Transportation Consortium of South-Central States (Tran-SET)

Development of a Self-Powered Structural Health Monitoring System for Transportation Infrastructure

Highlight | Feb. 2018

Project No. 17PTAM03

PI: Dr. Aydin Karsilayan (TAMU), Dr. Samer Dessouky, Dr. Athanassios Papagiannakis (UTSA)

POP: May 2017 – November 2018

Developing and evaluating a thermoelectric generator prototype, generating electricity from the temperature gradient of pavement and its sublayers

It is anticipated that the United States' population growth and economic expansion will drive an increase in the demand for roadway access and use. This in turn will generate a higher demand for a sustainable approach to manage infrastructure assets. This study aims to develop a thermoelectric energy harvesting prototype for asphalt pavement roadways. This is an emerging research field, encompassing technologies that capture existing thermal energy in pavements to generate electricity without depleting natural resources.

In lower latitudes, such as South Texas, the asphalt pavement surface temperature in the summer is as high as 120°F . Soil temperatures below the pavement, however, are roughly constant (i.e., 80°F to 90°F) at relatively shallow depths (6 in). This thermal gradient between the surface temperature and the pavement substrata can be used to generate electrical power through thermoelectric generators (TEGs). This study develops a TEG prototype that collects heat energy from the pavement surface and transfers it to a thermal collector module embedded under the pavement near the pavement edge. The evaluation of this prototype will be carried out through laboratory testing and field experiments. Preliminary results suggest that the 2.5-in x 2.5-in TEG prototype is capable of generating an average of 10 mWatt of electric power continuously over a period of 8 daylight hours, for the weather conditions encountered in South Texas. Scaling up this prototype using multiple TEG units could generate sufficient electricity to sustainably power low-watt LED lights, roadway/traffic sensors, or health monitoring systems at off-grid remote areas.

Problem Statement

Small urban and rural communities account for 83% of the landmass, 20% of the population (50 million people), 18% of jobs, 14% of earnings, and 2,300 of approximately 3,000 counties in the United States. Rural roads make up 70% of national road-miles, including more than 450,000 bridges, and carry 40% of vehicle miles traveled. Despite only serving 19% of the US population, rural roads account for 54% of all fatalities, which is 2.4 times greater than the fatality rate in urban areas. Despite lower populations, rural economies are critically dependent on wellmaintained and reliable transportation systems. Yet, these roadways are becoming increasingly inadequate in serving rural communities due to their poor condition caused by large trucks serving oil/gas and agriculture activities. In addition, rural transportation networks are rapidly deteriorating due to climate change and natural disasters, and are rendered unsafe due to limited resources for expansion/capacity improvements.

Summary

The goal of this study is to develop a sustainable source of low-power to be used in structural health monitoring systems and in signage to improve traffic safety. The expected outcome is a robust, low-cost, self-power traffic and roadway sensing module capable of monitoring roadway structure conditions (e.g., loading, temperature, moisture) and capturing traffic data (e.g., vehicle counts, speed and axle configurations). It will utilize power through harvesting thermal energy from pavements using thermal collectors. This technology is especially attractive for remote or rural areas where there is no roadside access to the electric power grid. This encompasses about 70% of the roadway network in Texas, which is heavily used for fossil fuel and agricultural production.

The thermoelectric energy harvesting system consists of three basic components (Figure 1): (1) a thermal isolated copper plate, (2) a thermal collector module or TEG, and (3) a heat sink connected to the bottom of the TEG. The copper plate allows transferring of heat from the pavement surface down to the top of the TEG module, while the heat sink provides a relatively constant temperature over time, while dissipating the heat that gets conveyed across the TEG. The more temperature gradient it ensures, the more output (electrical power) is produced.

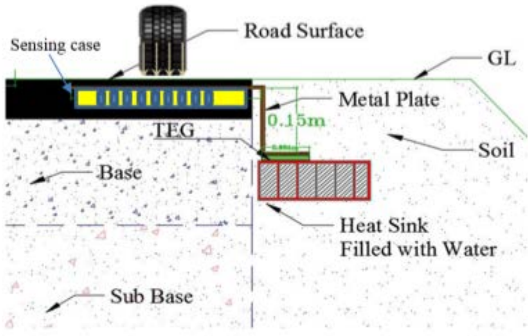

Figure 1. Schematic of the proposed energy harvesting prototype.

Findings

The thermoelectric energy harvesting prototypes were tested in a section of asphalt roadway pavement on the campus of the University of Texas at San Antonio.

Figure 2 shows the system installation in pavement and the LED illumination from lab testing. The two-TEG system yielded a maximum output power of 14.3 mWatt while the four-TEG system yielded 9.8 mWatt.

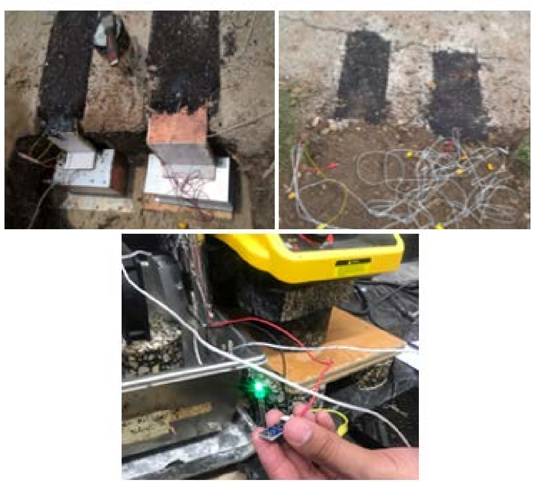

Figure 2. System installation in pavement (top left and right) and LED output from lab testing (bottom).

Impacts

Early-detection of critical infrastructure needs by monitoring structural health will enable transportation agencies to opt for low-cost preservation treatments (decreasing the life-cycle cost of transportation infrastructure and reducing the financial resources necessary for its rehabilitation and reconstruction). Expected impacts of this project are to:

- Enhance the structural and surface conditions of rural infrastructure through continuous monitoring and early damage detection.
- Provide traffic monitoring in remote areas not served by the electrical grid (enabling wide-spread pavement monitoring and potential safety improvements).
- Develop maintenance-free sensors (resulting in cost-effective maintenance of these infrastructure in metropolitan and rural areas).
- Bring together researchers from a multitude of engineering fields including civil, electrical and materials to develop, test, and implement these sensors in roadway infrastructure.

Tran-SET

Tran-SET is Region 6's University Transportation Center. It is a collaborative partnership between 11 institutions (see below) across 5 states (AR, LA, NM, OK, and TX). Tran-SET is led by Louisiana State University. It was established in late November 2016 "to address the accelerated deterioration of transportation infrastructure through the development, evaluation, and implementation of cutting-edge technologies, novel materials, and innovative construction management processes".

Learn More

For more information about Tran-SET, please visit our website, LinkedIn, Twitter, Facebook, and YouTube pages. Also, please feel free to contact Mr. Christopher Melson (Tran-SET Program Manager) directly at transet@lsu.edu.

Tran-SET