Pacific Earthquake Engineering Research Center (PEER)

PEER Transportation Systems Research Program – Request for Proposals: Solicitation PEER TRSP-10-01

Research strategy

PEER has continuing funding from the State of California related to the seismic performance of transportation systems. The purpose of this research is to lessen the impacts of earthquakes on California's transportation systems, including highways and bridges, port facilities, high speed rail, and airports. We expect that the research undertaken will utilize and extend PEER's performance-based earthquake engineering (PBEE) methodologies and integrate fundamental knowledge, enabling technologies and systems. We further expect that the overall research program will integrate seismological, geotechnical, structural, and socio-economical aspects of earthquake engineering, and involve computational, experimental and theoretical investigations.

The planning and selection of projects within the Transportation Systems Research Program (TSRP) will consider how individual projects strategically contribute to (1) fundamental knowledge, enabling technologies, or systems integration, and (2) advances in the areas of transportation systems, bridges, ports, and railways. Some projects may focus on one issue, while others may span across several. The PEER TSRP is being developed to focus on strategic goals considering input and suggestions from researchers and practitioners in the PEER community. It is being coordinated with ongoing research efforts of the PEER Lifelines program, Caltrans, and other State DOT's. This may result in some worthwhile proposals being funded in later years so that they can benefit from knowledge or tools generated in earlier years.

More than twenty active research projects are currently underway. A partial list of funded projects and presentation slides related to the ongoing research can be found on the PEER Transportation Research Program website at: http://peer.berkeley.edu/transportation/index.html

The PEER TSRP is coordinated by a Transportation Research Committee (TRC) consisting of Yousef Bozorgnia, Joel Conte, Steve Kramer and Bozidar Stojadinovic. The TRC is committed to fostering a diverse mix of educational and collaborative opportunities across the PEER community. This includes opportunities for researcher and practitioner interactions.

Many of the projects are interrelated and it is anticipated that investigators selected will interact with the TRC and other PEER investigators as part of an integrated team to help achieve the overall goals of the TSRP. Investigators are expected to attend two coordination meetings each year. To maximize development of accessible computational tools that can be used to model transportation systems, it is expected that the primary computational framework used in these investigations will be OpenSees.

Process & important dates

Proposals should be submitted using the downloadable **form** that has been posted on the website (see the link below). The project description should not exceed two pages, and a two-page biographical sketch of the PI(s) should be included along with a one-page draft budget. Final budgets with campus Sponsored Project Office (SPO) approval can be prepared after selection of successful proposals and agreement on final scope and budget.

Proposals **should be submitted on-line** at:

http://peer.berkeley.edu/transportation/request_for_proposals.html

The **key dates** for responding to Solicitation PEER TSRP-10-01 are:

November 30, 2010: Proposals due online.
December 15, 2010: Successful proposals will be identified, and paperwork for funding initiated.

The proposals will be reviewed by a small ad hoc review committee and administered by the TRC.

Budgetary constraints

Budgets should be limited to one month of summer support (or its equivalent) for the PI, one graduate student researcher, reasonable miscellaneous funds (travel to two PEER coordination meetings per year, travel to the PEER annual meeting, computing, and supplies), and any other costs specific to the type of proposals (e.g., experimental costs). Due to the source of funds for the TSRP, the indirect costs recovery rate for University of California campuses is zero. Other campuses and organizations are also strongly encouraged to apply the same indirect cost rate.

Other requirements

For this solicitation, principal investigators submitting proposals must be a faculty member at one of PEER's core institutions. BIP and researchers at other institutions may be included as subawardees in proposals submitted by eligible PIs.

The TRC may approach proposers to negotiate possible revisions to scope and budget to better fit overall program goals.

Specific research topics for this solicitation:

Proposals are solicited for research on the following seven topics. Note that projects will not necessarily be awarded in all topic areas, and multiple projects in some areas are possible. PEER will provide the ground motion ensembles to be used in projects addressing these research topics.

1. Ground motion studies for improving PBEE analysis and design

Incremental Dynamic Analysis (IDA) methodologies are used as part of PEER's PBEE approach, as well as by others, to assess the collapse potential of transportation and other structures. However, current IDA techniques suffer from a number of conceptual and practical limitations. Thus, studies to improve current approaches for assessing risk of collapse, with applications to multi-degree-of-freedom systems with more than a single load path capable of resisting collapse are of interest. Studies to streamline the IDA procedure with a goal to make it amenable for use in design practice are also of interest (Target project duration: 1 year)

2. Prediction of Ground Deformations and Related Damage

Bridges and other transportation structures are susceptible to damage from transient and permanent ground deformations. A number of procedures for estimation of ground deformations are available – these range from empirical procedures based on field case histories to more complicated procedures based on sophisticated numerical analyses, an increasing number of which have seen use in practice and research in recent years. Prediction of earthquake losses depends on the accuracy and uncertainty of ground deformation predictions, which may vary from one set of soil conditions to another. Proposals focused on characterization and/or reduction of ground deformation uncertainty are sought. Within this general area, specific items of interest include:

a. Assessment of protocols for use of advanced numerical analyses for multi-dimensional response analyses, and benchmarking of analyses with emphasis on characterization of model uncertainty in their predictions for soft/weak (but non-liquefiable) and liquefiable soils. (Target project duration: 2 years)
b. Studies of the cyclic and permanent deformation characteristics of transitional soils. These would include marginal plasticity soils (e.g., low-plasticity silts, sandy silts, silty sands) and large-particle soils (i.e., gravelly sands and sandy gravels). This work would include review and summary of past work and a laboratory testing program. (Target project duration: 1-2 years)
c. Investigation of the relationship between damage and ground deformations; a literature review and survey of current practice, along with soil-foundation-structure interaction analyses, are needed to characterize the capacities of transportation structures to accommodate ground deformations. This information can then be used to improve performance-based prediction of damage and loss from ground deformations. (Target project duration: 1-2 years)

3. Seismic Performance of Underground Construction

Urban congestion has led to the increasing use of underground transportation structures. These structures can range from relatively shallow cut-and-cover structures to deep bored tunnels, and can involve a wide variety of different soil conditions. The performance criteria for these structures can also vary significantly, as the structures can range from a simple two-lane roadway undercrossing to a structure used for high-speed rail travel. Because underground structures have not received a great deal of attention from the research community to date, a thorough literature review is needed. The results of recent and planned tests, for example, at the E-Defense shaking table, should be incorporated into the review. There is also a need to better understand the fundamental kinematic and inertial response of underground structures, in terms of both contact stresses and deformations, for different soil/structure conditions and over a wide range of ground shaking levels. The project should evaluate existing analytical methods for prediction of that response, and explore the development of simplified tools for approximating the response of such structures. While this work would emphasize underground transportation structures, its results could have important applications for other underground structures such as pipelines, buried water tanks, and other infrastructure elements. (Target project duration: 1-2 years)

4. **Learning from Past Earthquakes**

In the past few years, transportation systems and components of the type constructed in the western part of the US were strongly shaken by earthquakes world wide (e.g., 2008 Wenchuan; 2010 Ferndale, CA; 2010 Chile; 2010 Baja California; 2010 Canterbury region, NZ, etc.). These events provide a unique opportunity to assess current design and analysis methods highway and railway structures, ports, waterways, and airports, especially where strong motion instrumentation is available on or near the system. Summary of findings and the lessons learned from the recent earthquakes are not restricted to but shall include: quantitative characterization of instrumented transportation infrastructure, performance of infrastructure systems employing new technologies, and characterization of systems that exhibiting unusual modes of behavior. Note that PEER is already funding research related to the response of the instrumented central channel crossing of the Humboldt Bay Bridge at Samoa, CA during the 2010 Ferndale area earthquake. (Target project duration: 1 year)

5. **Advanced technologies for resilient bridge columns**

PEER's transportation systems research is currently investigating several earthquake resistant bridge column concepts based on advanced technologies and new materials. These are intended to reduce the construction cost, accelerate construction speed and minimize post-earthquake damage and disruption for bridge systems. PEER seeks to continue and expand this research effort. Specifically, PEER is seeking proposals to investigate the potential for modular and accelerated construction technologies, possibly coupled with new and composite materials and/or response modification techniques to design the next-generation resilient bridges. Due to budget limitations, proposals should focus on one approach, rather than on a comprehensive array of systems and techniques. However, researchers are invited to submit proposals that contain an integrated conceptual, analytical, experimental and design study. (Target project duration: 2 years)

6. **Detailed PBEE studies of a next generation bridge system**

It is desired to apply the PEER PBEE methodology to assess the seismic performance of a particular type of bridge, improve the underlying theoretical and empirical basis of the methodology as needed, and identify the characteristics of the bridge system considered that are most effective in improving performance. Previously, detailed PEER investigations have focused on partially prestressed, reinforced concrete self-centering bridges, conventional reinforced concrete bridges on firm soil sites as well as sites susceptible to liquefaction, skewed bridges, and bridges with rocking/uplifting foundations. Proposals are now being sought that extend these earlier studies to include in-depth consideration of PBEE issues related to one particular type of bridge system. Specific issues of interest include bridges (a) having curved, irregular or other configurations that might induce higher than expected demands, (b) situated on soil conditions that may impose special demands, or (c) incorporate advanced technologies such as modular or precast construction procedures, seismic isolation or other innovative strategies. The accepted team is expected to work with the Transportation Research Committee to develop the testbed bridge configuration. This testbed may be used by others for future PBEE assessments of other bridge types. Multi-investigator teams may be proposed to cover the range of expertise needed. (Target project duration: 2 years)

7. Further development of PEER performance-based earthquake engineering methodology

The performance-based earthquake engineering (PBEE) methodology developed by PEER in the last decade integrates probabilistically, using the total probability theorem, seismic hazard analysis, structural/geotechnical response analysis, capacity/damage analysis, and loss/consequence analysis, in order to provide probabilistic measures of seismic performance of structural, geotechnical, and soil-foundation-structure-interaction (SFSI) systems, accounting for all pertinent sources of uncertainty related to earthquake intensity, ground motion time history, parameters of structural and soil materials, modeling & prediction uncertainty, repair techniques & costs, repair time, casualties & injuries, etc.

Proposals extending the existing PBEE methodology while applying it to actual structural, geotechnical and SFSI systems, with real-world complexities, are sought. (Target duration: 1-2 years). Specific items of interest include, but are not limited to, the following:

a. Inclusion of multiple ground motion component input and vector-valued ground motion intensity measures (for both single and multiple component earthquakes) in the PBEE methodology. The earthquake response of actual structural and geotechnical systems, three-dimensional in nature, is often strongly statistically correlated to more than one (scalar) ground motion intensity measure. Full-blown and simplified treatment of vector-valued intensity measures in the PBEE methodology are of interest.

b. Approach to define the seismic input for distributed/long-span systems, e.g., long bridge with discrete (i.e., p-y, t-z, Q-z springs) and continuous modeling of the foundation soil. Issues of spatial distribution of earthquake ground motions with wave passage and incoherence effects must be addressed.

c. Approach to include near-fault pulse-like ground motion effects in the PBEE methodology.

d. Verification of the typical assumptions made in the formulation of the PBEE methodology. Such assumptions include: the conditional independence between the analysis stages through the use of the intermediate variables (IM, EDP, DM).

e. Inclusion of the statistical dependence between EDPs (i.e, inclusion of vector-valued EDPs) and various damage mechanisms in the PBEE methodology.

f. Investigation of the effects of modeling uncertainty at various levels (e.g., seismic hazard, material and kinematic models of the system) on the probabilistic performance assessment results in the context of an existing or new test-bed based on a real structural, geotechnical or SFSI system.

To date, the PEER PBEE methodology has focused mainly on probabilistic performance assessment of a given structure at a given location with a specified seismic hazard (a forward analysis). However, the design of a new structural, geotechnical, and SFSI system requires an inverse PBEE analysis consisting of determining how to design or re-design a system rated for given seismic performance objectives expressed in probabilistic terms. Proposals focusing on the development of a performance-based design framework closely related to the PEER PBEE analysis methodology (i.e., formulated as an inverse PBEE analysis) are sought with application to an existing or new test-bed. (Target duration: 2 years)