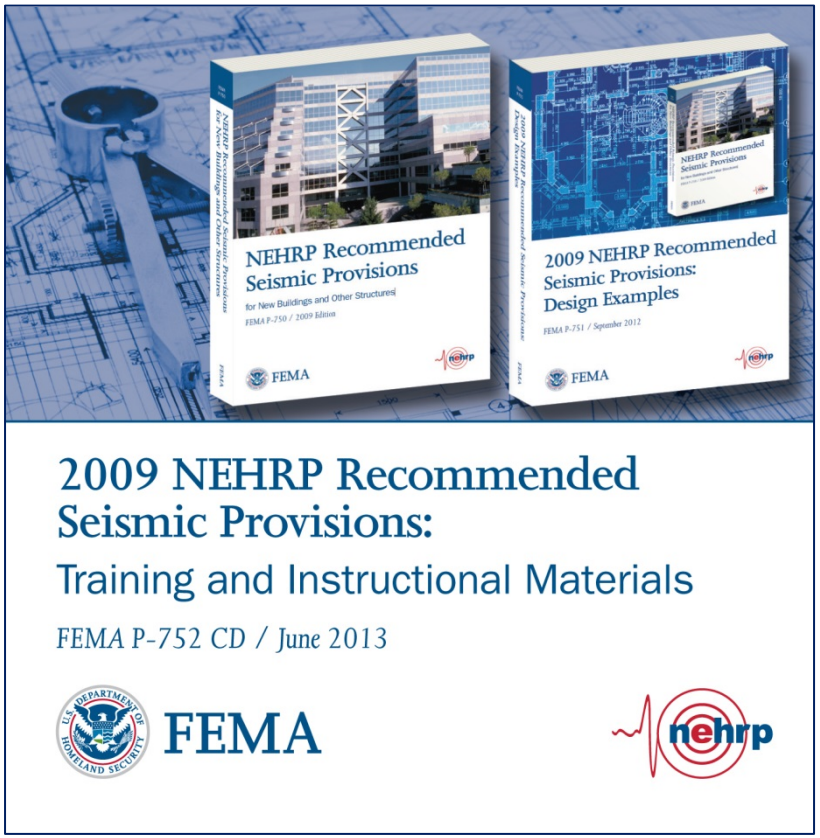
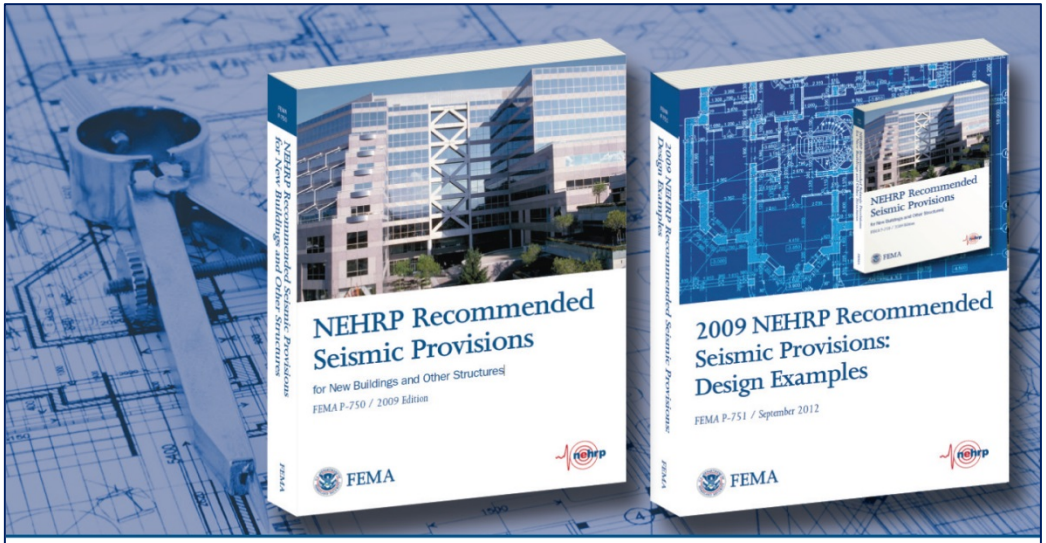


1

Introduction

Robert G. Pekelnicky, P.E., S.E.

NEHRP Recommended Provisions: Instructional Materials (FEMA P-752)



2009 NEHRP Recommended Seismic Provisions:

Training and Instructional Materials

FEMA P-752 CD / June 2013

FEMA

nehrp

NEHRP Recommended Provisions: Instructional Materials (FEMA P-752)

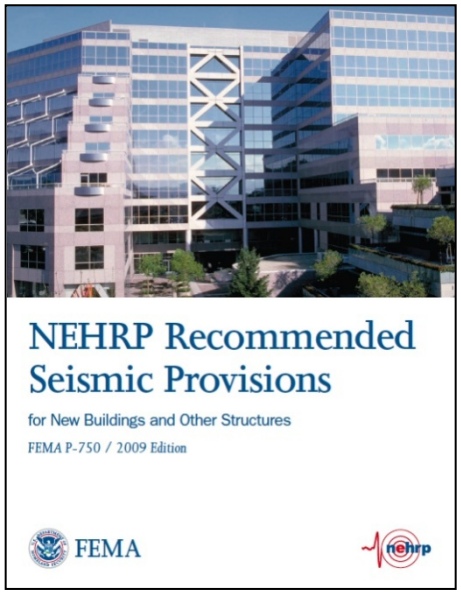
- These instructional materials complement FEMA P-751 CD, *NEHRP Recommended Seismic Provisions: Design Examples*

- Users should have the FEMA P-751 CD; and FEMA P-750, *The* 2009 *NEHRP Recommended Seismic Provisions for New Buildings and Other Structures*

FEMA P-750 and P-751

Single copies of both publications are available at no charge from FEMA publication warehouse

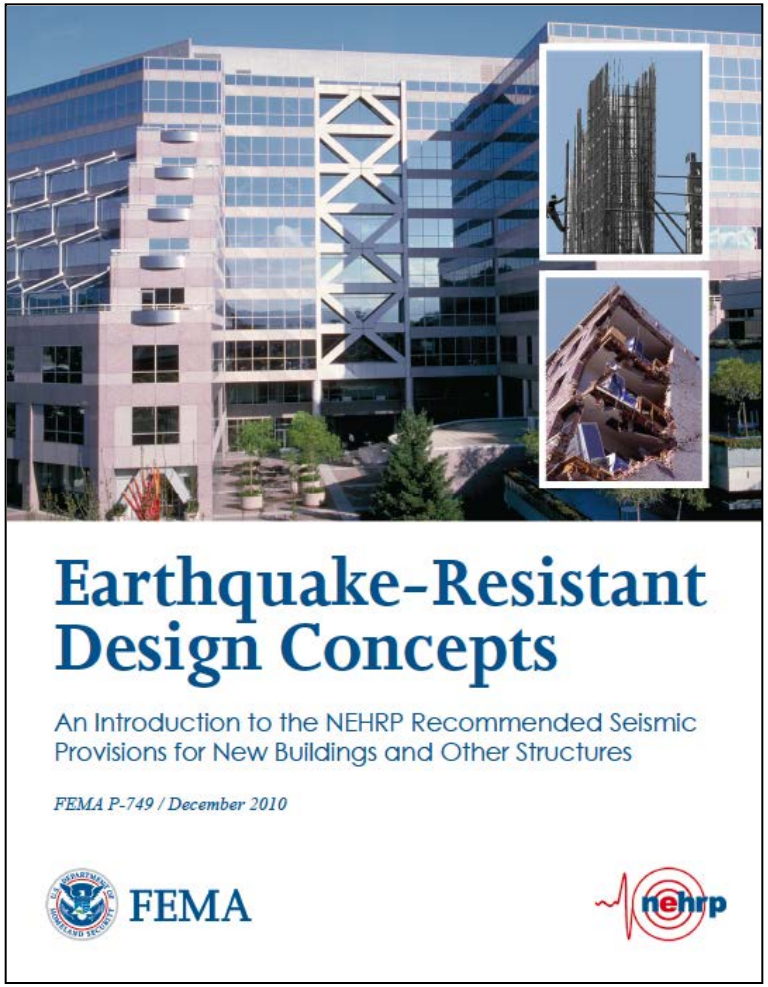
Call 1-800-480-2520 to order



FEMA P-750

FEMA P-751

FEMA P-749



Also Available at FEMA online library

http://fema.gov/library

Development of the Provisions

- FEMA P-750, P-751, and P-752 were developed for FEMA by the Building Seismic Safety Council (BSSC) of the National Institute of Building Sciences (NIBS).
- The *NEHRP Recommended Provisions* has been updated through a consensus process at the BSSC since its first edition was published in 1985. The 2009 edition is the 7th update.
- For information about the BSSC and the current activities related to the NEHRP Provisions, see

http://BSSC.nibs.org

Slide Sets Included in FEMA P-752

- Topic 1: Introduction
- Topic 2: Fundamentals of Earthquake Engineering
- Topic 3: Ground Motions
- Topic 4: Structural Analysis (Parts 1 and 2)
- Topic 5: Foundation Design
- Topic 6: Steel Structures
- Topic 7: Reinforced Concrete
- Topic 8: Precast Concrete
- Topic 9: Composite Steel/Concrete
- Topic 10: Masonry Structures
- Topic 11: Wood Design
- Topic 12: Seismic Isolation
- Topic 13: Non-building Structures
- Topic 14: Nonstructural Components
- Topic 15: NONLIN and EQ Tools (not part of FEMA P-751)

Note: The "Topics" 1-14 of FEMA P-752 correspond to the example "Chapters" in FEMA P-751. Topic 15 is not part of P-751 but is included here as a means of providing information about this software.

About the NEHRP Program

NATIONAL
EARTHQUAKE
HAZARDS
REDUCTION
PROGRAM

Response to 1971 San Fernando EQ

- Damage to Olive View Hospital
  - Stair tower separated from building
  - Near collapse in second story

Responses to San Fernando EQ

- 1972 Workshop - Improve codes
- 1974 SEAOC - Quick Change
  - Higher forces
  - Soil factor
  - Importance factor
- 1974-76 ATC-3 Project
  - Fundamental changes
- 1977 Earthquake Hazard Reduction Act
- 1990 Executive Order 12699

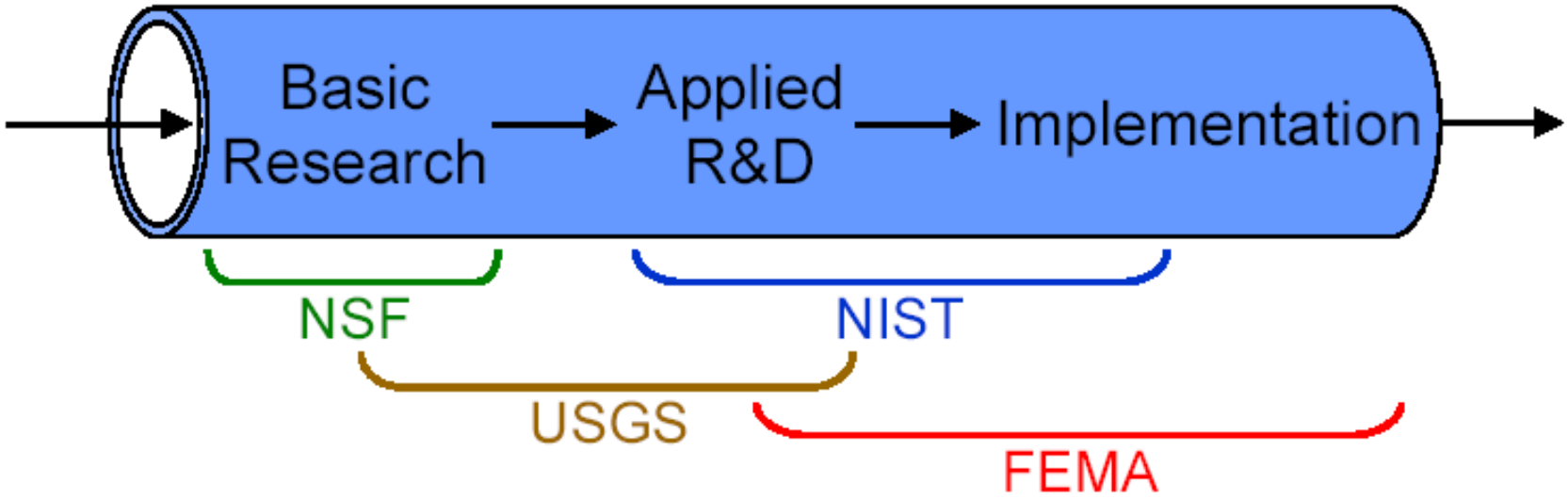
Creation and Reauthorization of NEHRP

- Public Law 95-124: EHRA of 1977 –
  "to reduce risks to life and property from future earthquakes in the United States."
  - Seismic safety of construction
  - National model building codes
  - Plus response, recovery, and other concerns
- The NEHRP was last reauthorized in 2004 (PL 108-360)

The NEHRP Agencies

- Federal Emergency Management Agency
- National Institute of Standards and Technology (lead agency)
- United States Geological Survey
- National Science Foundation

NEHRP Research to Practice Pipeline



ATC 3-06 Report

ATC 3-06
NSF 78-8

TENTATIVE PROVISIONS
FOR THE DEVELOPMENT OF
SEISMIC REGULATIONS FOR BUILDINGS

A Cooperative Effort with the Design Professions, Building Code Interests and the Research Community

Prepared by

ATC APPLIED TECHNOLOGY COUNCIL

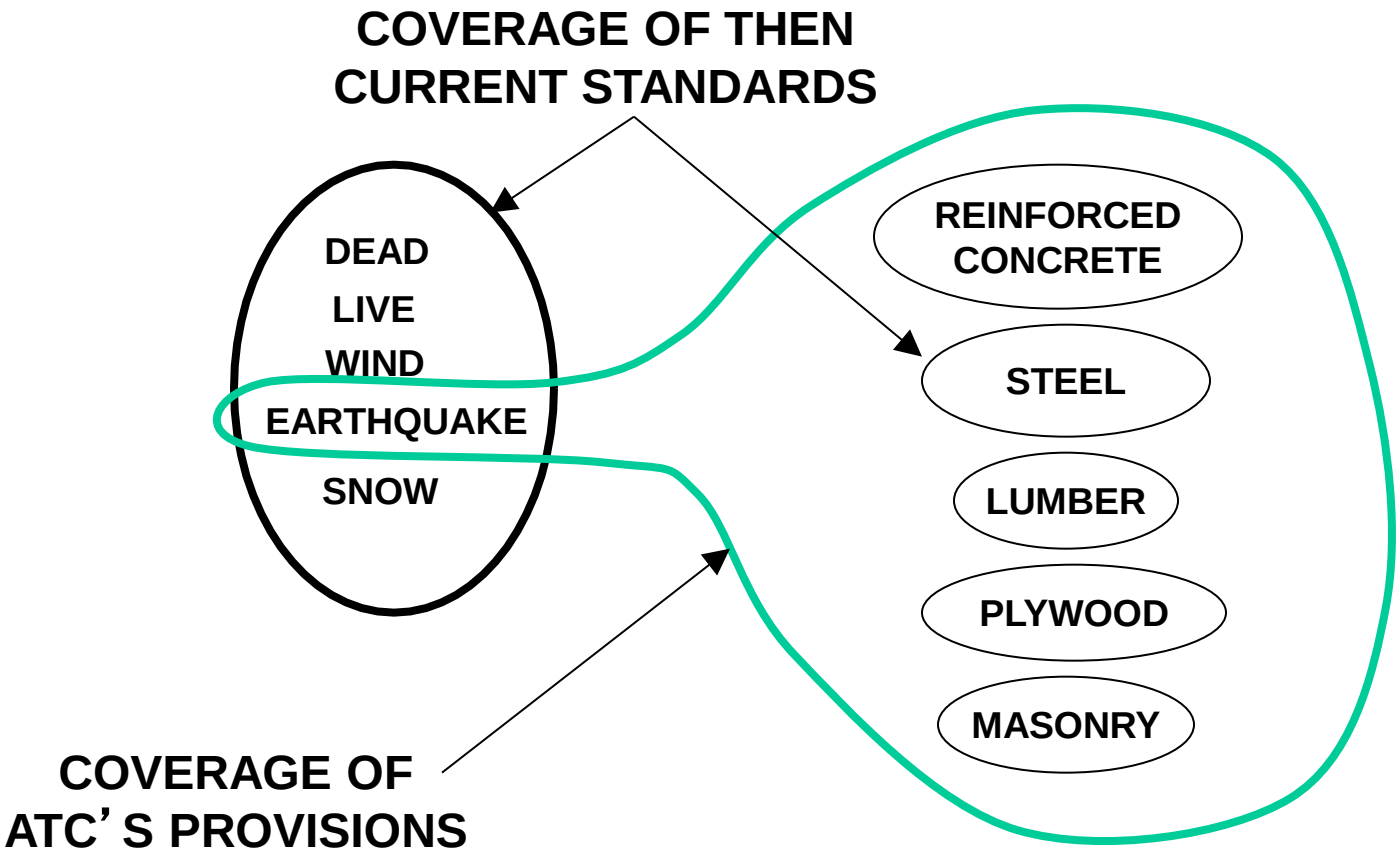
Associated with the Structural Engineers Association of California

National Science Foundation

National Bureau of Standards

- 1978 Publication of ATC / NSF / NBS
- New approaches:
  - Nationwide
  - Probabilistic
  - Inelastic behavior
  - Strength level
  - Nonstructural
  - Existing Buildings

Standards for Structural Design vs. ATC's Provisions



History of NEHRP Provisions

- 1974-78 ATC 3 Tentative Provisions
- 1979-80 Review Committees
- 1981-84 Trial Designs
- 1985 Edition (first edition to be “Recommended”)
- New editions in 1988, 1991, 1994, 1997, 2000, 2003, and 2009

The Role of the NEHRP Recommended Provisions for Federal Buildings

- The Interagency Committee on Seismic Safety in Construction (ICSSC), the federal committee to coordinate the implementation of Executive Order 12699, recommended the use of seismic design standards and codes equivalent to or exceeding those in the most recent or immediate proceeding edition of the *NEHRP Recommended Provisions*

Creation of the BSSC

Building Seismic Safety Council

BSSC

- Private, Voluntary
- Now a council of NIBS
- 50+ Member Organizations
  - Consensus Process to evaluate new knowledge and technology for seismic safety of buildings
  - National and professional forum to foster improved seismic safety provisions for the nation

The 2009 Provisions Update Process

TS1:	TS2:	TS3:	TS4:	TS5:	TS6:	TS7:	TS8:
Document Composition	Design Criteria & Advanced Technologies	Foundations & Geotech.	Concrete	Masonry	Steel	Wood	NBS/Non-structural

IT1:	IT2:	IT3:	IT4:
Performance Criteria	Design Parameters	Base Plate & Anchors	Seismic Maps

↓

Provisions Update Committee

↓

Board of Direction

↓

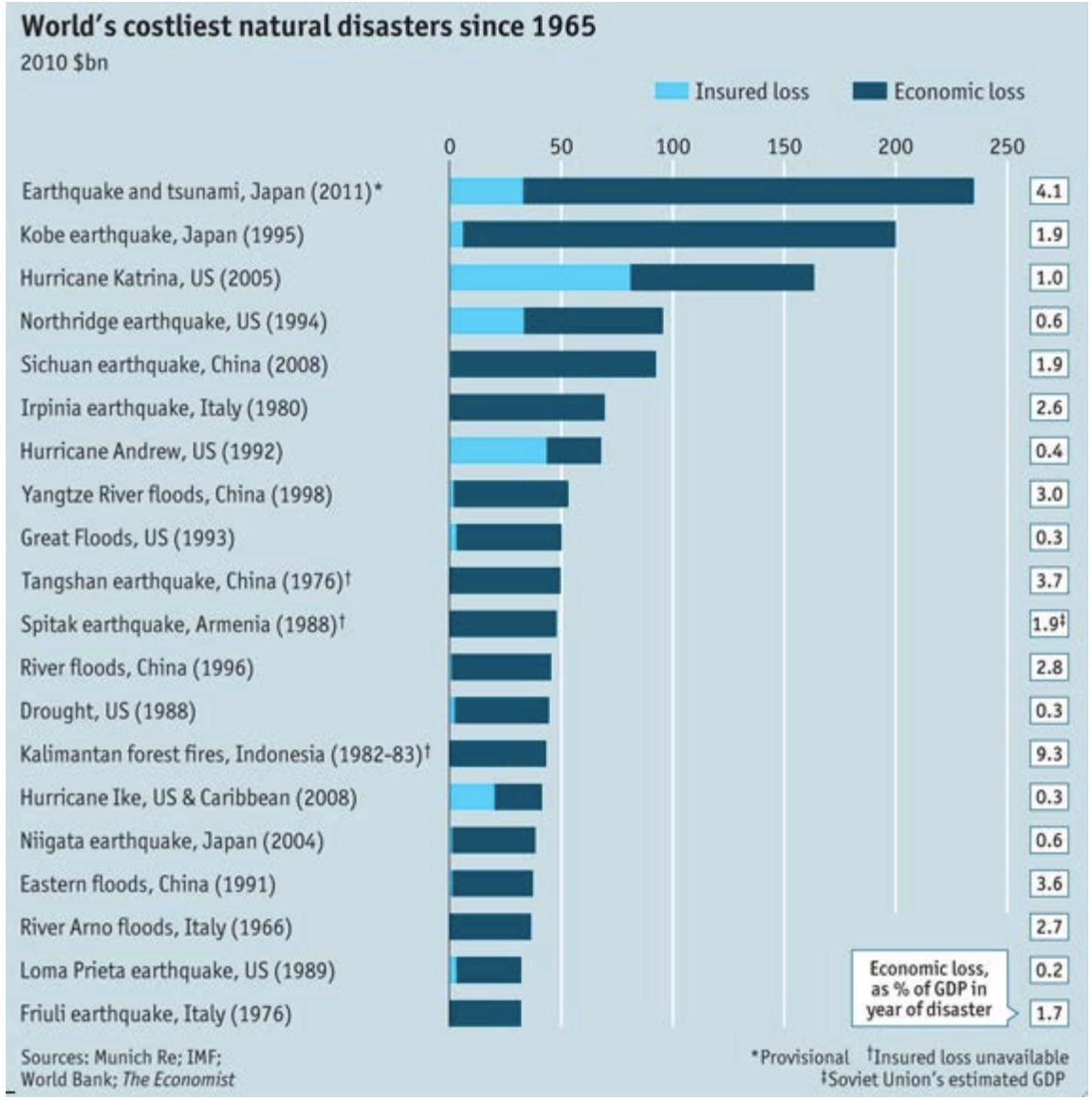
BSSC Members (not a complete list):

ACI AF&PA AIA AISC AISI AITC APA ASCE ASME ASHRE ATC BIA EERI ICC IBHS NAHB NCMA NAHB NCSEA NFPA PCA PCI RMI SEAOC TMS

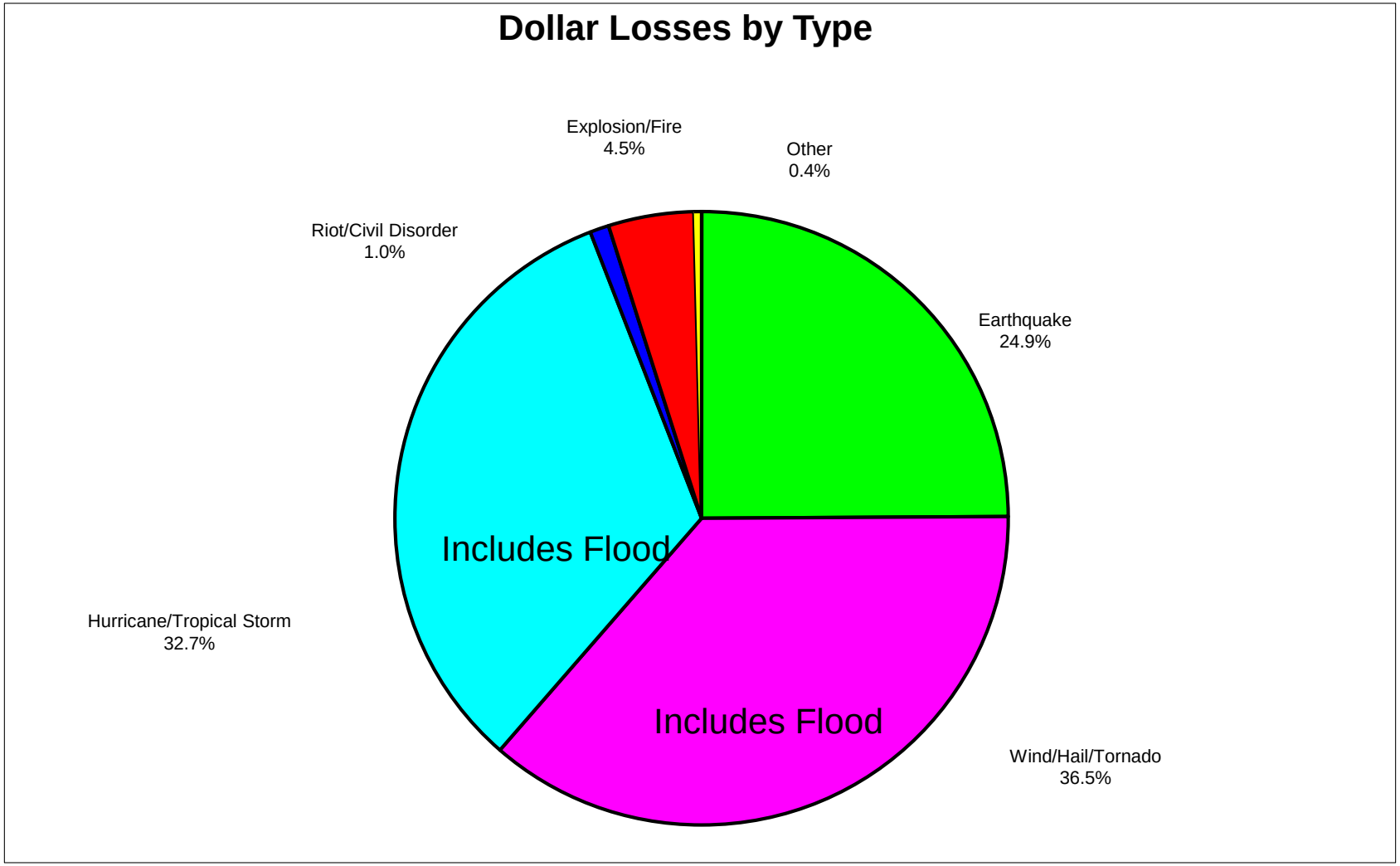
Motivation for Earthquake Engineering

- Minimize human death and injury
- Minimize economic loss
  - Direct (collapse and damage)
  - Indirect (loss of use, business interruption)
- Maintain lifelines

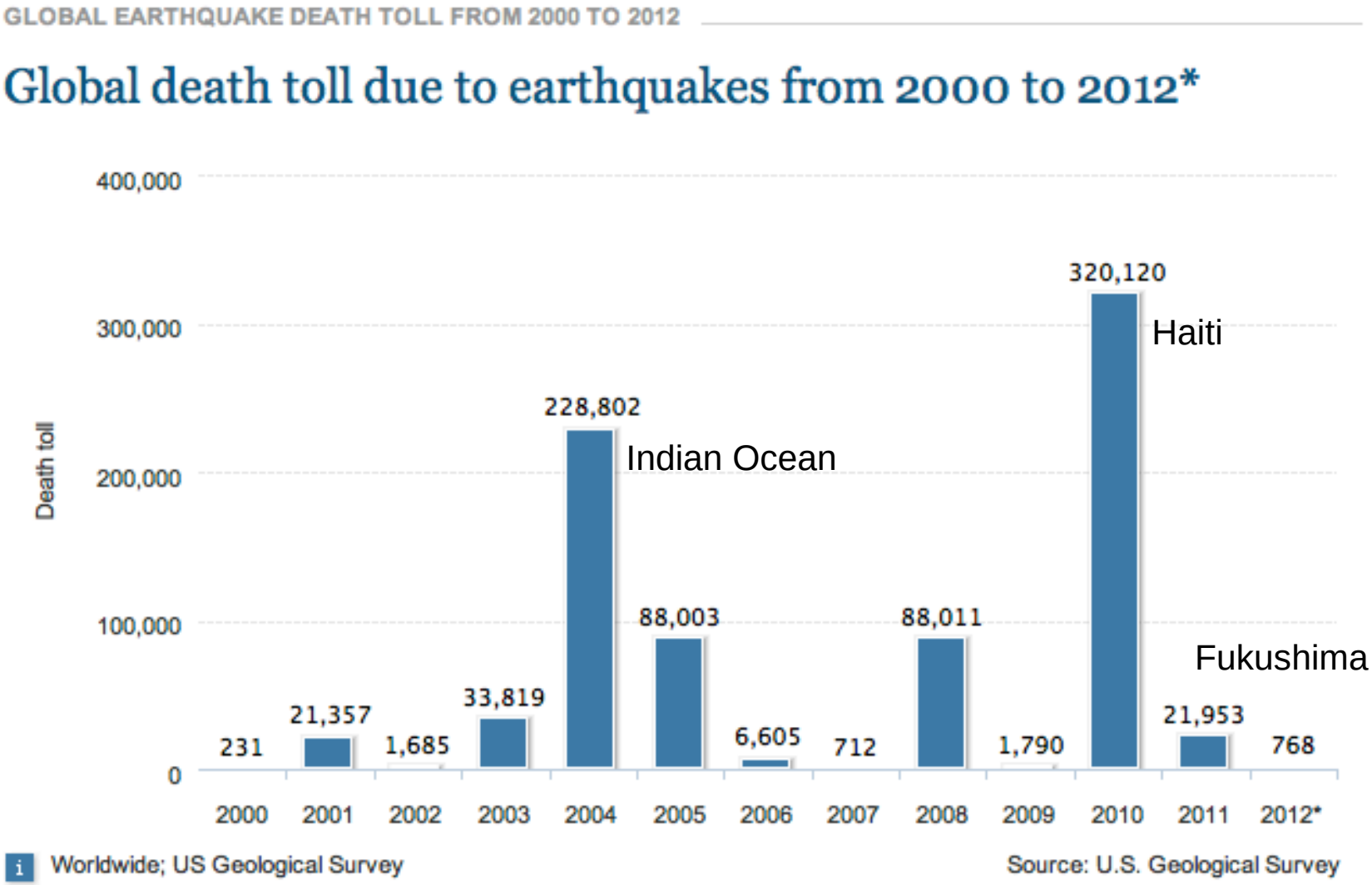
Losses Due to All Hazards



A Significant Portion of Dollar Loss Is Due to Earthquakes



Deaths due to Earthquakes



Examples of US Earthquake Losses

- 1906 San Francisco CA
- 1933 Long Beach CA
- 1964 Alaska AK
- 1971 San Fernando Valley CA
- 1989 Loma Prieta CA
- 1994 Northridge CA
- 2001 Nisqually WA
- 2011 Mineral VA

1971 Earthquake in the San Fernando Valley of California

NISEE

Earth dam located about 20 km from the epicenter. Part of the upstream face lost bearing strength and slipped beneath the water.

1971 San Fernando Valley Earthquake

"Soft story" failure of the Olive View Hospital. The column failure caused a collapse that pinned the ambulances under the rubble, rendering them useless.

1989 Loma Prieta Earthquake

Oakland Bay Bridge failure.

1989 Loma Prieta Earthquake

A collapsed wood frame residential building in Marina District

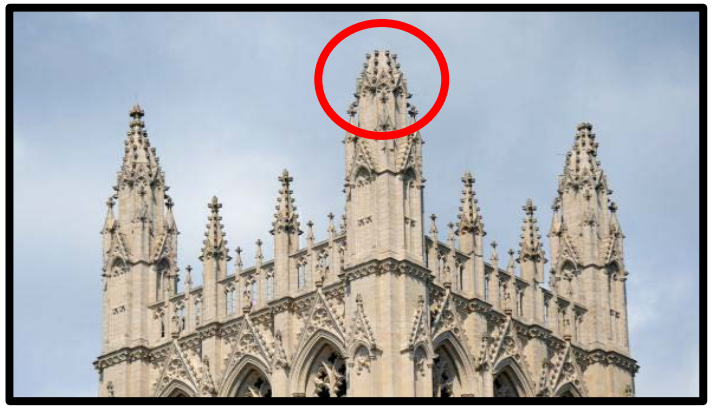
1994 Northridge Earthquake

Bull Creek Canyon Channel Bridge on the Simi Valley freeway near the epicenter to the north. Shear failure of a flared column.

Northridge Earthquake

Gavin Canyon Undercrossing on I-5

2011 Mineral VA Earthquake



Damage to DC landmarks, including the National Cathedral and the Washington Monument

Examples of Earthquake Losses Outside the United States

- 1923 Tokyo
- 1927 China
- 1960 Chile
- 1985 Chile
- 1985 Mexico City
- 1988 Armenia
- 1993 Hokkaido
- 1995 Kobe
- 1999 Turkey, Taiwan
- 2001 India
- 2003 Iran
- 2005 Sumatra
- 2008 China
- 2010 Haiti, Chile
- 2011 New Zealand, Japan, Turkey

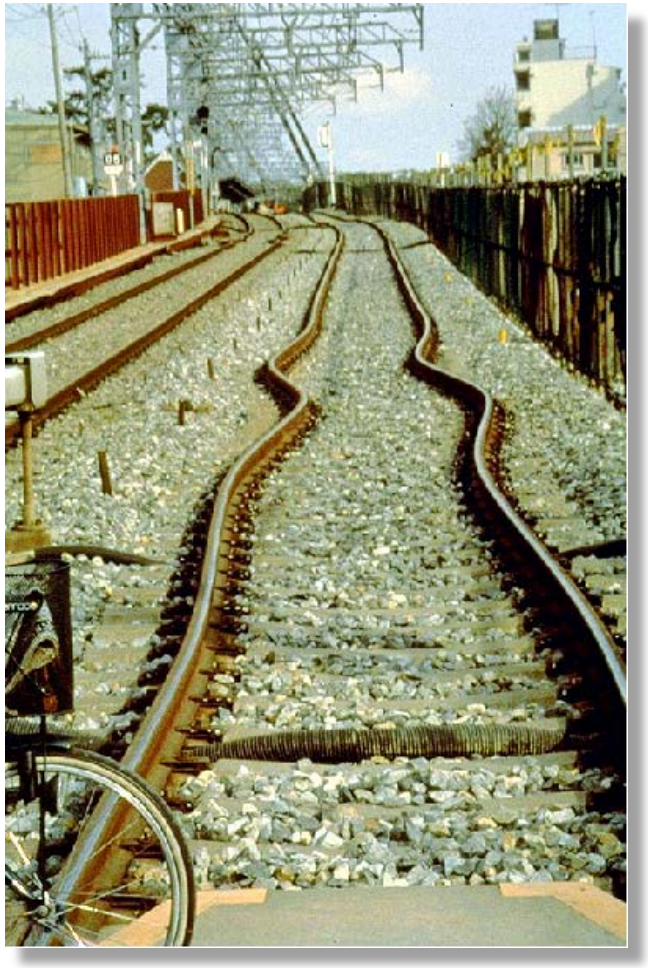
1985 Mexico City Earthquake

Pino Suarez Towers looking north -- one of the few steel frame buildings to collapse.

1988 Leninakan, Armenia, Earthquake

Damage to a stone bearing wall building. The floor planks were not tied to the supporting bearing walls.

1995 Kobe, Japan, Earthquake

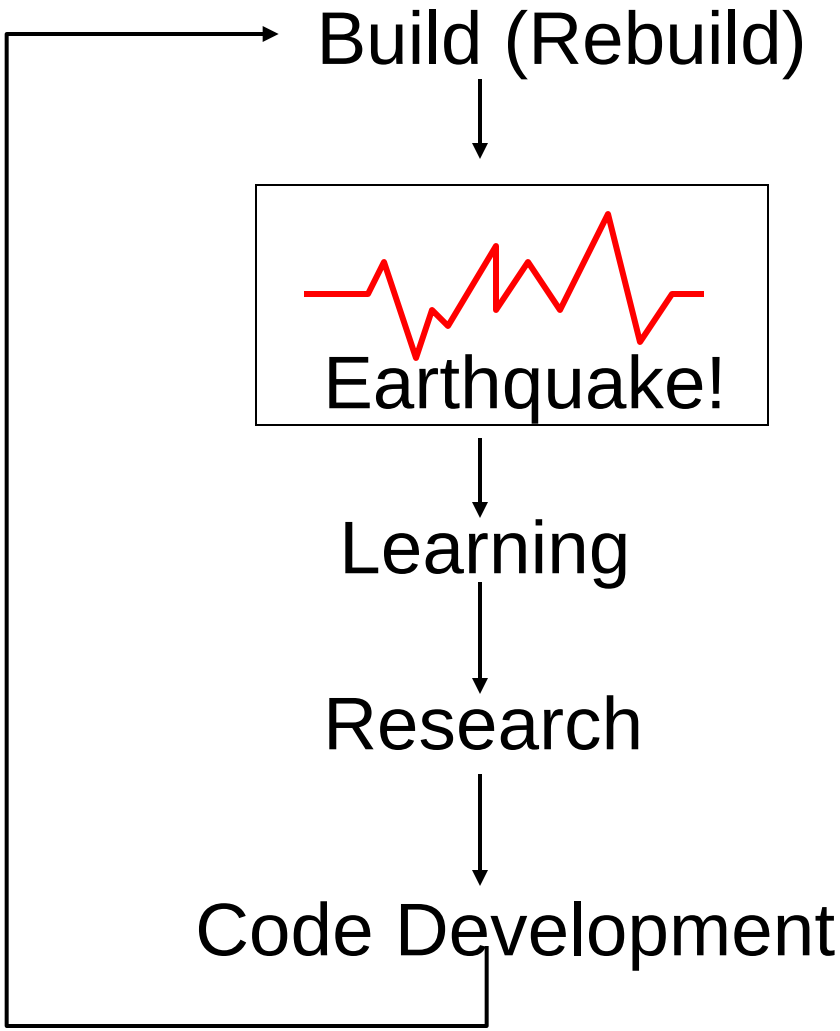


Distorted train tracks

2011 Christchurch, New Zealand, Earthquake

Collapsed Pyne Gould Guinness building

Typical Build/Event/Learn Cycle



Who is Involved in Earthquake Hazard Mitigation?

Construction

Architecture

Sociology

Economics

Seismology

Materials

The Built Environment
(new and existing)

Buildings
Bridges
Dams
Lifelines
Other……

Government

Insurance

Research

Education

Geology

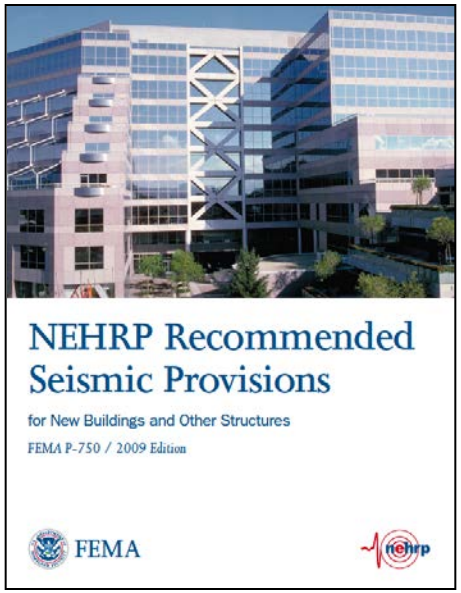
Engineering

Hazard Risk Assessment

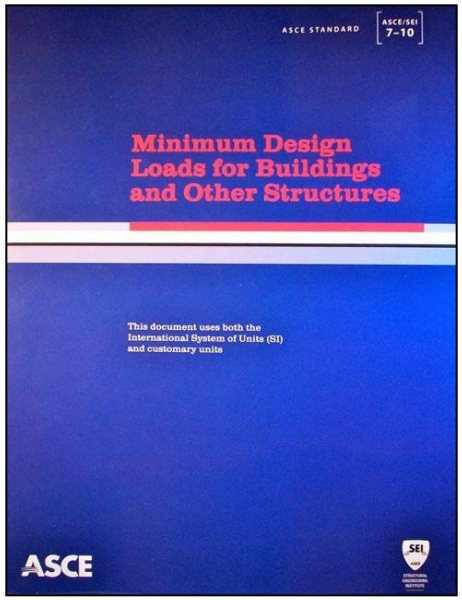
These Instructional Materials FOCUS on STRUCTURAL ENGINEERING and…

- New buildings
- Hazards associated with ground shaking
- "Force-Based" approach of 2009 *NEHRP Recommended Provisions* (FEMA P-750)
- Examples presented in *NEHRP Recommended Provisions: Design Examples* (FEMA P-751)
- Probabilistic and deterministic based ground motions

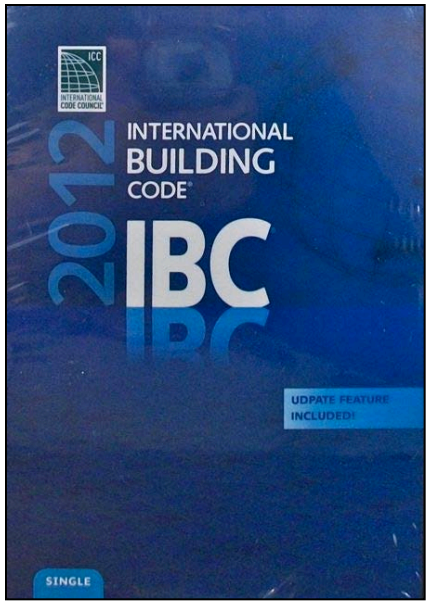
Published Design Documents For New Buildings



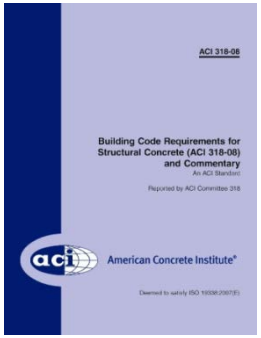
FEMA P-750

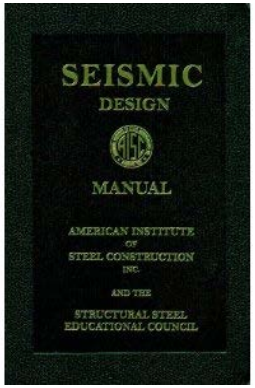


ASCE 7



IBC





Materials Standards

New Buildings: the 2009 *NEHRP Recommended Provisions*

- Uses risk-targeted seismic hazard map (1% chance of collapse in 50 years) as criterion
- Relies on "equal displacement" concept to establish design forces
- Based on *linear elastic* static or dynamic analysis
- Deformations checked globally
- Intended result (obtained somewhat *implicitly*)

- Little or no damage for frequent earthquake
- Minor nonstructural damage for common earthquake
- Life-safety or collapse prevention for rare earthquake

Structural engineering is

the art of using materials

that have properties which can only be estimated

to build real structures

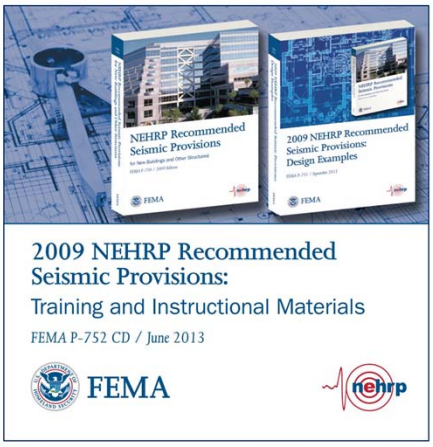
that can only be approximately analyzed

to withstand forces

that are not accurately known

so that our responsibility to the public safety is satisfied

Questions



1

Introduction

Robert G. Pekelnicky, P.E., S.E.

FEMA nehrp

Instructional Material Complementing FEMA P-751, Design Examples

Title slide.

Slide showing cover of FEMA P-752 the 2009 NEHRP Recommended Provisions: training and instructional materials. This FEMA publication is developed to support the FEMA P-751, Design Examples and FEMA P-750 the 2009 NEHRP Provisions.

NEHRP Recommended Provisions: Instructional Materials (FEMA P-752)

- These instructional materials complement FEMA P-751 CD, *NEHRP Recommended Seismic Provisions: Design Examples*
- Users should have the FEMA P-751 CD; and FEMA P-750, *The* 2009 *NEHRP Recommended Seismic Provisions for New Buildings and Other Structures*

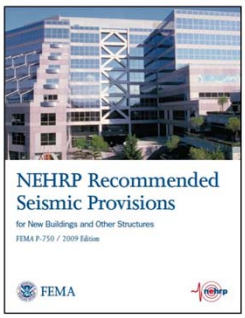
FEMA nehrp Instructional Material Complementing FEMA P-751, Design Examples Introduction 1 - 3

The instructional materials (P-752) are related to the design examples (P-751) which are based on the Provisions (P-750). The users are recommended to obtain the P-750 and P-750 along with the P-752. Because the 2009 NEHRP Provisions have adopted ASCE 7-05 by reference for part I, Provisions. Users may want also to get a copy of the ASCE7 for reference.

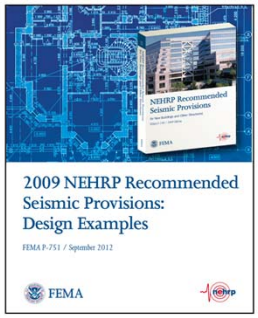
FEMA P-750 and P-751

Single copies of both publications are available at no charge from FEMA publication warehouse

Call 1-800-480-2520 to order

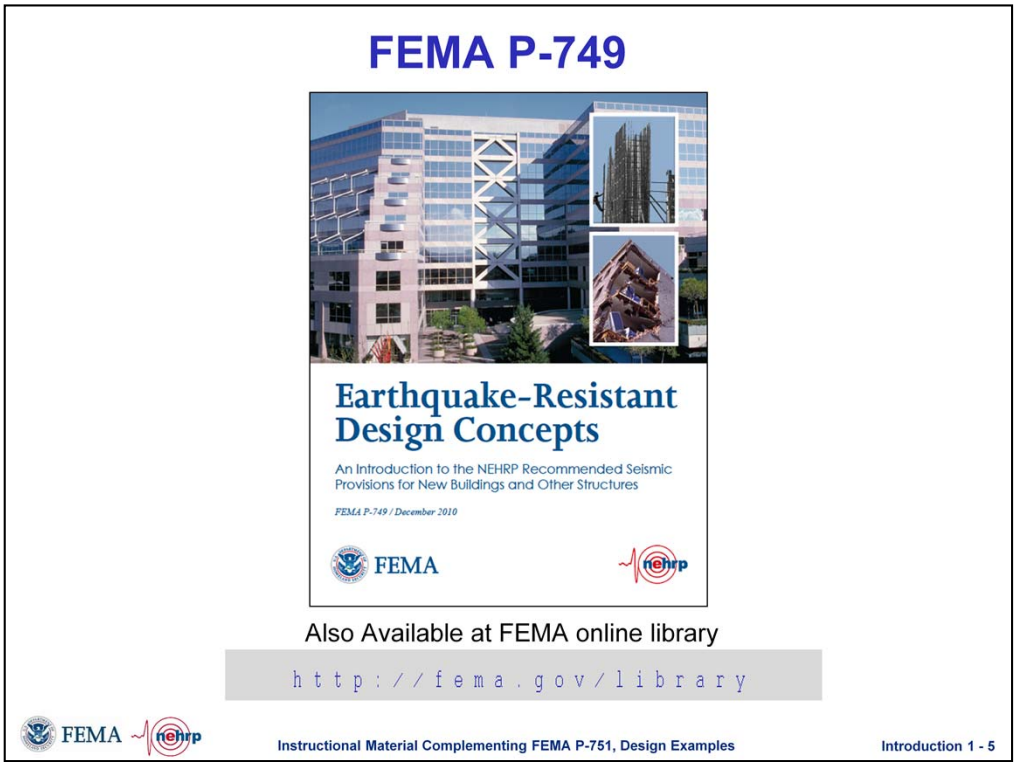


FEMA P-750



FEMA P-751

Information on how to obtain FEMA documents from FEMA publication warehouse.



While not specifically discussed in this training materials, the FEMA P-749 document, shown in the slide, is an excellent resource on the technical background of FEMA P-750. It provides an introduction of the basic concepts of seismic design including the response spectrum, maximum considered earthquake and its related maps, and seismic design categories (SDC).

Development of the Provisions

- FEMA P-750, P-751, and P-752 were developed for FEMA by the Building Seismic Safety Council (BSSC) of the National Institute of Building Sciences (NIBS).
- The *NEHRP Recommended Provisions* has been updated through a consensus process at the BSSC since its first edition was published in 1985. The 2009 edition is the 7th update.
- For information about the BSSC and the current activities related to the NEHRP Provisions, see

http://BSSC.nibs.org

FEMA nehrp Instructional Material Complementing FEMA P-751, Design Examples Introduction 1 - 6

For additional information about the NEHRP provisions, other related materials (e.g. the seismic maps) and current NEHRP Provisions update activities, users may check the indicated BSSC web site.

Slide Sets Included in FEMA P-752

- Topic 1: Introduction
- Topic 2: Fundamentals of Earthquake Engineering
- Topic 3: Ground Motions
- Topic 4: Structural Analysis (Parts 1 and 2)
- Topic 5: Foundation Design
- Topic 6: Steel Structures
- Topic 7: Reinforced Concrete
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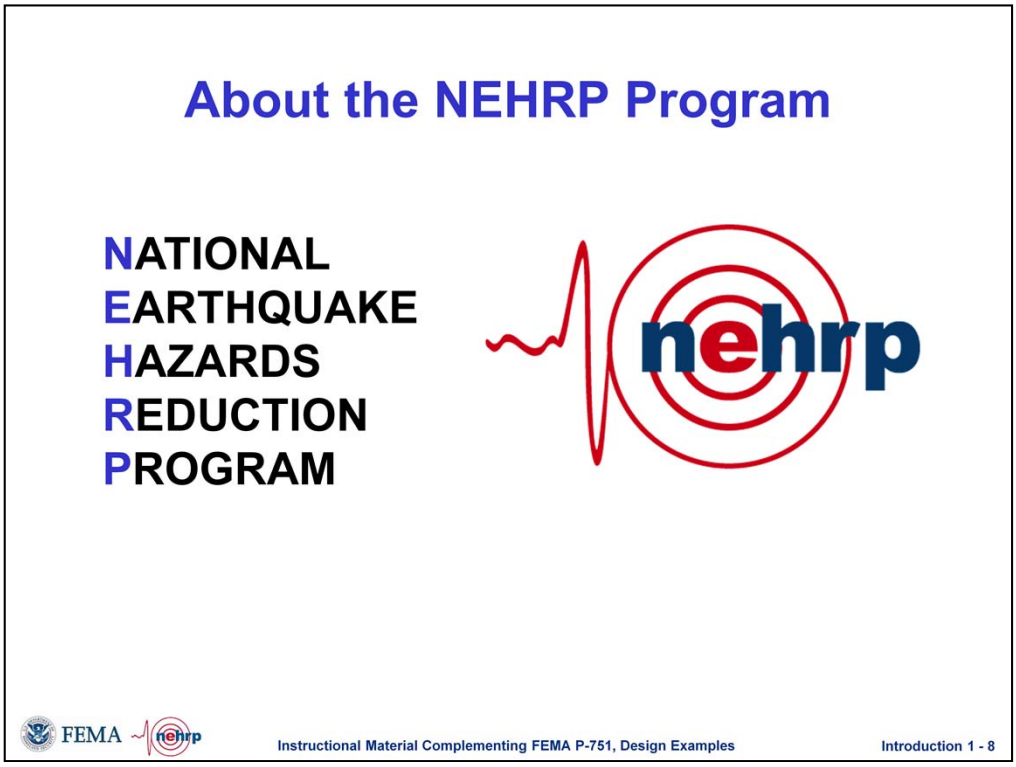
- Topic 14: Nonstructural Components
- Topic 15: NONLIN and EQ Tools (not part of FEMA P-751)

Note: The "Topics" 1-14 of FEMA P-752 correspond to the example "Chapters" in FEMA P-751. Topic 15 is not part of P-751 but is included here as a means of providing information about this software.

FEMA nehrp Instructional Material Complementing FEMA P-751, Design Examples Introduction 1 - 7

This FEMA publication contains 15 slide sets. The FEMA P-752 superseded FEMA 451B. Some of the sets (e.g. Analysis, Precast Concrete) are new, and are very closely associated with the design examples. Others (e.g. Steel, Concrete) were updated for consistency with the design examples, but contain mostly the same theoretical materials from the previous FEMA 451B. For ease of teaching, all of the content related directly to the design examples has been moved to the end of each individual topic.

It is expected that these materials can be presented in two days, with seven hours of instruction per day. The course leader will need to select materials from the full slide sets to customize for the audience, and to make the course presentable in two days.



NEHRP: acronym for National Earthquake Hazards Reduction Program. This federally-funded program was created in 1977 by Congress under the Earthquake Hazards Reduction Act (Public Law 95-124 and its later amendments). The primary objective of NEHRP is "to reduce the risks of life and property from future earthquakes in the United States." NEHRP also promotes earthquake resistant construction, helps to improve national model building codes, translation of research results for the design practice community. NEHRP supports greater understanding of seismic phenomena, dissemination of information, education, and research.

Response to 1971 San Fernando EQ

- Damage to Olive View Hospital
  - Stair tower separated from building
  - Near collapse in second story

FEMA nehrp Instructional Material Complementing FEMA P-751, Design Examples Introduction 1 - 9

Photo of severe structural damage caused by San Fernando earthquake (1971); illustrates inadequacies of then current design and construction practices. Although the 1964 Alaska earthquake was studied carefully as well and captured the interest of the academic community, the 1971 earthquake was the one that really got the interest of the federal government. It was far from the most intense earthquake that could strike, and yet it caused great damage and disruption. The building construction community worried about what would happen in potentially much larger earthquakes that could strike major urban areas. It called for federal government support to examine the seismic design level and requirements imposed under then current building code.

Responses to San Fernando EQ

- 1972 Workshop - Improve codes
- 1974 SEAOC - Quick Change
  - Higher forces
  - Soil factor
  - Importance factor
- 1974-76 ATC-3 Project
  - Fundamental changes
- 1977 Earthquake Hazard Reduction Act
- 1990 Executive Order 12699

FEMA nehrp Instructional Material Complementing FEMA P-751, Design Examples Introduction 1 - 10

1972 Workshop: Covered building practices for disaster mitigation (earthquake, wind, and other dynamic loads). Result: Building Science Series 46, *Building Practices for Disaster Mitigation*; recommended action on national level to implement existing knowledge and identified gaps where research was needed. "Model code provisions and commentary should be prepared on a top priority basis to bring the minimum level of practice into line with current state of knowledge and analytical techniques."

1974 SEAOC Quick Change: Immediately incorporated into UBC; required force levels increased, particularly for 5 to 10 story buildings, and the importance factor introduced.

ATC-3 Project: Continued response spectrum work of ATC-2. Joint project of ATC, NSF, and NBS. (More detail on a later slide)

1977: The National Earthquake Hazards Reduction Program, as previously described, was created.

1990: Executive order EO 12699 signed by President Bush. The EO requires all federally owned, leased and regulated or financially assisted buildings to incorporate adequate seismic safety measures.

Creation and Reauthorization of NEHRP

- Public Law 95-124: EHRA of 1977 – "to reduce risks to life and property from future earthquakes in the United States."
  - Seismic safety of construction
  - National model building codes
  - Plus response, recovery, and other concerns
- The NEHRP was last reauthorized in 2004 (PL 108-360)

FEMA nehrp Instructional Material Complementing FEMA P-751, Design Examples Introduction 1 - 11

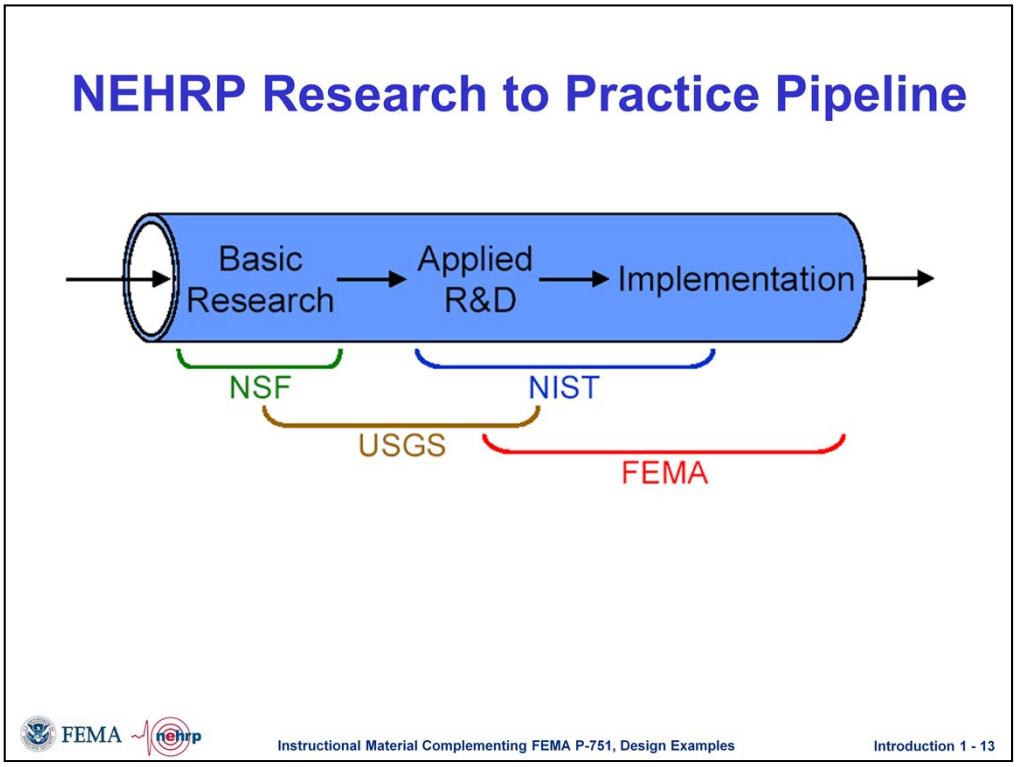
Congress catches up with federal agencies and sets forth objectives for government. NEHRP Program created by executive branch in response to this act. Goals to be met by improving seismic resistance of constructed facilities. Implemented through model codes.

The NEHRP Agencies

- Federal Emergency Management Agency
- National Institute of Standards and Technology (lead agency)
- United States Geological Survey
- National Science Foundation

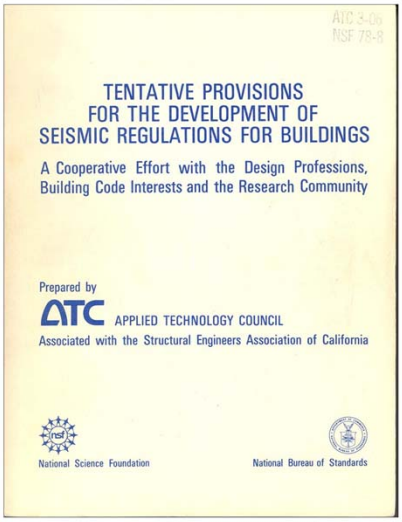
FEMA nehrp Instructional Material Complementing FEMA P-751, Design Examples Introduction 1 - 12

The designated federal agencies to support NEHRP: FEMA - not formed when NEHRP was created, but subsequently named as the administrative organization; NIST(previously NBS) – named lead agency in 2005 and coordinates ICSSC (Interagency Committee on Seismic Safety in Construction), which represents all government bodies involved in construction(HUD, GSA, the armed forces, Veterans' Administration, etc.); USGS - seismology and related topics; NSF - funds basic and applied research on earthquake engineering and policy. USGS and NSF have the largest budgets for NEHRP. FEMA's mitigation program has supported the development of improved standards for design and construction of new buildings as well as evaluation and rehabilitation of seismic hazards in existing buildings.



All NEHRP agencies support the process of moving knowledge from "research-to-practice." National Science Foundation and U.S. Geological Survey support the basic research that produces scientific advances. USGS, National Institute of Standards and Technology and FEMA incorporate these advances into applied research that leads to development of mitigation tools and information. FEMA and NIST promote use of tools thru distribution and training of designers, regulators, contractors, and public officials, and FEMA supports program implementation at the State and local level.

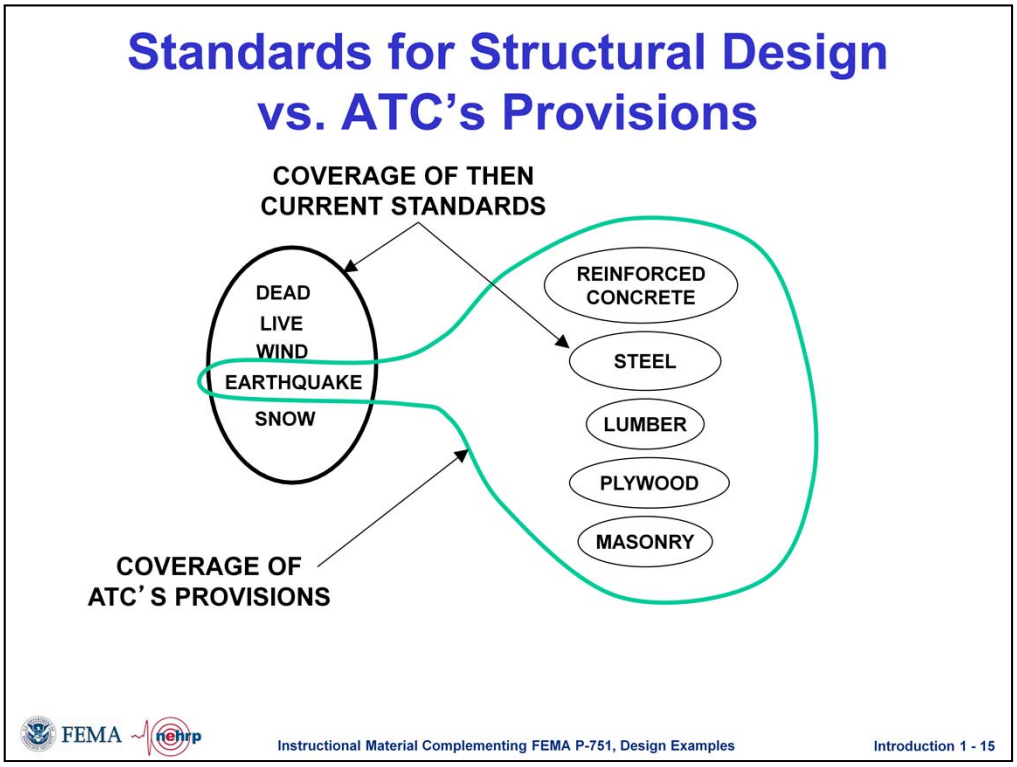
ATC 3-06 Report



- 1978 Publication of ATC / NSF / NBS
- New approaches:
  - Nationwide
  - Probabilistic
  - Inelastic behavior
  - Strength level
  - Nonstructural
  - Existing Buildings

FEMA nehrp Instructional Material Complementing FEMA P-751, Design Examples Introduction 1 - 14

ATC 3-06 innovations included: applicable nationwide, realistic ground motions, inelastic behavior, varying levels of analysis, yield level design, nonstructural aspects, and existing buildings. Each is a departure from past practice and each continues in the *NEHRP Recommended Provisions*, except: existing buildings no longer covered. Existing buildings covered by ASCE Standard 31, *Seismic Evaluation of Existing Buildings*, and ASCE Standard 41, *Seismic Rehabilitation of Existing Buildings*. Existing buildings beyond the scope of this course.



This compares scope of then existing standards (all types of loads in one standard, separate standards for design of materials individually) to ATC 3-06 (and *NEHRP RP*) coverage (earthquake loads only, applied to all materials). Thus many organizations directly affected by these seismic provisions. ATC document represented new approach to model codes.

History of NEHRP Provisions

- 1974-78 ATC 3 Tentative Provisions
- 1979-80 Review Committees
- 1981-84 Trial Designs
- 1985 Edition (first edition to be "Recommended")
- New editions in 1988, 1991, 1994, 1997, 2000, 2003, and 2009

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Point out large effort and necessary deliberate pace.

The NEHRP Provisions was the code-language resource document for the national standard ASCE 7 and the national model building codes UBC, SBC and BOCA.

The NEHRP Recommended Provisions was directly edited into the 1st edition of the IBC and reformatted into ASCE7-05.

The Role of the NEHRP Recommended Provisions for Federal Buildings

- The Interagency Committee on Seismic Safety in Construction (ICSSC), the federal committee to coordinate the implementation of Executive Order 12699, recommended the use of seismic design standards and codes equivalent to or exceeding those in the most recent or immediate proceeding edition of the *NEHRP Recommended Provisions*

FEMA nehrp Instructional Material Complementing FEMA P-751, Design Examples Introduction 1 - 17

The role of the NEHRP Provisions to meet the requirements of Executive Order 12699 for federal buildings

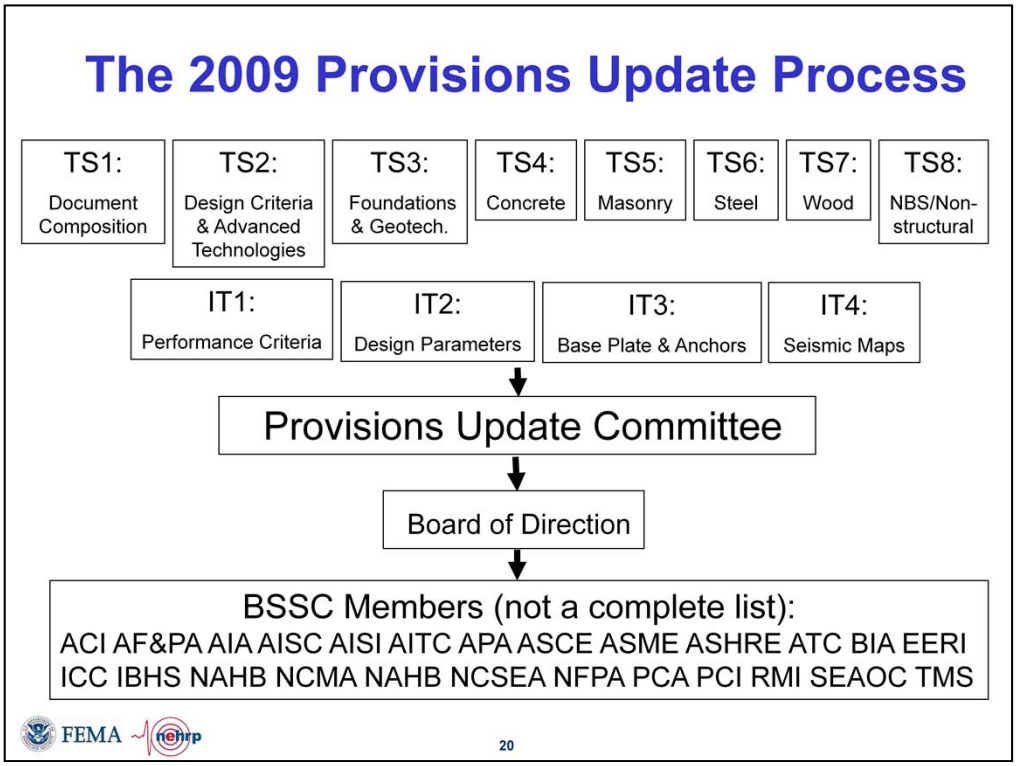
The BSSC, established in 1979, assisted in (and later took over) task of reviewing the new provisions. The BSSC members are organizations (such as ACI and SEAOC) not individuals. Its aim: improve seismic provisions for buildings. To a great extent, the demand for BSSC was created by recognition that improved mitigation of seismic risk in building design and construction demanded coordinated effort across many organizations with a stake in the model codes and the standards of practice.

BSSC

- Private, Voluntary
- Now a council of NIBS
- 50+ Member Organizations
  - Consensus Process to evaluate new knowledge and technology for seismic safety of buildings
  - National and professional forum to foster improved seismic safety provisions for the nation

FEMA nehrp Instructional Material Complementing FEMA P-751, Design Examples Introduction 1 - 19

Review nature of BSSC as noted on slide. NIBS is the National Institute of Building Sciences, a federally chartered private institution.



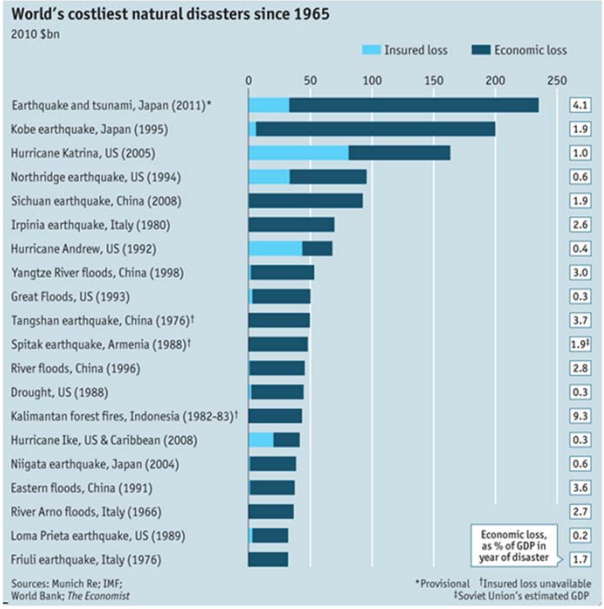
This chart shows the BSSC consensus process for evaluation and approval of technical changes adopted by the 2009 NEHRP Provisions. The BSSC consensus process also requires that all negative ballot must be resolved to the satisfactory of the PUC and BOD.

Motivation for Earthquake Engineering

- Minimize human death and injury
- Minimize economic loss
  - Direct (collapse and damage)
  - Indirect (loss of use, business interruption)
- Maintain lifelines

Motivation for earthquake engineering is primarily life safety. In some cases performance at lower level ground motions is important, and new procedures called Performance Based Earthquake Engineering principles are being developed and used.

Losses Due to All Hazards



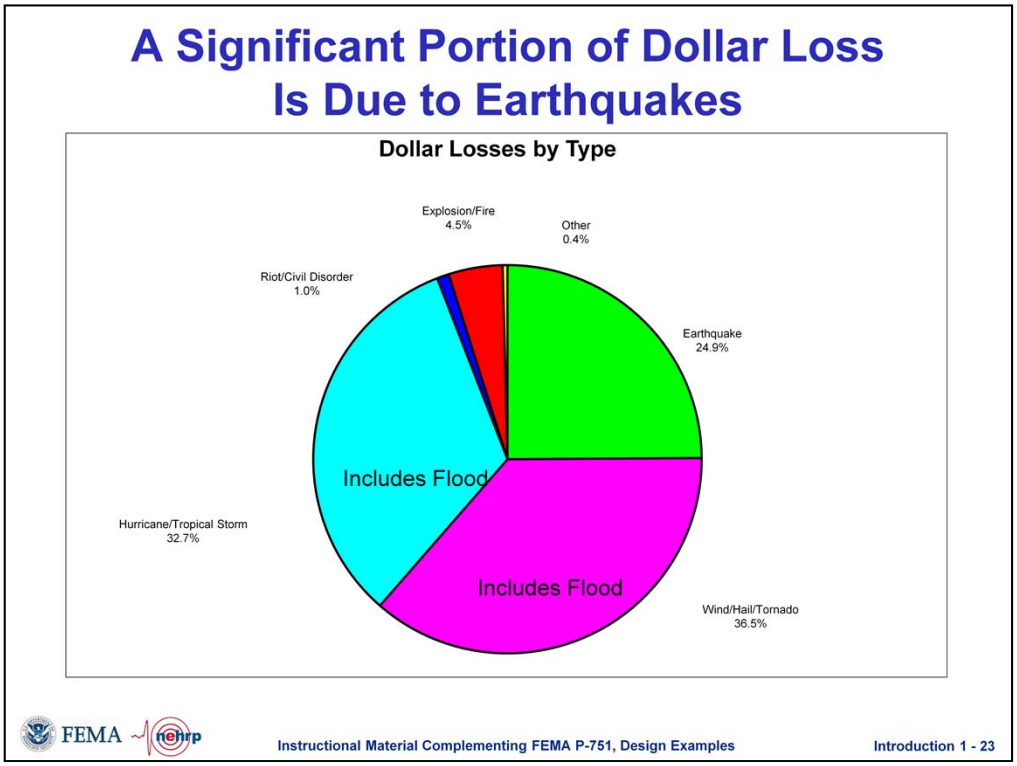
FEMA nehrp

Instructional Material Complementing FEMA P-751, Design Examples

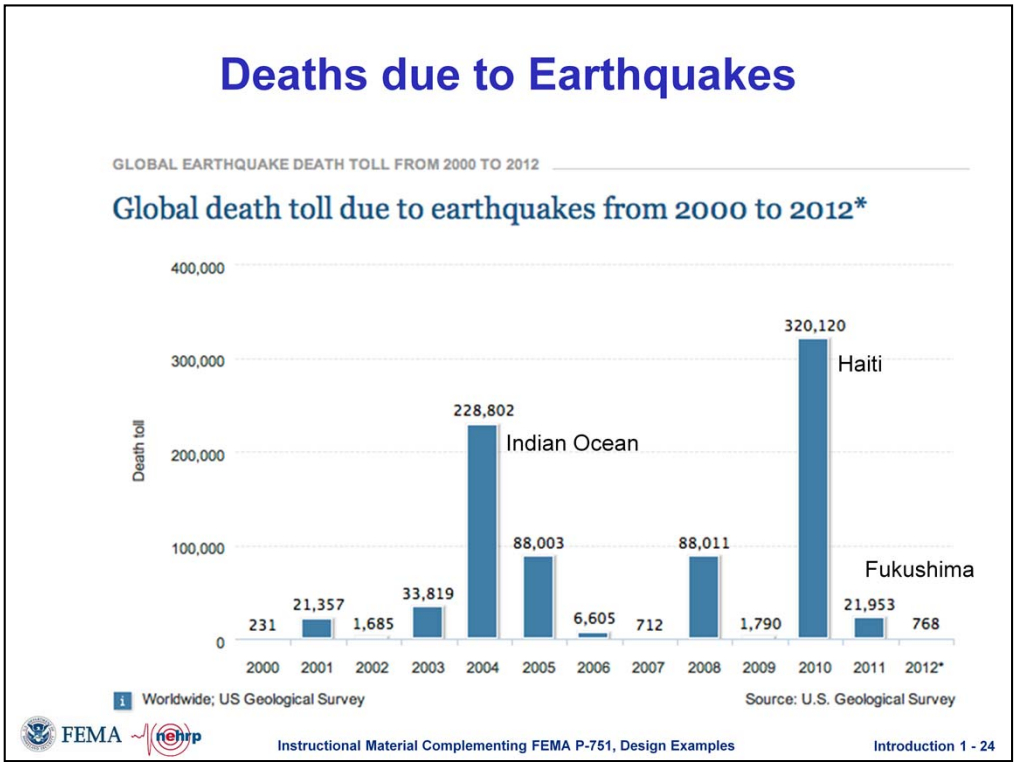
Introduction 1 - 22

Natural hazards can be catastrophic to life and property. This slide indicates dollar losses for all natural hazards in the world for the past several years.

The increasing density of construction and changing value of the dollar will combine to even larger losses in the future. Recent earthquakes in Haiti, Chile, New Zealand, Japan, and Turkey demonstrate the potential for greater losses.



Earthquakes are a significant hazard, but generally cause less dollar damage than wind, rain, and associated flooding. This slide does not break out flood damage, however, it should be emphasized that floods are one of the largest sources of losses due to natural disasters.



This slide shows deaths due to major earthquakes, with a few of the single events labeled. Most of the deaths are due to ground shaking or tsunamis.

Examples of US Earthquake Losses

- 1906 San Francisco CA
- 1933 Long Beach CA
- 1964 Alaska AK
- 1971 San Fernando Valley CA
- 1989 Loma Prieta CA
- 1994 Northridge CA
- 2001 Nisqually WA
- 2011 Mineral VA

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These are but a few of the earthquakes occurring in the U.S. during the previous century. This class will emphasize the Loma Prieta and Northridge earthquakes.

The Loma Prieta earthquake was M 6.9, depth 11 miles, a slip of San Andreas fault with 63 casualties. Some areas in San Francisco and Oakland with unstable soil suffered severe damage. One major area of property damage is Marina District (60 miles from epicenter) which suffered significant soil liquefaction with 4 buildings destroyed by fire, 7 collapsed and 63 damaged. The total number of homes damaged in the EQ is around 12,000. The worst case of damage was the failure of a 1.3 mile section of the Interstate 880 Cypress Viaduct killing 42 people.

The Northridge earthquake, like the 1971 San Fernando Valley earthquake, was a "wakeup" call to engineers and ultimately resulted in significant changes to building codes. Much of the current emphasis on Performance Based Engineering is due to the greater than expected damage that occurred as a result of the Northridge earthquake.

The recent Mineral VA earthquake occurred on Aug 23, 2011. It was M 5.8 with depth 4 miles, the EQ was an intra-plate earthquake with maximum MMI VII (out of XII). The EQ was felt across the eastern US and Canada and reported to the USGS Did-You-Feel-It program from a wide area. The strong ground motions are used in NGA East models. Damages were reported in great Washington DC area,

Maryland, Delaware and West Virginia – 100 miles away. Noticeable damages include cracks on national monument and falling of four pinnacles on national cathedral. Most commonly seen damages are falling chimney, parapets, gable walls and building contents. A Louise County public school building near the epicenter was structurally damaged. It is a significant event in VA where most areas are under SDC B.

1971 Earthquake in the San Fernando Valley of California

NISEE

Earth dam located about 20 km from the epicenter. Part of the upstream face lost bearing strength and slipped beneath the water.

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Photo shows liquefaction damage to a dam. This slide emphasizes the fact that damage occurs to non-building structures as well as building structures.

1971 San Fernando Valley Earthquake

"Soft story" failure of the Olive View Hospital. The column failure caused a collapse that pinned the ambulances under the rubble, rendering them useless.

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Photos show damage to a hospital building. The first story of the building is almost completely collapsed.

Damage to the Olive View Hospital was particularly disturbing, because the structure was relatively new, and was designed according to the "modern" code at the time. The building was a complete loss, and had to be demolished. Note that the ambulance canopy in the foreground is a separate structure, and was also a complete loss. Also significant is the fact that the ambulances were trapped in the collapsed canopy and were not available for use.

During the 1994 Northridge earthquake, the new structure fared rather well, but there were significant losses associated with nonstructural elements and components.

1989 Loma Prieta Earthquake

Oakland Bay Bridge failure.

Damage to the San Francisco-Oakland Bay Bridge, where one span collapses. There were more serious highway collapses in Oakland where several people lost their lives.

1989 Loma Prieta Earthquake

A collapsed wood frame residential building in Marina District

The photo shows a collapsed residential building in Marina District during the Magnitude 6.9 Loma Prieta Earthquake October 18, 1989.

1994 Northridge Earthquake

Bull Creek Canyon Channel Bridge on the Simi Valley freeway near the epicenter to the north. Shear failure of a flared column.

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Photo showing the failure of a column supporting a bridge. The concrete has virtually exploded and all the rebar is buckled.

Freeways in the Los Angeles area were also not immune to damage during the Northridge earthquake. Ironically, many of the bridges that failed were scheduled for rehabilitation prior to the earthquake.

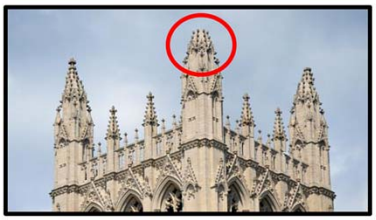
Approximately 60 people were killed by the quake.

Northridge Earthquake

Gavin Canyon Undercrossing on I-5

Photo showing damage to the Gavin Canyon undercrossing during Northridge earthquake. Note the truck on the bridge!

2011 Mineral VA Earthquake



Damage to DC landmarks, including the National Cathedral and the Washington Monument

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Introduction 1 - 32

A M5.8 earthquake hit Mineral VA on Aug 23, 2011 and caused non-structural damage in Washington DC area as shown in the pictures. This moderate earthquake impacted a wide area of low to moderate seismicity and caused sizable damage.

Examples of Earthquake Losses Outside the United States

- 1923 Tokyo
- 1927 China
- 1960 Chile
- 1985 Chile
- 1985 Mexico City
- 1988 Armenia
- 1993 Hokkaido
- 1995 Kobe
- 1999 Turkey, Taiwan
- 2001 India
- 2003 Iran
- 2005 Sumatra
- 2008 China
- 2010 Haiti, Chile
- 2011 New Zealand, Japan, Turkey

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Earthquakes occur all over the world and often produce unimaginable destruction. Codes and enforcement in developing countries are often decades behind those of the industrialized world.

1985 Mexico City Earthquake

Pino Suarez Towers looking north -- one of the few steel frame buildings to collapse.

FEMA nehrp Instructional Material Complementing FEMA P-751, Design Examples Introduction 1 - 34

Photo shows the complete collapse of a multistory steel moment frame building and a practically undamaged building nearby.

The damage in Mexico City was due to an earthquake that occurred more than 350 km away from the city center. **The main shock killed 10,000, left 50,000 homeless**, and caused four billion dollars damage.

The vast destruction was attributed in large part to dynamic amplification of seismic waves through the soft soil in Mexico City. The dominant seismic waves had a period of about **2.0 seconds**, wreaking havoc on buildings in the 10- to 20-story range.

1988 Leninakan, Armenia, Earthquake

Damage to a stone bearing wall building. The floor planks were not tied to the supporting bearing walls.

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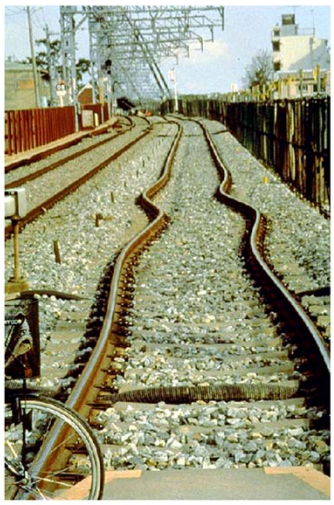
Photo shows an almost completely collapsed precast concrete and masonry building in Armenia.

This is an example of the devastation caused by earthquakes in countries without adequate seismic design and/or enforcement.

Many (almost complete destruction) precast concrete frame buildings collapsed because of inadequate detailing. This earthquake **killed at least 25,000 people**, and left 500,000 homeless. Dollar damage was estimated in excess of **13 billion**.

In Leninakan, 95% of the precast frame structures (5 to 12 stories) collapsed or were damaged beyond repair.

1995 Kobe, Japan, Earthquake



Distorted train tracks

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Photo shows distorted (bent) rails in a train track.

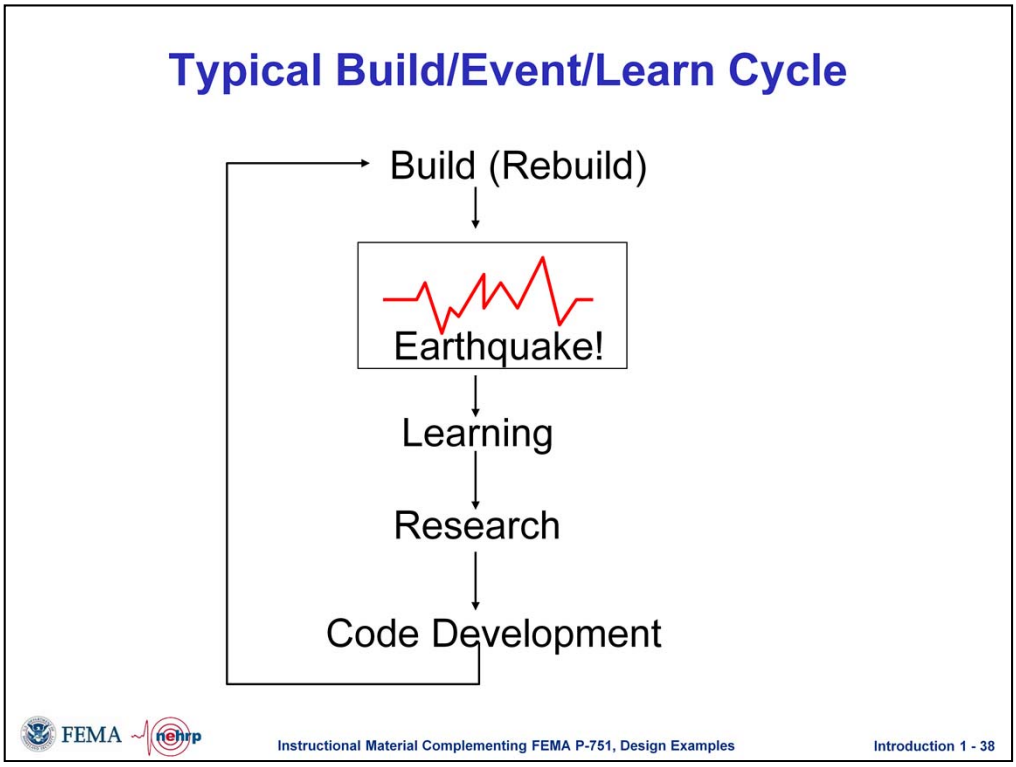
The Kobe earthquake **killed more than 5,000 people**, and **injured 26,000** others. More than 56,000 buildings were destroyed. Losses were estimated at more than **200 billion** dollars. This is more than 10 times the dollar loss for the Northridge earthquake, which occurred exactly one year earlier in southern California.

This slide was selected to emphasize the point that loss to nonbuilding structures and lifelines can have a significant effect on society.

2011 Christchurch, New Zealand, Earthquake

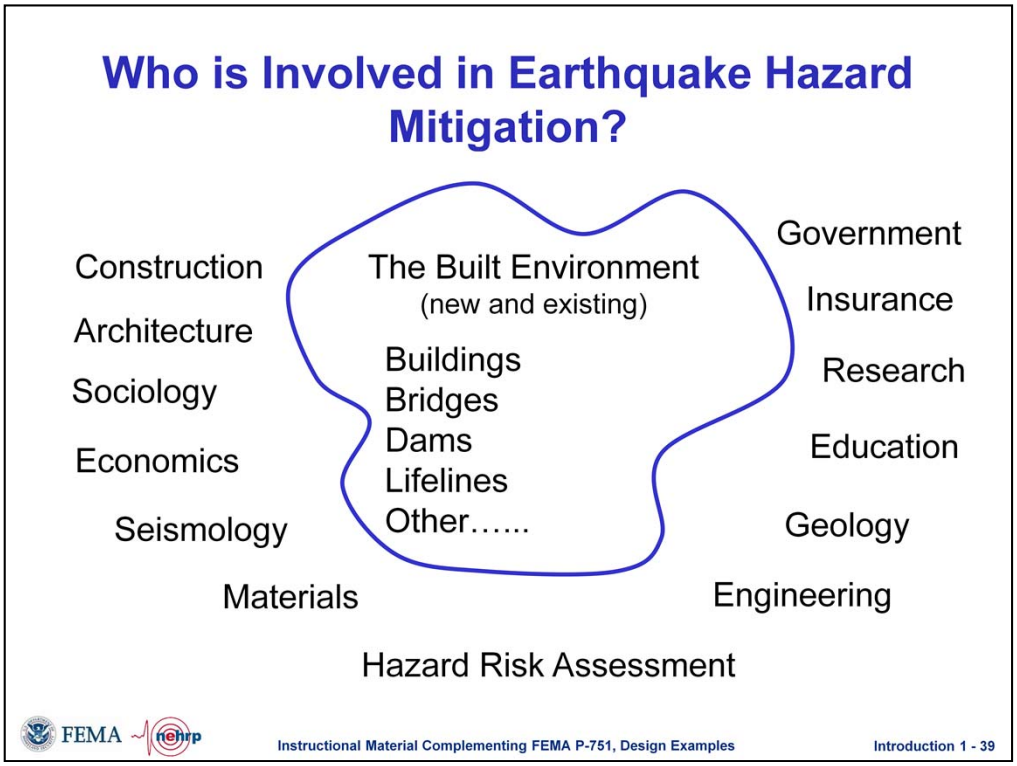
Collapsed Pyne Gould Guinness building

PGG was built in 1963 compliant to the building code then. After the 2010 Canterbury EQ, the building was inspected and found only minor structural damage. During the 2011 earthquake, PGG collapsed completely. The collapse appeared to begin from the shear wall between the first and second levels. The structure between the ground and the first levels was much stiffer than the structure between first and second levels, thus triggering the failure in the wall above the first level. Some later studies compared PGG to the current building code and found the building was not adequate for the current seismic provisions.



If there is any fortunate aspect of earthquakes, it is that the built environment is an excellent proving ground. Damage occurring during earthquakes is extensively studied, leading to research, and ultimately to the development of improved building codes.

It seems that no matter how diligently we react to earthquakes, we are taught new and serious lessons when the next quake strikes. The damage occurring to welded frame structures during the Northridge earthquake is an excellent example.



Many disciplines are involved in earthquake hazard mitigation. All groups must work together to provide the level of protection needed by society.

These Instructional Materials FOCUS on STRUCTURAL ENGINEERING and…

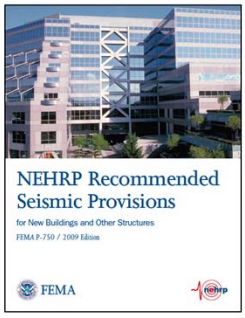
- New buildings
- Hazards associated with ground shaking
- "Force-Based" approach of 2009 *NEHRP Recommended Provisions* (FEMA P-750)
- Examples presented in *NEHRP Recommended Provisions: Design Examples* (FEMA P-751)
- Probabilistic and deterministic based ground motions

FEMA nehrp Instructional Material Complementing FEMA P-751, Design Examples Introduction 1 - 40

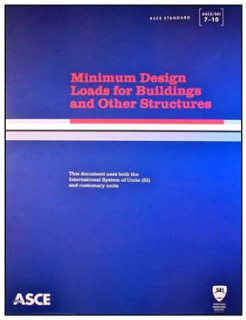
The Earthquake Protective Design portion of the MBDSI focuses almost entirely on new buildings. However, some information is provided for existing buildings, particularly as related to performance-based engineering.

The course concentrates on ground shaking, only one of the many hazards associated with earthquakes (e.g. fault rupture, liquefaction, landslides, flooding, and fire).

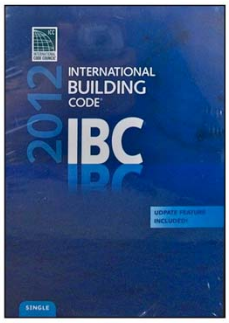
Published Design Documents For New Buildings



FEMA P-750



ASCE 7



IBC

Materials Standards

FEMA nehrp Instructional Material Complementing FEMA P-751, Design Examples Introduction 1 - 41

Slide shows photos of latest design Seismic Design documents: FEMA P-750, ASCE 7, IBC, And Steel and Concrete standards.

New Buildings: the 2009 *NEHRP Recommended Provisions*

- Uses risk-targeted seismic hazard map (1% chance of collapse in 50 years) as criterion
- Relies on "equal displacement" concept to establish design forces
- Based on *linear elastic* static or dynamic analysis
- Deformations checked globally
- Intended result (obtained somewhat *implicitly*)

  - Little or no damage for frequent earthquake
  - Minor nonstructural damage for common earthquake
  - Life-safety or collapse prevention for rare earthquake

This slide emphasizes the underlying principles of the 2009 NEHRP. Performance is evaluated somewhat implicitly, meaning that local deformations in members are not addressed. Before the Northridge earthquake, it was thought that this methodology was sufficient. Many engineers are now moving towards performance based concepts, particularly in the rehabilitation of existing buildings.

Structural engineering is
the art of using materials
that have properties which can only be estimated
to build real structures
that can only be approximately analyzed
to withstand forces
that are not accurately known
so that our responsibility to the public safety is satisfied

A variation on an “old saying” attributed to Dr. E.H. Brown, a British structural engineer (and many others). This quote began in popular in the 70’s and still is.

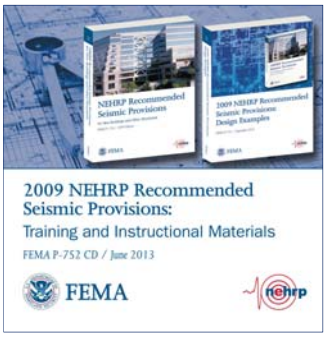
Slide to initiate questions from participants.

1

Introduction

Robert G. Pekelnicky, P.E., S.E.

NEHRP Recommended Provisions: Instructional Materials (FEMA P-752)



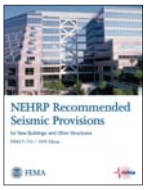
NEHRP Recommended Provisions: Instructional Materials (FEMA P-752)

- These instructional materials complement FEMA P-751 CD, *NEHRP Recommended Seismic Provisions: Design Examples*
- Users should have the FEMA P-751 CD; and FEMA P-750, *The* 2009 *NEHRP Recommended Seismic Provisions for New Buildings and Other Structures*

FEMA P-750 and P-751

Single copies of both publications are available at no charge from FEMA publication warehouse

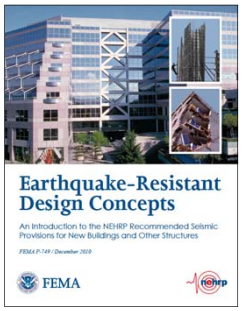
Call 1-800-480-2520 to order



FEMA P-750

FEMA P-751

FEMA P-749



Also Available at FEMA online library

http://fema.gov/library

Development of the Provisions

- FEMA P-750, P-751, and P-752 were developed for FEMA by the Building Seismic Safety Council (BSSC) of the National Institute of Building Sciences (NIBS).
- The *NEHRP Recommended Provisions* has been updated through a consensus process at the BSSC since its first edition was published in 1985. The 2009 edition is the 7th update.
- For information about the BSSC and the current activities related to the NEHRP Provisions, see

http://BSSC.nibs.org

Slide Sets Included in FEMA P-752

- Topic 1: Introduction
- Topic 2: Fundamentals of Earthquake Engineering
- Topic 3: Ground Motions
- Topic 4: Structural Analysis (Parts 1 and 2)
- Topic 5: Foundation Design
- Topic 6: Steel Structures
- Topic 7: Reinforced Concrete
- Topic 8: Precast Concrete
- Topic 9: Composite Steel/Concrete
- Topic 10: Masonry Structures
- Topic 11: Wood Design
- Topic 12: Seismic Isolation
- Topic 13: Non-building Structures
- Topic 14: Nonstructural Components
- Topic 15: NONLIN and EQ Tools (not part of FEMA P-751)

Note: The "Topics" 1-14 of FEMA P-752 correspond to the example "Chapters" in FEMA P-751. Topic 15 is not part of P-751 but is included here as a means of providing information about this software.

FEMA nehrp Instructional Material Complementing FEMA P-751, Design Examples Introduction 1 - 7

About the NEHRP Program

NATIONAL
EARTHQUAKE
HAZARDS
REDUCTION
PROGRAM

FEMA nehrp Instructional Material Complementing FEMA P-751, Design Examples Introduction 1 - 8

Response to 1971 San Fernando EQ

- Damage to Olive View Hospital
  - Stair tower separated from building
  - Near collapse in second story

FEMA nehrp Instructional Material Complementing FEMA P-751, Design Examples Introduction 1 - 9

Responses to San Fernando EQ

- 1972 Workshop - Improve codes
- 1974 SEAOC - Quick Change
  - Higher forces
  - Soil factor
  - Importance factor
- 1974-76 ATC-3 Project
  - Fundamental changes
- 1977 Earthquake Hazard Reduction Act
- 1990 Executive Order 12699

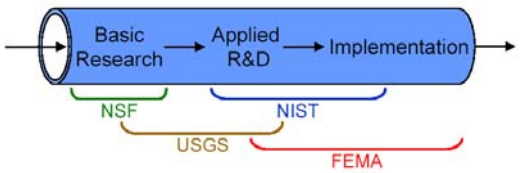
Creation and Reauthorization of NEHRP

- Public Law 95-124: EHRA of 1977 – "to reduce risks to life and property from future earthquakes in the United States."
  - Seismic safety of construction
  - National model building codes
  - Plus response, recovery, and other concerns
- The NEHRP was last reauthorized in 2004 (PL 108-360)

The NEHRP Agencies

- Federal Emergency Management Agency
- National Institute of Standards and Technology (lead agency)
- United States Geological Survey
- National Science Foundation

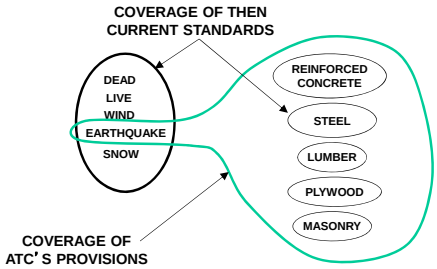
NEHRP Research to Practice Pipeline



ATC 3-06 Report

- 1978 Publication of ATC / NSF / NBS
- New approaches:
  - Nationwide
  - Probabilistic
  - Inelastic behavior
  - Strength level
  - Nonstructural
  - Existing Buildings

Standards for Structural Design vs. ATC's Provisions



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Creation of the BSSC

Building Seismic Safety Council

BSSC

- Private, Voluntary
- Now a council of NIBS
- 50+ Member Organizations
  - Consensus Process to evaluate new knowledge and technology for seismic safety of buildings
  - National and professional forum to foster improved seismic safety provisions for the nation

The 2009 Provisions Update Process

TS1: Document Composition
TS2: Design Criteria & Advanced Technologies
TS3: Foundations & Geotech.
TS4: Concrete
TS5: Masonry
TS6: Steel
TS7: Wood
TS8: NBS/Non-structural

IT1: Performance Criteria
IT2: Design Parameters
IT3: Base Plate & Anchors
IT4: Seismic Maps

↓

Provisions Update Committee

↓

Board of Direction

↓

BSSC Members (not a complete list):
ACI AF&PA AIA AISC AISI AITC APA ASCE ASME ASHRE ATC BIA EERI ICC IBHS NAHB NCMA NAHB NCSEA NFPA PCA PCI RMI SEAOC TMS

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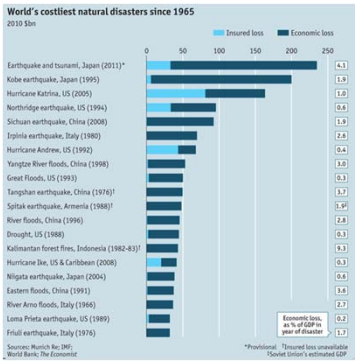
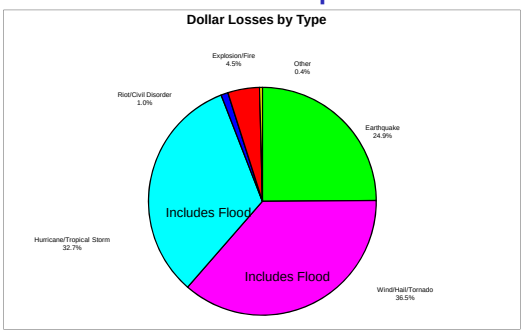
Losses Due to All Hazards



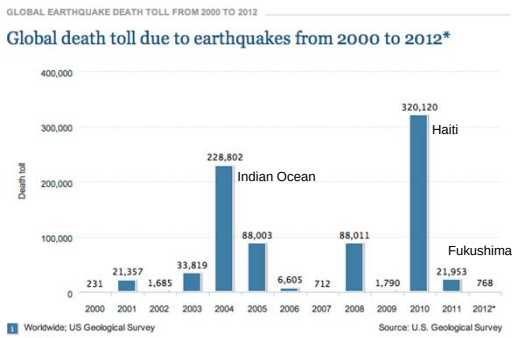
FEMA NEHRP Instructional Material Complementing FEMA P-751, Design Examples Introduction 1 - 22

A Significant Portion of Dollar Loss Is Due to Earthquakes



FEMA NEHRP Instructional Material Complementing FEMA P-751, Design Examples Introduction 1 - 23

Deaths due to Earthquakes



FEMA NEHRP Instructional Material Complementing FEMA P-751, Design Examples Introduction 1 - 24

Examples of US Earthquake Losses

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NISEE

Earth dam located about 20 km from the epicenter. Part of the upstream face lost bearing strength and slipped beneath the water.

1971 San Fernando Valley Earthquake

"Soft story" failure of the Olive View Hospital. The column failure caused a collapse that pinned the ambulances under the rubble, rendering them useless.

1989 Loma Prieta Earthquake

Oakland Bay Bridge failure.

1989 Loma Prieta Earthquake

A collapsed wood frame residential building in Marina District

1994 Northridge Earthquake

Bull Creek Canyon Channel Bridge on the Simi Valley freeway near the epicenter to the north. Shear failure of a flared column.

Northridge Earthquake

Gavin Canyon Undercrossing on I-5

2011 Mineral VA Earthquake

Damage to DC landmarks, including the National Cathedral and the Washington Monument

Examples of Earthquake Losses Outside the United States

- 1923 Tokyo
- 1927 China
- 1960 Chile
- 1985 Chile
- 1985 Mexico City
- 1988 Armenia
- 1993 Hokkaido
- 1995 Kobe
- 1999 Turkey, Taiwan
- 2001 India
- 2003 Iran
- 2005 Sumatra
- 2008 China
- 2010 Haiti, Chile
- 2011 New Zealand, Japan, Turkey

1985 Mexico City Earthquake

Pino Suarez Towers looking north -- one of the few steel frame buildings to collapse.

1988 Leninakan, Armenia, Earthquake

Damage to a stone bearing wall building. The floor planks were not tied to the supporting bearing walls.

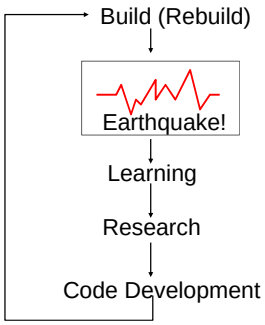
1995 Kobe, Japan, Earthquake

Distorted train tracks

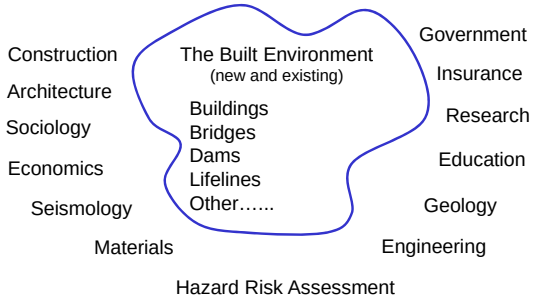
2011 Christchurch, New Zealand, Earthquake

Collapsed Pyne Gould Guinness building

Typical Build/Event/Learn Cycle



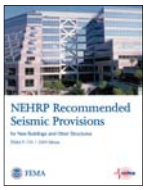
Who is Involved in Earthquake Hazard Mitigation?



These Instructional Materials FOCUS on STRUCTURAL ENGINEERING and…

- New buildings
- Hazards associated with ground shaking
- "Force-Based" approach of 2009 *NEHRP Recommended Provisions* (FEMA P-750)
- Examples presented in *NEHRP Recommended Provisions: Design Examples* (FEMA P-751)
- Probabilistic and deterministic based ground motions

Published Design Documents For New Buildings



FEMA P-750

ASCE 7

IBC

Materials Standards

New Buildings: the 2009 *NEHRP Recommended Provisions*

- Uses risk-targeted seismic hazard map (1% chance of collapse in 50 years) as criterion
- Relies on "equal displacement" concept to establish design forces
- Based on *linear elastic* static or dynamic analysis
- Deformations checked globally
- Intended result (obtained somewhat *implicitly*)

  - Little or no damage for frequent earthquake
  - Minor nonstructural damage for common earthquake
  - Life-safety or collapse prevention for rare earthquake

Structural engineering is
the art of using materials
that have properties which can only be estimated
to build real structures
that can only be approximately analyzed
to withstand forces
that are not accurately known
so that our responsibility to the public safety is satisfied

Questions