PEER
PACIFIC EARTHQUAKE ENGINEERING RESEARCH CENTER

Research Project Highlight

Resolution of Non-Convergence Issues in Seismic Response Analysis of Bridges

Project # Lifelines Non-Convergence

Principal Investigator
Professor Filip C. Filippou, UC Berkeley

Research Team
- Thanh N. Do, Postdoctoral Researcher, UC Berkeley
- Jade Cohen, Graduate Student Researcher, UC Berkeley
- Jiawei Chen, Graduate Student Researcher, UC Berkeley

Start-End Dates:
6/1/2017-5/31/2018

Abstract
The project will develop guidelines for overcoming non-convergence issues under large displacements and corresponding deformations for bridge structures under extreme seismic excitations. Such guidelines will allow users to perform robust nonlinear dynamic analyses (NDAs), and assess the collapse risk of bridge structures in a fashion consistent with physical behavior and experimental observations.

Analytical models for typical reinforced concrete bridges in California (refer to *Project Image a*) will be generated for study. After identifying the sources of numerical non-convergence in nonlinear bridge models, the following three critical aspects will be addressed simultaneously: 1) material models, 2) element models, 3) solution strategies. Material models with robust non-convergence characteristics at large strain that are suitable for bridge analyses will be identified. Bridge piers will be represented with nonlinear elements that account for the complex interaction of axial, flexural, and shear forces without resorting to external zero-length spring or hinge elements which introduce additional global degrees of freedom (DOF) leading to numerical sensitivities under the unbalanced dynamic forces at these DOFs. Adaptive solution strategies will be developed in the form of solution scripts with intelligent switching between suitable nonlinear solution schemes and integration methods in response to monitored local and global variables. Because of the interaction between the nested iterations between element, section and material, it is important to coordinate the evaluation of the structural, element, and material response with the help of intelligent solution scripts.

An extensive set of NDAs under a large ensemble of ground motions will then be performed to develop guidelines for robust NDAs and the consistent collapse risk assessment of bridges. Collapse fragility

Resolution of Non-Convergence Issues in Seismic Response Analysis of Bridges

curves (refer to *Project Image b*) will be used to correlate different Engineering Demand Parameters (EDPs) at relevant limit states in order to identify realistic criteria for describing physical collapse.

Deliverables

The project will result in a PEER report and a few conference and journal papers describing the cause of non-convergence in selected case studies of NDAs of bridges, the recommended material and element models and solution strategies for robust NDAs, and the criteria for describing the physical collapse of bridge models.

Research Impact

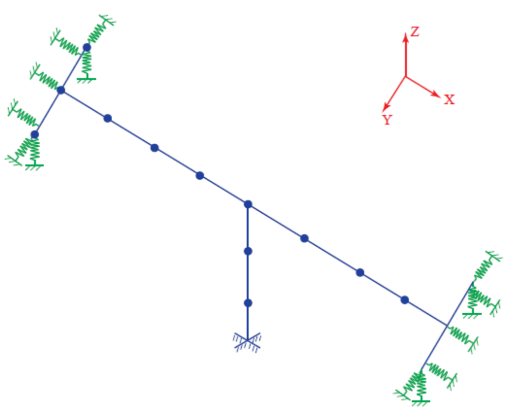
The Performance-Based Earthquake Engineering (PBEE) concepts show great promise for improving design practice. The safety performance objective is defined in terms of an “acceptable” probability of collapse. Collapse shall be quantified as realistically as possible, using NDA which incorporates several suites of ground motions. A challenge with the proposed analysis procedure is that under 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 as representing physical collapse would result in an overestimation of the collapse probability.

A comprehensive set of guidelines will form the starting point for addressing the complexity inherent in nonlinear softening response under large displacements and deformations and will contribute to the acceptance of nonlinear response studies in professional practice. The deployment of a new class of bridge pier models that account for localized phenomena such as shear and reinforcement pull-out in a consistent iterative element formulation will help minimize the non-convergence issues that arise with the large collection of zero length nonlinear spring and plastic hinge elements currently in use in nonlinear bridge response simulations. The development of intelligent nonlinear solution strategies that coordinate the structure, element and material state determination will improve the state of the art and practice of nonlinear dynamic analysis of structures for sophisticated structural elements accounting for multi-axial interaction and several local phenomena. The standardized templates for element testing and NDAs of bridge structures will form the starting point for the collaborative growth of improved methods for nonlinear dynamic analysis of bridge models. It stands to reason that these tools will be useful for other types of structures.

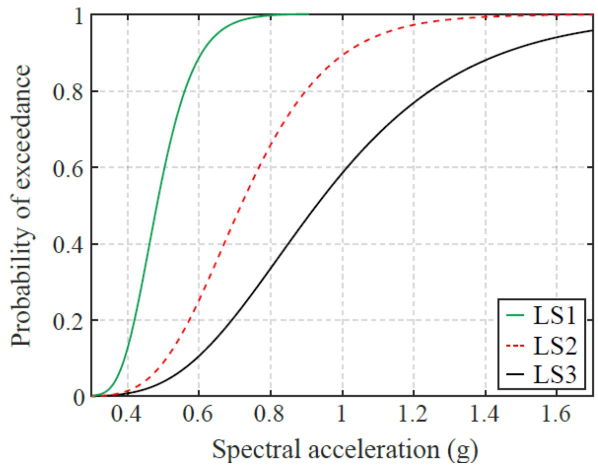
Research Project Highlight

Resolution of Non-Convergence Issues in Seismic Response Analysis of Bridges

Project Images



(a) Analytical model of a typical bridge



(b) Sample fragility curve of a bridge component

PEER Center – 325 Davis Hall, UC Berkeley, CA 94720 | peer_center@berkeley.edu