the pattern of moisture loss/change/content due to room-drying and oven-drying. The correlation of absolute moisture content in concrete and the corresponding SAR image is the key to remove background noise in the SAR images of damaged (cracked) concrete specimens and structures and to decipher the meaning of SAR amplitudes and distribution.



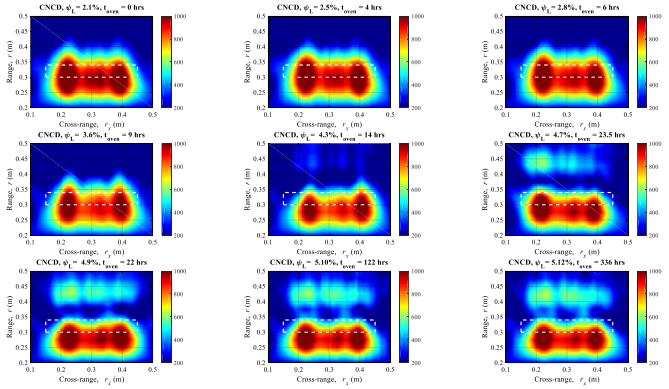
(a) Specimen CNI



(b) Specimen CNC



(c) Specimen CNCW



(d) Specimen CNCD

Figure 2. Oven-dried SAR images of all four 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 three journal manuscripts to *NDT&E International*, *Construction and Building Materials* and *Journal of Electronic Imaging* We also have updated our project websites by providing interview videos with faculty researchers for each project (https://www.uml.edu/Research/tidc/projects/).

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), and Ms. Jade Man (part-time undergraduate RA, Bachelor's student, CEE). 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 2: Laboratory radar imaging of concrete specimens – To be completed in the next two months.
Task 3: Preliminary field radar imaging of concrete bridges – Will continue working on.
Task 4: Development of EM database – Will continue working on.
Task 5: Data analysis and image interpretation – Will continue working on.

We attended the 2019 QNDE (Quantitative Non-Destructive Evaluation) Symposium in Portland, OR during July 14~18, 2019 and delivered a presentation. We plan to attend two conferences (2019 Asian Pacific Congress on Computational Mechanics and 2020 SPIE Smart Structures/NDE Symposium) in the near future.