Semi-Annual Progress Report

TIDC Transportation Infrastructure Durability Center AT THE UNIVERSITY OF MAINE

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: *06.01.2019 to 07.31.2019*
Date: *09.30.2019*

Overview: (Please answer each question individually)

Overview and summary of activities performed during previous six months

The funded start date of this project is 06.01.2019. The primary activities have been:

1. Fill out the project research team – Dr. Ting Tan, Associate Professor in Civil and Environmental Engineering at the University of Vermont, has joined the project team as a Co-PI. Dr. Tan has expertise in the mechanics of civil engineering materials. Zhuang Liu, a Ph.D. candidate in Mechanical Engineering at the University of Vermont, will join the project in June 2019.

2. Planning for the research – A key item for planning was to decide which active fiber technology to pursue – polymer-based or metal-based. Based on the potential capability of producing high performance concrete, it was decided to focus on metal-based methods during the first round of developments.

3. Conduct steel fiber tests – The present focus is on steel fibers with prestress release techniques.

   Materials: The concrete used for this study was Portland cement based fast-setting concrete mix (Product No.1004-50), manufactured by Quikrete.

   Specimen preparation: The prepared water and concrete were mixed at a weight ratio of 1:10 with a steel fibers added. The diameters of steel fibers are 0.58 mm, and the lengths are 30 mm. The tensile strength of steel fiber is ~200 MPa. The concrete and fiber mixture were put into the molds stirred with a vibration shaker for 20 minutes to remove air bubbles. The final specimens were sized at 3 x 3 x 12 inches. Two batches samples of two different fiber volume ratio were prepared, with 8-10 beams of each batch, fiber volume ratios are 0.5% and 1.0% respectively. The specimens were left in curing room for 7 and 28 days.

   Experiment: In this study, four-point bending tests were performed using the Tinius Olsen Universal Testing machine (Horsham, PA). The loading span was 80 mm, and the supporting span was 240 mm. A constant loading rate of 0.03 in/min was applied in each test, and 100 Hz sampling rate was used to record the data. Meanwhile, Sensor Highway III data acquisition system was used to monitor the cracks using eight PK6I 60 kHz resonant acoustic sensors and 2-D locations software A schematic of the experimental system set up is shown in Figure 1.

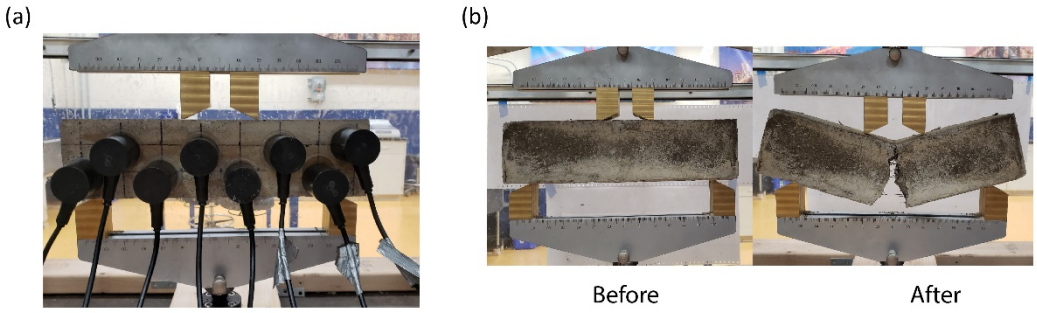

Figure 1 Experimental system set up. A four-point bending set up was established, and eight acoustic emission sensors were placed. a) before cracking b) after cracking.

Results: The average strength of 28 days concrete beams is observed higher than 7 days concrete beams. Both 0.5% volume ratio and 1.0% volume ratio beams with steel fiber-reinforcement exhibited significant improvement in ductility. The flexural stress vs time curve for specimens that set for 7 days and 7days are shown in figure 2 and figure 3. The summarized flexural strength for each batches is shown in figure 4. Acoustic emission detection for 7 days concrete specimens is shown in figure 5.

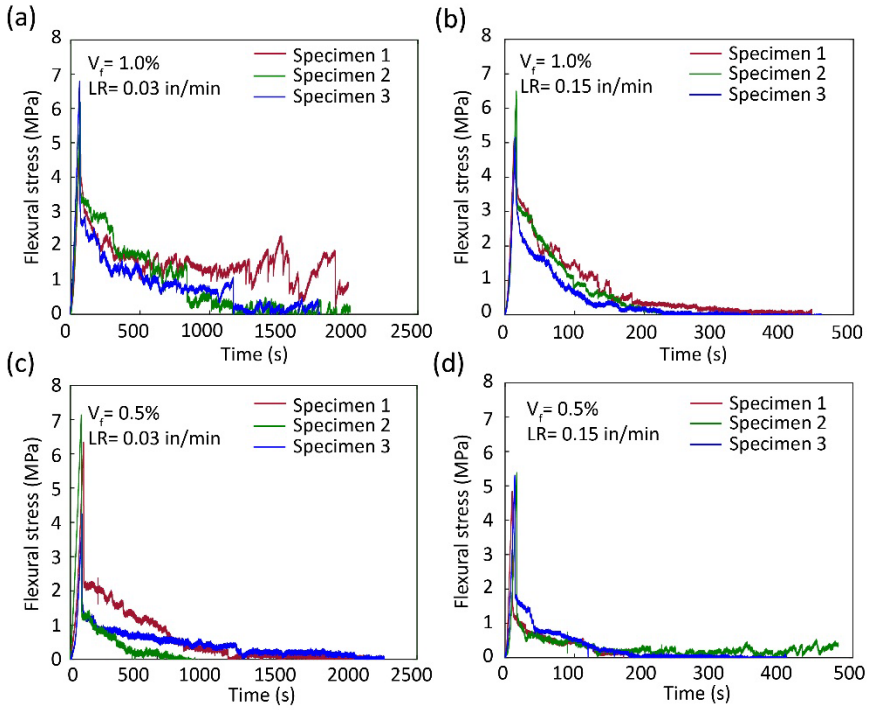

Figure 2 (a)- (d) Stress vs time curve of each testing batch for 7 days concrete specimens

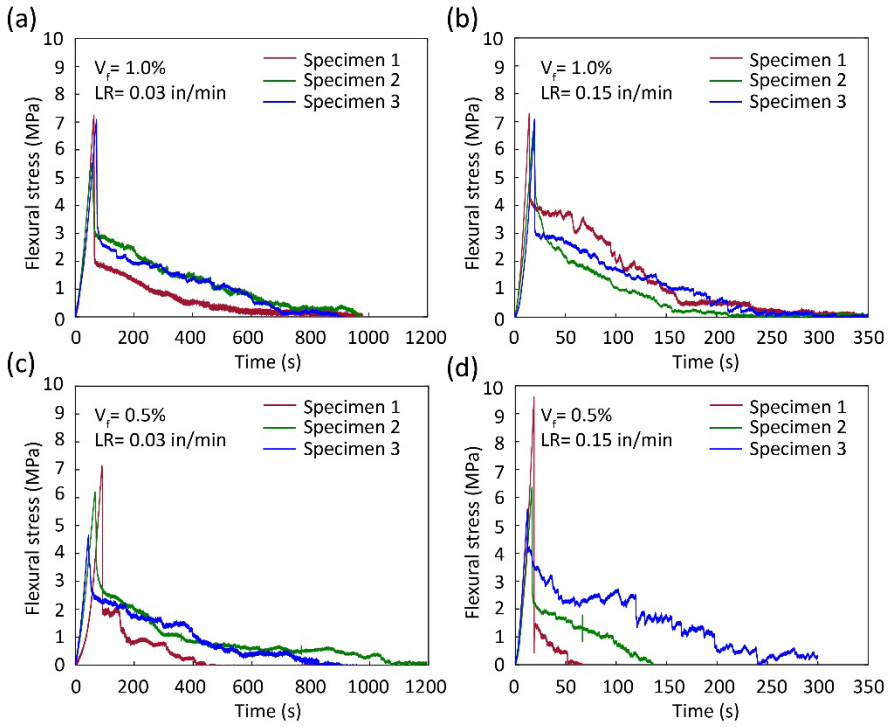

Figure 3 (a)- (d) Stress vs time curve of each testing batch for 28 days concrete specimens

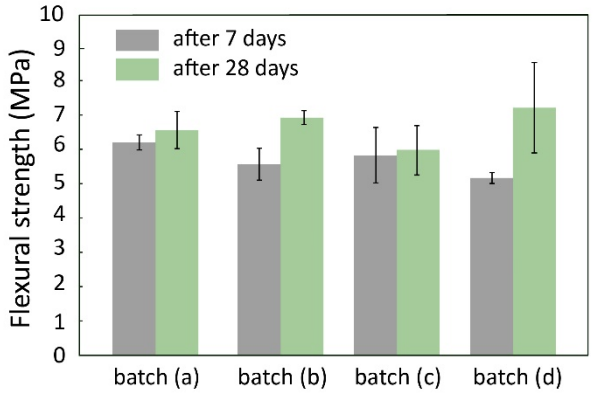

Figure 4 Summarized flexural strength for each batches is shown in figure 4.

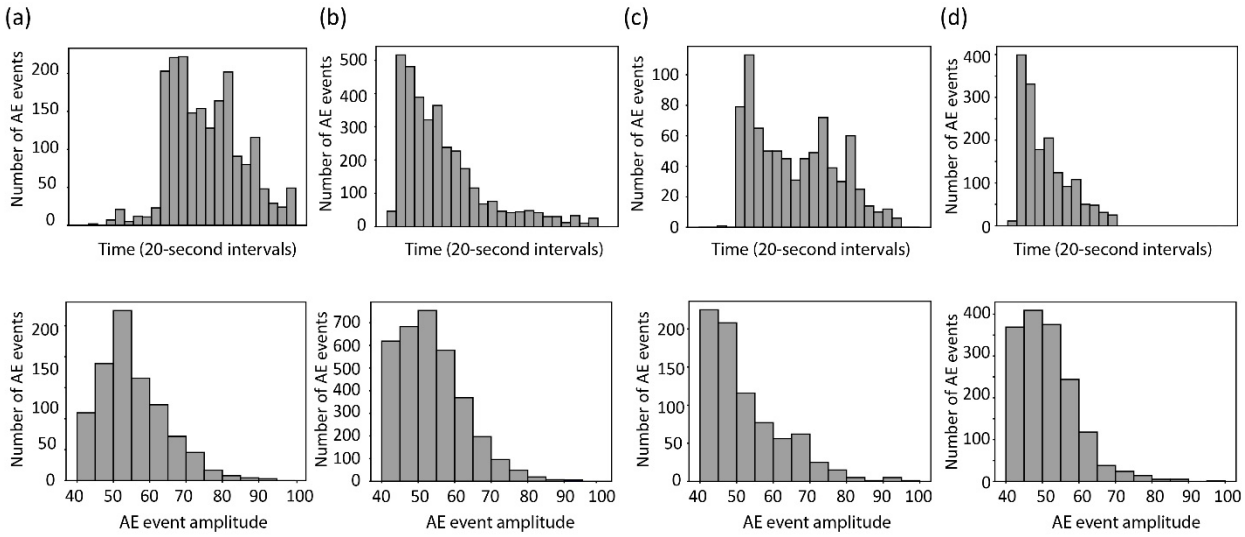

Figure 5 Acoustic emission detection 7 days concrete specimens, in (a)-(d) each batch contains histogram of AE event time (top) and histogram of AE event amplitude (bottom)

Context as to how these activities are helping achieve the overarching goal of the project

The objectives of this project are to:

a. 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
b. Test performance in larger laboratory specimens
c. Develop mechanical models to describe and predict enhanced performance due to port-tensioning shrinking fibers

The activities during this reporting period cover objectives a. and b.

Accomplishments achieved under the project goals

The accomplishments are primarily the experimental results reported above, i.e. the implementation of tests and test results for steel fiber reinforced concrete. An additional accomplishment is the conceptual design of circular and other nonlinear shaped shrinking fiber concepts based on the dissolution of inserted polymer elements.

Opportunities for training/professional development that have been provided

UVM engineering undergraduate Tyler Barney is participating in the research effort under the UVM Research Experience for Undergraduate program.

Activities involving the dissemination of research results

Liu Z, Worley || R, Tan T, Huston D. (2019) "A Study on the Flexural Behavior of Pre-Stressed Steel Fiber-Reinforced Concrete" paper submitted to 2020 Transportation Research Board Annual Meeting, under review

Liu Z, Worley || R, Tan T, Huston D. (2019) "High Performance Concrete with Post-Tensioning Shrinking Fibers" to be presented at 32nd Transportation Forum, Rhode Island, October 2019

Participants and Collaborators:

Faculty participants:

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Graduate Student

Civil and Environmental Engineering Department
Role on project: unfunded technical assistance

Tyler Barney
Undergraduate Student – Junior

Civil and Environmental Engineering Department
Role on project: assisted in experiments as a UVM-funded researcher in REU program

Organizations have been involved as partners on this project - NA

Other collaborators or contacts:

Vermont Agency of Transportation personnel have provided advice on the potential utility of a positive outcome of the research.

Changes:

No delays or project plan changes during this reporting period.

Planned Activities:

Description of future activities over the coming months.

Planned future work includes design and testing of prestressing steel fibers. Figure 6 shows the designed prestressing mechanisms, we will also test the beam specimens with different fiber volume ratios.

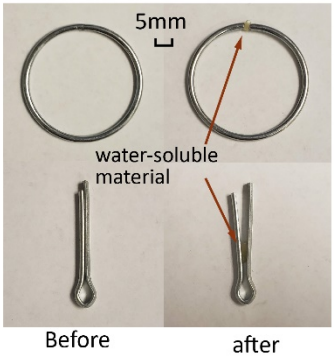

Figure 6 Two prestressing mechanism were designed, the top are prestressing design using steel rings, the bottom shows prestressing design using cotter pins, where water soluble materials are applied.