FY 07/08 Research Initial Scope of Work

I. Project Title: **S058**

Effect of Skew on Shear Loads in Multi-cell Box Girder Bridges

II. Background:

If a bridge is skewed in plan view, the exterior girder at the obtuse corner experiences much higher shear force effects than if the bridge were straight. Three-dimensional analysis is required to evaluate the magnitude of this increase. However, most typical bridges are designed using two-dimensional analysis. In the past, a skew factor (Caltrans *Bridge Design Aids* p5-32, 1990) has been used to estimate the appropriate increase in force effects to be used in bridge design. This policy reduced the need for three-dimensional analysis and the resources needed to perform the analysis.

The Department has adopted the *AASHTO LRFD Bridge Design Specifications* that provide skew factor equations. However, the resulting skew factors for multi-cell box girder bridges were based on a grillage model. Grillage modeling does not necessarily capture the torsional force effects correctly. Also, the AASHTO factors were intended for live load distribution only, and direction isn't provided for dead loads.

Currently, Caltrans has directed its designers to use the more conservative factors in Caltrans *Bridge Design Aids*. The factors are based on a limited parametric study that focused on single-span bridges. In the case of multi-span bridges, the skew factors may be over-conservative. This conservatism coupled with new truck loads and improved estimates of prestress losses, has led to girders with excessive construction cost in terms of girder dimensions and bar reinforcing requirements. With a comprehensive parametric study, designers can use a reasonable and constructable girder shear reinforcement design.

III. Project Problem Statement:

Develop skew modification factors for use in designing multi-cell box girder bridges skewed in plan up to 60^o. The multi-cell box girder is one of the most common and economical bridge types in Caltrans' bridge inventory. The *AASHTO LRFD Bridge Design Specifications* are mandated for use on federally funded projects commencing on or after Oct. 1, 2007, and the factors therein aren't adequate for this bridge type unique to primarily California. Without these factors, either bridges will be more costly due to excessive conservatism, or require more design time along with expensive computational tools and training. Therefore, how can we reduce the need for three-dimensional shell-element analysis when designing skewed multi-cell box girder bridges?

FY 07/08 Research Initial Scope of Work

IV. Objective:

The objective of this research is to develop skew factors for bridges that can be applied to two-dimensional analysis of bridges, so the tools and training to do three-dimensional analysis aren't routinely needed. The factors currently being used were developed over 30 years ago based on a parametric study limited to simple-span bridges in a limited range of plan geometries, and, using analytical techniques of the time.

V. Description of Work and Expected Deliverables:

Create a dataset of continuous multi-cell multi-span post-tensioned concrete box girder bridges that capture the full range of cell height-width ratios, depth-to-span ratios, span configurations, column-heights and support fixity, and skews including 0 degrees. This dataset must be approved by the Caltrans Loads and Analysis Committees before work can proceed. (Deliverable 1; teleconference with oversight panel) Then, create solid element bridge models and companion single-spine models with planar supports. All abutments are seat-type. Justify boundary support conditions on the simple models in order to have meaningful comparison to the complex models. Generate permanent, and permanent plus live load shear force effects for both. The influence-surface concept must be used for positioning live loads on the complex models. Recommend skew adjustment factors for shear that, when applied to single-spine analysis, best match the finite element analysis. Justify application of the same factors for both the HL93 and P15 design loads. (Interim or draft final report--Deliverable 2; face-to-face presentation/meeting with oversight panel) Demonstrate application of the skew adjustment factors in an example problem. Calculations are to show both the load and shear resistance using 'β-θ' method. Match analytical results with a set of example torsion calculations. (Deliverable 3—including written response to panel questions and comments) Submit final report. (Deliverable 4) Make final presentation to AASHTO T5. (Location TBD--Deliverable 5).

VI. Estimate of Duration:

18 months

VII. Related Research:

Wallace, Mark R. "Skew Parameter Studies – An Implementation of the Finite Element Program, CELL", Caltrans Research Report CA-DOT-DS-1129-1-76-3, June 1975

Sennah, M. and Kennedy, J. "Literature Review in Analysis of Box-Girder Bridges", *Journal of Bridge Engineering* p134-143, March/April 2002

Zokaie, T., Osterkamp, T., and Imbsen, R. "Distribution of Wheel Loads on Highway Bridges", Final Report (Volumes I and II) for NCHRP 12-26, March 1991
Wallace, Mark R. "Skew Parameter Studies – An Implementation of the Finite Element Program, CELL", Caltrans Research Report CA-DOT-DS-1129-1-76-3, June 1975

Sennah, M. and Kennedy, J. "Literature Review in Analysis of Box-Girder Bridges", *Journal of Bridge Engineering* p134-143, March/April 2002

Zokaie, T., Osterkamp, T., and Imbsen, R. "Distribution of Wheel Loads on Highway Bridges", Final Report (Volumes I and II) for NCHRP 12-26, March 1991

VIII. Deployment Potential:

Deployable product will be either a simple California Amendment to Section 4 of the *AASHTO LRFD Bridge Design Specifications*, and/or a re-issue of *Bridge Design Aids* pp5-31 thru 5-38.

IX. Date: July 18, 2007