PEER Request for Proposal:
Solicitation TSRP-PEER 18-01

Introduction

The Pacific Earthquake Engineering Research (PEER) is a multi-campus center that has continuing funding from the State of California related to the seismic performance of transportation systems. This funding supports the Transportation Systems Research Program (TSRP), the purpose of which is to lessen the impacts of earthquakes on the transportation systems of California, including highways and bridges, port facilities, high-speed rail, and airports.

Funding from the TSRP supports transportation-related research that uses and extends PEER's performance-based earthquake engineering (PBEE) methodologies, and integrates fundamental knowledge, enabling technologies and systems. The program also aims to integrate seismological, geotechnical, structural, hydrodynamic and socio-economical aspects of earthquake engineering, and involve theoretical, computational, experimental and field investigations. The program encourages vigorous interactions between practitioners and researchers.

The PEER TSRP is coordinated by a Research Committee (PEER-RC) consisting of Pedro Arduino (University of Washington), Jack Baker (Stanford University), Judy Liu (Oregon State University), Khalid Mosalam (ex-officio, University of California, Berkeley), Gilberto Mosqueda (University of California, San Diego), and Tom Shantz (ex-officio, Caltrans). Proposals will be reviewed by external reviewers, who will be determined by this committee, among experts who have not submitted proposals.

Requested Proposals

The PEER-RC is soliciting proposals for one- and two-year projects related to the seismic and tsunami performance of transportation systems. The proposed projects should be aligned with the current TSRP research priorities (Appendix A) and vision (http://peer.berkeley.edu/transportation).

Regardless of the technical area, all projects must:

1. be led by investigators from the PEER core institutions[1]. *PEER Business and Industry Partners (BIPs)* interested in this solicitation are strongly encouraged to collaborate with the researchers at PEER's core institutions and submit a joint proposal.
2. contribute substantially to the PBEE of transportation systems.
3. enable substantial progress for a reasonable investment (e.g., based on previous research or matching opportunities).
4. have significant broader impacts and potential to be expanded as bigger projects.

[1]PEER combines resources of major research universities in western USA (UC Berkeley, CALTECH, OSU, Stanford, UC Davis, UCI, UCLA, UCSD, UNR, USC, and UW) where earthquake hazards are largest.

Investigators must commit to:

1. working as part of the overall TSRP team, sharing information, data, models, outcomes and ideas needed for other projects.
2. attending coordination meetings every six months, with one of these meetings usually coinciding with the PEER Annual Meeting.
3. submitting two-page progress reports every six months, approximately one month before the meeting date, for review by the PEER-RC, and
4. writing a PEER report documenting the project contributions.

Where possible, the projects should:

1. leverage the investments of other programs within or outside of PEER.
2. engage the practitioner community.
3. use OpenSEES as the primary computational platform, and if applicable, contribute (or improve) and document new elements, material models or numerical solution strategies and share any developed analytical models with the PEER community. PEER researchers are encouraged to incorporate NHERI SimCenter computational tools as appropriate in their research proposals. Details of SimCenter computational tools can be found at https://simcenter.designsafe-ci.org/research-tools/overview/, these include many tools, e.g. uncertainty quantification with OpenSEES and other finite element codes, computational wind tools, PBE tools, and a large 1.8M building regional seismic risk workflow example that can be leveraged for multiple purposes. All SimCenter software is open source and thus ideally suited for research use and modification. Tools are designed to run locally as well as on DesignSafe/TACC[2].
4. if experimental in nature, use the PEER core institution testing facilities and organize blind prediction contests from the test outcomes, if possible.

In addition to the considerations above, projects will be selected to result in a diversity of areas of specialization, a variety of research institutions, and a range of investigator seniority.

Proposals in this round are expected to have annual budget **not to exceed $100,000**. The review process for the proposals will involve external reviewers selected by the PEER-RC. As an outcome of this RFP, funding is expected for 5 to 7 projects, which will amount to a total of **approximately half a million dollars of research funding**. All proposed research will be subject to final approval by the PEER Director.

A list of the current and past TSRP projects is posted on the PEER website at: https://peer.berkeley.edu/research/transportation-systems/projects.

Proposal Submission Instructions

Format

Submit proposals online at https://peer.berkeley.edu/research/transportation-systems/request-proposals. Proposals should be submitted using the form found in the above site and should include:

[2]Texas Advanced Computing Center

- a two-page project description
- a two-page biographical sketch of the PI(s), and
- a one-page draft budget.

Budget

All proposed work should be completed within a period less than or equal to two years. Annual budgets should be limited to:

1. one month of summer support (or its equivalent) for the PI,
2. one graduate student researcher,
3. experimental expenses,
4. computing expenses,
5. travel to two PEER coordination meetings (including the PEER annual meeting) per year,
6. project-related supplies, and
7. other reasonable expenses, as approved by the PEER-RC.

It is expected that proposing institutions will waive indirect costs, as is the practice for University of California institutions. Final budgets with campus Sponsored Project Office (SPO) approval can be prepared after the initial selection of successful proposals, and agreement on scope and budget.

To meet the needs of the TSRP program, PEER-RC may approach proposers to negotiate possible revisions to scope and budget to better fit the program goals. For projects that extend beyond one year, the awarding of funds for the 2nd year will be contingent upon available funds and on satisfactory project progress.

Important Dates

The **key dates** for responding to Solicitation PEER 18-01 are:
15 October 2018: proposal submission deadline
14 December 2018: completion of the review process of all proposals
15 January 2019: project start date

Appendix A: Research Topics for this Solicitation

Proposals are solicited for research on the topics listed in this appendix. Projects will not likely be awarded in all areas, and it is possible that multiple projects will be selected in some areas.

Geotechnical Engineering

The longer-term TSRP research priorities in the geotechnical area are summarized on the PEER TSRP website. For this solicitation, it is expected that the TSRP will focus on important research needs and opportunities that exist in the area of soil liquefaction. Proposals are solicited to address the following issues:

G.1. Triggering criteria: Critical controversies over the selection of triggering criteria can be resolved with data gathering and evaluation from recent earthquakes in New Zealand and Japan, in cooperation with partners from those countries.

G.2. Estimation of permanent deformations: The empirical or semi-empirical estimates of predictions of permanent soil deformations have been shown to produce highly uncertain estimates. Detailed testing and analysis programs are needed to develop the scientific basis for estimates of permanent deformation, and numerical models need to be validated.

G.3. Constitutive modeling: Development and validation of constitutive models for soils subjected to cyclic loads (including sands, clays and intermediate soils) to be used in 2D and 3D geotechnical modeling are needed. Furthermore, parameters of existing constitutive models should be calibrated. These studies can be complemented with numerical and experimental studies at multiple scales including the use of CT scan images and DEM simulations to understand behavior.

PBEE of Bridge and Other Transportation Systems

Over the past 15 years, much progress has been made in development of consistent estimates of ground-motion hazard. Numerical models have been developed to improve the estimates of structural response, and in some cases, the likelihood of damage. Far less progress has been made in evaluating the consequences of damage in terms of the resilience, including the downtime, cost of repair or demolition, of transportation facilities.

In the past, the TSRP has supported the development of enabling tools and technology integration mainly in the area of the evaluation of existing technologies. Recently, TSRP has supported shaking table tests of different new damage-resistant, self-centering column systems, repaired columns and conventional cast-in-place concrete columns. Based on the results of these tests, improved systems might be developed, which would then need to be tested.

Port facilities, high-speed rail infrastructure and airports are critical systems. The disruption of their functionality after an earthquake may lead to severe negative consequences on a community. Such systems provide opportunities to evaluate the benefits of PBEE beyond those currently considered by the TSRP.

Proposals are solicited to address the following issues:

S.1. Development of the fundamental knowledge, as well as enabling technologies for transportation systems to make it possible for decision-makers to evaluate life-cycle design options, for example, proposals could address the following questions: How does damage to transportation systems affect functionality? What are the costs of loss of functionality? What are the cost of repair, demolition and replacement of damaged facilities?

S.2. Evaluation of cost, seismic resilience, durability and constructability of new bridge systems (such as those with self-centering resilient columns or other protective systems) as one of the most promising applications of PBEE. Herein, it is expected to develop/evaluate new systems within the PBEE framework. In addition, mechanical properties and sustainability characteristics of promising new materials must be established to enable the design of such systems.

S.3. Studying ports, high-speed rails and airports with PBEE or PBTE (Performance-based Tsunami Engineering) to evaluate the severity of earthquake and tsunami damage consequences and to incorporate Earthquake Early Warning (EEW) systems to maintain functionality of these systems.

PBEE Methodology

The performance-based earthquake engineering (PBEE) methodology developed by PEER in the last decade integrates probabilistically seismic and tsunami hazard analysis, structural/geotechnical response analysis, capacity/damage analysis, and loss/consequence analysis. The methodology seeks 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 and prediction uncertainty, repair techniques, as well as costs, downtime, casualties and injuries.

Proposals extending the existing PBEE methodology and applying it to structural, geotechnical and SFSI transportation systems with real-world complexities, are encouraged in these areas:

M.1. Improved characterization of ground motions and hazard intensity for PBEE and consideration of ground motion effects (such as pulses or multi-directional characteristics) that influence response of structures.

M.2. Physical simulation of earthquakes as input to the structural analysis stage of PBEE.

M.3. So far, the development of the PEER PBEE methodology has focused mainly on the forward analysis (i.e., computation of the probabilistic performance assessment of a given structural and/or geotechnical system at a given location with a specified seismic hazard). This forward analysis is needed for the seismic assessment of existing structures. However, the design of new structural, geotechnical, and SFSI system or retrofit of existing systems 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.

M.4. Hybrid simulation and shaking table tests of conventional and resilient bridge systems that can provide input to the structural and damage analysis stages of the PBEE methodology.

M5. Cost effective instrumentation and field testing of bridges and development of testbeds for validating PBEE approaches.

M.6. Use of protective systems in transportation networks that validate PBEE approaches.

PBEE Tools

The relative complexity of PBEE has been an obstacle to widespread adoption of this methodology. Tools must continue to be developed to ease the consideration of ground-motion and tsunami hazard, geotechnical and structural response computations, and consequences to design and analysis. These tools must make it possible for decision-makers to understand the magnitudes and consequences of uncertainties, and to optimize the designs.

OpenSees provides the main platform for integrating the various aspects of PBEE. This enabling technology makes it possible to consider the hazard, geotechnical, structural engineering and economic aspects of a PBEE analysis. OpenSees also provides tools for optimization, as well as for evaluation of sensitivities and uncertainties. The development of improved elements, material constitutive models and numerical solution strategies in OpenSees will remain a priority for the PEER-TSRP. Within the OpenSees environment, reliable and convenient tools are needed and proposals are solicited in the following areas:

T.1. Visualization, data mining and artificial intelligence tools needed to facilitate checking and generation of input data and evaluation of output data, including uncertainty quantification.

T.2. Improvement or verification of highly nonlinear elements and materials, necessary for modeling structures to the point of collapse.

T.3. Tools needed for incorporating a wide range of uncertainties into the PBEE of transportation systems.

T.4. Further research focused on highly complex models that include tens of thousands of variables and large networks.

Areas of Application

The TSRP will continue to devote most of its application-specific research funds to the PBEE of new and existing highway bridges. In addition, the PEER-RC encourages investigators to submit applications in the following three areas of application:

A.1. Earthquakes during the past few years in Chile and Japan have highlighted the threat of tsunamis on the coastal transportation infrastructure. Research is needed to develop the design and evaluation criteria, the methodologies and the tools needed to incorporate tsunamis into the performance evaluation of port facilities and design of bridges.

A.2. The development of high-speed rail networks provides an ideal application for PBEE. These systems have new design criteria (passenger comfort, extreme seismic reliability expectations) and complex structures (dynamics, track vibration, long geometries). Research is needed to develop the fundamental knowledge necessary to develop the PBEE basis for such systems.

A.3. Going beyond earthquakes and learning from past development of PBEE in the face of earthquakes, proposals are solicited in extending the PBEE methodologies to other natural hazards including multi-hazards applied to transportation systems.