BridgePBEE
Workshop & Training Session

PEER Annual Meeting
Berkeley, CA
October 27, 2012

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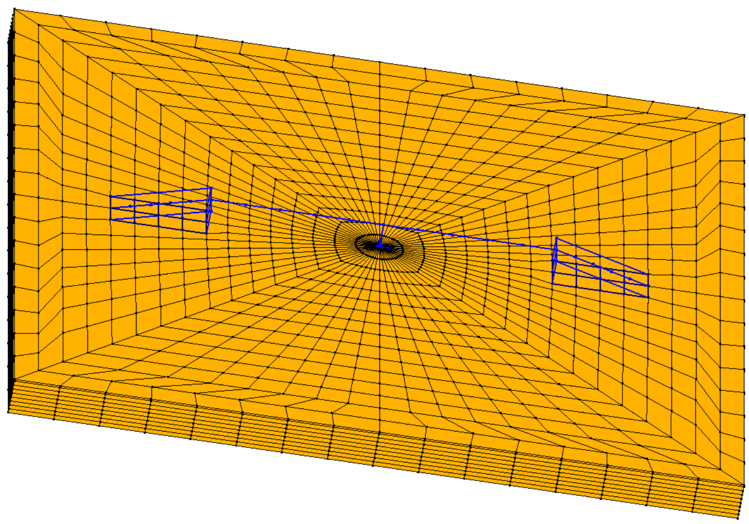

http://peer.berkeley.edu/bridgepbee/

Overview & Introduction to BridgePBEE

BridgePBEE is a PC-based graphical pre- and post-processor (user-interface) for conducting performance-based earthquake engineering (PBEE) studies for bridge-ground systems. The user interface allows for: 1.) management of ground motions, 2.) simplified structure and soil mesh generation, 3.) simplified assignment of material properties for both the soil and structure, 4.) time history and PBEE analyses, and 5.) visualization of output data. The current version of the interface is limited to ordinary bridge overpasses with two spans and a single-column bent. In addition to full PBEE analysis, the interface can also visualize pushover analysis, modal analysis, and single 3D base input acceleration analysis.

The interface is unique because it enables complete PBEE studies in a single GUI-driven package. The PBEE implementation employed is based on the PEER Center's performance-based earthquake engineering framework, and the underlying finite element computations are performed using OpenSees. The framework includes several building blocks (intermediate probabilistic models) that allow the user to generate probabilistic estimates of repair cost and repair time (consequences or decision variables) directly. These results are obtained seamlessly in the interface alongside more traditional outputs such as displacements, strains, etc.

The intermediate models require:

- Hazard model that uses earthquake ground motion data to determine an intensity measure (IM)
- Demand model uses response from dynamic analysis to determine an engineering demand parameter (EDP)
- Damage model connects the EDP to a damage measure (DM) or discrete set of damage states (DS)
- Repair model describes repair methods and repair quantities (Q) necessary to return the DSs to original functionality
- Loss model links Qs to consequences that are termed the decision variables (DV). Repair cost and repair time can be thought of as two possible decision variable (DV) outcomes characterized probabilistically by the framework.

The models are required for each performance group (PG). PGs represent a collection of structural components that act as a global-level indicator of structural performance and that contribute significantly to repair-level decisions. Performance groups are not necessarily the same as load-resisting structural components. The interface handles all of the above-mentioned intermediate models and provides default data for the case of reinforced concrete box girder bridges. The decision variables that can be generated as output are the repair cost ratio (RCR), or the ratio of repair cost to replacement cost, and the repair time (RT) or repair effort, measured in terms of crew working days (CWD).

PBEE outcomes are presented graphically as loss models conditioned on earthquake intensity. In addition, site-specific ground motion hazard can be specified, and the user-interface will then also generate loss hazard curves (mean annual frequencies of exceeding different loss levels). The loss hazard curves are presented graphically as mean annual frequencies or return periods. An important feature of the interface is that the PBEE analysis can be executed sequentially: ground motion selection, time history analysis, loss modeling, hazard, and visualization. However, once a final selection of geometry and materials has been made (the FEA model is not changing), the time history analyses do not need to be repeated. These are the most time and resources intensive portions of the complete analyses. Once the time history results are computed, the user may perform what-if scenarios by changing any of the parameters of the intermediate damage, loss, and hazard models.

Getting Started

It will be helpful to download the "rigid base" input files from the BridgePBEE website (PBEE analysis of a bridge on rigid ground – Example 3) as a way of performing faster computations to get yourself better acquainted with BridgePBEE. In addition, download the various available ground motion bin sets. It is not necessary to use all of them, or even all of the motions within each bin, but be aware of the format if you plan to find some of your own ground motions for analysis. You may want to begin with (for example) 10 ground motions and run either Example 3 (rigid base) or Example 5 (simple soil mesh) just to acquaint yourself with the software and possible outputs.

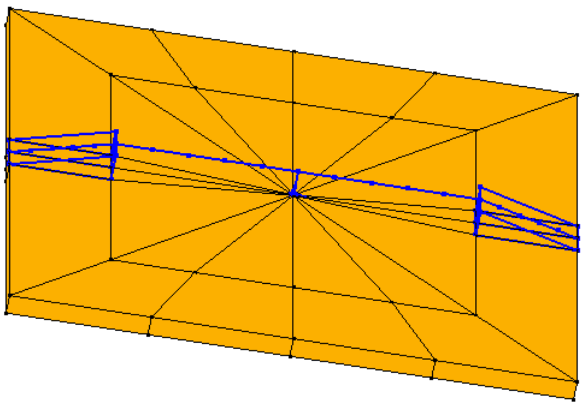

FIGURE 1 - Mesh for Example 3

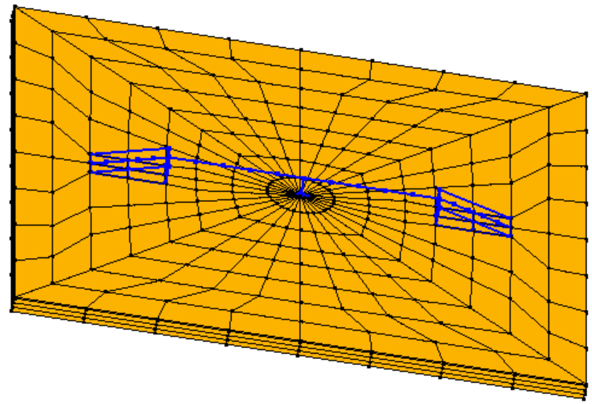

FIGURE 2 - Mesh for Example 5

Finally, the user manual will be an indispensable resource, it is available online, or follow this link directly:
http://peer.berkeley.edu/bridgepbee/wp-content/uploads/2011/11/BridgePBEE_UserManual_2011Dec.pdf

Investigations & Assignment

Using BridgePBEE as a tool for bridge performance investigation, select one of the following topics. You should be able to complete a majority of the time history analyses before coming to the workshop due to the time constraints of obtaining response data for dense soil meshes. It is recommended that you use the Example 3 mesh (or something similar) when performing PBEE investigations (many ground motions), or the Example 5 mesh (with a limited subset of ground motions) when performing structural/geotechnical response investigations. The investigations are categorized by anticipated difficulty and previous experience of the user (particularly with PBEE).

Relatively easy, no previous experience necessary

- Perform an analysis of how many ground motions you need to stabilize results. While 3 or 7 ground motions may give a realistic estimate (and some statistical information) for response of single structures, look at how many motions you may need to stabilize losses. Look not only at the trends in the demand models (ensemble responses), but also the effect of ground motion numbers of different loss quantities (you will likely come up different suggestions as the loss metric changes from repair cost to repair time).
- Selection and scaling of ground motions: sensitivity of demand and loss response. Given the ability to select different bins and scale motions in the ground motion module, as well as the ability to identify maximum responses by bin in the ensemble response plots, consider the effects of ground motion selection on any of: individual time histories of response, demand model (ensemble response) trends, or the loss model.
- Minimize the overall losses by modifying the properties of the column. Vary the properties within reason (the models were not intended to properly reproduce behavior of 15 ft diameter columns, for example).
- Effect of bridge constitutive model parameters on losses. Experiment with changing the constitutive models for steel or concrete, for example. What effect do these changes have

on the triggering of losses in different performance groups (look at the disaggregation plots after PBEE analysis). This may also include coming up with a column design with the same strength but different longitudinal reinforcement ratio, or different diameter, etc.

Moderate, some prior knowledge of time history analysis and PBEE a plus

- Comparison of near-fault and directivity effects (from ground motions) on demand and loss response. Similar to the selection and scaling investigation, consider addition of ground motions with possible directivity effects. Consider the alignment of the fault normal and fault parallel components of the motions with respect to the individual time histories of response, demand model (ensemble response) trends, or the loss model.
- Sensitivity to meshing (superstructure mass for example, or mesh refinement of soil domain). BridgePBEE allows control over mesh refinement in the column, superstructure, and soil domain. Without generating excessively dense soil meshes, look at the stabilization of response or loss quantities as you refine the mesh.
- Attempt to select soil parameters so that the bridge effectively becomes “isolated”. Assess isolation by the relative contribution of the column, superstructure, and abutment performance groups on the losses (look at the disaggregation plots after PBEE analysis).
- Parametric study that assesses the effect of bridge geometry on losses. For example, what trends are there in losses (and the relative contributions to loss coming from each performance group) due to modification of basic design parameters like column diameters, column heights, or span lengths.

Difficult, these require more analysis, inputting your own motions, or modifying the code

- Effect of soil constitutive models (and model parameters) on losses. How sensitive are the triggering of different performance group losses to the soil models (look at the disaggregation plots after PBEE analysis)? This may include selecting constitutive model parameters to give different strength and stiffness profiles with depth to see the effect on overall losses.
- Come up with a BridgePBEE model to compare to the San Diego single column shake table blind (now hind) contest. See http://nisee2.berkeley.edu/peer/prediction_contest/ for details of the test and data. This would only be a comparison of response (not PBEE quantities).
- Try and modify BridgePBEE and recompile to perform some PBEE parameter sensitivity studies. The manual gives directions on how to modify damage states, repair quantities, unit costs, and production rates. This may include attempting to analyze a bridge with differenct components than the default RC ones in the interface (for example, the columns are constructed using ECC).
- Assess the sensitivity of losses to the selection of the abutment model as well as the parameters for each abutment model. Note that there are many abutment models available, so do not try and look at sensitivities to all model and parameters, but focus on one or two models and the parameters that control stiffness, gap size, etc. Make sure to verify effect on losses by looking at the disaggregation of loss by bearing and abutment performance groups.