Advanced Seismic Assessment Guidelines
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Advanced Seismic Assessment Guidelines, developed by researchers at Stanford University and tested and refined by structural engineering practitioners, offer improvement over previous methods for seismic evaluation of buildings where post-earthquake safety is a concern. The *Guidelines* consist of two documents, published by the Pacific Earthquake Engineering Research (PEER) Center: *Advanced Seismic Assessment Guidelines* (PEER report 2006/05) lays out the principles of the method and its probabilistic basis. *Test Applications of Advanced Seismic Assessment Guidelines* (PEER report 2005/09) presents case studies of example buildings, and it offers recommendations on technical issues for engineers applying the method.

Features of the *Guidelines* include:

- Green Tag, Yellow Tag, and Red Tag as quantifiable performance levels. The *Guidelines* define these performance levels based on the capacity of the damaged structure (after a hypothetical earthquake) to survive an aftershock without collapse.
- Probability-based approach. The method incorporates estimates of uncertainty regarding how a building will respond to ground motions, as well as uncertainty about structural capacity. End products of the method include fragility curves, which present the probability of achieving each performance level for any level of seismic hazard.
- Structural analysis of the "Intact" structure and the "Damaged" structure in several hypothetical damaged conditions. In addition to analyzing a building in its intact (pre-earthquake) condition, the *Advanced Seismic Assessment* method also includes analysis of the damaged (post-earthquake) structure to assess the structure's remaining capacity to withstand aftershocks.
- Emphasis on identifying the structure's governing mechanism of nonlinear response. Engineers use the principles of capacity design to determine which structural elements will yield first in an earthquake and how the post-yield behavior of these elements (e.g. ductility, strength gain, and strength degradation) affect the overall earthquake-resisting capacity of the building.
- Use of the *SPO2IDA* [5] program to infer nonlinear dynamic response results from nonlinear static analysis. Given a nonlinear static force-displacement relationship (pushover curve) and the fundamental period of vibration of a building, *SPO2IDA* infers nonlinear dynamic behavior of the structure using empirical relationships derived from incremental dynamic

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[5] Vamvatsikos, D. and Cornell, C.A., 2002, "Direct Estimation of the Seismic Demand and Capacity of Oscillators with Multi-Linear Static Pushovers through Incremental Dynamic Analysis," *Proceedings of the 7th National Conference on Earthquake Engineering*: Boston, July.

analyses of thousands of single-degree-of-freedom systems having different force-displacement characteristics and subjected to different ground motions. This program provides a consistent and practical method for addressing behavior characteristics such as strength degradation.
- A method for including the effect of residual drift on the capacity of the damaged structure to resist aftershocks.

The basic steps of the *Advanced Seismic Assessment* method are as follows:
- Step 1: Nonlinear analysis of the intact structure
- Step 2: Nonlinear analysis of the damaged structure in several hypothetical damaged conditions
- Step 3: Occupancy limit states (Figure 1)
- Step 4: Fragility curves for each limit state

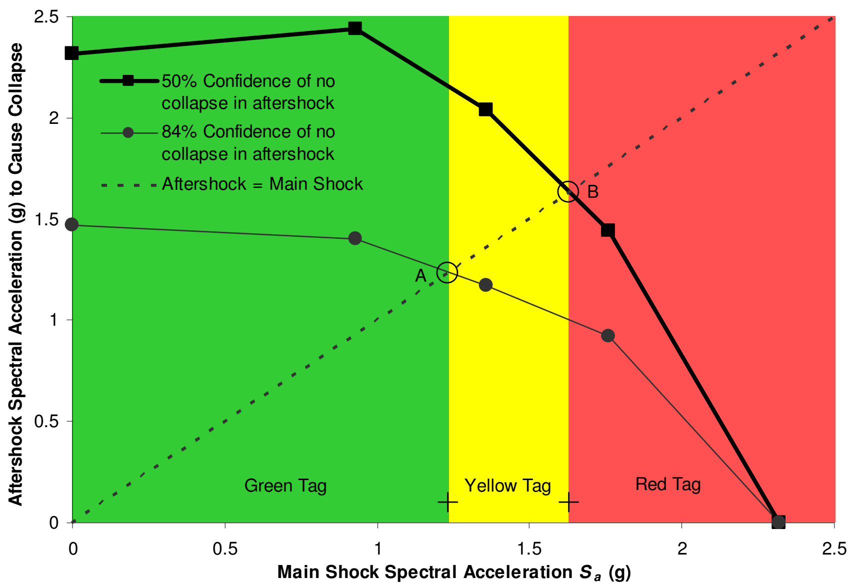

Figure 1. Occupancy limit states. For a given spectral acceleration demand, the building's expected seismic performance level (Green Tag, Yellow Tag, or Red Tag) is based on the capacity of the damaged structure (after an earthquake) to survive an aftershock without collapse. This figure plots the main-shock spectral acceleration to cause each damage state (from Step 1) versus the aftershock acceleration that would collapse the damaged structure (from Step 2). Point A marks the limit state "Onset of Yellow Tag"; point B marks "Onset of Red Tag."

Rutherford & Chekene Consulting Engineers has used this method to perform seismic assessments for several buildings in the Pacific Gas & Electric Company utility network. For each building, PG&E identified seismic performance goals in terms of the post-earthquake occupancy "tagging" required to enable PG&E personnel to safely perform essential duties following an earthquake. For example, an electrical substation should achieve Yellow Tag or Green Tag performance so that PG&E technicians may safely access switching equipment in the building to help bring power networks back online, in the event of outages caused by an earthquake.

In several cases, the method demonstrated that the desired performance can be achieved with a reduced scope of retrofitting compared to previous methods. PG&E has completed retrofit work for some of these buildings, and others are in progress.