FEMA FACT SHEET

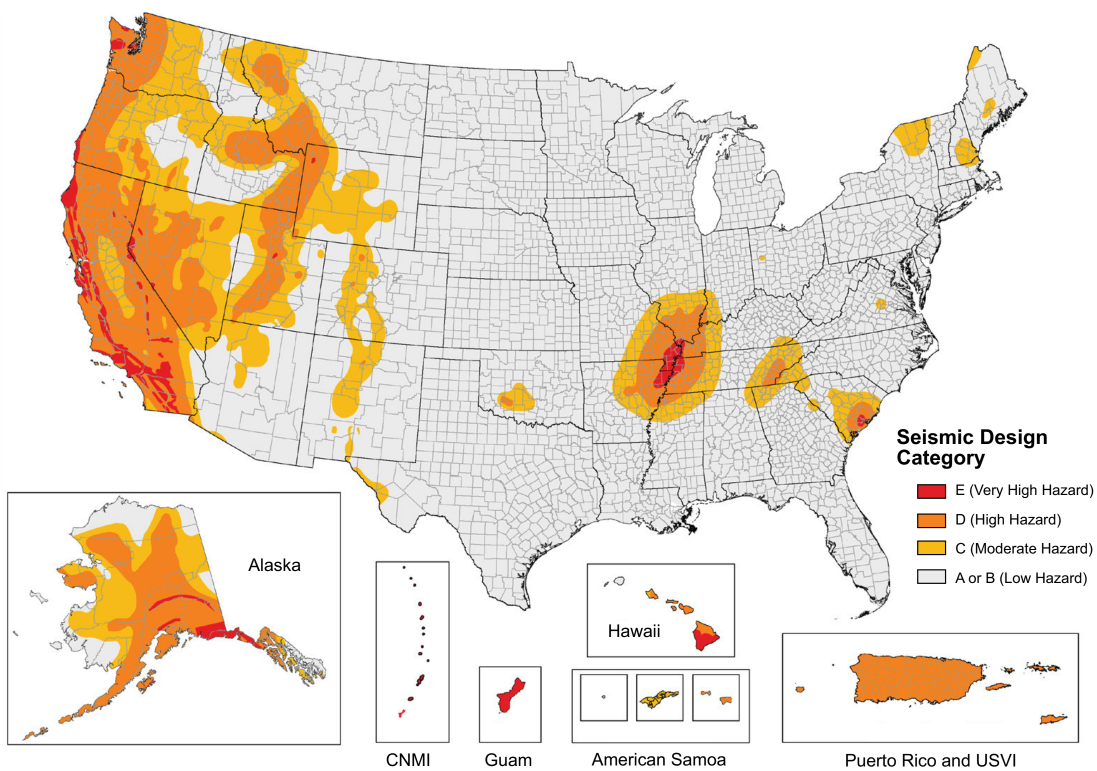
Seismic Building Code Provisions for New Buildings to Create Safer Communities

Earthquake Resistance Through Building Codes

Earthquakes are some of the most destructive and unpredictable natural phenomena, causing deaths, injuries, and extensive property damage in populated areas. As of 2015, roughly half of all Americans in the conterminous United States are exposed to potentially damaging ground shaking from earthquakes (USGS, 2015). The population exposed to seismic hazard has been steadily growing, leading to a higher potential for losses from seismic events. The estimated earthquake losses per year, known as Annualized Earthquake Losses (AEL), are calculated by FEMA to be $6.1 billion per year in the United States, and 55 metropolitan areas account for 85 percent of the AEL (FEMA, 2017). Review the map in Figure 1 to determine your community's exposure to seismic hazard.

How to Read the Map

The colors in the map denote "Seismic Design Categories" (SDCs) based on the seismic map of the 2018 International Residential Code (IRC), which reflect the likelihood of experiencing earthquake shaking of various intensities that damage buildings. Building design and construction professionals use SDCs specified in building codes to determine the level of seismic resistance required for new buildings.



- Very High seismic hazard areas (red) are most likely to experience violent ground-shaking, intense enough to destroy buildings, as they are located near a major fault.
- High seismic hazard areas (orange) could experience very strong shaking capable of producing great damage in poorly built structures.
- Moderate seismic hazard areas (yellow) may experience strong shaking during earthquakes which can cause considerable damage in poorly built structures.
- Low seismic hazard areas (gray) could experience moderate intensity shaking.

Figure 1: Seismic Hazard in the United States. Source: *Adapted from International Code Council (2018).*

Although we can't prevent earthquakes striking in the communities where people work and live, we can take action to impact the most important factor in saving lives and reducing losses from an earthquake: adopt and enforce up-to-date building codes. As seismic-preparedness experts often remind us, "Earthquakes don't kill people, but collapsed buildings do."

Building codes regulate the design, construction, alteration, and maintenance of structures in the United States. They specify the minimum requirements to safeguard the health, safety, and welfare of building occupants. Throughout the nation, the national model building codes are adopted and enforced by the state, local, tribal, and territorial (SLTT) authorities, not by the federal government. Evidence from past earthquakes indicates adoption and enforcement of the latest model building codes is one of the most effective seismic mitigation strategies available to communities.

Figure 2: The recently opened Olive View Hospital was heavily damaged during the 1971 San Fernando earthquake. It was razed and rebuilt with a stronger, more seismic-resistant structure; see Figure 3. The San Fernando earthquake demonstrated deficiencies in the building code provisions of the time and was a motivating factor for the creation of NEHRP. *Source: USGS (2003).*

Earthquake provisions in modern building codes have advanced and evolved significantly over the last century. The earliest seismic design provisions in the United States were introduced in the 1927 Uniform Building Code (UBC). By 1949, the UBC contained the first national seismic hazard map. Then, in 1976, the UBC introduced new provisions based on the lessons of the 1971 San Fernando Earthquake (Figure 2). By the 1990s, the use of seismic provisions had become more widespread.

Three model building codes were in wide use in the 1990s, all of which included seismic provisions:

- The International Conference of Building Officials (ICBO) published the Uniform Building Code (UBC), mainly adopted in the western states.
- The Building Officials and Code Administrators International, Inc., (BOCA) published the BOCA National Building Code (BOCA/NBC), mainly adopted in the northeastern and central states.
- The Southern Building Code Congress International, Inc., (SBCCI) published the Standard Building Code (SBC), mainly adopted in the southeastern states.

Figure 3: The new Olive View Hospital survived the 1994 Northridge earthquake with only minor structural damage. *Source: USGS (2003).*

In 1994, these three regional model code organizations formed the International Code Council (ICC) to develop a single set of national model building codes for the entire United States, reducing the cost and complexity of constructing buildings. The ICC published the first International Codes (I-Codes) in 2000 and has since updated them every three years. The I-Codes include the International Building Code (IBC), International Residential Code (IRC), International Existing Building Code (IEBC), and other model codes. As of today, most states and communities in the United States adopt the I-Codes (FEMA, 2019), which include seismic design and inspection requirements and seismic reference standards. The I-Codes continue to incorporate the latest technical standards, including publications such as the American Society of Civil Engineers (ASCE), Structural Engineering Institute (SEI) Standard 7, *Minimum Design Loads and Associated Criteria for Buildings and Other Structures* (ASCE/SEI 7), which provides earthquake engineering design requirements and other hazard-resistant and loading provisions for buildings and other structures.

Each year, thousands of new residential homes and other new buildings are constructed in high and very high seismic hazard areas. From the years 2010 to 2018, the annual number of permits for residential home starts in these areas grew from approximately 17,000 to 25,000 (United States Census Bureau, *Building Permits Survey*). New buildings constructed in compliance with recent editions of the building codes are more resilient than those built using no building code or outdated and inadequate building codes. More resilient buildings mean a more resilient community.

Adopting and enforcing national model building codes with seismic provisions unweakened by amendment offers one of the greatest opportunities for communities to reduce their seismic risk. The 2015 and 2018 editions of the IRC contain the latest seismic design provisions and reference standards to provide life safety protection for many detached one- and two-family homes and certain townhouses from major earthquakes. In the 2015 and 2018 editions of the IBC, seismic design provisions provide safeguards for larger or more complicated homes, as well as other engineered residential and non-residential buildings. Contact your state and local building departments to determine whether the latest model building codes have been adopted to protect your community.

Federal Partnership to Reduce Earthquake Risks through NEHRP

Earthquakes cannot be prevented, but their destructive impacts on life, property, and the economy can be mitigated. Congress first authorized the National Earthquake Hazards Reduction Program (NEHRP) in 1977 (Public Law 95-124), to “reduce the risks of life and property from future earthquakes in the United States through the establishment and maintenance of an effective earthquake hazards reduction program.” NEHRP was most recently reauthorized in 2018 (Public Law 115-307).

NEHRP is a collaborative effort among four federal agencies to improve the understanding of earthquake hazards and risk and to reduce the nation’s vulnerability to earthquakes. NEHRP focuses its efforts on earthquake-related monitoring and research, building codes and standards, technical guidance, awareness, education, and state earthquake grants. The four federal agencies are

- Federal Emergency Management Agency (FEMA);
- National Institute of Standards and Technology (NIST), the NEHRP lead agency;
- National Science Foundation (NSF); and
- U.S. Geological Survey (USGS).

NEHRP fosters a collaborative process among its four affiliated agencies to improve the nation’s earthquake resilience. This process enables communities to benefit from effective seismic-resistant building codes and standards. The steps in this process include conducting earthquake research, developing new tools and techniques for earthquake-resistant design and construction, incorporating research findings into model building codes and standards, and encouraging communities to adopt and enforce the latest edition of the model codes and standards.

The NEHRP *Recommended Seismic Provisions for New Buildings and Other Structures* (the *Provisions*) is the latest knowledge- and technology-based seismic code resource developed for improving national model building codes and standards. The NEHRP *Provisions* helps to improve building seismic performance, update seismic design maps, evaluate new seismic force resisting systems, upgrade seismic code provisions, and review seismic design requirements for new construction techniques and material standards. Since its first publication in 1985, the *Provisions* has been regularly updated every three to six years, most recently in 2015, with the next edition expected in late 2020. This resource is key for NEHRP to advance its mission of reducing the risks to life and property for new construction in future earthquakes. Today, most of the changes recommended in the *Provisions* have been adopted into ASCE/SEI 7, and thus into the national model building codes. Some notable earthquakes and developments which led to the creation and update of the NEHRP *Provisions* are shown on the timeline in Figure 4.

Seismic Events, NEHRP *Provisions*, and Code Upgrades

1906 ······ San Francisco Earthquake, M7.9, 3,000 Deaths, $10.5B Losses*

The 1906 earthquake led to the first government-commissioned scientific investigation into earthquakes in the United States. This investigation produced a detailed report describing earthquake building damage and data about the Earth's movement in the earthquake. From this initial understanding and the knowledge gained from succeeding events and organizations, building codes have been developed to help buildings withstand earthquakes. This timeline identifies some noteworthy earthquakes which provided data for the advancement of building codes and shows some of the damage from a few of those earthquakes.

1927 ······ The Uniform Building Code (UBC), with seismic provisions, was published by the International Conference of Building Officials (ICBO).

1933 ······ Long Beach Earthquake, M6.4, 115 Deaths, $819M Losses*
More than 70 schools were destroyed and hundreds of others damaged.

1933 ······ The vulnerability of school buildings in the Long Beach Earthquake led to the Field Act (*Cal. Education Code §17280 et seq. and §81130 et seq.*), which established regulations for their earthquake resistance. It was the first instance in the United States of requiring higher levels of safety and performance for certain buildings.

1949 ······ The first national seismic hazard map was published in the UBC.

1959 ······ The Structural Engineers Association of California published seismic standards, the Blue Book, reflecting the latest seismic design knowledge, for use throughout the state.

1964 ······ Great Alaskan Earthquake, M9.2, 131 Deaths, $2.6B Losses*

1971 ······ San Fernando Earthquake, M6.6, 66 Deaths, $3.3B Losses*

1973 ······ Substantial upgrades were made to seismic design requirements with lessons learned from the San Fernando Earthquake.

1977 ······ Congress passed the Earthquake Hazards Reduction Act, forming the National Earthquake Hazards Reduction Program (NEHRP).

1978 ······ Applied Technology Council (ATC) published ATC 3-06, *Tentative Provisions for the Development of Seismic Regulations for Buildings*, intending it to serve as the basis for a completely new national seismic code. The publication was the culmination of a multi-year project relying on the input of hundreds of seismic design experts.

1985 ······ Mexico City Earthquake (Mexico), M8.0, 9,500 Deaths, Over $7.2B Losses*
Mexico City has soft soil conditions similar to some United States cities, which can amplify earthquake shaking.

1985 ······ FEMA published the first edition of the NEHRP *Recommended Provisions for the Development of Seismic Regulations for New Buildings*, as developed by the Building Seismic Safety Council of the National Institute of Building Sciences, based on ATC 3-06.

1989 ······ Loma Prieta Earthquake, M6.9, 63 Deaths, $12.1B Losses*

1992 ······ All three model codes required seismic designs consistent with the NEHRP *Provisions*.

1994 ······ Northridge Earthquake, M6.7, 60 Deaths, Over $23.0B Losses*

1995 ······ The Interagency Committee on Seismic Safety and Construction found that the 1994 Uniform Building Code, 1993 National Building Code, and 1994 Standard Building Code provided a level of seismic safety substantially equivalent to the 1991 NEHRP *Provisions*.

1995 ······ Kobe Earthquake (Japan), M6.9, 5,502 Deaths, $344B Losses*
Japan uses building codes similar to those in the United States.

1997 ······ The 1997 edition of the UBC added requirements to evaluate and account for a building's structural redundancy. Investigations after the 1994 Northridge earthquake revealed that a design trend toward fewer, larger structural members contributed to many failures by removing redundancy.

2000 ······ The I-Codes, a set of comprehensive national model codes, were introduced with the NEHRP *Provisions* serving as the basis for the seismic code language.

2010 ······ Maule Earthquake (Chile), M8.8, 523 Deaths, $35.7B Losses*
Chile uses building codes similar to those in the United States.

2011 ······ Tohoku Earthquake (Japan), M9.1, 15,703 Deaths (Including 14,228 Tsunami-Induced Deaths), $357B Losses*

2016 ······ ASCE/SEI 7-16 adopted the 2015 NEHRP *Provisions* and included a new Tsunami Loads and Effects chapter, the first national standard for tsunami resilience.

2018 ······ A national study finds seismic designs for new construction using the 2018 IBC and IRC rather than 1988 UBC save $12 for every $1 spent. (NIBS, 2018.)
The 2018 IBC and IRC included new seismic design maps based on the 2015 NEHRP *Provisions*.

* All losses are given in the equivalent 2020 dollars.

Sources: USGS, n.d. "1906 Marked the Dawn of the Scientific Revolution"; USGS, n.d. "Earthquake Lists, Maps, and Statistics"; United States Senate Committee on Printing (1906); United States Army Corps of Engineers (1964); Nakata (1989b); USGS (1994); McCord (2011).

Figure 4: Timeline of Seismic Events & Code Upgrades

The upcoming 2020 NEHRP *Provisions* will introduce the following major changes and other important improvements, modifications, new concepts, and background information:

- New seismic design ground motion values and maps based on the 2018 USGS National Seismic Hazard Model, which includes new seismic ground motion models for the central and eastern United States, basin effect modeling for the Los Angeles, Seattle, San Francisco, and Salt Lake City areas, and updates to the catalog of past earthquakes;
- New multi-period response spectra which improve the accuracy of earthquake design ground motion criteria and correct an underestimation of earthquake impact for mid- to high-rise buildings at soft soil sites near major faults;
- A new design force formula for non-structural components which will improve seismic resistance for major nonstructural systems such as architectural, mechanical, and electrical components;
- New alternate design procedures for improving the seismic performance of large one-story commercial and industrial buildings constructed with rigid walls (e.g. masonry or tilt-up concrete) and flexible roof diaphragms (e.g., wood sheathing or bare metal deck). Such buildings are commonly used as warehouses and large department or grocery stores; and
- New provisions for concrete and composite steel coupled shear wall buildings, which have been shown to provide good seismic performance for high-rise buildings in high seismic hazard areas.

Codes Continue to Advance Seismic Resilience

Seismic-resistant building codes establish a level of protection to minimize the likelihood of building collapse during earthquakes like that shown in Figure 5. However, depending on the earthquake's severity, even well-designed buildings may be damaged. To advance seismic resilience, building codes provide higher protection and damage reduction for critical facilities like hospitals and essential public utility structures, as well as for schools and storage buildings containing hazardous materials. Building codes also restrict or prohibit some seismically vulnerable types of building construction in high hazard areas.

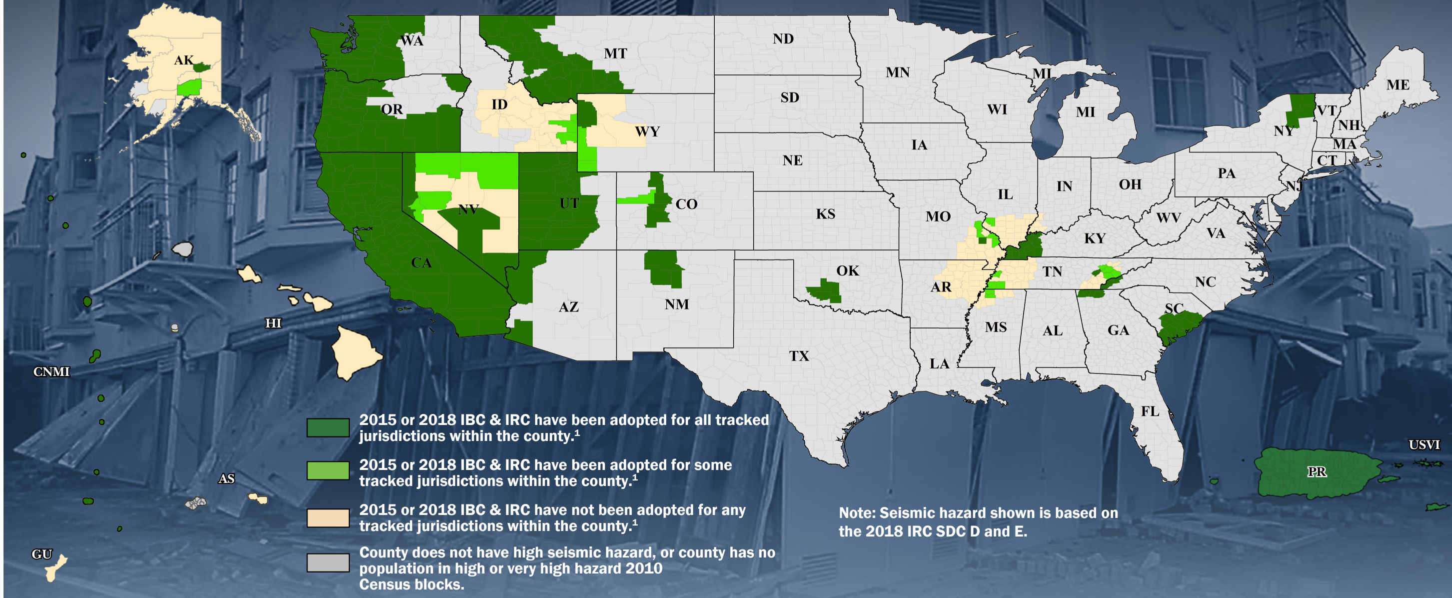
Current building codes and standards in the United States have several noteworthy requirements:

- Public utility facilities and high occupancy school and college buildings are designed for at least 25 percent more seismic load than common buildings.
- Hospitals with emergency treatment, fire suppression water storage and pumping facilities, highly hazardous material storage facilities, emergency communication centers, and shelters are designed for at least 50 percent more seismic load than common buildings.
- Ordinary plain masonry and plain concrete buildings (without steel reinforcing) are not permitted for moderate or higher seismic hazard regions.
- Ductile seismic force resisting systems, special construction techniques, and corresponding inspections are provided for new buildings in high and very high seismic hazard regions.

Figure 5: The Alto Rio 15-story apartment building in the city of Concepción, Chile, that collapsed during the 2010 Maule earthquake. *Source: USGS (2011).*

- Major mechanical, electrical, plumbing (MEP) and architectural components are tied and/or anchored to resist earthquake force and motion.

Figure 6: Population and Current Building Code Adoption for High and Very High Seismic Hazard Areas



State/Territory	2010 Census Population Exposed to High & Very High Seismic Hazard	Population in High & Very High Seismic Hazard Areas Adopting the 2015 and/or 2018 IBC & IRC	IBC Adoption in Effect as of September 2020	IRC Adoption in Effect as of September 2020
Alaska	615,782	175,724	2012	Local
Arizona	51,748	51,748	Local	Local
Arkansas	567,687	0	2012	2012
California	32,970,456	32,970,456	2018	2018
Colorado	22,145	15,718	Local	Local
Georgia	10,208	10,208	2018	2018
Hawaii	1,127,905	0	2006	2006
Idaho	112,422	16,271	2015	2012
Illinois	466,529	0	2015, 2018, or Local	2015, 2018, or Local
Indiana	60,487	0	2012	2018
Kentucky	264,701	264,701	2015	2015
Mississippi	218,374	40,320	2012, 2015, 2018 or Local	2012, 2015, 2018 or Local
Missouri	415,144	94,532	Local	Local
Montana	264,613	264,613	2018	2018
Nevada	670,921	620,519	Local	Local
New Mexico	2,044	2,044	2015	2015
New York	362	362	2018	2018
North Carolina	5,148	5,148	2015	2015
Oklahoma	34,547	34,547	2015	2015
Oregon	3,377,247	3,377,247	2018	2015
South Carolina	854,938	854,938	2018	2018
Tennessee	2,267,345	1,383,207	2012 or Local	2009 or Local
Utah	2,546,903	2,546,903	2018	2015
Washington	5,236,725	5,236,725	2015	2015
Wyoming	49,356	37,895	2018 or Local	Local
American Samoa	1,143	0	(1964 UBC)	Local
Commonwealth of the Northern Mariana Islands	53,883	53,883	2018	2018
Guam	159,358	0	2009	2009
Puerto Rico	3,725,789	3,725,789	2018	2018
U.S. Virgin Islands	106,405	106,405	2018	2018

The map shows adoption of the two most recent building code editions (2015 and/or 2018 IBC & IRC) by or on behalf of tracked jurisdictions[1] within counties or county equivalents that contain high or very high seismic hazard areas. The table shows the estimated exposed population within each state or territory and the estimated exposed population within areas adopting one of the two most recent IBC and IRC editions. Building codes may be adopted by state or territorial governments or by local Authorities Having Jurisdiction (AHJs) such as tribes, counties, cities, towns, villages, municipalities, territories, etc.

Some local AHJs adopt codes which are more recent than the state building codes. These more current building codes incorporate more recent knowledge of earthquake resistance into all subsequent building construction.

The map is based in part on 2018 IRC Figure R301.2(2). When SDC D or E includes a county or a significant portion of one, the entire county is colored dark green, light green, or tan on the map. However, the population counts in the associated table include only jurisdictions within the actual seismic hazard contours and therefore do not necessarily include the entire population of a county.

Note: The best available data was used to prepare this table. Official FEMA policy determines grant or other benefit eligibility.

[1]Building code adoption information provided by Insurance Services Office, Inc., and additional research. Sources: FEMA (2020) and additional research. Photo Source: Nakata (1989a).

Building codes are cornerstones of seismic resilience. FEMA therefore encourages all SLTTs to adopt and enforce the most recent model building codes. Figure 6 shows building code adoption within high and very high seismic hazard areas. The table in Figure 6 shows the populations of states and territories exposed to high seismic hazard, along with the portion of those populations living in areas adopting the latest two model code editions either at the state or local level. Adopting the most recent model building codes, i.e. IBC and IRC, implies incorporation of the latest seismic-resistant code requirements into all subsequent new building construction.

Building codes are generally not retroactive, which means existing buildings comply with the codes that were in effect at the time of their design and construction. Consequently, certain old existing buildings do not meet current performance requirements for new construction. In some circumstances, when existing buildings undergo major alterations, repairs, additions, or changes in occupancy, the current codes will be triggered and may require seismic upgrades.

Communities that have large stocks of seismically vulnerable existing buildings may need to address the problem through local earthquake mitigation programs. Local authorities can pass a seismic ordinance requiring the evaluation and retrofit of vulnerable building types or critical public buildings such as schools and hospitals. Building owners can also conduct voluntary seismic retrofits to reduce seismic vulnerability for their structures as allowed by the building codes. The International Existing Building Code (IEBC) and national reference standard ASCE/SEI 41, *Seismic Evaluation and Retrofit of Existing Buildings*, are commonly used for these types of seismic retrofit projects. FEMA has provided support for the improvement of the IEBC and ASCE/SEI 41 and has developed various technical resources for treatment of seismically vulnerable buildings, such as unreinforced masonry buildings, non-ductile concrete buildings, and multi-unit woodframe buildings with weak first stories. The recently completed Performance-Based Seismic Design (PBSD) methodology, assessment, and guidelines found in the FEMA P-58 series provide valuable tools for decision makers and engineers to plan and design seismic retrofits and high-performance new buildings.

To survive earthquakes and remain resilient, communities should also strengthen their core infrastructure, lifelines, and critical facilities. Buildings fully compliant with the seismic provisions of the latest building codes are the best earthquake mitigation investment for communities with seismic risk.

Recent Changes to Hazard Mitigation Programs and Policies

The FEMA NEHRP State Assistance Grant Program supports earthquake risk reduction efforts such as building code adoption, vulnerability assessment, risk awareness, and mitigation activities of states and local communities. Based on the level of seismic hazard in states and local communities, the program makes funding available through competitive grants with non-profit organizations and institutions of higher education and through cooperative agreements with individual at-risk states.

Recent legislation has made significant changes in how FEMA supports pre- and post-disaster hazard mitigation, including seismic mitigation. An example is the Disaster Recovery and Reform Act (DRRA) of 2018 (Public Law 115-254), which amended the Robert T. Stafford Disaster Relief and Emergency Assistance Act (Stafford Act) of 1988 (Public Law 100-707). DRRA Section 1234 amends Stafford Act Section 203 to promote cost-effective mitigation via modernization of state and local building codes. With various funding measures, Section 1234 creates an incentive structure that encourages communities to adopt and enforce the most recent building codes. This section allows certain disaster mitigation funding determinations to be positively or negatively impacted by a community's efforts in adopting and enforcing the latest editions of model building codes, defined as the two most recent editions.

Section 1234 also creates the National Public Infrastructure Pre-Disaster Hazard Mitigation Grant Program, which FEMA has named Building Resilient Infrastructure and Communities (BRIC). BRIC will be funded through the Disaster Relief Fund as a 6 percent set-aside from estimated disaster grant expenditures. FEMA envisions that this new program will incentivize innovative large infrastructure projects and will rely on building codes as the cornerstone of a resilient community.

The DRRA makes changes to the Hazard Mitigation Grant Program (HMGP), which was established under Stafford Act Section 404(a), and which establishes funding sources to restore and improve community resilience after a major disaster. The DRRA adds language to Section 404(a) to make clear that increasing resilience is one of the purposes of the HMGP.

FEMA has also recently made a change to the 5 Percent Initiative for HMGP. This program allows grantees to use up to 5 percent of total grant funds for projects that are difficult to evaluate using current FEMA-approved cost-effectiveness methodologies but which reduce the risk of loss of life and property, including many building code-related activities. HMGP funding can be set aside to improve post-disaster hazard resistance through various building code activities, including adopting the most recent model building codes, raising awareness of disaster resistant building techniques, and updating provisions in communities' existing codes. FEMA now allows the 5 percent set-aside amount to be increased up to 10 percent for eligible mitigation activity for all hazards. Before 2015, FEMA's Hazard Mitigation Assistance Guidance restricted this Additional 5 Percent Initiative funding to tornado and high wind mitigation. Mitigation activities receiving this additional funding must incorporate resilience through disaster-resistant building techniques.

For more information on FEMA's NEHRP activities, programs, and resources, and to subscribe to FEMA NEHRP email updates, visit the FEMA National Earthquake Hazards Reduction Program website and NEHRP.gov.

Resources

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