Quarterly Progress and Performance Indicators 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: 4/1/2022 ~ 6/30/2022
Submission Date: 7/6/2022

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 specimens was conducted, exploring the multiple failure modes under pull-out test depending on the mixtures.
- The results reveal that the responses are dependent on the mixture proportions and the dosage of (basalt) fibers. Nonetheless, the designated variations of the experimental variables produced the post peak behavior (i.e., decay profile).

Meeting the Overarching Goals of the Project:

- The corrosion model is incorporated with the damage model, herein, the bond-slip failure. To correlate to the degree of corrosion, the calibration data representing various failure modes must be obtained. While the mode depends on the size of reinforcement, concrete mixture and its strength, cover depths, and the capacity of available testing machines, it is critical to find the sweet spot in terms of those experimental conditions. During this reporting term, the research team successfully identified as testing the wide variations of the specimens.

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	97%
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)	$73,563.41 (WNEU)	86.5%

Is your Research Project Applied or Advanced?

☒ **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?
   N/A

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?

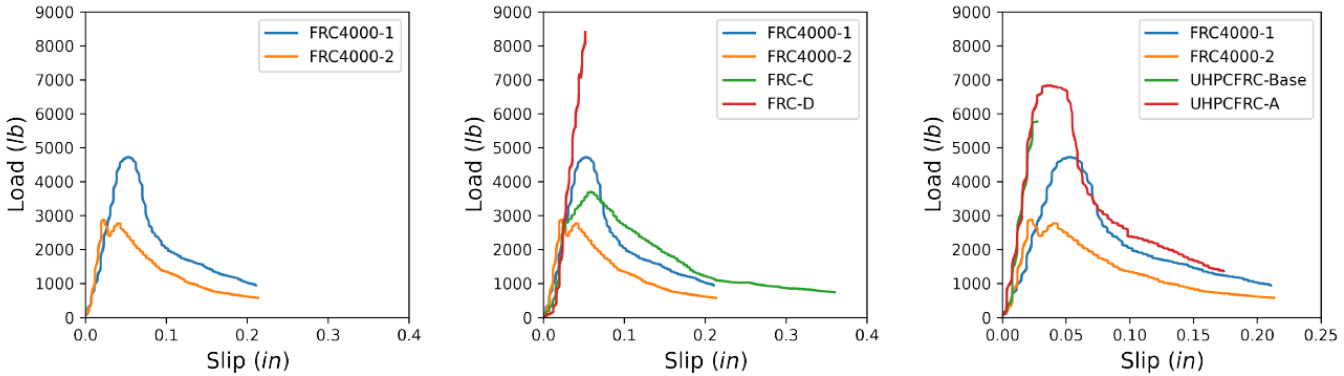
N/A

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 Student Day" on 4/3/2022, 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)**

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



(a) Reference Concrete (b) Comparison to FRC-series (c) Comparison to UHPC-FRC-series

Fig.1: Bond slip responses of various samples (Note: FRC4000: 4000 *psi* concrete without fibers, FRC-C (V_f=1.5%)/D(V_f=2.0%): 4000 *psi* concrete with fibers, UHPCFRC-Base: 12,000 psi concrete without fiber, UHPCFRC-A: 12,000 concrete with V_f=1.0%

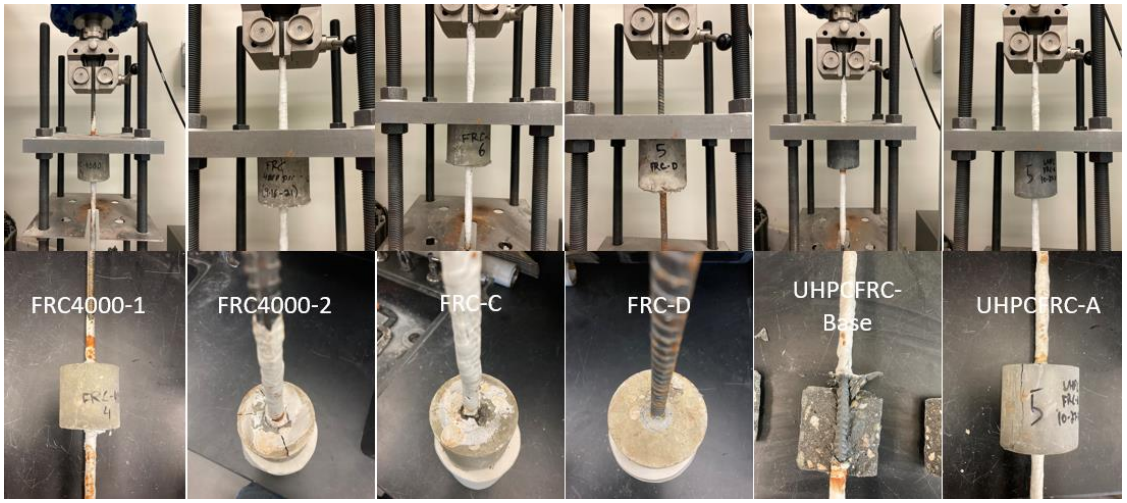


Fig.2: Experimental setup (upper panels) and failure mode (lower panels)

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).
   N/A

Outputs:

- The pull-out test results for concretes with various mixtures including fiber-reinforced and high-performance concretes.

Outcomes:

- N/A

Impacts:

- 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	4/1/2022 ~ 6/30/2022	Tzuyang_Yu@UML.EDU	Civil & Environmental Engineering	Project principle investigator and Institutional Lead at UML; overseeing all projects and working on radar imaging and interpretation
Susan Faraji	4/1/2022 ~ 6/30/2022	Susan_Faraji @UML.EDU	Civil & Environmental Engineering	Structural analysis and design of bridge girders
Chang Hoon Lee	4/1/2022 ~ 6/30/2022	Changhoon.Lee@wne.edu	Civil & Environmental Engineering	Development of degradation model and design concrete for pull out test specimen.
Moochul Shin	4/1/2022 ~ 6/30/2022	Moochul.Shin@wne.edu	Civil & 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	4/1/22	6/30/22	Prof. Lee		UG	Civil Engineering	TIDC	Stress-free mold design
Pierre Carriere	4/1/22	6/30/22	Prof. Lee		UG	Civil Engineering	Course credits, WNE CEE Department	Construction of circuit
Adam Garstka	4/1/22	6/30/22	Prof. Lee		UG	Civil Engineering	Course credits	Experimental set up
Charles Maloy	4/1/22	6/30/22	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?**

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?**

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		Kiewit Corporation	5/14/22	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