Seismic Safety Technology and Regulations: A Look at the Near Future (Summary of a Symposium) (1992)

Pages
33

Size
5 x 9

ISBN
0309299357

Federal Construction Council; Task Group on Seismic Safety; National Research Council

Technical Report

No. 120

SEISMIC SAFETY TECHNOLOGY AND REGULATIONS: A LOOK AT THE NEAR FUTURE

(Summary of a Symposium)

Federal Construction Council
Task Group on Seismic Safety

NATIONAL ACADEMY PRESS
Washington, D.C.
1992

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PREFACE

A symposium was held in October 1991 at the National Institute of Standards and Technology (NIST) to alert the building community in general, and federal officials in particular, to important technical and regulatory developments in the offing concerning both structural and nonstructural aspects of seismic safety. This report comprises summaries of four papers presented at the symposium, which was organized by the Federal Construction Council Task Group on Seismic Safety. The summaries were prepared by the speakers themselves.

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SOME BASICS ON WHO'S WHO AND WHAT'S WHAT IN SEISMIC SAFETY

Diana Todd
National Institute of Standards and Technology

Introduction

The tendency of both governments and engineers to form acronyms seems to reach an apex in the U.S. earthquake engineering community. Almost every group, program, and document in the public and private sectors is referred to by an acronym or idiom. This paper defines organization acronyms in Table 1* and presents short idiomatic and official titles of earthquake-related documents in Table 2. The text uses a description of the Federal earthquake program, the world of building codes, and the history of the NEHRP Recommended Provisions to illustrate the way in which many of these organizations and documents are related.

Federal Earthquake Organizations

The National Earthquake Hazards Reduction Program (NEHRP) was created by the President in 1978 in response to the Earthquake Hazards Reduction Act passed by Congress in 1977. The NEHRP is a broad-based multi-departmental program of basic and applied research; emergency services and recovery planning; education; and development of improved design and construction procedures. The most recent reauthorization of the NEHRP, Public Law 101-614, was signed in November 1990.

The Federal Emergency Management Agency, as the lead agency, is responsible for coordinating the program and reporting on NEHRP efforts and results to Congress. The four program agencies of the NEHRP are:

- Federal Emergency Management Agency (FEMA)
- United States Geological Survey (USGS)
- National Science Foundation (NSF)
- National Institute of Standards and Technology (NIST)

*Tables and figures are at the end of the paper.

Other contributing agencies include the Bureau of Reclamation, the Departments of Defense, Energy, Transportation, and Veterans Affairs, the National Oceanic and Atmospheric Administration, the Nuclear Regulatory Commission, and the Tennessee Valley Authority. See Figure 1.

Figure 2 illustrates the NEHRP coordination mechanisms. Policy level representatives from the four program agencies (FEMA, USGS, NSF, and NIST) participate in the Policy Coordinating Group (PCG) where overall planning decisions are made and budgeting efforts are coordinated. Program level personnel represent the four program agencies on the Interagency Coordination Committee (ICC). These two committees provide coordination mechanisms which help avoid duplication of effort and identify overlooked or underemphasized elements.

The Interagency Committee on Seismic Safety in Construction (ICSSC) is a subcommittee of the ICC. See Figure 3. This committee, which currently is made up of 25 member agencies, provides a forum for the transfer and exchange of information between Federal agencies. The ICSSC publishes technical reports produced by its five standing committees, and consensus documents which have been approved by the full committee. The ICSSC also sponsors symposia and workshops. P.L. 101-614 calls upon the ICSSC to support the development of standards for assessing and retrofitting existing Federally owned and leased buildings.

In the 1980s, the ICSSC wrote and endorsed the document which eventually became Executive Order 12699, "Seismic Safety of Federal and Federally Assisted or Regulated New Building Construction." Two informational studies and a consensus guidance document, "Guidelines and Procedures for Implementation of the Executive Order on Seismic Safety of New Construction" (RP 2.1), have been produced by the ICSSC to support Federal agency efforts to implement the Executive Order.

The World of Building Codes

One major product of the NEHRP is the reference document titled "NEHRP Recommended Provisions for the Development of Seismic Regulations for New Buildings" (NEHRP Recommended Provisions). This document is not itself a building code, but is intended to serve as a resource document for organizations that do produce building codes. Its role in the development of improved building codes is described below and illustrated in Figure 4.

In the United States, the authority to adopt and enforce building codes is delegated to state, county, and local jurisdictions. There are approximately 40,000 jurisdictions that adopt and enforce building codes. However, most jurisdictions adopt one of three major model building codes rather than develop an independent code.

The term "building code" refers to a legally adopted and enforced statute. Developed specifically for adoption by legal jurisdictions, model codes are not themselves standards or codes, but are models that can be used to create a legal building code.

Model codes are developed to cover all aspects of building design and construction. In addition to model building codes, which cover primarily structural and architectural concerns, mechanical, fire, plumbing, and other model codes exists. The three major model building codes incorporate, for the most part, the same national standards. Significant differences exist in requirements for environmental forces such as wind, snow, and seismic loads. Each code also has its own format for organizing requirements, and each includes some specific provisions that are unique.

The three major model codes are:

- the Uniform Building Code, published by the International Conference of Building Officials (ICBO)
- the National Building Code, published by Building Officials and Code Administrators International (BOCA), and
- the Standard Building Code, published by Southern Building Code Congress International (SBCCI).

These codes are known colloquially by several terms. ICBO's model code is known as the UBC or the Uniform code. The BOCA model code is referred to as BOCA, the National code, or the BOCA National code. The model code of the SBCCI was formerly referred to primarily as the Southern code; the term Standard code is coming into more common use. The terms Uniform code, National code and Standard code will be used in this paper.

Each of the model codes can be adopted and applied anywhere in the country, but in actuality, each is used on a largely regional basis. The Uniform code is used in the western half of the country, the National code is used in the Midwest and Northeast, and the Standard code is used in the South.

A fourth model code that is used throughout the country is published by the Council of American Building Officials (CABO). CABO is an organization that represents the three major model code organizations, and publishes the One and Two Family Dwelling Code, made up largely of tables and drawings, that is meant to be applied by home builders for simple residential buildings that do not require the design expertise of an architect or engineer.

National standards include design requirements for materials, such as the American Concrete Institute's "Building Code Requirements for Reinforced Concrete" (ACT 318), the American Institute of Steel Construction's "Specifications for the Design, Fabrication, and Erection of Structural Steel for Buildings," the American Society of Civil Engineers standards ASCE 5 and 6, "Building Code Requirements for Masonry Structures" and "Specifications for Masonry for Masonry Structures," and the National Forest Products Association's "Design Values for Wood Construction." Testing, inspection, and construction standards developed by the American Society for Testing and Materials (ASTM) and organizations such as the American Welding Society (AWS) are also in this category. The American Society of Civil Engineers has recently taken over promulgation of "Minimum

Design Loads for Buildings and Other Structures." This document, formerly known as American National Standards Institute ANSI A58.1, is now published as ASCE 7.

For seismic design, there currently exist two resource documents: the NEHRP Recommended Provisions mentioned previously and the Structural Engineers Association of California (SEAOC) "Recommended Lateral Force Requirements and Commentary," or the Blue Book. The SEAOC Blue Book has been published since 1959. The NEHRP Recommended Provisions were first published in 1985. These documents serve as resources for the model codes. Information exchange between the resource documents and the national standards flows both ways.

Improvements to seismic provisions in the resource documents and the national standards, and thus to the model and locally enforced codes, come from research results, post-earthquake investigations, and feedback from designers and building officials. Federal efforts under the NEHRP and efforts from the private sector (many of them Federally funded) lead to research and investigation results that improve seismic design and construction standards.

Until the NEHRP Recommended Provisions were published, the SEAOC Blue Book was the only document that attempted to methodically incorporate research and investigation results into a comprehensive seismic design document. A new edition of the Blue Book would typically be adopted almost verbatim into the Uniform code during its regular update cycle. ANSI A58.1 also rapidly incorporated advances in seismic design presented in the Blue Book. The National and Standard codes adopted the updated design recommendations from ANSI A58.1 See Figure 5.

Today the NEHRP Recommended Provisions present a second resource document that model codes can turn to for up-to-date seismic design and construction recommendations. While the NEHRP Recommended Provisions and the SEAOC Blue Book both incorporate the same research and investigation results, the documents differ because the NEHRP Recommended Provisions use ultimate strength design and the Blue Book uses allowable stress. The two also differ in how they address building occupancy or importance. National and Standard have adopted the format and requirements of the NEHRP Recommended Provisions in their 1992 supplements and additions. ASCE 7 is currently considering adoption of the NEHRP Recommended Provisions. See Figure 6.

History of the NEHRP Recommended Provisions

The 1971 San Fernando earthquake (Richter magnitude 6.4) killed 64 people and caused the collapse of several hospital buildings and highway overpasses. Other buildings and lifelines, including a dam, suffered severe damage. A workshop on building practices held in 1972 by the National Bureau of Standards (NBS, previous name of NIST) concluded that the Federal government should support the development of improved seismic design and construction standards. The project, funded by NSF and managed by NBS, used a private sector contractor, the Applied

Technology Council (ATC), to pull together research and investigative results into early drafts of the document which would become the NEHRP Recommended Provisions.

ATC was formed by SEAOC in the early 1970s as a private non-profit research arm of SEAOC. It has since become independent of SEAOC, and now has a nationwide focus. The results of ATC studies are commonly known by their ATC report number. This first report produced by ATC for the improved seismic design project was issued in 1974 as ATC 2, "An Evaluation of a Response Spectrum Approach to Seismic Design of Buildings." The sixth version of the first draft of the new design provisions was published at ATC 3-06 in 1978. This document is still commonly referred to as ATC 3-06 or ATC 3, rather than its official title of "Tentative Provisions for the Development of Seismic Regulations for Buildings."

FEMA was created and became the lead agency of the newly formed NEHRP in 1978. As FEMA took over the project, it recognized that ATC 3-06 needed a thorough review for technical validity, usability, and economic and social impact. The Building Seismic Safety Council (BSSC) was formed in 1979 to take on these tasks.

The BSSC was created as an affiliated council of the National Institute of Building Sciences (NIBS). Its mission is to provide consensus review of Federally developed seismic design provisions. The review is provided by the independent and voluntary membership representing both the public and private sectors. Government bodies, voluntary and professional organizations, the design professions, the construction industry, the research community, and the general public are represented on the BSSC.

A combined BSSC-NBS review panel drafted a revised version of ATC 3-06 which was used in a trial design program conducted in the early 1980s. The results of the trial designs were used to further refine and improve the design document. The document was revised still further during the BSSC consensus approval process, which was completed in 1985 with the publication of the first edition of the NEHRP Recommended Provisions. BSSC, committed to a three-year update cycle, continued to revise, improve, and update the provisions, resulting in 1988 and 1991 editions. BSSC is currently reviewing guidance documents on seismic assessment and retrofit of existing buildings.

TABLE 1

Acronyms in the U.S. Earthquake Community

Federal Organizations

NEHRP	National Earthquake Hazard Reduction Program
NIST	National Institute of Standards and Technology
FEMA	Federal Emergency Management Agency
NSF	National Science Foundation
USGS	United States Geological Survey
ICSSC	Interagency Committee on Seismic Safety in Construction
ICC	Interagency Coordination Council
PCG	Policy Coordinating Group

Private Sector Organizations

EERI	Earthquake Engineering Research Institute
ATC	Applied Technology Council
ASCE	American Society of Civil Engineers
TCLEE	Technical Council on Lifeline Earthquake Engineering of ASCE
NIBS	National Institute of Building Sciences
BSSC	Building Seismic Safety Council
SEAOC	Structural Engineers Association of California
SEAONC	Structural Engineers Association of Northern California
SEAOSC	Structural Engineers Association of Southern California

Consortia and Quasi-governmental Organizations

NCEER	National Center for Earthquake Engineering Research
CUREe	California Universities for Research in Earthquake Engineering
SCEC	Southern California Earthquake Center
CUSEC	Central United States Earthquake Consortium
CSSC	California Seismic Safety Commission
BAREPP	Bay Area Regional Earthquake Preparedness Project
SCEPP	Southern California Earthquake Preparedness Project
WSSPC	Western States Seismic Policy Council

Building Code Organizations

ICBO	International Conference of Building Officials
BOCA	Building Officials and Code Administrators
SBCCI	Southern Building Code Congress International
CABO	Council of American Building Officials

Other Acronyms of Interest

IDNDR	International Decade for Natural Disaster Reduction

TABLE 2

Documents: Short Idiomatic Names and Official Titles

Design Documents	
ASCE 7	Minimum Design Loads for Buildings and Other Structures (formerly ANSI A58.1)
ANSI A58.1	see ASCE 7
UBC	Uniform Building Code, published by ICBO
Uniform	" " " " " "
BOCA	National Building Code, published by BOCA
National	" " " " " "
Southern	Standard Building Code, published by SBCCI
Standard	" " " " " "
1 & 2 Family	One and Two Family Dwelling Code, published by CABO
CABO	see 1 & 2 Family
Blue Book	Recommended Lateral Force Requirements and Commentary, published by SEAOC
ATC 3-06	Tentative Provisions for the Development of Seismic Regulations for Buildings (superseded by NEHRP Recommended Provisions)
NEHRP Prov.	NEHRP Recommended Provisions for the Development of Seismic Provisions for New Buildings, published by BSSC and FEMA
Existing Building Guidance	
ATC 14	Evaluating the Seismic Resistance of Existing Buildings (precursor to ATC 22)
ATC 22	A Handbook for Seismic Evaluation of Existing Buildings
no idiom yet	NEHRP Handbook for the Seismic Evaluation of Existing Buildings (BSSC consensus version of ATC 22)
ATC 28	Development of Recommended Guidelines for Seismic Strengthening of Existing Buildings: Issues Identification and Resolution
URS/Blume	Techniques for Seismically Rehabilitating Existing Buildings (Preliminary)
no idiom yet	NEHRP Handbook of Techniques for the Seismic Rehabilitation of Existing Buildings (BSSC consensus version of URS/Blume)
Interagency Committee on Seismic Safety in Construction Recommended Practices	
ICSSC RP 1	Seismic Design Guidelines for Federal Buildings
ICSSC RP 2	Guidelines and Procedures for Implementation of Executive Order on Seismic Safety (superseded by RP 2.1)
ICSSC RP 2.1	Guidelines and Procedures for Implementation of the Executive Order on Seismic Safety of New Construction
ICSSC RP 3	Guidelines for Identification and Mitigation of Seismically Hazardous Existing Federal Buildings
Federal Requirements	
EO 12699	Executive Order 12699, "Seismic Safety of Federal and Federally Assisted or Regulated New Building Construction"
P.L. 101-614	Public Law 101-614, "National Earthquake Hazards Reduction Program Reauthorization Act"

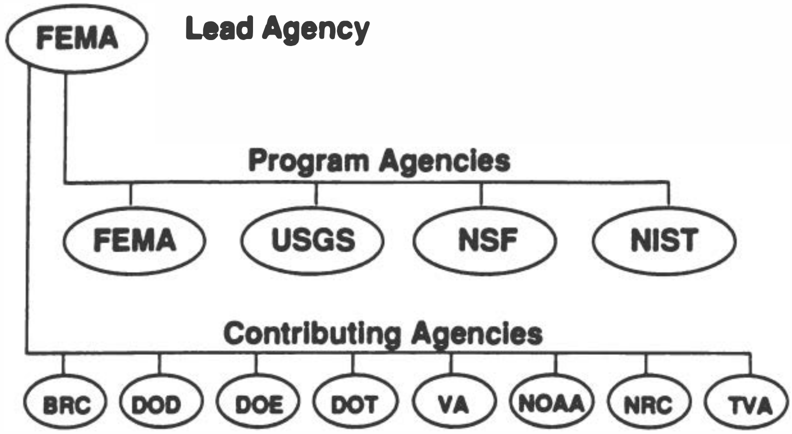

Figure 1 - NEHRP Federal Agencies

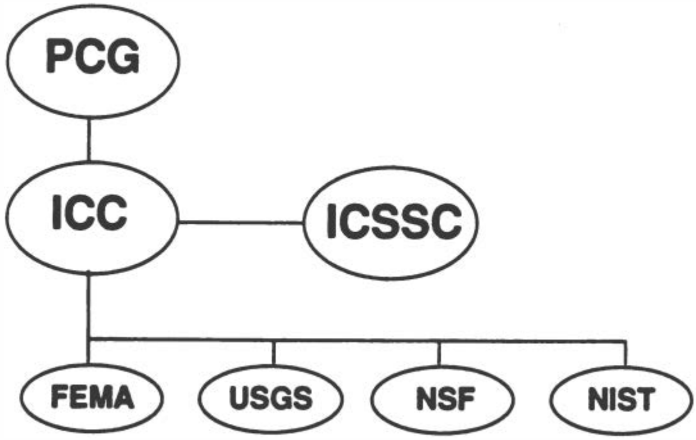

Figure 2 - NEHRP Coordination

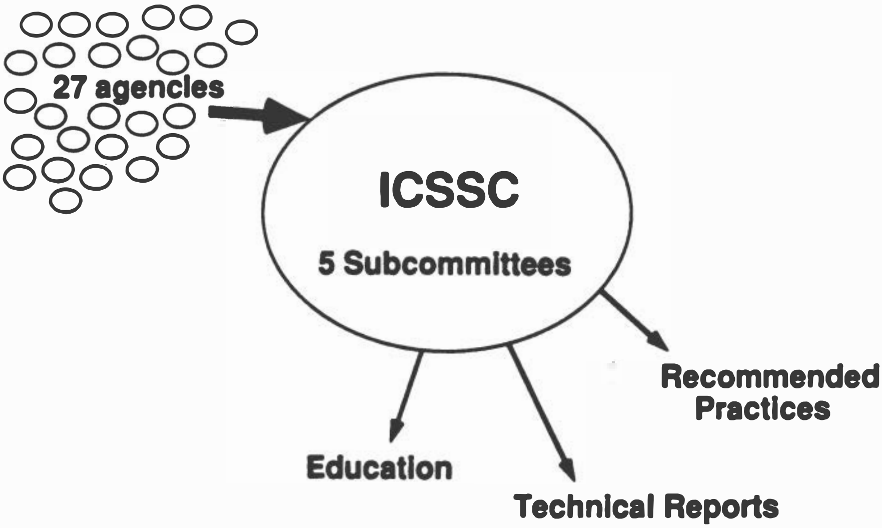

Figure 3 - Interagency Committee on Seismic Safety in Construction

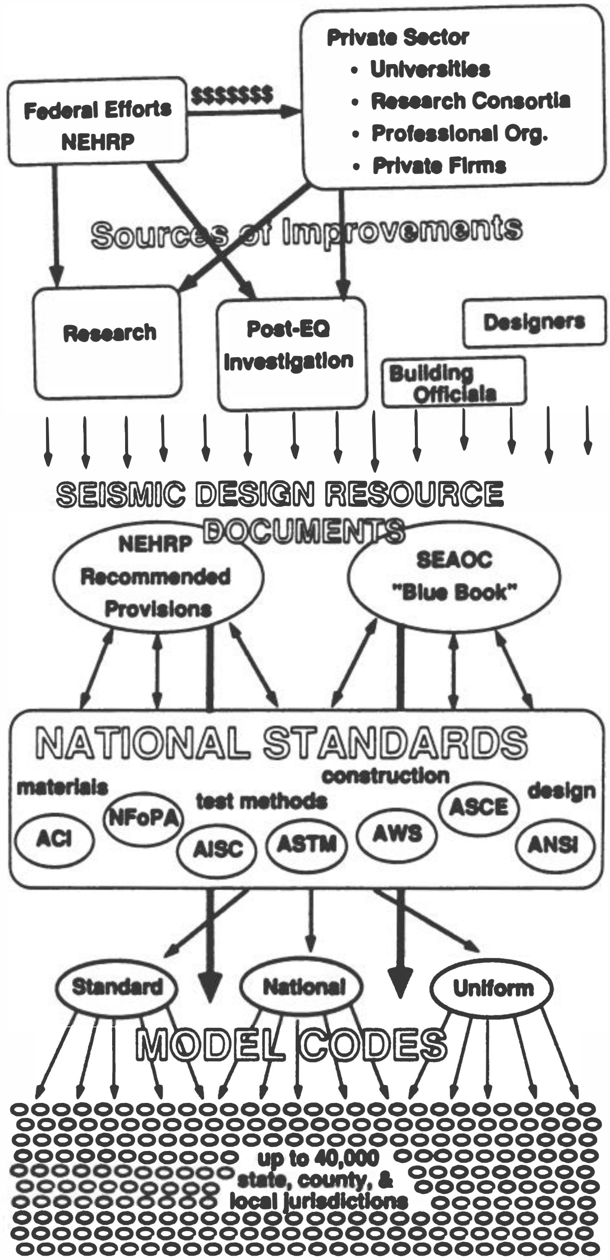

Figure 4 - The World of Building Codes

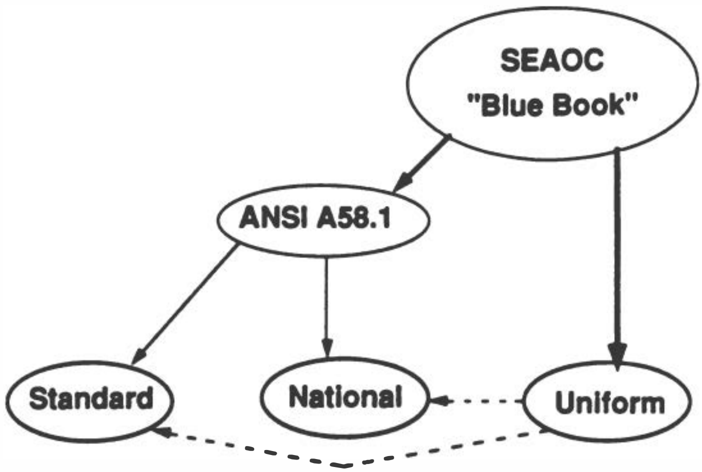

Figure 5 - Pattern of Seismic Code Improvement - pre-1980's

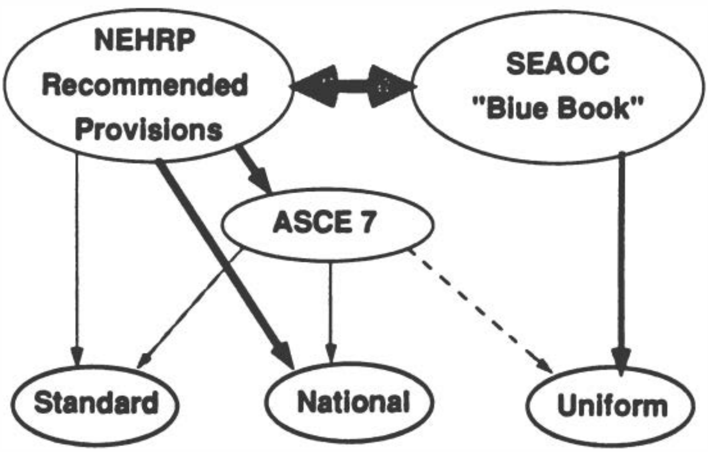

Figure 6 - Current Sources of Seismic Code Improvement

WHAT'S COMING FROM THE NATIONAL EARTHQUAKE HAZARDS REDUCTION PROGRAM

Gary D. Johnson
Federal Emergency Management Agency

I appreciate this opportunity today to have a few minutes of your time, to give you my thoughts on the future direction of the National Earthquake Hazards Reduction Program, also known as "NEHRP" (pronounced nee-herp).

Apropos this topic, I want to emphasize from the start the recently issued five year plan for NEHRP. It covers the Federal fiscal years of 1992 to 1996. It lists tasks and milestones for the Program, thus the Program's progress can be assessed. The statute which authorizes NEHRP requires that FEMA prepare and update the Program plan (in coordination with the other NEHRP agencies) and submit it to the Congress at least every three years. The last five year plan for NEHRP was for the 1989 to 1993 period and was submitted in September 1988.

The preparation and issuance of the 1992-1996 Plan was clearly a timely requirement. Much had transpired in the field of earthquakes since the 1989-1993 Plan. The events of 1989, 1990, and 1991 are interrelated, but can generally be characterized by two broadly stated activities:

1) **Congressional oversight of NEHRP** - Congress conducted and completed an exhaustive scrutiny and oversight of NEHRP. The immediate basis for this examination was the reauthorization process for NEHRP. But certainly, the Loma Prieta event of October 1989 also motivated much of the intense focus on NEHRP activities. The process resulted in Public Law 101-614, the NEHRP Reauthorization Act of 1990, which the President signed into law on November 16, 1990. P.L. 101-614 is the most far reaching piece of earthquake legislation since the original Earthquake Hazards Reduction Act of October 1977. It is definitive and specific about the Agencies' role under the Program. It creates a non-Federal NEHRP Advisory Committee to advise the FEMA Director and the other Agencies on the Program. Moreover, P.L. 101-614 contains many particular requirements, with statutory due dates, with respect to seismic design and construction standards; and

2) **The Loma Prieta Earthquake** - This event which captured the attention of the Nation for the earthquake problem occurred nearly two years ago, to the day. It was, as I mentioned above, timely in the context of the Congressional oversight activities. Most importantly, it validated that NEHRP was on the right track, and

that, overall, the correct course had been set for the Program. It also resulted in the first substantial infusion of new funds to the program Agencies, through the FY 1990 supplemental appropriation--a total of $20 million. The Bush Administration has been supportive, overall, of NEHRP activities. The NEHRP Agencies have, to a degree, been able to sustain the momentum generated by the Loma Prieta event and NEHRP, taken as a whole, has had about one-third more funds available for its work since the 1989 event.

The NEHRP Five Year Plan for 1992-1996, then, responds to and blends together 1) the statutory direction provided to the Program by the Congress, e.g., its tasks and milestones are replete with reference to the various requirements; and 2) the lessons of Loma Prieta, i.e., that NEHRP is collectively on the right path to achieving earthquake hazards reduction. In addition, the Plan, to the extent practicable, is responsive to the comment and advice provided by the Congressionally authorized non-federal NEHRP Advisory Committee.

Before I discuss with you the content of the NEHRP Five Year Plan for 1992-1996, I want to make one final observation about the Plan's parameters. In addition to its being responsive to the statutory direction and the lessons we've learned, it also needed to be prepared within a difficult budgetary framework. Despite any success the Agencies may have collectively achieved into FY 1992, the plan needed to be prepared assuming essentially level funding beyond 1993. Given the climate for the Federal fiscal budget, this is realistic. But it does add to the challenges facing NEHRP.

So, the Plan is the future of NEHRP, at least for the next three to five years. What does the Plan say?

The Plan describes how the Agencies' responsibilities and roles have been assigned through the "Program Structure" (see Table 1). The Structure is key to the actual chapter layout of the Plan, and anyone looking at the Plan should become familiar with it, at least in general terms.

Taken as a coordinated whole, the NEHRP Five Year Plan expresses the Program Agencies' commitment to build toward and emphasize:

- collaborative activities--dealing with this Nation's earthquake problem will take the joint work of all of us. NEHRP collaborative activities currently include earthquake loss estimation initiatives and the continuing update of the NEHRP Recommended Provisions for New Buildings;
- new knowledge--developing data about the actions and reactions of the earth and our society to earthquake occurrences;
- focused geological research--resolving specific questions about the size, location and frequency of earthquakes. USGS, for example, is currently focussing research in the Mid-Continent and Pacific Northwest regions;
- understanding earthquake effects--analyzing how different parts of our environment react to earthquakes;
- a safer built environment--determining the best techniques for enhancing the seismic resistance of our buildings and lifeline systems. As I mentioned, the Reauthorization Act for NEHRP had very specific requirements in this arena (in

TABLE 1

THE PROGRAM ELEMENTS AND RESPONSIBLE AGENCIES		
A. Leadership	1. NEHRP Coordination and Participation	FEMA
	2. NEHRP Planning and Reporting	FEMA
B. Fundamental Earthquake Studies	1. Implications of Plate Tectonics	NSF
	2. Earthquake Processes	NSF
C. Earthquake Hazard Potential	1. Theoretical, Laboratory, and Field Studies of Earthquake Source	USGS
	2. Regional Geologic Framework and Earthquake Potential	USGS
	3. Local Earthquake Potential and Fault-Specific Forecasting	USGS
	4. Earthquake Prediction Experiments	USGS
D. Earthquake Effects and Engineering Research	1. Earthquake Ground Shaking	USGS/NSF
	2. Ground Failure, Siting, and Geotechnical Research	USGS/NSF
	3. Mapping Earthquake Effects and Loss Estimates	USGS
	4. Structural Analysis and Design	NSF
	5. Architectural and Nonstructural Components	NSF
	6. Research Facilities	NSF
	7. Earthquake Systems Integration	NSF
	8. Research for Standards	NIST
E. Planning for and Mitigating Earthquakes	1. Design Practices and Manuals	FEMA/NIST
	2. State and Local Earthquake Hazard Reduction	FEMA
	3. Federal Response Planning	FEMA
	4. Risk Analysis and Applications	FEMA
	5. Insurance	FEMA
F. Information Systems and Dissemination	1. Engineering Data and Technology Transfer	FEMA/NSF/ USGS/NIST
	2. Seismological Data and Information Services	
	3. Education and Dissemination	
G. Postearthquake Studies		FEMA/NSF/ USGS/NIST
H. International Cooperation	1. International Research and Information Exchange	NSF/USGS/ NIST/FEMA
	2. International Decade for Natural Disaster Reduction	

fact an entire section, Section 8, is devoted to this topic) and the plan reflects those. I want to dwell a moment on this Section's requirements because I think they are of particular interest to you:

1) In the new buildings area, the statute reaffirms the requirements of Executive Order 12699, Seismic Safety of Federal and Federally Assisted or Regulated New Construction, signed by President Bush on January 5, 1990. NIST and FEMA are required to work together on its implementation and the Act requires the President to ensure that Agencies' rules and regulations for implementation of the E.O. be completed by February 1, 1993;
2) Existing buildings are also addressed. The President must adopt by December 1, 1994 standards for assessing the seismic safety of existing buildings, constructed or leased by the Federal Government. Also, by that date, the President needs to submit a report to the Congress on the manner in which these standards could be applied with respect to buildings for which Federal financial assistance has been obtained or the structural safety of which are regulated by a Federal Agency;
3) And in the lifelines area, FEMA, working with NIST, is required to have a lifelines Plan of Action completed by June 30, 1992.

Let me continue now with two or three more areas that the Agencies, under the NEHRP Five Year Plan, are emphasizing in the near future:

- research applications--transferring knowledge and techniques into products that are easily utilized. This is an important area, and one in which the NEHRP Advisory Committee took special interest. In fact, in response to their comment, Element F of the NEHRP Program structure, Information Systems and Dissemination, was revised and that section of the Plan was enhanced to a more comprehensive and integrated level;
- enhanced implementation--motivating actions that have a measurable impact and reduce the earthquake threat; and
- information availability--tied in to research applications, the NEHRP Agencies want to ensure that the knowledge and techniques developed by the Program are accessible to those that will use them.

These then summarize the foci of NEHRP in the near future, as defined by the NEHRP Five Year plan 1992-1996. I have a few copies of the Plan with me for those that might wish a copy. If you prefer, you can also write for a copy to FEMA, P. O. Box 70274, Washington, D.C. 20024 and request one.

Thank you very much for your attention, I'll be glad to answer any questions you may have.

DEVELOPMENT OF SEISMIC DESIGN AND CONSTRUCTION STANDARDS FOR LIFELINES

James D. Cooper[1]
Federal Highway Administration
and
Robert D. Dikkers[2]
National Institute of Standards and Technology

1. INTRODUCTION

Lifelines are defined as those utilities, facilities, and structures that are required to function following an earthquake to facilitate search and rescue, provide emergency services, allow for the movement of goods and materials and form a network which is required for post event reconstruction. Electric power and communications, gas and liquid fuel, transportation and water and sewer systems form today's modern lifeline network. Each lifeline is comprised of numerous components, some of which are critically vulnerable to earthquake induced damage and whose loss of function renders the lifeline useless. For example, a break in a major gas, oil, or water transmission pipeline can cause system failure. However, a break in a gas or water service line may eliminate service to a very local area only. In either case, failure may induce secondary problems such as fire caused by escaping gas from a broken pipe or the inability to control fires because of a broken water pipe.

Increased attention was focused on the lifeline problem following the 1971 San Fernando earthquake. Since then, numerous post earthquake investigations have been made and damage assessment reports prepared documenting the performance of lifelines. Basic research is providing engineers an understanding of how and why components of lifelines perform the way they do. Yet little has ben published in the open literature to provide detailed guidance for the design and construction of lifelines to resist strong ground shaking.

The design and construction of integrated lifelines involves the application of multidisciplinary topics and experience gained from previous earthquakes where weaknesses in design, construction, system architecture, and management have been

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highlighted. The performance and reliability of lifelines can affect a broad geopolitical area requiring the involvement of community leaders, public officials and the private sector to mitigate damaging effects. Pre-earthquake considerations include the identification of expected variations in earthquake intensity, engineering factors, and policies influencing risk and reliability. The planning process for each lifeline system will significantly influence the expected outcome of the effects of a seismic event. The process includes an understanding of the geologic factors that produce the seismic intensity levels that cause structural damage and ground failure. This knowledge supports systematic evaluation of hazards and risks required for planning reliability needed to mitigate earthquake damage. The easiest, most cost-effective way in which to mitigate seismically induced damage is to upgrade seismic design and construction procedure for new construction. This approach will take decades to enhance the seismic resistance of lifelines, but will ultimately reduce the potential for catastrophic impact in the event of a great earthquake. Limited seismic design procedures and details for lifelines have been developed over the past 20 years. However, some newer structures incorporating these procedures have been exposed to relatively strong earthquakes and have performed quite satisfactorily. Design and construction costs associated with enhanced seismic resistance is still being evaluated. A range of from one to 20 percent increased project costs for upgraded seismic resistance has been suggested and is highly dependent on the level of seismic detailing incorporated into the design. Nonetheless, these costs distributed over time become an inexpensive investment to significantly reduce the sudden loss potential from a great earthquake.

A second method to mitigate seismically induced damage is to retrofit existing lifelines. Retrofit is typically much more costly than planning in advance for the seismic design of new construction. However, retrofit can be cost-effective even in regions outside of the traditionally thought of seismically active zones. For example, if potentially vulnerable transportation routes are identified, a large number of bridges along these critical routes could be "restrained" at low cost. Since this retrofit technique typically cost between 10 and 20 thousand dollars per bridge, 150 bridges could be retrofit for the approximate cost of one structure! For other types of lifelines, retrofit may not be cost-effective except in unusual circumstances. Retrofit details and designs are becoming more common in traditional seismically active areas, although retrofit is not yet a generally accepted policy in these areas.

2. EARTHQUAKE HAZARDS REDUCTION ACT OF 1977

In 1977, the Congress of the United States enacted the Earthquake Hazard Reduction Act of 1977 to reduce risks of life and property from future earthquakes. This act forms the basis for the formation of the National Earthquake Hazards Reduction Program (NEHRP). Several specific objectives cited in the NEHRP include the charge to develop seismic design and construction standards for Federal use; develop guides for facilities that are Federally owned, constructed or financed to ensure serviceability following an earthquake and coordinate the development of guides for the consideration of seismic risk in the development of Federal lands.

In 1978, the Interagency Committee on Seismic Safety in Construction (ICSSC) was established as part of the NEHRP to assist Federal departments and agencies involved in construction to develop earthquake hazard reduction measures for incorporation in their ongoing programs. The measures will be based on existing standards when feasible.

In meeting its responsibilities, the ICSSC cooperates with State and local governments and private organizations in developing nationally applicable earthquake hazard reduction measures. Five subcommittees of the ICSSC are responsible for responding to the charge contained in the NEHRP:

1. Standards for New and Existing Buildings
2. Lifelines
3. Evaluation of Site Hazards
4. Federal Domestic Assistance, Leasing and Regulatory Programs
5. Post Earthquake Response Investigations

The mission of the Lifelines Subcommittee is to identify existing guidelines or standards for seismic design, construction and retrofit of energy, transportation, water, and telecommunication systems; to recommend Federal adoption of such standards when found adequate; and to encourage development of new standards where there are significant omissions. The Subcommittee will also study techniques for evaluating the seismic vulnerability of existing lifelines and for improving their resistance to seismic protection for ease of repair.

The Lifelines Subcommittee is also considering strategies that will permit identification of those lifelines facilities important in the emergency, immediate recovery, and long-term economic recovery periods, and provide guidance for appropriate levels of seismic protection for each type.

3. NEHRP REAUTHORIZATION ACT OF 1990

Section 8(b) of the National Earthquake Hazards Reduction Program Reauthorization Act, Public Law 101-614, which was approved on November 6, 1990 requires the Director of the Federal Emergency Management Agency (FEMA), in consultation with the National Institute of Standards and Technology (NIST), to submit to the U.S. Congress, not later than June 30, 1991, a plan, including precise timetables and budget estimates, for developing and adopting, in consultation with appropriate private sector organizations, design and construction standards for lifelines. The plan is also required to include recommendations of ways Federal regulatory authority could be used to expedite the implementation of such standards.

4. FUTURE LIFELINE DESIGN STANDARDS

The overall lifelines standards plan development process presently being implemented has been established with the advice of a Steering Group organized by FEMA. The Group, chaired by Dr. Ronald Eguchi, Chairman, ASCE Technical Council on Lifeline Earthquake Engineering (ASCE TCLEE), includes representatives from FEMA, NIST, Department of Energy, Federal Energy Regulatory Commission, National Center for Earthquake Engineering Research (NCEER), Interagency Committee on

Seismic Safety in Construction and several members from various private sector organizations. During its first meeting in March, 1991, the Steering Group approved a strategy for the lifelines standards development process. The strategy included using lifelines experts to prepare and review draft plans for the development of design and construction standards for the various lifeline systems. The experts identified by the Steering Group and selected to author the draft plans are:

- Water and Sewer Systems--Mr. Donald Ballantyne, Kennedy/Jenks/Chilton, Federal Way, Washington.
- Transportation Systems--Dr. Ian Buckle, NCEER, Buffalo, New York.
- Gas and Liquid Fuel Systems--Dr. Douglas Nyman, D. J. Nyman and Associates, Houston, Texas.
- Electrical Power Systems--Dr. Anshel Schiff, Stanford University, Palo Alto, California.
- Telecommunication Systems--Mr. Alex Tang, Northern Telecom Canada Ltd., Ontario, Canada.
- Federal Implementation and Other Issues--Mr. Crane Miller, Attorney, Washington, D.C.

In each of the above areas, five expert reviewers have also been identified and selected. These individuals reviewed the draft plans and participated in a discussion of the plans at a workshop held in Denver, Colorado, on September 25-27, 1991. Approximately 85 percent of the key individuals involved in the plan development process described above are active in the ASCE TCLEE.

In general, the plan will include the following information for the various lifeline system categories: seismic vulnerability; current design and construction practices and standards; available knowledge to improve existing practices; recommended standards to be developed for new and existing construction; and recommended research to fill identified knowledge gaps. It will also contain recommended timetables and budget estimates and recommendations of ways Federal regulatory authority could be used to expedite the implementation of such standards.

The current scheduled completion date for the final draft lifelines standards development plan is January 1, 1992. After this date, the plan will be submitted by FEMA to the Office of Management and Budget for review prior to its submission to the U.S. Congress not later than June 30, 1992.

5. CONCLUSION

Although significant attention has been focused on the efforts earthquakes have on lifelines in recent times, relatively little guidance is available for the seismic resistant design and retrofit of these facilities. Clearly the intent of the Congress is to focus attention on the need to adopt existing standards where appropriate and develop new standards where appropriate and feasible to enhance the seismic resistance of Federal and private lifeline structures. In so doing, it is critically important to involve both the public and private sectors in the process. Federal agencies, acting through the ICSSC, academia, trade and professional associations are being called upon to collaborate in the development and implementation of reasonable, technically feasible, economically justifiable standards for lifelines.

WHAT'S COMING IN ABATEMENT AND MITIGATION METHODS: ACTIVE AND PASSIVE SYSTEMS FOR EARTHQUAKE PROTECTION

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Earthquake protective systems for buildings and bridges are innovative solutions to the seismic hazard problem. Also referred to as structural control, these systems have the potential to substantially improve the seismic safety of a wide range of structural types for nominal cost. Passive, active, and hybrid systems together make up this family of protective devices which enable a structure to withstand earthquake loads, not by adding strength but by diminishing the structure forces.

Passive systems, which include base isolation, are the most well developed of the three systems mentioned above. Isolation decouples a structure from earthquake ground motion with consequential reductions in earthquake forces. Today there are more than 125 structures, worldwide, which have been built using this technique. In the United States, 15 buildings and bridges have now been completed with at least another 15 under construction or in the design stage. Decoupling is achieved through the use of isolation bearings that support the weight of the building while permitting relative movements to occur between the ground and the building. The technique can be applied to both new construction and the retrofit of existing structures. In the latter case, significant cost savings can be achieved when compared to conventional methods of strengthening. The isolation bearings can either be made of high quality elastomers or use sliding surfaces (e.g., stainless steel and Teflon) to permit the required decoupling to occur.

Other passive systems include mechanical energy absorbers which may be installed in structures so as to dampen relative motion during earthquakes. In some bridges, hydraulic shock absorbers have been used, whereas in buildings visco-elastic dampers have been incorporated into bracing elements and wall panels.

Active control involves the use of an active energy source to maintain (or control) a structure within predetermined limits during an earthquake. Laboratory and computer models have been studied extensively and their feasibility demonstrated. Both active mass dampers and active bracing systems are now being used in trial installations in prototype buildings. Early results from the field indicate performance is as expected.

Hybrid systems involve the active control of base isolated structures and are attractive because many of the advantages of active control are retained while enhancing reliability, reducing power demands and extending the range of applicable structures.

Earthquake protective systems are the direct result of aggressive research programs funded in the United States by the National Science Foundation, the National

Center for Earthquake Engineering Research and the Department of Energy. Other countries, who also are active in the design and implementation of these systems include New Zealand, Japan, France, and Italy.

By the turn of the century, such systems will be commonplace and the construction of the intelligent building will be one step closer.