Semi-Annual Progress Report

TIDC Transportation Infrastructure Durability Center AT THE UNIVERSITY OF MAINE

Project Number and Title: 2.10 Durability Evaluation of Carbon Fiber Composite Strands in Highway Bridges
Research Area 2: New materials for longevity and constructability

PI: *Roberto Lopez-Anido, University of Maine*
Co-PI(s): *Keith Berube and Andrew Goupee, University of Maine*

Reporting Period: *06/01/2019 to 09/30/2019*
Date: *09/28/19*

Project Goal:

The objectives of this project are to monitor the structural performance of CFCC strands in the Penobscot-Narrows cable-stayed bridge to evaluate long-term durability, and to assess durability of CFRP strands for pre-stressed concrete bridges.

Overview:

- Graduate student started literature review on subjects related to the project including:
    - Current CFRP cable sensor system installed at Penobscot Narrows Bridge (PNB)
    - Material properties of CFRP strands/cables
    - Other bridge sites with CFRP strands/cables
    - CFRP strand/cable anchoring systems
    - Testing performed on CFRP (i.e. bending, shearing, etc.)
    - CFRP strands/cables used for post-tensioning and pre-stressing of concrete
    - Traditional steel cable use in bridges including post-tensioning
    - Structural monitoring of bridge cables
- Researched existing wireless data acquisition (Wdaq) systems that will meet the needs of monitoring our existing PNB sensor system.
- Tested and verified a sample Wdaq system in a controlled laboratory environment and in an outdoor environment.
- Wrote standard operating procedures for using the Wdaq and FOS software.
- Contacted MaineDOT officials to determine what currently exists for IT infrastructure at the PNB site and what remote access protocols are currently in place.
- Arranged PNB site visit protocol with MaineDOT officials.
- Conducted initial bridge site visit to record data at each of the six stay anchorage locations to verify existing sensor functionality. CFCC load cells and load chair deflection sensors were operating as expected. However, the internal temperature sensors were not operating as intended. Problem has been identified as a power supply cable issue.
- The Wdaq system was verified at the bridge site. This was accomplished by setting up the sample Wdaq system at stay anchorage 17B and transmitting the sensor signals back to the North tower. Stay anchorage 17B was selected as the test anchorage due to the fact that it is the farthest distance from the proposed receiver location. The system successfully transmitted the CFCC force, the load chair displacement, and the temperature sensor signals back to the wireless receiver unit over the course of the week-long trial. The unfiltered raw data is presented in Figure 1.
- Tested and verified the Fiso 32-channel DMI fiber optic sensor (FOS) data acquisition system in a controlled laboratory environment.
- Worked on RS-232 (serial-port) communication Labview program to interface with Fiso DMI FOS data acquisition system.

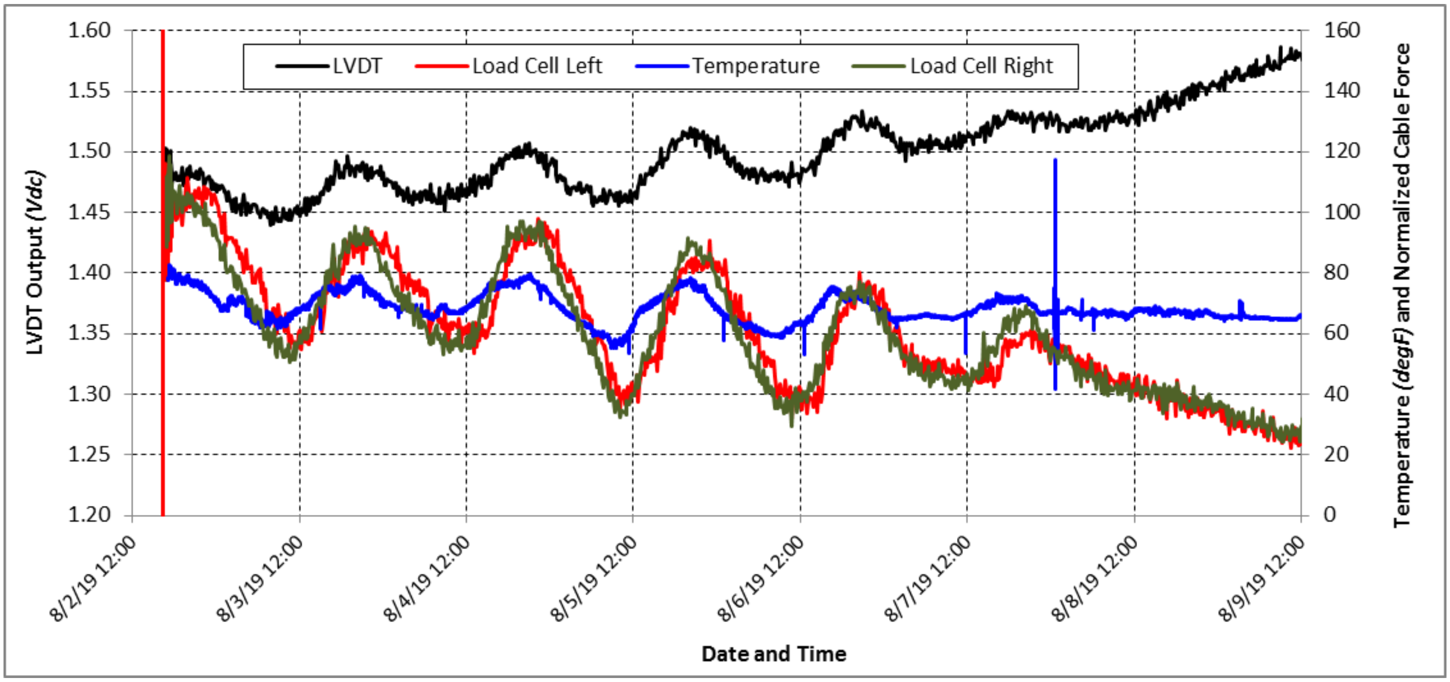


Figure 1. Wireless Bridge DAQ results from Stay anchorage 17B (unfiltered data)

- Installed a DAQ system at stay anchorage 10B to obtain continuous data from CFCC load cells and the internal and external temperature sensors. While post-processing the first week-long set of data, a noise issue was identified in the CFCC load cell data. Further processing of the noisy data can filter most of the noise, but the cause of the noise needs to be identified. The week-long data set with noisy load cell data is presented in Figure 2. The DAQ system remains active at the site and will allow debugging of the noise issues and continue to provide additional continuous data sets.

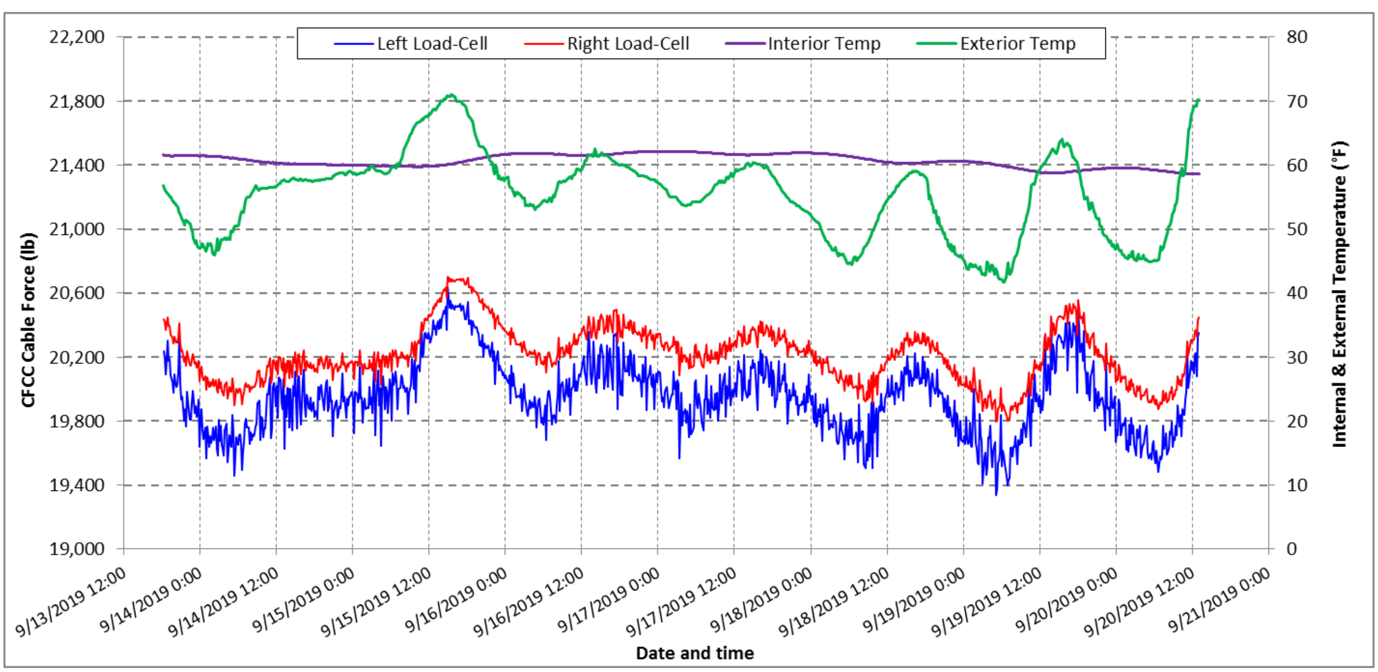
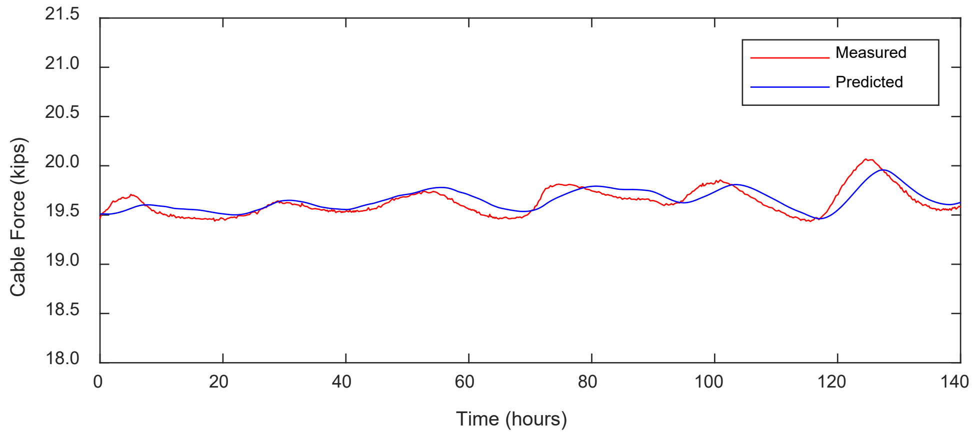
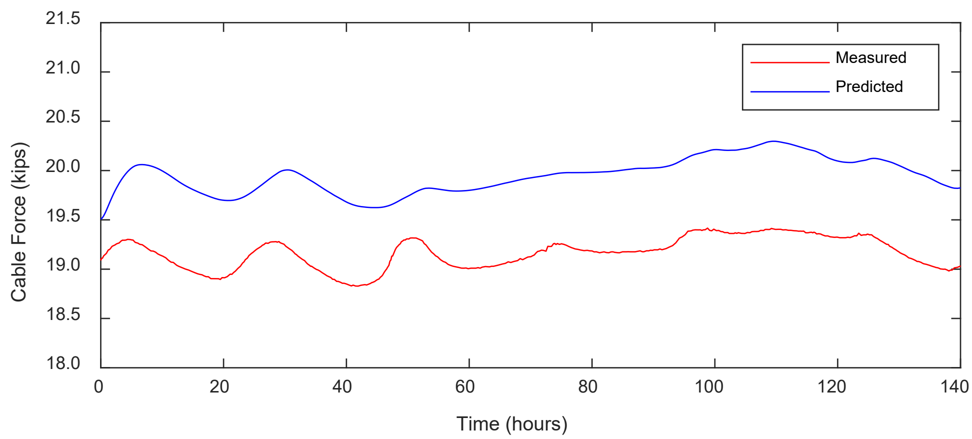


Figure 2. Wireless Bridge DAQ results from Stay anchorage 17B (unfiltered data)

- A recent set of continuous data from one of the CFCC load cells at stay 10B was used with the existing thermoelastic model and then compared with prior modeling for the same location in 2008 and 2013. Results are presented in Figure 3. The general magnitude (500-800 lb) in the offset between measured and predicted CFCC force in the recent continuous data set is comparable to the offset in the March 2013 continuous data set.



A)



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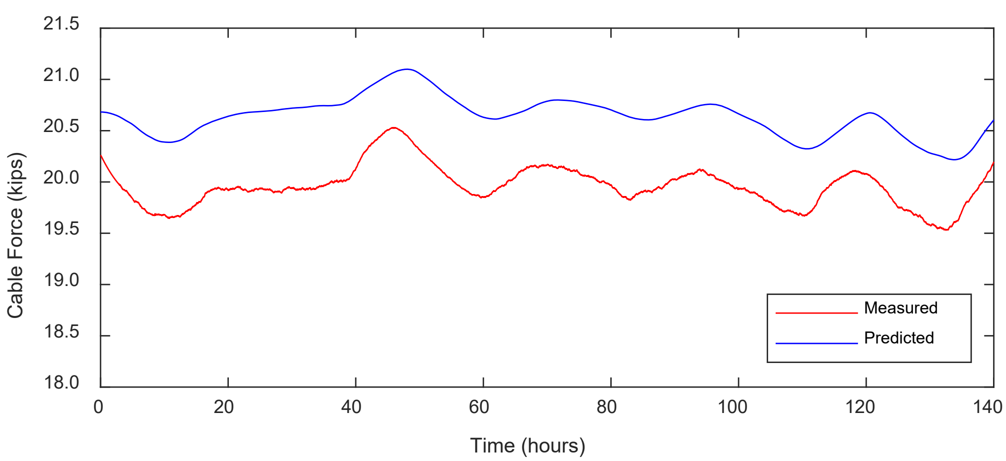

C)

Figure 3. Comparison of the measured and the thermoelastic analytical prediction of CFCC force at stay anchorage 10B **A)** in March 2008, **B)** in March 2013, and **C)** in September 2019.

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The activities conducted during this period (outlined in the previous section) served the following purposes:

1) Provided the graduate student with the necessary background information on the CFRP cables and the current PNB sensor system.
2) Established MaineDOT contact for onsite logistics and PNB site network capabilities.
3) Verified the current state of the existing structural monitoring sensors and supporting hardware systems.
4) Help verify the viability of transitioning to a wireless data acquisition (Wdaq) system with online data access.
5) Provided current continuous data to use with the existing thermoelastic analytical model to assess CFCC durability.

The progress towards the accomplishment of the project goals included:

- The ability to use a wireless data acquisition system for structural monitoring at the bridge site was confirmed.
- Provided continuous CFCC force data to be used by the graduate student with the existing thermoelastic analytical model.
- Preliminary results of continuous data at one of the stay anchorage locations (10B) would suggest that the cable response may not have changed since 2013. This is a positive sign for the durability of the CFCC system. HOWEVER, data sets of much longer duration will be required to verify the complex interaction of the CFCC strands with the steel cables and the concrete bridge.

Opportunities for the training of the graduate student have included:

- The Graduate student is becoming proficient with data acquisition for sensor systems and in writing Labview software to communicate with various DAQ hardware systems

Public awareness of the project has occurred during this period in the form of:

- A brief write-up on the project was provided to the University of Maine Alumni Association regarding the Penobscot Narrows Bridge's monitoring system and the connection to UMaine and the ASCC.
- Laurie Schreiber from Mainebiz magazine interviewed some of the UMaine TIDC project PIs in preparation of an upcoming Mainebiz article on the Transportation Infrastructure Durability Center. She plans to include our project on long-term durability of carbon fiber composite cables for civil infrastructure in the Mainebiz article.

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Participants and Collaborators:

Roberto Lopez-Anido, Ph.D. P.E., Professor of Civil and Environmental Engineering, UMaine

- Project PI, structural lead, and co-advisor of project's graduate student

Andrew Goupee, Ph.D., Assistant Professor of Mechanical Engineering, UMaine

- Project Co-PI, modelling lead, and co-advisor of project's graduate student

Keith Berube, Ph.D., P.E., Assistant Professor of Mechanical Engineering Technology, UMaine

- Project Co-PI and instrumentation lead

Braedon Kohler (braedon.kohler@maine.edu) is the Graduate Research Assistant (Mechanical Engineering) working on this project. He has conducted background research, setup instrumentation, and written data acquisition programs that will assist with the structural monitoring of the CFCC strands at the bridge site. He is also using the existing thermoelastic analytical model to compare experimental data with model predictions to assess the durability of the CFCC strands.

The organizations that have been involved as partners on this project to date:

Maine DOT has provided access to the bridge site and information on the existing IT infrastructure at the site that will enable the online structural monitoring system to be installed.

Aside from Maine DOT (as described above), no other collaborators have been involved to date. However, outreach is underway to identify potential collaborators.

Changes:

There has been a delay in selecting and purchasing the final hardware for the online system. This is due to a sensor output noise issue that was identified during obtaining continuous data at the stay anchorage locations. Trials are underway with different grounding and filtering techniques of the sensor output data to resolve the problem. This will determine what will be required for the final hardware in order to provide reliable sensor output data.

Aside from delays in purchasing equipment as discussed above, there are no additional changes planned at this time.

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Planned Activities:

The following activities are planned for the next period:

- Address the sensor output noise issue.
- Fiber optic sensor (FOS) system will be placed onsite to verify FOS Labview DAQ program.
- Purchase necessary components for the online structural monitoring system.
- Determine temperature effects on response of purchased hardware components through laboratory environmental chamber tests.
- Prepare existing bridge site wiring to interface with new structural monitoring system components.
- Continuous data of CFCC force and temperature will be obtained from the bridge site on a regular basis from at least one of the stay anchorage locations. This will provide data for modeling purposes and help debug onsite noise issues that were previously identified
- Graduate student will complete project literature review.
- Graduate student will continue work with the analytical model using blocks of continuous data obtained from stay anchorage locations.
- Consult with MaineDOT to identify possible outside collaborations.
- Work with UMaine TIDC Program Manager to identify opportunities for potential collaborators.