FY 07/08 Research Initial Scope of Work

I. Project Title: **S101**

The Effect of Live Loads on the Seismic Response of Bridges

II. Background:

Live loads are sometimes combined with earthquake loads for seismic design. During the retrofit of the Benecia-Martinez Bridge, a uniform live load of 27 psf was applied across the bridge deck and combined with the seismic load. For the West Spans of the Oakland Bay Bridge a 20 psf uniform live load was applied. The bridges were analyzed with and without the live load and the loading that caused higher demands governed. The additional mass was not considered since the stiffness and damping of vehicles moving across the bridge deck has been difficult to model.

III. Project Problem Statement:

Engineers need to determine if live loads should be combined with earthquake loads for the seismic design of bridges. Current practice is highly arbitrary due to lack of knowledge of how bridges respond to ground motion while supporting vehicles. A parametric study is required that determines when live plus earthquake loads have a significant impact on seismic demands. These parameters may include vehicle and structural mass, damping, and stiffness as well as vehicle placement on the deck. All three orthogonal directions on the bridge need to be studied to see how vehicles modify structural periods and mode shapes. Does traffic moving over a bridge change its earthquake response? Are heavily loaded bridges more vulnerable to earthquake damage? Should the live load be included in the seismic analysis and for what types of bridges?

IV. Objective:

The objective of this research is to determine the influence that live load has on bridge seismic behavior. The final product will be guidelines identifying when live load needs to be considered and how it should be included in the seismic analysis of bridges. It should include the determination of relevant bridge and live load parameters, a database of observations useful for calibration of the models, and descriptions of alternative, simplified methods of analysis for seismic design.

V. Description of Work and Expected Deliverables:

Tasks that shall be considered to achieve these objectives include:

1. Perform a search of the existing literature to determine current state of knowledge on how vehicle loads affect a bridge's response during earthquakes.
2. Look at instrumented bridge earthquake records to see how the response changes based on time of day and the number of vehicles on the bridge.

3. Perform ambient vibration studies on bridges at different times of the day to see if increased traffic changes mode shapes and periods.
4. Perform shake table tests to see how vehicle loading affects structural response and level of earthquake damage.
5. Perform a detailed structural analysis (of the bridges and bridge models studied above) to identify live load parameters that strongly influence earthquake response.
6. Perform a detailed structural analysis to identify bridge parameters that are sensitive to live loads during earthquakes.
7. Determine when live load needs to be considered in seismic analysis of bridges.
8. Develop advanced and simplified procedures for including live load in seismic analysis.
9. Write a detailed report describing research, results, and how to implement them.

VI. Estimate of Duration:

30 months

VII. Related Research:

1. Brady, Sean P (2006). "Effect of Vehicle Velocity on the Dynamic Amplification of a Vehicle Crossing a Simply Supported Bridge." Journal of Bridge Engineering, Vol. 11 No. 2, American Society of Civil Engineers.
2. Brady, Sean P (2006). "Effect of Vehicle Velocity on the Dynamic Amplification of Two Vehicles Crossing a Simply Supported Bridge." Journal of Bridge Engineering, Vol. 11 No. 2, American Society of Civil Engineers.
3. Ghosn, Michel (2005). "Load Combination Factors for Extreme Events." 6th International Bridge Engineering Conference: Reliability, Security, and Sustainability in Bridge Engineering Journal: Transportation Research Record: Journal of the Transportation Research Board No. CD 11-S.
4. Calcada, R. (2005). "Analysis of Traffic-Induced Vibrations in a Cable-Stayed Bridge. Part II: Numerical Modeling and Stochastic Simulation." Journal of Bridge Engineering, Vol. 10 No. 4 American Society of Civil Engineers.
5. Kawatani, Mitsuo (2005). "Three-Dimensional Finite Element Analysis for Traffic-Induced Vibration of a Two-Girder Steel Bridge with Elastomeric Bearings." 6th International Bridge Engineering Conference: Reliability, Security, and Sustainability in Bridge Engineering, Transportation Research Record: Journal of the Transportation Research Board, Transportation Research Board Year.
6. Xia, He, Nan Zhang (2005). "Dynamic Analysis of Railway Bridge Under High-Speed Trains." Computers and Structures, Vol. 83 No. 23-24
7. Li J. (2003) "Natural Frequency Of Railway Girder Bridges Under Vehicle Loads." Journal of Bridge Engineering, Vol. 8 No. 4 American Society of Civil Engineers.
8. Xu, Y.L.(2003). "Dynamic Response of Suspension Bridge to High Wind and

Running Train." Journal of Bridge Engineering, Vol. 8 No. 1 American Society of Civil Engineers.

9. Kim, C.Y. (2003). "Effect of Vehicle Weight on Natural Frequencies of Bridges Measured from Traffic-Induced Vibration, Earthquake Engineering and Engineering Vibration," Vol. 2 No. 1, Science Press.
10. Costantino, C J (1989). "Seismic Effects On Elevated Transit Lines Of The New York City Transit Authority." National Center for Earthquake Engineering Research.
11. ABE, H (1983). "Prediction of Earthquake Motion for Railway Structures." Railway Technical Research Institute, Quarterly Reports, Vol. 24 No. 2 Corp. Japanese National Railways; Railway Technical Research Institute/Tetsudo Gijutsu Kenkyujo.

VIII. Deployment Potential:

Currently, there is no seismic criteria addressing live-load for bridges. Project-specific design criterion has been developed for long-span bridges on a case-by-case basis. Some elements in the seismic design of bridges are well established while other elements are subject to considerable speculation. Research is needed to develop a rational policy to address the issue.

IX. Date: July 18, 2007