EXHIBIT A
SCOPE OF SERVICES

FEASIBILITY OF VIBRATION-BASED LONG-TERM BRIDGE MONITORING USING THE I-35W ST. ANTHONY FALLS BRIDGE

BACKGROUND

The overall approach for structural health monitoring (SHM) is the comparison of current performance to a known benchmark and to identify if differences are a function of damage. The dynamic properties of a structure, including the natural frequencies and mode shapes, form a fingerprint that can be used as a benchmark for comparison. One advantage of using modal analysis for SHM is that ambient vibration detected with relatively few sensors can be used to capture the behavior. However, correlating system behavior with damage outside of a laboratory environment can be challenging due to time-dependent and temperature effects, and data quality. In order to use vibration sensors effectively on bridges in Minnesota, it will be important to understand how temperature and potentially temperature gradients affect the natural frequencies and mode shapes.

Minnesota offers the unique opportunity of using the acceleration data from the I-35W Saint Anthony Falls Bridge to evaluate the effectiveness of vibration-based techniques for long-term monitoring. A very cursory look at the accelerometer data from the 35W Bridge indicated that the natural frequencies have non-linear temperature dependence. During the proposed project, the existing accelerometer data along with newly collected data will be mined to look for trends in the natural frequencies and mode shapes with mean structure temperature and temperature gradient. The existing bridge monitoring system is likely able to detect problems with the bearings, but is not likely sensitive to issues within the concrete boxes themselves. An accelerometer-based monitoring system has the potential to augment the current monitoring system. Additionally, accelerometer based monitoring systems are easily installed post construction; hence methodologies developed within this project may be easily transferable to the monitoring of existing bridges in Minnesota.

OBJECTIVE

The expected benefits of this project include an understanding of the feasibility of using accelerometer measurements for long-term monitoring of the I-35W Saint Anthony Falls Bridge. A key component of the feasibility is the time and temperature dependence of the acceleration measurements. Minnesota bridges experience some of the largest temperature gradients throughout the United States, making bridge monitoring in Minnesota more challenging than in many other states. The results from the proposed project could be expanded to the long-term monitoring of bridges throughout Minnesota. Additionally, the fidelity of these measurements will be examined to see if it would be possible to use the accelerometer data with some sophisticated signal processing as a component in a more advanced system that might be able to estimate vertical deflections.

SCOPE

The study will focus on two key components: the fidelity of the acceleration measurements and the long-term variation of dynamic properties.

For the fidelity of the acceleration measurements, the amplitude and frequency content of the collected acceleration data will be analyzed. Previous work on the I-35W Bridge found temperature and time-dependent effects to predominate the response of the longitudinal bridge movement as measured by the linear string potentiometers at the bearings and the strain gages embedded in the concrete boxes. (Hedegaard et al. 2013). The vibration response of the bridge under normal traffic and environmental loading will be used to determine the feasibility of using vibration-based monitoring techniques for large-scale concrete bridges. The resolution of the acceleration measurements in both the time and frequency domain is essential for successful monitoring.

Whereas the first component addresses the fidelity of the data, the long-term variations of dynamic properties address the use of vibration-based monitoring for damage detection. The acceleration data will be used in conjunction with output-only system identification techniques, such as NEXT-ERA, to determine the natural frequencies and mode shapes of the bridge. Before model analysis can be successfully implemented to identify damage, there needs to be an understanding of the variation in modal properties of the structure due to natural environmental changes such as temperature and humidity. Five years worth of acceleration and structural temperature data from the I-35W Bridge have already been collected and can be mined to increase the understanding of the changes in the bridge's modal properties associated with time dependent and environmental conditions. Additionally, a simplified analytical beam model will be used to evaluate the thermal gradient effects on modal properties. The insight gained from the model will help interpret the results from the I-35W Bridge, which is a more complicated structural system.

ASSISTANCE

Data collected from the I-35W Saint Anthony Falls Bridge is owned by MnDOT. The research team will need remote access to the server to download data. MnDOT maintains the server, along with the data acquisition sensors and equipment. It is possible to perform the work described herein entirely using existing data.

WORK PLAN

Task Descriptions

Task 1: Long-Term Acceleration Data Processing

Under this task, the University will process the long-term acceleration data from the I-35W Bridge to determine magnitude, resolution, and fidelity. Evaluate the majority of the data from year one to identify times of the year and or day when the data can provide mode shapes and natural frequencies with the least uncertainty. The University will verify that these patterns continue in subsequent years, so that a process for identifying useful data for future vibration monitoring can be determined.

Task 2: Determine Natural Frequencies and Mode Shapes

The University will use the time periods identified in Task 1 to isolate a subset of the acceleration data for further processing. The University will determine the natural frequencies and mode shapes with output-only system identification techniques (methods that work when the loads on the bridge are unknown). The University will evaluate the variation of vibration properties over time in comparison to mean structural temperature and temperature gradient.

Task 3: Facilitate Operation and Maintenance of Bridge Monitoring System

The University will facilitate the operation and maintenance of the I-35W Bridge monitoring system. The project team will aid in the upkeep of the data acquisition system and identify possible repair solutions, if necessary. However, the project budget does not cover the cost of any repair solutions.

Task 4: Compile Report, Technical Advisory Panel Review and Revisions

The University will prepare a draft report will be prepared, following MnDOT's publication guidelines, to document project activities, findings and recommendations.

Task 5: Editorial Review and Publication of Final Report

During this task, the Approved Report will be processed by MnDOT's Contract Editors. The editors will review the document to ensure it meets the publication standard. This task must be completed within the contract time because the editors will provide editorial comments and request information from the University's Principal Investigator.

Task Deliverables

Task:	Deliverable(s):
1:	A 2-3 page report detailing the summary of the findings
2:	A 2-3 page report detailing the summary of the findings
3:	A report that summarizes any modifications and repair to the monitoring system
4:	A Draft Report and Final Report Approved for Publication
5:	Final Published Report

PROJECT SCHEDULE

	2015				2016											Draft Deliverable	Final Deliverable
Months:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Due Date	Due Date
Task 1	X	X	X	X	X											November 30, 2015	January 31, 2016
Task 2			X	X	X	X	X	X	X	X	X	X				June 30, 2016	August 31, 2016
Task 3	X	X	X	X	X	X	X	X	X	X	X	X				July 31, 2016	August 31, 2016
Task 4											X	X	X			July 31, 2016	September 30, 2016
Task 5														X	X		November 30, 2016