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 # *TPF-5(449)*	**Transportation Pooled Fund Program - Report Perio** Quarter 1 (January 1 – March 31, 2023) Quarter 2 (April 1 – June 30, 2023) x 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	
Project Manager: **Phone:** **E-mail:** Khyle Clute 239-1471 khyle.Clute@iowadot.us	
Project Investigator: **Phone:** **E-mail:** Simon Laflamme 294-3162 laflamme@iastate.edu	

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	$263,857	60%

Quarterly Project Statistics:

Total Project Expenses This Quarter	Total Amount of Funds Expended This Quarter	Percentage of Work Completed This Quarter
$42,878		

Project Description:

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

- TAC meeting on January 25th 2022.
- Presented results at the MidContinent Workshop, September 15th 2022.
- ISU investigated direct painting of the SEC on steel. Figure below comapres signals from the sensor bonded using epoxy (left) and directly painted (right). The directly painted sensor's signal is noticeably less noisy. Other tests were conducted comparing data against strain gauges and similar results were obtained.

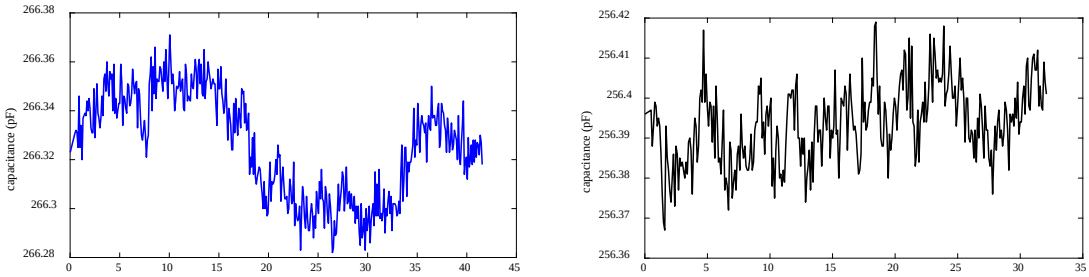
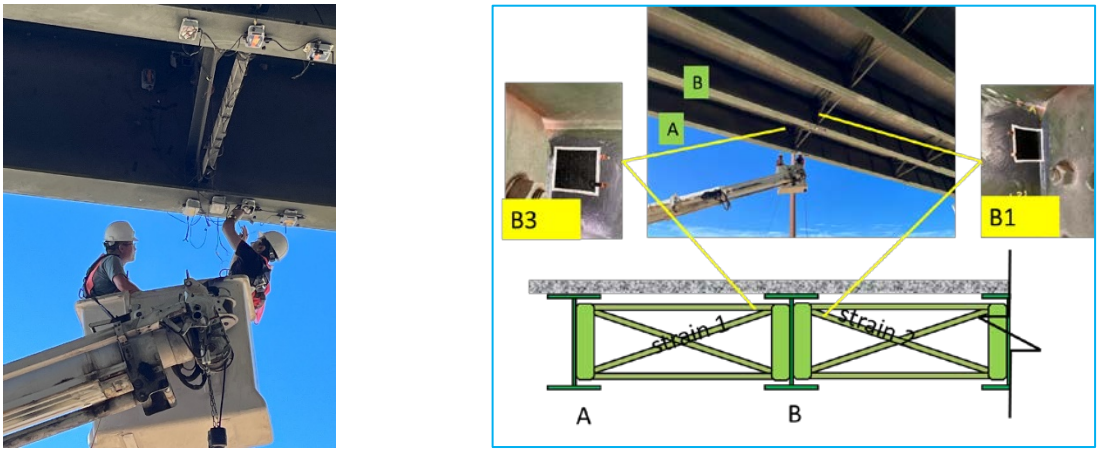


Figure: SEC signal: (left) epoxy-bonded; (right) direct bonding

- ISU investigated a new materials mix enable spray-deposition of the sensor; the current mix is not very practical for direct painting because of the presence of toluene. The new mix uses a pure silicon in liquid form. At this stage, we only tested an electrode layer made of silicon+carbon black. The new layer yielded better resistance/connectivity.
- On July 12, 2022, KU made a field trip to the I-70 highway bridge near Kansas City to fix and investigate issues including the sensor power and the unwanted low-frequency signal. Figure below shows a photo of the field crew working on the sensors.

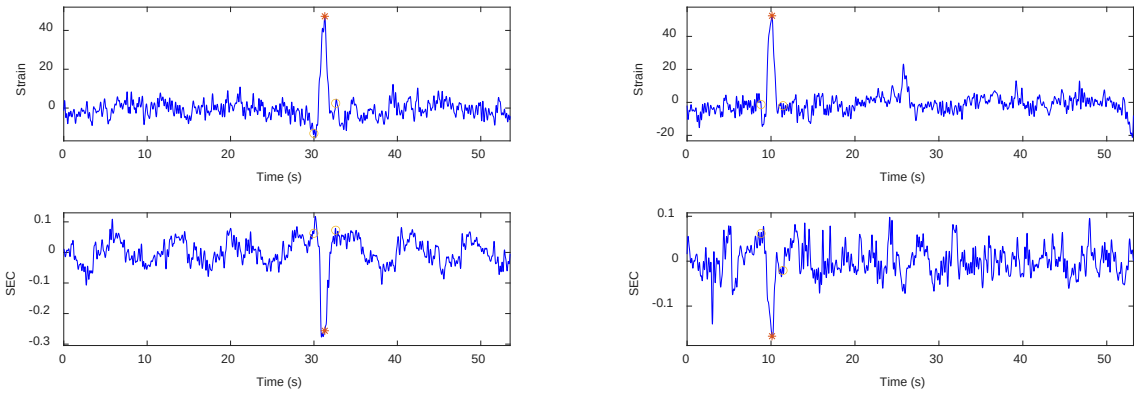


a b

Figure: Field deployment and the detail of the girders

- KU fixed the power issue of the WLASS, which brought the sensor network offline, by changing the batteries of the sensor nodes. The power issue was likely caused by in appropriate trigger threshold that led to power drainage. The WLASS has been brought back online.
- KU investigated the issue of signal noise, which occurred when multiple SECs were connected to the same power source. Data was collected and analyzed for girder B1 and B3 (Figure above, b). Figure below shows two analyzed data sets from girder B3, which were recorded on October 27, 2021, and July 17, 2022, respectively. An impulsive traffic loads was successfully captured using the SECs and highlighted with the red asterisks in the figure. The data of SEC from October 27, 2021, experienced signal noise with low-frequency content as multiple SECs were connected to the same sensor node

and hence shared the same power. In contrast, the data collected on July 17, 2022, does not contain the signal noise, indicating the source of noise is likely the power source.

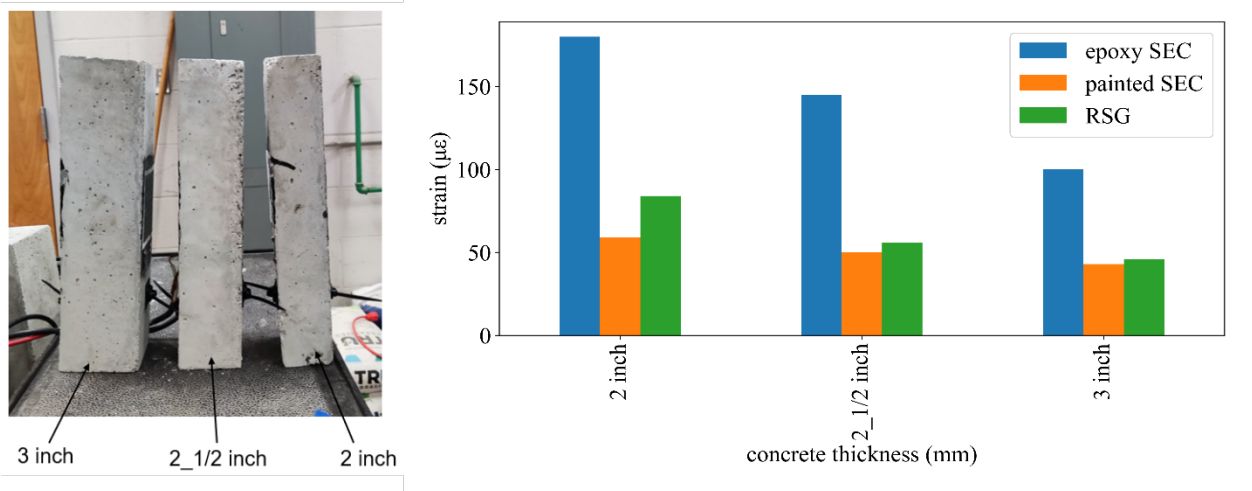


The SEC data with noise
October 27, 2021

The SEC data without noise
July 17, 2022

Figure 2: The strain and SEC data for girder B3 before and after the field work on July 12, 2022

- USC investigated painted sensors on concrete as well as the effect of concrete thickness on the signals using the concrete samples shown in the figure below. Sensors were painted textured SEC and epoxy-adhered SEC of similar thicknesses. Both SECs were attached to the concrete with constant load, and strain data were compared to those from strain gauges (RSGs). The results from the figure show that as the thickness of concrete increases and loading remains unchanged (concrete thickness-independent), and that the painted SEC yielded signals simialr to those from the RSG, thus pointing towars bonding issues for concrete materials.



(a) (b)

Figure:s train investigations on concrete with different thicknesses showing the: (a) samples of thicknesses 2-inch, 2 1/2 inch and 3-inch, and; (b) strain results from SEC and RSG.

- UA placed the order for the production of 15 sensor boards. The PCB fabrication is already completed by the manufacturer and the final assembled boards are expected to be delivered by mid-October.
- UA debugged some software issues, e.g. fine-tuning initial values of several parameters (i.e. initial resistance in the SEC side and reference side, gain setting resistances in the amplifiers), storing the optimized resistance values obtained during calibration in the digital potentiometer memory. The feasibility of the automated calibration and scheduling function was validated with different test setups

(cantilever steel plate, shear frame), power source (DC power supply source, battery), and SECs with different nominal capacitances (280pf~350pf).

Anticipated work next quarter:

- ISU will continue working on the sprayable electrode mix, and investigate a full sandwich structure.
- KU will work on testing the next generation senor boards with automated balancing and Shunt calibration in the laboratory and deploy them to the bridge.
- KU will continue to collect and analyze data from the WLASS for long-term fatigue crack monitoring.
- UA will continue to test the sensor boards on the sensor network of shear frame.
- USC will continue investigating painting the SEC steel structures with references to offsets in joints.
- USC will continue testing on concrete with the modified SECs from Iowa.

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Significant Results:

- Demonstrated that direct bonding of the sensor led to better results.
- Found a promising mix for spray-depositing the sensor.
- Power issue resolved, and source of noisy signal in the field identified.
- Sensor boards have been ordered and will be delivered mi-Octover.

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