

**Office of Research and Implementation**

**FFY 2022 Request for Proposals**

Research Problem Statement Title:

**A Fatigue Assessment for Steel Bridges using Fiber Optic Sensors and Machine Learning**

Problem Statement:

Bridge deterioration is a significant problem in the United States (U.S.) with approximately 10% of the Nation’s bridges classified as structurally deficient. A large number of new and existing bridges in the U.S. are constructed with steel girders. Fatigue crack propagation is recognized as one of main deterioration mechanisms in steel girders. Detection of fatigue cracks and quantifying their effects on the integrity and performance of bridges is often a challenging task. Accordingly, there is a need for practical and reliable methodologies that can facilitate damage detection and performance assessment of steel bridge girders under fatigue effects. Structural health monitoring (SHM) activities are essential for achieving a realistic characterization of bridge structural performance levels. These activities can help detect structural damage before the potential occurrence of component- or system-level structural failures. In addition to their application at discrete times, SHM systems can also be installed to provide long-term accurate and reliable data continuously throughout the entire service life of a bridge. SHM activities often involve instrumenting structural components with sensors that can provide accurate and reliable data throughout the bridge service life. Owing to their superior accuracy and long-term durability compared to traditional strain gages, distributed fiber optic sensors are ideal in extracting accurate real-time strain and temperature data of bridge components. In contrast to embedded optic fiber sensors, these sensors are installed to the surface of the components and are ideal for monitoring steel bridge components. These systems have the potential to be the first truly automated technique that can be deployed on existing or newly constructed bridges to automatically alert the bridge manager of the presence of damage in the girder due to fatigue, truck overload, corrosion, temperature gradients, and/or collision, among others. Furthermore, research is still needed to integrate the effect of realistic truck loading, fatigue cracks, temperature variations, and boundary conditions in the detection algorithm.

Proposed Research:

The proposed project should have a large-scale laboratory testing of steel girders with different design attributes under a set of conditions that mimic truck loading and fatigue crack propagation. The beams should be instrumented and tested within a lab. Advanced machine-learning-based algorithms should be developed to detect different damage modes of the girder. The project team will also program a standalone industrial controller to be deployed for field monitoring in remote locations. After developing the system and conducting laboratory testing, with the help of Oklahoma DOT, the team will work on implementing the system by instrumenting and installing the detection system on existing bridge girders.

Suggested Tasks (to include but not limited to):

1. Literature Review and sensor acquisition A thorough literature review will be conducted to cover new advancements in fiber optic sensing and machine learning algorithms. 2. Analysis of steel girder damage modes and design of test matrix;In this task, several steel bridge types that are widely used in the state of Oklahoma will be identified. A comprehensive analysis will be conducted to identify the leading damage modes in the selected bridge types. 3. Sensor configuration for detecting different failure modes in steel bridges Given the selected girder types, critical details, sensor attributes, and the data acquisition device, a configuration for sensor placement and instrumentation will be designed to achieve a reliable and accurate structural health monitoring system. 4. Instrumentation, sensor installation, and testing of the designed steel girders; The team will construct the test setup within a lab and collect data during controlled dynamic load tests identified by the test matrix. The constructed girders will be instrumented using the designed sensor configurations. 5. Data analysis and damage detection algorithm development In this task, the collected data from experimental testing will be post-processed. A machine-learning-based damage detection algorithm will be developed to assess the performance of the girders. The collected experimental data in pre- and post-damage stages will be used to for training and evaluating the efficiency of the developed damage detection procedure. 6. After coordinating with ODOT Bridge Division personnel, the team will select a bridge for field investigation. 7. Given the characteristics of the selected bridge, the hardware and software designs will be refined to meet the needs of the investigated bridge in the field conditions. 8. After refining the hardware design based on the selected bridge, the bridge girders will be instrumented using distributed fiber optic sensors. The functionality of the installed sensors will be tested. 9. A communication device will be installed to transfer the recorded data to the data collection hub. The initial data will be used to calibrate the damage detection algorithm. The data collected during the service life of the bridge will be used to assess the long-term bridge performance. An investigation will be conducted based on the collected data to estimate the fatigue life of different critical details in the investigated bridge. 10. This task covers the preparation of the project monthly progress reports and final report, in addition to presentations to the ODOT personnel. It also consists of preparing the conference and journal publications required to ensure the proper dissemination of the results. A workshop will be organized and to demonstrate the system attributes and train interested ODOT personnel on the using of the system.

Implementation:

The proposed research can greatly help bridge officials in long-term performance assessment of highway steel bridges. A proper performance assessment can assist in planning optimal maintenance and repair actions that improve the reliability of bridges against long-term deterioration processes and minimize the associated cost of maintenance.

Benefits:

The proposed system has the potential to be the first truly automated technique that can be deployed on newly constructed or existing bridges to automatically alert the bridge manager of the presence of damage in the girder, due to fatigue crack propagation, truck overload, corrosion, temperature gradients, and collision, among others. Accordingly, it can significantly assist in improving the safety of bridges and reduce repair expenditures.

Deliverables:

All projects require the submission of the following reports:

* Monthly Progress Reports
* Multi-Year Projects require a Year-end Annual Report
* Copies of the project Draft Final Report in Microsoft Word and ADA accessible Adobe Acrobat pdf electronic formats
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The Year-end Annual Report, Draft Final Report, Final Report and Color Article should be submitted to satisfy all federal and state requirements pertaining to the accessibility of documents including but not limited to:

* Oklahoma State Statute 62 § 41.5e and the Americans with Disability Act (ADA) of 1990, 42 USC 12.01 et seq.

The PI must also participate in the following project meetings:

* New project initiation meeting
* Semi-annual project meeting
* Close-out project meeting
* Continuing project meeting
* Estimated completion time three years.

Existing Research found in separate attached file.