CALTRANS PROBLEM STATEMENT
FOR
POTENTIAL NATIONAL INTEREST

I. PROBLEM STATEMENT TITLE

Development of a Transparent Fatigue Design Procedure for Orthotropic Steel Bridge Decks

II. RESEARCH PROBLEM STATEMENT

How can the fatigue design of orthotropic steel bridge decks be performed by a reliable and transparent procedure?

Orthotropic steel bridge decks are widely used for long-span bridges. Experience in Japan and elsewhere has indicated that this type of deck is prone to fatigue cracking (Xiao et al. 2006). Although the majority of fatigue cracks result from out-of-plane distortion or other secondary stresses at fatigue-sensitive details, design criteria in the 2004 AASHTO LRFD Bridge Design Specifications are vague and difficult to use. Two fatigue-sensitive details exist in orthotropic decks. First, cracks that are prone to occur at the rib-to-diaphragm welded joint are classified in AASHTO as "load-induced," yet a "rational analysis" to compute the stress range is not provided in AASHTO. Fortunately, Connor and Fisher (2006a) recently filled this gap by developing a consistent approach that relies on a finite element analysis to compute the stress range at a location where the S-N curve is experimentally established. Second, according to recent research funded by Caltrans, the fatigue at the rib-to-deck partial-penetration groove weld has a tendency to be affected by weld melt-through and other fabrication related issues. This type of fatigue is even less understood, hence, it is classified in AASHTO as "distortion-induced". No fatigue detail category is given; AASHTO considers the fatigue strength to be satisfactory "if requirements for geometric properties and welding details … are satisfied." For a rational fatigue design of orthotropic steel decks, a consistent approach that allows the designer to determine the fatigue detail category and the fatigue life should be developed.

III. OBJECTIVE

The objective of this research is to develop a simple yet robust design procedure for steel orthotropic decks that incorporates fatigue resistant details.

IV. BACKGROUND

A significant number of toll bridges in California use orthotropic steel decks. Unfortunately, the fatigue design criteria for this type of construction are either vague or prescriptive in bridge design specifications. A recent Caltrans-sponsored testing program of six large-size orthotropic steel deck specimens (10m long x 3m wide) revealed that a fatigue crack at the rib-to-deck partial-penetration

groove weld may occur. The objective of this research was focused on the effects of two fabrication issues (weld melt-through and heat-straightening). Although the test results showed that these two issues may have an effect on the fatigue strength of the welded joint, the nature of the testing program did not allow for the useful S-N curves to be established because (1) the loading level was kept at a constant level to facilitate a direct comparison of the performance among all deck specimens, (2) the loading locations were fixed. Many smaller pieces cut out from lightly loaded regions of outer ribs in these deck specimens can be re-used efficiently for further fatigue testing to establish the S-N curves. One possible loading scheme is shown in Fig. 1; the load can be repositioned to produce a different stress state. The load level and the position of the load need to re-produce a stress state similar to the actual condition. Following the consistent approach recently proposed by Connor and Fisher (2006a), the rib-to-deck weld detail can be reclassified as load-induced and a transparent fatigue design procedure which includes both the fatigue detail category classification and stress calculation based on finite element analysis can be established for both new design and remaining fatigue life prediction of existing orthotropic steel bridge decks. Weld melt-through is difficult to avoid in actual fabrication, therefore, such an effect on fatigue strength should be addressed. The research should also investigate effective retrofit and repair techniques.

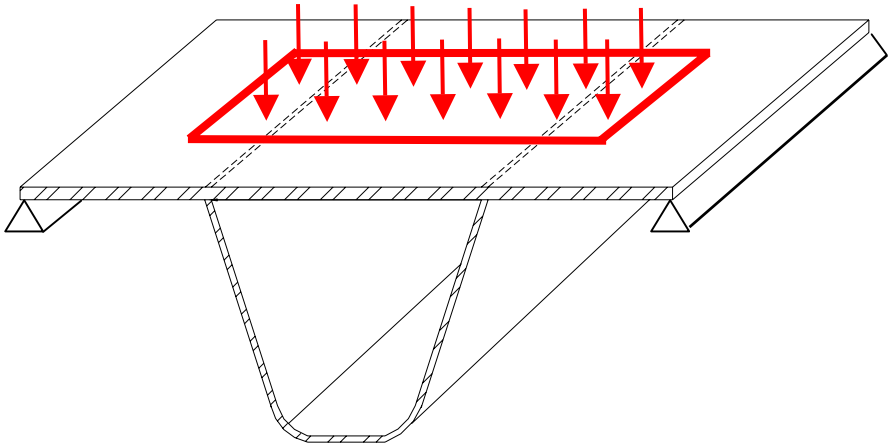

Figure 1 Test Setup

V. ESTIMATE OF FUNDING

Estimated Funding: $200,000

VI. DURATION OF RESEARCH

Duration of Research: 24 months

V1I. URGENCY, BENEFITS, AND EXPECTED RETURN ON INVESTMENT

A reliable yet transparent fatigue design procedure for orthotropic steel bridge deck is long overdue. After using this type of construction for several decades,

Japanese researchers have reported numerous fatigue cracks in orthotropic bridge decks. Since weld details, plate proportions, welding practice used in the United States and other countries are different, research that addresses the fatigue design of welded joints in orthotropic steel decks constructed in accordance with the US practice is needed. New fatigue design procedures from this research can be developed for adoption in the AASHTO LRFD Bridge Design Specifications

VIII. RELATED RESEARCH

- Connor, J.R. and Fisher, J.W., "Consistent Approach to Calculating Stresses for Fatigue Design of Welded Rib-to-Web Connections in Steel Orthotropic Bridge Decks," Journal of Bridge Engineering, ASCE, Vol. 11, No. 5, pp. 517-525, 2006a.
- Connor, J.R. and Fisher, J.W., "Identifying Effective and Ineffective Retrofits for Distortion Fatigue Cracking in Steel Bridges Using Field Instrumentation," Journal of Bridge Engineering, ASCE, Vol. 11, No. 6, pp. 745-752, 2006b.
- Sim, H.B. and Uang, C.M., "Effects of Weld Melt-Through and Heat Straightening on the Fatigue Strength of Rib-to-Deck Partial-Penetration Groove Welded Joints of Orthotropic Steel Decks," SSRP Report, University of California, San Diego, 2007. (in preparation)
- Xiao, Z.G., Yamada, K., Inoue, J., and Yamaguchi, "Fatigue Cracks in Longitudinal Ribs of Steel Orthotropic Deck," Vol. 28, pp. 409-416, International Journal of Fatigue, 2006.

IX. DEPLOYMENT POTENTIAL

New fatigue design procedure can be adopted directly for future use in both the Caltrans Bridge Design Specifications and the AASHTO LRFD Bridge Design Specifications.

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