Interim Testing Protocols for Determining the Seismic Performance Characteristics of Structural and Nonstructural Components

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Interim Testing Protocols for Determining the Seismic Performance Characteristics of Structural and Nonstructural Components

Prepared by the

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Notices

Any opinions, findings, conclusions, or recommendations expressed in this publication do not necessarily reflect the views of the Department of Homeland Security's Federal Emergency Management Agency (FEMA), the National Science Foundation (NSF), the Applied Technology Council (ATC), the Mid-America Earthquake (MAE) Center, the Multidisciplinary Center for Earthquake Engineering Research (MCEER), or the Pacific Earthquake Engineering Research (PEER) Center. Additionally, neither ATC, FEMA, MAE, MCEER, NSF, PEER, nor any of their employees makes any warranty, expressed or implied, nor assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, product, or process included in this publication. Users of information from this publication assume all liability arising from such use.

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Cover Photo: Roof-top Air Handling Unit being tested on a shake table in the Structural Engineering and Earthquake Simulation Laboratory at the University at Buffalo. Photo courtesy of the American Society for Heating Refrigerating and Air-Conditioning Engineers and MCEER.

Foreword

One of the primary goals of the Department of Homeland Security's Federal Emergency Management Agency (FEMA) is prevention or mitigation of this country's losses from hazards that affect the built environment. To achieve this goal, we as a nation must determine what level of performance is expected from our buildings during a severe event, such as an earthquake. To do this, several years ago FEMA contracted with the Applied Technology Council (ATC) to develop next-generation performance-based seismic design guidelines, which would allow stakeholders and their representatives to assess the probable seismic performance of new and existing buildings, and to be able to design or improve their structures to meet their performance goals. These guidelines could be voluntarily used by engineers and designers to: (1) assess and improve the performance of buildings that are currently designed to a building code "life safety" level, which would, in all likelihood, still suffer significant structural and nonstructural damage in a severe event; and (2) more effectively meet the performance targets of current building codes by providing verifiable alternatives to current prescriptive code requirements. This program is based on a long-term plan published as FEMA 445, which was developed with the input of the nation's leading seismic professionals.

One of the key requirements in performance based seismic design is the ability to test and evaluate the intended performance of the various structural and nonstructural components that make up a building. To develop this testing criteria, the project worked closely with the three Earthquake Engineering Research Centers (EERC) funded by the National Science Foundation. The three EERC's are:

- The Mid-America Earthquake Center (MAE)
- The Multidisiplinary Center for Research in Earthquake Engineering Research (MCEER)
- The Pacific Earthquake Engineering Research Center (PEER)

The three EERC's and others involved in the project have done an excellent job developing these interim testing protocols for structural and nonstructural components. These protocols will go a long way towards bringing consistency to the future testing of these components, and will help the various industries by providing a clear seismic performance target towards which they can now aim.

It is FEMA's hope that as performance based seismic design moves into the mainstream, these protocols will ultimately become standardized and more broadly used.

FEMA wishes to express its sincere gratitude to all who were involved in this project and in the development of this publication. The result of their hard work and dedication will play an important role in helping the nation move towards performance-based seismic design and reducing losses suffered by our citizens in future earthquakes.

—Federal Emergency Management Agency

Preface

In October 2001 the Applied Technology Council (ATC), with funding from the Federal Emergency Management Agency (FEMA), Department of Homeland Security, commenced work on a multi-year project to development performance-based seismic design guidelines for eventual incorporation in existing standards for the seismic design of new buildings and the upgrade of existing buildings (ATC-58 project). The plan for development of the guidelines is defined in the companion FEMA 445 report, *Next-Generation Performance-Based Seismic Design Guidelines, Program Plan for New and Existing Buildings*, which was prepared under the ATC-58 project and published by FEMA in 2006.

As part of the initial work on the ATC-58 project, interim recommended protocols (documented herein) were developed for testing of structural and nonstructural components and systems found in buildings, for the purpose of establishing their seismic performance characteristics. The protocols were developed through a cooperative effort of ATC and the three National Science Foundation-funded Earthquake Engineering Research Centers (EERCs): the Mid-America Earthquake (MAE) Center at the University of Illinois, Urbana; the Multidisciplinary Center for Earthquake Engineering Research (MCEER), University at Buffalo, The State University of New York; and the Pacific Earthquake Engineering Research (PEER) Center at the University of California, Berkeley.

Two interim protocol types are provided in this document:

- Interim Protocol I – Quasi-Static Cyclic Testing, which should be used for the determination of performance characteristics of components whose behavior is primarily controlled by the application of seismic forces or seismic-induced displacements (e.g., cladding panels, glazing panels, drywall partitions, piping and ducting system connections, ducts, and various types of anchors and braces); and
- Interim Protocol II – Shake Table Testing, which should be used to assess performance characteristics of components whose behavior is affected by the dynamic response of the component itself, or whose behavior is velocity sensitive, or sensitive to strain-rate effects (e.g., mechanical and electrical equipment).

The document also contains an introductory chapter that presents an overview of performance-based seismic design (to provide context for the recommended interim testing protocols) and discussions on a variety of topics and issues germane to these protocols. A Commentary is provided for each protocol (in the chapter immediately following the protocol), and an appendix is included that describes the process used to develop nonstructural component fragility functions based on laboratory testing.

Christopher Rojahn
ATC Executive Director

Acknowledgements

Numerous individuals and institutions deserve credit for the development of the interim protocols provided in this document. The need for the protocols was first recognized by the FEMA Performance-Based Seismic Design Project (ATC-58) Nonstructural Performance Products Team, consisting of Robert Bachman (Team Leader), David Bonowitz, Philip Caldwell, Andre Filiatrault, Robert Kennedy, Gary McGavin, Eduardo Miranda, and Keith Porter. The protocol development effort was carried out by three protocol teams: (1) the Shaking Table Testing Protocol Team, consisting of Andre Filiatrault (Team Leader), Philip Caldwell, Peter Dusicka, Tara Hutchinson, Ahmad Itani, Eduardo Miranda, Gokhan Pekcan, Andrei Reinhorn, Jose Restrepo, and James Wilcoski; (2) The Racking Testing Protocol Team, consisting of Helmut Krawinkler (Team Leader), David Bonowitz, Barry Goodno, Steven Kuan, Joseph Maffei, Ali Memari, Jose Restrepo, and Chia-Ming Uang; and (3) the Component Cyclic Testing Protocol Team, consisting of Manos Maragakis (Team Leader), George Antaki, Scott Campbell, and Robert Kennedy.

Additional guidance and input was provided by participants in the FEMA/ATC-58 Workshop on *Interim Protocols for Seismic Performance Assessment Testing of Nonstructural Component* , held on November 4-5, 2004 in the San Francisco Bay area. Participants included the individuals cited above as well as members of the Project Team, FEMA representatives, and invited participants: Dennis Alvarez, John Caffrey, James Carlson, Mary Comerio, Craig Comartin (Risk Management Products Team Leader), William Gates, Jeff Gatscher, Nathan Gould, Ronald Hamburger (Project Technical Director), Robert Hanson (FEMA Technical Monitor), Brian Kehoe, Charles Kircher (Risk Management Products Team Member), Richard Lloyd, Mike Mahoney (FEMA Project Officer), Sami Masri, Kelly Merz, Christopher Rojahn (Project Executive Director), Anshel Schiff, John Silva, Donald Smith, Greg Soules, William Staehlin, and Chris Tokas.

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