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): Ting Tan, University of Vermont
Reporting Period: 7/1/21 – 9/30/21
Submission Date: September 30, 2021

Overview:

Freeze-thaw testing examined the ability of shrinking fibers to enhance the durability of mixes. A hypothesis is that shrinking during curing reduces micro-voids, which resist water penetration. The results of the freeze-thaw testing are quite promising with specific mix ratios surviving much longer than other mix ratios, use of passive preshrunk fibers, and no fibers. Figure 1 shows a mass of chitosan fibers using an improved manufacturing method. Figure 2 shows concrete samples with active shrinking fibers and passive pre-shrunk fibers, with the active fiber beams performing much better. Figure 3 plots the freeze-thaw performance of concrete beam samples with various mix ratios and compositions using fundamental frequency of vibration as a measure. The beams with active shrinkage fibers in 1% and 2% weight mix ratios clearly performed the best.

Figure 1. Chitosan fiber produced by improved manufacturing technique

Figure 2. After 168 freeze-thaw cycles; 0.24 wt% active fiber specimen with minimal damage (top) and 2% passive fiber specimen with significant damage (bottom)

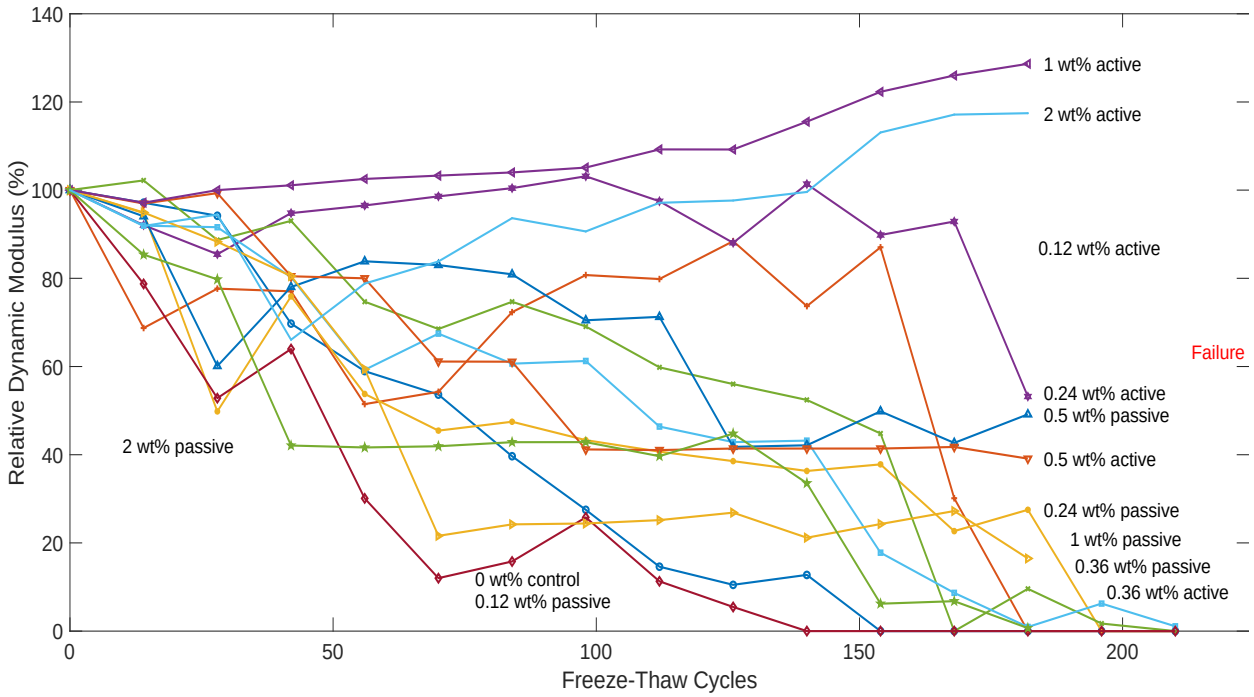

Figure 3. Freeze-thaw durability of various wt% chitosan fiber reinforced concrete

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 port-tensioning shrinking fibers

Accomplishments:

The primary accomplishment was to demonstrate that the shrinking fibers had large potential to extend the durability of concrete. Freeze-thaw test results were consistent with the hypothesis that shrinking fibers affect the microstructure ina way that reduces hydraulic permeability and enhances freeze-thaw durability. A secondary, but nonetheless important, development was improved methods of fabricating larger quantities of chitosan fibers.

Task Progress and Budget:

Table 1: Task Progress			
Task Number	**Start Date**	**End Date**	**% Complete**
Task 1: Shrinking Fiber Development and Manufacture	6/1/19	12/31/21	90%
Task 2: Laboratory Performance Testing	6/1/19	5/30/21	85%
Task 3: Mechanical Modeling	6/1/19	5/30/21	65%
Overall Project:	6/1/19	5/30/21	80%

Table 2: Budget Progress		
Project Budget	**Spend – Project to Date**	**% Project to Date***
$220,000	$208,680.71	94.85%

Professional Development/Training Opportunities:
NA

Technology Transfer:

Table 3: Presentations at Conferences, Workshops, Seminars, and Other Events				
Title	**Event**	**Type**	**Location**	**Date(s)**
High Performance Concrete with Post-Tensioning Shrinking Fibers	VT STIC Stakeholders Meeting and the 2021 AOT Research and Innovation Symposium	Poster and online presentation	Online	9/8-9/2021

Table 4: Publications and Submitted Papers and Reports				
Type	**Title**	**Citation**	**Date**	**Status**
Conference paper	Chitosan-Based Shrinking Fibers for Post-Cure Stressing to Increase Durability of Concrete"	abstract submitted to SPIE Smart Structures NDE 2022 Behavior and Mechanics of Multifunctional Materials XVI	9/24/21	pending

Participants and Collaborators:

*Use the table below to list **all** individuals (compensated or not) who have worked on the project.*

Table 5: Active Principal Investigators, faculty, administrators, and Management Team Members			
Individual Name	**Email Address**	**Department**	**Role in Research**
Dryver Huston	dryver.huston@uvm.edu	Mechanical Engineering	PI
Ting Tan	Ting.Tan@uvm.edu	Civil and Environmental Engineering	Co-PI

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

Table 6: Student Participants during the reporting period				
Student Name	**Email Address**	**Class**	**Major**	**Role in research**

Diarmuid Gregory		M.S./Senior	Mechanical Engineering	Graduate research assistant

Use the table below to list any students who worked on this project and graduated during this reporting period. Include information about the student's accepted employment (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 7: Students who Graduated During the Reporting Period

Student Name	Degree	Graduation Date	Employment or continued degree
NA			

Use the table below to list organizations have been involved as partners on this project and their contribution to the project.

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
NA						

Have other collaborators or contacts been involved? If so, who and how? (This would include collaborations with others within the lead or partner universities; especially interdepartmental or interdisciplinary collaborations.)

Table 9: Other Collaborators

Collaborator Name and Title	Contact Information	Organization and Department	Contribution to Research
James Wild	Vermont Agency of Transportation	Materials	Technical Champion

Who is the Technical Champion for this project?
Name: James Wild
Title: Concrete Materials Manager
Organization: Vermont Agency of Transportation
Location (City & State): Montpelier, VT
Email Address: Jim.Wild@vermont.gov

Changes:

There are no anticipated changes in the overall technical plan for the research.

Planned Activities:

The planned activities in the next quarter are:

1. Scale up production of improved shrinking chitosan fibers.

2. Use shrinking fibers in laboratory tests of performance on small cylinders and more standard sized beams and cylinders. Include freeze-thaw, hydraulic permeability and durability tests into the performance tests as a supplement to strength testing.
3. Based on success with the above steps, interaction with VTrans Technical Champion Jim Wild to formulate a plan on moving the concept of self-prestressing concrete into a more durable high-performance material that finds use in transportation structures.
4. Prepare final report as the project is presently scheduled to finish at the end of 2021.