<u>**Quarterly Progress and Performance Indicators Report**</u>:
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: 1/1/2022 ~ 3/31/2022
Submission Date: 05/27/22

Overview:

The objective of this project is to assess the condition of corroded prestressed concrete (PC) bridge girders in New England by performing multiphysical field inspection and developing an integrated assessment framework. During the reporting period, our focus is on i) radar data processing at UML for predicting corrosion level in reinforced concrete (RC) cylinders, and ii) experimental data collection at WNEU for calibrating a corrosion model for RC structures. During the reporting period, the WNEU research team has been revised and conducted the accelerated corrosion test (i.e. Task 2).

- The revision of the experimental set was (1) to resolve the issues of the corrosion in the unexpected part of the specimen. (i.e., A certain development length of reinforcement is required for the pull-out test.)
- From the different methods to protect the corrosion three different methods were tested depending on the different sealants and the ways to apply them.

Meeting the Overarching Goals of the Project:

- The current ASTM G109 method can track the degree of corrosion; however, the specimen used for this test cannot be used for measuring the mechanical properties. Thus, this investigation will provide an opportunity to further investigate the effect of corrosion on any structural behavior of testing concretes.

Accomplishments:

- We found that the using sealant only will provide good protection for the penetration of solution and unexpected corrosion.
- However, the success rate is about 80% (4 out of 5 specimens). Also, the influence on the bond strength was negligible.

Task, Milestone, and Budget Progress:

Table 1: Task Progress

Task Number: Title	Start Date	End Date	% Complete
Task 1: (Component- and System-Level) Field Inspection/Measurements	3/1/19	9/30/19	100%
Task 2: (Meso-to-Macro Level) Development of Macro-Scale Mechanical Damage Model due to corrosion	9/1/19	12/31/22	95%
Task 3. (System Level) Development of capacity reduction model for PC bridges due to corrosion	10/1/19	12/31/22	75%

Table 2: Milestone Progress			
Milestone #: Description	**Corresponding Deliverable**	**Start Date**	**End Date**
Milestone 1: Design of laboratory reinforced concrete (RC) specimens at various corrosion levels	Experimentation design matrix; manufactured RC specimens (100%); Quarterly reports on 3/31/19, 6/30/19, and 9/30/19.	3/1/19	9/30/19
Milestone 2: Manufacturing of laboratory RC specimens at various corrosion levels / Laboratory SAR imaging of corroded RC specimens and development of a robust baseline SAR image of concrete	Manufactured RC specimens (100%); SAR images of RC specimens (97%); Quarterly reports on 9/30/19, 12/31/19, 3/31/20, 6/30/20, 9/30/20, 12/31/20, 3/31/21, 6/30/21, 9/30/21, 12/31/21, and 3/31/22.	9/1/19	12/31/22
Milestone 3: Laboratory SAR imaging of corroded RC specimens and development of a robust baseline SAR image of concrete / Field inspection of corroded RC structures	SAR images of RC specimens and structures (90%); Quarterly report on 12/31/20, 3/31/21, 6/30/21, 9/30/21, 12/31/21, and 3/31/22,	12/1/20	03/31/22
Milestone 4: Development of capacity reduction model for PC bridges due to corrosion	Capacity reduction models (87%); Quarterly reports on 12/31/19, 3/31/20, 6/30/20, 9/30/20, 12/31/20, 3/31/21, 6/30/21, 9/30/21, 12/31/21, and 3/31/22.	10/1/19	12/31/22
Milestone 5: Documentation and dissemination of our research outcomes	Quarterly reports on 3/31/19, 6/30/19, 9/30/19, 12/31/19, 3/31/20, 6/30/20, 9/30/20, 12/31/20, 3/31/21, 6/30/21, 9/30/21, 12/31/21, and 3/31/22.	3/1/19	12/31/22

Table 3: Budget Progress		
Project Budget	**Spend – Project to Date**	**% Project to Date (include the date)**
$89,403 (UML)	$89,403 (UML)	100%
$85,000 (WNEU)	$73,490.91 (WNEU)	86.5%

<u>Is your Research Project Applied or Advanced?</u>

☒ **Applied** (*The systematic study to gain knowledge or understanding necessary for determining the means by which a recognized and specific need may be met.)*

☐ **Advanced** (*An intermediate research effort between basic research and applied research. This study bridges basic (study to understand fundamental aspects of phenomena without specific applications in mind) and applied research and includes transformative change rather than incremental advances. The investigation into the use of basic research results to an area of application without a specific problem to resolve.)*

Education and Workforce Development:

1. Did you provide any workforce development or training opportunities to transportation professionals (already in the field)? If so, what was the training? When was it offered? How many people attended?

   The research team held a meeting with Kiewit to consult the practical applicability on the job site (02/24/2022). The team presented an overview of the project, hearing the concerning points when transforming the technology into the practice.

2. Did you hold meetings with any transportation industry organizations or DOTs? If so, what was the meeting's purpose? When was it offered? How many people attended?

   N/A

3. Did you host/participant in any K-12 education outreach activities? If so, what was the activity? What was the target age/grade level of the participants? How many students/teachers attended? When was the activity held?

   The WNE research team gave a presentation about the corrosion of reinforcements and the project overview in "Academic preview day" where high-school juniors/seniors and their parents (i.e., about 25) attended.

Technology Transfer:

Table 4: Presentations at Conferences, Workshops, Seminars, and Other Events					
Type	**Title**	**Citation**	**Event & Intended Audience**	**Location**	**Date(s)**
N/A	N/A	N/A	N/A	N/A	N/A

Table 5: Submitted/Accepted Publications, Technical Reports, Theses, Dissertations, Papers, and Reports				
Type	**Title**	**Citation**	**Date**	**Status**
N/A	N/A	N/A	N/A	N/A

From our previous experimental results, we discovered the issue with corroded sections of steel rebar at the interface between the extended steel rebar length and the concrete cylinder. This issue prevented us from conducting successful pull-out test on RC specimens since the failure mode was always dominated by the breaking of corroded steel rebar outside the concrete cylinder. To resolve this issue, we use two different sealants (with different limestone contents; 10-30% vs. 30-60%) to prevent premature corrosion of steel rebar at the interface between the extended steel rebar length and the concrete cylinder. Figure 1 (a) and (b) show our RC specimens using two different sealants. Furthermore, we tested the RC specimens in two different ways: 1) sealants with water-proof tapes (Figure 1 (a) and (b)) and 2) sealant-only (Figure 1 (c) and (d)). This investigation is critical to obtain reliable corrosion data, confirming that the initial current and the decreasing slope with time provides the meaningful information to track the degree of corrosion. Figure 2 shows the accelerated corrosion chamber at WNEU.

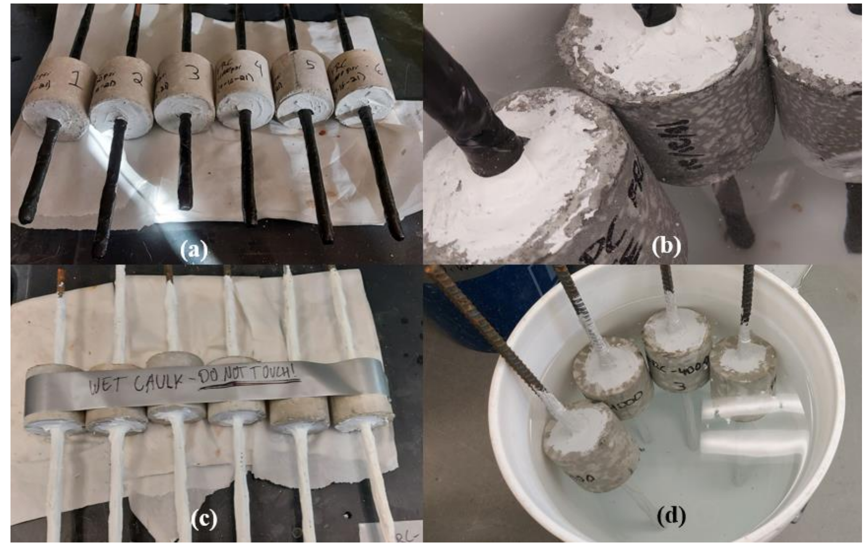

Fig. 1: Laboratory RC specimens with different sealants

Answer the following questions (N/A if there is nothing to report):

1. Did you deploy any technology during the reporting period through pilot or demonstration studies as a result of this work? If so, what was the technology? When was it deployed?
   N/A

2. Was any technology adopted by industry or transportation agencies as a result of this work? If so, what was the technology? When was is adopted? Who adopted the technology?
   N/A

3. Did findings from this research project result in changing industry or transportation agency practices, decision making, or policies? If so, what was the change? When was the change implemented? Who adopted the change?
   N/A

4. Were any licenses granted to industry as a result of findings from this work? If so, when? To whom was the license granted?
   N/A

5. Were any patent applications submitted as a result of findings from this research? If so, please provide a copy of the patent application with your report.
   N/A

6. Did industry organizations or DOTs provide cost-share (cash or in-kind) to your research during the reporting period? Who was the organization? Please provide an in-kind support invoice from the organization with your report (this is kept confidential and used for record keeping purposes only).
   LeHigh Cement Company (in-kind donation of cementitious materials (i.e., ground granulated blast furnace slag)

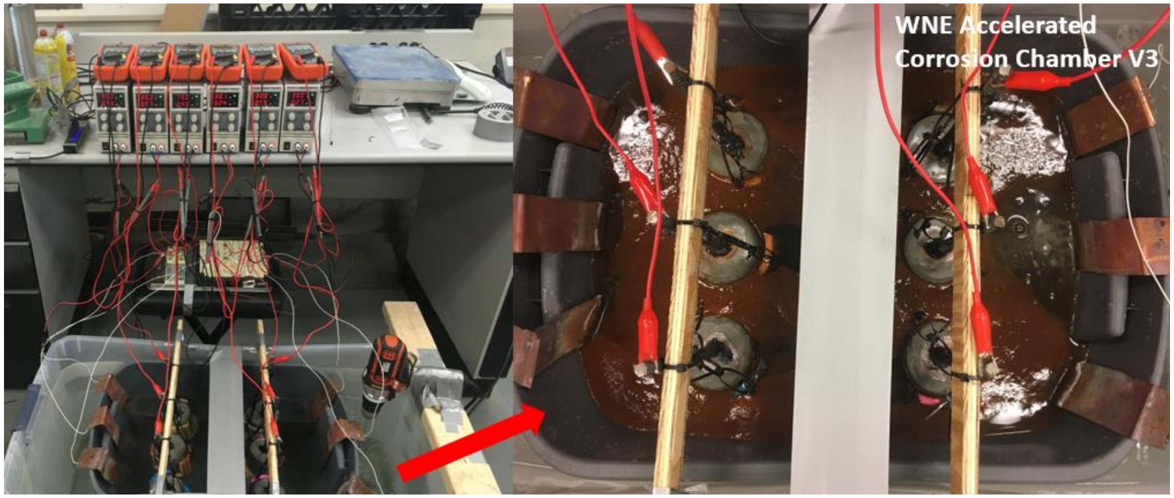

Fig. 2: Accelerated corrosion chamber (version 3) at WNEU / Unlimited size, shape, configuration of RC specimens

<u>Outputs:</u>

- The third generation of accelerated corrosion chamber was built by the WNEU team.

<u>Outcomes:</u>

- N/A

<u>Impacts:</u>

- N/A

Participants and Collaborators:

Table 6: Active Principal Investigators, faculty, administrators, and Management Team Members				
Individual Name & Title	**Dates involved**	**Email Address**	**Department**	**Role in Research**
Tzuyang Yu	1/1/2022~3/31/2022	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	1/1/2022~3/31/2022	Susan_Faraji @UML.EDU	Civil and Environmental Engineering	Structural analysis and design of bridge girders
Chang Hoon Lee	1/1/2022~3/31/2022	changhoon.lee@wne.edu	Civil & Environmental Engineering	Development of degradation model and design concrete for pull out test specimen.
Moochul Shin	1/1/2022~3/31/2022	moochul.shin@wne.edu	Civil and Environmental Engineering	Data analysis of the pull-out test results.

Table 7: Student Participants during the reporting period								
Student Name	**Start Date**	**End Date**	**Advisor**	**Email Address**	**Level**	**Major**	**Funding Source**	**Role in research**
Tyler Yesu	10/01/21	12/17/21	Prof. Lee		UG	Civil Engineering	TIDC	Stress-free mold design
Pierre Carriere	10/01/21	12/17/21	Prof. Lee		UG	Civil Engineering	Course credits, WNE CEE Department	Construction of circuit
Dante Talamini	10/01/21	12/17/21	Prof. Lee		UG	Civil Engineering	N/A	Experimental set up
Roberto Brea	10/01/21	12/17/21	Prof. Lee		UG	Civil Engineering	N/A	Experimental set up
Adam Garstka	10/01/21	12/17/21	Prof. Lee		UG	Civil Engineering	Course credits	Experimental set up
Charles Maloy	10/01/21	12/17/21	Prof. Lee		UG	Civil Engineering	Course credits	Experimental set up

Table 8: Students who Graduated During the Reporting Period			
Student Name	**Degree/Certificate Earned**	**Graduation/Certification Date**	**Did the student enter the transportation field or continue another degree at your university?**
N/A	N/A	N/A	N/A

Table 9: Industrial Internships			
Student Name	**Degree/Certificate Earned**	**Graduation/Certification Date**	**Did the student enter the transportation field or continue another degree at your university?**
N/A	N/A	N/A	N/A

Table 10: Research Project Collaborators during the reporting period						
Organization	**Location**	**Contribution to the Project**				
		Financial Support	**In-Kind Support**	**Facilities**	**Collaborative Research**	**Personnel Exchanges**
City of Lowell	Lowell, MA				X	X
LeHigh Cement Company	Glen Falls, NY		X			

Table 11: Other Collaborators				
Collaborator Name and Title	**Contact Information**	**Organization and Department**	**Date(s) Involved**	**Contribution to Research**
Mark Jen		Michael Baker Engineering, Inc.	12/16/21	Technical champion

Table 12: Course List						
Course Code	**Course Title**	**Level**	**University**	**Professor**	**Semester**	**# of Students**
CIVE 5110	Inspection and Monitoring of Civil Infrastructure	Graduate	UMass Lowell	Tzuyang Yu	Spring 2022	17
ENGN 2070	Dynamics	Undergrad	UMass Lowell	Tzuyang Yu	Spring 2022	37
CEE310	Civil Engineering Research	Undergraduate	WNEU	Chang Hoon Lee	Spring 2022	4
CEE410	Civil Engineering Research	Undergraduate	WNEU	Chang Hoon Lee	Spring 2022	1
CEE451	Construction Materials	Undergraduate	WNEU	Moochul Shin	Spring 2022	23

Changes:

- N/A

Planned Activities:

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

- 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