FY 07/08 Research Initial Scope of Work

I. Project Title: **S100**

Development of Fragility Curves for In-Span Hinge Unseating

II. Background:

One of the most common (and deadly) collapse mechanisms during earthquakes is for bridges to come apart at hinges. Considerable work has been done recently on developing software to forecast building and lifeline damage due to earthquakes and other disasters. HAZUS software is routinely used by FEMA and government agencies to allocate resources following a disaster. SERA software is used by the Bay Area Rapid Transit (BART) to come up with the cost from various earthquake scenarios in order to develop their seismic retrofit program. REDARS has been used to forecast highway closures in Los Angeles and the Bay Area due to earthquakes on different faults. With AASHTO LRFD and the ATC-35 project, an effort is being made to design bridges so that they will have the same risk of earthquake damage whether they are in Memphis or in San Francisco.

III. Project Problem Statement:

All of these programs rely on a database of the nation's bridges that identifies parameters that makes them vulnerable to ground shaking and other earthquake hazards. They also rely on well-calibrated fragility curves that accurately reflect the likelihood of damage and collapse for varying hazard levels.

The ability of risk software to accurately predict bridge and highway closures has been limited by the information available in the National Bridge Inventory (NBI), which doesn't include parameters such as seat width, column height, retrofit date, etc. that could be used to evaluate the seismic vulnerability of the highway system. Also, fragility curves need to be developed that identify the different vulnerabilities and the likelihood of damage and collapse as the hazards increase in size.

A first step in this effort would be to address the unseating vulnerability of US bridges. Research is required to determine which parameters need to be added to the NBI to capture in-span hinge unseating. Obviously, the seat length is required, but how can the relative stiffness of adjacent frames be captured for each bridge? Then, fragility curves are required that relate the hazard to the likelihood of bridge closure as the expansion joints open and to collapse when the opening becomes too large.

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IV. Objective:

The objective of this research is to develop fragility curves to capture in-span hinge unseating. These curves should relate spectral acceleration (or spectral displacement) to the likelihood of unseating for different structural periods and for different structure types.

V. Description of Work and Expected Deliverables:

1. Perform a search of the existing literature to determine current state of knowledge on fragility curves of bridges.
1. Identify minimum number of parameters that need to be added to NBI to accurately predict in-span hinge unseating.
2. Develop suite of fragility curves that relate ground motion to increased probability of unseating for different periods and different bridge types.
3. Test fragility curves using database of bridge inventories and bridge damage from previous earthquakes.
4. Write a report that identifies additional data required to capture unseating and fragility curves that can be used to calculate risk of unseating for U.S. bridges.

VI. Estimate of Duration:

24 months

VII. Related Research:

1. Luco, N. (2007), "Risk-Targeted Approach to Selecting Return Periods for Design Maps," Third ATC-35/USGS National Earthquake Ground Motion Mapping Workshop.
2. Karim, K.R., (2007). "Effect of Isolation on Fragility Curves of Highway Bridges Based on Simplified Approach," Soil Dynamics and Earthquake Engineering. Vol. 27, no. 5, pp. 414-426.
3. Wang, E.P. (2006) "Optimizing Bridge Seismic Retrofit Strategy: Implementing Bridge Fragility Curves," Proceedings of the 2006 Structures Congress: Structural Engineering and Public Safety.
4. Tien, Y.M., (2006) "Development of Fragility Curves for the 1999 Chi-Chi, Taiwan, Earthquake," 100th Anniversary Earthquake Conference.
5. Nielson, B.G., (2006) "Seismic Fragility Methodology for Highway Bridges," Proceedings of the 2006 Structures Congress: Structural Engineering and Public Safety.
6. Bignell, J.L., (2006) "Seismic Fragility Analysis Of Wall Pier Supported Bridges On Southern Illinois Priority Emergency Routes," 100th Anniversary Earthquake Conference.
7. Campbell, K.W., (2006). "Using HAZUS To Investigate The Impact Of Varying Seismic Hazard Definitions On Scenario Loss Estimates," EOS Transactions, American Geophysical Union. Vol. 87, no. 52, Suppl. 26.

8. Mackie, K. (2004), "Fragility Curves for Reinforced Concrete Highway Overpass Bridges," 13th World Conference on Earthquake Engineering Paper No. 1553.
9. Werner, S.D., (2004) "New Developments In Seismic Risk Analysis Of Highway Systems," 13 WCEE: 13th World Conference on Earthquake Engineering Conference Proceedings
10. Hwang, H. (1999). "Expected Seismic Damage to Memphis Highway Systems," Optimizing Post-Earthquake Lifeline System Reliability, Proceedings of the 5th U.S. Conference on Lifeline Earthquake Engineering; pp. 1-10.

VIII. Deployment Potential:

As a result of this research, Caltrans can identify and retrofit those bridges most at risk from unseating. The risk algorithms that are developed will lead to improved safety of the California highway bridge system and eliminate potential repair costs after an event.

IX. Date: July 18, 2007