Stretching exercises: Using digital images to understand bridge failures

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(PhysOrg.com) -- With a random-looking spatter of paint specks, a pair of cameras and a whole lot of computer processing, engineer Mark Iadicola of the National Institute of Standards and Technology has been helping the Federal Highway Administration (FHWA), in cooperation with the American Association of State Highway and Transportation Officials (AASHTO), to assure the safety of hundreds of truss bridges across the United States. Iadicola has been testing the use of a thoroughly modern version of an old technique—photographic measurement or "photogrammetry"—to watch the failure of a key bridge component in exquisite detail.

The impetus for the FHWA project was the disastrous collapse of the Interstate 35-W bridge in Minneapolis, Minnesota. On Aug. 1, 2007, in the middle of the evening rush hour, a thousand feet of the bridge's main deck truss collapsed, part of it falling 108 feet into the Mississippi River. Thirteen people died. One hundred and forty five were injured.

According to FHWA engineer Justin Ocel, an investigation by the National Transportation Safety Board (NTSB), assisted by FHWA, determined that the immediate culprit was a failed gusset plate, a flat heavy piece of steel bolted in pairs to join the ends of the steel members that make up the bridge truss. As a result of a design error decades before, the gusset plates in the bridge were about half as thick as they should have been.

Although that design flaw was clearly a major factor in the disaster, Ocel says, the collapse highlighted the fact that gusset plates were not generally considered by engineers during periodic reviews of bridge capacity, a process called load rating. It was assumed that gusset plates were properly sized to be stronger than the members they connect. “One of the recommendations from the NTSB was that we include gusset plates in load ratings, and until that point it hadn't been done,” Ocel explains. “To assist the states with this process we developed a guidance document on how to load rate gusset plates.”

In developing the guidance, Ocel says, FHWA used the best available data on the failure modes of gusset plates in major bridges—but there wasn’t much. So at the FHWA's Turner-Fairbank Highway Research Center in Virginia they began building full-scale models of bridge gusset plate joints and pulling them apart with a huge hydraulic test machine.

NIST’s Iadicola is there to watch what happens as the plate stretches and fails. He covers the plate with an irregular pattern of paint speckles and then trains a pair of carefully calibrated, high-definition digital cameras on it. The cameras repeatedly image the plate, send the pictures to a computer that uses custom software to compare each image to the previous one, and calculate which of the paint spots have moved, in what direction and by how much. Using two cameras allows the computer to “see” the plate in three dimensions, so it can tell if points on the surface move in or out as well as up, down or sideways.

“The NIST digital image correlation method is a good complement to the FHWA measurement methods,” Iadicola explains. “Their techniques—strain gages and photoelasticity—are very good for the normal range of stress in which the plate will stretch and spring right back to its original shape. Our method can tell you a little about that, but it really shines in showing you what happens past that point, when the plate starts permanently deforming and finally rips apart. The failure modes.”

After more than a year of experiments, Ocel says, the FHWA has learned a lot about how to predict what loads will cause a gusset plate to fail. Currently, FHWA is working with AASHTO to translate those findings into language that can be adopted into the AASHTO Bridge Design Specification and Manual for Bridge Evaluation, two documents used throughout the country for designing and load rating bridges.

The FHWA project is just one of a range of applications for digital image correlation being studied at NIST, Iadicola says. “We’ve been using it in looking at sheet metal forming—you have very high strains during the forming process—and we’ve used it at very small scales, looking at targets with an optical microscope.”

Provided by National Institute of Standards and Technology

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