Doctoral Defense

“Modeling, Behavior and Design of Collapse-Resistant Steel Frame Buildings”

Honghao Li

Date: April 23, 2013
Time: 11:30 am
Location: 2355 GGB

Chair: Sherif El-Tawil
Professor, Civil & Environmental Engineering

Progressive collapse is a complex process in which failure of a single component of a structure leads to collapse of a disproportionately large part of the system. Recent building and bridge failures have highlighted the seriousness of such events and generated widespread research interest. The objective of this study is to address current gaps in the progressive collapse research area, focusing specifically on seismically-designed steel frame structures.

Four different types of nonlinear dynamic computational models are created for a prototype 10-story special moment frame building. The models include a 3-D micro-model, 3-D macro-model, planar micro-model and planar macro-model. After calibration and validation, the models are used to conduct a comprehensive study of the effect of various types of modeling approximations on simulated collapse behavior. The numerical results show that accounting for 3-D effects, specifically the floor slab, is critical for accurate collapse modeling. It is also shown that well-calibrated macro-models can be accurate and that the results of planar analyses are not necessarily conservative.

Simulation results suggest that the prototype building is more vulnerable to loss of columns in the upper stories than in the lower ones and is particularly vulnerable to loss of interior gravity columns at all floor levels. The simulation models are used to clarify the role of different structural components and parameters at the various stages of collapse response. The floor slab is shown to contribute significantly to the robustness of the structure, especially at the early stages of collapse; however, it is a double edge sword that can also be detrimental in the final stages of collapse.

Design requirements in the Unified Facilities Criteria published by the US Department of Defense are evaluated using the developed models. Simulations studies show that the Tie Force Method is effective in protecting buildings from progressive collapse and can significantly reduce deformation under column loss scenarios. However, the Dynamic Impact Factor proposed in the document is deemed problematic and a new energy-based approach is proposed to assess the peak dynamic displacement. The new method is shown to be accurate and reasonably conservative.