FY 07/08 Research Initial Scope of Work

I. Project Title: **S098**

The Effect of Vertical Ground Motion on Column Shear Capacity

II. Background:

There has been a great deal of research during the last few years on vertical ground motion and its impact on bridges. Most of this research suggests that vertical ground motion during earthquakes is not a life-safety issue for most bridges. However, one area where results have caused concern is in the shear capacity of bridge columns. Near a fault, vertical ground motion can put a column into tension for short durations of time, reducing the column's shear capacity to just the shear strength of the transverse reinforcement.

III. Project Problem Statement:

Research is required to determine whether this is a serious problem. One question is whether columns designed to resist shear using the combined shear strength of the concrete and the transverse reinforcement may be vulnerable during high vertical ground motion. This is a complex issue since strong vertical motion occurs near the beginning of the earthquake record and at high frequency. How this couples with the longer period lateral ground motion to cause column shear damage needs to be investigated. Because columns should never fail in shear, further research is required to determine whether vertical ground motion increases the probability of a sheer failure.

IV. Objective:

The objective of this research is to determine the effects of large vertical ground motions on the shear capacity of columns designed using the latest AASHTO LRFD guidelines. If the columns are found to be deficient, then the final product will be recommendations on when vertical ground motion needs to be considered in column design and methods to determine the shear capacity. A comprehensive study of past research will help the researchers determine how to select the largest vertical ground motions that are likely to occur. This may be aided by a determination of the relationship between vertical and lateral ground motion in the frequency domain.

V. Description of Work and Expected Deliverables:

Bridge column tests (designed to the latest AASHTO LRFD Guide Specifications/ Caltrans Seismic Design Criteria) with recorded near-field ground motion on a shaking table will be required. The shaking table should be capable of vertical and lateral motion. Because of the catastrophic nature of shear failure, some precaution

must be taken to prevent damage to equipment (and to personnel) during these tests. The columns should be tested with only lateral ground motion and with a combination of lateral and vertical ground motion to see how the vertical component impacts the column. Single column bents and two-column bents should be tested to see how each performs. If a bent fails in shear, it should be rebuilt with more transverse reinforcement or with other details to make it stronger and retested to see if it can be designed to survive the earthquake. The bent models should be analyzed and their parameters adjusted until the same results are achieved. After the tests, a design procedure should be developed that identifies when vertical acceleration needs to be considered, and how to design the column and bents to survive the combined ground motion without shear failure. The steps includes:

1. Perform a search of the existing literature to determine current state of knowledge on vertical ground motion, how it combines with lateral ground motion, and how it impacts the shear capacity of columns.
2. Select ground motions with large vertical and lateral components that appear likely to damage one and two column bents.
3. Design the bents for the ground motion that would occur at the sites where these recorded ground motions were obtained.
4. Perform shake table tests without and with the vertical component of ground motion to see if bridge bents designed to the current seismic criteria are vulnerable to shear damage.
5. Perform a detailed structural analysis (of the bent models studied above) to identify column and ground motion parameters that cause column damage.
6. Rebuild any bents that failed in shear and retest to see if they can be designed to survive the combined ground motion.
7. Develop advanced and simplified procedures for including vertical ground motion in the seismic design of bents.
8. Write a detailed report describing research, results, and how to implement them.

VI. Estimate of Duration:

30 months

VII. Related Research:

1. Tehranizadeh, M., (2006). “Effects of Near-Field Vertical Ground Motions on Structural Response,” 100th Anniversary Earthquake Conference.
2. Kunnath, S., et al (2006). “Assessment of the Effects of Vertical Ground Motions on Seismic Response of Highway Bridges,” 100th Anniversary Earthquake Conference.
3. Esmaeily, A. (2005) “Behavior of Reinforced Concrete Columns Under Variable Axial Loads,” ACI Structural Journal. Vol. 102, no. 5, pp. 736-744.
4. Bozorgnia, Y., (2004). “Study of the Effect of Near-Source Vertical Ground Motion on Seismic Design of Precast Concrete Cladding Panels,” Journal of

Architectural Engineering. Vol. 10, no. 4, pp. 167-184.

5. Elgamel, A., (2004). "Vertical Earthquake Ground Motion Records: An Overview," Journal of Earthquake Engineering. Vol. 8, no. 5, pp. 663-697.
6. Taniguchi, T. (2004). "Coincident Vertical Response Analysis of Structure at Maximum Horizontal Response," 13th World Conference on Earthquake Engineering Conference Proceedings.
7. Rahai, A. (2004). "Effect of Earthquake Vertical Motion On RC Bridge Piers," 13th World Conference on Earthquake Engineering Conference
8. Ruiz, D. (2004). "Response of Large Span Steel Frames Subjected to Horizontal and Vertical Seismic Motions 13th World Conference on Earthquake Engineering Conference
9. Lopez, O. (2004). "Structural Design for Multi-Component Seismic Motion," 13th World Conference on Earthquake
10. Borzognia, Y. (2004). "The Vertical-to-Horizontal Response Spectral Ratio and Tentative Procedures for Developing Simplified V/H and Vertical Design Spectra," Journal of Earthquake Engineering. Vol. 8, no. 2, pp. 175-207.
11. Campbell, K. (2003). "Updated Near-Source Ground-Motion (Attenuation) Relations for the Horizontal and Vertical Components of Peak Ground Acceleration and Acceleration Response Spectra," Bulletin of the Seismological Society of America. Vol. 93, no. 1, pp. 314-331.
12. Elnashai, A. (2002) "Inelastic Seismic Analysis of RC Bridge Piers Including Flexure-Shear-Axial Interaction," Lee, D H; Elnashai, A S Techno-Press, Structural Engineering and Mechanics (South Korea). Vol. 13, no. 3, pp. 241-260.
13. Elnashia, A. (2001). "A Procedure For Combining Vertical And Horizontal Seismic Action Effects," Journal of Earthquake Engineering. Vol. 5, no. 4, pp. 521-539.

VIII. Deployment Potential:

This research can be implemented into Caltrans Seismic Design Criteria and into the AASHTO LRFD Seismic Guide Specifications.

IX. Date: July 18, 2007