Structural Health Monitoring of America's Infrastructure

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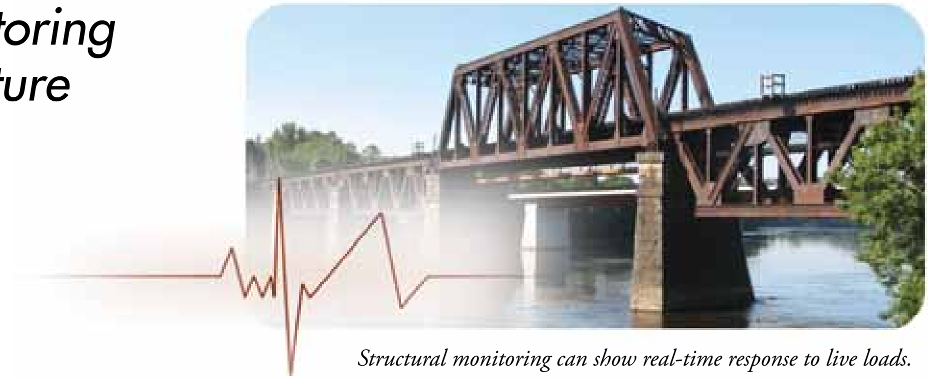

Structural monitoring can show real-time response to live loads.

When we think of bridge health evaluation, the traditional means and methods have been inspection by engineers in the field and ratings based on loading assumptions. Bridge inspectors are the original non-destructive evaluators, using observation and diligent records to establish how a bridge is performing during its life cycle. The term Non-Destructive Evaluation (NDE) has a greater implication, though; we are doing more than a visual evaluation. NDE is becoming the term to differentiate between what we think of as customary inspection techniques, and using advanced electronics and data evaluation.

A subset of NDE is Structural Health monitoring (SHM), a term that indicates response monitoring, damage detection system(s), or other observation systems for structural response over time. SHM has steadily increased in the bridge community's vernacular over the past few decades. Once, the thought of placing system response instruments on or near bridges was solely the domain of academia and research. SHM, however, has the capability to provide a direct link between loads and bridge behavior; it can surpass traditional assumptions for ratings and provide actual structural response to loads.

SHM has been evolving since its inception as a means to establish the effects of load on bridges and structures. The main workhorses of SHM remain strain gages, tilt-meters, accelerometers, and displacement gages. For those not familiar with these devices: strain gages evaluate a nominal displacement of a surface over a known gage length; tilt-meters measure the change in rotation; accelerometers measure the rate of change in position; and displacement gages measure movement with respect to a fixed reference. Each of these instruments is limited to the specific location where it is placed. With these instruments, we are able to monitor how bridges strain and move under load in real time. Taking it one step further, engineers can do things such as evaluate local stresses at fatigue details, monitor earthquake accelerations, calibrate finite element models, or monitor real-time response as a super-load crosses a bridge.

A realization arose in the bridge evaluation community that there is a great opportunity to combine traditional inspection techniques and structural response monitoring to obtain a more complete picture of the health of a bridge. In one respect, inspection is still vital to grasp an overall evaluation of a bridge. A visual inspection by a trained engineer provides a wealth of information. However, a visual inspection can't *see* the stress in a structural member under live load. It can't *see* the out-of-plane transverse deflection. Moreover, an inspector can't be on site for 24 hours a day, every day. On the other hand, SHM monitoring can indicate the stress in a member, and it can determine structural movement. But, as of today, it can't provide an overall view of a bridge that a visual inspection can. So, in pairing the two, SHM becomes a rather powerful option for assessing the health of a bridge. It has become another tool in the engineer's tool box. One of the best uses has been to verify structural live load response where the behavior is questionable or unknown (e.g. live load distribution).

There are other advantages to SHM beyond evaluating an instantaneous response to load. Long term monitoring can aid in event response. For example, what happens to a structure at the precise moment it incurs an extreme load? Engineers and owners might also be interested in long term monitoring to capturing a maximum response over a period of time, or to monitor the effects of weigh-in-motion traffic, or to capture a complete load history for a fatigue evaluation. If we have instruments in place to monitor long term response, we have the ability to capture an abnormal event such as a vehicle strike or an extreme overload. In a practical real-world example, a simple accelerometer was placed on a bridge because the owner thought it was getting struck by trucks bi-monthly, or so. They set an alert to be triggered every time there was a horizontal acceleration that exceeded a certain threshold, and snapped a picture of the event. As it turns out, once the device was installed, the first e-mail alert went off the same night they activated the system. The alert message started firing once or twice a day, and provided evidence of each hit. Information like this can be vital in prioritizing decisions in a bridge management program.

But SHM isn't always that simple. For example, SHM has the ability to create massive volumes of data without the ability to process what is being recorded. With a new flood of data, one of the most important advances for SHM will be the development of data management systems. Other industries have adapted self-learning computer programs, and the same should be done for long term monitoring for SHM. The type and level of instrumentation continue to evolve as well. Fantastic techniques, like image correlation and adaptation of ground-penetrating radar, are opening up the possibilities of taking the aspects of a visual inspection and incorporating them digitally.

There are also possibilities to integrate SHM into our daily management of bridges. According to Zee Duron, Engineering Department Chair of Harvey Mudd College "Engineers have got to get smarter about what the sensors are telling us, and we've got to get more politically astute in terms of how we take that information and turn that into economic and public policy that actually improves the infrastructure of the United States." Conversely, John Fisher, Professor Emeritus at Lehigh University stresses instrumentation should be judiciously applied, "It has to be rationalized because, one, there's a cost associated with it, and two, why make measurements if they're not needed?"▪

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