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nehrp SeismicWaves

How the National Earthquake Hazards Reduction Program Is Advancing Earthquake Safety

From Prescriptive to Predictive

Milestones on the Road Toward Performance-Based Seismic Design

Prescriptive building codes and standards, which specify types of materials that must be used and how they must be designed and constructed, govern the design of most new buildings in the United States. Buildings designed in accordance with such regulations provide "life safety" for their occupants. This means that occupants will normally be able to exit these buildings safely after earthquakes as powerful as those planned for in their designs. However, costly damage may still occur. Direct costs can accrue through needed repairs or, worse, demolition and replacement. Moreover, the buildings may not be able to accommodate their former occupants and functions for some time. These effects can greatly impact the *resilience* of a community, that is, its ability to "bounce back" to prior levels of economic and social activity.

Professionals involved in designing buildings in earthquake-prone areas—and the building regulators, owners, tenants, lenders, and insurers that have a stake in these designs—are typically concerned about costs and resilience as well as safety. Designers have been working for two decades to enable improved consideration of earthquake risks through the development of **Performance-Based Seismic Design** (PBSD), and they are entering an important stage of this work.

PBSD—What's Different About It?

When designing under prescriptive building codes, engineers follow code-prescribed design specifications, normally with the intent of providing life-safety protection for occupants.[1] Under PBSD, a building's designers and stakeholders specify the level of earthquake protection, or seismic performance, that they desire for the structure, which can be higher than the code-prescribed life-safety level, and engineers then develop a building-specific design tailored to provide that level of performance.

Once PBSD methods are fully developed, engineers will be able to assess how design or retrofit options will affect the seismic performance of buildings and to measure this performance in terms of the risks that are important to building stakeholders, allowing the costs and benefits of alternative performance levels to be evaluated. When stakeholders select the desired level of seismic performance for a building, PBSD will enable engineers to devise design solutions that may be more economical or efficient than those prescribed in codes, and to show building regulators that these designs will meet or exceed the performance achievable through prescriptive code compliance.

FEMA Shepherds Advances in PBSD Methods

The Federal Emergency Management Agency (FEMA) began developing the first formal PBSD approach in the early 1990s, for use in seismically retrofitting existing buildings. These early procedures were refined over the years and eventually published as an American Society of Civil Engineers (ASCE) standard in 2006 (ASCE/SEI Standard 41-06, *Seismic Rehabilitation of Existing Buildings*). This is regarded as the first generation of PBSD.

Based on extensive interaction with leading seismic-design practitioners and researchers, FEMA recognized the limitations of these first-generation procedures, and in 2001, engaged the Applied Technology Council (ATC)[2] in the first phase of a two-phase project to develop next-generation PBSD procedures using *Next-Generation Performance-Based Seismic Design Guidelines: Program Plan for New and Existing Buildings*, published as FEMA 445. Known as the ATC-58 project, this work has since drawn upon the expertise of many leading practitioners and researchers.[3]

The first phase of the project is producing a PBSD performance-assessment methodology and the computer-based Performance Assessment Calculation Tool (PACT). For any new or retrofit building design, the methodology will identify all structural and nonstructural components and systems that are vulnerable to earthquake-induced damage, relate potential earthquake

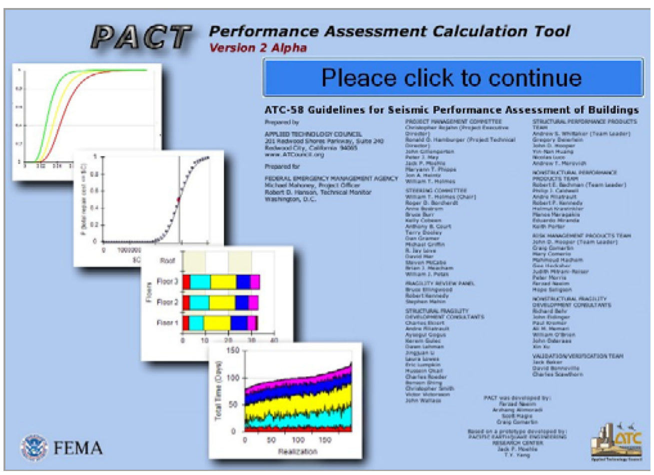
[1] Current model building codes contain simplified provisions for designing buildings whose contents or functions pose greater risk than minimum life safety. These provisions largely focus on increasing design force levels, to provide greater margins of safety in building performance in anticipated earthquakes.

[2] The nonprofit ATC (www.atcouncil.org/) develops and promotes state-of-the-art, user-friendly engineering resources and applications for use in mitigating the effects of natural and other hazards on the built environment.

[3] See the ATC-58 Project Overview at www.atcouncil.org/Projects/atc-58-project.html.

intensities to levels of expected damage in these components, and relate expected damages to their risk-specific consequences, resulting in predicted seismic performance. PACT will help designers compile design-specific seismic hazard and building data and, with embedded fragility and consequence data, perform the calculations required by the methodology.

The first phase of the ATC-58 project is scheduled to be completed in early 2012, and the results of this work will be published by FEMA under publication number FEMA P-58. The second phase of the project was designed to allow for further refinement of the PBSD methodology and for the development of three ancillary products: a design guideline showing use of the methodology for several building types; an implementation guide for building owners; and for PACT, an expanded database containing fragility functions for additional building components. However, recent reductions in the budget for FEMA's earthquake mitigation program have for the time being halted plans to proceed with this phase.



Sample screen from PACT, currently under development for the Federal Emergency Management Agency by the Applied Technology Council.

NIST Paves the Way for Next-Generation Implementation

Recognizing that additional research is needed to develop the data and tools required to support full implementation of the new PBSD methodology, the National Institute of Standards and Technology (NIST) engaged the Building Seismic Safety Council (BSSC)[4] to identify and report on these research needs. The BSSC consulted experts with extensive PBSD experience who prepared a report for NIST containing a prioritized list of 33 recommended research topics.[5] The topics were all deemed to be in need of immediate attention, either to encourage greater use of first-generation PBSD or to take full advantage of the forthcoming next-generation methodology. The report stated that full implementation of next-generation PBSD will require "robust data on the expected seismic performance of most, if not all, structural systems, nonstructural components and systems, foundations, and supporting soil types as well as improved ability to predict the specific characteristics of ground motions at any site."[6]

NIST has responded by initiating several ongoing projects that target high-priority research needs identified in the report. They include benchmarking studies aimed at delineating appropriate and effective use of first-generation PBSD procedures; research designed to improve the accuracy of the earthquake ground motions input to PBSD methodologies; and studies focused on refining the analytical models that predict how a building's response to ground motions will be influenced by soil-structure interaction.

NIST plans to conduct or support additional high-priority research over the next several years, and the National Science Foundation is including the BSSC report as a reference in its research solicitations. Through these concerted activities, NEHRP will continue to contribute to the development and implementation of next-generation PBSD.

[4] The BSSC (www.nibs.org/index.php/bssc) is a membership council established by the National Institute of Building Sciences to develop and promote building earthquake risk-mitigation regulatory provisions for the Nation.
[5] BSSC. (2009). *Research Required to Support Full Implementation of Performance-Based Seismic Design*, NIST GCR 09-917-2 (www.nehrp.gov/pdf/NISTGCR09-917-2.pdf).
[6] BSSC, *Research Required*, 7.