PEER Request for Proposal:
Solicitation TSRP-PEER 19-01

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 and related systems. This funding supports the Transportation Systems Research Program (TSRP), the purpose of which is to lessen the impacts of earthquakes and other natural hazards on the transportation systems of California, including highways and bridges, port facilities, high-speed rail, airports, and other related systems.

Funding from the TSRP supports transportation-related research that uses and extends PEER's performance-based engineering (PBE) 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 PEER Research Committee (PEER-RC). Proposals will be reviewed by external reviewers, who will be determined by this committee, among experts who have not submitted proposals to this solicitation.

Requested Proposals

The PEER-RC is soliciting proposals for one- and two-year projects related to the performance of transportation and related systems exposed to seismic, tsunami and other natural hazards. The proposed projects should be aligned with the current TSRP research priorities (Appendix A) and vision (http://peer.berkeley.edu/transportation). Each investigator is limited to be the PI on **one** proposal only. However, an investigator may be a co-PI on unlimited number of proposals.

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 PBE of transportation systems,
3. Enable substantial progress for a reasonable investment (e.g., based on previous research or matching opportunities), and
4. Have significant broader impacts and potential to be expanded as bigger projects.

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[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 at least two meetings per each year of funding: the PEER Annual Meeting (usually held in January) and the PEER Researchers' Workshop (usually held in summer),
3. Submitting a research highlight at the beginning of the project for distribution to the PEER community,
4. Writing a PEER report at the end of the project, documenting the project contributions, and
5. In the case of two-year projects, submitting a detailed progress report at the end of the first year, along with a plan for the second year, for review by the PEER-RC.

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.
4. Incorporate NHERI SimCenter computational tools as appropriate in the proposed research. 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].
5. If experimental in nature, use the PEER core institution testing facilities and organize blind prediction contests from the test outcomes, if possible, with additional in-kind support from the PEER headquarters staff and researchers.

In addition to the above considerations, projects will be selected to result in a diversity of specialization.

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 10 projects. In addition to the regular research proposals, proposals focusing on organizing workshops in one of the areas in Appendix A will be accepted in this round. These workshop proposals are limited to a budget of **$20,000**. Depending on the number of proposals, funding is expected for up to 3 proposals in this category. The total amount of provided funding is expected to be **approximately $600,000**. All proposed research and workshops 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.

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[2] Texas Advanced Computing Center

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 including:

- a two-page project description
- a two-page biographical sketch of the PI(s), and
- a one-page draft budget.
- Filename of the attachment should follow the format:
  "<category>_<Last name>_RFP2019_<optional title less than 50 characters>"

  for example:

  "M5_Mosalam_RFP2019_Resilient bridge column testing-hybrid simulation.pdf (.doc)"
  or
  "A1_Buckle_RFP2019.pdf (or .doc)"

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 any negotiated agreement on scope and budget.

To meet the needs of the TSRP program, PEER-RC may approach proposers to negotiate possible revisions to the scope and budget to better fit the program goals.

Important Dates

The **key dates** for responding to Solicitation PEER 19-01 are:
15 October 2019: submitting questions to peer_center@berkeley.edu
31 October 2019: proposal submission deadline
16 December 2019: completion of the review and selection process of all proposals
1 February 2020: 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 of the 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. Near fault ground motions at high intensities of shaking (such as the Maximum Considered Earthquake, MCE level) can lead to highly nonlinear soil response and the developed constitutive models should be able to simulate this nonlinear response accurately.

G.4. Site characterization: Better geology considerations are needed for site characterization, including integrated site characterization. Furthermore, there is a need for the development and usage of new intensity measures to characterize liquefaction.

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 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 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 can 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 or other natural hazards may lead to severe negative consequences on a community. Such systems provide opportunities to evaluate the benefits of PBE beyond those currently considered by the TSRP.

Proposals are solicited to address the following issues:

S.1. Develop 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 costs of repair, demolition and replacement of damaged facilities?

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

S.3. Study ports, high-speed rails and airports with PBE to evaluate the severity of damage and its consequence caused by earthquakes, tsunami, and other natural hazards and to incorporate Early Warning Systems (EWS) to maintain functionality of these systems.

PBE Methodology

The performance-based earthquake engineering (PBEE) methodology developed by PEER in the last decade integrates probabilistic 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 to other natural hazards 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, consideration of ground motion effects (such as pulses or multi-directional characteristics) that influence response of structures for increased understanding of near-fault ground motions and their effects on transportation systems, and development of consistent models for intensity measures other than spectral acceleration (e.g. Fourier amplitude spectrum, Arias intensity, Cumulative absolute velocity, etc.).

M.2. Physical simulation of earthquakes as input to the structural analysis stage of PBEE making use of physics-based and stochastic ground motion modeling and development of non-ergodic

Ground Motion Prediction Equations (GMPEs) as an effective approach to improve ground motion modeling and hazard analysis.

M.3. Forward uncertainty quantification: This includes record-to-record variability, parameter uncertainty, modeling uncertainty, and material uncertainty with investigation of these uncertainties on important bridges, port facilities, airports, etc. Other related topics are lifecycle cost analysis and Bayesian calibration for parameter identification.

M.4. Backward uncertainty quantification: This includes its use for performance-based design, benchmarking current design practice, development of simplified performance-design procedures (e.g. trading off between design parameters), use of optimization and multi-fidelity analyses in performance-based design, and performance-based design for a network, not only for a single facility.

M.5. Hybrid simulation and shaking table tests of conventional and innovative bridge systems that can provide input to the structural and damage analysis stages of the PBE methodology including blind predictions for modeling uncertainty quantification.

M.6. Cost effective instrumentation and field testing of bridges and other structures including development of testbeds for validating PBE approaches, collecting data and developing effective models and algorithms for artificial intelligence and machine learning methods, making use of technologies such as non-contact measurement methods, laser scanning, laser-based sensors, mobile sensing systems, UAV, etc.

M.7. Use of protective systems in transportation networks that validate PBE approaches and also developing cost effective retrofit methods for existing bridges and their evaluation using PBE methods applied to single facility or a network of multiple components and sub-systems.

PBE Tools

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

OpenSEES provides an important platform for integrating the various aspects of PBE. This enabling technology makes it possible to consider the hazard, geotechnical, structural engineering and economic aspects of a PBE 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, including various modeling aspects relevant to transportation systems subjected to natural hazards, such as soil-structure interaction, and fluid-structure interaction.

T.3. Tools for incorporating a wide range of uncertainties into the PBE of transportation and other related systems.

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

T.5. Tools for increasing resilience through analytical simulations, experiments and field studies (e.g. extreme events, such as earthquakes, reconnaissance efforts).

Areas of Application

The TSRP will continue to devote most of its application-specific research funds to the PBE 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 and fires on the coastal transportation infrastructure. Research is needed to develop the design and evaluation criteria, the methodologies and the tools needed to incorporate tsunamis and fires 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 PBE. These systems have new design criteria (passenger comfort, extreme seismic and wind reliability expectations) and complex structures (dynamics, track vibration, long geometries). Research is needed to develop the fundamental knowledge necessary to develop the PBE 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.