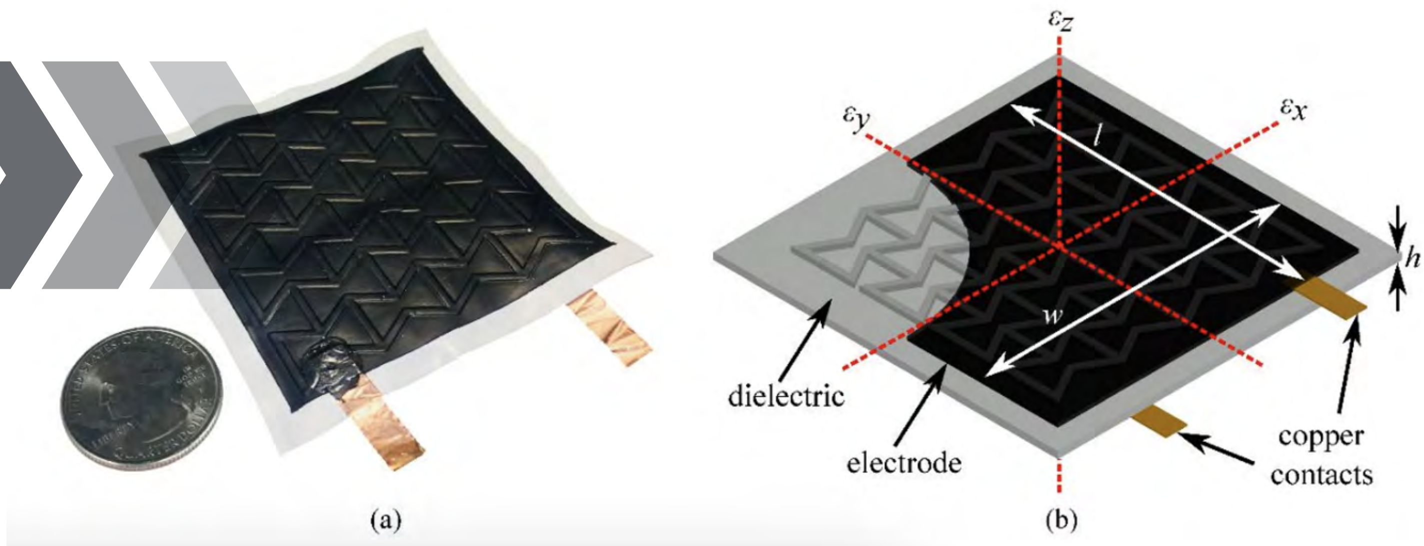
Attaching wireless sensing skin to bridge surfaces can provide a cost-effective option for monitoring and detecting dangerous fatigue-induced cracking.



RESEARCH SOLUTIONS

Monitoring bridge fatigue cracking with wireless sensors

Iowa DOT and engineers throughout the country need an effective and efficient method for identifying bridges with dangerous fatigue-induced cracking. In this first phase of research, investigators demonstrated that a wireless skin sensor network that engineers applied to the girders of a steel bridge could accurately monitor fatigue cracks. Study results suggest wireless skin sensors could provide a cost-effective solution to identifying and monitoring fatigue cracking in bridges.

THE NEED

Bridges in Iowa and throughout the country are experiencing dangerous fatigue-induced cracking. In 2020, federal inspectors found 7.5 percent of 617,000 U.S. bridges were in poor condition and classified as structurally deficient. Identifying and repairing these bridges are essential for public safety and commerce. However, visual inspection — the most popular method for detecting fatigue cracks — is expensive and time-consuming for staff and has a low probability of detecting early-stage cracks.

To better identify bridges in need of repair and maintenance, researchers developed wireless skin sensors that engineers can apply to bridge surfaces to collect and provide autonomous and continuous safety data that indicates if repair or maintenance is necessary.

RESEARCH APPROACH

Soft elastomeric capacitors (SECs) detect strain caused by surface deformations on a bridge. The data collected by SECs is used with an algorithm to identify fatigue cracking. The sensing skin, validated through

(continued)

> **"The results of this project validated a methodology for continuous monitoring of bridges that can reduce costs and improve safety on the roads."**
>
> **– MICHAEL TODSEN,**
> **Iowa DOT Bridge Maintenance and Inspection Engineer**

laboratory testing, is autonomously solar-powered and transmits data wirelessly. Unlike other common monitoring techniques, which can only observe a small footprint, SECs can be configured in a network to monitor large surface areas of a bridge and identify new crack formations.

To field-test and evaluate the use and effectiveness of the wireless skin sensor networks, investigators conducted a small-scale test of the linearity, sensitivity, resolution, and accuracy of the sensing skin to formulate a crack growth index algorithm. Then they deployed the flexible sensing skin network on a steel highway bridge girder, with one sensor placed directly over an existing fatigue crack.

The sensing skin consisted of numerous SECs (approximately 3 x 3 inches) that were capable of measuring local bridge strains over large surfaces, such as a bridge girder or bridge surface. Researchers collected data and measurements from October 2021 to April 2024.

Researchers also investigated the sensing skin's effectiveness at measuring angular motion in steel components and monitoring cracks on fillet welds. This evaluation was conducted by deploying the sensors in a folded configuration.

WHAT IOWA LEARNED

The results demonstrated the effectiveness of the sensing skin to monitor fatigue cracks in the girders of steel bridges, including deployments in folded configurations. For example, the sensing skin detected a fatigue crack 0.28 mm long on a flat surface and 0.48 mm long on a folded configuration. Further, the sensor placed over an existing fatigue crack measured a constant crack growth index throughout the observation period.

Additionally, the sensing skin can detect cracks in concrete bridges, but engineers must first layer the application surface with a polymer to minimize noise caused by dielectric coupling.

Results from the testing also demonstrated that the hardware developed in this project outperforms existing commercial systems and can effectively transmit low-amplitude data wirelessly.

PUTTING IT TO WORK

With the successful field implementation and testing of the skin sensing network on bridges, investigators recommend developing larger skin sensing sheets that engineers can easily deploy onto bridges for monitoring. By deploying sensors over large areas of bridges, Iowa DOT will be better able to identify new fatigue cracks and monitor these cracks over time. Overall, using skin sensors will allow more timely corrective measures, which will enhance bridge safety and reduce maintenance and repair costs.

ABOUT THIS PROJECT

PROJECT NAME: Robust Wireless Skin Sensor Networks for Long-Term Fatigue Crack Monitoring of Bridges (Phase I)

Final Report | Technical Brief

PROJECT FUNDING PROGRAM: Robust Wireless Skin Sensor Networks for Long-Term Fatigue Crack Monitoring of Bridges, a four-state collaborative research effort

PROJECT NUMBER: TPF-5(449)

REPORT DATE: May 2024

PROJECT CHAMPION:
Michael Todsen, P.E.
Bridge Maintenance and Inspection Engineer
Iowa DOT
michael.todsen@iowadot.us
515-233-7726

PROJECT MANAGER:
Khyle Clute, P.E.
SPR Research and Pooled Fund Programs Manager
Iowa DOT
khyle.clute@iowadot.us
515-239-1646

PRINCIPAL INVESTIGATOR:
Simon Laflamme
Iowa State University
laflamme@iastate.edu
515-294-3162

IOWA DOT RESEARCH:
iowadot.gov/research
ideas.iowadot.gov