Design and Fabrication Standards to Eliminate Fracture Critical Concerns in Two Girder Bridge Systems.

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BACKGROUND

The two girder bridge system was developed in the two decade period starting in the 1950's. Designers recognized the inherent structural efficiency of these systems and a number of bridges were built. Unfortunately, knowledge of the fatigue and fracture limit states was not sufficiently advanced to avoid problems in service. A number of these early bridges suffered from fatigue and fracture problems in service. Following the Silver Bridge collapse, the concept of a "fracture critical" bridge was introduced that required extra quality assurance and inspection measures for bridge types with "low" structural redundancy. This had the beneficial effect of reducing weld defects and improving quality in the fabrication shop. However, the fracture control plan also saddled "fracture critical" bridges with a lifetime requirement for more rigorous in-service inspection. The purpose is to discover relatively small fatigue cracks before they grow large enough to present a fracture risk. Experience has shown that fatigue is only one of many causes of fracture, and there are few reported cases where fracture critical inspection has helped prevent brittle fracture. Despite the fact that fracture critical inspection provides limited benefits, it is still mandated in the U.S. for steel bridges deemed to have low load path redundancy. This is a major cost burden for bridge owners, consequently few "fracture critical" bridges are being built today in the US. This contrasts with practice around the world where there are no special inspection requirements for "fracture critical" concerns.

For major steel bridge structures, it may be reasonable to expect 20% to 30% initial cost savings for a two girder system compared to multi-girder alternate designs. Surveys of world practice indicate that two-girder systems are routinely built and are performing well in service without any special "fracture critical" concerns. There are many other situations where structural efficiency may be improved through use of cross girders or other elements that are currently avoided because they are classified as "fracture critical". There is a clear economic benefit associated with elimination of fracture critical in-service inspection requirements. However, it is recognized that this will represent a major change in practice and it can only be considered if there is an assurance that bridge safety is not compromised.

Three major advances in practice have occurred since the fracture critical designation was invented. Modern 3D structural analysis methods provide an advanced tool that enables a much more detailed understanding of structural behavior and redundancy. It is now possible to understand the load carrying capability of concrete decks and other members that is missed in traditional girder line analysis. The causes of fatigue and distortional fatigue are now well understood, and with proper detailing there is a high probability that fatigue will never occur in new structures. The third major advance is the introduction of high performance steels (HPS). These steels, through their excellent weldability and toughness, reduce the possibility of initial welding defects and provide much higher fracture resistance than conventional structural steels. This greatly reduces or eliminates the potential for brittle fracture that was the primary reason for the fracture critical designation. Taken together, it is now possible to engineer low redundancy members (i.e. two girder systems) that are not vulnerable to the fatigue and fracture limit state.

The goal of this research is to set standards for a new class of low redundancy structures that no longer require fracture critical in-service inspection. This will involve standards and protocols for advanced analysis, strict detailing rules to eliminate fatigue, and a supplemental material specification to greatly reduce the risk of fracture. Material toughness requirements will be established to provide damage tolerant design and protection from "pop-in" type dynamic fracture. In most cases, proper design and defect free fabrication will result in a structure that is not vulnerable to fracture. However, the higher toughness of HPS can serve as the safety net if fatigue occurs due to some unforeseen defect slips through the construction process. It also serves to eliminate the risk of fracture due to vehicle impacts and other dynamic events.

SCOPE

This project will involve the following tasks that establish the protocols for design and construction of non-fracture critical structures:

- Experimental study of fracture in I-girders to determine supplemental toughness requirements
    - Full scale fracture tests
    - Fracture Mechanics Tests
- Establish damage tolerant design concepts to utilize toughness and set in-service inspection requirements.
- Detailed, 3D Finite element modeling of a two girder bridge system to set detailing requirements for redundancy. Ideally this will include analysis of a two girder concept for an actual bridge project.
- Develop a guide specification for design and fabrication of non-fracture critical low redundancy structures.

ESTIMATED COST: $500 to $750 k

Individual state contributions: $60k total ($20,000 per year); or one lump-sum contribution.

DURATION: 3 years (FY 2010 – FY 2012)

PAYOFF

The FHWA currently has the authority to allow owners to forego fracture critical inspection for low redundancy bridge structures on a case by case basis, but this has rarely been done since no guidance is available for ensuring bridge safety. This project will establish guidance that provides a high level of bridge safety that can then form the basis for in-service inspection decisions.

When considering the estimated projects costs, it must be recognized that the results of this research 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 introduction of modular concepts for short span bridges.