Quarterly Progress Report:
Project Number and Title: 2.7 High Performance Concrete with Post-Tensioning Shrinking Fibers
Research Area: Thrust 3 Use new materials and systems to build longer-lasting bridges and accelerate construction
PI: Dryver Huston, University of Vermont
Co-PI(s):
Reporting Period: 10/1/21 – 12/31/21
Submission Date: December 31, 2021

Overview:

- Continued with freeze-thaw testing of laboratory specimens with various levels of shrinking chitosan fiber loading, leading to results that confirm the increase in durability due to the fibers, Figure 1.
- Tested laboratory specimens for chloride penetration resistance with Wenner probe measures of electrical resistivity, Figure 2, leading to results confirming that the shrinking fibers have the positive effect of reducing the drop in electrical resistance characteristic of increased chloride penetration, Figure 3.

Meeting the Overarching Goals of the Project:

The overarching goal(s) of the project are:

1. Expand the range of tested shrinking fibers beyond the present chitosan and shape memory polymers to include preloaded steel, shape memory alloy (nitinol) and possibly other polymers
2. Test performance in larger laboratory specimens
3. Develop mechanical models to describe and predict enhanced performance due to post-tensioning shrinking fibers

- The freeze-thaw testing addressed Goal 2 by testing larger laboratory specimens.
- The chloride penetration tests addressed Goal 2 by testing larger laboratory specimens
- Both freeze-thaw and chloride penetration tests addressed Goal 3 by leading to the development of a hypothesis based on the change of concrete microstructure during curing with the action of shrinking fibers.

Accomplishments:

List any accomplishments achieved under the project goals in bullet point form…

- Completed freeze-thaw and chloride penetration tests of larger laboratory specimens as indicated in Goal 2.
- Formulated a a hypothesis based on the change of concrete microstructure during curing with the action of shrinking fibers as indicated in Goal 3.

Task, Milestone, and Budget Progress:

Table 1: Task Progress			
Task Number: Title	**Start Date**	**End Date**	**% Complete**
Task 1: Shrinking Fiber Development and Manufacture	6/1/19	12/31/21	95%
Task 2: Laboratory Performance Testing	6/1/19	5/30/21	90%
Task 3: Mechanical Modeling	6/1/19	5/30/21	75%
Overall Project:	6/1/19	5/30/21	87%

Table 2: Milestone Progress			
Milestone #: Description	**Corresponding Deliverable**	**Start Date**	**End Date**
Milestone 1: NA			
Milestone 2: NA			
Milestone 3: NA			
Milestone 4: NA			
Milestone 5: NA			
Milestone 6: NA			
Milestone 7: NA			
Milestone 8: NA			
etc.			

Comment: There does not appear to be a list of milestones and deliverables in the original proposal.

Table 3: Budget Progress		
Project Budget	**Spend – Project to Date**	**% Project to Date (12/31/2021)**
$220,000	$233,372.15	106.08%

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:

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

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? NA

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? NA

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? NA

Technology Transfer:

Complete all of the tables below and provide additional information where requested. Please provide ALL requested information as this is one of the most important sections for reporting to the USDOT. ***ONLY provide information relevant to this reporting period.***

Use the table below to complete information about conference sessions, workshops, webinars, seminars, or other events you led/attended where you shared findings as a result of the work you conducted on this project:

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

Use the table below to report any publications, technical reports, peer-reviewed articles, newspaper articles referencing your work, graduate papers, dissertations, etc. written as a result of the work you conducted on this project. Please list only completed items and exclude work in progress.

Table 5: Submitted/Accepted Publications, Technical Reports, Theses, Dissertations, Papers, and Reports

Type	Title	Citation	Date	Status
Poster	Chitosan-Based Shrinking Fibers for Post-Cure Stressing to Increase Durability of Concrete	TIDC Student Poster Contest	12/1/2021	Presented
MS Thesis	Chitosan-Based Shrinking Fibers for Post-Cure Stressing to Increase Durability of Concrete	M.S. Thesis, Mechanical Engineering, University of Vermont	12/1/2021	Accepted

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? NA

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? NA

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? NA

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

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. NA

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). NA

Insert figures here

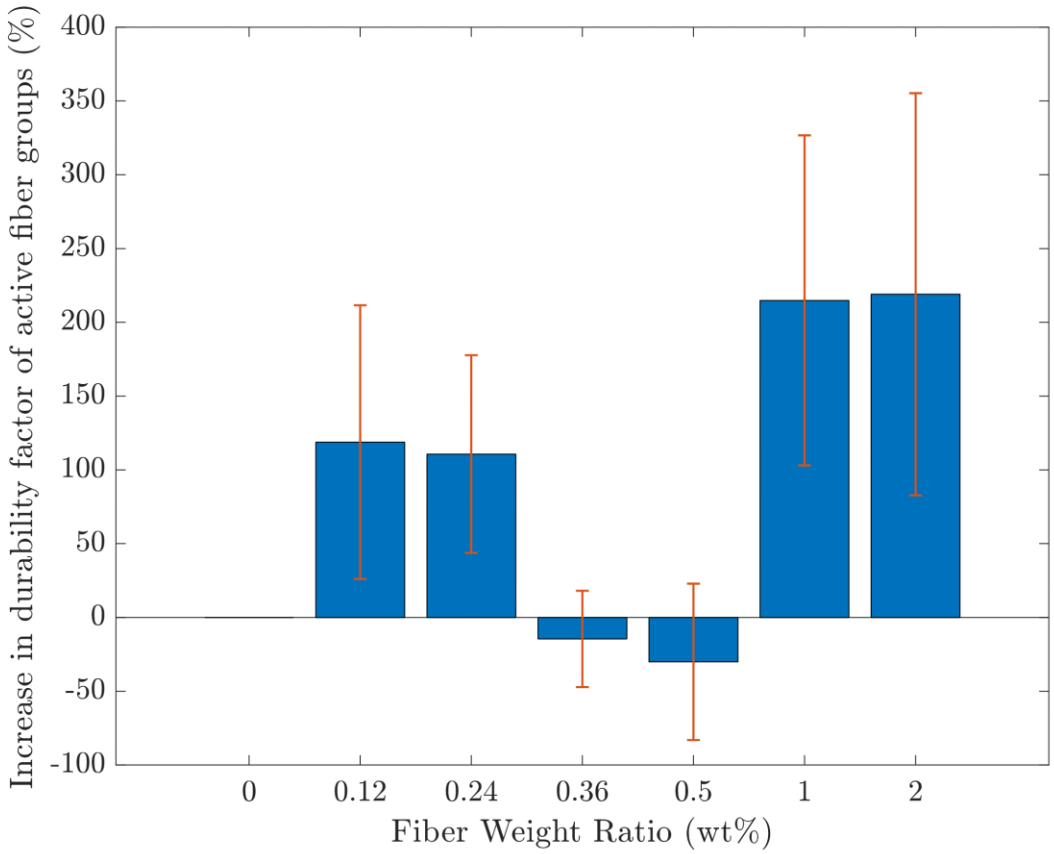

Figure 1. Durability index from freeze-thaw beam vibration tests versus amount of shrinking chitosan fiber loading

a.  b. 

Figure 2. Chloride penetration testing of concrete specimens with various loadings of shrinking fibers: a. specimens soaking is saline bath, b. specimen with embedded electrodes for Wenner probe testing.

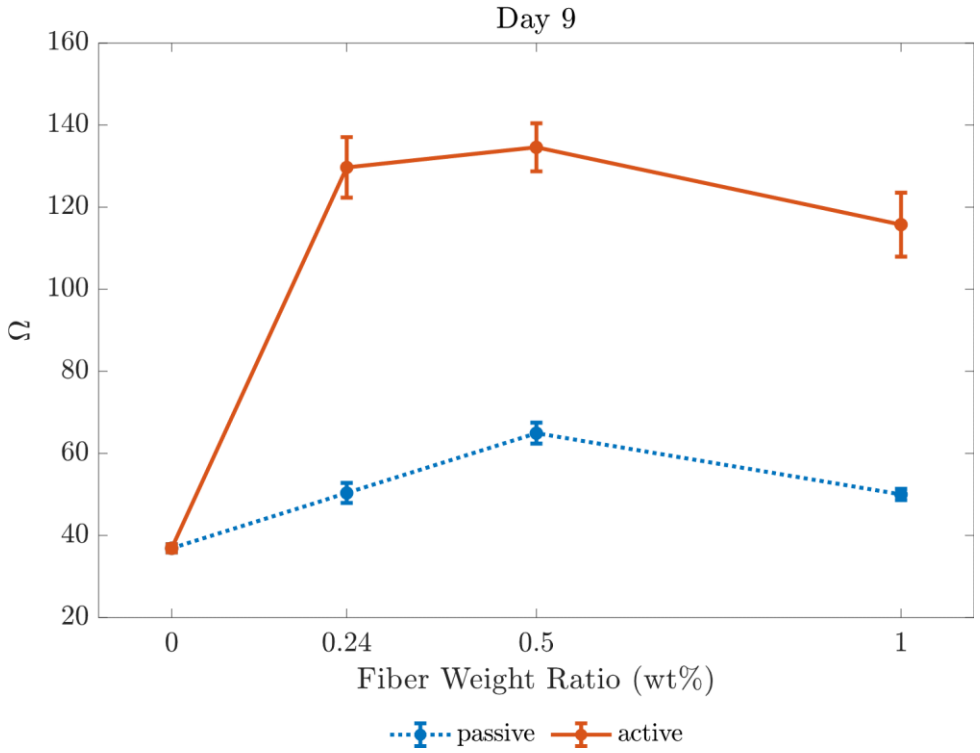

Figure 3. Wenner probe electrical resistivity test results versus amount of shrinking fiber in the mix following nine days of saline bath soak

Describe any additional activities involving the dissemination of research results not listed above under the following headings: Graduate Student Diarmuid Gregory (Mechanical Engineering, University of Vermont) received 2021 TIDC Graduate Student of the Year Award; Undergraduate students Matt Kaplita and Josh Allen were recognized for their contributions to the project as part of TIDC Student Recognition Night 2021.

Outputs:

Definition: Any new or improved process, practice, technology, software, training aid, or other tangible product resulting from research and development activities. They are used to improve the efficiency, effectiveness, and safety of transportation systems. List any outputs accomplished during this reporting period:

- Experiments (freeze-thaw and chloride penetration) confirmed that chitosan shrinking fibers can increase the durability of concrete. It is hypothesized that this effect is due to an alteration of the microstructure during curing.

Outcomes:

Definition: The application of outputs; any changes made to the transportation system, or its regulatory, legislative, or policy framework resulting from research and development activities. List any outcomes accomplished during this reporting period:

- NA

Impacts:

Definition: The effects of the outcomes on the transportation system such as reduced fatalities, decreased capital or operating costs, community impacts, or environmental benefits. The reported impacts from UTCs are used for the assessment of each UTC and to make a case for Federal funding of research and education by demonstrating the impacts that UTC funding has had on technology and education. NOTE: The U.S. DOT uses this information to assess how the research and education programs (a) improve the operation and safety of the transportation system; (b) increase the body of knowledge and technologies; (c) enlarge the pool of people trained to develop knowledge and utilize technologies; and (d) improves the physical, institutional, and information resources that enable people to have access to training and new technologies. List any outcomes accomplished during this reporting period:

- NA

Participants and Collaborators:

Use the table below to list individuals (compensated or not) who have worked on the project other than students.

Table 6: Active Principal Investigators, faculty, administrators, and Management Team Members

Individual Name & Title	Dates involved	Email Address	Department	Role in Research
Dryver Huston	10/1/2021-12/31/2021	dryver.huston@uvm.edu	Mechanical Engineering	PI

*Use the table below to list **all** students who have participated in the project during the reporting period. (This includes all paid, unpaid, intern, independent study, or any other student that participated in this project.) **ALL FIELDS ARE REQUIRED.***

Table 7: Student Participants during the reporting period								
Student Name	**Start Date**	**End Date**	**Advisor**	**Email Address**	**Level**	**Major**	**Funding Source**	**Role in research**
Diarmuid Gregory	10/1/2021	12/31/2021	D. Huston		M.S./Senior	Mechanical Engineering	TIDC	Graduate research assistant
Matt Kaplita	10/1/2021	12/31/2021	D. Huston		Junior	Civil Eng	TIDC	Laboratory testing
Josh Allen	10/1/2021	12/31/2021	D. Huston		Senior	Mech Eng	TIDC	Laboratory testing

Use the table below to list any students who worked on this project and graduated or received a certificate during this reporting period. Include information about the student's accepted employment during the reporting period (i.e. the student is now working at MaineDOT) or if they are continuing their students through an advanced degree (list the degree and where they are attending).

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?**
Diarmuid Gregory	M.S.	12/1/2021	TBD

Use the table below to list any students that participated in Industrial Internships during the reporting period:

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?**
NA			

*Use the table below to list **organizations** that have been involved as partners on this project and their contribution to the project during the reporting period.*

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**
NA						

*Use the table below to list **individuals** that have been involved as partners on this project and their contribution to the project during the reporting period. (**List your technical champion(s) in this table.** This also includes collaborations within the lead or partner universities who are not already listed as PIs; especially interdepartmental or interdisciplinary collaborations.)*

Table 11: Other Collaborators				
Collaborator Name and Title	**Contact Information**	**Organization and Department**	**Date(s) Involved**	**Contribution to Research**
James Wild, Concrete Materials Manager	Jim.Wild@vermont.gov	Vermont Agency of Transportation	10/1/2021-12/31/2021	Technical Champion

Use the following table to list any transportation related course that were taught or led by researchers associated with this research project during the reporting period:

Table 12: Course List						
Course Code	**Course Title**	**Level**	**University**	**Professor**	**Semester**	**# of Students**
NA						

Changes:

Co-PI Prof. Ting Tan unexpectedly left the project due to a change in his employment status.

The project end date is 12/31/2021. A small amount of the budget remains unexpended, while there is considerable opportunity to explore the technology developed in this project. A no-cost extension request is being submitted along with this project report.

Planned Activities:

If the no-cost extension is granted, the following activities will be undertaken in the next quarter

- Repeat the freeze thaw beam vibration tests with chitosan loadings of 0.25 to 0.75% by weight to confirm the variation in durability as seen in Figure 1
- Attempt microscopic imaging to assess the hypothesis that the positive effect of the chitosan fibers is to alter the microstructure of the concrete.
- Continue to develop mechanical models on the action of the shrinking chitosan fibers.