Quarterly Progress Report:
Project Number and Title: 2.3: Avalanche study of the fiber-reinforced cementitious composites
Research Area: Thrust 3 Use New Materials and Systems to Build Longer-lasting Bridges and Accelerate Construction
PI: *Ting Tan, University of Vermont*
Co-PI(s): *Co-PIs and home institution(s)*
Reporting Period: *05.01.2020 to 06.30.2020*
Date: *Date*

Overview: (Please answer each question individually)

Overview and summary of activities performed during previous three months
The primary activities have been:

1. Fill out the project research team – PI Ting Tan has been working with a graduate student Zhuang Liu for the avalanche study between the steel fiber and cement matrices.

2. For the experimental part, PI Tan and Zhuang Liu has performed four-point bending experiments for steel fiber reinforced concrete beams with 1% fiber volume fractions at different loading rates (0.03 and 0.15 in/min). Characteristic avalanches need to be collected and categorized from the filtered data.

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

The research objectives of this project are to understand the dynamic stress-drop behavior between fiber reinforcements and cementitious matrices, such as steel fibers and cement matrices, including

1. High resolution experimental measurements on stress-time avalanches between steel fibers and cementitious matrices

2. Filter design and processing of the high temporal resolution data

Accomplishments achieved under the project goals
The accomplishments are primarily the results reported above, i.e., experimental study on stress-time avalanches between steel fibers and cement matrices, and interpretation of avalanche mechanism based on a mean-field model.

Complete the following tables to document the work toward each task and budget

Table 1: Task Progress

Task Number	Start Date	End Date	% Complete
Task 1: Steel/cement interfacial avalanche measurements	8/01/2019	12/31/2019	80
Data processing and model explanation of stress-time avalanches	01/01/2020	06/30/2020	50
Overall Project:	Initial Start Date	Planned End Date	

Table 2: Budget Progress

Project Budget	Spend – Project to Date	% Project to Date
$179,377	0	0%

Opportunities for training/professional development that have been provided

UVM engineering graduate Zhuang Liu participated in the avalanche study during the spring 2020.

Activities involving the dissemination of research results

Table 3: Presentations at Conferences, Workshops, Seminars, and Other Events				
Title	**Event**	**Type**	**Location**	**Date(s)**
Presentation title	Name of event (i.e. TIDC 1st Annual Conference)	i.e. Conference, Symposium, Seminar,		
N.A.	N.A.	N.A.	N.A.	N.A.

Table 4: Publications and Submitted Papers and Reports				
Type	**Title**	**Citation**	**Date**	**Status**
i.e. Peer-reviewed journal, conference paper, book, policy paper	Publication title	Full citation		I.e. Submitted, accepted, under review
Peer-reviewed journal	Z. Liu, R. Worley, C, Giles, F. Du, M. Dewoolkar, D. Huston, T. Tan. Avalanches during flexure of early-age steel fiber reinforced concrete beams, *Materials and Structures*, 53, 76, 2020	0	Jan, 2020	Published

Figures

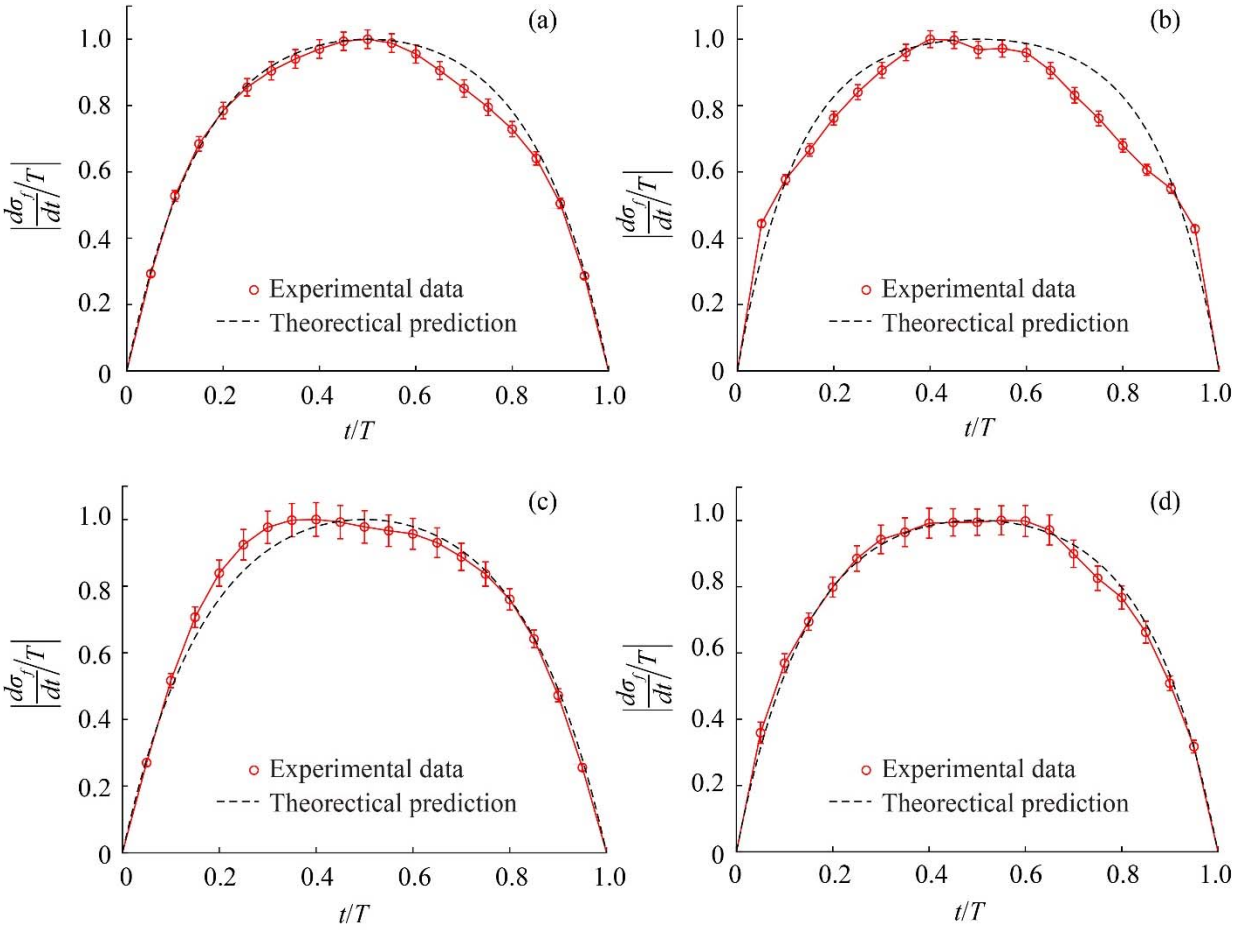


Fig. 1. Flexural stress drop rate profiles scaled by its maximum rate over the duration T for all small avalanches in the scaling regime, where. $\left|\frac{d\sigma_f}{dt}/T\right| = (\frac{d\sigma_f}{dt}/T)/(\frac{d\sigma_f}{dt}/T)_{max}$. (a) 1.0% fiber volume, 0.76 mm/min loading rate, weakening parameter $k_1 = 5.14 \pm 0.19\ s^{-1}$. (b) 1.0% fiber volume, 3.81 mm/min loading rate, weakening parameter $k_2 = 20.94 \pm 1.31 s^{-1}$. (c) 0.5% fiber volume, 0.76 mm/min loading rate, weakening parameter $k_3 = 1.69 \pm 0.12 s^{-1}$. (d) 0.5% fiber volume, 3.81 mm/min loading rate, weakening parameter $k_4 = 11.16 \pm 0.80\ s^{-1}$.

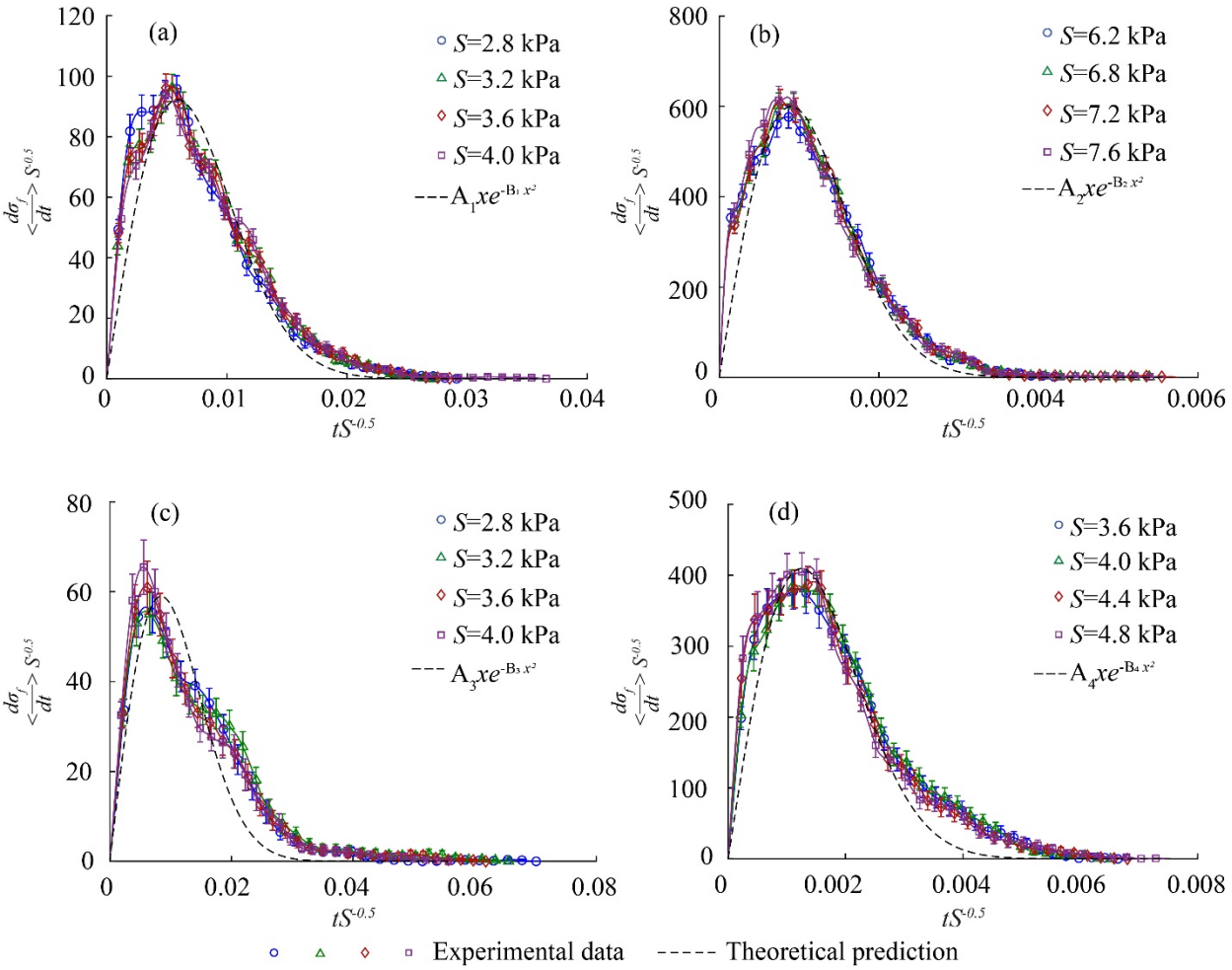
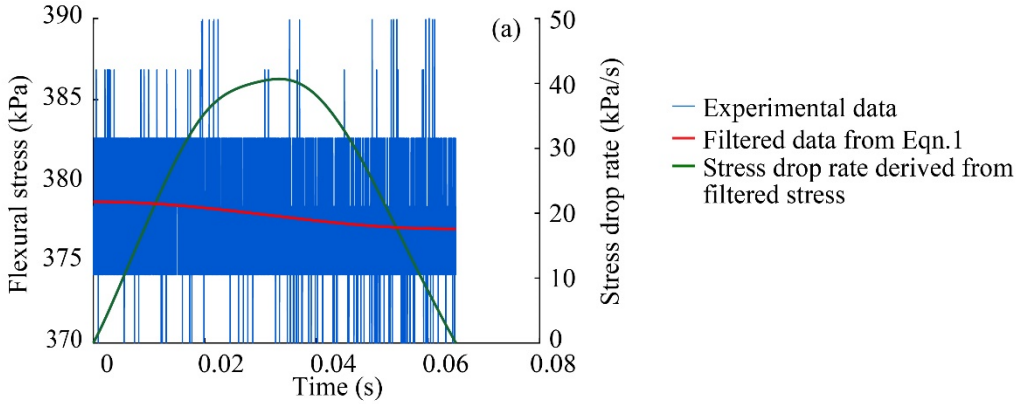
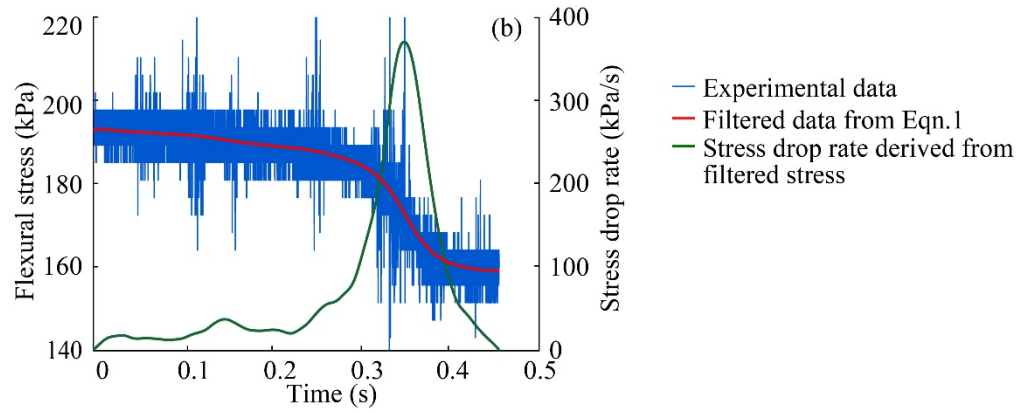
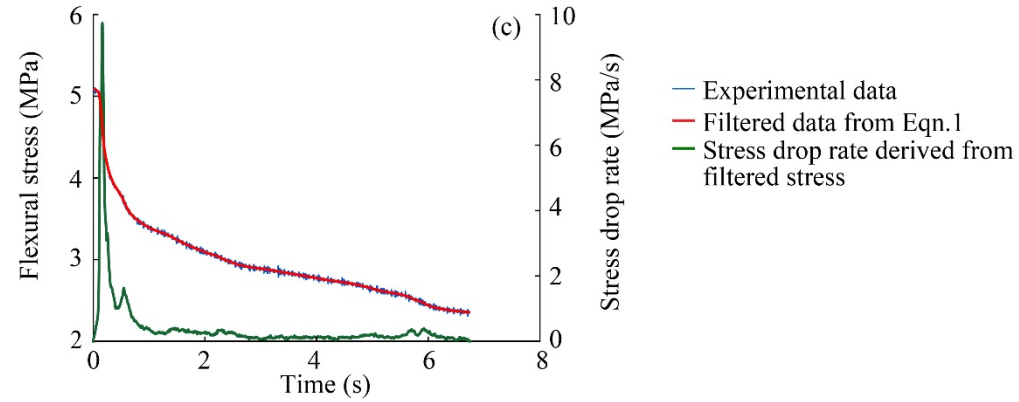


Fig. 2. Scaled average flexural stress drop rate profiles for avalanches in the scaling regime, collapsed by scaling both axes by a factor of $S^{-0.5}$. The black dash lines were the predicted curves with nonuniversal constants A and B. (a) 1.0% fiber volume, 0.76 mm/min loading rate, A_1= 2.6*e*4 and B_1=1.4*e*4. (b) 1.0% fiber volume, 3.81 mm/min loading rate, A_2= 1.1*e*6 and B_2=6.2*e*5. (c) 0.5% fiber volume, 0.76 mm/min loading rate, A_3= 1.2*e*4 and B_3=7.0*e*3. (d) 0.5% fiber volume, 3.81 mm/min loading rate, A_1= 5.0*e*5 and B_1=3.2*e*5.


(a)
Flexural stress (kPa)
Stress drop rate (kPa/s)
Time (s)
Experimental data
Filtered data from Eqn.1
Stress drop rate derived from filtered stress


(b)
Flexural stress (kPa)
Stress drop rate (kPa/s)
Time (s)
Experimental data
Filtered data from Eqn.1
Stress drop rate derived from filtered stress


(c)
Flexural stress (MPa)
Stress drop rate (MPa/s)
Time (s)
Experimental data
Filtered data from Eqn.1
Stress drop rate derived from filtered stress

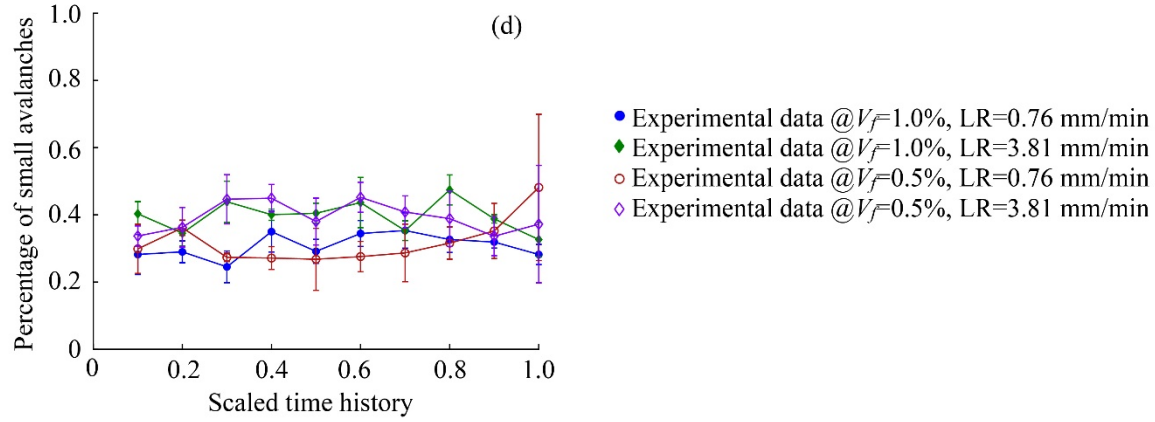

(d)
Percentage of small avalanches
Scaled time history
Experimental data @V_f=1.0%, LR=0.76 mm/min
Experimental data @V_f=1.0%, LR=3.81 mm/min
Experimental data @V_f=0.5%, LR=0.76 mm/min
Experimental data @V_f=0.5%, LR=3.81 mm/min

Fig. 3. Flexural stress and stress drop rates for a beam with 1.0% fiber volume tested at 0.76 mm/min loading rate. (a) a representative small avalanche in the scaling regime, (b) a representative large avalanche beyond the scaling regime, and (c) a representative giant avalanche occurred at the cracking of bottom concrete. (d) Fractions of small avalanches over scaled time histories.

Participants and Collaborators:

Table 5: Active Principal Investigators, faculty, administrators, and Management Team Members			
Individual Name	**Email Address**	**Department**	**Role in Research**
	Email is not included in the external report and is only used for internal purposes.		
Ting Tan	Ting.Tan@uvm.edu	Civil and Environmental Engineering	PI
Dryver Huston	Dryver.Huston@uvm.edu	Mechanical Engineering	Co-PI

Use the table below to list all students who have participated in the project.

Table 6: Student Participants during the reporting period				
Student Name	**Email Address**	**Class**	**Major**	**Role in research**
	Email is not included in the external report and is only used for internal purposes.	(i.e. Junior, Master's Ph.D)		
Zhuang Liu		Ph.D	Civil Engineering	Perform experiments on avalanche study

Use the table below to list any students who worked on this project and graduated during this reporting period.

Table 7: Student Graduates			
Student Name	**Role in Research**	**Degree**	**Graduation Date**
N.A.	N.A.	N.A.	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**
		Mark the appropriate				

		contribution with an "x"				
Vermont Tech College	Randolph Center, VT	N.A.	N.A.	X	X	X

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Changes:

Actual or anticipated problems or delays and actions or plans to resolve them

PI Tan started a new project on avalanches of fiber-reinforced cementitious materials during flexure. No changes have been made

Changes in approach and the reasons for the change: NA

Planned Activities:

Planning for the research – Experimentally, we will test other types of fiber-reinforced cementitious materials to compare their avalanche behavior.