Quarterly Progress Report:
Project Number and Title: C3. Condition Assessment of Corroded Prestressed Concrete Bridge Girders
Research Area: Thrust #1: Transportation Infrastructure Monitoring and Assessment for Enhanced Life
PI: Tzuyang Yu (UMass Lowell)
Co-PI(s): Susan Faraji (UMass Lowell), Chang Hoon Lee and Moochul Shin (Western New England University or WNEU)
Reporting Period: 01/01/2021 ~ 03/31/2021
Submission Date: 03/31/2021

Overview:

The objective of this project is to assess the condition of corroded prestressed concrete (PC) bridge girders in New England by performing multiplysical field inspection and developing an integrated assessment framework. During the reporting period, our focus is on the experimental test conducted at WNEU on reinforced concrete (RC) cylinder specimens. The development of the corrosion damage model at WNEU is performed at two phases: (a) determination of corrosion degree in the context of structural behavior, and (b) integration of the corrosion degree model with the mechanistic behavior model, herein, bond-slip response. When merging the specimen into the electrolyte (i.e., salt solution), observations of the detail process are challenging because the solution is contaminated by corrosion products. Thus, a new testing platform was built, enabling one to observe at least the top surface of the cylindrical specimen in the progress of corrosion.

Figure 1 shows the corroded RC cylinder specimens with our observation. We also conducted pull-out tests to evaluate the bond strength of the specimen at the state (3) (i.e., a major crack, of which width is 1-2 mm, is propagated from the reinforcement to the surface over the longitudinal direction.). From the comparison (See Figure 2), it is observed: (a) the tangential bond-slip stiffnesses at the beginning of the response are similar, thus no significant deduction is observed; (b) the secant stiffness and the peak bond capacity are significantly reduced due to the corrosion damage; (c) the post-peak response driven by increasing the exiting crack opening and forming new structural cracks is observed for the corroded specimens.

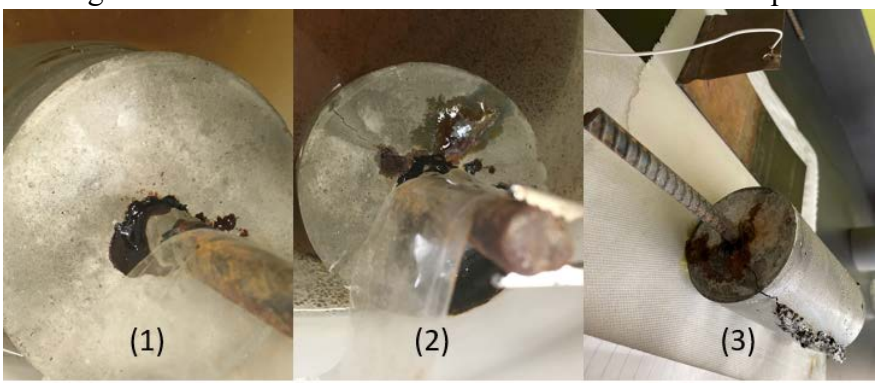

Fig. 1. *Observation of corrosion progress; (1) $Fe(OH)_2$ is leaked from the top surface. No visible crack (about 0.5mm to 1mm) is detected, (2) Hair line cracks were initiated around the rebar. However, they are not propagated to the side surface. (3) A primary visible crack (i.e., 1-2mm) is propagated to the surface. (Note that all observations were detected at the latest time of each phenomena, possibly being occurred before the observations.)*

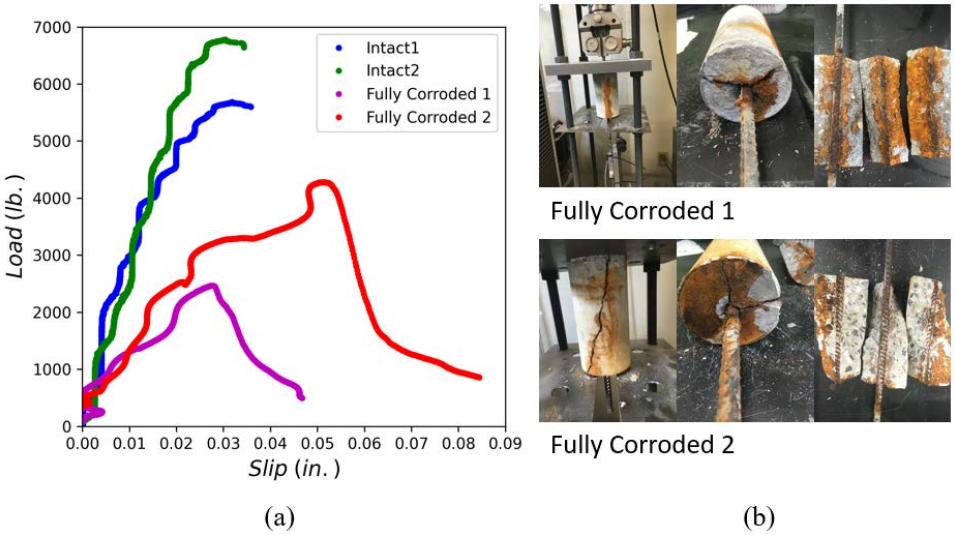

Fig. 2: *(a) Comparison of bond-slip response between intact and "fully" corroded specimens (State (3)). (Note that the term, "fully," is used for the convenience, and the quantification is in-progress.) (b) Failure modes of the specimens; Other than the existing crack due to corrosion, two additional structural cracks were formed during the pull-out test. The difference in the response between Fully corroded 1 and 2 would be induced by different time span between State (1) and (3).*

Table 1: Task Progress			
Task Number	**Start Date**	**End Date**	**Percent Complete**
Task 1	3/1/19	9/31/19	100%
Task 2	9/1/19	9/31/21	90%
Task 3	10/1/19	9/31/21	65%

Table 2: Budget Progress		
Entire Project Budget	**Spend Amount**	**Spend Percentage to Date**
$89,403 (UML)	$84,932 (UML)	95% (8/30/2020)
$85,000 (WNEU)	$63,052.86(WNEU)	74.2% (8/30/2020)

Table 3: Presentations at Conferences, Workshops, Seminars, and Other Events				
Title	**Event**	**Type**	**Location**	**Date(s)**
Short-term Mechanical Strength Prediction of Ultra-High Performance Concrete using Noncontact Synthetic Aperture Radar Imaging	2021 SPIE Smart Structures/NDE Conference	Conference presentation	Virtual meeting	March 22, 2021

Table 4: Publications and Submitted Papers and Reports				
Type	**Title**	**Citation**	**Date**	**Status**
Conference paper	Short-term Mechanical Strength Prediction of Ultra-High Performance Concrete using Noncontact Synthetic Aperture Radar Imaging	doi: 10.1117/12.2584809	March 22, 2021	Published

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
Susan Faraji	Susan_Faraji @UML.EDU	Civil and Environmental Engineering	Structural analysis and design of bridge girders
Chang Hoon Lee	changhoon.lee@wne.edu	Civil & Environmental Engineering	Task 2: Development of degradation model and design concrete for pull out test specimen.
Moochul Shin	moochul.shin@wne.edu	Civil and Environmental Engineering	Task 2: Data analysis of the pull-out test results.

Table 6: Student Participants during the reporting period

Student Name	Email Address	Class	Major	Role in research
Harsh Gandhi		Doctoral	Civil and Environmental Engineering	Manufacturing of laboratory specimens, laboratory radar imaging
Ronan Bates		Senior	Civil and Environmental Engineering	Manufacturing of laboratory specimens, laboratory radar imaging
Andrew Masullo		Senior	Civil and Environmental Engineering	Construction of Corrosion Chamber.
Cameron Cox			Civil and Environmental Engineering	Construction of Corrosion Chamber.
Jacob Eberli		Senior	Civil and Environmental Engineering	Construction of Corrosion Chamber.
Tyler Yesu		Junior	Civil and Environmental Engineering	Construction of Corrosion Chamber.
Daniel Doyle		Junior	Civil and Environmental Engineering	Construction of Corrosion Chamber.
Christa Cicerone		Sophomore	Civil and Environmental Engineering	Construction of Corrosion Chamber.
Archer Parker		Sophomore	Civil and Environmental Engineering	Construction of Corrosion Chamber.
Brian LeClair		Sophomore	Civil and Environmental Engineering	Construction of Corrosion Chamber.

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 Transportation (MassDOT)	Boston, Massachusetts				X	X
City of Lowell	Lowell, Massachusetts			X	X	X
LeHigh Cement Company	Glen Falls, NY		X			

Changes:

1. At UML, our Phase 3 plan has been carried out with extra caution. The UML is gradually opening campus to increase population density on campus. But our students are still vulnerable to the covid-19 pandemic. Some student was inflected by his roommates at home and had to stay home for a two-week quarantine.
2. Due to the COVID-19, the university's administrative procedures (e.g., procurement, hiring students) become slow.

Planned Activities:

- The UML team will perform field inspection of corroded concrete structures on selected bridges in Massachusetts in the next reporting period.

Task 2: (Meso-to-Macro Level) Development of Macro-Scale Mechanical Damage Model due to corrosion
Task 3. (System Level) Development of capacity reduction model for PC bridges due to corrosion