AGC Annual

Scholarship Winners

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Wireless Bridge Monitoring
Short term deployment:
A Clarkson University scientist, Kerop D. Janoyan, PhD., P.E., helps develop a solution to preventing possible bridge failure with a fresh set of eyes.

By Ron Long

Have you heard this? During the U.S.-Soviet Union space race to the Moon, the U.S. spent millions of dollars and thousands of engineering hours developing a pen that would work in zero gravity. The Russians just took a pencil.* It illustrates the elegance of simplicity, something a team at Clarkson University is keeping in mind. (*The story is not true, in the beginning we both used pencils and then the U.S. went on to develop the “Fisher pen”, which the Russians also used later on.)

In research being done now in upstate New York, at Clarkson University, a team is working on a relatively simple short term deployment of a sophisticated wireless bridge monitoring system that could become part of DOT biannual inspections, perhaps throughout the U.S. While others are looking for a more complex solution, this may be the way to go right now, for quantitative analysis of bridge conditions, which, if properly used, can conceivably save lives.

The science involved is world-class and the ramifications have international scope. The expert, Kerop D. Janoyan, PhD, and his work, have been the focus of much interest, especially since the Minneapolis bridge collapse. His expertise includes geotechnical and structural engineering design and analysis. He teaches classes as a newly tenured Associate Professor at Clarkson in Potsdam, N.Y. including: Foundations, Stability, and Retaining Structures, Senior Structural and Geotechnical Design, Advanced Foundation Design, Advanced Topics in Geotechnical Engineering.

Developing and designing a low-cost and automatic system for structural health monitoring and condition assessment of bridges is only one of the research interests of Professor Janoyan. In addition to bridge monitoring, I later learned that Professor Janoyan’s research activities in his laboratory group also include:

- Dynamic Soil-Structure Interaction, including Soil-Foam Interaction and Soil-Tool Interaction
- Foundation Engineering, particularly Laterally Load- ed Deep Foundations
- Innovative Bridge Design, Monitoring and Evaluation
- Laboratory and Field Measurements in Geotechnical and Structural Engineering
- Advanced Sensor Development and Measurement Tools for Civil, Environmental and Industrial Applications
- Sustainable Transportation Infrastructure, including Impacts of Systems on the Environment

Before the interview I was concerned that it could be an exercise in futility. Would I get a handle on the concepts and speak his language? Would we be able to communicate and would I be able to tell Low Bidder readers something meaningful from which they would benefit? I was in luck. I was talking to a very well educated man, whose feet are very much planted on the ground. He’d talked his way through college and graduate school all the way up to his doctorate and that work included laboring as a contractor. He received his B.S., M.S. and Ph.D. in civil engineering from the University of California, Los Angeles.

When I met Professor Janoyan in his small office adorned with stacks of papers and the artwork of his two children we began by talking about an article I’d recently read in the New York Times, which discussed the advantage of a “fresh set of eyes” being a good way to get experts to both talk about their fields without using too much technical jargon, and for outsiders to provide new insights. I noticed a small smile come over his face as I told him this. It turns out that he had read the same article and throughout our interview he referred to the idea of a “fresh set of eyes” and how it had helped him in this research.

ESSENSE OF THE PROJECT
His insights into the mechanisms involved in bridge monitoring were very clear. Later I received a tour of the scale model bridge constructed by his assistants in their laboratory. At the heart of the research is the measurement and characterization of the mobilization of component interface stresses. Janoyan has been deeply involved in the development and deployment of a universal and low-cost system for structural health monitoring (SHM), load rating and condition assessment of bridges. The project has been funded by the New York State Energy Research and Development Authority (NYSERDA). The program is also being tested on projects funded by the Federal Highway Administration (FHWA) Innovative Bridge Research and Construction (IBRC) Program.

Collaborators include Ratan Jha, Associate Professor in the Mechanical and Aeronautical Engineering Department at Clarkson University, and his colleagues to develop and deploy wireless sensors for load rating and condition monitoring of New York State bridges. The agencies funding the research recognize the critical relationship between a
The Clarkson University Wireless Sensor Solution (WSS) provides a tool for complementing visual inspections with quantitative measurements of structural performance as well as a platform for long-term bridge monitoring installations.

By eliminating the cabling needed to instrument a bridge, the WSS system provides a lower cost, rapidly deployable solution for monitoring the strains, vibrations, and temperatures across the bridge. The system consists of a network of strain and vibration sensors connected to a compact local data acquisition systems. The data is transmitted in real-time to a central computer using an off-the-shelf radio frequency (RF) transceiver platform. While several researchers have produced similar wireless sensors networks for bridge monitoring, this system is unique in that it can support a large number of sensors and high rates of acquisition, without the data loss generally associated with wireless sensor networks.

Full scale testing has been performed on a single-span bridge with an installation of 40 sensors in a single network and on a three-span bridge with 60 sensors over two networks, all sampling in real-time at 128 samples per second.

Within the National Bridge Inventory (NBI), the most frequent basis for classification of structurally deficient bridges is insufficient load capacity, which is often the case with older bridge for which no plans exist and load capacity can only be estimated rather than rigorously calculated. In this situation, the calculated load rating factor, used in combination with visual inspections to determine Highway Bridge Program funding, may be an inaccurate measure of the actual structural capacity of the bridge. The consequence is premature appropriation of resources from the limited budget, thereby potentially withholding resources from structures more critically in need. The WSS system enables rapid deployment of sensors for short-term strain measurements that enable engineers to experimentally determine the load capacity of the bridge as well as predict the remaining service life. Furthermore, the majority of bridge failures are a consequence of a triggering event, such as collision, overloading, or flooding, although collapse of the bridge does not necessarily occur immediately following collision, overloading, or flooding, although collapse of the bridge does not necessarily occur immediately following collision, overloading, or flooding, although collapse of the bridge does not necessarily occur immediately following collision, overloading, or flooding, although collapse of the bridge does not necessarily occur immediately following collision, overloading, or flooding, although collapse of the bridge.

Janoyan is a registered Professional Engineer in California. He has researched and written extensively on innovative bridge design, testing, monitoring and evaluation, including the project at hand: development of advanced wireless sensor technologies for transportation infrastructure. Among his many other research interests, Janoyan also studies winter impacts along the Cascade Lakes in the Adirondack Mountains. His research includes alternative road-way designs for de-icing and anti-icing, including long-term structural road-way design elements and electrically conductive concrete overlays.

DIFFERENT SET OF EYES

Janoyan’s work includes research and development of tools for both industrial applications and civil applications but not necessarily directly to bridges. He speaks about his interests more broadly as work in: “Dynamic monitoring of structures in general. So it was interesting to be able to understand the bridge side of it and have the background in the other side of things and marry the two. In many ways I wanted those fresh set of eyes, where people have tried similar things in the past and come to the conclusion that it may be a dead-end or may not be a dead-end. Revisiting it, where the technology is changing so fast there may be new opportunities go in an reapply things, some old some new, and marry the two. Regarding the NY-SDOT approach, one of the challenges of any DOT has been what technology first? Whose is the guinea pig, and even if you have the technology on board, who is the person with an agency who is going to be responsible for maintaining it? Most of the time it’s going to be one person within an agency that’s going to be the champion of these things and they have to have a whole group around them. And that’s been the challenge facing these research projects, you have what you think is a good solution but they can’t necessarily bring it (to fruition) because there is no mechanism by which to do that. It’s a realistic concern, because if you have something like this on a bridge, number one, who is going to be in charge of actually looking at the data and the monitoring system?”

One of the things that has come from Janoyan’s fresh perspective is “people are making it much more complicated than it needs to be. What we can start with is really some basic outcomes from these very high tech sensors. It’s something existing inspectors can use, as opposed to having a new set of people.” He explains that short term deployments can come first, “As we are working on the long term deployments, the short deployments (can be) set up so that the inspectors go out to do the bi-annual inspections and set out the sensors. While they are doing that, the inspectors get some quantitative measurements that get along with their qualitative inspections.” (Visual, hammer and listen approach.) One of the things this new system provides is something that is much easier to set up. Depending on the bridge type, the sensors can be set up with clamps, magnetic techniques, and epoxy which have been used in testing for longer term deployment in this research phase. “The concept is having the inspector also get quantitative measurements of the bridges’ performance.” So, essentially, Janoyan’s approach is just adding a small number of additional data fields into the sheets the inspectors currently use. This would not require more people. “Instead of carrying a hammer or a nuclear density gauge for soil, for example, you are just carrying another set of sensors you just put on the bridge.” Using a laptop PC, the data can easily be gathered. With respect to the distances the sensors can transmit to, Janoyan says this is one of the things they have been verifying. “It’s line-of-sight typically.” With obstructions such as concrete piers for example, you can use an extended antenna as a repeater and get the whole network of sensors on it by jump- ing and multi-hop some of these signals. The user would not have to worry about these things; it would be plug- and- play almost. It would be a deployable sys-
system where you are getting measurements.

The measurements, at this time, have gauged strain, acceleration and temperature but it’s not limited to those things. For short term deployments it is very important to measure strain. Measuring strain gives you an understanding of how the transfer of load takes place within a bridge, without knowing what the loads are. The inspector does not have to know whether it’s a ten ton-truck or a two-ton truck, the system will help determine how a load transfers between the girders. “So if you understand that, and you say for example, that this girder took 59% of the load this year, and two years later it took only 30% of the load, that means the load went somewhere else because that member can’t take the load anymore. So that girder should be inspected further. Maybe there is deterioration, sectional loss in that girder. If it’s acting stiffer then maybe there are some bearings that are stuck. So the combination of strain and vibration measurements can give those kinds of understanding, which can be invaluable. It may not be a final determination of the condition of the object, but at least it gives you some quantitative measurement so that you can make comparative analysis and track changes.”

Janoyan had told the New York Times last year that the system is the analogous to the neurological system in a human body. He elaborated that the short term deployments which involve embedding the sensors into the structure. He thinks this has been an important difference with his approach because the interested parties in this field have been pushing long term deployments which involve competing against the service life of the structure itself. While it’s important to continue to develop the concept of long term deployments, something Janoyan and his team are also working on; Janoyan says the short term deployments may provide more immediate relief for the challenges faced by the DOT. It’s less about bureaucratic issues and concerns than about a realistic, practical, focus on enabling DOT inspectors to gather quantitative measurements that will help them determine what problems with bridges right now and in the immediate future.

In researching this we came across research being conducted involving “acoustic emissions.” Janoyan seemed less interested in this area saying there were other people who were working in this area. I got the sense that he didn’t consider it to be as practical near term universal solution.

Janoyan thinks the challenge for the DOT is adopting technology. In his estimation the short term deployment may be a way to introduce and fuse the tools into their existing system without dramatically changing anything. Parallel to this, they are also concerned with new bridge structures. “How do you get on board from day one and have it become the smart structure that everybody talks about. Smart structure means, obviously, that provides a snapshot of the condition of the system, which can then be compared to previous inspection data reports from the system. A physician always wants to compare a new EKG to a previous EKG to determine whether there has been damage. This bridge monitoring system operates on the same principle. Janoyan says this has been an important difference with his approach because the interested parties in this field have been pushing long term deployments which involve embedding the sensors into the structure. He thinks this is a much harder way to go in to this business because then you are competing against the service life of the structure itself. While it’s important to continue to develop the concept of long term deployments, something Janoyan and his team are also working on; Janoyan says the short term deployments may provide more immediate relief for the challenges faced by the DOT. It’s less about bureaucratic issues and concerns than about a realistic, practical, focus on enabling DOT inspectors to gather quantitative measurements that will help them determine what problems with bridges right now and in the immediate future.

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that you get feedback continuously and you understand what is going on.”

As the professor and I drove to get lunch I asked a question and I assumed what his answer would be. It was something along the lines of, “So professor, this must be a pretty good life up here.” I was referring to the relaxed pace of life in Potsdam, as well as his tenure as a professor, which can mean a comfortable, less strenuous career. His answer caught me by surprise. He said the pressure was intense. He noticed my surprise and he elaborated that the level of intensity was not caused by the administration, or other outside sources, he put the pressure on himself, to conduct the absolute best possible research, to write superior, distinctive papers publishing his research and to help lead the engineering program at the University. It struck me that what was driving him was the thing that drives everyone who is seeking excellence. Self motivation, pride in doing a job the right way.

I thought about that attitude as I returned from my meeting with Professor Janoyan. I felt some comfort as I crossed many bridges on my way back. Some of the best minds anywhere were driven by a pursuit of excellence, and they were working on making these bridges we all cross safer.

This spring will bring new answers to the research project, and the Low Bidder will report them.