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Bridging Gaps

A new project seeks to devise ways to monitor the structural health of bridges, from initial design through years of repairs and alterations

By Marjorie Howard

When a gleaming, new bridge opens, speeches and perhaps a bottle of champagne mark the occasion. But decades later, as cracks appear in the roadway or a vehicle slams into a support beam, few remember the ceremonies, let alone the structural designs devised by the original engineers.



With proper maintenance and repair, the design life of bridges can be extended, as is the case with the Tobin Bridge in Boston, says Masoud Sanayei. Photo: Alonso Nichols

“The day they cut the ribbon and open the bridge, design documents are filed away in a safe place, because the bridge is open and working, and everybody is happy,” says Masoud Sanayei, professor and chair of the department of civil and environmental engineering. “They’re happy, that is, until something goes wrong. Then a new team of engineers comes and inspects the bridge, without necessarily knowing what the original designers envisioned.”

Sanayei and a team of faculty and students from Tufts and the University of New Hampshire, along with two engineering firms, want to change that scenario. With a \$600,000 grant from the National Science Foundation’s Partnership for Innovation program, they are developing ways to monitor the structural health of bridges over their lifetimes, from design through years of repairs and alterations.

One goal is to build a three-dimensional computer model that will live on as the bridges age. As bridges are repaired or retrofitted, the model will be updated. “We will live with the

bridge just as a doctor lives with a patient,” says Sanayei, who is the principal investigator for the project. “All the changes will be documented in a computer model that captures the behavior of the bridge.”

There’s a real need for this information. According to Sanayei, about 40 percent of the 600,000 bridges in the U.S. Interstate Highway System are structurally deficient—or obsolete. “This doesn’t mean they’re not safe,” he says, “but they have outlived their useful design life, typically considered to be about 50 to 75 years. Many of those bridges were built in the period after the Second World War.”

With proper maintenance and repair, a bridge’s design life can be extended. This is particularly true for prominent bridges such as the Brooklyn Bridge, which are essentially rebuilt instead of replaced. “Unfortunately, many other bridges are becoming deficient at a faster rate than they are being repaired,” Sanayei says. “They’re safe, but we need to pay attention to them.”

A Bridge Too Far

The same research team, under leadership of Fay, Spofford & Thorndike, an engineering firm based in Burlington, Mass., has also been selected by the Massachusetts Port Authority, or Massport, to develop computer modeling for the Tobin Bridge in Boston. They beat out 11 competitors to win the contract for the 18-month project, which entails devising a 3-D computer model that will replicate the bridge and how it behaves under the daily stress of traffic. The bridge will also be studied for calibrations of the analytical model and better understanding of its load transfer system—the parts of a bridge such as floor beams and support bearings that are responsible for safely carrying traffic loads.

The Tobin, at 2.25 miles, is the longest bridge in Massachusetts. Built 60 years ago, it has three lanes of traffic each on two different levels and connects the Charlestown section of Boston to Chelsea and the North Shore. Some 26 million vehicles drive across it each year. Massport ensures that the Tobin Bridge is well-maintained, structurally sound and in satisfactory condition.

The two projects are complementary, says Brian Brenner, a professor of the practice at the School of Engineering and an associate at Fay, Spofford & Thorndike. The research team also includes Erin Santini Bell, E98, E03, an assistant professor of civil engineering at the University of New Hampshire, and Geocomp of Boxborough, Mass., a company that specializes in infrastructure instrumentation for assessing risk factors.

While the Tobin Bridge assessment is hands-on and practice-based, the NSF project is more theoretical and research-oriented. Together, say Brenner and Sanayei, the projects will apply what is learned from the research to the real world.

To that end, the Tobin project will benefit from advances developed by the team for the bridge structural health monitoring project. In addition, the researchers will determine what instruments should be used on the bridge to measure stress and where they are placed to be able to anticipate and prevent potential problems.

Engineers like to refer to bridges as having “signatures,” Sanayei says, just as people have personalities. The way a bridge reacts to various loads and stress makes up its own unique behavior and characteristics, he says.

The Tobin is no exception. It faces not only heavy use but extremes of weather, including the use of de-icing chemicals and salt in the winter. The Tobin Bridge undergoes a detailed, hands-on inspection every two years, per federal law, with other components inspected

more frequently as needed. Massport's goal is to use the technology developed by the team to observe what is happening to the bridge on an ongoing basis.

"We want to capture the baseline performance of the structure," says Brenner. "If a truck drives across, we expect this to happen; if the wind blows, we expect that to happen. If you start to measure a different bridge signature, that can alert the engineers that something is changing." The team will take into account environmental conditions, such as temperature and humidity, and build them into its model.

There are numerous ways bridges can be damaged over their lifetimes. Accidents and fires are dramatic examples. But over time, most bridges gradually deteriorate due to road salt, rust on steel components and overloaded trucks driving across them.

As for the Tobin, the research team is working on developing a system that eventually will provide a continuous electronic stream of supplemental information on the bridge's condition, all of which should help keep the bridge maintained for its next 60 years.

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