FY 16/17 Research Initial Scope of Work

I. Project Title:

Accurate Damping Model for Nonlinear Time History Analysis

II. Project Problem Statement:

Nonlinear seismic time history analysis has been used in several cases for analysis of important bridges with good success. Recent advances in software and analysis methods have made it possible to perform nonlinear analysis of most bridges in an efficient manner. Guidelines are available for preparation of analysis models which can capture nonlinear behavior of most components. However, modeling of damping has not changed in recent years and most common modeling technique is Rayleigh damping with mass and stiffness proportional matrices. Studies are needed to find the most appropriate damping model and to calibrate damping values for best results.

III. Problem Statement Background/Context:

Nonlinear time history analysis (NLTHA) tools are becoming more commonly available to engineers. These tools are mainly available in general-purpose analysis software such as SAP2000 and OpenSees. The choice of modeling details can have a major effect on the results of analysis and the efficiency of the model. While most components' nonlinear behavior can be captured relatively well with current capabilities, modeling of the damping is by-and-large unknown. Most engineers use Rayleigh damping mainly due to its convenience. However, here is disagreement among experts as to what level of damping (2% to 5%) to use when hysteretic damping is modeled in plastic hinges and abutment backfill springs, or if initial or tangent or secant stiffness shall be used. For example, when abutment backfill springs are models with cyclic behavior, some recommend not to include the stiffness of such elements in calculation of damping matrices. In recent trial studies at Caltrans it was found applying Rayleigh damping to abutment backfill spring models for a typical two-span bridge affected maximum bent displacements by more than 50%.

IV. Research Objective:

To perform parametric studies and laboratory tests to determine the best damping model, whether Rayleigh, a modified version of it, or other method, to obtain the best analytical results. The analytical studies are expected to consider various nonlinear components' behaviors, and be confirmed with laboratory experiments. Laboratory tests are expected to include multiple-span bridges on shake tables and study the effect of backfill as well as the structure's nonlinear components, and may be performed as part of this study if appropriate results are not available.

V. Support California Bridges & Structure Strategic Direction:
(http://onramp.dot.ca.gov/hq/des/spi/docs/Final_California_Bridges_Structures_Strategic_Direction_9-11-14.pdf)

The proposed research work will improve the second step of performance based earthquake engineering which is well line with California Bridges and Structures Strategic Direction 2014 - Objectives 3, 8, 12 and associated Strategies 3.1, 8.1, 8.3, & 12.2.

VI. Description of Work:

It is our goal to develop guidelines for modeling damping that can produce results with highest possible accuracy. The following are the issues to be studied:

- Is Rayleigh damping the most appropriate model for NLTHA
- What periods should be used for calculating the masa and stiffness ratios
- What level of damping should be used to determine the mass and stiffness ratios
- What stiffness matrix should be used in calculating damping matrices
- What stiffness elements, if any (hinges, shear keys, support springs, foundation/shaft springs, isolation bearings), should be skipped when calculating damping matrices

It is anticipated that OpenSees is the most efficient tool for this study. However, other tools such as CSiBridge or Midas-Civil are more commonly used in practice due to their graphical interface. Experimental study is also an important part of this study and does require facilities that can tests multi-span bridges with and without abutment soil model.

Report and guidelines that are based on available and improved software, and can be published and used for consistent, efficient and reliable seismic analysis of ordinary bridges. The report shall outline the best methods for modeling of damping for nonlinear time history analysis, and the sensitivity of analytical results to deviations from such models.

VII. Related Research:

FY 16/17 Research Initial Scope of Work

VIII. Deliverables/Deployment Potential:

The outcome of this research will include guidelines for more accurate modeling of damping in structural analysis. It may also include recommendations for damping models that are not currently available in commercial software. In addition example shall be provided to illustrate sensitivity of the analytical results to deviations from the best/recommended models.

High - Time History Analysis is accepted as the most reliable method for seismic analysis of bridges. Having reliable guidelines and tools that allows bridge engineers to use this method for design of ordinary bridges will improve safety and sustainability of the transportation system across California and enhance the performance of bridges in seismic events.

IX. Sponsor: Office of Earthquake Engineering
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