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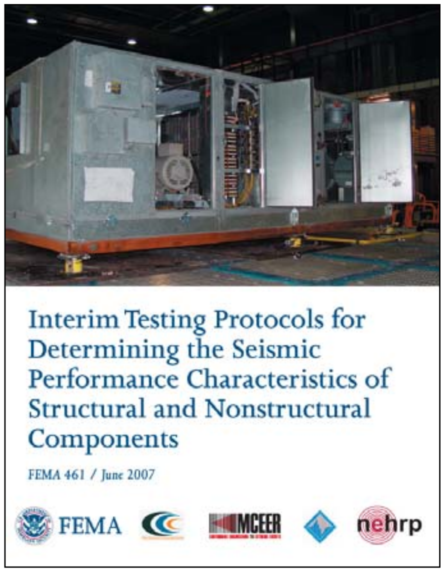
nehrp SeismicWaves

How the National Earthquake Hazards Reduction Program Is Advancing Earthquake Safety

FEMA Advances Efforts to Reduce Earthquake Losses Through Performance-Based Seismic Design

The work done by the Federal Emergency Management Agency (FEMA) in preventing and mitigating losses before disaster strikes is as important and far-reaching as are its post-disaster services. This is especially true for earthquakes, where FEMA is steadily supporting advancements in mitigation to help prepare the Nation for these potentially devastating disasters.

FEMA has reached another milestone in these efforts with the recent publication of *Interim Testing Protocols for Determining the Seismic Performance Characteristics of Structural and Nonstructural Components* (FEMA 461). For the first time, this publication provides methodologies to determine the seismic performance of a building's structural or nonstructural components in a consistent and comparable manner.



Progress in Seismic Design

Over the past century, perhaps the single most important development in reducing earthquake losses has been the incorporation of seismic design provisions into the Nation's building codes. These codes prescribe minimum standards that must be met in designing and constructing buildings in order to protect the health and safety of occupants.

In recent years, the limitations of minimum standards have become more apparent as building owners, managers, and regulators have recognized that other factors besides structural safety, such as repair costs, downtime, and the performance of nonstructural components, need to be considered in designing specific facilities. This has led to the emergence of a performance-based approach to design and construction. Under this method, individual buildings or classes of structures can be designed to perform at levels commensurate with applicable hazards, risks, and risk tolerances.

Performance-based methods have the potential to significantly enhance many aspects of building design, including seismic protection. This potential will be realized as the approach is further developed and refined and becomes more widely used and integrated into building codes.

As it relates to seismic design, this approach has been termed Performance-Based Seismic Design (PBSD). Development of PBSD began in the mid-1990s, largely for use in evaluating and upgrading existing buildings. With support from the National Science Foundation (NSF), the Pacific Earthquake Engineering Research Center (PEER) built upon these first-generation procedures, developing a conceptual framework for the next generation of PBSD. Since 2000, FEMA has led efforts to develop this new generation of PBSD procedures via the *Action Plan for Performance Based Seismic Design* (FEMA 349), which is being implemented through a contract with the Applied Technology Council (ATC), a California-based nonprofit organization working to advance engineering applications for hazard mitigation.

Toward Next-Generation PBSD

In 2006, FEMA published an updated project plan for developing next-generation PBSD guidelines, *Next-Generation Performance-Based Seismic Design Guidelines: Program Plan for New and Existing Buildings* (FEMA 445). The completion of FEMA 461 is one of the first major accomplishments in carrying out that plan. To develop the 113-page FEMA 461 report, the ATC collaborated with the NSF-funded National Earthquake Engineering Research Centers: MCEER, the Mid-America Earthquake Center, and PEER.[1] The project team also made use of input provided by more than 40 experts from government, industry, and academia who participated in the FEMA-sponsored Workshop on Interim Protocols for Seismic Performance Assessment Testing of Nonstructural Components.

[1] MCEER (formerly the Multidisciplinary Center for Earthquake Engineering Research) is headquartered at the University at Buffalo, the State University of New York; the Mid-America Earthquake Center at the University of Illinois at Urbana-Champaign; and PEER at the University of California, Berkeley.

FEMA 461 describes in detail laboratory testing protocols that can be used to determine *fragility functions* for various building systems and components. Fragility functions express in mathematical terms the likelihood that a component will sustain a specified level of damage when exposed to a specified level of demand (e.g., force, acceleration, displacement). These functions are of fundamental importance to PBSD.

Next-generation PBSD procedures are being developed so that building stakeholders can reliably know, before choosing from among design options, how those options will affect seismic performance. Performance is defined as the probable consequences of earthquake damage, including fatalities, injuries, and the costs of repairing, replacing, and temporarily doing without facilities. To determine performance, it is essential to first know what levels of damage are likely to result from the demands that could be placed on a building design by earthquake ground motions, and this is calculated through the creation and use of fragility functions.

Two protocols are presented in FEMA 461. The first, Quasi-Static Cyclic Testing of Structural and Nonstructural Components and Systems, can be used to test shear walls, beam-column assemblies, drywall partitions, cladding panels, pipes, ducts, and other elements whose behavior is sensitive to the relative motion of several floors or vertical connections within a building. The second protocol, Shake Table Testing of Structural and Nonstructural Components and Systems, is designed for testing mechanical and electrical equipment and other elements "that are sensitive to the dynamic effects of motion imparted to the component at a single point of attachment, typically its base."[2]

An Important Piece of the Puzzle

The protocols in FEMA 461 are intended as interim methods that will be finalized over time as they are used and evaluated by researchers nationwide. They are nevertheless a significant step forward in the development of PBSD. Ultimately, this technology will have the potential to improve earthquake loss mitigation in several ways: by facilitating the design of structures that are more resistant to losses—or equally resistant to losses, but with lower construction costs or more design flexibility—than are buildings designed using existing building codes; and by enabling more precise assessment and enhancement of the seismic adequacy of building codes.

FEMA 461 can be ordered free of charge from FEMA at 1-800-480-2520, or it can be downloaded from the ATC website at http://www.atcouncil.org/pdfs/FEMA461.pdf. For additional information on the protocols, contact the ATC at 201 Redwood Shores Parkway, Suite 240, Redwood City, California 94065 (telephone 650-595-1542, e-mail ATC@ATCouncil.org).

[2] Applied Technology Council, *Interim Testing Protocols for Determining the Seismic Performance Characteristics of Structural and Nonstructural Components* (FEMA 461), June 2007, 53.