Semi-Annual Progress Report

Project Number and Title: 1.11 Energy Harvesting and Advanced Technologies for Enhanced Life
Research Area: Development of Improved Road and Bridge Monitoring and Assessment Tools
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Overview:

Pavements accumulate and dissipate solar energy on daily cycles. The increased heat absorbed in pavement has many detrimental effects, including accelerated degradation of pavement, heat island effect, urban warming, increased cost to transportation agencies, increased costs for cooling nearby inhabited structures, and possibly contributing to climate change. Various technologies are available to reduce the extreme temperatures in pavements and harvest the energy for productive applications such as reducing pavement failure due to extra hot temperature and deicing of bridge deck and roadways. Solar energy recovery from pavements has the potential to provide many substantial benefits such as extending the service life of pavements, improving the air quality, lowering impacts to the climate, and producing energy.

The URI research team recently performed an experiment using Andrew Correia's previous apparatus that was used for thermal heat extraction from asphalt pavement using embedded conductive pipes. However, the results of this experiment were inaccurate due to the embedded thermocouple sensors being 8 years old. Therefore, a new apparatus that will help us optimize the efficiency of the solar harvesting collector is being constructed.

A review of the previous URI study by A. Correia and PI Lee (August 2012) was also performed. This review has helped create a plan on how to create the next apparatus. The experiment performed showed that it is possible to extract heat from pavement and raise the temperature of water. However, the URI research team has realized a few sources of error in the previous experiments. A. Correia did not consider the heat created by the pump which sits in the pool of water used for the test. In the past weeks the URI research team performed an experiment using the same setup as the A. Correia's experiment and it was determined that the pump accounted for approximately 50% of the heat inputted to the water. To correct this, the contribution of the heat from the pump will be accounted for in the future experiments. For future experiments the URI team also plans to calculate how much water is required for this small-scale experiment to accurately portray a larger scale life size application.

To further increase the accuracy of the experiment the URI team has been researching temperature sensors to use. It was determined that type k, exposed tip fiberglass thermocouples will give accurate results for this experiment. The previous URI experiment in 2012 recorded the temperatures of each layer of the apparatus by hand every hour for 16 hours straight. This introduced human error into the experiment as recording temperatures by hand for such long hours can create human error. This is also inaccurate because the temperature of the sample is only known once per hour while temperature changes can happen rapidly between that time frame. To combat these problems the URI team researched to find a suitable data acquisition unit. The TC-08 eight channel thermocouple data logger was determined to be the best fit for this experiment. Two of these units were purchased along with 12 type k thermocouples that were mentioned earlier. This data logger will record the temperature of each pavement layer every second which eliminates the possibility of human error from the data recording. This will give the most accurate recording of the temperatures for each pavement layer, the water temperature and the ambient room temperature.

The URI team has also researched into piping materials that can be embedded into pavement systems. The first type of piping that was looked into was copper piping because it has such a high thermal conductivity. The next piping material looked at was PEX piping which has a much lower thermal conductivity yet, is used in many conductive piping systems. In a study performed by J. Patterson and R Miers (2009) it was determined that the usage of copper pipes has no thermal benefit compared to the usage of PEX piping. Further research into snow and ice melting systems utilized in driveways in walkways shows that PEX piping is exclusively used for embedded piping as it much cheaper than copper, easier to install, more durable and more resistant to freezing according to the Plastic Pipe Institute. Based on this research the URI research team has chosen to use PEX piping for the planned embedded conductive pipe solar harvesting unit.

Figure 1: Solar Harvesting *Apparatus used for Previous URI 2012 Experiment*

The URI research team is also looking at other methods to extract heat from asphalt pavement. The research team at Texas A&M University supported by the Transportation Consortium of South-Central States (Trans-SET) led by P.I Aydin I Karsilayan performed a study on the development of a self-powered battery-less structural health monitoring (SHM) system capable of processing analog voltage input from a variety of sensors, such as strain gauges, and piezoelectric weighing strips. Their system was powered by an energy harvester driven by thermoelectric generators (TEGs). TEGs function on the Seebeck/Peltier principal. TEGs translate the thermal differences between the upper and lower layers of asphalt concrete pavements into electrical energy. The Seebeck effect is a phenomenon in which a temperature difference between two dissimilar electrical conductors or semiconductors produces a voltage difference between the two substances. This study was successful in producing a prototype SHM system that is self-powered, battery-less and provides continuous data storage and wireless transmission and it is now ready to be tested in the field. This is a promising study which URI research team to validate and continue working on the system utilizing the Seebeck/Peltier principal

Participants and Collaborators:

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Changes:

The URI research team originally planned to use the same apparatus that was used by Andrew Correia for thermal heat extraction from asphalt pavement using embedded conductive pipes. However, it was determined that the thermocouples embedded in the apparatus used for measuring the temperatures were no longer accurately portraying the temperatures of the pavement structure. Therefore, a new apparatus is being developed so the URI research team can perform more experiments and optimize the solar harvesting unit. This is the largest change as many new materials must be purchased and researched. A data logger will be used to increase the accuracy of the experiment. To further increase the accuracy of this experiment, glycol will be added to the water as this is consistent with current snow and ice melting systems to prevent freezing of the pipes.

Planned Activities:

The URI research team is planning to:

(1) to investigate important aspects of energy harvesting that will accelerate its use.
(2) to develop a perpetual pavement system with embedded solar harvesting unit
(3) to perform a thermodynamic analysis of the pavement cooling system and the pavement system with embedded solar harvesting unit
    (i) to ascertain the maximum benefits that are possible within the constraints of thermodynamics, and
    (ii) to identify the most important sources of losses and inefficiencies within each system.

A short-term goal in the coming weeks for the URI research team is to create an experimental solar harvesting unit based off of the previous URI experiment performed 8 years ago. The plan is to make a new apparatus that will conform to the asphalt pavement specifications of RIDOT. Once this specimen is constructed the new technology will be utilized to perform a variety of tests that aim to minimize any source of error and optimize the solar harvesting unit by running a variety of tests. Variables like fluid quantity, fluid type, and duration of pumping will be analyzed. The results of these experiments will be thoroughly analyzed to determine if this is a practical system that has the potential to be used in the field. The URI Research team will also continue to perform research on how to create an efficient asphalt pavement solar collector utilizing the Seebeck effect. After finishing literature review on the Seebeck effect an experiment like the one performed at Texas A&M that will potentially lead to better results.