FEMA

Seismic Building Codes in the U.S.

A Thirty-Five Year Retrospective of NEHRP Provisions

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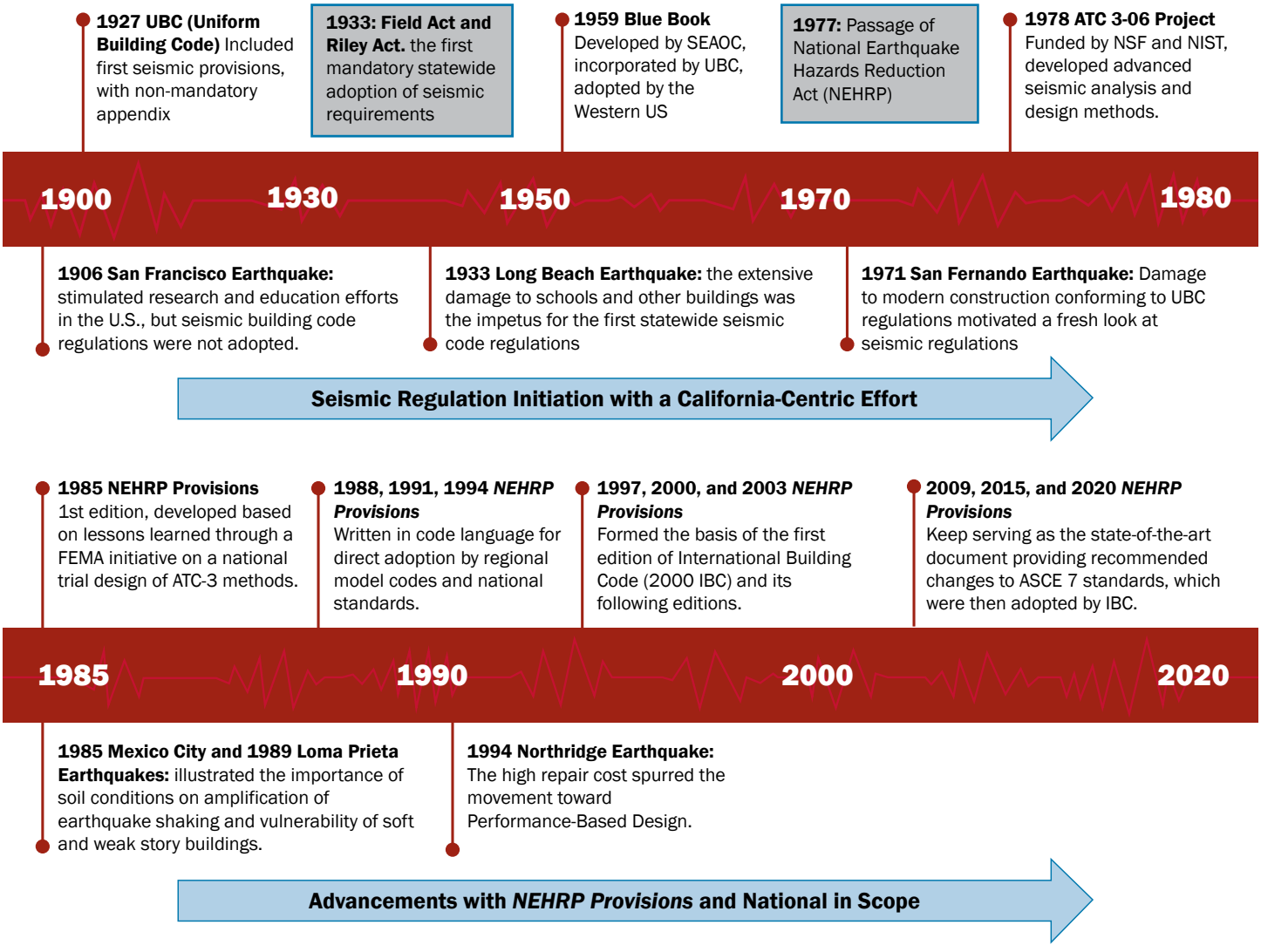
Background

The *National Earthquake Hazards Reduction Program (NEHRP) Recommended Seismic Provisions for New Buildings and Other Structures* (called here the *NEHRP Provisions*) is a technical resource document for improving national seismic design standards and model building codes. Regularly updated by the Building Seismic Safety Council (BSSC) and published by the Federal Emergency Management Agency (FEMA), its first edition was published in 1985 and the tenth edition was published in 2020.

Because earthquakes can cause building damage, significant losses, and disruption of operations, building codes that strengthen and improve building seismic performance are of great importance. The national model building codes in the U.S., which regulate the design, construction, alteration, and maintenance of buildings and other structures, are adopted and enforced by state, local, tribal and territorial jurisdictions. This is one of the primary ways a community safeguards itself from potential earthquake losses. Forty years ago, state and local governments did not adopt the same nationwide seismic regulations, causing inconsistencies in levels of protection.

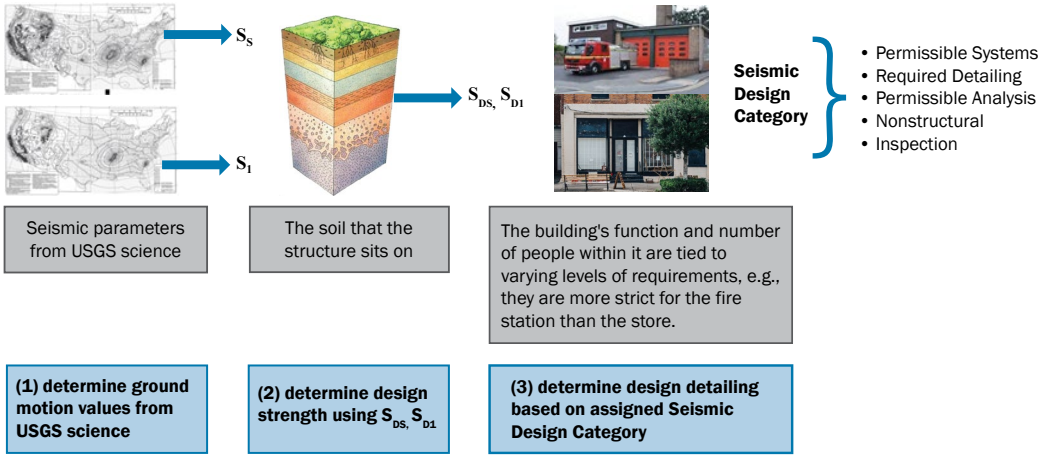
Since its inception, the *NEHRP Provisions* has sought to provide nationwide consistency in seismic code regulations while accounting for varying seismicity and different approaches for designing new buildings and other structures. The *NEHRP Provisions* offers the latest geoscience information about varying levels of seismicity and provides the benefit of making the architecture, engineering, construction, and construction materials industries operate more efficiently.



Key Facts about the *NEHRP Recommended Seismic Provisions*

- Essential to the development of nationally applicable seismic codes including the U.S. Seismic Design Maps
- Developed and updated by the national experts on the NIBS/BSSC through a consensus process supported by FEMA
- Provide state-of-the-art information and is the starting point of seismic code changes
- A key innovation under the NEHRP to convert the effort of four NEHRP agencies and bridge public and private sectors

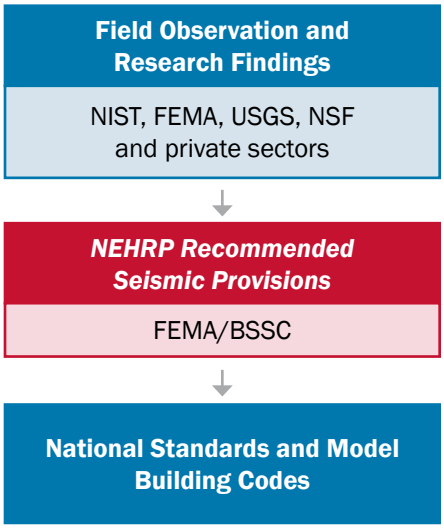
Fundamentals of Seismic Design Process



The Role of the *NEHRP Provisions*

Designing structures to be resistant to major earthquakes is a complex process, and developing seismic design provisions and codes that are applicable across the nation is even more daunting. The *NEHRP Provisions* is an essential platform to help advance our seismic design practices effectively and efficiently.

Over the past thirty-five years, the *NEHRP Provisions* has been the starting point of seismic code changes and the mechanism to transfer research into application. The *NEHRP Provisions* is the focal point of the efforts of the four NEHRP agencies (National Institute of Standards and Technology (NIST), FEMA, U.S. Geological Survey (USGS), and National Science Foundation (NSF)), research and practicing engineers, codes and standards officials, and earthquake science experts to reduce seismic risk through modern building codes.

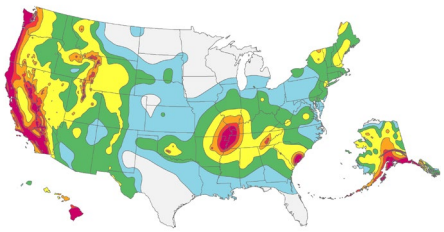


Selected Important Advancements

The *NEHRP Provisions* has been at the forefront of seismic design innovation, including this selection of important changes.

Seismic Mapping

When the earthquake science community advances our understanding of the intensity and frequency of earthquakes, engineers need to update their design basis by translating the science into engineering terms. The modern generation of U.S. seismic design maps was first introduced in the 1997 *Provisions*, through a collabortive effort among FEMA, BSSC, and USGS, which instituted new processes for developing the national seismic design maps from the USGS National Seismic Hazard Model. Since then, major updates to the U.S. seismic design maps have been introduced approximately every ten years, in 2007 and 2017, through the *NEHRP Provisions*.



National seismic hazards maps display earthquake ground motions for various probability levels across the United States. These maps are the basis for seismic design provisions of building codes, insurance rate structures, and land-use planning. (credit: USGS)

The *NEHRP Provisions* has provided a central forum where the relevant information and expert opinion on earthquake motions for design can be shared, a great model of marrying science and engineering into building science. This coordinated process has sharpened the role of USGS over the years as the central provider of ground motion mapping for design purposes.

Keeping Up with Building Technology

As materials and methods of constructing buildings change and improve, updates to the *NEHRP Provisions* must consider new building innovations. It provides a national, authoritative forum to evaluate and assess new technologies of all kinds with a focus on new seismic design methods and innovative new seismic structural and nonstructural systems.

The three new seismic-force-resisting systems introduced in the 2020 *NEHRP Provisions* are shown to the right.

Design for Tall Buildings

Nonlinear response history analysis is a sophisticated procedure in which a building design is subjected by computer analysis to a number of simulated earthquakes the building may experience. Through this process, weak spots are identified so that the results envelop the worst results based on engineering parameters. A revised design is then finalized to address these weaknesses.

The nonlinear response history analysis procedure is recognized as a more precise tool to analyze and design most new tall buildings in seismically active regions of the world and those which employ advanced protective technologies. A complete reformulation of the procedure was introduced in the 2015 *Provisions*.

Detailed Nonstructural Protection Provisions

Prior to the NEHRP Recommended Seismic Provisions, building code seismic regulations for nonstructural components, including the architectural, mechanical, electrical, and plumbing systems of a building, were only generally stated. The NEHRP Provisions modernized this process by categorizing many specific types of components and their acceptable performance, and in the case of some equipment in essential occupancies, continued functionality after an earthquake.

Investment Returns (Benefit vs. Cost)

A study conducted by the National Institute of Building Sciences Multi-Hazard Mitigation Council concluded that enhanced earthquake design requirements over the last 30 years could **save $7 billion per year in losses** while **only adding $600 million per year** in construction cost, producing a national average **Benefit-Cost Ratio of 12:1**.

The Benefit-Cost Ratio is highest where seismicity is greatest, but the net benefits are also evident in areas of moderate seismicity. Designing up to the requirements of the *NEHRP Recommended Seismic Provisions* does not guarantee complete protection free of damage, but it does lead to greatly reduced damage.

Reinforced concrete ductile coupled walls (credit: MKA)

Cross-laminated timber shear wall (credit: Lendlease)

Steel and concrete coupled composite plate shear walls (credit: MKA)

Future Improvements

The *NEHRP Provisions* has become a well-known brand name in the earthquake field and has pervasive influence.

Staying Up to Date

The *NEHRP Provisions* continues to be updated by FEMA and BSSC today through evaluation of the large volume of new seismic information produced every year from analytical studies, laboratory testing, earth science research, new construction products and methods, input on practical seismic design aspects from the building industry and design practitioners, and by the lessons learned from recent earthquakes.

Community-Based Design

Consideration has been suggested to expand seismic design to consider the entire community. Currently, structures are evaluated individually, but this would expand consideration to lifelines, utilities systems such as electricity, water, and wastewater, transportation, and more. The process by which the *NEHRP Provisions* are developed for buildings is instrumental for the development of more robust standards and guidelines for lifelines/utilities. The 2015 and 2020 editions included white papers on conceptual post-earthquake functional recovery and economic performance criteria, and a more comprehensive effort is recommended to address resilience-based seismic design through the consideration of functional recovery.

Outreach, Education, Dissemination

The FEMA program in support of the *NEHRP Provisions* is not limited to the development and publication of each new edition. The *NEHRP Recommended Seismic Provisions* and companion documents are widely referenced throughout the U.S. and globally as a university-level earthquake engineering teaching resource. Special publications provide design examples to walk a practicing engineer through the process of using the *NEHRP Provisions*. Outreach, education, and dissemination activities to support the application of the *NEHRP Provisions* will continue to be an important objective.

In the United States, about half the American population across more than 20 states has a moderate or high risk of experiencing damaging earthquakes. Earthquakes are a real threat. Our nation's seismic risk is largely mitigated through earthquake resistant buildings, which are regulated by model building codes.

City skyline in California (credit: Cameron Venti)

Learn More

A comprehensive companion document, *The Role of the NEHRP Recommended Seismic Provisions in the Development of Nationwide Seismic Building Code Regulations: A Thirty-Five Year Retrospective* (FEMA P-2156), explains in more detail the topics that are briefly presented here as well as covering other technical aspects of the *NEHRP Recommended Seismic Provisions*.