New fracture analysis plan would change bridge fabrication, inspection

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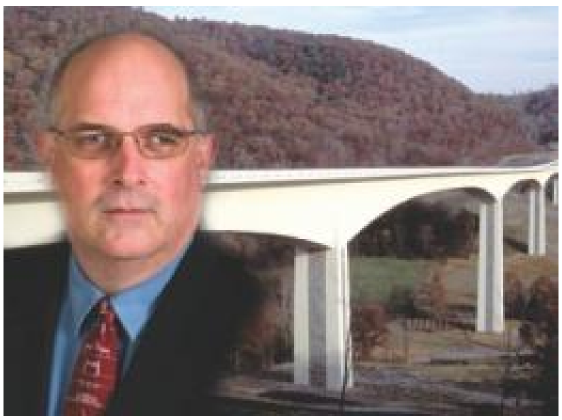

William J. Wright, faculty member in civil and environmental engineering at Virginia Tech, is designing a fracture critical analysis system for bridges and improved fracture toughness specifications for structural steels used in critical members of low redundancy structures, such as two-girder bridge systems. Credit: Virginia Tech Photo

One size does not fit all. By adding the word "not", this now completely revised adage rings true for at least one civil engineer.

"The devil is in the details," said William Wright, a scholar who was once named the Engineer of the Year by the Federal Highway Administration. The agency cited him for his work on " high performance steel that led to reduced initial cost, lower maintenance, and longer life for many new bridges nationwide," according to the highway administration's press release announcing his award.

Wright, an associate professor of civil and environmental engineering at Virginia Tech, is concerned about size, especially when it relates to how materials will perform in structures where failures might lead to catastrophes. As today's engineers investigate the rebuilding of much of the nation's infrastructure, a lot of which was constructed in the 1950s, they are using much improved materials and analysis tools.

"These advances can be combined to greatly reduce the risk of failure of steel bridges by brittle fracture," Wright said.

Based on his expertise in engineering and materials for bridge spans, the Virginia Tech civil engineer predicts his new work on a fracture control plan for steel bridges "promises to change bridge fabrication and inspection practices."

Currently the highway administration requires more intensive inspection for structures that are at risk from fracture failure, a major cost factor for bridge maintenance budgets. The current fracture control plan was developed in the 1960s and has not kept up with advances in materials and computerized system analysis.

Wright is in the initial stages of this new study, funded by the Transportation Research Board, to identify critical members in steel bridges that need to be protected from failure by fracture. Working with him is Robert J. Conner of Purdue University's Civil Engineering Department. Together, they received a $350,000 grant to develop an improved method to determine the structural consequence if brittle fracture occurs.

"Most bridge engineers now have the capability of performing a particular evaluation – a three-dimensional elastic finite element system of analysis of bridges. This is a powerful tool that provides a platform for studying internal load re-distribution in damaged structures such as bridges. However, the problem remains that the ultimate strength of a structural system made of steel and concrete is a highly non-linear problem," Wright said. There is limited information available about the ultimate strength of bridge systems.

Wright refers to the problems as "non-linear" because they can involve combinations of steel yielding, steel buckling, concrete crushing, and connection failure. The elastic three-dimensional method of analysis "can greatly over estimate strength and reliability of a damaged bridge if all factors are not considered," Wright explained.

So, Wright and Conner are working to create a more comprehensive approach. They want to develop an all-inclusive systems method that would reliably predict the fatigue and fracture limit states of steel, the ultimate strength of the connections in the structure, the stability of the system, the overall condition, and the value of having an in-service inspection.

They believe a significant cost savings could be achieved through their approach. If states will pay a modestly higher, up front cost for better materials, the financial burden of lifetime inspections can be reduced, Wright said.

"The bridges we build today present a much lower risk of fracture compared to those built prior to about 1980. The reasons are the higher quality standards for fracture critical member fabrication, greatly improved knowledge about fatigue design and detailing to prevent in-plane fatigue as well as distortion cracking issues, and improved material quality. However, there is little evidence that fatigue critical in-service inspection contributes significantly to this improvement," Wright said.

Due to these advancements in engineering, new bridges should have less need for inspection for fatigue issues when compared to the older vintage bridges.

As Wright investigates this fracture critical analysis system for the Transportation Research Board, he is simultaneously working on a multi-state pooled fund project administered by the Indiana Department of Transportation to develop improved fracture toughness specifications for structural steels used in critical members. His goal is to design and fabricate standards to eliminate fracture critical concerns in low redundancy structures, such as two-girder bridge systems.

Working with a host of partners including the Commonwealth of Virginia, the Army Corps of Engineers and the Federal Highway Administration, Wright suggests the results of this study "will be transformative for the steel bridge industry. For the first time, material selection, design, and inspection will be rationally integrated to eliminate fracture concerns. This can result in significant cost savings for medium and long-span bridges and facilitate the introduction of modular concepts for short-span bridges."

The highway administration has the authority to allow the owners of bridges to forego fracture fatigue critical inspection for low-redundancy bridge structures on a case by case basis. However, this reprieve rarely occurs since there is little guidance to insure bridge safety, Wright said.

"This project will establish guidance that provides a high level of bridge safety that can then form the basis for in-service inspection decisions," Wright said.

Wright received his bachelor's degree in civil engineering from the University of Maryland at College Park in 1986, his master's degree in structural engineering, also from University of Maryland in 1988, and his Ph.D. in civil engineering from Lehigh University in 2003.

Throughout his career, Wright's primary research interests have involved development and experimental evaluation of new, innovative bridge systems that can meet three critical requirements: rapid construction, life cycle durability, and cost effectiveness. He has targeted this "Bridge of the Future" goal as the overriding principal guiding the Federal Highway Administration research program. The current research on fracture critical bridge systems is an enabling technology for the "Bridge of the Future".

Among his honors, Wright received the 2008 Richard S. Fountain Award from the American Iron and Steel Institute and the AASHTO T-14 Steel Bridge Committee for his outstanding contributions to the steel bridge industry. In 2007, he received a U.S. Department of Transportation Gold Medal for his work on the Minnesota I-35W Bridge Response Team. In 2006, Wright earned the George S. Richardson Medal, presented by the Engineers Society of Western Pennsylvania and Roads and Bridges magazine for his development of the Load and Resistance Factor Design Unified Steel Design Code.

In 1997 the Civil Engineering Research Foundation of ASCE presented him with its Charles Pankow Award for Innovation for his work on the development of high performance steels for highway bridge applications.

Provided by Virginia Tech

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