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INSPECTORS' GADGETS

Drones, new kinds of sensors and advances in current technologies are making bridge inspection work faster and safer

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COVER STORY
INSPECTION TECHNOLOGY

TAKING A CLOSER LOOK AT BRIDGES

Drones provide unprecedented access and new techniques allow extensive analysis, but final decisions still call for a trained human eye

By Aileen Cho

Ted Zoli, national chief bridge engineer with HNTB, compares bridge inspections to taking his kids to the doctor. “Every few years you take another set of pictures of the bridge, and ultimately you can pattern it. You pay attention in a deeper way to responses, and have a record.” But like parents who don’t want to send kids to the doctor at the first sign of a sniffle, once managers understand the characteristics of a bridge and its behavior, they don’t need to do constant in-depth reinspections. They are constantly looking for ways to make better decisions with the data they already have. “We spend a lot of money inspecting bridges,” says Zoli. “The question becomes whether there is a more technologically efficient way to do it.”

Drones are part of the answer. On Dec. 5, Intel announced its collaboration with the Minnesota Dept. of Transportation and the Kentucky Transportation Cabinet applying Intel’s advanced commercial drone solutions—including preflight planning software, the Falcon 8+ drone and postprocessing data management—to inspect complex bridge infrastructure. Intel’s software is used to design the flight plan and image capture locations. That mission can be duplicated year after year for subsequent missions, giving inspectors an “apples-to-apples” comparison of the bridge’s changing quality and potential deterioration, says the company announcement. The drone can capture detailed aerial data for 3D reconstruction, down to millimeter accuracy for ground sample distance.

Used for an asset like a bridge, the technology can also help inspectors connect multiple data sets to the infrastructure asset, giving engineers the ability to monitor changing conditions over time. Each asset and its data easily can be recalled by name, location and date, according to the Intel release.

Paul McGuinness, bridge inspection lead with Michael Baker International, which has been involved with the Kentucky part of the Intel drone-inspection collaboration, says that feedback has been positive so far. “Drones are not replacing [manual] inspections, but they’re a screening tool before going in for a physical inspection,” he says.

The drone supplemented the work of Michael Baker’s rope-climbing inspectors—and that technology, too, has undergone improvements. “We’ve doubled productivity using power seats,” he says, describing a power-assisted “bosun’s chair” Michael Baker’s inspectors have started using to speed up aerial inspections. “You feed the rope through the seat and ascend the cable, rather than rappelling. You can inspect going both up and down. It’s twice as fast and doesn’t fatigue the climbers,” he says.

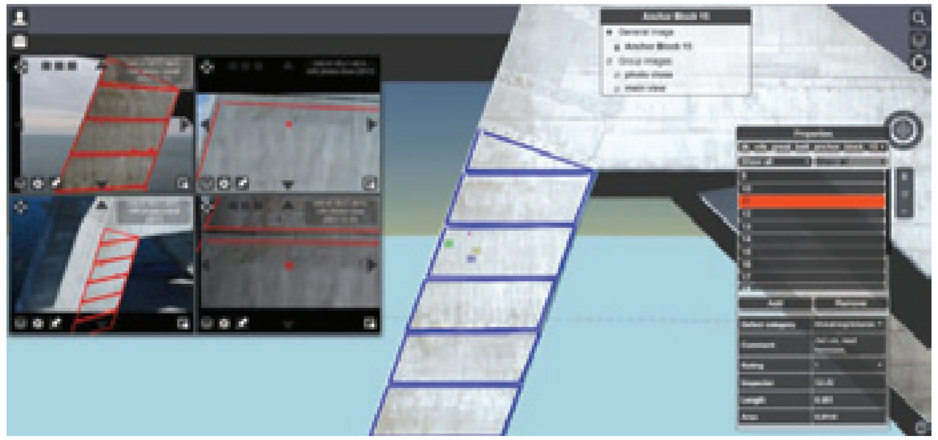
Finn Gottfredson, project director, Bridges Scandinavia for COWI Denmark, says his bridge engineering firm has developed its own drone-based virtual inspection tool over the last two years. “For many years, we have been taking pictures from planes to make digital models. We thought we could do something similar during inspections,” he says.

CLIMB, FLY, INSPECT In addition to traditional methods, like walking cables, Michael Baker International inspectors are using power seats (bottom right) and drones to assess bridge conditions.

FLYING HIGH A drone hovers above the Daniel Carter Beard Bridge over the Ohio River in Cincinnati (right).

PHOTOS COURTESY OF MICHAEL BAKER INTERNATIONAL

NEW VISIONS
COWI uses its own drone-driven data capture to create images of a bridge or tunnel.



IMAGES COURTESY OF COWI

"NOBODY WANTS TO BE FIRST, BUT NOBODY WANTS TO BE LAST, EITHER."

—ED MCSPEDON, BRIDGE ENGINEER, ON PUBLIC AGENCIES TRYING NEW INSPECTION TECHNOLOGIES

The firm inspected two anchor blocks on the Stoerbelt, a major suspension bridge in Denmark, and used both close-up and distance photos to create specialized 3D models. The camera's direction of view and the position of the drone relative to the bridge all can be seen in the model, which helps engineers making observations and notes in the model better understand what they are seeing and where the issue is in relation to the whole structure. "We used these models to navigate—you could easily lose the feel of where you are when you look at pictures. You can draw a circle around your observation and register it in a database."

COWI is working on incorporating such model-inspection evaluation data into an asset management system, says Gottfredson. "Asset management systems and building information modeling will merge in the years to come," he predicts.

Unusual Sensors

Ed McSpedon, a lifelong civil engineer, decided to help out a startup, Metal Fatigue Solutions, that targeted the infrastructure market with two new types of sensors. "It couldn't have picked a more difficult market for a startup. Our industry is not the most open to change and innovation," he says. "Many clients are in government, so there's no reward to be innovative. Nobody wants to be first, but nobody wants to be last, either."

One of the sensors is an electrochemical fatigue sensor. It is placed on a bridge crack, and a cavity inside the sensor is filled with an electrolyte that creates a passive layer of rust atop the steel. If the crack begins to grow, it opens up a previously unexposed steel layer and changes the current flowing through the electrolyte coating, alerting inspectors to the crack's growth.

The other product is a fatigue fuse that looks like a flat fork. Each tine in the fork has a different notch. Each notch will break at a certain percentage of the expected fatigue life of the structure. If an inspector sees that a tine reflecting, for example, the 40% fatigue life has broken sooner than expected, it indicates the steel member is failing prematurely.

Marybeth Miceli, a materials science engineer and expert in non-destructive testing, started Miceli Infrastructure Consulting LLC eight years ago to help public infrastructure stewards figure out what types of inspection tools work best for them. "At the same time, we help tech companies figure out parallel technology transfer, like bringing aerospace solutions into the bridge industry. You have to speak [bridge owners'] language. How will it make their job easier? How will it reduce inspection man-hours? If they can make the right repair decisions at the right time, how does that affect the overall asset management plan?"

There are scores of improved or new techniques available or in testing. For example, bridges often have a problem with the quality of grout. Miceli recalls one bridge that had concentrations of chlorides up to 400% greater than expected. "We used to just look for voids. Now we need more comprehensive techniques that would allow for finding the corrosion without voids. You could use ultrasonic guided waves or acoustic emissions to listen for fiber breaks," she says.

Scour is another issue that is being addressed. A company named Sensr Monitoring Solutions uses three accelerometers and tilt meters positioned in two directions to monitor pier movements during a high-velocity water event, says Miceli. What are those forces? When looking at absolute tilt, she asks, "Did the pier come back to its original place?"

Last January, a crack in a truss on the Delaware River-Turnpike Toll Bridge, an arched steel, four-lane, continuous truss bridge crossing the Delaware River between Burlington Township, N.J., and Bristol Township, Pa., led to a temporary closing. That gave Ashley Thrall, associate professor of structural engineering at the University of Notre Dame, and her student Yao Wong a chance to use three-dimensional "digital image correlation" for stress analysis.

Nondestructive Monitoring

DIC is a noncontact, nondestructive photographic monitoring technique that measures full-field strains and displacements using pattern recognition and photogrammetric triangulation principles. For bridge monitoring, DIC provides additional advantages as it is portable and does not require wiring or an installed on-site data acquisition system.

The researchers used two cameras mounted on a rigid bar to take photos of surface strains in seven members of the north truss throughout the repair process, which included vertically jacking the structure from the towers to restore the position of the trusses, followed by post-tensioning and splicing the fractured member to restore the original dead load force.

DIC has been around for a while, but "now we're using it on exciting projects," says Thrall. She has used DIC on the Mario Cuomo Bridge in New York and several steel girder bridges in Indiana, monitoring how much strain is being put on girders after they have been hit by vehicles. DIC has its drawbacks, but combining it with other evolving technologies holds promise for improvement. "It does take a full day to pattern and photograph," she says. She also had to use a man-lift, but complementing DIC with technologies such as drones "would certainly make things easier," she says.

Other existing bridge monitoring technologies are also evolving. "The evolution of ground-penetrating radar is one of the things on our list," says Chris Williams, assistant state structure and bridge engineer for safety inspections with the Virginia Dept. of Transportation (VDOT). "In the past, we were using a device with a single frequency. Now we're experimenting with 3D GPR, with the advantage of [using] multiple frequencies simultaneously. You can go deeper into a concrete deck and get higher resolution of detail."

Regarding infrared thermography, "rather than a single camera, we're trying time-lapse infrared cameras," says Williams. "Multiple images are combined to create a clear image over time." VDOT engineers have also used gamma ray radiation to scan post-tensioned tendon ducts, and satellite imaging to scan large areas on a couple of bridges.

"A lot of these technologies are not for everyday use, but we can apply them as needed or when conventional methods aren't able to give us the answer we need," says Bernard Kassner, research scientist with VDOT.

With the evolving technologies comes the issue of interpreting the data. "I'd like to see improvements in quantifying data; there's a bit of a gap right now," says Scott Roux, national practice lead for bridges at Michael Baker International. "With these new technologies, some data can be easily misinterpreted."

Drowning in Data

COWI's Gottfredson concurs. "You can drown in all this data," he says. "It's difficult to know what is serious and what is noise. In Denmark, we try to keep monitoring at lower levels. But with the internet of things, it's getting so easy to capture data."

Williams notes that the speed of data collection, pro-

PHOTOS COURTESY OF MICELI INFRASTRUCTURE CONSULTING

NEW IDEAS
Metal Fatigue Solutions offers a sensor that monitors steel crack growth using an electric current.

COVER STORY
INSPECTION TECH

ASSESSING THE DATA
Technologies such as drones are augmenting the inspection process, but engineers also see the need to better manage data that is generated.

PHOTO COURTESY OF MICHAEL BAKER INTERNATIONAL

WE NEED RELIABLE REMOTE ACCESS, BUT THERE'S NO SUBSTITUTE FOR TACTILE INSPECTION.
—CHRISTOPHER WILLIAMS, VIRGINIA DOT

cessing power, sophistication of current software and the analytics involved have all allowed for more powerful usage of data. "We are looking at augmented reality, photogrammetry and lidar. We've experimented a bit with HoloLens and how inspectors could utilize that to pull up data of a bridge on site. It's all rapidly evolving—but it's still evolving," he says.

No matter how evolved, sensors, drones and other techniques will only augment, not replace, human inspections. "Visual inspections are still important and will remain that way for a long time," says Soundar Balakumaran, VDOT research scientist. "I'd like to see technologies that can augment human participation in the nondestructive testing stages."

Williams adds that "countless times we've seen what looks like a beam end with some scaling rust, but it looks solid, and if you take a picture or video … that's what it shows. Then you tap it with a hammer and a 6-inch piece falls out."

This makes the point, Williams says, that there is no substitute for tactile inspection and a human eye trained to understand what that patch of scaling rust means and how urgent the finding is. The process requires an understanding of bridge mechanics, he says. "Perhaps some tasks could be automated, but the final decision point needs humans."

Engineers say that anything leading to improved safety and efficiency in inspections is desirable. "We need reliable remote access," says Williams. "If there was a way to equip a crawling drone or aerial drone or underwater drone, the sensor capability would not just show the surface, but give a penetrating view to show subsurface deficiencies. It would allow us to zero in on areas requiring hands-on follow-up. For example, we have a truss bridge over a mile long. Rather than traditional methods, we could utilize remote technologies to know in advance what areas to look at."

As engineers seek to merge existing practice with emerging technologies, it looks like autonomous drones and integrated analytics will play a big part. But Cindy Ng, head of marketing for Intel's drone group, believes drones also will need autonomy, intelligence and advanced flight safety technology built in so that bridge inspection operations can be executed automatically without a pilot.

"I'd like to see drone technology make it easier and more effective to conduct bridge inspections on a repeatable and regular cadence so that motorists, commuters, tourists and pedestrians won't have to wonder if the bridge they're crossing is safe," Ng says. ■