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: 10/1/19 – 12/31/19
Submission Date: December 20, 2019

Overview:

Task 1: *Shrinking Fiber Development and Manufacture*. A manufacturing technique for self-stressing steel fibers has been developed. This uses steel fibers in curled shapes that are prestressed by the insertion of polyvinyl acetate (PVA) polymer slugs. These slugs are water-soluble and will slowly dissolve when the combined piece is inserted into wet concrete, Figure 1. A key design issue is to select the geometry so that the PVA slug has a mechanical advantage so that it induces a prestress in the steel, even though it is much softer than the steel. Another design consideration is that the slug must stay in place in a stable configuration during concrete mixing. Steel rings that have a PVA slug inserted into a cut produced a prestressed configuration that compresses the concrete with an encircling action when the PVA dissolves. Dimples embossed into the ends of the slug stabilize the prestressed configuration.

Task 2: *Laboratory Performance Testing*. 4-point bending tests loaded small laboratory sized beams at a constant displacement rate up to failure while measuring the corresponding loads and acoustic emissions, Figure 2. The beams contained various mix ratios of the prestressing rings as shown in Figure 1. The results of these tests were encouraging but indicated that the method needs more refinement. Examination of fractured beams indicate that the rings set into the concrete in a deformed prestressed state following dissolution of the PVA, Figure 3. When loaded to failure, the beams with prestressing rings carried a somewhat larger load than the control beams with non-stressing rings, Figure 4. The acoustic emission results show a difference between the control beams with non-stressing rings and beams with prestressing rings, Figure 5. The prestressed beams carried loads longer into the cracking failure than the beams with non-stressing rings.

Task 3: *Mechanical Modeling*. Minimal efforts addressed mechanical modeling of the prestressing rings on concrete beam behavior.

Table 1: Task Progress

Task Number	Start Date	End Date	Percent Complete
Task 1: Shrinking Fiber Development and Manufacture	6/1/19	5/30/21	35%
Task 2: Laboratory Performance Testing	6/1/19	5/30/21	30%
Task 3: Mechanical Modeling	6/1/19	5/30/21	5%

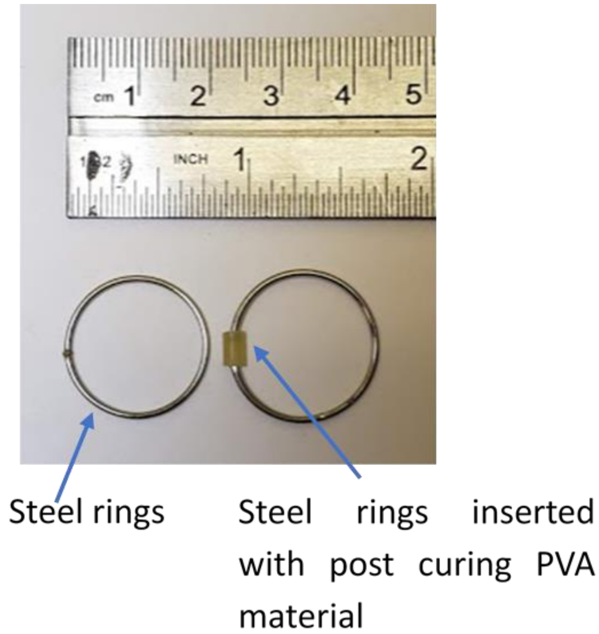

Figure 1. Steel ring (on left) in unstressed state and steel ring (on right) in prestressed state with inserted PVA slug. Dimples on the end of the slug help to stabilize the stressed configuration

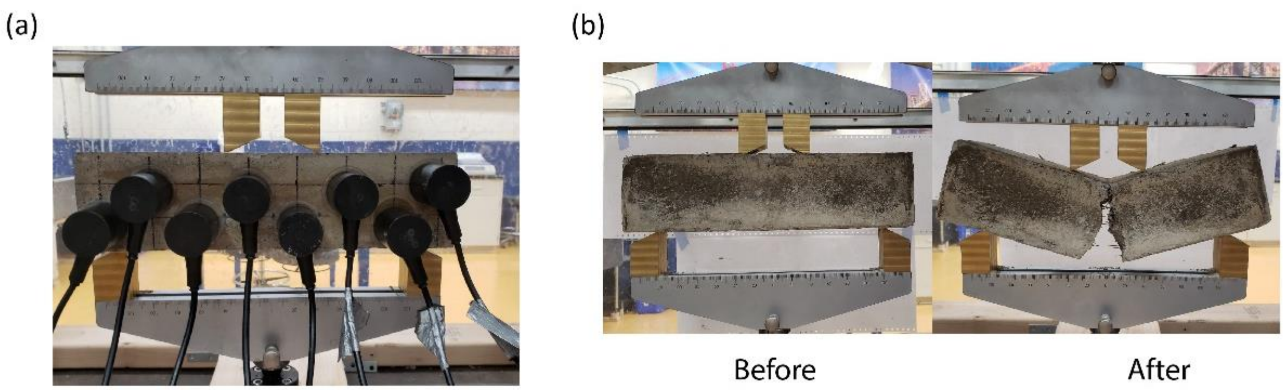

Figure 2. 4-point load tests of laboratory beams containing prestressing rings, a. with acoustic emission sensors, and b. load to failure

Figure 3. The ring is deformed when imbedded in the beam, but returns to its original shape after removal from the concrete matrix. This confirms that the rings set into the concrete in a deformed prestressed state following dissolution of the PVA.

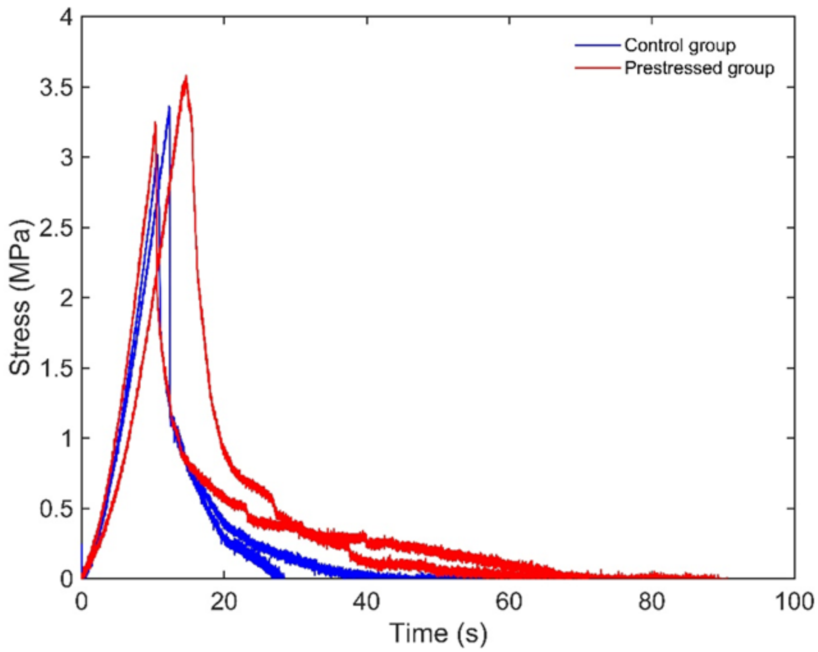

Figure 4. The beams with prestressing rings have a relatively higher strength than the control group with non-stressing rings

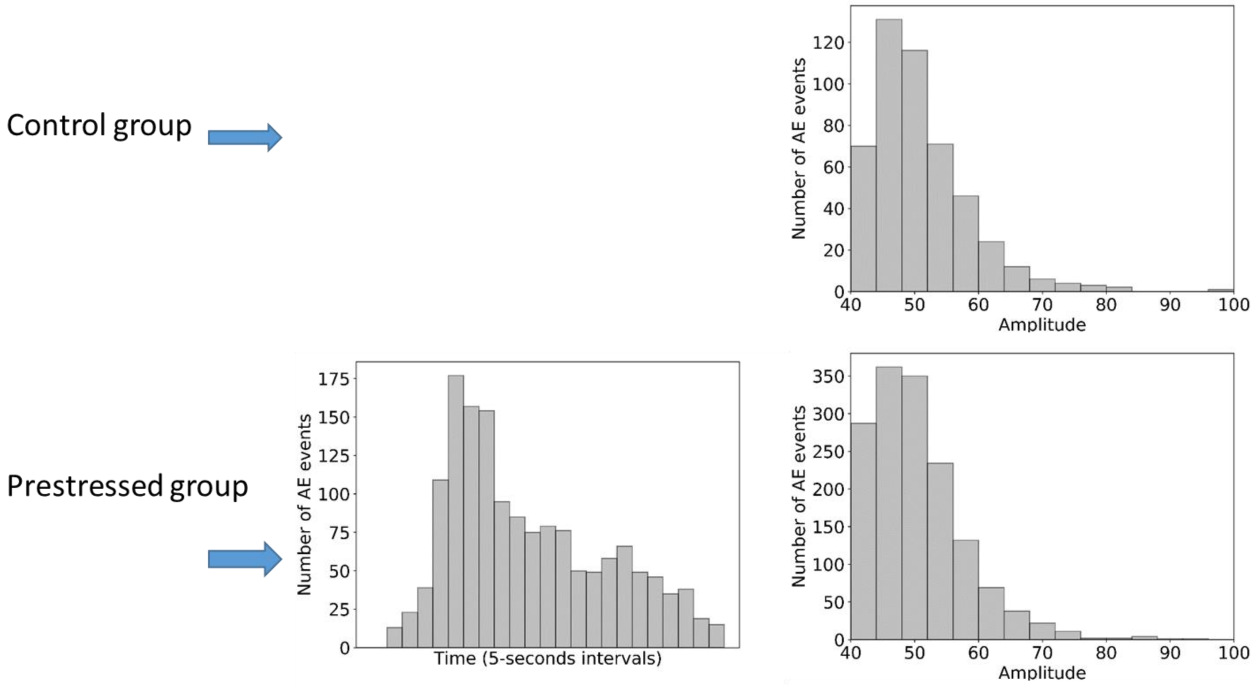

Figure 5. Acoustic emission behavior of control beams with unstressed rings and beams with prestressing rings indicate that the rings carry loads at a larger cracking deformations of the beam

Table 2: Budget Progress		
Entire Project Budget	**Spend Amount**	**Spend Percentage to Date**
$220,000		

Opportunities for training/professional development

Graduate student Zhuang Liu visited the FHWA Mobile Concrete Research Laboratory while it was at the VTrans Material Test Laboratories in October 2019.

Activities involving the dissemination of research results

Table 3: Presentations at Conferences, Workshops, Seminars, and Other Events				
Title	**Event**	**Type**	**Location**	**Date(s)**
High Performance Concrete with Post-Tensioning Shrinking Fibers	32nd Annual Rhode Island Transportation Forum	Symposium	University of Rhode Island	October 25, 2019

Table 4: Publications and Submitted Papers and Reports				
Type	**Title**	**Citation**	**Date**	**Status**
Peer-reviewed journal	Avalanches During Flexure of Early-Age Steel-Fiber Reinforced Concrete Beams	Cement and Concrete Research	12/19/19	under review

Participants and Collaborators:

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

Table 6: Student Participants during the reporting period				
Student Name	**Email Address**	**Class**	**Major**	**Role in research**
Zhuang Liu		Ph.D.	Mechanical Engineering	Actively participated

Table 7: Student Graduates			
Student Name	**Role in Research**	**Degree**	**Graduation Date**
N/A			

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**
N/A						

List all other outputs, outcomes, and impacts here (i.e. patent applications, technologies, techniques, licenses issued, and/or website addresses used to disseminate research findings). Please be sure to provide detailed information about each item as with the tables above. N/A

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. N/A

Changes:

The focus at the moment is on metallic fibers for providing prestressing, instead of the chitosan-based polymer fibers, since the steel fibers have the potential to create very high-performance concrete. It is anticipated that polymer based shrinking fibers will be addressed at a later stage in this project.

Planned Activities:

The planned activities during the coming months will primarily involve methods of creating better performing prestressing fibers. The focus will be on steel fibers, but other fiber types will be considered, including those made of shape memory alloy nitinol fibers and polymer variant. Mechanical models of the behavior of prestressing fibers will also be developed.