The Exploratory Advanced Research Program Fact Sheet

Adaptive Highway Bridge Bearings

Towards Intelligent Infrastructure Systems

Exploratory Advanced Research . . . Next Generation Transportation Solutions

Is it possible for a bridge to "feel" changes in loading caused by traffic or the environment and respond by redistributing loads throughout the structure? Answering this intriguing question is the goal of research supported by the Federal Highway Administration (FHWA) Exploratory Advanced Research (EAR) Program. The project, "Self-Sensing Adaptive Material for a New Generation of Multifunctional Bridge-Bearing Systems," is part of a 3-year EAR Program-funded inquiry into developing responsive smart materials for bridge components. The University of Nevada, Reno (UNR), is conducting the research under the EAR Program.

Smart Materials That Respond to Changing Conditions

According to the FHWA, more than 30 percent of the Nation's 600,000 bridges have exceeded their 50-year theoretical design life.[1] One significant component of the day-to-day deterioration of bridges is vibration caused by traffic and wind. Conventional passive bearings can suppress vibration and help mitigate vibration-induced deterioration, but they perform with a predetermined stiffness. Bridge bearings that incorporate adaptive materials can regulate their stiffness and damping properties in response to loading information received from the bridge that they support. "Smart bearings can tune themselves in real time to accommodate dynamic loading conditions," says Sheila Duwadi of FHWA's Office of Infrastructure Research and Development. "Incorporating adaptive materials can enhance structural performance, extending bridge service life."

Developing a Self-Tuned Bearing

UNR researchers are developing self-sensing adaptive bearings (SSAB) that exploit the characteristics of a smart material known as magnetorheological elastomer (MRE). MREs are polymeric solids embedded with iron particles. One adaptive MRE characteristic is piezoresistivity, which changes the material's electrical properties in response to mechanical strain. This change is used to quickly measure physical loading. MREs also exhibit magnetoresistance, which realigns embedded iron particles within the polymer matrix in response to applied magnetic fields and changes the material's physical properties. SSABs that incorporate MRE can measure structural loading continually and transmit that information to a monitoring system. The bearing design incorporates a wireless sensing system, which can measure electrical resistance; receive, store, and transmit data; and be used to control the SSAB system as part of a structural health-monitoring scheme.

Design and Features of SSAB Systems

Project researchers have focused on the design, development, and testing of a SSAB system featuring MRE to function both as an adaptive smart bridge bearing and a wireless sensor. MRE material development has achieved so far two major objectives: (1) MRE layers within the bearings maintain stable adaptive mechanical properties while withstanding realistic large forces; and (2) the electrical properties can be adjusted to feasible ranges so that changes in electrical resistance can be measured and correlated to bearing forces. UNR researchers designed two scaled models of SSABs to mimic conventional elastomeric bearings. The bearings

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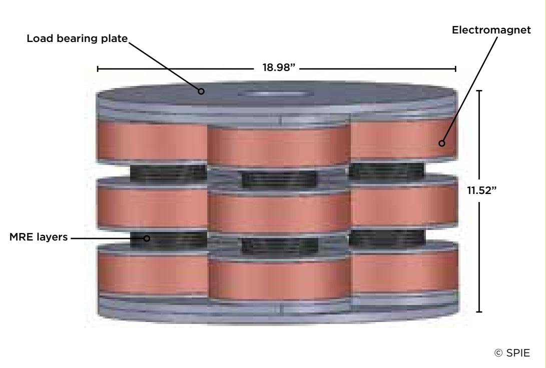

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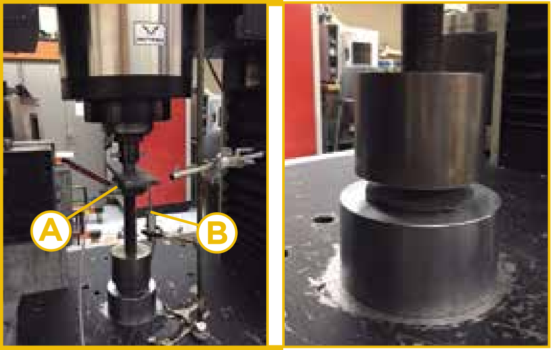
Bearings composed of MRE material sandwiched between electromagnet arrays adjust stiffness and dampening properties in response to strain.[2]

are equipped with electromagnets used to induce a magnetic field through alternating MRE and steel layers. This feature is essential for the regulation of stiffness and damping properties. The SSABs are fail-safe—that is, they continue to work as conventional bearings even if the electrical system fails.

“Test results show that the SSABs can modulate the magnetic field applied to the MRE in milliseconds, adjusting the bearing’s stiffness. This allows a bridge to almost instantaneously adjust its dynamic characteristics in response to vibrations because of traffic and wind,” says Faramarz Gordaninejad, UNR’s principal investigator.



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Left: Compression test apparatus includes a load cell (A) that measures compressive force and a linear variable differential transformer (B) that converts linear motion within sample to an electrical signal.
Right: Sample of MRE material between test apparatus ram and baseplate.

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Future Efforts

UNR researchers are continuing the investigation to refine material properties of the SSABs. Additional material fabrication, testing, and characterization will be followed by simulation studies to further examine the use of SSAB systems in controlling vibration-induced forces and deformations. They also are considering use of the wireless sensing system as part of a structural health-monitoring scheme in future studies.

Learn More

For more information about this EAR Program project, contact Sheila Duwadi, FHWA Office of Infrastructure Research and Development, at 202-493-3106 (email: sheila.duwadi@dot.gov).

EXPLORATORY ADVANCED **RESEARCH**

What Is the Exploratory Advanced Research Program?

The EAR Program addresses the need for longer term, higher risk research with the potential for transformative improvements to transportation systems—improvements in planning, building, renewing, and operating safe, congestion-free, and environmentally sound transportation facilities. The EAR Program seeks to leverage advances in science and engineering that could lead to breakthroughs for critical, current, and emerging issues in highway transportation—where there is a community of experts from different disciplines who likely have the talent and interest in researching solutions and who likely would not do so without EAR Program funding.

To learn more about the EAR Program, visit www.fhwa.dot.gov/advancedresearch. The Web site features information on research solicitations, updates on ongoing research, links to published materials, summaries of past EAR Program events, and details on upcoming events.

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[1] U.S. Department of Transportation. *Bridge Preservation Guide: Maintaining a State of Good Repair Using Cost Effective Investment Strategies*. Publication No. FHWA-HIF-11-042.

[2] Behrooz, M., Yarra, S., Mar, D., Pinuelas, N., Muzinich, B., et al. (April 20, 2016). A self-sensing magnetorheological elastomer-based adaptive bridge bearing with a wireless data monitoring system. *Proc. SPIE 9803*, Sensors and Smart Structures Technologies for Civil, Mechanical, and Aerospace Systems 2016, 98030D; doi:10.1117/12.2218691; http://dx.doi.org/10.1117/12.2218691.