MPC-382

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Project Title: Seismic Behavior of Steel Bridges with Fatigue-prone Details

University: Colorado State University

Principal Investigators:

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Research Needs:

Steel bridges (with reinforced concrete substructures and steel superstructures) are generally considered to have a superior performance under earthquakes when compared to their reinforced concrete counterpart [1]. Such performance reputation stems from the fact that few steel bridges have been subjected to strong ground motion in the last decade in North America as opposed to the inherent capacity of the bridges [1]. In addition to the lack of seismic exposure of the bridges, research on the seismic performance of steel bridges' superstructure is limited to handful of studies [e.g., 2, 3, 4, 5, 6, 7, 8, 9, 10]. Noteworthy that none of the previously conducted studies addressed the behavior of fatigue details in the bridge superstructure, which are designed for traffic loading, under earthquake loading.

In the superstructure, fatigue is often the most prevalent problem, which contributes to approximately 90% of existing cracks. The cracks are a result of the repeated traffic cycles that are exerted on the bridge (fatigue cracks under traffic loads are termed high-cycle fatigue). For existing bridges, achieving satisfactory fatigue performance under traffic loading requires correct identification of the fatigue-prone details, coupled with well-planned inspection routines and the implementation of effective repairs. For existing bridges, the most recent changes to code design procedures and guidelines have proven to greatly minimize or even eliminate the main fatigue concerns.

Designing a new bridge superstructure and/or retrofitting an existing bridge to alleviate present fatigue cracks accounts only for traffic loading. The performance of the fatigue-prone details, designed for service loads, under earthquake ground motions demand is yet to be investigated.

Research Objectives:

- Conduct literature review on the fatigue performance of steel bridge' superstructures under seismic loading.
- Conduct analytical studies to assess the low and ultra-low cycle fatigue life of the details in question and evaluate if current high-cycle design and retrofit

methodologies are effective for seismic loading.
- Provide practical guidelines for retrofitting existing fatigue prone details to withstand seismic demand.

Research Methods:

The project will focus on conducting finite element analysis of prototype bridges. Detailed 3D finite element models of four prototypes steel bridges, which are located in CO, will be developed and will include the primary and secondary elements of the bridge as well as detailed geometrical characteristics of the connection. Stresses and strains will be evaluated at critical fatigue details and the hotspot stress approach will be used for estimating the fatigue life of the details under traffic loading. In addition, ground motion records will be selected and used to evaluate the performance of the bridges under horizontal and vertical earthquakes. The effect of various geometrical parameters on the performance of the superstructure will be investigated. The applicability of existing retrofit methodologies, used for alleviating high-cycle fatigue problems, for low and ultra-low cycle fatigue will also be examined.

Expected Outcomes:

The project is expected to enhance the knowledge of vulnerability of newly design bridges and effectiveness of retrofitted fatigue-prone details to earthquake loading. Analytical finite element models will be developed and will include various prototype bridges with different connection details and bridge geometry. The models will be used to estimate the high-cycle fatigue life of the details using the hotspot stress approach. In addition, the low cycle and ultra-low cycle fatigue life of the details will also be evaluated using mathematical models that are available in the literature.

Relevance to Strategic Goals:

This project will advance the knowledge on the susceptibility of existing effectiveness of existing fatigue retrofits under earthquake loading. Modifications to the existing repair strategies will be recommended. The project is also expected to allow the transportation agencies to apply effective measures to mitigate and retrofit the questionable details.

The above mentioned project objectives are expected to address various strategic goals including 1) Safety, 2) State of Good Repair, and 3) Economic Competitiveness.

Educational Benefits:

A graduate student will be hired as a research assistant on this project. The findings of the project will be utilized in a graduate course on fatigue and fracture, which will be developed by Dr. Mahmoud.

Work Plan:

Task 1: Conduct literature review

The research team at CSU will conduct a comprehensive literature review to identify common practice for designing and retrofitting fatigue-prone details in steel bridges and if the retrofits consider the seismic demand or only traffic loading.

Task 2: Selection of Prototype Bridges for Analysis

The outcome of the literature review will be utilized to aid in determining the bridge configurations to be used in the analytical studies and the critical parameters to be varied in the analysis. The bridges will be chosen to represent four different prototype steel bridges in Colorado with details susceptible to fatigue cracking. The bridges will be selected with varying parameters including bridge skewness, cross frame layout, depth of girders, etc.

Task 3: Conduct Finite Element Analysis:

Finite element models of the selected bridges will be developed and used to analyze the effectiveness of current fatigue design procedures and retrofit measures in mitigating cracking under earthquake motion.

Task 4: Development of Guidelines for Optimized Retrofit Schemes:

The results of the finite element analysis (FEA) will be used to modify existing methods for designing and retrofitting steel bridges with fatigue details. The retrofit schemes will be optimized to account for the vulnerability of the details along the bridge (i.e., different retrofits will be applied at different location along the bridge).

Task 5: Reporting and Dissemination

A final report will be produced describing the results of the research and will include the retrofit and design recommendations. A seminar focusing on findings of the study will be developed and presented to CDOT engineers and inspectors as well as at national conferences. The results of the study will also be disseminated in the form of scholarly papers which will be published in reputable journals.

Time Line:

	Months							
Task	1-3	4-6	7-9	10-12	13-15	16-18	19-21	22-24
1								
2								
3								
4								
6								

Project Cost:

Total Project Costs: $92,000
MPC Funds Requested: $46,000
Matching Funds: $46,000   Source of Matching Funds: PI research time during the academic year

TRB Keywords: Steel bridges, fatigue cracking, effective retrofits, earthquake loads, low-cycle fatigue, ultra-low cycle fatigue

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