Caltrans-PEER Lifelines Research Program

Request for Proposal 2016-01

Proposal Submission Deadline: Nov. 14, 2016

Over 70% of Caltrans' nearly 13,000 bridges and a similar number of local agency-owned bridges have design loads that are dominated by seismic loading. Several hundred more bridges cross active fault zones and roughly a thousand more are potentially vulnerable to the effects of liquefaction. Though fewer than 50 Caltrans bridges are vulnerable to tsunamis, a large number of local agency-owned bridges are located near the Pacific shoreline and subject to tsunami inundation.

These seismic hazards represent both a threat to life safety and a potential for prolonged operational downtime. Geographic scope of the hazards and bridges exposed to seismic hazards incorporates most regions of the state and all major population centers. Caltrans' seismic retrofit program has made great strides in improving the capacity of bridges to withstand earthquakes. However, this program has not completely eliminated the seismic threat with 75% of the State bridge inventory remaining unretrofitted. Furthermore, knowledge about the location and nature of potential earthquake sources continues to improve as does our ability to predict the level of ground shaking resulting from an earthquake as well as to determine the consequent response and performance of bridges subjected to different levels of ground shaking. Since retrofitting bridges is expensive, Caltrans has adopted a cost effective strategy of investing research funds to better characterize these hazards and the consequent bridge performance, so that retrofit and other forms of mitigation can be efficiently focused where the risk is highest.

The Caltrans-PEER Lifelines Research Program addresses a number of seismic research topics that support this strategy. The program will conduct research in six earthquake related topic/task areas. The primary objective in each task is the development of practical engineering models and/or guidance documents that improve the characterization of seismic hazards for engineering design and the determination of the consequent structural response and earthquake performance of bridges subjected to the characterized hazard. Some tasks focus also on cost effective strategies for addressing these hazards. This Request For Proposals (RFP) document provides details on one of these tasks.

Objective: Develop methods and criteria for distinguishing between non-convergence in nonlinear time-history analysis and physical collapse.

Background: Caltrans is exploring ways to adopt Performance-Based Earthquake Engineering (PBEE) concepts into design practice. Most schemes include consideration of both operational and safety (non-collapse) performance objectives. In the most basic manner, the safety performance objective will be defined in terms of an "acceptable" probability of collapse. Furthermore, performance definition in probabilistic terms, such as the prediction of the probability distribution of downtime and repair losses considering different sources of uncertainty, is of importance to Caltrans. For these objectives, collapse should be quantified as realistically as possible, using Nonlinear Time-History Analysis (NTHA) which incorporates several suites of ground motions, each representative of a specific Intensity Measure (IM) of the hazard level. The resulting distribution of Engineering Demand Parameters (EDP's), from the ground motions that do not lead to collapse, will be used in conjunction with component level fragility curves to estimate the probability of reaching or exceeding different damage states.

A challenge with the proposed analysis procedure is that at high levels of loading, a significant percentage of nonlinear time history analyses fail to converge. Ignoring these runs completely may result in a substantial underestimation of the true collapse probability. Conversely, assuming all instances of non-convergence reflect physical collapse would result in an overestimation of the collapse probability.

When nonlinear time history analyses fail to be completed, how should they be interpreted? Realistic collapse criteria and well-defined descriptions are needed to identify whether a run termination was due to imminent collapse or just a numerical, non-collapse related convergence issue. If a termination was not due to the onset of collapse, does the termination suggest an elevated probability that it would have collapsed if the analysis had been able to continue?

Recommendations are also sought for mitigation of non-convergence problems using improved numerical methods such as explicit integration or adaptive switching between integration methods and nonlinear solvers.

Requirements: Recommendations should be applicable to modern reinforced concrete highway bridges. Proposed solutions must be implementable in several software platforms including *OpenSees* and *CSiBridge*.

Project Duration: 12 months (up to $100,000)

Proposal Submission Instructions:

1. Proposals are due by 11:59 PM (PST) on November 14, 2016.

2. Use the PEER-Lifelines proposal blank form posted at:
   http://peer.berkeley.edu/lifelines/rfp/

3. Proposals should be submitted (uploaded) via PEER web site at:
   http://peer.berkeley.edu/lifelines/rfp/

4. According to the Master Agreement between the funding agency and the University of California, **for this RFP**, only public universities are eligible to submit proposals. Other research projects funded by PEER generally have less restrictive requirements.

5. Proposals should have the following "PEER-Lifelines Proposal – Non-Convergence" as part of their title.

6. At this point, proposals need not to be submitted via organizations' official sponsored project offices. However, a budget sheet is required (the last page of the blank proposal form).

7. Items typically allowed for the budget include (but are not limited to): Support for undergraduate or graduate students and postdocs (however, non-resident tuition **cannot** be charged to this Caltrans-sponsored project), summer support for faculty, cost for computational and/or experimental research, domestic travel, and indirect cost as specified in the budget form.

Questions about this RFP should be sent by **11:59 PM, October 31, 2016** to the PEER website at http://peer.berkeley.edu/lifelines/rfp/. Questions and responses will be posted to the same website around 5 PM, November 4, 2016.