Research Problem Statement

ODOT Research Section
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I. TITLE

17-029 Feasibility of Energy Harvesting from Roadways using Piezoelectric-based Devices

II. PROBLEM

Harvesting energy from roadways is a new and innovative field within the transportation industry. Energy-producing technologies embedded in pavements and attached to structures that generate energy from passing traffic and vibrations have been developed and are now commercially available in the US. Harvested energy can potentially be used to power roadway lighting, traffic control, in-situ data acquisition instruments, and other roadside electrical devices. For bridges, the ability to harvest energy is especially of interest when considering implementing wireless technologies for structural health monitoring of the bridge. The available technologies commonly utilize piezoelectric materials, which are currently also used within many ODOT loop detection devices. Piezoelectricity is the electrical charge that is created by certain materials (commonly crystals and some ceramics) when the materials experience applied mechanical stress. Repeated passage of vehicles over a bridge, for example, creates stress, deformation, and vibration in the bridge elements which, if embedded with or connected to piezoelectric materials, can produce electrical energy. The captured energy can be used to power nearby electrical systems and also wireless data communication systems that provide information about bridge and roadway conditions, traffic usage and patterns, and vehicle speeds.

Current research and development of energy harvesting technologies has focused on the potential for vibrations to create electrical energy, and the development of energy harvesting devices. For a pre-stressed, concrete highway bridge, research showed that mean power on the order of 0.03 mW can be produced, with a controlled voltage between 1.8 and 3.6 V (Peigney and Siegert 2013). A laboratory study of piezoelectric materials under asphalt pavements revealed that levelized cost of energy is relatively high, but potential energy generation can be improved by several variables (Kim et al. 2015). Another study of a suspension bridge revealed that the bridge can produce 0.46-0.72 μW of continuous (average) power independent of the location of the harvester on the bridge (Galchev et al. 2011). One study funded by NIST (Reichenbach et al. 2012) found that likely candidates for vibration energy harvesting are flexible, long-span bridges that see heavy truck traffic. Research has been conducted to develop prototype energy harvesters as well. While some studies have tested devices in-situ (e.g., Peigney and Siegert 2013), other studies have investigated prototypes in a laboratory setting (e.g., Galchev et al 2011).

Energy harvesting devices are now being manufactured in the US, however full-scale, long-term, in-situ evaluation of complete energy harvesting systems has not yet been conducted. Much of the previous research has focused on short-term timeframes and the performance of a single, in-house, custom-made device. There is an urgent need to conduct long-term studies regarding this technology, especially with the commercially available products in the US (Kim et al. 2015). This problem statement proposes research to test and evaluate the use of an energy harvesting system on an Oregon bridge and/or roadway. ODOT has recently received inquiries from other DOTs (including CalTrans and Vancouver, BC) about the possibility of collaborating on research related to this topic. Given the widespread interest in the topic, the study would be a good candidate for a pooled funds study.

III. PROPOSED RESEARCH, DEVELOPMENT, OR TECHNICAL TRANSFER ACTIVITY

The objective of this study is to implement and evaluate an energy harvesting system on a bridge and/or roadway to determine its long-term feasibility, reliability, capabilities, and performance for implementation on a larger scale. To do so, an energy harvesting system will be selected and acquired, and the system will be installed on a bridge and/or roadway and connected to monitoring devices. Once installed, the reliability, performance, and maintainability of the system will be assessed. The research activities to meet this objective are as follows:

1. Identify a bridge and/or roadway on which to install energy harvesting devices. Instrument the site(s) to measure and monitor the current vibrations at various selected locations under different traffic conditions (vehicle speed, volume, and composition).

2. Identify the different types of energy harvesting devices that have been developed and are commercially available. Collect information and conduct laboratory testing on each type such that they can be compared in terms of capabilities, cost, and the expected performance, reliability, and maintainability. Meet with ODOT representatives to select one or more types of energy harvesting devices to evaluate in the research study. Coordinate with the system developer/manufacturer to identify financial arrangements for ODOT to acquire the system(s).
3. Install the energy harvesting devices at the selected sites. Work with the device developer/manufacturer to ensure that the devices are installed correctly and operating as designed.
4. Monitor and measure the performance of the system over a long period of time (e.g., several years) to determine the level of energy output and the ability to record traffic conditions (speed, volume of traffic, etc.). Determine how to efficiently collect and utilize the energy and information created. Assess the reliability of the devices and expected maintenance requirements. Measure the environmental conditions at the site, and the extent of application of deicer chemicals, to assess their impact on the devices. Assess the ability of the wireless monitoring components to reliably record site conditions.
5. Prepare a research report that describes the research study and findings, and provides ODOT with recommendations for implementation on a larger scale and/or further research.

IV. POTENTIAL BENEFITS

The benefits of an energy harvesting system are potentially great given the number of bridges and lane miles present in the state. If the system is proven to be economically feasible, reliable, easy to maintain, and an energy producing system, the research will provide ODOT with a means to improve the sustainability of its bridges while also providing a potential energy source for instrumentation or an agreement with the local utilities to off-set operational costs. Further, a wireless monitoring system will benefit ODOT by helping to monitor the health of the bridge/roadway and traffic flow, and inform ODOT planners and designers of how to improve the lifespan of the bridges/roadways.

V. IMPLEMENTATION

The results of the research are expected to include information and guidance about the implementation and performance of a large-scale energy harvesting system. This information may also be useful to ODOT project managers when developing new construction projects to determine if an energy harvesting system is applicable and feasible on future bridge, preservation, and new construction projects.

VI. LIST OF REFERENCES *(optional)*

Galchev, T., McCullagh, J., Peterson, R.L., and Najafi, K. (2011). "Harvesting traffic-induced bridge vibrations." *Solid-State Sensors, Actuators and Microsystems Conference* (TRANSDUCERS), 16th International, 2011.

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Peigney, M. and Siegert, D. (2013). "Piezoelectric energy harvesting from traffic-induced bridge vibrations." *Smart Materials and Structures*, 22, 095019, IOP Publishing, Ltd.

Reichenbach, M., Fasl, J., Vasileios, A.S., Wood, S., Helwig, T. and Lindenberg, R. (2012). "Evaluating vehicular-induced bridge vibrations for energy harvesting applications." *Proceedings of SPIE*, Vol. 8347, 13 pages.

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