October 2007
SeismicWaves
How the National Earthquake Hazards Reduction Program Is Advancing Earthquake Safety

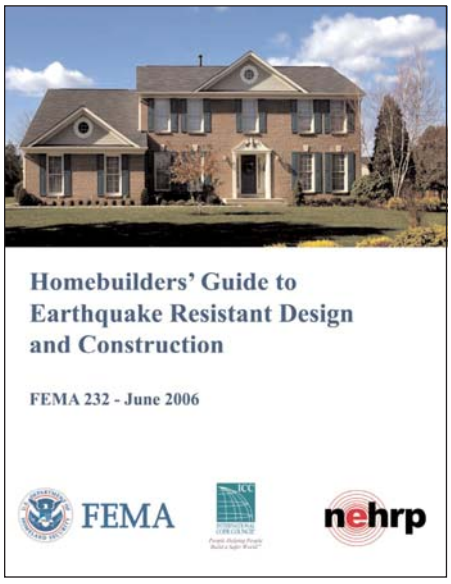
FEMA Homebuilders' Guide to Earthquake-Resistant Design and Construction

Under the National Earthquake Hazards Reduction Program (NEHRP), the Federal Emergency Management Agency (FEMA) works to reduce the ever-increasing risks to people and property posed by earthquakes and related hazards in the United States. Preventing losses by designing and constructing buildings to withstand anticipated earthquake forces is one of the key components of mitigation and one of the most effective ways of reducing the costs of future disasters. As part of its mitigation responsibilities under NEHRP, FEMA develops, publishes, and disseminates technical guidance on the design and construction of earthquake-resistant structures.

One- and two-family dwellings have traditionally performed fairly well in earthquakes because of their relative lightness and regular shape, and, as a result, little technical guidance on the earthquake-resistant design and construction of these dwellings has been developed. While one- and two-family houses typically do not collapse in earthquakes, recent events have shown that they can sustain significant damage and be rendered uninhabitable. This is especially true when sufficient attention is not paid to construction details and when contemporary design dictates the use of large expanses of windows and irregular footprints. Given the sheer number of these buildings in the United States, even minor earthquake damage to houses can result in significant aggregate loss and heavy demand for temporary housing.

FEMA's first guidance on earthquake-resistant housing was a manual for homebuilders published jointly by FEMA and the Department of Housing and Urban Development in 1992, based on data collected after the 1971 San Fernando earthquake. FEMA later updated and reissued this manual in 1998. That version has now been replaced by the current *Homebuilders' Guide to Earthquake-Resistant Design and Construction* (the Guide), which FEMA published in June 2006.

Two important developments provided the impetus for producing the 2006 edition. The first was the completion of the Consortium of Universities for Research in Earthquake Engineering (CUREE)-Caltech Woodframe Buildings Project. This project used FEMA Hazard Mitigation Grant Program funds available after the 1994 earthquake in Northridge, California, to study the unexpected amount of damage to wood-frame residential structures incurred in that event. The study combined academic research and actual full-scale testing of wood-frame buildings and components with the development of engineering-based design guidance for future construction.



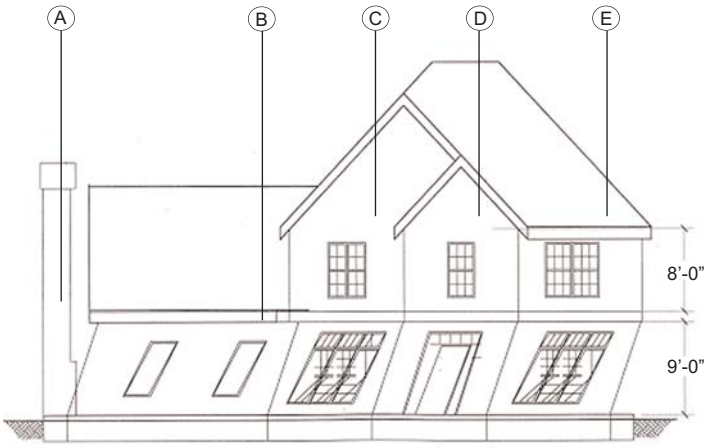
The second development was publication in 2000 of the first *International Residential Code* (IRC) by the International Code Council (ICC). This document, which the ICC updated in 2003 and 2006, is the principal governing building code for residential construction in the United States. The IRC reflects the requirements found in the latest edition of the *NEHRP Recommended Provisions and Commentary for Seismic Regulations for New Buildings and Other Structures* (FEMA 450) and addresses the earthquake risk to nonengineered residential construction—in other words, to one- and two-family houses built with little or no direct assistance from architects or engineers.

Because of these developments, FEMA funded the National Institute of Building Sciences' Building Seismic Safety Council (BSSC) to revise the 1998 version of the homebuilders' manual. The primary authors of the resulting Guide, who also authored one of the CUREE-Caltech project reports, are J. Daniel Dolan of Washington State University, Pullman, Washington; Kelly Cobeen of Cobeen and Associates Structural Engineering, Lafayette, California; and James Russell, Building Code Consultant, Concord, California.

The Guide presents seismic design and construction guidance in a manner that can be utilized by homebuilders,

knowledgeable homeowners, and other non-engineers. It incorporates and references the seismic provisions of the IRC as well as the results of the CUREE-Caltech project. It presents prescriptive building detailing plans based on state-of-the-art earthquake-resistant design applicable to nonengineered one- and two-family detached dwellings. The Guide also includes recommended "above-code" measures expected to improve the earthquake performance of these houses to levels above those afforded by compliance with IRC requirements alone.

The Guide begins by describing how houses respond to earthquake ground motions. Characteristics such as strength, stiffness, and ductility, which are key to how buildings perform in earthquakes, are explained and illustrated. Separate chapters address the major components of residential structures—from foundations and floors to walls and roof-ceiling systems—by discussing relevant principles of earthquake-resistant design, IRC requirements, findings from recent research and analyses, and above-code recommendations. Other chapters provide guidance on anchoring water heaters and other home contents and on incorporating earthquake-resistant design when remodeling or adding on to existing houses.



Guide illustration of soft-story deformation in model house.

The above-code measures are supported not only with findings from the CUREE-Caltech project but also with results from earthquake loss investigations and from analyses conducted by the BSSC specifically for the Guide. Using analytical software developed for the CUREE-Caltech project, the BSSC compared the performance of a typical 2,500-square-foot "model" house designed and constructed to meet IRC requirements to the performance of that same structure when above-code measures had been employed. The Guide also provides estimates of the added costs associated with the major above-code recommendations. These costs are expressed as a percentage of the basic framing cost for the model house to allow for their estimation by homebuilders in different parts of the United States. By including cost information along with comparative performance data, the Guide provides homebuilders and prospective homeowners with the information they need to accurately weigh the costs and the benefits of following the above-code recommendations.

It is commonly believed that buildings "designed to code" will not be damaged by earthquakes. The Guide makes clear that, while the goal of the IRC and comparable building codes is to prevent loss of life during earthquakes, they are not sufficient—and are not intended to be sufficient—to prevent all earthquake damage.

The ICC is cosponsoring efforts to disseminate the Guide, and FEMA has sent more than 5,000 copies to the ICC for distribution to its governmental members free of charge. Other dissemination efforts have included presentations on the Guide to architects, homebuilders, and code officials as it was being developed and the publication of a paper about the Guide in several venues.[1]

The *Homebuilders' Guide to Earthquake-Resistant Design and Construction* (FEMA 232) can be obtained free in print from FEMA by calling 1-800-480-2520. It also can be downloaded from FEMA via the NEHRP website at http://www.nehrp.gov/resources/index.htm#guidance, or from BSSC's site at http://bssconline.org. This publication has become one of the most popular earthquake risk mitigation documents published by FEMA and is being used by local building departments to improve seismic design and construction practices among homebuilders.

[1] Dolan, **J.D., Cobeen, K.E., Russell, J.E., Mahoney, M.G., Heider, C.M. (2006). The FEMA Homebuilders' Guide to Earthquake-Resistant Design and Construction**, *Earthquake Engineering Research Institute Eighth National Conference on Earthquake Engineering*, **April 2006**; *Applied Technology Council 12th US-Japan Workshop on the Improvement of Structural Design and Construction Practices*, **September 2007**.