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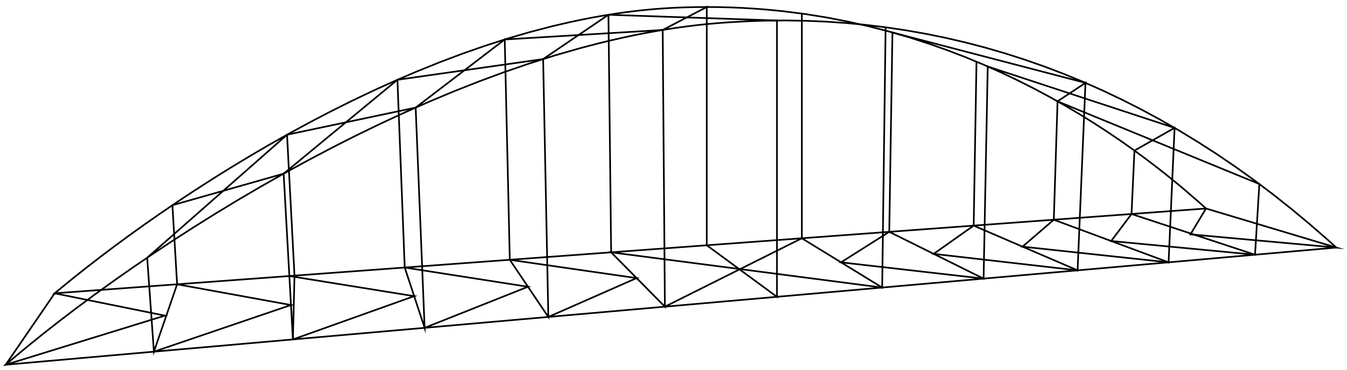
Enhancing Bridge Safety and Operation with Response Modification

"Bridge response modification could safely extend bridge life by decades at a fraction of the cost of bridge replacement." —Arturo Schultz



The U.S. infrastructure is aging, and bridges are no exception. A large number of U.S. bridges are reaching the end of their lives and are subjected to heavier traffic than originally intended. Though many of these bridges are designated "deficient" or "structurally obsolete," replacing them is cost-prohibitive. As a result, affordable solutions to safely extend bridge life are urgently needed.

Researching a Solution

Response modification is most commonly used in seismic zones to protect buildings should an earthquake strike. In this study, researchers designed a response modification device that could be added to aging bridge components under repeated heavy loads. The device uses data from sensors to adapt how it responds to specific loads—adding more support for an overweight vehicle, for example. To test their design, the researchers used an existing computer model of an in-service Minnesota bridge.

Understanding Response Modification

Successful response modification has four key components: understanding common bridge vulnerabilities, employing bridge loading models, deploying response modification devices, and monitoring with bridge monitoring systems.

Common bridge vulnerabilities

Information on common bridge vulnerabilities is readily available. Transportation researchers have thoroughly studied numerous modern-day bridge failures to identify bridge vulnerabilities. Others have documented how common these potentially problematic details are across the nation. Two of the most common fatigue problems for steel bridges are partial-length cover plates and transverse stiffener web gaps.

Bridge loading models

"Loading" is defined by the weight of a bridge and the vehicles it carries, as well as temporary effects from vehicular motion and the environment. Traffic, vehicle crashes, and earthquakes are all examples of the types of loading a bridge may experience. To determine how these loads interact with the bridge, researchers use computer modeling. For this study, researchers relied primarily on the most widely used source for bridge loading: the American Society of State Highway and Transportation Officials' (AASHTO) heavy truck bridge loading model.

Response modification devices

Response modification devices can be installed on a bridge to change the way it responds to loads. They fall into three main categories, as illustrated in the table below.

	Characteristics	Power Usage	Examples
Passive Devices	Properties are constant	None	Retrofit to stiffen a bridge component, replacement of a connection, passive damper
Semi-Active Devices	Adapts to changing bridge behavior; can perform without power as a stable passive device	Low	Magneto-rheological variable dampening devices (fluid-filled devices controlled by a magnetic field), variable orifice dampener
Active Devices	Adapts to changing bridge behavior; more complexity means higher probability of problems arising and the possibility of becoming unstable	High	Mass damper systems, pulse generation systems, tendon systems and brace systems

For bridge response modification, semi-active devices are the best choice because of their effectiveness in dispersing bridge loads, small required power consumption, and inherent stability.

Health monitoring systems

The final crucial component to successfully modifying bridge behavior is selecting a monitoring system. These systems observe a bridge's response to loading, allowing engineers to ensure response modification devices are working effectively. For active and semi-active devices, the monitoring system also provides the information needed to tailor device properties so they can effectively reduce bridge stresses. Monitoring systems can be used to measure both the response modification device's effectiveness and overall bridge health.

Case in Point: In-Service Bridge

A hypothetical example demonstrates the promise of this bridge response modification technique for safely and cost-effectively extending the lifespan of our nation's aging bridges. Using an existing computer model for an in-service bridge, University of Minnesota researchers examined the effect a scissor-jack response modification device and a simple dampening device could have on the bridge. Presently, the bridge has documented stress concentrations at joints where the hangers and floor beams are connected to the box girder, even though the bridge has not experienced any cracking or visible damage.

Researchers found the response modification device would effectively reduce stress on vulnerable bridge connections. As a result, the stress ranges were reduced by 39 percent, which could lead to a bridge life extension of up to 61 years. In a later study, researchers discovered using multiple modification devices could extend bridge life even further—as much as 81 years. Overall, their results indicate that, combined with bridge health monitoring and advanced sensors, the device has the potential to extend bridge life by decades at a fraction of the cost of bridge replacement.

The proposed device promises to be a highly effective tool for extending the safe life of existing steel bridges, but additional research is needed to investigate optimal placement of the device and the best methods for attaching the device to the bridge.

About the Research

Response Modification for Enhanced Operation and Safety of Bridges was authored by graduate student Andrew Gastineau, Professor Arturo Schultz, and Assistant Professor Steven Wojtkiewicz of the University of Minnesota's Department of Civil Engineering and sponsored by the Center for Transportation Studies. The final report is available at www.cts.umn.edu/Research/ProjectDetail.html?id=2010037.