March 31, 2009 Progress Report on Pooled Fund Study TPF-5(189)

Introduction

Transportation Pooled Fund study TPF-5(189), "***Enhancement of Welded Steel Bridge Girders Susceptible to Distortion-Induced Fatigue***," is progressing well. Erection of the test frame to be used for loading the steel girder specimens is scheduled for early May, 2009. Specimens to be tested in distortion-induced fatigue loading are being studied analytically to ensure that stresses are well-understood before experimental research is begun. Component-level studies intended to capture the behavior of fatigue specimens with the various enhancement techniques applied are ongoing while the 3D test set-up is being constructed.

Test Frame

A one-bay by one-bay steel test frame has been released for fabrication, configured as shown in Fig.1. Erection of the test frame is scheduled to begin May 4, 2009. The 330-kip actuator is scheduled to arrive in mid-April.

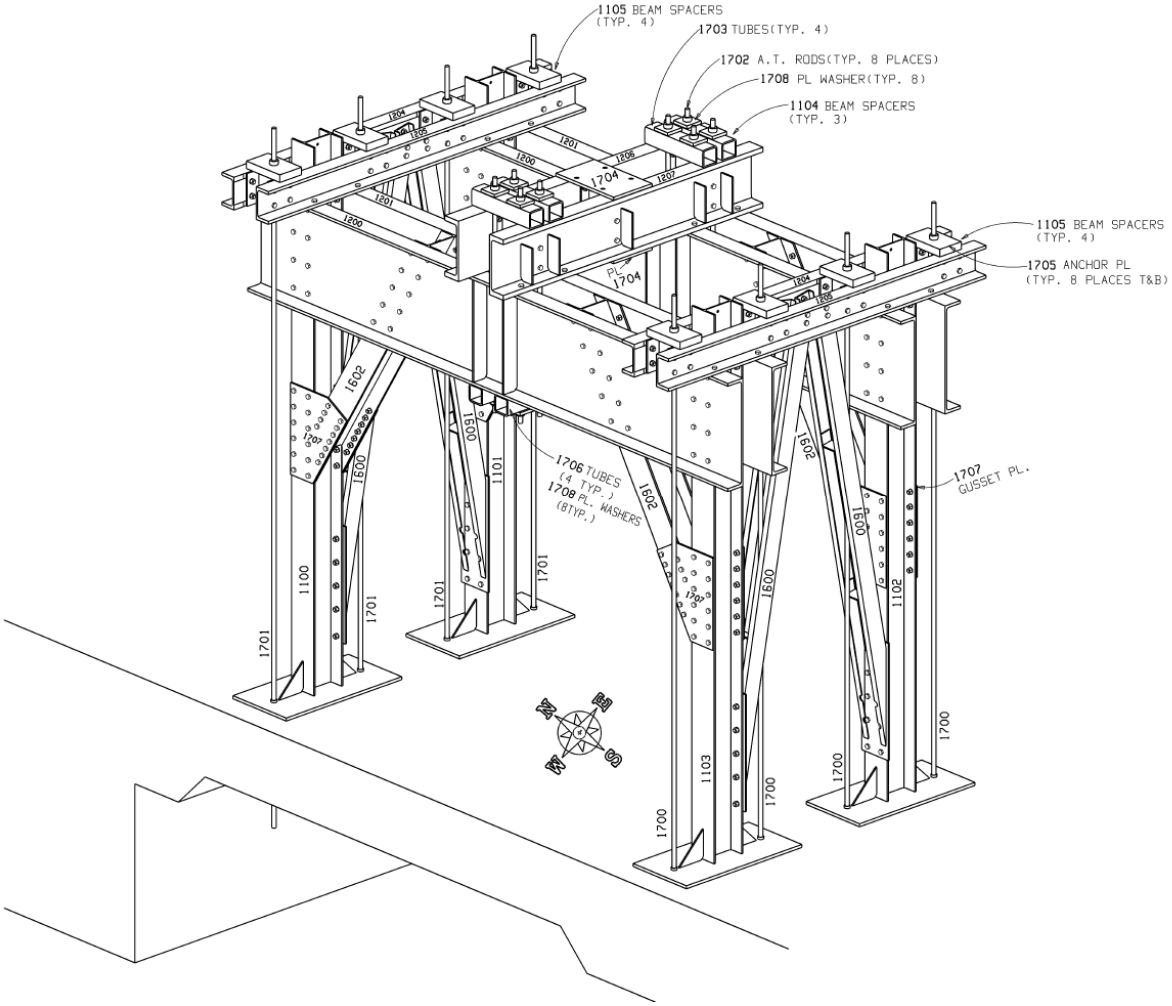

Fig. 1. Configuration of test frame for loading of test girders

Test Specimen Design

Analytical studies are being performed to aid in determining specimen and detail configurations. Finite element models have been generated using the commercially-available software package, ABAQUS. Based on initial grillage analyses, test specimen girder dimensions were identified. The dimensions of the built-up girder to be tested are approximately half scale of the bridge girder examined in the NSBA/AISI publication "Four LRFD Design Examples of Steel Highway Bridges" (1), and are shown in Fig. 2.

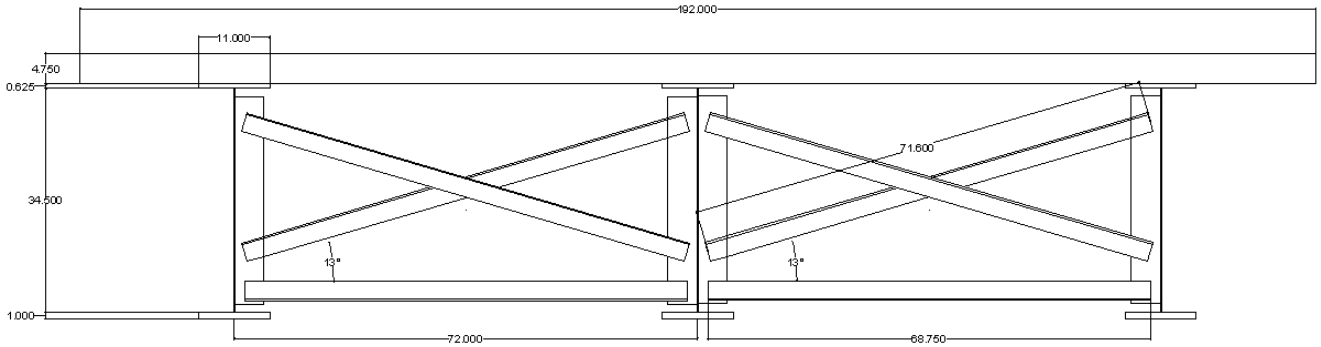

Fig. 2. Dimensions of test specimens examined analytically

The following parameters are being investigated in the finite element models, with the goal of optimizing web gap stresses to produce fatigue cracking:

1. Cross-brace configuration and geometry
2. Web gap dimension
3. Deck composition and length

Other connection details will be examined analytically before final test specimen configurations are decided. Fig. 3 shows the overall geometry of the test specimen girder assemblage being studied. Fig. 4 shows the deflected shape of the interior and exterior girders under a pressure load applied at midspan of the interior girder. The view shown is a 'cut-away' at midspan. Fig. 5 shows the deflected shape of the web-gap region at midspan of an exterior girder.

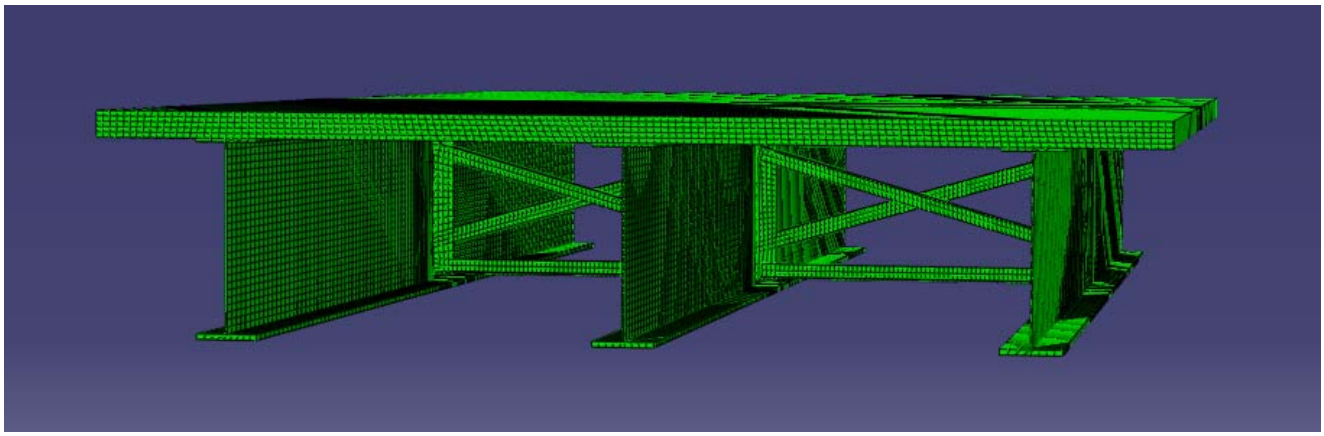

Fig. 3. **Finite element model of half-scale test girder assemblage**

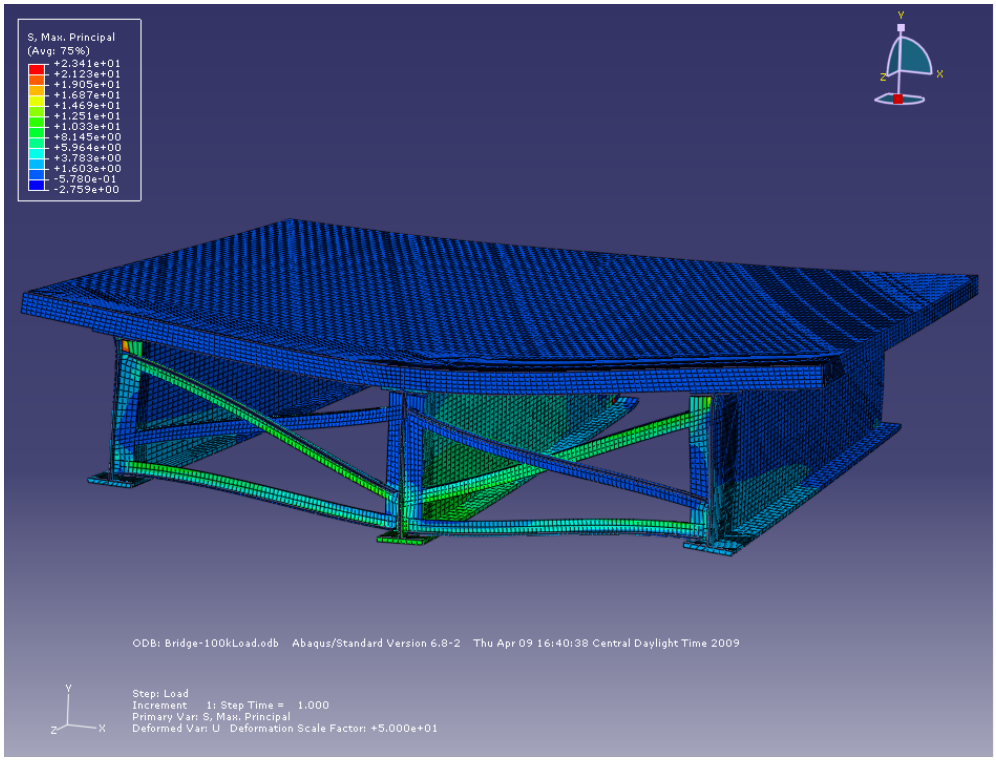

Fig. 4. **Deflected cross-section of girder assemblage under applied pressure load over center girder at midspan**

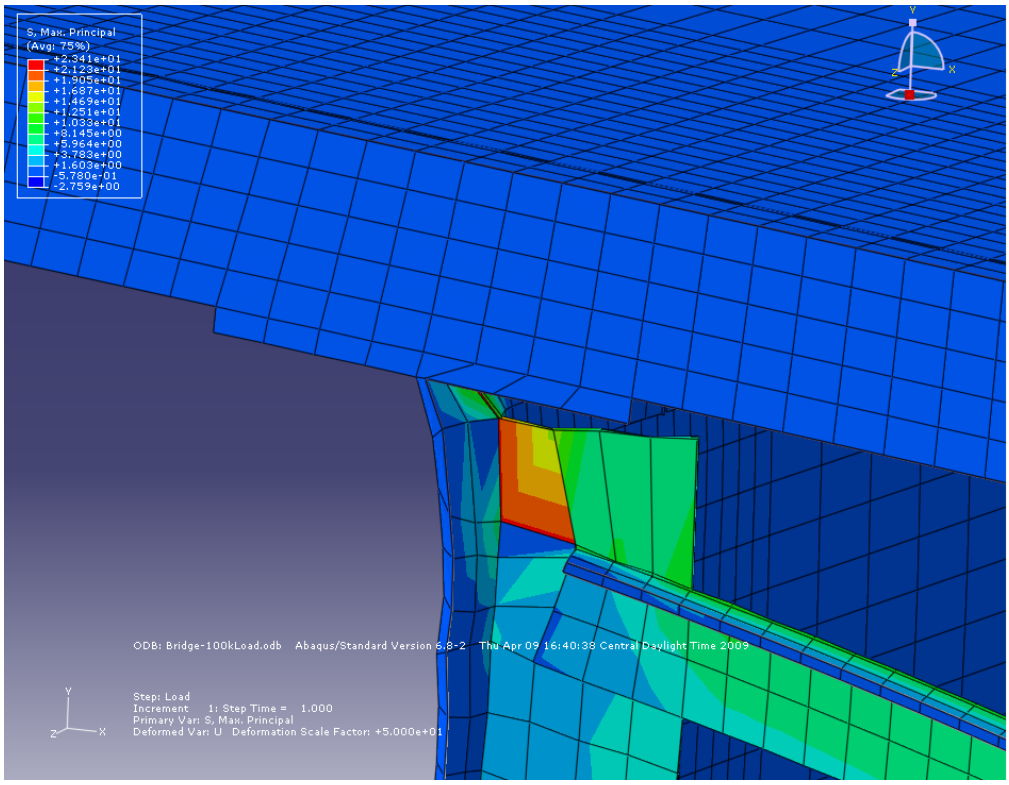

Fig. 5. Cross-section view of deflected shape, showing web-gap distortion of exterior girder

Component-Level Studies

Two parallel studies are being performed concurrent to the outlined activities that will feed directly into the pooled fund study activities once 3D testing commences. These studies are:

1. Characterization of sprayed chopped carbon fiber composite on steel fatigue details, and
2. Development and application of a PICK tool to treat the inside surface of undersized crack-stop holes.

In addition, results from the use of molded carbon fiber reinforced polymer (CFRP) composites to improve steel fatigue detail performance can be found in references 2 and 3.

Chopped-Fiber Application A commercial grade chopped-fiber spraying system has been purchased and utilized on component-level steel assemblages representative of a girder flange and welded coverplate. Experimental tests are being performed on coupons to characterize the material properties of the chopped CFRP. Fatigue testing of Cat. E' details on steel assemblages coated with chopped CFRP will be performed.

Treatment of Undersized Crack Stop Holes

The PICK tool has been developed, and is currently being characterized and tested for effectiveness. Sheet-type fatigue specimens with untreated drilled holes have been tested in fatigue in tension at high stress ranges (32 ksi). Similar specimens with treated drilled holes will be fatigue tested to determine the fatigue performance when treated using the PICK tool.

Upcoming Tasks

Given the current project activities, the following tasks are expected to occur in the next quarter:

1. Erection of the test frame and actuator
2. Selection of test specimen details and girder configuration
3. Advanced finite element analyses of test specimen details

Conclusion

Significant progress has been made this quarter on project TPF-5(189). Specifically, the test frame has been released for fabrication, test girder geometry has been selected, various test specimen configurations are being investigated analytically, and multiple component-level studies are being performed to refine and better understand fatigue enhancement techniques that will be applied to the scaled test girders.

Contact Information

Please contact Caroline Bennett at (785)864-3235 or crb@ku.edu with any questions or discussion items.

References

1. AISI, NSBA. (1997). "Four LRFD Design Examples of Steel Highway Bridges," American Iron and Steel Institute (AISI) and National Steel Bridge Alliance (NSBA), Chicago, IL.

2. Kaan, B.,‡ Barrett, R., Bennett, C., Matamoros, A., and Rolfe, S. (2008). "Fatigue enhancement of welded coverplates using carbon-fiber composites," Proceedings of the 2008 ASCE / SEI Structures Congress, Vancouver, BC, April 24 – 26, 2008.

3. Kaan, B. (2008). "Fatigue enhancement of category E' details in steel bridge girders using CFRP materials," thesis, presented to the University of Kansas, Lawrence, KS in partial fulfillment of the requirements for the degree of Masters of Science.