EXPERTS TALK

Structural Health Monitoring with Duncan Paterson

Better Data Can Mean Improved Asset Management, More Resilient Structures

Structural health monitoring systems have graduated from the halls of university research to more robust, but user-friendly systems that can be purchased right off the shelf. These powerful systems allow engineers to focus less on the equipment used and more on the data collected. While SHM systems don't generally influence design, scrutiny of the data allows for evaluation of construction or rehabilitation of more resilient structures.

Duncan Paterson, Ph.D, PE, holds his bachelor's, master's and doctorate degrees in civil engineering. He serves as our program manager for the FHWA Long-Term Bridge Performance program, drawing on two decades of industry experience. He has led design and project management for many complex roadway and railroad bridges — both new and existing. His expertise in structural health monitoring has helped our clients bring greater precision to capital expenditure plans, and make data-driven decisions about bridge design and maintenance. Contact **Duncan Paterson** for more information on structural health monitoring.

Q. How is Structural Health Monitoring generally different today than it was 20 years ago?

A. It is vastly different; the technology has graduated from the realm of university research, developing into equipment we can purchase off the shelf. It is also much more user-friendly. Automation, self-calibrating instruments and plug-and-play interfaces, coupled with greater computing power, allow us to focus less on the equipment and more on the data being recorded.

Q. And how has that difference influenced bridge design?

A. I wouldn't say there has been a direct influence on design. We as designers are still governed by design codes, and our primary concerns are structural integrity, redundancy and design life. Where we have seen instrumentation enter into the design phase, however, is when thinking about overall asset management.

Direct measurement of a structure's behavior in near real time can now comprise part of an asset management plan. Traditionally, we have depended only on mandatory periodic inspections — which continue to be vitally important. But now, structures such as New York City's Gov. Mario M. Cuomo Bridge, and others, are being built or retrofitted with instrumentation for structural monitoring as part of a strategy to help provide information to maintain the structures. There is synergy in this effort by having the designers, who best understand the structure, help select the most appropriate monitoring systems.

Additionally, the data collected from structural monitoring has provided greater overall understanding of structural behavior over time. Thanks to instrumentation of structures, we now have verifiable evidence that, in general, structures are inherently more stiff and resilient in their constructed condition.

Q. What impact can modern SHM technologies have on the planning for, and cost of, maintenance? Can you share any examples?

A. HDR has incorporated SHM technologies into structures to help their owners evaluate when special inspections or maintenance should be scheduled. Additionally, we have used sensors to update bridge-load ratings and truck weight-limit postings. But on a more holistic level, the Long-Term Bridge Performance Program — a research effort undertaken by the FHWA — has the potential to change how the industry evaluates bridges. As a participant of the program, HDR will help collect Non-Destructive Evaluation and visual-inspection data from bridges all over the country. The LTBP project goals are to *"improve knowledge of bridge performance, advance research in deterioration and predictive models,"* and *"promote the next generation of bridge and bridge management systems,"* among many others. Quantitative NDE data will be collected in different regions during a period of many years to look at, for example, how conditions in a northern climate with seasonal snow versus conditions in a southern desert climate could affect deterioration. Exciting programs like this have the potential to update how we think about evaluating and maintaining bridges for the long term.

Q. If I represent an agency responsible for maintaining bridges, what is the most significant SHM technology available today that I should consider installing in the next year or two?

A. I would argue that it is not a particular technology, but the implementation of a monitoring *system that integrates a variety of technologies.* That is the way to go. If there is anything I've learned during the past 14 years with HDR, it's that each bridge is different. Even the same design when built by different contractors has the potential to behave differently. The monitoring system and the technologies it uses should be tailored to particular conditions for each bridge. For example, if a bridge has substructure issues, we would want to design a monitoring system to plot trends in the data to evaluate movement over time. If a bridge has issues with recurring overloads, we would want to monitor targeted strain values with preset alerts. If issues with delamination of the bridge deck are identified, then a deck scanning tool would be most appropriate. Consequently, I hesitate to say that one SHM technology has an advantage over another. Just like other aspects of engineering, effective SHM needs a person who is knowledgeable about the various technologies and can recommend the right solution based on the parameters of a specific need.

Q. What innovations are on the horizon for SHM?

A. I look at unmanned aerial surveillance as a potential game changer. The industry seems to be very close to making this an exceptional tool for safe and repeated inspections. Combined with computer learning and global positioning on predetermined flight paths, Unmanned Aerial Systems have the potential to access exactly the same locations on a structure, take exactly the same images or other data records, and visually alert an engineer to changes. Picture highlighted areas on a structure with missing bolts, coating deterioration, changes in crack sizes, or even more advanced issues such as changes to a structure's thermographic signature. Additionally, all of this UAS data collection could take place while being unobtrusive to the traveling public, which could mean fewer lane closures and greater safety for workers, who would no longer need to be in harm's way to perform inspections.

The advent of UAS inspection would not take people out of the equation, though! Engineers with inspection experience will still be needed to critically assess important details and make engineering decisions or maintenance recommendations. Overall, the technology adaptation seems to be moving toward UAS capturing data with greater depth and enhancing our ability to make decisions with it — all while reducing the risk of injury because inspectors will spend less time near traffic.

Moreover, and regardless of the monitoring device being used, I would anticipate the largest leap to come from the computing power supporting these efforts. The big tech companies have already started realizing that machine learning for data processing could unlock doors to consistent empirical data, or perhaps, at least, narrow the number of plausible interpretations of data. I am still surprised to what extent engineering is an art form requiring interpretation — and sometimes perspectives differ based on our personal experiences. But sensors on a bridge providing data that is fed into a self-learning algorithm could add new depths to the availability of data, simplifying the process of interpreting it — or even give us a perspective we haven't yet thought of.

Inspiration & Advice

Q. What inspired you to become a bridge engineer?

A. Lego and roller coasters. I loved both growing up. They are both about fun structures. I think I declared to my parents about age 10 that I wanted to "design big stuff like buildings and bridges." Much later, I got involved with the steel-bridge design team in college. For grad school, I worked on both offshore structures and naval vessels, but neither had the same appeal to me as bridges.

Q. What advice do you have for bridge designers who are new to the profession?

A. Three big ticket items. First, find a mentor. Or, at least look around and try to connect with a person that is doing the job you see yourself doing when you get to his or her age. Ask that person both smart and stupid questions. Learn. Second, get to know as many people in the industry as you can. I spent years awkwardly attending local and national meetings. It was uncomfortable because, at that age, I tended to be an introvert, but now, in hindsight, I can't emphasize enough how important meeting people is. Get to learn what they are good at, and let them know what you are good at. That way, when you need to ask for help (and you will), you have a network of support. And say "yes" when people ask for your help. Again: learn. And third, develop your skill set by developing new skills. Invest in yourself. And don't expect your employer to provide every opportunity for training. Find an example of how to use a program and teach yourself, review sections of AASHTO, or AREMA, or ACI 318, or whatever. To reiterate: learn!

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