TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency (FHWA or State DOT): ____IOWA DOT______________________________________

INSTRUCTIONS:
Project Managers and/or research project investigators should complete a quarterly progress report for each calendar quarter during which the projects are active. Please provide a project schedule status of the research activities tied to each task that is defined in the proposal; a percentage completion of each task; a concise discussion (2 or 3 sentences) of the current status, including accomplishments and problems encountered, if any. List all tasks, even if no work was done during this period.

Transportation Pooled Fund Program Project #	**Transportation Pooled Fund Program - Report Perio**
TPF-5(449)	X Quarter 1 (January 1 – March 31, 2022) Quarter 2 (April 1 – June 30, 2022) Quarter 3 (July 1 – September 30, 2022) Quarter 4 (October 1 – December 31, 2022)

Project Title:
Robust wireless skin sensor networks for long-term fatigue crack monitoring of bridges

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Lead Agency Project ID:	**Other Project ID (i.e., contract #**	**Project Start Date:**
	Addendum 736	May 15, 2020
Original Project End Date:	**Contract End Date:**	**Number of Extensions:**
May 14, 2023	May 14, 2023	

Project schedule status:
x On schedule □ On revised schedule □ Ahead of schedule □ Behind schedule

Overall Project Statistics:

Total Project Budget	**Total Cost to Date for Projec**	**Total Percentage of Work Completed**
$ 540,000	$208,135	38%

Quarterly Project Statistics:

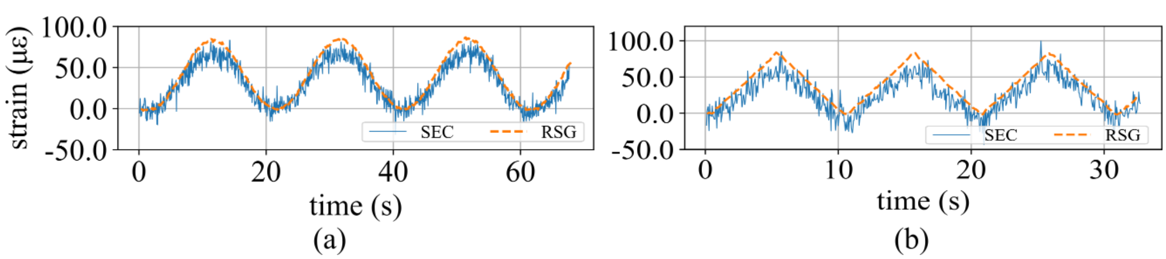
Total Project Expenses This Quarter	**Total Amount of Funds Expended This Quarter**	**Percentage of Work Completed This Quarter**
$20,210		

Project Description:

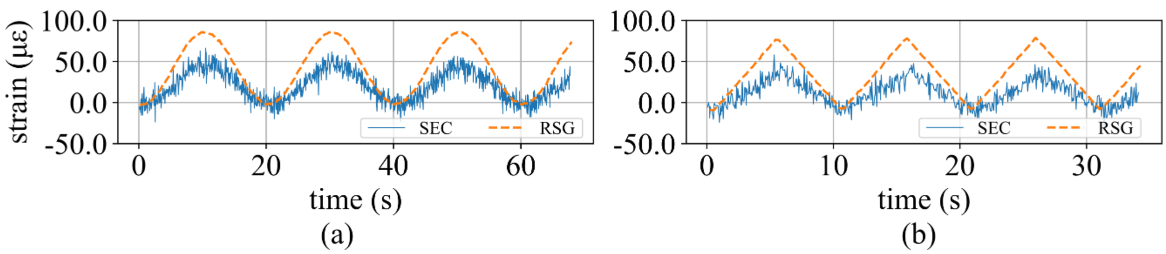
Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):

- TAC meeting on January 25th 2022.
- ISU & USC worked together on achieving a paintable sensor for concrete applications and studied the use of a shielding layer on the sensor.
- ISU investigated different coatings of sensors to improve bonding on concrete. The figure below shows the extra layers of SEBS adhered onto the top and bottom surfaces of the sensor. It was found that adding these layers significantly reduce noise in the signal, likely attributable to extra shielding.

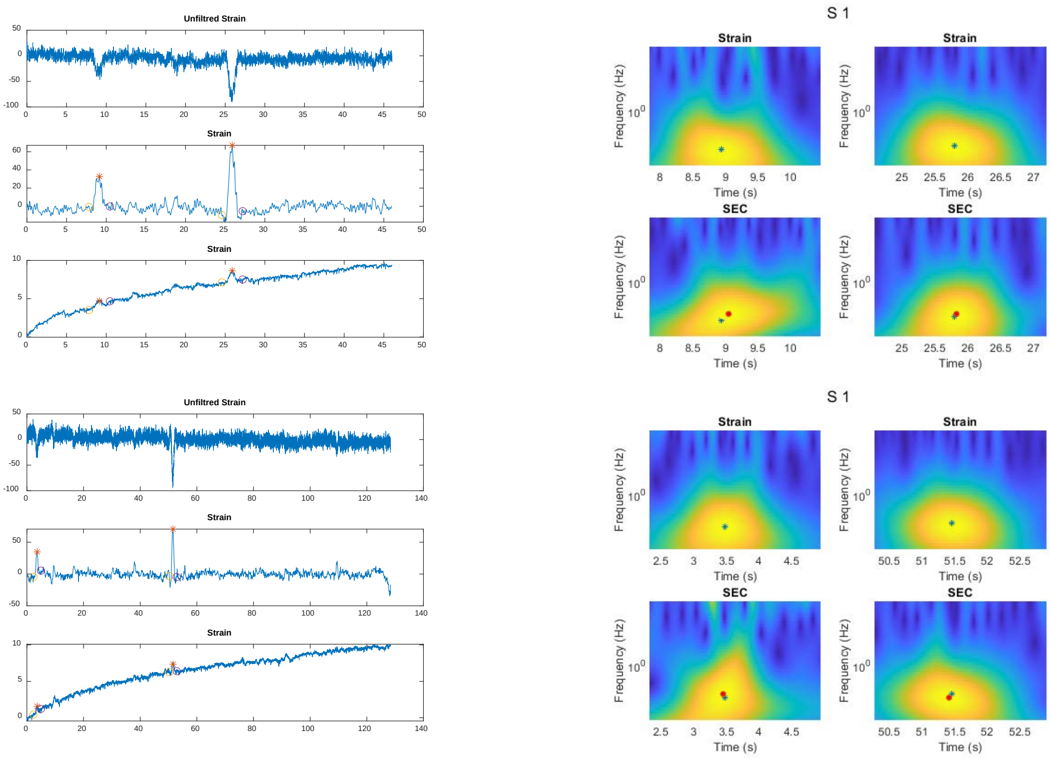
- USC conducted tests on the shielded sensor on concrete and compared against off-the-shelf resistive strain gauges (RSG). The figure below shows comparable measurements from both technologies, thus that the shielding layer does improve contact with concrete.



- USC conducted test without the shielding layer. Results, plotted in the figure below, show disagreement in magnitures between the SEC and RSG, thus demonstrating that theuse of a shielding layer improves on sensing performance.



- KU was continuously monitoring the wireless sensor network installed on the I-70 highway bridge near Kansas City through the web interface and cloud server, downloading and analyzing new data.
- KU has updated the crack growth index (CGI) algorithm for autonomous fatigue crack monitoring. The proposed algorithm is based on automated peak detection and the generalized Morse wavelets (GM-CWT). The peak detection is identified using local maxima based on change of derivatives. The proposed algorithm consists of three steps: peak detection, computing the amplitudes of wavelet coefficients and finding the window of interest (WOI), and computing the modified CGI. The figure below shows the performance of the first two steps under two different datasets to detect impulse events and compute the amplitudes of wavelet coefficients under the WOIs. The red dots in the figures show the detected peaks.



(a) (b)

Peak detection and wavelet analysis for fatigue crack monitoring using two different datasets

The last step in the algorithm estimates the crack growth containing the modified CGI. The modified CGI is equal to the ratio of the maximum peaks between the SEC signal and the cross strain measured from strain gauge for normalization. The performance of the proposed algorithm was examined using 22 datasets. The modified CGI was computed for all datasets. The means and standard deviations of the modified CGIs are shown in Figure 2. As shown in the figure, the mean CGI stays relatively constant which indicates no crack growth over the monitoring period.

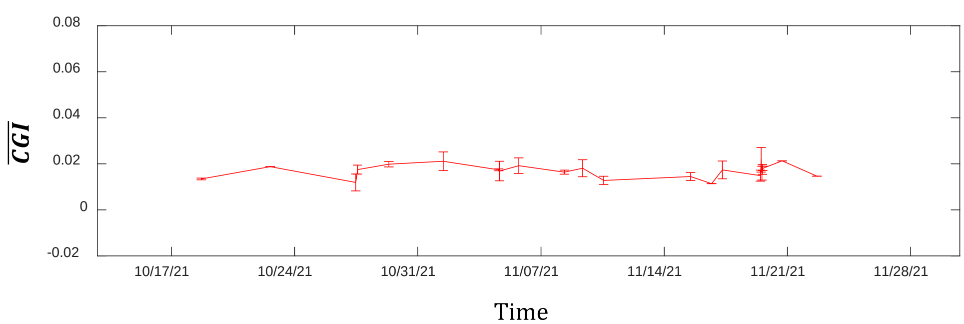


Figure 3. The modified CGI for fatigue crack monitoring

- KU attended the SPIE Smart Structures and NDE conference in Long Beach, California between March 6-10 and presented on the results of this research.
- UA assembled three new sensor boards. One of them was tested to ensure proper bridge balancing, amplification and shunt calibration. The performance was compared with off-the-shelf capacitance measurement toolkit PCAP02.
- Several power consumption tests were conducted to estimate current consumption of the sensorboard at different stages. The figure below shows the test result. Comparing it with the signal coming from SEC, different stages of current consumption can be identified (i.e. bridge balancing and amplification, shunt calibration, static and dynamic condition). The subsequent figure shows the comparison of current consumption

at these stages. The average current consumption is around 40 mA and there is not significant difference in consumed current at these stages. During the test, the average current consumption can go up to 53 mA. This can be attributed to the extra circuitry.

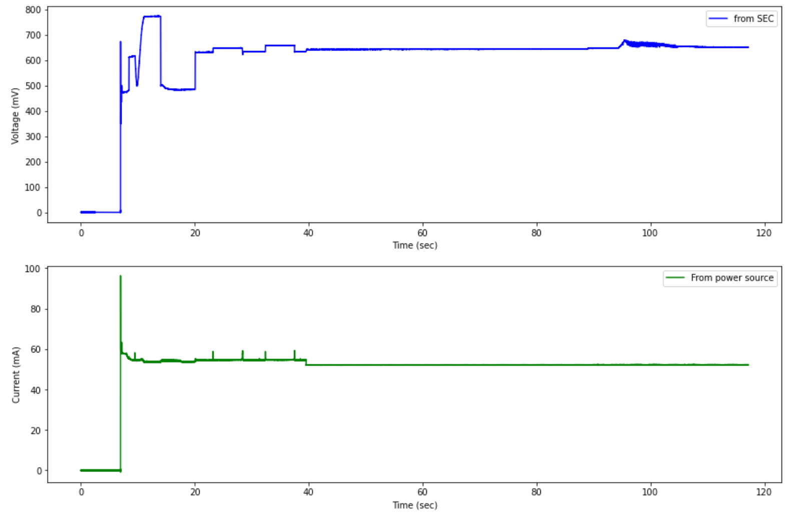
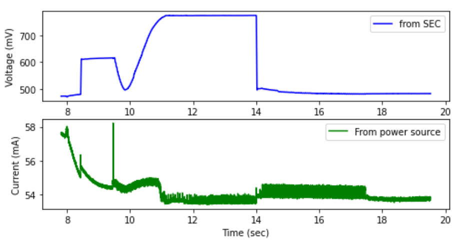
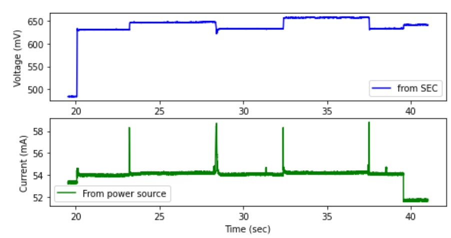


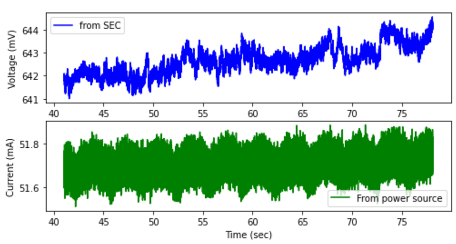
Figure: Current consumption test



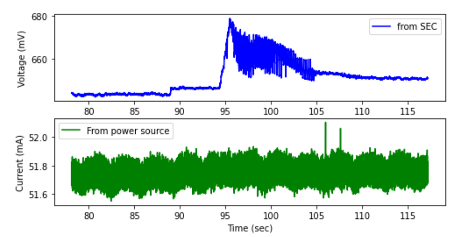
a) Bridge balancing and amplification stage



b) Shunt calibration stage



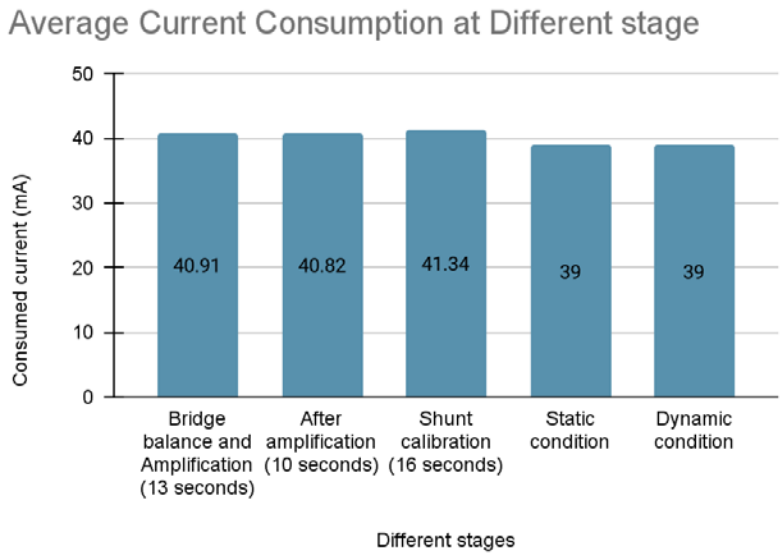
c) During static condition



d) During dynamic condition

Figure: Comparison of current consumption at different stages

- The table shows the average estimated current and the total duration of different stages. The estimation is made based on the actual current consumption during static condition (i.e. 39 mA)



Anticipated work next quarter:

- ISU will continue working with USC to establish fabrication and installation procedures for concrete applications.
- USC will continue investigating strain sensing with the SEC with multiple layers of SEBS and textured SEC by varying dielectric layer thickness.
- USC will continue the investigation on the painted bersion of the SEC on concrete while also varying the thickness of the dielectric layers and validating results using Digital Image Correlation.
- KU will continuously monitor the wireless sensors using web server and cloud server and download and analyze data.
- KU will further validate the updated CGI algorithm.
- UA will updated software to add a scheduling function to control the frequency of bridge balancing & calibration process and enable a sleeping mode for the CPU of the sensorboard. Additional scheduling function may be able to reduce unnecessary power consumption of the sensorboard.
- UA will test updated sensorboards and performance validated.

Significant Results:

- Demonstration that shielding the SEC results in smaller noise and better adhesion to concrete.
- Updated and verified CGI algorithm.
- Energy consumption of sensor boards studied, and there is no significant differences in energy consumption across stages.

Circumstance affecting project or budget (Describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope, and fiscal constraints set forth in the agreement, along with recommended solutions to those problems). N/A