ATC 71

NEHRP Workshop on Meeting the Challenges of Existing Buildings

Part 2: Status Report on Seismic Evaluation and Rehabilitation of Existing Buildings

Applied Technology Council

Funded by
Federal Emergency Management Agency

Under the Auspices of the
National Earthquake Hazard Reduction Program

Applied Technology Council

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ATC-71

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Part 2: Status Report on Seismic Evaluation and Rehabilitation of Existing Buildings

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2009

Preface

In September 2006 the Federal Emergency Management Agency (FEMA) awarded the Applied Technology Council (ATC) a multi-year project, under Task Order Contract HSFEHQ-04-D-0641, to carry out the Program Definition and Guidance Development Phase of a longer term effort intended to "Update Seismic Rehabilitation Guidance." Designated the ATC-71 Project, its purpose was to develop and produce a comprehensive seismic rehabilitation guidance package for FEMA, including necessary implementation strategies for the creation, update, and maintenance of seismic evaluation and seismic rehabilitation documents for existing buildings. The initial major activity was the *NEHRP Workshop on Meeting the Challenges of Existing Building,* which was held in San Francisco on September 19-20, 2007. The Workshop was co-organized by ATC and the Earthquake Engineering Research Institute, and funded by all four agencies of the National Earthquake Hazards Reduction Program (NEHRP): FEMA, the National Institute of Standards and Technology (NIST), the National Science Foundation (NSF), and the U.S. Geological Survey (USGS). The results of that workshop, attended by a broad range of specialists and stakeholders in seismic evaluation and rehabilitation of buildings, are documented in the companion ATC-71 Report, *NEHRP Workshop on Meeting the Challenges of Existing Buildings, Part 1: Workshop Proceedings* (ATC, 2008).

Guidance developed under the ATC-71 Project will explore new and creative ways to promote more widespread evaluation and rehabilitation of vulnerable existing buildings by addressing the technical and practical needs of engineering practitioners, and the policy, implementation, and regulatory needs of building officials, government agencies, and other stakeholders with jurisdiction over existing buildings.

As one of the building blocks for the overall project, this document provides a status report on seismic evaluation and rehabilitation of existing buildings, including an assessment of the extent to which objectives and tasks of the FEMA 315 Report, *Seismic Rehabilitation of Buildings: Strategic Plan 2005* (FEMA, 1998) have been carried out, and an in-depth investigation of: (1) the current state of policies and regulations governing existing buildings; (2) the current state of engineering practice on existing buildings; and (3) available technical resources. The report also identifies major impediments to seismic evaluation and rehabilitation, along with recommendations on how to overcome the most significant of these.

This report is one of several in a collection arising from the NEHRP Workshop that includes the ATC-71 Report, *NEHRP Workshop on Meeting the Challenges of Existing Buildings, Part 1: Workshop Proceedings* (ATC, 2008) and the ATC-73 Report, *NEHRP Workshop on Meeting the Challenges of Existing Buildings, Prioritized Research for Reducing the Seismic Hazards of Existing Buildings* (ATC, 2007). Guidance for FEMA's future activities related to the creation, update, and maintenance of seismic evaluation and rehabilitation documents for existing buildings will be based on this information, and provided in the ATC-71 Report, *NEHRP Workshop on Meeting the Challenges of Existing Buildings, Part 3: Action Plan for the FEMA Existing Buildings Program* (ATC, 2009).

ATC is indebted to a broad range of individuals for their efforts in managing, researching, and preparing this report. The Project Management Committee, consisting of Thomas McLane (Project Manager), Andrew Merovich (Lead Technical Consultant), David Bonowitz, Lawrence Brugger, Craig Comartin, Edwin Dean, and James Harris had overall responsibility for the development of this document. Review and guidance was provided by a Project Review Panel consisting of Richard Bernknopf, Nick Delli Quadri, Melvyn Green, Nathan Gould, Chris Poland, Thomas Tyson, and Sharon Wood. The affiliations of these individuals are provided in the list of Project Participants.

ATC also acknowledges the numerous individuals who volunteered their time and expertise through participation interviews with Project Management Committee members and in workshop deliberations. Their names and affiliations can be found in Appendix D and in *Part 1: Workshop Proceedings*.

ATC also gratefully acknowledges Cathleen Carlisle (FEMA Project Monitor) and Dan Shapiro (FEMA Subject Matter Expert) for their input and guidance, Gerald Brady for technical editing services, and Peter Mork for report production services.

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Chapter 1
Introduction

Since 1984, the Federal Emergency Management Agency (FEMA) has sponsored efforts to address the problems of seismically hazardous existing buildings. FEMA's support has led to a host of publications that provide technical and public policy guidance regarding the identification of vulnerabilities and the mitigation of seismic risk through building rehabilitation. The development of these products has been substantially accomplished through FEMA's Existing Buildings Program.

To guide the process of selecting projects that will be the most effective in promoting evaluation of potentially seismically vulnerable buildings and in rehabilitating those found to be at risk, the Existing Buildings Program has relied on the development of the FEMA 90 Report, *An Action Plan for Reducing Earthquake Hazards of Existing Buildings*, and the FEMA 315 Report, *Seismic Rehabilitation of Buildings: Strategic Plan 2005*. Each of these plans has identified specific tasks that were judged to accomplish important objectives in support of achieving the overall goal of reducing future earthquake losses. With the release of the reference American Society of Civil Engineers (ASCE) standard ASCE 31, *Seismic Evaluation of Existing Buildings*, and standard ASCE 41, *Seismic Rehabilitation of Existing Buildings*, which are based on the FEMA 310 *Handbook for the Seismic Evaluation of Buildings: A Prestandard*, and the FEMA 356 *Prestandard and Commentary for the Seismic Rehabilitation of Buildings*, respectively, FEMA has accomplished a major objective in supporting the development of a set of nationally applicable, consensus-based, engineering guidance documents on the seismic evaluation and rehabilitation of existing buildings. In the FEMA 315 Report, *Seismic Rehabilitation of Buildings Strategic Plan, 2005*, however, important Existing Buildings Program objectives included the development of new seismic rehabilitation tools and the identification of new program directions. Many of the tasks defined to advance these objectives have not as yet been undertaken.

The ATC-71 Project has been initiated with the objective of developing a ranked list of tasks (including those uncompleted tasks from *Strategic Plan 2005*) that best serve the overarching goal of increasing the number of identified "at risk" buildings and reducing their risk to an acceptable level by rehabilitation. Another objective of the ATC-71 Project includes the development of recommendations for promoting and updating the ASCE 31 and ASCE 41 standards in ways that reflect research and other technical developments and in ways that facilitate their broader application.

This status report has been assembled to reflect a current understanding of the many factors affecting seismic evaluation and rehabilitation in the United States. The report has been developed through a process that has involved research, interviews, and a two-day workshop that included the active participation of over 90 individuals representing the viewpoints of engineering practitioners, researchers, regulators, building owners, and public policy experts. For a detailed discussion of the workshop, see the ATC-71 Report, *NEHRP Workshop on Meeting the Challenges of Existing Buildings, Part 1: Workshop Proceedings*.

To aid in the task of organizing and reporting the investigative efforts of the ATC 71 project team, three interconnected areas of knowledge and activity have been identified. These three areas include:

- the current regulatory structure, and public and private policies, that define when and how seismic evaluations and rehabilitations are undertaken,
- the current state of structural engineering practice involving existing buildings, and
- the available technical material that can be used by structural engineers to perform seismic evaluations and rehabilitations.

The connections among these three areas provide a generalized description of how seismic evaluations and rehabilitations are being done today. A regulatory policy, either public or private, serves to initiate the actions of an engineering practitioner to assess an existing building's seismic sufficiency (or to design a rehabilitation) using available technical material. Impediments to seismic evaluation and rehabilitation arise from limitations in the policies that initiate action and in the experience of the engineering practitioners, the expense and complexity of the work, and the availability and reliability of the technical material.

The extent to which seismic evaluation and rehabilitation efforts are undertaken, and how they are executed, depend on the initiating mechanism, which can either be mandated, triggered, or voluntary. As discussed in the following chapters, the initiation mechanism strongly influences how public policy, engineering practice, and technical material are interwoven in today's treatment of seismically vulnerable existing buildings.

1.1 Mandated Rehabilitation

Mandated programs are those that require seismic rehabilitation (or at least evaluation) for specified buildings regardless of an owner's intent. Also called "active programs," mandates are frequently driven by legislation or by some policy authority other than the building owner. The rationale for legislation varies but usually involves a persistent pattern of poor seismic performance, with a sizable remaining inventory of susceptible building stock. Historically, the mere presence of risk, without poor performance, has not been sufficient to result in the enactment of a rehabilitation mandate.

Technical requirements for mandated work are typically set by the driving legislation, though they are sometimes given only at a conceptual level. Mandated work generally involves a compliance review by the mandating authority, so it typically involves the application of a specific standard or guideline against which a design can be checked. To the extent that specific compliance guidelines are developed, "equivalent" procedures using alternative standards, guidelines, or references might not be allowed, or might be allowed only as supplements to the specified criteria.

Examples of mandated rehabilitation programs include the improvements to California hospitals (Senate Bill 1953), the evaluations of California public school facilities (Assembly Bill 300) and courthouses (Senate Bill 1732), and certain local programs for unreinforced masonry buildings in response to California's 1986 Unreinforced Masonry Law (Senate Bill 547).

1.2 Triggered Rehabilitation

In triggered programs, also called "passive programs," seismic evaluation, and sometimes rehabilitation, might not be intended by the building owner but is required, or triggered, based on the scope of repairs, additions, alterations, changes of building occupancy (or building use), or other nonseismic work initially proposed. Most triggered rehabilitation is driven by a business decision to improve a property for other than seismic reasons. Once seismic rehabilitation is triggered, it is *effectively* mandatory if the proposed nonseismic work is to be done. The proposed work may be scaled down or skipped completely in order to *avoid* triggering the seismic rehabilitation work component. Because triggered work includes this aspect of choice, it is distinguished from mandated rehabilitation.

While mandated programs typically address specific building types or risks, triggered work is typically broader and is generally driven by building codes or by institutional policies. For example, the *International Existing Building Code* and Chapter 34 of the *International Building Code* both use triggers for rehabilitation that are generally independent of structure type. Some federal and California state agencies require seismic evaluation (which may trigger rehabilitation) as part of due diligence policies for acquiring new space.

Technical requirements for triggered work are typically specified by the driving code or policy. Because the triggers are generic, however, the technical requirements are often vague or require considerable engineering judgment for application and compliance review. Like most work driven by building codes, triggered seismic evaluation and rehabilitation generally involve a compliance review. As with mandated work, when the triggering provisions include clear technical criteria, equivalent procedures using alternative standards, guidelines, or references might not be allowed, or might be allowed only as supplements to the specified criteria. As a practical matter, the limitations of the referenced technical requirements tend to encourage the use of engineering alternatives, more than do mandated programs.

1.3 Voluntary Rehabilitation

Voluntary rehabilitation is work initiated by the building owner (or another stakeholder) and is subject only to minimal outside requirements. Voluntary work is generally driven by institutional policy or by an individual owner's risk sensitivity.

Voluntary rehabilitation ranges from nominal bracing of existing architectural components, contents, and equipment to complete structural upgrade intended to achieve a specified performance objective. Anecdotal evidence suggests that in booming economies, businesses (especially high-tech manufacturers) undertake rehabilitation to limit potential business disruptions; in slower times, businesses tend to have other priorities. Institutions such as K-12 schools, colleges, and hospitals undertake voluntary work to fulfill what they see as management responsibilities to their constituents.

Because decision-making is commonly based on financial loss and other loss considerations, technical materials emphasizing life safety protection, such as is found in engineering standards, are often not the best tools for informing the decision process. Owners are more likely to use probable maximum loss (PML) or other loss-estimation tools, increasingly with consideration of business interruption to establish decision metrics.

Building officials will generally permit any voluntary modifications provided they do not make a building *less* conforming. Still, codes and standards, despite their mandatory wording, are often used to guide voluntary work since PML and other loss-estimation tools do not provide appropriate guidance for current component-based rehabilitation design procedures.

Jurisdictions sometimes offer incentives to motivate seismic improvements, though the work itself remains entirely voluntary. When incentives are offered, it becomes necessary to establish compliance or qualification standards, and the available technical resources are often used for this purpose.

Unlike new construction, for which an appropriate level of seismic resistance is mandated as an integral component of the structural engineering process, the seismic sufficiency of existing buildings is considered only in a limited set of circumstances. This difference reflects the most fundamental impediment to more widespread identification of at-risk buildings and their rehabilitation. Knowledge of the seismic vulnerability of existing buildings is not common and a commitment to dedicate funding to address the problem is not widely shared. Understanding the three ways in which seismic evaluation and rehabilitation efforts are currently initiated (i.e., whether they are mandated, triggered, or voluntary) permits a better framework for addressing the impediments and opportunities within each of the areas of focus of the ATC-71 project: regulations and policy, engineering practice, and technical resource material.

1.4 Report Organization

This report is organized into six chapters. Following this introduction (Chapter 1) is a brief description of FEMA's Existing Buildings Program and the FEMA 315 *Strategic Plan 2005* (Chapter 2). The next three chapters of the report discuss seismic evaluation and rehabilitation from different perspectives. In Chapter 3, a discussion of the regulatory policies and processes that affect existing buildings in the United States is provided. Chapter 4 provides a description of current structural engineering practice for the seismic evaluation and rehabilitation of existing buildings that includes important geographical variations as well as the various types of projects undertaken and implementation impediments. In Chapter 5, the currently available technical resource material for use by practitioners is identified, described and assessed. In conclusion, Chapter 6 discusses the considerations that play a significant role in the treatment of existing buildings today, summarizes what is needed, from the perspective of practitioners, regulators, and owners, to overcome the most significant impediments to building seismic rehabilitation, and discusses the potential future directions the Existing Buildings Program might take to improve its effectiveness in reducing the seismic vulnerability of today's existing buildings.

Supplemental information is provided in four appendices: Appendix A provides a list of key resources for seismic evaluation and rehabilitation of buildings; Appendix B provides samples of federal and state legislation for improving the seismic performance of existing buildings; Appendix C contains verbatim objectives and tasks from the *Seismic Rehabilitation of Buildings Strategic Plan 2005* (FEMA 315 Report), which was published by FEMA in 1998 (a major resource for the development of this document); and Appendix D contains a list of seismic rehabilitation specialists who assisted in a state-of-the-practice interview process. Following the appendices is a list of Acronyms and Other References.

Chapter 2
FEMA Existing Buildings Program

2.1 Historical Context

Since 1984, the Federal Emergency Management Agency (FEMA) has devoted a portion of its earthquake-related funding to addressing the problems of seismically hazardous existing buildings. Through its Existing Buildings Program, FEMA has maintained a national focus on this issue and supported the development of analytical and technical material (technical information, manuals, software, and educational and instructional materials) to support the activities of those engaged in addressing the issue. FEMA has provided reports to both the U.S. President and the U.S. Congress on seismic rehabilitation concerns, coordinated the related activities of others within the federal government and served as a resource to external professional and technical organizations in their efforts to improve the understanding of, and to reduce, the seismic risk of existing buildings.

2.2 1985 Action Plan

In 1985, FEMA launched an effort through the ABE Joint Venture (a partnership of the Applied Technology Council, Building Seismic Safety Council and the Earthquake Engineering Research Institute) to develop an action plan to guide the Existing Buildings Program. The ABE Joint Venture commissioned a series of white papers by experts in technical and socioeconomic aspects of earthquake hazard reduction. These papers seeded discussion at a workshop of over 50 experts whose recommendations formed the basis for *An Action Plan for Reducing Earthquake Hazards of Existing Buildings* (FEMA 90).

In executing the 1985 Action Plan, FEMA published the following resource documents in support of the Existing Buildings Program objectives:

FEMA 154: *Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook* (ATC, 1989; second edition, 2002).

FEMA 156, 157: *Typical Costs for Seismic Rehabilitation of Existing Buildings, Volume I: Summary*, second edition (Hart Consultant Group, 1994), and *Typical Costs for Seismic*

Rehabilitation of Existing Buildings, Volume II: Supporting Documentation, second edition (Hart Consultant Group, 1994).

FEMA 178: *NEHRP Handbook for the Seismic Evaluation of Existing Buildings (Preliminary)* (BSSC, 1992).

FEMA 227, 228: *A Benefit-Cost Model for the Seismic Rehabilitation of Buildings, Volume 1: A User's Manual,* and *A Benefit-Cost Model for the Seismic Rehabilitation of Buildings, Volume 2: Supporting Documentation* (VSP Associates, 1992).

FEMA 237: *Seismic Rehabilitation of Buildings—Phase I: Issues Identification and Resolution* (ATC, 1992).

FEMA 255, 256: *Seismic Rehabilitation of Federal Buildings: A Benefit/Cost Model, Volume I: A User's Manual,* and *Seismic Rehabilitation of Federal Buildings: A Benefit/Cost Model, Volume II: Supporting Documentation* (VSP Associates, 1994).

FEMA 273, 274: *NEHRP Guidelines for the Seismic Rehabilitation of Buildings,* and *NEHRP Commentary on the Guidelines for the Seismic Rehabilitation of Buildings* (ATC/BSSC, 1997).

FEMA 310: *Handbook for the Seismic Evaluation of Buildings* (ASCE, 1998)**.**

With the publication of these documents, FEMA completed the major tasks of the 1985 Action Plan (FEMA 90), and initiated the development of *Seismic Rehabilitation of Buildings: Strategic Plan 2005* (FEMA 315).

2.3 Seismic Rehabilitation of Buildings: Strategic Plan 2005 (FEMA 315)

The initial tasks of *Strategic Plan 2005* included an assessment of the effectiveness of the 1985 plan. The 1985 plan had included five elements:

1985 Plan Elements

I. Technical and Engineering Requirements

II. Public Policy, Legal, and Financial Strategies

III. Special Requirements for Historic Buildings

IV. Multihazard Assessment

V. Information Transfer and Dissemination

Among these five elements, 20 objectives were identified that included 32 specific tasks. The assessment concluded that of the 20 objectives identified within the five elements, eight were judged as fully attained, while six were judged partially completed and six were judged as not completed (with no actions taken toward their completion).

Among the objectives identified as being partially completed were the following:

- Recommend comprehensive standard procedures for compiling building inventory.
- Compile and evaluate local and state laws, ordinances and regulations.
- Produce revised historic building policy directives.
- Produce annotated bibliographies of case studies worldwide.
- Develop and present a series of education and training programs.

Objectives judged not to have been completed included:

- Design, test and apply a methodology to identify areas that are likely candidates for a hazardous building identification and abatement program.
- Complete case studies of the social and economic impacts of existing programs.
- Prepare guidelines on potential legal issues.
- Conduct an analysis of current hazard-abatement measures.
- Conduct an assessment of multihazard abatement techniques.
- Assess the relationships among mitigation objectives.

The *Strategic Plan 2005* document, published by FEMA in 1998, concluded that while the 1985 plan had led to the development of numerous resource documents, it had included tasks that fell outside the scope of FEMA's Existing Buildings Program and required significant multi-agency activity that could not be effectively managed in the context of achieving the plan's objectives.

The *Strategic Plan 2005* document was crafted to address the objectives for FEMA's Existing Buildings Program only, rather than a multi-agency program of action, as was done for the 1985 plan. The document defined four program objectives that included a total of 25 tasks:

Strategic Plan 2005 Objectives

1. *Promote* seismic rehabilitation *and advance* the implementation of previously developed technical material (10 tasks)
2. *Monitor* the use of, *and refine*, existing material (2 tasks)
3. *Develop* new seismic rehabilitation *tools* (7 tasks)
4. *Consider new* program *directions* (6 tasks)

Appendix C contains a list of *Strategic Plan 2005* tasks (by objective) and brief explanatory comments.

2.4 Accomplishments Related to the Strategic Plan 2005

Table 2-1 lists the tasks achieved in *Strategic Plan 2005*, along with the objective to which they were assigned and the products that fulfilled their achievement. As indicated in the table, one of the ten tasks of Objective 1 has been completed, both tasks of Objective 2 have been completed, one of the seven tasks of Objective 3 has been completed, and one of the six tasks of Objective 4 has been completed. Clearly, the plan's Objective 2: Monitor the Use of, and Refine, Existing Technical Materials, has been a significant accomplishment of the plan.

2.5 Unfinished Tasks of the Strategic Plan 2005

The *Strategic Plan 2005* tasks were initially formulated to address perceived impediments to more widespread seismic evaluation and rehabilitation of existing buildings. Of the 25 tasks identified in *Strategic Plan 2005*, 20 have not yet been completed or are only partially completed (see Table 2-2).

The underlying impediments associated with these tasks were used by the ATC-71 project team to organize discussions and identify global issues during the 2007 *NEHRP Workshop on Meeting the Challenges of Existing Buildings*. The global issues (identified at the NEHRP Workshop) associated with each *Strategic Plan 2005* task are also provided in Table 2-2.

An outcome of the *NERHP Workshop* was the creation of a comprehensive list of impediments that limit widespread seismic evaluation and rehabilitation. The impediments were ranked by Workshop participants to aid in the ranking of tasks for the next phase of FEMA's Existing Buildings Program. The top 10 priority rankings are discussed in Section 4.4.

Table 2-1 Accomplishments of Strategic Plan 2005, FEMA 315

Objective	Task Number / Name	Products Fulfilling Task & Objective
1. Promote seismic rehabilitation and advance the implementation of previously developed technical material	Task 2: Prepare, disseminate, and support the use of the first generation of a series of technical implementation manuals	FEMA 149, *Seismic Considerations: Elementary and Secondary Schools* FEMA 150, *Seismic Considerations: Health Care Facilities* FEMA 151, *Seismic Considerations: Hotels and Motels* FEMA 152, *Seismic Considerations: Apartment Buildings* FEMA 153, *Seismic Considerations: Office Buildings*
2. Monitor the use of, and refine, existing material	Task 11: Periodically evaluate, improve, and disseminate the most important and widely used seismic rehabilitation documents and technical material produced since 1985, especially the *NEHRP Guidelines and Commentary for the Seismic Rehabilitation of Buildings* (FEMA 273 and 274)	FEMA 356, *Report on the Prestandard and Commentary for the Seismic Rehabilitation of Buildings* ASCE 41, *Seismic Rehabilitation of Existing Buildings*
	Task 12: Conduct systematic evaluations of the Existing Buildings Program products and materials	ASCE 31 *Seismic Evaluation of Existing Buildings* ASCE 41 *Seismic Rehabilitation of Existing Buildings*
3. Develop new seismic rehabilitation tools	Task 17: Prepare guidelines on the repair of earthquake-damaged buildings	FEMA 306, *Evaluation of Earthquake Damaged Concrete and Masonry Wall Buildings, Basic Procedures Manual* FEMA 307, Evaluation of Earthquake Damaged Concrete and Masonry Wall Buildings, Technical Resources FEMA 308, Repair of Earthquake Damaged Concrete And Masonry Wall Buildings
4. Consider new program directions	Task 20: Create and disseminate information about effective partial and incremental structural and nonstructural rehabilitation strategies and techniques	FEMA 395, *Incremental Seismic Rehabilitation of School Buildings, K-12* FEMA 396, *Incremental Seismic Rehabilitation of Hospital Buildings* FEMA 397, *Incremental Seismic Rehabilitation of Office Buildings* FEMA 398, *Incremental Seismic Rehabilitation of Multifamily Apartment Buildings* FEMA 399, *Incremental Seismic Rehabilitation of Retail Buildings* FEMA 400, *Incremental Seismic Rehabilitation of Hotel/Motel Buildings* FEMA 401, *Incremental Seismic Rehabilitation of Storage Buildings* FEMA 402, *Incremental Seismic Rehabilitation of Emergency Buildings* FEMA 420, *Engineering Guideline for Incremental Seismic Rehabilitation*

Table 2-2 Partially Completed and Uncompleted Tasks of Strategic Plan 2005, FEMA 315

Objective	Task Number / Name	NEHRP Workshop Global Issue
1. Promote seismic rehabilitation and advance the implementation of previously developed technical material	Task1: Design, implement, and support for the next 10 years an aggressive "Seismic Rehabilitation Marketing Strategy."	Advocacy to Encourage More Seismic Retrofit (G057)
	Task 3: Prepare a comprehensive manual on financial incentives to help overcome the investment barriers to seismic rehabilitation	Incentives for Seismic Rehabilitation (G079) (see also G059, G060)
	Task 4: Prepare guidance on the legal implications of seismic rehabilitation	Legal Implications of Seismic Rehabilitation (G062)
	Task 5: Sponsor regional technical information transfer workshops and short courses	Education of Practitioners (G007)
	Task 6: Establish a "mentoring" program to improve professional capabilities	Unfinished Business in the Strategic Plan 2005 (G061)
	Task 7: Provide coordination with related regional and state efforts.	Unfinished Business in the Strategic Plan 2005 (G061)
	Task 8: Develop, disseminate, and provide training on software to support seismic rehabilitation	Unfinished Business in the Strategic Plan 2005 (G061)
	Task 9: Develop seismic rehabilitation materials suitable for college and university instruction	Seismic Rehabilitation Materials for College/University Instruction (G063)
	Task 10: Improve information services to support the collection and dissemination of seismic rehabilitation information	Accessibility of Information (G010)
3. .Develop new seismic rehabilitation tools	Task 13: Conduct case studies of buildings to correlate code design with actual damage	Case Studies to Correlate Seismic Design with Actual Damage (G064)
	Task 14: Establish a system for the comprehensive and systematic collection and analysis of damage and loss data	Comprehensive and Systematic Collection of Damage and Loss Data (G065)
	Task 15: Develop simplified rehabilitation techniques for engineered structures	Development of Simplified Procedures (G015)
	Task 16: Develop improved and internally compatible analytical tools, acceptance criteria, and modeling rules and procedures	Improvement of Advanced Structural Analysis Procedures (G075)
	Task 18: Prepare materials focused on the building "pounding" issue in seismic rehabilitation	Explicit Consideration of Building Adjacencies (G056)
	Task 19: Develop technical material focused specifically on the implications of local geology and detailed soil conditions on the seismic rehabilitation of buildings	Improvement of Foundation Design (G020)

Table 2-2 Partially Completed and Uncompleted Tasks of Strategic Plan 2005, FEMA 315 (continued)

Objective	Task Number / Name	Global Issue No.
4. Consider new program directions	Task 21: Develop a standard and uniformly acceptable building performance rating system	Development of a Uniformly Acceptable Standard Building Performance Rating System (G066)
	Task 22: Systematically collect, analyze, and apply more and better data about building performance in earthquakes (the "best laboratory")	Improvement of Seismic Assessments of Existing Buildings (G077)
	Task 23: Provide guidance on implementing seismic rehabilitation in multihazard environments	Multihazard Coordination and Linkage with other Building Mitigation Actions (G004)
	Task 24:Develop seismic rehabilitation guidelines for non-engineered buildings	Development of Rehabilitation Guidelines for Non-Engineered Buildings (G067)
	Task 25: Develop improved building inventory methods	Unfinished Business in the Strategic Plan 2005 (G061)

Note: Global Issue Nos. appear in the ATC-71 Report, *NEHRP Workshop on Meeting the Challenges of Existing Buildings, Part 1, Workshop Proceedings,* 2008.

Chapter 3
Current State of Policies and Regulations Governing Existing Buildings

3.1 Public Policy, Regulations, and Enforcement

Building codes for new construction and the rehabilitation of existing structures are enacted by elected officials as an expression of public policy. These regulations, like others, are enforced by government agencies. The federal government is rarely involved directly with building regulations that govern the use of structures not owned or operated by it. This authority is the prerogative of state governments. In some states, this responsibility is delegated to local jurisdictions.

In addition to developing and enforcing building regulations for buildings that it owns or operates, the federal government provides funding for the development of seismic evaluation and rehabilitation standards as well as financial relief in the reconstruction efforts after damaging earthquakes. Specific requirements have been established for the funding eligibility of community reconstruction efforts. Essentially, minimum building standards must be in place, before an earthquake, for FEMA to provide funds to improve public buildings beyond their deficient pre-earthquake condition. These requirements include building standards for the repair of existing buildings, for the construction of new buildings, and for assessing earthquake damage sustained by a building.

State governments define the process by which building regulations are adopted and enforced. In general, there are three approaches used. These approaches are described in Section 3.3.

A local jurisdiction is generally responsible for the enforcement of building regulations for most of the buildings within the jurisdiction. Jurisdictional authority, however, can be a function of building ownership and building occupancy (or the building's use). For example, buildings owned by the federal government are exempt from local jurisdictions. In California, hospital and school buildings are regulated by state agencies. Privately owned construction, however, is regulated under the jurisdiction of local municipal and county authority.

3.2 Current Seismic Evaluation and Rehabilitation Regulations in the United States

The currently enforceable regulations for seismic evaluation and rehabilitation that exist today have usually been the result of the response to damage from earthquakes. Shortly after the destructive 1933 Long Beach earthquake, the California State legislature mandated that all buildings be designed for earthquake forces, and thirteen days after that earthquake, the Long Beach City Council outlawed the use of unreinforced masonry in the construction of new buildings. Similarly, the City of Los Angeles adopted a mandatory seismic retrofit ordinance for concrete tilt-up buildings shortly after the 1994 Northridge earthquake.

Most jurisdictions adopt building codes that regulate in some way the continuing use of existing buildings. For the most part, code provisions regarding existing buildings are predominantly policies of triggered rehabilitation (see Chapter 1). Additionally, some jurisdictions provide economic incentives to encourage voluntary seismic rehabilitation. Lastly, in a limited number of California jurisdictions, there are unique ordinances that mandate seismic evaluation or rehabilitation to address specific earthquake risks. Code provisions that serve as engineering resource material for the seismic evaluation and rehabilitation of existing buildings are discussed in Chapter 5.

There is considerable variation across the United States in the level of review of structural plans for new buildings, and of structural plans for the repair or rehabilitation of existing buildings. In general, smaller jurisdictions utilize very little, if any, plan review for structural compliance. Structural plans are usually only reviewed in larger municipal jurisdictions. This is not true for some states like California, but is generally true for most of the nation. These smaller jurisdictions also have few mandatory seismic programs or triggers that mandate rehabilitation. In general, smaller jurisdictions allocate less community resources and funding to the regulation of existing buildings.

To gain perspective on current approaches and programs for seismic evaluation and rehabilitation being undertaken by various municipalities, a sample group of regulatory officials was questioned about the technical requirements and programs for seismic evaluation/rehabilitation enacted within their communities, or with which they were otherwise aware. The cities and regulatory officials questioned are provided in Appendix D. The collective input of these regulatory officials was supplemented during discussions at the 2007 *NEHRP Workshop on Meeting the Challenges of Existing Buildings*.

3.2.1 Mandatory Regulations

There are few mandatory seismic retrofit ordinances in place throughout the United States. California has mandated local jurisdictions in high seismic areas to identify the unreinforced masonry (URM) bearing-wall buildings within their jurisdictions and to develop mitigation or risk-reduction programs to address them. California has also incorporated Appendix A1 from the 2006 *International Existing Building Code* into a *California Existing Building Code* as a building standard for the rehabilitation of URM buildings.

In recent years, the state of California has also identified soft-story buildings as potentially hazardous. The state's actions are advisory in nature, and few local jurisdictions have responded by adopting mandatory seismic evaluation and rehabilitation programs for these types of structures. Even fewer local jurisdictions have enacted mandatory programs independently of state actions that define potential hazards. The City of Los Angeles requires owners of pre-1976 concrete tilt-up buildings to seismically rehabilitate their buildings; the City of Burbank has a welded-steel moment-frame retrofit ordinance; and the City of Berkeley has a soft-story retrofit ordinance. These are examples of the small number of locally initiated mandatory programs developed independently of state-mandated action.

3.2.2 Triggering Regulations

The nature and degree of substantial change that is planned for an existing building and that triggers seismic strengthening appears to vary significantly among regions of the country and to a lesser extent among jurisdictions within a region. The majority of jurisdictions do not require seismic upgrades when a building is remodeled, regardless of the extent of remodeling. In general, provided the remodeling does not make the building "unsafe," no seismic evaluation or rehabilitation will be required. In active seismic areas, however, this policy has been improved on. The *City of Los Angeles Building Code* requires a building be upgraded to current code requirements when the cost of cumulative alteration or repair is in excess of 50% of the replacement cost of the building. The City and County of San Francisco has similar provisions. This requirement, based on the scope of planned alterations, is unique to a jurisdiction and is not contained in the model building codes. (See Chapter 5 for further discussion of building code provisions for existing buildings.) These seismic safety triggers are substantially higher (coming into force when 50% of the replacement cost is reached) than those required for accessibility triggers. (Remodels exceeding $113,587.07 require mitigation or the provision of access).

Several jurisdictions outside California have adopted triggers for seismic rehabilitation. The City of Seattle encourages the use of ASCE 31 for evaluation of seismic sufficiency, but only requires FEMA 178. An existing building must be evaluated and shown compliant or rehabilitated if:

- it has been vacant for 2 or more years,
- it has been substantially damaged in an earthquake,
- it is of URM construction and its occupancy load is significantly increased, or
- the useful life is substantially extended through the replacement of plumbing, electrical or mechanical installations.

Some jurisdictions are reported to negotiate a seismic strengthening scope with the building owner during a major remodel. This negotiation can involve the design criteria to be used, or the building portions affected, or both. In many instances, simply stated criteria are proposed, such as requiring lateral resistance at least equivalent to seismic demands that are 75% of the current code requirements for new construction. While simple to state, such criteria can produce an abundance of confusion for those interpreting the criteria in regard to the criteria's application to archaic forms of construction, now prohibited by current codes.

Many jurisdictions have zoning regulations that address vacant buildings, especially buildings vacant for more than a year. These regulations often require the use of the building be brought into conformance with current zoning regulations regardless of the past use. The building effectively loses its non-conforming use permit when it is left vacant for a period of time. The zoning regulations, however, do not specifically address the consideration of seismic safety. As a consequence, the non-conforming use may be discontinued but the archaic, potentially vulnerable, non-conforming seismic system of structural resistance may be deemed acceptable for new, different occupancies.

Historically, building officials have been granted wide-ranging authority to identify dangerous conditions such as fire hazards, sanitary hazards or structural deterioration that compromises safety. These conditions have been characterized as posing an imminent hazard to occupants and neighbors. The consequent abatement is triggered by the building official's declaration of a hazardous condition. Seismic vulnerability, however, has not been considered an imminent threat since the imminent occurrence of a potentially damaging earthquake is judged to be less than likely. Presently there is some debate in California about the appropriateness of increasing the authority of building officials to trigger demolition, evaluation, or rehabilitation based on the judgment that a structure may be seismically unsafe for occupancy (see California Assembly Bill 2793). At the present time, however, this authority is only being used after a damaging earthquake has occurred and aftershocks are anticipated as likely occurrences.

3.2.3 Voluntary Policies

Wholly voluntary seismic rehabilitation work is generally allowed by building officials provided the building is "no less conforming" when the work is complete. When no specific design criteria are followed, however, design and construction quality assurance becomes unclear. Consumer protection can become an issue if the owner mistakes a building permit for certification that the design meets a level of earthquake protection commonly associated with new construction.

Some jurisdictions have adopted standards or prescriptive provisions to guide voluntary work. While some have adopted or referenced provisions of the *International Existing Building Code*, most continue to rely on the *International Building Code* or other model codes for new construction (see Chapter 5 for further discussion). Very few jurisdictions, like the City of Los Angeles, have developed their own applicable voluntary standards into their building code. Examples of buildings for which there are unique requirements include:

- existing wood-frame residential buildings with weak cripple walls and unbolted sill plates,
- existing wood-frame residential buildings with soft, weak or open front walls,
- existing hillside buildings,
- existing reinforced concrete buildings and concrete frame buildings with masonry infill walls, and
- existing reinforced concrete and reinforced masonry wall buildings with flexible diaphragms.

3.3 Regulation Adoption Process

States generally specify the building standards that are to be enforced by local jurisdictions. Some states (for example, Oregon and Washington) require a model state code to be enforced by local jurisdictions without changes. Other states require minimum statewide standards as contained in a model code, but permit local jurisdictions to adopt more restrictive, overriding requirements. An example is California. Still other states require local jurisdictions to decide the building standards to be enforced, like Alaska and Arizona.

States generally rely on model codes that are developed through consensus balloting to establish their building standards. The two primary model codes for new construction are the *International Building Code* (IBC) and *National Fire Protection Association 5000* (NFPA 5000). According to the International Code Council (ICC) (http://www.iccsafe.org/government/adoption.html), as of January 2008 the IBC has been adopted at the state or local level in 47 states and the District of Columbia.

Both the IBC and NFPA 5000, however, are primarily intended for the design of new structures and give relatively little attention to rehabilitation issues. IBC Chapter 34 addresses "Existing Structures." NFPA 5000 Chapter 15 addresses "Building Rehabilitation."

The leading model code developed specifically for existing buildings is the *International Existing Building Code* (IEBC), published by ICC. In only its third edition, the IEBC is not widely adopted. Nevertheless, as part of the ICC's family of codes, it is likely to become the model code of choice as more jurisdictions recognize the value of code provisions to help regulate their existing building inventory.

3.3.1 Model Codes

The IEBC provides three "compliance alternatives." One of these alternatives defaults to IBC Chapter 34 and one of them focuses primarily on fire safety. The third approach (Chapters 4 through 12) identifies multiple triggers based on the scope of repair, alteration, addition, or change of occupancy intended by the permit applicant. With respect to seismic evaluation and rehabilitation, the IEBC triggers extend the more generic approach of IBC Chapter 34 in much the same way that local code provisions in, for example, San Francisco and Portland, had already done.

The IEBC also includes an Appendix A entitled *Guidelines for the Seismic Retrofit of Existing Buildings* (GSREB). As the successor to the discontinued *Uniform Code for Building Conservation* (UCBC), its five chapters offer mostly prescriptive provisions for the rehabilitation of specific building types with poor performance histories.

IEBC Appendix A chapters are available for voluntary work but are also referenced by the body of the IEBC as acceptable alternatives where seismic evaluation or rehabilitation is triggered. Some of the Appendix A chapters have also been adopted by local jurisdictions in support of specific rehabilitation programs. Thus the IEBC Appendix chapters that evolved from local amendments are now returning to local use as model code provisions with national consensus. Examples from California include the following:

- In 2007, California adopted its own *California Existing Building Code* consisting of one chapter for unreinforced bearing-wall buildings identical to IEBC Appendix A1.
- Small jurisdictions that only recently developed URM programs in accordance with California law (see Section 3.2), including Paso Robles following the 2003 San Simeon earthquake, have adopted IEBC Appendix A1.
- San Francisco Bay Area jurisdictions allow the use of a prescriptive plan set for cripple-wall bracing and sill-plate anchoring developed by local ICC Chapters based on IEBC Appendix A3.

In 2005, California passed Assembly Bill 304 into law, allowing jurisdictions to adopt model codes such as IEBC Appendix A4 in support of soft-story risk-reduction programs. Berkeley was among the first to do so.

The IBC and IEBC model codes are developed and published by the International Code Council on a triennial cycle, with mid-cycle supplements. The ICC's history as three separate legacy organizations (including the International Conference of Building Officials, publisher of the discontinued *Uniform Building Code*) and its full rules and procedures are available online at www.iccsafe.org. The ICC's code development process involves the following basic steps, each of which affords opportunities for stakeholder input:

- **Individuals submit code change proposals.** Any individual or organization may propose any number of specific code changes, each submitted with a reason statement. Proposals range from small editorial clarifications, to wholesale chapter revisions, to suggestions for entire new chapters. Recently, most of the substantive proposals related to seismic evaluation and rehabilitation of existing buildings were submitted by the Existing Buildings Subcommittee of the National Council of Structural Engineers Association (NCSEA) Code Advisory Committee. Many of those proposals were initiated in local structural engineers associations in California and Washington and were vetted for national consensus by NCSEA. While there is no rule against it, code change proposals generally do not come directly from researchers. Instead, building professionals and organizations cite relevant research in the supporting statements for their proposals. Rarely, however, do structural engineering research results move directly from academic publication to the model codes without the explicit support of a standards organization (like ASCE) or multiple expert stakeholders (like the Building Seismic Safety Council and NCSEA). Because the model codes must address generic conditions, vendors of specialty rehabilitation products (such as energy dissipaters, narrow shear walls, and fiber-reinforced polymer overlays) typically develop design guides in coordination with the model codes but avoid proposing actual code provisions.

- **ICC organizes and publishes the proposals.** Each proposal is assigned a unique identifying number, and the proposals are coordinated to account for overlaps and to ensure that each is assigned to the proper ICC committee for hearing. Because the IEBC must be coordinated with IBC Chapter 34, proposals related to existing buildings are often heard by multiple committees. Proposals related to seismic provisions for existing buildings are typically heard by one or both of the IBC Committees (the IBC General Committee or the IBC Structural Committee). ICC committee hearings are public. ICC committees are composed of ICC-member code officials chosen for their expertise with the subject code. For each proposal, the committee hears brief in-person testimony from the proponent (to supplement the published reason statement) and from those in support or in opposition. On issues of seismic safety and existing buildings, frequent participants include representatives of NCSEA and other professional associations, including ASCE; FEMA and the other National Hazards Reduction Program-(NEHRP)-funded organizations; BSSC, through its Code Resource Support Committee; Fire Marshals and organizations of code officials; stakeholder groups such as the Institute for Business and Home Safety or the Building Owners and Managers Association; building materials organizations such as the American Concrete Institute (ACI) and the American Institute for Steel Construction (AISC); trade organizations such as the National Association of Home Builders or the Concrete Reinforcing Steel Institute; vendors such as Simpson Strong-Tie or Hardy Frames; and individual code officials, researchers, or practitioners. Following testimony, the committee votes to recommend approval (as submitted or as modified) or disapproval of each proposal. The audience of ICC-member code officials may overrule the committee, though this is rare. Proposals of limited scope, supported by clearly reasoned statements, incisive testimony, and a coalition of variously interested stakeholders (often organized in advance of the hearings), tend to be successful.

- **Individuals submit and ICC publishes public comments.** Any individual or organization may submit a public comment challenging the vote of the ICC committee. Public comments allow input from individuals and organizations who were unable to attend the hearings. Public comments are useful to address unintended conflicts or overlaps resulting from the committee hearings (such as different positions taken by different committees on similar topics) and may be used to introduce new arguments or information in response to concerns raised at the hearings.
- **The ICC holds final action hearings.** At a final set of hearings by the general ICC membership (not by code-specific ICC committees) public comments are heard, and the audience of ICC members votes to confirm or alter the committees' recommendations from the initial hearings.

Upon publication of the updated codes, states and other jurisdictions follow their specific procedures to modify and adopt them. NFPA's code development process is also consensus-driven but relies more on committee participation and less on public input. The NFPA code is currently of marginal influence with respect to seismic risk and existing buildings.

3.3.2 Jurisdictional Supplements

Model building codes have been supplemented in two ways to account for the broader set of performance issues raised by existing buildings:

1. Jurisdiction-specific revisions or amendments to the model code.
2. Special-purpose model codes developed for existing buildings.

Local amendments have frequently addressed issues that would later motivate special-purpose model codes like the *International Existing Building Code* (IEBC). Examples of local revisions or amendments to the national model codes include:

- The State of California maintains special provisions for seismic evaluation and rehabilitation of state-owned facilities (formerly in *California Building Code* (CBC) Chapter 16, Division VI-R; now in 2007 CBC Sections 3415-3420).
- The City of Los Angeles maintains several chapters dedicated to the seismic rehabilitation of specific building types (Divisions 88 and 91 through 96). Used largely for voluntary work, some of these chapters have become the basis for model code provisions in IEBC Appendix A.
- San Francisco has long maintained a set of alteration-based and repair-based rehabilitation triggers that eventually became the basis of the

IEBC's seismic provisions. San Francisco has now redrafted its amendments to fit within Chapter 34 of its IBC-based building code.

- Portland, Oregon, and San Jose, California, have adopted provisions similar to those in the IEBC. Seattle and Salt Lake City are among the other jurisdictions in the process of adopting building code provisions to address seismic risks posed by existing buildings.
- California maintains a Historical Building Code intended to address earthquake safety while respecting the historic value of qualifying buildings.

In addition to code amendments, jurisdictions routinely maintain internal code interpretations and bulletins to fill the inevitable gaps of any model code. In particular, these bulletins are needed to help regulate the use of new rehabilitation technologies (especially proprietary products) whose design parameters have not yet been codified. These can range from fasteners, to wall or column components, and to whole seismic force-resisting systems. Unfortunately, the supporting technical data is often geared to the technology's use in new construction and must be modified to address the framework of ASCE 41 or the model code provisions for existing buildings.

3.4 Effectiveness of Current Policies and Regulations

The effectiveness of a seismic evaluation and rehabilitation program can be measured by the percentage of buildings that comply with the program. The higher the compliance rate, the more effective the program. Therefore, it is worthwhile to analyze the components that go into a successful program as well as the impediments that cause a low compliance rate.

A low rate of compliance may be due to such impediments as poorly articulated or confusing rehabilitation regulations, required work that is too costly to be economically viable, lack of enforcement or non-uniform enforcement, or a lack of awareness of the importance of seismic rehabilitation.

An example of a program that was not effective due to lack of compliance occurred in the City of Seattle, Washington in the 1970s. The city adopted a mandatory seismic retrofit ordinance and identified buildings that needed to be evaluated and strengthened. A large number of owners did not comply because of the cost and lack of flexibility in the regulations. As a result, many of the buildings were simply vacated.

Today, the City of Seattle has made significant improvements in the compliance rates by adopting standards and guidelines like ASCE 31 and

FEMA 178. This suggests that one factor in the improved rate of compliance was due to the use of well-developed rehabilitation standards and guidelines.

The City of Los Angeles' mandatory unreinforced masonry (URM) bearing wall program was effective. At the time of the 1994 Northridge earthquake, over 90% of the existing 7000 URM buildings were strengthened and the remaining ones were vacant. Less than 500 of the buildings were damaged from the 1994 earthquake with only about 200 buildings having damage levels in the moderate-to-severe range. There were no deaths and no reports of injuries to the occupants of these buildings, which was the stated objective of the ordinance. Unfortunately, many owners of the damaged buildings were disappointed in the performance of their "seismically retrofitted" buildings. While poor engineering application of the ordinance requirements cannot be ruled out as a possible explanation for the variations in damage observed, dissatisfied owners clearly expected more than the stated ordinance's purpose or reducing the risk of death or injury. This points out the need to improve communication on the difference between a life-safety level of performance and a property protection level.

In the early 1990s, the City of Long Beach developed a bond-financing program that allowed owners of URM buildings to obtain financing for the required work. This provided financing for those owners who were not able to obtain traditional financing, and as a result, increased the compliance rate for these buildings.

3.5 Impediments to Implementation of Additional Regulations

Numerous impediments to the implementation of mandated seismic rehabilitation programs exist. The economic cost to be borne by building owners is the most obvious impediment. These costs can be substantial, but generally do not produce increased revenue to the owner, nor are they widely seen as a building enhancement. Economic incentives can offset some of the cost, but incentive programs have generally not been substantial enough to overcome resistance.

It is common for there to be additional code requirements imposed on owners when doing any type of work on an existing building, including work to seismically strengthen the building. For example, when doing seismic strengthening work on a building, the owner is required to improve the building's accessibility for the disabled. In the past, advocates for the disabled community have opposed laws that would allow owners to seismically strengthen their buildings without improving access for the disabled. The advocates have expressed the concern that the useful lives of the buildings should not be extended without upgrading the accessibility. They have argued that if the building were damaged in an earthquake, the repaired or replaced building would be required to meet accessibility standards. To a large extent, this argument has been politically persuasive on the federal, state and local level.

Business tenants are generally most interested in cosmetic improvements that make the buildings more attractive and possibly more productive for their businesses. Other advocates press building owners to spend additional resources on fire alerting and suppression improvements. These funding requests are seen by both tenants and owners as “value added” and compete with seismic strengthening for available resources.

Underlying all of these impediments is a genuine lack of knowledge about the dangers of existing buildings with regard to earthquakes. Owners, bankers, insurance companies, elected officials and building officials do not have a realistic understanding of the threat earthquakes pose to seismically vulnerable buildings. This appears most true for elected officials. They are the ones elected to establish appropriate policies to protect the public welfare and it is primarily through their actions that requirements for existing buildings are adopted. Major earthquakes have brought about significant legislation to address seismic hazard. After the 1933 Long Beach earthquake, several laws were enacted that protected the California public from hazardous buildings. The use of unreinforced masonry bearing walls was prohibited and the review and approval of school building construction was assigned to the Office of the State Architect.

Mandated seismic work, which typically involves negotiated legislation, can face obstacles or unintended consequences. Senate Bill 1953, California’s law requiring hospital seismic evaluation and rehabilitation led to unanticipated results. Large numbers of facilities were found deficient and required extensive rehabilitation. The significant costs and lack of funding sources resulted in the closure of some facilities. To improve the ranking of vulnerabilities, California’s Office of Statewide Healthcare Planning and Development elected to use the HAZUS loss estimation tool to supplement its FEMA 356-based evaluation criteria. Similarly, Senate Bill 1732, a California law requiring due diligence seismic evaluation of courthouses, resulted in disagreements between the state and its counties about which would be responsible for correcting identified seismic deficiencies and thereby stalled the implementation of related legislation. Follow-up legislation several years later (Senate Bill 10) partially solved the problem through a complex assignment of liability for future earthquake-related losses.

Legal issues may arise when buildings are analyzed for seismic deficiencies. Building owners have a potentially increased liability for harm to occupants in the event of an earthquake if the owners are aware of seismic deficiencies in their buildings and have not taken appropriate action. As a consequence, building officials are generally reluctant to assemble, or require owners to assist in the assembly of, an inventory of the potentially hazardous buildings within their jurisdictions. Such actions, as a practical matter, require the establishment of a political mandate from the community since the potential impact to building owners can have significant economic consequences. These consequences can take the form of increased liability, costs of rehabilitation, or lower property values.

3.6 Opportunities

Despite the numerous impediments to more widespread seismic evaluation of risk, and rehabilitation to reduce future losses, several significant trends in public policy awareness present promising opportunities for change. In recent years, the popularity of building sustainability has captured media attention and driven state legislatures to mandate actions aimed at reducing the energy consumption of buildings, reducing the landfill waste generated by building construction and demolition, and increasing the use of locally-produced recycled materials. The “green” building movement has become a significant force of change in the building design process.

Embedded in the concept of green building construction is the notion that choices should be made to maximize the use of renewable resources, particularly those uses that minimize both the depletion of carbon resources and the release of harmful emissions. Structural rehabilitation of seismically vulnerable existing buildings can effectively extend the useful life of a significant portion of our building stock, while achieving many of the goals of the green building movement. Articulating these attributes of building rehabilitation through the lens of resource renewal and sustainability could be an effective advocacy strategy for policy change.

In many communities, awareness exists of the importance of historic building stock as a significant cultural resource. To the degree that these cultural resources can be protected for future generations to inherit a sense of place, seismic rehabilitation may be a necessary intervention. Communicating the vulnerability of these resources may be an important opportunity to rally community preservation advocates toward support of mandatory, triggered or voluntary rehabilitation policies.

The terrorist attacks of September 11, 2001, have prompted a greater awareness of infrastructure resiliency in our nation. A significant vulnerability exists today in the form of seismic risk. This vulnerability should be an important topic of consideration in any plan to improve the resiliency of this nation's infrastructure. Emphasizing mitigation as an issue of improved resiliency may improve the effectiveness of attracting incentive funding from federal sources.

The events of Hurricane Katrina have brought to national attention the vulnerability to natural disasters faced by our poorest citizens and the political repercussions of the limited resiliency of poorer communities. Those who can least afford the consequences are among those most at risk. In seismically hazardous regions of the country, as elsewhere, the poorest of our citizens generally reside in older and sometimes more vulnerable forms of construction. Advocacy aimed at raising awareness of this community vulnerability may garner political support in those quarters where sensitivity to the underserved is strong.

Lastly, in the aftermath of the occurrence of a significant, damaging earthquake in the United States, the interest and attention of the public, *vis a vis* the media, can create a fertile opportunity for policy change. Regional opportunities are likely to exist for political sponsorship of mandatory, triggered or voluntary policies of seismic evaluation and rehabilitation. To leverage this opportunity fully, however, advocates for change should develop, in advance, proposed policies that identify vulnerable infrastructure, address funding concerns, and offer simple and enforceable rules of application. Such pre-event preparation can greatly facilitate political acceptance during the window of opportunity provided by a significant damaging earthquake.

Chapter 4

Current State of Engineering Practice for Existing Buildings

The current state of engineering practice throughout the United States for existing buildings reflects a broad diversity of regulatory environments, regional economics, historically prevalent building construction materials, age of the building infrastructure, presence of multiple hazards and variations in seismicity. To gain a perspective on current practices, a select demographic of engineering practitioners was questioned about the types of rehabilitation projects they undertake, their approach to rehabilitation design, the technical resources they have used, and the nature of future improvements that could most reward their efforts in the seismic evaluation and rehabilitation of existing buildings.

Starting with the engineering firms that participated in the FEMA 273 Case Studies Project[1] and supplemented with recognized experts in seismic rehabilitation practice, a list of 49 candidates for interviewing was identified. From this list, engineering practitioners from 22 firms agreed to participate in a series of interviews to offer their insight into the current state of engineering practice for existing buildings. See Appendix D for the list of these firms and practitioners.

The work of these practitioners included efforts in 16 states that represent the regions of highest seismic risk in the United States. Their professional experience ranged from 15 to 38 years with an average of 25 years. This experience included building types from one-story to multi-story construction serving multiple uses and occupancies. Construction types included structural steel, masonry, wood, and concrete expressed in a wide range of structural systems. These practitioners worked with a variety of clients and building owners including public sector owners like federal, state,

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[1] The Case Studies Project was sponsored by FEMA in 1999 to assess the applicability of the FEMA 273 (and 274) *Guidelines (and Commentary) for the Seismic Rehabilitation of Buildings.* The case studies produced technical material that provides state-of-the-art examples for seismic evaluation and rehabilitation of existing buildings using the guidelines outlined in FEMA 273 and included comparisons with prevailing practice at that time. The case studies included, for example, government office buildings, post offices, hospitals, fire stations, and courthouses.

and local governments, public school districts, and port authorities; public and private institutions such as universities and hospitals; private developers and architects; insurance companies; high-tech manufacturers; and individual homeowners. The collective experience of these practitioners was supplemented by discussions at the September 2007 *NEHRP Workshop on Meeting the Challenges of Existing Buildings* held in San Francisco.

4.1 Nature and Extent of Current Rehabilitation Work

Seismic rehabilitation of an existing building can range from a minor incremental strengthening (where, for example, the sole purpose is to mitigate nonstructural risks) to an effort to bring a building into general compliance with the current building code requirements for new construction. Seismic rehabilitation may be the prime project objective, or as is more commonly the case, an incidental part of a broader improvement or modification strategy for an existing facility. Examples might include a change in occupancy or use, a building addition, adaptive reuse, or a major renovation. The project scope is frequently influenced by the nature of the triggering-mechanism for the rehabilitation, the local jurisdictional mandates, and the real or perceived economic value or benefit of the rehabilitation. There are arguably as many different types of seismic rehabilitation projects as there are buildings seismically rehabilitated. Each individual building poses technical and construction challenges unique to its construction, configuration, occupancy, age, particular jurisdiction and seismicity. Additionally, projects have varying objectives in addressing seismic rehabilitation. As has been previously noted, seismic rehabilitation can be classified as being mandated, triggered or voluntarily undertaken.

Mandated seismic upgrades occur in a limited number of jurisdictions or states that have passed legislation requiring specific earthquake risks to be addressed. These typically impose strengthening for specific types of building construction or occupancy. Examples include unreinforced masonry bearing-wall buildings, soft-story buildings, or hospitals. Some jurisdictions have mandated programs that address specific building components such as masonry parapets or tilt-up building wall-to-roof anchors.

A great many seismic rehabilitation projects are reported to be triggered as a part of a larger building rehabilitation associated with a change in use or occupancy or a building addition that serves as an improvement to the original. These projects are driven by business decisions to increase the value of the property. Substantial changes to improve a building may trigger application of building code requirements, which expand the project scope beyond the functional or aesthetic improvements and include an element of seismic risk reduction. The nature and degree of substantial change that triggers seismic strengthening is reported to vary significantly among regions of the country and to a lesser extent among jurisdictions within a region.

The extent of voluntary seismic rehabilitation varies substantially throughout the country from regions of lower seismicity, where there are very few projects, to regions of high seismicity where there are more. These types of seismic rehabilitation were common in the 1990s and early 2000s as business, particularly high-technology manufacturers, looked to limit their potential risk of business disruption caused by an earthquake event by improving their building infrastructure. This voluntary rehabilitation is reported to have diminished recently due to economic circumstances that have refocused business priorities.

While there are many different types of seismic rehabilitation, each one is undertaken to fulfill a specific project objective. This objective may be defined by the owner, or imposed by mandates of a jurisdiction considering the changes being undertaken, or by the dictates of the jurisdiction for certain types of construction.

4.2 Regional Variations in Engineering Problems and Practice

There are significant regional variations in the seismic evaluation and rehabilitation of existing buildings. These variations are rooted in the political, jurisdictional, economic, and seismic realities of the many regions within the United States. Those areas of the country that have experienced significant, damaging earthquakes within the last 50 to 100 years have a much greater awareness of seismic risk than those areas that do not carry this memory in their collective consciousness. By and large, seismic design was not incorporated into the majority of our existing building inventory. Even when it was explicitly considered, the risk has historically been under-estimated by today’s standards. This leaves much of our existing building inventory at risk to earthquakes.

4.2.1 West Coast and Inter-Mountain West

Seismic design has its longest history on the west coast, particularly California, as the result of numerous devastating 20th century earthquakes. Seismic design has been an integral part of building design in California since the 1930s, particularly after the Long Beach earthquake of 1933. Seismic design also has a long history in the seismically active region around Seattle, Washington, after large seismic events in the 1940s. Oregon and the metropolitan area around Portland, have a much more recent understanding of seismic risk gained in the 1980s. The same is true of Salt Lake City and the potential effects of the Wasatch Fault. Collectively, the potential seismicity evident, or in fact demonstrated, in California, the Pacific Northwest and Inter-Mountain West has resulted in dramatic changes in design for earthquakes over the past 70 years, and most dramatically over the past 25 years.

The occurrence of significant damaging earthquakes has resulted in seismic design becoming an integral part of structural design practice throughout the west for new construction and for the seismic rehabilitation of existing buildings. Practitioners report that there are significant variations in approaches and perspectives to seismic rehabilitation within this region. Practitioners in California report that the majority of their seismic rehabilitation projects are the result of upgrades that are triggered by changes in use and occupancy. Many mandated rehabilitation programs exist in California that have produced a significant number of projects. These mandates have included unreinforced masonry bearing-wall buildings statewide and parapet bracing requirements in San Francisco and Los Angeles, and soft-story and tilt-up strengthening ordinances in a few jurisdictions.

Some jurisdictions having the requisite authority require that these upgrades be brought into compliance with the *California Building Code* (CBC) and are generally unwilling to consider other design approaches, such as those embodied in ASCE 41 (successor to FEMA 356, *Prestandard for the Seismic Rehabilitation of buildings*), since these are not explicitly referenced by the CBC. A notable exception can involve the rehabilitation of an historic building. Historic buildings in some jurisdictions are subject to the requirements of the UCBC (which has been superseded by Appendix A of the IEBC). California maintains a separate building code for historic buildings that encourages building-specific structural criteria. (See Chapter 5 for further discussion of these technical documents.)

In Seattle, practitioners report more frequent use of technical resources such as ASCE 31 and ASCE 41 (or FEMA 356) as acceptable alternative rational engineering approaches permitted by building officials enforcing the code. Practitioners in Portland expressed similar experiences to those in Seattle. Practitioners in Utah report that much of the building seismic rehabilitations are undertaken as voluntary improvements and as such are permitted greater flexibility in selecting criteria to meet.

Armed with the recent historic perspective of damaging earthquakes on active faults, regions in the West Coast and Inter-Mountain West have adopted different but progressive approaches to the seismic risks that they face.

4.2.2 Midwest

The seismicity of the midwest is dominated by the seismic sources of the New Madrid region, an area near Memphis, Tennessee, which experienced three large earthquakes in 1811 and 1812. These events were felt in cities across five midwestern states. There has been little significant or damaging seismic activity in this region since these three events. Not surprisingly, seismic design has not been a significant design consideration. Practitioners in the region report that there is a strong reluctance in much of the community to acknowledge the potential seismic risk. Many practitioners today do not consider earthquake shaking to be a significant risk to buildings in this region, and there are few mandated programs of seismic rehabilitation. Seismic rehabilitation of existing buildings does, however, occur on a voluntary basis for industrial facilities and hospitals. In these instances, progressive management is vitally interested in sustaining operational continuity. Seismic considerations in building construction in the midwest are relatively recent and recognition of the risks to the existing building stock have not been fully accepted by the community in general.

4.2.3 East Coast

The eastern United States is comprised of areas that are of low to moderate seismicity (for example, in the northeast) and high seismicity (for example, around Charleston, South Carolina). The eastern U.S. possesses the oldest building inventory in the nation, much of it constructed without consideration of seismic design. Practitioners report a limited number of seismic rehabilitation projects. Where seismic rehabilitation does occur, it is largely triggered by changes in use and occupancy in a building renovation or addition and is met with significant resistance. Notable exceptions include business owners interested in voluntarily reducing their risk of business disruptions in the event of an earthquake. In most rehabilitation projects, however, there is no consideration given to seismic design issues.

4.3 Technical Resource Material Applied in Practice

Practitioners reported utilizing a variety of technical resources to implement their seismic rehabilitation designs. Many are relying on ASCE 31, *Seismic Evaluation of Existing Buildings*, and the recently released ASCE 41, *Seismic Rehabilitation of Existing Buildings* (or its predecessor, FEMA 356, *Prestandard for the Seismic Rehabilitation of Buildings*). Others continue to attempt to apply the building code for new construction in the form of the

Uniform Building Code or *International Building Code*. This is particularly true for a seismic upgrade that is triggered by a change of use or occupancy and requires the subject building to be brought into general compliance with current code. In some areas, and in particular for historic structures of unreinforced masonry construction, the *Uniform Code for Building Conservation* provides the framework for the seismic rehabilitation of existing buildings. Also in limited use is the *International Existing Building Code*. For a more detailed discussion of technical resources, see Chapter 5.

Practitioners report that due to the complex nature of seismic rehabilitation they exercise considerable engineering judgment in developing their designs. Due to the unique configuration and use of building materials in each existing building, and the limitations and constraints required in the application of the analytical and design procedures, extensive judgment is necessary. The standardization of ASCE 41 has created a reference, which, by its nature, uses mandatory language that eliminates design flexibility. The prescriptive nature of the standard will in general promote greater consistency among designs but constrains the creative and adaptive design opportunities that existed previously. As with all standards and guidelines, the expectation is that ASCE 31 and 41 will need to continue to evolve in order to improve their applicability to the variety of conditions that must be addressed. Some of the areas that require further development are highlighted in Chapter 5, and in the following Section 4.4, which explores the impediments to broader implementation of seismic rehabilitation that the practitioner faces.

4.4 Impediments to Seismic Evaluation and Rehabilitation – A Consensus Perspective

The 2007 *NEHRP Workshop on Meeting the Challenges of Existing Buildings* provided a wide-ranging discussion of current issues faced by practitioners engaged in seismic rehabilitation. Workshop participants identified many practical impediments to broader implementation of seismic rehabilitation. These issues were explored in a series of breakout sessions on the second day of the workshop. Nineteen workshop attendees participated in one or more of the three Practical Impediments breakout sessions. The Practical Impediments breakout sessions focused on the identification and discussion of issues related to the practical application of engineering standards perceived as impediments to more widespread seismic rehabilitation of existing buildings.

Discussions were structured to identify salient points and different perspectives on the issues, which led to a consolidation of many related issues. These discussions resulted in the identification of the following issues, with a summary discussion following each, as the most significant impediments.

- **Lack of building-specific loss-estimation procedures.** For voluntary and triggered work, quantifiable earthquake loss estimation procedures are not available for rational decision-making regarding seismic risk. Owners need a rational means to make informed decisions about rehabilitation options. Procedures that can provide benefit/cost ratios for alternative risks such as fire and earthquake are not available to the engineering community. Currently available seismic evaluation methods do not include financial summaries useful, to stakeholders, to portray relative risk among hazards. This information could better inform rehabilitation choices and priorities. Emphasis on financial summaries will call for training that most engineers do not currently receive and will begin to involve engineers in decision-making processes that are not governed by anything as straightforward as a building code.
- **Lack of resources to facilitate engineers' communication with owners and stakeholders about seismic rehabilitation.** Engineers' expressed great difficulty in communicating with owners, architects and builders about many aspects of seismic rehabilitation. Documents that present seismic rehabilitation concepts to various stakeholders, such as owners, architects, and builders, would help bridge the communication gap. These documents need to be written in language and format tailored to the target audience. The documents can be used to introduce seismic rehabilitation strategies and bring into focus the economic (cost/benefit ratio) risks (financial and operational). These technical resources need to incorporate illustrative examples of actual projects and decision processes.
- **Limitations on engineering judgment imposed by existing seismic rehabilitation standards.** Seismic rehabilitation techniques must reflect unique project-specific building characteristics and require a significant amount of engineering judgment to implement. The process of "standardization" requires the introduction of mandatory language to what were previously fairly comprehensive engineering "guidelines" from which engineers could select appropriate requirements. The use of mandatory language can lead to interpretations that invoke requirements that should not apply, that have never (or rarely) been executed, or are not technically achievable. A specific example of this is the extent of material testing required for buildings that have otherwise good documentation of the design. The recent development of ASCE 41, Supplement 1 (reference needed) is a favorable improvement to the

constraints previously imposed on non-ductile concrete systems due to the lack of research data on the extreme performance characteristics of these systems. More changes that will permit engineering judgment to expand applicability and avoid onerous restrictions are needed.

- **Lack of guidelines for business continuity planning.** Business continuity planning that appropriately weighs the benefits and costs with due consideration of the risks has been a proven rationale for implementing seismic rehabilitation, even in areas of the country that have not experienced significant earthquakes in a great many years. No generally applicable guidance is available on this topic. Guidelines that foster a consistent rationale are a useful tool for decision makers and few consensus-based technical resources are available for design professionals to use in implementation of such strategies with the business community.
- **Inconsistent code enforcement.** Enforcement of the application of code or standard requirements for seismic rehabilitation of existing buildings is inconsistent among jurisdictions and needs to be improved. Compounded by the inherent complexity of ASCE 31 and 41, there are issues of inconsistency in the way various documents work together (including references to other standards). Improvements to these linkages, combined with improvements in education and training, will reduce confusion and reluctance within the engineering community to undertake seismic rehabilitation efforts.
- **Limited availability of education and training for structural engineers in seismic rehabilitation.** The appropriate application of ASCE 31 and ASCE 41 requires training. A design professional who picks up ASCE 41 for the first time and attempts to apply it to a real project is more likely than not to obtain questionable results. Training of practitioners and regulatory officials is needed, along with the development of a broad spectrum of example applications. FEMA has generated numerous training seminars and workshops for many documents related to seismic evaluation and rehabilitation. There is also a good deal of material developed by other organizations [e.g., ATC, the Earthquake Engineering Research Institute (EERI)] that could be very applicable. How this material can be assembled, adapted, and maintained for future use is the core issue. Additionally, preparing curricula and training materials could promote instruction of emerging professionals in the current methodologies and speed the dissemination of this material into practice.
- **Lack of acceptance of incremental mitigation strategies for seismic rehabilitation.** Over time, small increments of rehabilitation can have a

significant effect on reducing the overall vulnerability of a large population of highly vulnerable structures. Incremental approaches to addressing a population of vulnerable buildings are presently impeded by a lack of readily available technical guidelines and lack of acceptance by building officials. The dissemination of existing technical material on this subject into the community of practicing design professionals and building officials provides a vital stimulus to the process of reducing community vulnerability. The incremental approach to seismic rehabilitation contained in the current FEMA publications (FEMA 395-400 and 420; see Appendix A) are not based on performance-based design because this concept did not exist when incremental rehabilitation was first developed. Existing performance-based design approaches should be reviewed for applicability to incremental rehabilitation and documentation should be prepared to facilitate practical application of performance-based design for occupancies covered by the FEMA series. Also, new performance-based design approaches should be developed specifically applicable to incremental rehabilitation and they should be made available to design professionals. Since the concept of incremental seismic rehabilitation has been validated by FEMA and occupancy-specific guidance on its application has been developed, FEMA should take the next step to develop and implement a dissemination plan that is linked to the current performance-based design methodologies. Such an effort might be particularly effective in expanding triggered rehabilitation to encompass lower thresholds with less significant impacts of cost and scope on project economics.

- **Inconsistencies in the evaluation and rehabilitation of nonstructural components.** Inconsistencies among the requirements for the treatment of existing and new nonstructural components are a concern among engineers (particularly for performance objectives that include damage control as well as safety). The majority of earthquake damage repair costs are associated with nonstructural components, particularly when considered on a probabilistic basis. In low-to-moderate seismic regions, anchorage and bracing of these components may represent the best value solution in an incremental strengthening approach. Particular attention needs to be paid to industrial components like shelving and piping.

- **Lack of simplified and prescriptive procedures.** The ASCE 41 Simplified Procedure requires further simplification. The treatment is still too complicated. In areas of low-to-moderate seismicity, the infrequent use of this standard is a challenge to practitioners because of the steep learning curve associated with its implementation each time it is utilized. Greater simplification through either prescriptive models for common building types or emphasis on load-path alone (tying building elements together) could significantly improve potential use.

- **Lack of special policies and guidelines for seismic rehabilitation of historic structures.** Historic structures pose a unique challenge that is presently not addressed by the ASCE 31 and 41 standards. On one hand, cultural resources deemed historic warrant a level of property protection that seems higher than the community has placed on non-historic structures. On the other hand, improving the seismic performance of historic structures will likely require the incorporation of new building materials that compromise historical features. These somewhat diametrically opposed perspectives create a particular problem for historic structures, for which guidance is needed and none is available.

Practitioners voiced a great variety of suggestions to improve the application of seismic rehabilitation design technologies. Suggestions ranged from document-specific technical modifications to a convergence between new and existing building design procedures. Programs and efforts aimed at addressing the above-described ten highest-priority impediments, listed in Table 4-1, are believed to be the most effective way to improve engineering practice regarding existing buildings.

Table 4-1 Top Ten Priority Impediments Identified by Participants in the 2007 *NEHRP Workshop on Meeting the Challenges of Existing Buildings*

Priority Ranking	Impediments
1	Lack of Building-Specific Loss-Estimation Procedures
2	Lack of Resources to Facilitate Engineers' Communication with Owners and Stakeholders about Seismic Rehabilitation
3	Limitations on Engineering Judgment Imposed by Existing Seismic Rehabilitation Standards
4	Lack of Guidelines for Business Continuity Planning
5	Inconsistent Code Enforcement
6	Limited Availability of Education and Training for Structural Engineers in Seismic Rehabilitation
7	Lack of Acceptance of Incremental Mitigation Strategies for Seismic Rehabilitation
8	Inconsistencies in the Evaluation and Rehabilitation of Nonstructural Components
9	Lack of Simplified and Prescriptive Procedures
10	Lack of Special Policies and Guidelines for Seismic Rehabilitation of Historic Structures

Chapter 5

Available Technical Resource Material for Seismic Evaluation and Rehabilitation

Regulation development and engineering practice rely on technical tools and resource material. They also influence those resources, which are, most often, documents written by and for engineers and code officials.

This chapter briefly reviews the available technical resource material, identifying their apparent shortcomings and the obstacles they present to seismic evaluation and rehabilitation. Two broad themes emerge, representing opportunities to enhance the available resources or develop new ones:

1. Despite the availability of resource material targeted to existing buildings, building codes continue to trigger and regulate seismic work with reference to provisions for new construction, an inappropriate reference.
2. A growing interest in seismic performance beyond mere safety – including damage control, business continuity, and community resilience – is not yet well-served by available resource material.

5.1 Available Resources and their Applicability

Appendix A lists references related to the seismic performance of existing buildings. Except for the examples of institutional policies, this chapter and Appendix A are limited to government-funded/developed tools and consensus documents. (Here, a "consensus document" is one developed through a transparent process open to public or multi-stakeholder input, typically a model code or a technical standard.) The multitude of *non*-consensus resources – such as research reports, journal articles, example manuals, handbooks, code commentaries, trade publications, and software – are not much discussed, though they are routinely used by practitioners to supplement the codes and standards, and some issues they raise do find their way into consensus documents.

Table 5-1 (with the discussion that follows it) lists the main consensus documents and describes, briefly, how they are used for the distinct tasks of seismic evaluation and seismic rehabilitation design. See Appendix A for complete citations. The documents are listed approximately in order from more generic code provisions to more specific guideline documents. A related task – post-earthquake assessment – is supported by a number of documents as well but is outside the scope of this report.

Table 5-1 Selected Technical Resource Material for Seismic Evaluation and Rehabilitation

<table>
<tr><th>Resource Document (with Notes)</th><th>Use for Evaluation</th><th>Use for Rehabilitation</th></tr>
<tr><td>IBC Chapter 34
• Model code chapter for existing structures.
• Includes only triggers; cites other code chapters (or, potentially, other reference standards) for technical provisions.
• Substantial changes expected for 2009 edition.</td><td colspan="2">• 2006 edition triggers evaluation / rehabilitation for certain additions, alterations, and change of occupancy (but not repair).
• 2006 edition cites only IBC Chapter 16 for technical provisions.</td></tr>
<tr><td>IEBC
• Alternative model code for existing buildings.
• Considers “code level” demand and performance levels as well as equivalents in ASCE 31 and ASCE 41.
• Moderate changes expected for 2009 edition.</td><td colspan="2">• Triggers evaluation / rehabilitation for certain additions, alterations, change of occupancy, and repairs.
• Targets certain deficiencies such as URM parapets.
• Cites IBC Chapter 16, ASCE 31, ASCE 41, and IEBC Appendix A as options for technical provisions.</td></tr>
<tr><td>IBC Chapter 16 / ASCE 7, Minimum Design Loads for Buildings and Other Structures
• Model code provisions for new construction.
• Considers only “code level” demand and performance levels.
• Implicitly cited by 2006 IBC Chapter 34.
• Cited by 2006 IEBC as one option, with 75% demand reduction factor allowed in some cases.</td><td>• Appropriate only for basic force-level check or comparison.
• Does not account for obsolete structural systems, configuration, load path, member details, or building materials.</td><td>• Appropriate for the design of full structural systems (new or replacement) within existing buildings.
• Inappropriate for buildings relying on obsolete structural systems, details, or building materials.</td></tr>
<tr><td>ASCE 31, Seismic Evaluation of Existing Buildings
• Considers only the 2/3 Maximum Considered Earthquake (MCE) ground motions.
• Considers only Life Safety and Immediate Occupancy performance.
• Refers to ASCE 41 for inelastic Tier 3 analysis, with 75% demand factor allowed.
• Written in mandatory language.
• Cited by 2006 IEBC as one option.
• Not cited by 2006 IBC Chapter 34.</td><td>• National standard for evaluation (preceded by FEMA 178 and FEMA 310).
• Modifications appropriate for voluntary projects and other work not requiring strict compliance.</td><td>• Appropriate only for “deficiency removal” projects based on ASCE 31 evaluation.</td></tr>
</table>

Table 5-1 Selected Technical Resource Material for Seismic Evaluation and Rehabilitation (continued)

Resource Document (with Notes)	Use for Evaluation	Use for Rehabilitation
ASCE 41, *Seismic Rehabilitation of Existing Buildings* • Considers multiple structural and nonstructural performance levels. • Considers multiple hazard levels, but uses 10%-in-50-year probability of exceedance ground motion as opposed to 2/3 MCE ground motion. • Written in mandatory language. • Cited by 2006 IEBC as one option. • Not cited by 2006 IBC Chapter 34.	• Appropriate for complex evaluations, or as referenced by ASCE 31 Tier 3. • Otherwise more conservative than ASCE 31 due to different acceptance criteria for linear analyses.	• National standard for rehabilitation (preceded by FEMA 273 and FEMA 356). • Modifications appropriate for voluntary projects and other work not requiring strict compliance.
FEMA 154, *Rapid Visual Screening of Buildings for Potential Seismic Hazards* • Considers only normal occupancies. • Not cited by model codes.	• Appropriate for screening or basic ranking only. • Not appropriate for detailed evaluation.	• Not applicable.
HAZUS Software for Earthquake Loss Estimation • FEMA-developed software for loss estimation. • Predicts casualties, property losses, and repair time from generic fragilities. • Not cited by model codes.	• Appropriate for generic loss estimation and comparison of multiple buildings. • Appropriate as supplement to structural evaluation. • Not appropriate for detailed system or element evaluation.	• Sometimes used, but not intended, to set voluntary rehabilitation objective.
ASTM E 2026, *Guide for Estimation of Building Damageability* • Standard for probable maximum loss calculation. • Defines terms only; does not set compliance requirements or provide technical provisions. • Not cited by model codes.	• Appropriate for generic loss estimation and comparison of multiple buildings. • Appropriate as supplement to structural evaluation. • Not appropriate for detailed system or element evaluation.	• Sometimes used, but not intended, to set voluntary rehabilitation objective.

Table 5-1 Selected Technical Resource Material for Seismic Evaluation and Rehabilitation (continued)

Resource Document (with Notes)	Use for Evaluation	Use for Rehabilitation

IEBC Appendix A1-A4
• Largely prescriptive provisions [preceded by UCBC and the *Guidelines for the Seismic Retrofit of Existing Buildings* (GSREB)] for specific structure types,:
  • URM bearing wall
  • Rigid wall – flexible diaphragm
  • Wood-frame cripple wall
  • Soft, weak, open-front wood-frame
• Considers only "code level" performance and Occupancy Categories I and II.
• Considers only "code level" demand, with 75% demand reduction factor allowed.
• Cited by 2006 IEBC as one option.
• Not cited by 2006 IBC Chapter 34.
	• Appropriate and effective for specific building and structure types.
	• Targets specific deficiencies with "risk reduction" objective; less comprehensive than ASCE 31.
		• Appropriate and effective for specific building and structure types.
		• Targets specific deficiencies with "risk reduction" objective; less comprehensive and less conservative than ASCE 41.
		• Modifications appropriate for voluntary projects and other work not requiring strict compliance.

IEBC Appendix A5 • Strain-based analysis procedure for nonductile concrete. • 2006 version appropriate for concrete frames without infill. • Cited by 2006 IEBC as one option. • Not cited by 2006 IBC Chapter 34. • Substantial changes expected for 2009 edition.	• Alternative to ASCE 31 Tier 3.	• Appropriate as supplement to other provisions for existing concrete elements. • Modifications appropriate for voluntary projects and other work not requiring strict compliance.
FEMA 351, *Recommended Seismic Evaluation and Upgrade Criteria for Existing Welded Steel Moment-Frame Buildings* • Probabilistic analysis for pre-1984 Northridge welded steel moment frames. • Considers only Collapse Prevention and Immediate Occupancy performance levels. • Not cited by model codes.	• Appropriate supplement to ASCE 31 with respect to frame connection and column splice deficiencies.	• Appropriate supplement to ASCE 41 with respect to frame connection and column splice design and frame drift.
FEMA 74, *Reducing the Risks of Nonstructural Earthquake Damage - A Practical Guide* • Conceptual techniques for nonstructural component bracing and anchorage.	Not applicable.	• Appropriate as commentary and guidance.
FEMA 547, *Techniques for the Seismic Rehabilitation of Existing Buildings* • Conceptual techniques for addressing common structural deficiencies.	Not applicable.	• Appropriate as commentary and guidance.

Building codes are different from standards. While technical standards contain the detailed provisions for analysis and member acceptability, the triggers in local building codes often determine whether projects get started or progress from evaluation to rehabilitation. As indicated in Table 5-1, however, the leading model building code – the 2006 IBC – does not reference either ASCE 31 or ASCE 41 in its provisions for existing buildings. As a consequence, their usage is restricted because the code does not require or even acknowledge them. The IEBC, a model code developed specifically for existing buildings, does cite ASCE 31 and ASCE 41 as optional references, but the IEBC is a relatively new alternative and is not yet widely adopted.

Structural engineering is formulated differently for the design of new buildings and the designs for rehabilitating existing buildings. The building code for new construction does not serve adequately as a guide for seismic evaluation or rehabilitation, because new designs can reasonably presume certain salient conditions often lacking in existing buildings. Engineering concepts advanced in the technical resource material for existing buildings are not found in the building code for new construction. For example, both ASCE 31 and ASCE 41 dispense with the system R factor that guides many of the pseudo-elastic design provisions for new construction. Instead they identify acceptable levels of inelasticity of individual components. In new construction, building systems will be proportioned and detailed by prescriptive requirements so that system-wide estimates of potential inelastic behavior can be made. This is not the case for many existing buildings.

The standards also distinguish between structural members, otherwise similar, having different post-yield characteristics, something new designs need not consider as carefully. Engineering for new and existing buildings is even less similar in FEMA 351, *Recommended Seismic Evaluation and Upgrade Criteria for Existing Welded Steel Moment-Frame Buildings*, which reports evaluation results in probabilistic terms that more quantifiably represent the gray areas of seismic structural performance.

Evaluation and rehabilitation design are different. While some technical provisions are applicable to either task, the standards suggest correctly that evaluation may be simple or complex, and qualitative or quantitative, but rehabilitation design involves all the steps of any design project, including analysis, member sizing, and detailing – often for both new and existing elements. Thus ASCE 31 and other evaluation tools are not necessarily appropriate as design criteria, and ASCE 41 offers more complexity than many small projects need.

Evaluation and rehabilitation design also differ in terms of appropriate seismic demand levels. ASCE 31 and ASCE 41 reflect an industry consensus (missing from 2006 IBC Chapter 34) that evaluation is appropriately done with lower demands. The difference, while perhaps appropriate, can make it difficult to coordinate the two standards and to apply them beyond their most basic intended uses. As shown in Table 5-1, a 75-percent factor is typically applied to code-level demands, especially for evaluation purposes. The 75-percent factor has both practical and technical roots. Initially, it was applied to "grandfather" existing buildings when code requirements for new buildings were increased in the 1970s. This is the reason for the factor when applied to code-level demands, for example by the IEBC. Technically, the factor also represents an approximate reduction to the mean level of earthquake shaking (as opposed to the mean-plus-one standard deviation) considered appropriate for existing buildings whose remaining useful lifespan is shorter than that of new buildings. The reduction recognizes that while new designs have an inherent conservatism that comes with only marginal increased cost, the same conservatism applied to existing buildings would tag too many of them as deficient and would fail to recognize that existing components are typically stronger than evaluation fairly assumes them to be. This is the reason for the factor when applied, for example, in ASCE 31 Tier 3, and also why the *m* values in ASCE 31 differ from those in ASCE 41 (See FEMA 178 Section 1.3.2 and ASCE 31-03 Section C5.2.1.). Lastly, upgrading buildings to full compliance with the code for new construction is generally an unreasonable public policy (FEMA's "Disaster Assistance Policy 9527.4," Section VII.C.3.a).

Generic codes and standards are not necessarily suitable for all projects. As described in Chapter 1, seismic work is usefully classified as mandated, triggered, or voluntary. Because building codes and standards are generally developed for a range of conditions and are written in mandatory terms, they are most appropriate for triggered projects. In general, however, generic provisions are not sufficient as criteria for mandated projects, which deserve and benefit from criteria specific to the condition being targeted. Since mandated work is generally the product of legislation, it often comes with administrative regulations as well as technical provisions, all of which might be better suited to a jurisdiction's administrative code than to its building code.

Furthermore, the mandatory language of codes and standards is often inappropriate and can be confusing when used for voluntary work. Risk-reduction programs that rely on voluntary work often need clear-cut criteria to establish eligibility for subsidies, fee waivers, or other incentives.

Otherwise, however, the adoption of technical criteria written in mandatory terms can discourage voluntary projects by imposing requirements beyond the stakeholders' schedule, budget, or objective.

Safety is not the only objective. Increasing interest in loss-estimation tools such as HAZUS shows that while codes and standards continue to focus on safety (with the exception of certain "essential" facilities), stakeholders of existing buildings undertake seismic evaluations and rehabilitation as much to address financial losses from possible repairs or business interruption, an observation borne out by practitioners' reports in Chapter 4. Further, institutional and public sector funders (such as FEMA) now routinely require cost/benefit analyses to justify rehabilitation projects. As noted briefly in Chapter 3, local jurisdictions are also thinking about seismic risk reduction in the larger contexts of community preparedness and emergency management.

5.2 Ongoing Model Code Developments

Both the IBC and IEBC will be revised for 2009 editions. As of June 2008, significant revisions regarding seismic evaluation and rehabilitation are expected. If ratified at the Final Action Hearings, the 2009 model codes will reflect the following changes, among others.

- Use of the ASCE 31 and ASCE 41 standards will be allowed for all of the IEBC's compliance methods.
- Compliance with the IEBC will be deemed an acceptable alternative to compliance with IBC Chapter 34. This will allow IBC users to apply the ASCE 31 and ASCE 41 standards *in lieu of* IBC Chapter 16 provisions.
- IBC Chapter 34 will be reorganized for clarity, separating out the provisions for alterations, additions, and repairs.
- Repair-based triggers will be added to IBC Chapter 34 to match the spirit of those in the IEBC.
- IEBC Appendix A5 should be modified so that it no longer applies to nonductile concrete frames with unreinforced masonry infill.

At the February 2008 hearings, three separate ICC committees heard about ninety separate proposals related to existing buildings, over half of which addressed structural topics. About forty proposals were directly related to provisions affecting seismic evaluation or rehabilitation. From the committees' deliberations, the following trends in code development were evident.

- After three full development cycles, there is a growing acceptance of the IEBC and increasing coordination between the IEBC and IBC Chapter

34. Two of the IEBC's three compliance methods already duplicate material in Chapter 34, and the 2009 IBC will endorse the IEBC's third method as a deemed-to-comply alternative. Within one or two more cycles, it is likely that IBC Chapter 34 will be replaced entirely by the IEBC.

- Prescriptive or deficiency-specific provisions such as the seismic rehabilitation sections of IEBC Appendix A are seen as valuable and as models for new chapters. Though they were not approved for 2009, two new appendix chapters were proposed, one for seismic evaluation of nonductile concrete frames with masonry infill, and one for high-wind bracing of vulnerable gable end-walls. Both proposals were disapproved largely because they were new, and full preparation was possibly lacking. With additional vetting and consensus building, it is possible they will be adopted in the next cycle or two, especially if available reference standards do not incorporate them. This is how most of the current IEBC structural provisions, including the Appendix A sections, came into the model code; they were developed first as amendments by major jurisdictions, then they were incorporated into a national model code, and now they are effectively being disseminated back to local jurisdictions through periodic code updates. Whether this development and dissemination process will remain effective, however, will depend on whether ICC committees continue to give as much credence to local adoptions and regulations as they do to national standards committees.
- The ICC committees are trying, mostly with success, to defer to the standards development process. That is, instead of placing more technical provisions in the code itself, ICC prefers to adopt reference standards with minimal modification and to have any new technical provisions developed by standards committees. Partly this reflects a philosophy of code development, but it also reflects a recognition that many technical provisions are too complex for one small ICC committee to evaluate properly.
- The single committee that hears all IEBC proposals will soon need to specialize as the IBC committee structure already has. Specifically, there appears to be growing support for a specialized structural committee to handle all structural topics, whether related to the IBC, the IEBC, or even the *International Residential Code*. Currently, only the IBC has a separate structural committee, and the most effective solution would probably be to convert that IBC committee to a general structural committee.

5.3 Assessment of the Current Standards: ASCE 31 and ASCE 41

While building codes establish legal requirements for engineers and regulators, they no longer contain all the technical resource material or even all the technical evaluation and design criteria that engineers and code officials need. As discussed in Section 5.2, the trend in model code development is to have the code set basic policy but to put as much of the technical content as possible into reference standards. This has not yet been done with respect to seismic evaluation and rehabilitation, but the availability of ASCE 31 and ASCE 41 make it almost a certainty within the next few code cycles.

The question arises as to whether there are technical shortcomings in the current standards that might inhibit their acceptance and use by practicing engineers and regulators. These issues were discussed at the 2007 *NEHRP Workshop on Meeting the Challenges of Existing Buildings* (see *Proceedings*, ATC-71 Report, Part 1).

Over 70 percent of workshop participants – engineers, regulators, researchers, and other stakeholders – said the most progress toward meeting the seismic challenges posed by existing buildings would come from increasing public awareness, mobilizing political will, or demonstrating cost-effectiveness. Only seven percent said improving the standards would be the most valuable contribution. Nonetheless, all of the issues described below were identified as having the highest priority for improving the standards.

5.3.1 Technical Provisions

ASCE 31 and ASCE 41 use some engineering terms and procedures not found in the model building code or ASCE 7 provisions for the design of new structures. At the 2007 NEHRP Workshop, participants called for better explanation of these ideas and their intended effects. They specifically wanted more information about where these provisions came from and how they were derived from research or other sources. Nevertheless, while improvements to detailed provisions were highly ranked, they were considered within the scope of the ASCE standards update process. They deserve attention in the next edition of the standards, but the consensus of participants is that there is little FEMA can do to move them forward, short of supporting the largely analytical research that would lead to clarifications or revisions.

Among the detailed provisions cited by workshop participants are the following, none of which is commonly used in building-code-based designs of new structures:

- classification of primary and secondary components,
- classification of force-controlled and deformation-controlled actions,
- foundation-soil interface modeling and soil-structure interaction,
- target displacement determination,
- force-delivery reduction factor J,
- m values for new (i.e., added) and existing components,
- overturning factor R_{OT}, and
- material testing requirements and knowledge factor, κ.

Most of these concepts are no more arbitrary than the building code parameters that engineers and code officials are familiar with (such as R, system height limits, irregularity definitions, redundancy factors, or cutoffs for seismic design categories). In many cases they can be more rational. But they are still untested by damaging earthquakes, they are unfamiliar to engineers not designing rehabilitations, and they can lead to the abandonment of an existing building rather than the determination of what needs to be built new.

For a new building, the designer has little choice but to follow the established building code, and if the next edition requires a little more concrete or plywood, it is generally a marginal cost. But for an existing building, a standard that identifies an existing condition as deficient carries with it a specific technical judgment, a property condemnation, potential liability, and a host of "What do we do now?" questions for multiple stakeholders. Thus, even as engineers are coming to understand that building codes for new construction do not apply to the rehabilitation of existing buildings, they correctly recognize that the ASCE standards need substantiation by robust research results and calibration against observed fragility data.

5.3.2 Validation: Calibrating the Procedures

Improved global damage prediction. ASCE 31 and ASCE 41 offer acceptability criteria for different structural component types. The criteria, based largely on laboratory testing, are *de facto* damage predictors. The correlation, however, between the implied damage and actual damage observed after earthquakes is not well established. Actual buildings seem to have a toughness that is not captured by the standards' acceptability criteria.

This may be because the standards' criteria are too conservative, because the deterministic criteria do not represent full fragility curves. Better documentation of the correlation between actual damage patterns and the standards' criteria will improve practitioners' confidence in the standards.

Case studies to correlate seismic design with actual damage. Validation of the ASCE 31 and ASCE 41 technical criteria is essential to the ongoing development of the standards. Yet the earthquake engineering community still lacks a full complement of realistic case study analyses and rehabilitation designs, consistently performed and documented. Also lacking are case study analyses of realistic buildings comparing performance before and after rehabilitation.

Comprehensive and systematic collection of damage and loss data. Actual damage and loss data are essential to the development of technical standards like ASCE 31 and ASCE 41, as well as standards and guidelines for loss estimation, cost/benefit analysis, risk management, and public policy development. The earthquake engineering community, however, still lacks consistent documentation of past damage and lacks protocols for the systematic collection of future damage.

As new tools are developed to make more comprehensive performance predictions and risk assessments, substantiated fragility curves based on robust data will become indispensable. The FEMA-funded ATC-58 project, under which ATC is developing next-generation performance-based seismic design guidelines for new and existing buildings, is the current effort most directly related to performance prediction. The ATC-58 methodology will relate decision-making to probabilistic measures of damage, which are functions of structural response, ground motion, and component fragilities. The approach is feasible and rational, but the validity of any result is dependent on the reliability of the fragility relationships, which cannot be created or confirmed without careful and thorough data collection and maintenance.

5.3.3 Accuracy: Getting the Right Answer

Consideration of global performance. The earthquake performance of a structure is generally a function of more than any single component. ASCE 41 measures acceptability at the component level and does not explicitly consider the response of the structural system as a whole. Classification of certain elements as secondary does allow for relaxed acceptability criteria in some cases, but does not account for global behavior in a fully rational way.

Consistency in seismic evaluation results. Widespread acceptance of ASCE 31 requires confidence that it yields not only correct findings, but also reproducible findings. The current experience of engineers using the standards is that two evaluators frequently do not reach the same conclusions on some issues critical to building performance. This might be due, for example, to technical complexity, a lack of procedural clarity, differences in the skill or judgment of evaluators, or uncertainty inherent in the evaluation process.

A related issue involves the consistency between ASCE 31 and ASCE 41. If ASCE 41 is specified by a code or policy as the standard for rehabilitation, it should perhaps also be usable as an evaluation document to determine project scope, yet it is not fully coordinated with ASCE 31. Indeed, ASCE 41 is intentionally more conservative than ASCE 31. This reflects the philosophy that when rehabilitation is done for safety reasons, the rehabilitated building should provide comparable safety to that of a new building. To evaluate an existing building to that standard, however, may result in its being found deficient due to mere noncompliance with current code. The philosophy of evaluating existing construction differently from designing rehabilitation is rational, but presumes certain policy preferences that are not transparent to the user. It also presents a practical hurdle by forcing the engineer to shift criteria when moving from the evaluation phase to the rehabilitation design phase for the same building.

Possible over-conservatism of ASCE 31. Many engineers feel that strict application of ASCE 31 results in too many buildings being found deficient, especially when only Tier 1 or Tier 2 procedures are applied. If true, such over-conservatism could lead to rejection of the standard or to misapplication of rehabilitation funds. Some conservatism in an evaluation standard is necessary to avoid an unacceptable rate of false negatives. Nevertheless, over-conservatism might be due, for example, to a lack of data to support acceptability criteria, to the use of high-confidence (as opposed to mean) test data, or to conservative judgment applied by the evaluator.

Of particular concern is the impression that relatively new buildings might fail an ASCE 31 evaluation. ASCE 31-03 section 3.2 exempts newer buildings based on benchmark provisions, but those exemptions might need further calibration to improve reliability and should be demonstrable by application of the methodology.

Possible over-conservatism of ASCE 41. Many engineers feel that strict application of ASCE 41 too often leads to expensive and unnecessary rehabilitation measures. If true, such over-conservatism could lead to rejection of the standard or to decisions to avoid rehabilitation. Development of ASCE 41 Supplement 1 showed that some conservatism was due largely to the lack of relevant data to support acceptability criteria. Over-conservatism might also be due, for example, to the standard's focus on individual components (as opposed to system behavior), to overly rigid acceptability criteria, or to an accumulation of nominally conservative provisions and procedures.

5.3.4 Timeliness: Incorporating New Information

Transferring research into practice. While new research on existing buildings and seismic rehabilitation continues, new and past research findings are not generally presented or compiled in formats that facilitate incorporation into ASCE 31 and ASCE 41. The development of ASCE 41 Supplement 1 is a notable exception.

Evaluation and rating process for new technical information. Because seismic rehabilitation often takes advantage of new technologies (including new information about material or component behavior), a rehabilitation standard such as ASCE 41 must be able to accommodate alternative design criteria. While ASCE 41, Section 1.2, does allow for alternative criteria at the discretion of the code official, neither guidance nor incentive for discretionary approval is provided, and the process often becomes cost-prohibitive. Application thus differs between jurisdictions. Further, industry organizations that typically develop design data for new construction have not made the same commitment to existing building applications.

Coordination with other efforts. As of mid-2008, ASCE has not yet scheduled the next update cycle for either ASCE 31 or ASCE 41. Meanwhile, efforts by other organizations are leading to new ideas, findings, and technologies. These efforts will be most effective if they coordinate with the now standard methods of ASCE 31 and ASCE 41. By the same token, however, the standards must be ready to incorporate or acknowledge related material.

With respect to specific retrofit technologies, private sector vendors, often in concert with service-to-industry research, are constantly developing new products and materials. The range of their efforts, which cover everything from museum wax (which helps keep fragile items from sliding off shelves) to active-control and seismic isolation systems, is beyond the scope of this report. For the most part, however, the vendors respond through the marketplace to the provisions of standards and model codes. Broader philosophical developments, however, lead the next generation resource documents and should be tracked by the standards committees. Examples of these developments include:

- **Increasing use of probabilistic methods and terminology.** The latest methods in performance-based engineering do not reach pass/fail findings but instead provide the probability of performance at a given level. FEMA 351, *Recommended Seismic Evaluation and Upgrade Criteria for Existing Welded Steel Moment-Frame Buildings*, an evaluation guideline for pre-1984-Northridge welded steel moment frames, is an example.

- **Performance levels.** New methods deemphasize the traditional Life Safety performance level and focus instead on Collapse Prevention and Immediate Occupancy as better defined and more appropriately related to the mapped seismic demand levels. FEMA 351, for example, does not support a Life Safety evaluation. ASCE 31, by contrast, does not support Collapse Prevention evaluation. Resolving this disconnect will be essential in coordinating new technologies with existing codes, regulations, and institutional policies.

- **Building-material-specific or system-specific evaluation and design procedures.** In addition to the previously cited FEMA 351, recent work on steel braced frames, wood-frame construction, and concrete frames with masonry infill is likely to lead to tentative or proposed evaluation criteria. Maintenance of the standards is necessary to encourage consistency between these new ideas, the standards, and the model codes.

  – FEMA 547 *Techniques for the Seismic Rehabilitation of Existing Buildings*, is the latest resource on seismic rehabilitation techniques. Though it is not a design guide, its purpose is to share with the engineering community those approaches found to have been effective and practical. FEMA 74 *Reducing the Risks of Nonstructural Earthquake Damage - A Practical Guide*, offers similar tips for nonstructural improvements. ASCE 41 should be reviewed, at least to be sure that it accommodates the techniques in these two manuals.

  – The National Science Foundation (NSF) is funding a five-year, Network for Earthquake Engineering Simulation (NEES) Grand Challenge project to study nonductile concrete buildings. The Concrete Coalition, a project sponsored by the Earthquake Engineering Research Institute with initial phase funding from the California Governor’s Office of Emergency Services, will be working with local jurisdictions and stakeholder groups to implement research findings.

- The Structural Engineers Association of California has developed a strain-based methodology for masonry-infilled concrete frames, citing inadequacies in the ASCE 41 concrete provisions.
- ACI and ASCE have signed a Memorandum of Understanding to work together in developing new material for standards. ACI is planning to develop a rehabilitation code that will focus largely on repairs but is expected to have a component on earthquake damage that could be extended into guidelines on pre-earthquake improvements. ACI's Committee 369 on seismic rehabilitation expects to develop commentary and proposed revisions for a future edition of ASCE 41 by compiling and reviewing existing or in-progress research findings.
- AISC has no specific plans to produce new technical resources devoted to seismic rehabilitation but does support existing building work by maintaining specifications and data for outdated structural shapes. AISC publishes this data with its history in *Design Guide 15*, a technical resource that does not appear to be referenced directly by the current versions of either ASCE 31 or ASCE 41.
- The Masonry Standards Joint Committee has no specific plans to produce new technical resource material devoted to seismic rehabilitation but has begun work on a pre-standard for displacement-based design that could apply to existing structures.
- APA-The Engineered Wood Association, which develops product standards in coordination with model code provisions for new construction, does not have a coordinated program to address existing building issues. Vendors such as Simpson Strong-Tie and Hardy Frames tend to fill the gap with respect to technical resources to supplement building codes.

* **Nonlinear analysis.** New computing tools are focusing on displacement-based analysis and could make linear analysis with *m* factors obsolete. Other research is refining (and critiquing) the modeling of the typical force-deformation relationships assumed by ASCE 41. (Meanwhile, practicing engineers are not necessarily prepared for this analytical sophistication, some of which is not always needed; see Section 5.3.7.)
* **Evaluation tools incorporating expertise outside structural engineering.** As noted in Section 5.3.5, stakeholders in the seismic performance of existing buildings are increasingly seeking performance

measures related to risk management and loss estimation. Their interests look beyond the basic questions answered by traditional structural engineering. Standards for seismic evaluation and rehabilitation should evolve to support those needs.

5.3.5 *Value to Stakeholders: Translating Findings into Non-Engineering Terms*

Development of a uniformly acceptable, standard rating system for building performance. ASCE 31 and ASCE 41 will be more widely used if their implied performance predictions are presented in a format that allows relatively simple comparison of the risks posed by different buildings or by the same building before and after rehabilitation. Many in the earthquake engineering community feel this would be achieved if a uniform rating system based on ASCE 31 and ASCE 41 were developed.

In practice, however, every different rating *program* calls for a different rating *system*. That is, a system that works to produce mandated ratings might not be effective for self-declared voluntary ratings. A system designed to summarize engineering findings might not communicate usefully to the public at large. One focused on safety might be of little use to property buyers and sellers. Advocates of a uniform system therefore need to give some attention to the program they have in mind: Will it be mandatory or voluntary? Who will produce and maintain the ratings? Will the ratings be public or private? Clearly, the call for a single rating system is fraught with logistical problems. Further, there is scant evidence that poor ratings motivate seismic risk reduction. The California Seismic Safety Commission, which has monitored local jurisdictions' efforts to reduce risks from URM buildings, has found that placard programs (in which URM buildings are merely posted with warning signs) do not reduce risk. On the contrary, one could argue that posting a warning transfers responsibility from an owner to tenants and guests.

Still, the availability of a standard suggests that the current situation might be improved. Currently, every evaluation procedure – from ASCE 31, to the building code, to a Probable Maximum Loss analysis – represents a potential rating system. If these could be brought under a single umbrella, so that the findings from any evaluation could be translated into common terminology, that would indeed be valuable. The Structural Engineers Association of Northern California has proposed a system along these lines, geared toward a voluntary program in which ratings are produced in the course of a real estate transaction. A paper describing the effort was presented at the Structural

Engineers Association of California (SEAOC) Convention in September 2008.

Development of a realistic and valid methodology for cost/benefit analysis. ASCE 31 and ASCE 41 will be more widely used and understood when non-engineers have tools with which to assess the costs and benefits of seismic rehabilitation. Currently, however, the ASCE standards do not directly support and do not interface with other guidelines for performing cost/benefit studies, most of which require an estimate of damage, repair cost, functional loss, and repair duration.

This is a pivotal issue, because the decision to reduce earthquake risk – or to mandate or trigger its reduction – is more and more based on financial measures. FEMA requires a cost/benefit analysis in mitigation grant proposals, legislative bodies are pressed to do more with limited budgets, and individual owners (and their lenders) seek return on investment for any capital outlay. Model code retrofit triggers for flood hazards are already based on repair or alteration cost as a percentage of replacement cost. It is possible that seismic rehabilitation triggers will move in that direction as well.

New technologies are responding to these needs, and the evaluation and design standards will have to change to keep pace. HAZUS, the federally funded loss-estimation software, is already being used by local jurisdictions to understand community risk and by California's Office of Statewide Healthcare Planning and Development as a supplement to ASCE 31 and FEMA 356 assessments of hospitals. As noted above, ATC-58 is the ambitious developing technology for performance prediction. It is probabilistic and multi-dimensional, paying as much attention to damage, repair cost, and recovery time as it does to safety risk. ATC-58's success will depend heavily on the reliability of fragility functions (as discussed above) and on the results of structural analysis relating ground motion to building response. The analysis provisions in ASCE 31 and ASCE 41 will need to reach findings that the ATC-58 methodology can use.

Coordination with response and recovery planning. In a feasible emergency management plan, mitigation is linked to response and recovery. For example, a community (i.e., a *resilient* community) might plan to respond to, and recover from, any potential losses that it has not mitigated in advance. By the same token, if a community lacks the resources to follow a plan to respond and recover, it should be taking every opportunity to mitigate before an earthquake or other emergency occurs. As communities recognize this linkage as a rationale for mitigation planning (which could include mandates, triggers, and incentives for voluntary work), they may no longer seek evaluations that merely predict immediate performance – how many deaths, for example, or how much property damage. Rather, their questions could be: How long will it take to recover? How many shelter beds will be needed? How many jobs will be affected? If the current standards are to be useful in this context, some effort will be needed to translate ASCE 31 findings into these terms, and to pick appropriate performance objectives so that rehabilitation can be done not only for safety, but for resilience.

5.3.6 Usefulness: Application to Common and Typical Conditions

Development of simplified procedures. The same attributes that make ASCE 31 and ASCE 41 comprehensive standards suitable for any structure also make them unnecessarily complex for the simpler structures that comprise a sizable portion of the existing building stock nationwide. This complexity increases the cost of evaluation and design, discouraging rehabilitation, and might even result in errors. For example, ASCE 31 should not be necessary to identify an obvious soft-story condition, nor should ASCE 41 be necessary for the design of roof-to-wall anchors for a typical tilt-up warehouse.

Any of three sets of modified criteria would encourage and facilitate application of the standard: (1) subsets of the general criteria tailored to specific model building types such as those considered in ASCE 31; (2) simplified criteria appropriate to buildings that meet specific eligibility requirements or have a limited set of deficiencies identified by ASCE 31; or (3) prescriptive rehabilitation measures requiring no quantitative analysis or design, perhaps tied to specific deficiencies identified by ASCE 31.

Each of these approaches is represented by other rehabilitation codes or guidelines, such as Appendix A of the *International Existing Building Code*, discussed in section 5.2, or locally adopted chapters of the *City of Los Angeles Building Code*. A systematic comparison of ASCE 31 and ASCE 41 with IEBC Appendix A, FEMA 351, and other guidelines would be a valuable contribution.

5.3.7 Access: Usability by Engineers and Code Officials

Development of nonlinear analysis modeling guidelines. ASCE 31 and ASCE 41 allow (and often require) nonlinear procedures but provide little guidance as to why or how. Reluctance to use the nonlinear procedures, or incorrect application, can lead to unreliable findings or ineffective or wasteful recommendations.

New computing tools allow more engineers to use nonlinear analysis, but it is unclear whether the engineers (and the regulators who provide design quality assurance) are receiving adequate training and support. Software vendors do provide some training, but their expertise is in the “how,” not the “what.” Effective nonlinear analysis requires an understanding of structural component behavior in the inelastic range, differences between force-based and displacement-based design, and principles of capacity design.

Ground motion selection. Where the standards require or encourage response history analysis, selection of a suite of ground motion becomes a critical early step. This remains a subject outside most structural engineers’ expertise. Consensus guidance would be helpful on such topics as record selection, record scaling, separating and combining components, appropriate loading directions, and fault normal and fault parallel effects.

The standards also need to keep pace with developments in seismicity in general. One example of new work not referenced by ASCE 31 and ASCE 41 is the Next Generation Attenuation of Ground Motions project led by the Pacific Earthquake Engineering Research Center (PEER).

5.4 Recommendations

From the discussion of technical resources currently available for evaluation and rehabilitation standards, and as described in the introduction to this chapter, two themes emerge:

1. Despite the availability of resource material targeted to existing buildings, building codes continue to trigger and regulate seismic work with reference to provisions for new construction, which are inappropriate.
2. A growing interest in seismic performance beyond mere safety — including damage control, business continuity, and community resilience — is not yet well-served by the available resource material.

The first theme points to the need to continue developing the current standards, tightening their provisions, filling in their holes, and supporting their use by engineers and their acceptance by regulators, principally by recognizing them in model codes. The second identifies value in enhancing the standards’ effectiveness by aligning their scope and terminology with the interests of a broader stakeholder community including owners, tenants, lenders, insurers, risk managers, and public policy makers. Both needs call for broad strategic plans, as opposed to modest tweaks or pre-determined fixes.

This was the consensus of the technical community at the 2007 *NEHRP Workshop on Meeting the Challenges of Existing Buildings* (see *Proceedings*, ATC-71 Report, Part 1). Clearly there are many specific technical improvements to be made through the ASCE standards process in an incremental fashion. Outside of that process, and consistent with the breadth of issues discussed in this report, the following six efforts are recommended, each intended to address multiple key issues with work of substantial long-term value.

1. Collect and Organize Fragility Data

A systematic effort to collect earthquake response data — both past and future — would enhance the reliability and acceptance of the current standards, and extend their application to a wider set of conditions. It would provide a basis for validating and synchronizing results of recent testing at the new state-of-the-art laboratories. Perhaps most important, it would fill critical holes in the ambitious theoretical models being developed to predict losses in the terms most meaningful to decision-makers and risk-owners. The emerging NEHRP Postearthquake Information Management System (PIMS) project may serve as a framework for the construction of such a database.

2. Develop Cost/Benefit Methodologies

The ASCE standards incorporate the latest techniques in structural engineering, but their results are not directly usable by non-engineer decision-makers. Consensus methodologies for translating engineering findings into other terms will support the efforts of stakeholders trying to estimate repair costs, calculate return on investment, plan for emergency response and recovery, rank risk reduction, or design regulatory policy.

3. Produce Focused Case Studies

A suite of case studies of real (or realistic) existing buildings would: (1) identify shortcomings in the current standards; (2) provide a basis for comparing alternative or simplified analytical procedures; (3) provide a basis for comparing or demonstrating rehabilitation technologies; (4) generate consistent information for the ASCE standards committees; and (5) generate consistent information for non-engineering studies, including policy development.

While case-study results will be valuable, simply defining and documenting a set of case-study buildings will be an important contribution. Because existing buildings present a wide range of technical, economic, and regulatory constraints (much more so than new construction), case studies of past projects in the literature do not provide a useful basis for evaluating new analysis techniques or rehabilitation technologies. What is needed is a set of well-defined buildings usable by multiple parties over time.

In addition to defining the structure, architecture, and nonstructural components, it will also be important to define a study matrix of the non-technical attributes that often affect rehabilitation, such as historic status, occupancy, valuation, access compliance, fire safety, quality of materials and construction. This will facilitate studies of costs and regulatory policies vital to earthquake risk management. The broader the matrix, the more useful the case study can be. By including input from contractors on cost and scheduling, valuable insights can be achieved. Building inspectors, tenants, owners, as well as design professionals, can significantly enhance our understanding of rehabilitation.

4. Move Research Results into Practice

New and continuing research is important. Equally important is the compilation, interpretation, and translation of existing research results into practical tools that fit with the ASCE standards.

A model for this work is offered by the recent process used to produce Supplement 1 to ASCE 41, in which a joint committee of researchers and practitioners updated acceptability criteria for concrete elements based on several recent research programs.

5. Produce Application Examples

ASCE standards for seismic evaluation and rehabilitation are increasingly used and accepted, but they are still not familiar to many members of the community of engineers and code officials. Example manuals would introduce concepts and terminology found in the standards but not in the building code for new construction. Brief examples, supplementing commentary in the current standards, might demonstrate and discuss more specifically: (1) ASCE 31 evaluation procedures and criteria; (2) ASCE 41 analysis procedures and design criteria; and (3) nonlinear modeling and analysis of new and existing elements.

6. Establish Relationships Between Component Response and System Performance

Current standards measure acceptability on a component basis and make no distinction between a building with 5% of its components failing the criteria and a building with 50% failing. Further, research should help practitioners reconcile perceived inconsistencies between failure on the component level and acceptable performance on a system level.

Chapter 6
Summary and Discussion

Since 1984, FEMA's Existing Buildings Program has driven the development of technical and nontechnical resource documents to permit a sound engineering basis for evaluating the seismic vulnerability of existing buildings and to rehabilitate these buildings to reduce potential earthquake losses. The program has fostered the development of the national standards ASCE 31, *Seismic Evaluation of Existing Buildings*, and ASCE 41, *Seismic Rehabilitation of Existing Buildings*. At the present, these technical engineering improvements have just begun to make their way into the regulations and policies that establish when seismic evaluations and rehabilitations are done.

How effectively will they replace the current technical resource material used to address existing buildings? Do the engineering and regulatory communities see the documents as flawed? What role should the Existing Buildings Program play in regard to the improvement of these reference standards? Are there higher priorities for improving the effectiveness of the Existing Buildings Program to facilitate a significant increase in the identification and mitigation of at-risk buildings? To answer these questions, the project team has sought to develop a broad understanding of the regulatory, practitioner and building owner perspectives on the current treatment of existing buildings. From this effort, several important features were identified.

6.1 Current Levels and Range of Existing Building Treatment

The following considerations play a significant role in the treatment of existing buildings today.

Mandated, triggered, and voluntary rehabilitation. There are three ways in which the seismic evaluation and rehabilitation of existing buildings are initiated. Efforts are mandated, triggered, or voluntarily undertaken. Mandated work is generally established by state or jurisdictional authority to address a specific vulnerability and the legislative mandate identifies the technical evaluation and rehabilitation criteria to be used. There are very few mandatory retrofit ordinances in place throughout the United States and those that are do not reference ASCE 31 or ASCE 41. Because of the comprehensive nature of the ASCE 31 and 41 standards, they are not well formatted for incorporation into specifically focused mandatory programs.

A larger portion of seismic evaluation and rehabilitation work (according to practitioners) is initiated as a consequence of being triggered by the scope or nature of other proposed building modifications. At present, only in a very limited number of instances are the ASCE 31 and 41 standards identified to be used for the evaluation and scope of the triggered rehabilitation. This, however, can be expected to change as model codes are cyclically modified to incorporate updated and improved technical references. This is the most likely path for the broader dissemination of the ASCE 31 and 41 standards into practice.

Voluntary work is the third means by which existing buildings are seismically evaluated or rehabilitated. At present, it is unclear how much voluntary work is being done using the ASCE 31 and 41 standards, but some significant impediments to their use for this purpose are known to exist.

- Voluntary work is frequently undertaken to reduce future earthquake losses. These losses are determined by loss estimation methodologies that do not share an interface with the nomenclature and methodology of ASCE 31 and 41. Both dollar losses and downtime estimates are not accessible from ASCE 31 and 41 applications.
- The mandatory language of the standards may require more work than is affordable thereby stalling any rehabilitation improvements.
- Bracing and anchorage of architectural features, and of equipment for other components, to reduce future losses, may require more expensive and time-consuming engineering efforts, using these comprehensive standards, than is cost-effective.

Regional variation. Significant regional variations exist in the treatment of existing buildings and seismic vulnerability. In those areas of the country that have experienced significant damaging earthquakes within the last 100 years (the west coast and the inter-mountain west), mandatory, triggered and voluntary rehabilitation work is actively underway. Knowledge of available technical resources is high and communities have developed legislative mandates to address vulnerabilities. In other regions of the country where damaging earthquakes are a more distant memory (the midwest and the east coast) there is considerably less seismic evaluation and rehabilitation being done. There are no reported mandatory programs and triggered work is reported to be a negotiation process between owners and regulators. Voluntary work is rare and is driven by owner concerns of business disruption. In these regions of the country, there is generally very little experience with ASCE 31 and 41.

Building regulations and enforcement. Building regulations are generally established by state authorities with local (municipal and county) responsibility for enforcement. State authorities generally adopt model codes, which in turn are incorporating reference standards developed through a consensus process that includes the participation of knowledgeable technical experts. Local jurisdictions exhibit considerable variation in their degree of enforcement of building regulations. Larger jurisdictions generally provide more active review, while smaller jurisdictions provide less.

Green building movement. Currently, the most active area of building regulation change is the attempt to create more sustainable, energy-efficient construction. As a consequence of many factors, including the remarkably successful voluntary Leadership in Energy and Environmental Design (LEED) rating system, federal, state and local jurisdictions have mandated numerous regulations to improve (i.e., decrease) the energy consumption of the building process and the buildings themselves. Extending the useful life of the existing building stock clearly presents a significant opportunity to align seismic vulnerability and loss-reduction rehabilitation with the most actively advocated process of building regulation change today.

6.2 Opinions and Priorities of Practitioners, Regulators, and Owners

From interviews, focused workshop breakout discussions, and the polling of workshop participants, the following points reflect what is needed to overcome the most significant impediments to more widespread mitigation of future earthquake losses through building rehabilitation:

- Available financial data for seismic vulnerability and rehabilitation assessments, which can engage market forces in a voluntary decision making process, are needed.
- An understanding of seismic vulnerability in today’s building stock among the public, politicians and building owners is needed.
- Technical improvements to the ASCE 31 and 41 documents are needed and are important, although, as a practical matter, they are unlikely to increase significantly the identification of vulnerable existing buildings and their seismic rehabilitation.
- The language used to communicate seismic performance does not facilitate an actionable understanding among stakeholders.

- Expanded education among engineers and regulators in the less active seismic areas of the country is urgently needed to improve familiarity with the concepts and application of ASCE 31 and 41 to facilitate more widespread acceptance and integration into practice.
- For practitioners in areas of low to moderate seismicity who infrequently address seismic issues, the complexity of the ASCE 41 comprehensive structure is daunting. Greater simplification through prescriptive models for common building types or load-path requirements would significantly improve potential use.
- A focused program of research is needed to provide a better understanding of the extreme performance limits of building components, and the relationship between component fragility and global structural performance.
- With the release of ASCE 31 and 41, the ASCE standards update process should permit the introduction of incremental changes to the documents to improve understanding and application of numerous concepts, such as primary and secondary components, force and deformation controlled components, and the force-delivery reduction factor, *J*. The technical community expressed the belief that engineering organizations, researchers, and other industry participants can effectively work as they do in the ICC and ASCE 7 arena to make incremental improvements to the standards. Significant improvements, such as the ASCE 41 Supplement 1 effort, can best be accomplished if initiated and supported by the NEHRP agencies. Such focused efforts to integrate research and practice to address specific shortcomings in the standards is an exceptionally effective way to facilitate improvements.

6.3 Strategies for the Existing Buildings Program

To focus the Existing Buildings Program at targets likely to bring about the most significant increases in the identification and seismic rehabilitation of vulnerable existing construction, actions should be ranked according to the findings articulated in the preceding sections. Table 6-1 suggests a format for ranking tasks as to the potential for their success. The table reflects the nature of how evaluation and rehabilitation is initiated and the regional awareness or interest in seismic risk

Table 6-1 reflects the basic understanding that from west to east, interest in reducing seismic risk diminishes. Additionally, it recognizes that mandatory processes of initiation historically have required a unique combination of circumstances to be successful (primarily the occurrence of a significant damaging earthquake). Triggered work, however, is generally more common, and modifications to current procedures can be made through the model code development process. Lastly, voluntary methods that address the needs of owners face less regulatory resistance, although these approaches require “selling” to gain acceptance, not public policy change. Table 6-1 does not consider the number of potentially vulnerable buildings that could be affected.

Table 6-1 Potential for Success for Programs to Reduce Seismic Risk

Method of Initiation	Region		
	West	Midwest	East
Mandatory	Medium	Low	Very Low
Triggered	Good	Medium	Medium
Voluntary	Excellent	Good	Low

The suggested actions identified in Chapters 3, 4, and 5 can be evaluated using Table 6-1 to assign priorities for implementation. For example, a recommendation that occurs (or is implied) in multiple chapters is the development of a building rating system to communicate risk and stimulate voluntary rehabilitation. The table suggests that such a plan (if successfully accomplished) could potentially achieve greater success than a plan relying on building code provisions, whether triggered or mandatory. In general, plans or programs that rely on voluntary evaluations and rehabilitations have the greatest potential if they are effective in communicating seismic risk in market terms.

The programs with the next highest potential for success are those that are triggered by building regulations. An example for consideration in this category is the introduction of incremental rehabilitation to improve seismic performance as thresholds of remodeling work are planned to be reached.

In a similar fashion, actions that are targeted at the West are more likely to receive attention than those targeted at the East. Due to the significant regional differences in building stock, and in engineering experience in earthquake rehabilitations, it may be necessary to develop modules specifically tailored to each region to improve overall effectiveness for a given action item.

The numerous impediments and recommendations contained in this report, in conjunction with the 2007 *NEHRP Workshop on Meeting the Challenges of Existing Buildings*, can be evaluated and ranked, recognizing regional variations and regulatory processes, to develop actions for the Existing Buildings Program to follow that maximize the potential for effectiveness. With the partnering of NEHRP agencies, professional and standards organizations such as ASCE and NCSEA, and the research community actively engaged in the updating of the ASCE 31 and 41 standards, the timing for the Existing Buildings Program to develop new products and move in new directions has arrived.

Appendix A
Resource Documents for Existing Buildings

A.1 FEMA Reports with Socio-Economic and Historic Context

FEMA 90, 1985. *An Action Plan for Reducing Earthquake Hazards of Existing Building,* prepared by the ABE Joint Venture, a partnership of the Applied Technology Council, the Building Seismic Safety Council, and the Earthquake Engineering Research Institute, for the Federal Emergency Management Agency, Washington, DC.

FEMA 174, 1989. *Establishing Programs and Priorities for the Seismic Rehabilitation of Buildings: A Handbook*, prepared by Building Systems Development, Inc. for the Federal Emergency Management Agency, Washington, DC.

FEMA 198, 1990. *Financial Incentives for Seismic Rehabilitation of Hazardous Buildings – An Agenda for Action, Volume 1: Findings, Conclusions, and Recommendations,* prepared by Building Technology, Inc. for the Federal Emergency Management Agency, Washington, DC.

FEMA 199, 1990. *Financial Incentives for Seismic Rehabilitation of Hazardous Buildings – An Agenda for Action, Volume 2: State and Local Case Studies and Recommendations,* prepared by Building Technology, Inc. for the Federal Emergency Management Agency, Washington, DC.

FEMA 216, 1991. *Financial Incentives for Seismic Rehabilitation of Hazardous Buildings – An Agenda for Action, Volume 3: Applications Workshop Report,* prepared by Building Technology, Inc. for the Federal Emergency Management Agency, Washington, DC.

FEMA 227, 1992. *A Benefit-Cost Model for the Seismic Rehabilitation of Buildings, Volume 1: A User's Manual*, prepared by VSP Associates for the Federal Emergency Management Agency, Washington, DC.

FEMA 228, 1992. *A Benefit-Cost Model for the Seismic Rehabilitation of Buildings, Volume 2: Supporting Documentation,* prepared by VSP

Associates for the Federal Emergency Management Agency, Washington, DC.

FEMA 237, 1992. *Seismic Rehabilitation of Buildings – Phase I: Issues Identification and Resolution*, prepared by the Applied Technology Council for the Federal Emergency Management Agency, Washington, DC.

FEMA 254, 1994. *Seismic Retrofit Incentive Programs: A Handbook for Local Governments,* prepared by the Bay Area regional Earthquake Preparedness Project and the California Seismic Safety Commission, published by the Federal Emergency Management Agency, Washington, DC.

FEMA 261, 1995. *An Integrated Approach to Natural Hazard Risk Mitigation*, prepared by the Building Seismic Safety Commission for the Federal Emergency Management Agency, Washington, DC.

FEMA 275, 1997. *Planning for Seismic Rehabilitation: Societal Issues,* prepared by the Building Seismic Safety Council for the Federal Emergency Management Agency, Washington, DC.

FEMA 313, 1998. *Promoting the Adoption and Enforcement of Seismic Building Codes: A Guidebook for State Earthquake and Mitigation Managers,* prepared by the Department of Urban and Regional Planning, University of Illinois at Urbana – Champaign, for the Federal Emergency Management Agency, Washington, DC.

FEMA 315, 1998. *Seismic Rehabilitation of Buildings: Strategic Plan 2005,* prepared by the Earthquake Engineering Research Institute for the Federal Emergency Management Agency, Washington, DC.

FEMA 383, 2003. *Expanding and Using Knowledge to Reduce Earthquake Losses: The National Earthquake Hazards Reduction Program Strategic Plan 2001-2005,* prepared by the National Earthquake Hazards Reduction Program agencies, published by the Federal Emergency Management Agency, Washington, DC.

FEMA 389, 2004. *Primer for Design Professionals, Communicating with Owners and Managers of New Buildings on Earthquake Risk*, prepared by the Applied Technology Council for the Federal Emergency Management Agency, Washington, DC.

FEMA 445, 2006. *Next-Generation Performance-Based Seismic Design Guidelines: Program Plan for New and Existing Buildings*, prepared by the Applied Technology Council for the Federal Emergency Management Agency, Washington, DC.

A.2 Current Technical Resource Material

A.2.1 Guidelines and Standards for the Pre-Earthquake Assessment of Performance

In addition to the documents listed here, some of the rehabilitation resources listed in Section A.2.2 are also used for evaluation. Some of the policy documents listed in Section A.2.4 include quantitative criteria as well.

ASCE 31, 2003. *Seismic Evaluation of Existing Buildings* (ASCE/SEI 31-03), American Society of Civil Engineers, Reston Virginia.

ASTM E2026-07, 2007. *Standard Guide for Seismic Risk Assessment of Buildings*, ASTM International, West Conshohocken, Pennsylvania, www.astm.org.

ASTM E2557-07, 2007. *Standard Practice for Probable Maximum Loss (PML) Evaluations for Earthquake Due-Diligence Assessments*, ASTM International, West Conshohocken, Pennsylvania, www.astm.org.

ATC-13, 1985. *Earthquake Damage Evaluation Data for California*, Applied Technology Council, Redwood City, California.

ATC-13-1, 2001. *Commentary on the use of ATC-13 Earthquake Damage Evaluation Data for Probable Maximum Loss Studies of California Buildings*, Applied Technology Council, Redwood City, California.

ATC-40, 1996. *Seismic Evaluation and Retrofit of Concrete Buildings* (SSC 96-01), prepared for the Seismic Safety Commission, State of California, by the Applied Technology Council, Redwood City, California.

ATC-58 (50% Draft), 2009. *Guidelines for Seismic Performance Assessment of Buildings*, prepared for the Federal Emergency Management Agency, by the Applied Technology Council, Redwood City, California (www/ATCouncil.org).

FEMA 154 (2nd Edition), 2002. *Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook,* prepared by the Applied Technology Council for the Federal Emergency Management Agency, Washington, DC.

FEMA 178, 1992, *NEHRP Handbook for Seismic Evaluation of Existing Buildings*, prepared by the Building Seismic Safety Council for the Federal Emergency Management Agency, Washington, DC.

FEMA 310, 1998, *Handbook for the Seismic Evaluation of Buildings: A Prestandard*, prepared by the American Society of Civil Engineers for the Federal Emergency Management Agency, Washington, DC.

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HAZUS-MH. http://www.fema.gov/plan/prevent/hazus/index.shtm. HAZUS is the FEMA Software Program for Estimating Potential Losses from Disasters.

SEAOC/ICBO, 2001. *Guidelines for Seismic Evaluation and Rehabilitation of Tilt-up Buildings and Other Rigid Wall/Flexible Diaphragm Structures*, Structural Engineers Association of California, and International Conference of Building Officials, Sacramento and Whittier, California.

A.2.2 Guidelines and Standards for Seismic Rehabilitation

In addition to the documents listed here, some of the evaluation resources listed in Section A.2.1 are also used for rehabilitation design. Some of the policy documents listed in Section A.2.4 include quantitative criteria as well.

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ATC-69, 2008. *Reducing the Risks of Nonstructural Earthquake Damage: State-of-the-Art and Practice Report*, prepared for the Federal Emergency Management Agency, Washington, DC. by the Applied Technology Council, Redwood City, California. (ATC-69 Appendix B includes a list of technical resources related to nonstructural components.)

FEMA, *Seismic Rehabilitation Cost Estimator*, available online at http://www.fema.gov/srce/index.jsp. (This resource is an online database tool built from the data compiled in FEMA 156 and FEMA 157.)

FEMA 74, 1994. *Reducing the Risks of Nonstructural Earthquake Damage: A Practical Guide*, Third Edition, prepared by Wiss, Janney, Elstner for the Federal Emergency Management Agency, Washington, DC. (ATC-69 presents information intended to update FEMA 74.)

FEMA 156, 1994. *Typical Costs for Seismic Rehabilitation of Existing Buildings, Volume 1 - Summary (Second Edition)* prepared by the Hart

Consultant Group, Inc. for the Federal Emergency Management Agency, Washington, DC.

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FEMA 356, 2000, *Prestandard and Commentary for the Seismic Rehabilitation of Buildings,* prepared by the American Society of Civil Engineers for the Federal Emergency Management Agency, Washington, DC.

FEMA 357, 2000. *Global Topics Report on the Prestandard and Commentary for the Seismic Rehabilitation of Buildings,* prepared by the Applied Technology Council for the Federal Emergency Management Agency, Washington, DC. (FEMA 357 was developed as a companion document to the pre-standard FEMA 356, which has since been converted to a standard, ASCE 41.)

FEMA 420, (in press). *Engineering Guideline for Incremental Seismic Rehabilitation*. prepared by the Applied Technology Council for the Federal Emergency Management Agency, Washington, DC. (This publication is a companion document to a series of guidelines for owners and managers of buildings of various occupancies: FEMA 395, *School Buildings (K-12)*; FEMA 396, *Hospital Buildings*; FEMA 397, *Office Buildings*; FEMA 398, *Multifamily Apartment Buildings*; FEMA 399, *Retail Buildings*; FEMA 400, *Hotel and Motel Buildings*.)

FEMA 547, 2007. *Techniques for the Seismic Rehabilitation of Existing Buildings*, prepared by Rutherford and Chekene, Degenkolb Engineers, and Cobeen & Associates Structural Engineering, Inc., for the Interagency Committee on Seismic Safety in Construction, with coordination by the Applied Technology Council, published by the Federal Emergency Management Agency, Washington, DC.

A.2.3 Building Codes

The text of this report describes the relationship between local codes and model codes. Except for certain California codes, the following list includes model codes only. Noteworthy local codes are described in the text.

CBC, 2007. *2007 California Building Code*, California Building Standards Commission. (The CBC is also referenced as California Code of Regulations, Title 24, Part 2. The 2007 CBC is based on the 2006 IBC. Chapter 34 is

entitled "Existing Structures." Sections 3415 through 3421 give special provisions for state-owned and state-regulated buildings.)

CEBC, 2007. *2007 California Existing Building Code*, California Building Standards Commission. (The CEBC is also referenced as California Code of Regulations, Title 24, Part 10. The 2007 CEBC includes only one chapter, Appendix A1, based on 2006 IEBC Appendix A1.)

CHBC, 2007. *2007 California Historical Building Code*, California Building Standards Commission. (The CHBC is also referenced as California Code of Regulations, Title 24, Part 8.)

ICC, 2001. *Guidelines for the Seismic Retrofit of Existing Buildings*, International Code Council, updated in Appendix A of IEBC (2006).

IBC, 2006. *2006 International Building Code*, International Code Council. (Chapter 16 gives the requirements for earthquake design of new structures. Chapter 34 is entitled "Existing Structures.")

IEBC, 2006. *2006 International Existing Building Code,* International Code Council. (IEBC Appendix A, entitled "Guidelines for the Seismic Retrofit of Existing Buildings," is an updated version of the five-chapter GSREB) (ICC, 2001).

NFPA 5000, 2006. *Building Construction and Safety Code*, National Fire Protection Association. (Chapter 15 is entitled "Building Rehabilitation.")

A.3 Institutional Policies

Federal departments and agencies have largely coordinated their facilities criteria and now generally rely on the IBC, ASCE 31, and ASCE 41 for specific seismic evaluation and rehabilitation design requirements. Some agency-specific criteria and policies are noted here. These and others are available online through a service called the Construction Criteria Base, at http://wbdg.org/ccb/ccb.php.

CSU Seismic Requirements, The California State University, 2008. http://www.calstate.edu/cpdc/ae/CSU_Seismic_Policy_Manual.pdf.

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Seismic Safety of VHA Buildings (VHA Directive 2005-019), Department of Veterans Affairs, Veterans Health Administration, 2005.

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Standards of Seismic Safety for Existing Federally Owned and Leased Buildings (ISCCC RP 6, NISTIR 6762), 2002.
http://fire.nist.gov/bfrlpubs/build01/PDF/b01056.pdf

Unified Facilities Criteria: Seismic Review Procedures for Existing Military Buildings (UFC 3-330-03A), Department of Defense, 2005.

University Policy on Seismic Safety, University of California, Office of the President, 1995.
http://www.ucop.edu/facil/fmc/facilman/volume1/rpsafety.html.

Appendix B

Legislation Regarding Seismic Performance of Existing Buildings

Appendix B provides samples of existing federal and state legislation for improving the seismic performance of existing buildings. This is not a comprehensive list of all such legislation nor does it include any local jurisdiction that has adopted similar ordinances. It is only intended to provide examples of legislation that have addressed the issue of improving the seismic performance of existing buildings.

FEDERAL

Standards of Seismic Safety for Existing Federally Owned and Leased Buildings, RP6, prepared by The Interagency Committee on Seismic Safety in Construction, ICSSC. This standard is intended to identify common evaluation and mitigation measures for all Federal agencies. The standard was first developed in 1994 and is updated periodically to incorporate advances in earthquake engineering knowledge gained from research and observations from recent earthquakes.

The Robert T. Stafford Disaster Relief and Emergency Assistance Act, Public Law 100-707, signed into law November 23, 1988; amended the Disaster Relief Act of 1974, Public Law 93-288. This Act constitutes the statutory authority for most Federal disaster response activities especially as they pertain to FEMA and FEMA programs.

ARKANSAS

Section 15-21-601 (1999) requires seismic network for monitoring earthquakes, operated by the Arkansas Seismological Observatory.

Section 12-80-103 (1991) establishes zones of anticipated damage from the New Madrid Seismic Zone. Prohibits construction or alteration of buildings (except dwellings, and small apartment buildings and specific small commercial buildings) unless the structural elements are designed to resist anticipated forces of the designated seismic zone.

CALIFORNIA

Senate Bill 1953 (1994) requires the State to develop a program of seismic safety building standards for hospitals constructed after March 7, 1973. The program included developing an earthquake performance category for hospitals and rapid seismic evaluation procedures. *Section 15097.100 of the Health and Safety Code.*

Senate Bill 547 (1986) requires local building departments within the highest seismic zone to establish a hazardous building mitigation plan for unreinforced masonry buildings located within their jurisdictions. *Section 8875 of the Government Code.*

The Seismic Hazard Mapping Act of 1972 requires geotechnical reports be submitted and approved for developments within specified seismic hazard zones prior to the issuance of a building permit. *Section 2621 of the Public Resources Code.*

Assembly Bill 300 (1999) requires the State's Department of General Services to conduct an inventory of school buildings that do not meet the minimum requirements of the 1976 *Uniform Building Code* and to make recommendations. *Section 17317 of the Education Code.*

Assembly Bill 304 (2005) allows local jurisdictions to establish reconstruction standards for residential buildings with soft, weak or open-front wall lines and allows the use of IEBC Ch A4. (Section 19160 of the *Health and Safety Code.*)

Assembly Bill 2533 (2004) requires owners of unreinforced masonry buildings to post signs at the entrance warning people that the building is not safe in the event of an earthquake and to require the owner to include similar warnings in lease agreements. (Section 8875.8 of the *Government Code.*)

The Field Act (1933) requires the Division of the State Architect to have structural engineers review and approve the construction plans and specifications for all public schools and to furnish general construction supervision.

The Riley Act (1933) requires all buildings within the state, with few exceptions, to be designed for seismic forces. This act also required the plans for these buildings be reviewed by the local jurisdiction.

OREGON

Senate Bill 416 (2007) allows renovations for seismic upgrades to be exempted from property tax increases. (Chapter 718, ORS 358.540.)

Senate Bill 2 (2005) requires a seismic survey of several types of important buildings, including schools, hospitals, police and fire stations, and similar buildings.

UTAH

House Bill 358 (1994) created the Utah Seismic Safety Commission. The commission reviews earthquake-related hazards; prepares recommendations to identify and mitigate these hazards and present them to state and local government for adoption; presents a strategic seismic planning document to the Legislature; and periodically updates the document and monitor progress toward achieving the goal of loss reduction.

The Utah Parapet Ordinance (early 1990s) requires that whenever a building is being re-roofed, the parapets and other projections above the roof of the building be braced for seismic loads.

Appendix C
Seismic Rehabilitation of Buildings Strategic Plan 2005 Objectives and Tasks

The *Seismic Rehabilitation of Buildings 2005 Strategic Plan* includes 25 tasks aimed at achieving 4 major objectives. The 4 objectives are:

1. Promote seismic rehabilitation and advance the implementation of previously developed materials (10 tasks).
2. Monitor the use of and refine existing materials (2 tasks).
3. Develop new seismic rehabilitation tools (7 tasks).
4. Consider new program directions (6 tasks).

Following are task definitions (with explanatory notes) for each objective.

Objective 1: Promote seismic rehabilitation and advance the implementation of previously developed materials

Task 1: Design, implement, and support for the next 10 years an aggressive "Seismic Rehabilitation Marketing Strategy."

Such a program will raise interest, secure commitment, explain the benefits of rehabilitation, provide stakeholders with needed information, and provide them with the full range of decision-support and technical materials needed to succeed.

Task 2: Prepare, disseminate, and support the use of the first generation of a series of technical implementation manuals.

Building on the Existing Buildings Program's existing materials, these new manuals should target particular stakeholders and integrate technical, policy and implementation guidelines so that more effective rehabilitation decisions can be made.

Task 3: Prepare a comprehensive manual on financial incentives to help overcome the investment barriers to seismic rehabilitation.

Financing seismic rehabilitation can be difficult. This effort should draw on other fields where incentives have proven useful, provide information on how to develop and administer incentives, and contain detailed information about the effectiveness, or otherwise, of various incentives in different contexts.

Task 4: Prepare guidance on the legal implications of seismic rehabilitation.

Although tort and case law varies by state, there is a more universal need to address legal principles and concerns (especially liability implications) concerning implementation of risk-reduction policy; engineering practices and standards of care; owner decisions regarding performance objectives and subsequent obligations to tenants, building occupants, and the public; local government code adoption and enforcement; and movement from traditional prescriptive and specification standards to performance-based engineering designs.

Task 5: Sponsor regional technical information transfer workshops and short courses.

In conjunction with implementation activities related to the FEMA 273 *NEHRP Guidelines for Seismic Rehabilitation of Buildings* (ATC/BSSC, 1997), there is a need to initiate a series of seminars on rehabilitation techniques focusing on regional distribution of typical structural systems used in simpler but more common structures. The target audience should be design professionals and code officials who are expected to use FEMA 273.

Task 6: Establish a "mentoring" program to improve professional capabilities.

Actual rehabilitation project experience is the most powerful learning method in this specialized field; however, the experience is limited to a relatively small percentage of practitioners. There is, therefore, a need to develop and partially to underwrite a voluntary mentoring program in which less-experienced design professionals and code administrators learn about design, plan and peer review processes, and rehabilitation construction methods "on the job."

Task 7: Provide coordination with related regional and state efforts.

Independently, and with FEMA support, several states have recently completed or are working on policy-oriented long-range seismic safety plans. They address existing buildings and seismic rehabilitation in various ways. Examples include the *California Earthquake Loss Reduction Plan* and comparable plans for Missouri and Utah. Oregon is initiating a similar effort. Where appropriate, there is a need for FEMA to continue funding such efforts and to coordinate implementation of its Existing Buildings Program with state and university research efforts so as to reinforce these efforts.

Task 8: Develop, disseminate, and provide training on software to support seismic rehabilitation.

In addition to various technical documents and the *Guidelines*, there is substantial need to develop a wide range of supporting software for use by practicing engineers and others. This software would help expand the number of design professionals and other users who could incorporate applicable technical materials directly into their design process, a great deal of which is being done by computer programs. Both new software and the accompanying training must include admonitions and suggestions that "sound professional judgment" will be needed frequently when designing or undertaking seismic rehabilitation projects.

Task 9: Develop seismic rehabilitation materials suitable for college and university instruction.

The development of seismic design courses, or increasing emphasis in existing courses, requires a considerable amount of effort. This will be especially true of seismic rehabilitation. Technical resource material should be collected, developed, and organized for those who would teach such courses. Faculty training courses could be offered to increase instructional capabilities. The material should be aimed at senior or graduate level students and at practitioners who might be able to attend extension courses.

Task 10: Improve information services to support the collection and dissemination of seismic rehabilitation information.

Valuable online, print, newsletter, and staff help services are provided by the National Information Service for Earthquake Engineering (NISEE), the Center for Advanced Technologies in Earthquake Loss Reduction's Information Service (ATEL, formerly the National Center for Earthquake Engineering Research [NCEER]) and others. In the field of seismic rehabilitation, it appears that a great deal of useful information is highly dispersed and hard to locate. Thus, it is important that FEMA work with other agencies, such as the National Science Foundation, to strengthen the role of such services in providing a special focus on the subject of seismic rehabilitation.

Objective 2: Monitor the use of and refine existing materials

Task 11: Periodically evaluate, improve, and disseminate the most important and widely used seismic rehabilitation documents and technical material produced since 1985, especially the *NEHRP Guidelines and Commentary for the Seismic Rehabilitation of Buildings* (FEMA 273 and 274).

As of 1998, the *Guidelines* are the culmination of the initial phase of the Existing Buildings Program, and their imminent dissemination provided a basis for many of *Plan 2005*'s recommended tasks. There was a clear understanding at the workshop that the *Guidelines,* like their counterpart provisions for new buildings, need to be revised regularly (every three to five years). FEMA 273 has been updated through the standards process of ASCE (FEMA 356, Prestandard) and ASCE 41 supplement 1 has brought needed technical improvements to the methodology.

Task 12: Conduct systematic evaluations of the Existing Buildings Program products and materials.

In addition to the *Guidelines*, several other Existing Buildings Program products have been revised to be of greater use (e.g., volumes on typical costs of rehabilitation and methods for evaluating existing buildings). Several issue papers and discussions at the workshop defined a strong need to evaluate systematically the currency and utility of Existing Buildings Program materials prepared in years past, as well as those to be developed under this plan. In addition to responding to feedback from portions of the user community, there is a need to establish a formal evaluation procedure and process to provide the necessary basis for identifying and addressing those resource materials most in need of revision. This practice will sustain the value of the program investments made to date.

Objective 3: Develop new seismic rehabilitation tools

Task 13: Conduct case studies of buildings to correlate code design with actual damage.

Though a wide array of building damage information is collected following earthquakes, there is a significant need to conduct detailed analyses and performance studies of both rehabilitated and original design buildings, primarily to test and validate the analytical and rehabilitation methods contained in the *Guidelines*. Within another activity, FEMA is supporting a program of 36 case studies (trial analyses and designs) of federal buildings to compare the results of FEMA 178 building evaluations with FEMA 273 seismic rehabilitation designs.

This effort needs to be extended beyond federal buildings in two directions. First, there is a need to fund about 50 case studies of new buildings to check two design methods in the *Guidelines* (Linear Static and Nonlinear Static) to understand how well the suggested rehabilitation procedures compare with those followed in the original designs—not to "second guess" the original designs. Second, there is a need to conduct about 100 detailed post-earthquake analyses of damaged buildings (rehabilitated or not) to check all four analytical methods in the *Guidelines* to correlate them with the actual performance of the buildings in addition to checking the original design against the latest building code requirements for the area.

Such systematic analyses and demonstrations of the methodologies in the *Guidelines* will help convince practicing engineers to use the new methods instead of continuing to rely on more conventional and familiar but less-sophisticated ones. In addition, such studies could be useful in identifying problems in older buildings that, if they had been corrected using the *Guidelines*, might have resulted in less damage (thereby demonstrating the value of pre-earthquake seismic rehabilitation). These activities will be especially important as application of the *Guidelines* increases so their effectiveness in reducing losses can be shown.

Task 14: Establish a system for the comprehensive and systematic collection and analysis of damage and loss data.

Looking beyond earthquakes and building damages and taking advantage of existing information systems and data sources, there is a need to build a comprehensive national disaster loss information system. The Existing Buildings Program would be only one component of this major but necessary undertaking, and coordination will be required with comparable efforts in other programs.

With such a system, FEMA, other agencies and organizations, practitioners and researchers, and others could understand loss relationships; define cost-effective mitigation techniques, and support policy and program decision making. A necessary element of this effort would be development of standard data collection guidelines, protocols, and research methods to provide over time sets of consistent and comparable data to support improved analyses. This task suggests that there also be greater collaboration between the practicing and research engineers so that the results are more directly applicable.

Task 15: Develop simplified rehabilitation techniques for engineered structures.

Most buildings, even those that have been designed by architects and engineers, are relatively small and simple. Using a series of real or sample buildings, there is a need to complement the *Guidelines* with new information about simplified rehabilitation techniques applicable to multiple performance levels. This information will help expedite the relatively straightforward rehabilitation of such buildings. The resulting materials could lower engineering and project costs and be widely used in areas of low-to-moderate seismicity where seismic demands are more manageable. This work will need to be coordinated with that contained in Task 24.

Task 16: Develop improved and internally compatible analytical tools, acceptance criteria, and modeling rules and procedures.

Several issues merged into a focus on the need to develop various tools to more accurately predict the earthquake performance of existing buildings before or after rehabilitation. Rather than continuing to rely on modifying existing tools developed originally for new design, we need to develop calibration studies, analytical procedures, modeling rules, and other materials to strengthen the tools available specifically for seismic rehabilitation.

Task 17: Prepare guidelines on the repair of earthquake-damaged buildings.

Using the rehabilitation *Guidelines* as a point of departure, there is a valuable opportunity to meet a long-standing need: preparation of a set of consensus-based technical guidelines and an accompanying commentary to assist with evaluating and, more importantly, repairing, earthquake-damaged buildings. There is a great deal of experience available to help with this project, and the development of repair guidelines will support those critical early decisions about what to do, and how much to spend, on damaged buildings. Moreover, the guidelines will provide a broad range of users with commonly accepted techniques and a manual of practice to guide their decisions and activities.

Task 18: Prepare materials focused on the building "pounding" issue in seismic rehabilitation.

In the context of rehabilitation, there is a concern about how to control for damage to rehabilitated existing buildings caused by pounding from adjacent buildings (rehabilitated or not). This issue needs systematic exploration, and resource materials are needed to help engineers deal with this issue during the rehabilitation process. It may be that effective measures to counteract pounding can be included in a building's rehabilitation, or it may take some joint efforts of adjacent buildings. This specific issue could be combined with other tasks, possibly 16 or 17.

Task 19: Develop technical material focused specifically on the implications of local geology and detailed soil conditions on the seismic rehabilitation of buildings.

It was noted that the potential effects of site geologic hazards are often overlooked (or taken as a given) during seismic evaluations and rehabilitation projects. Nevertheless, geologic hazards need to be addressed, and materials are needed to address this issue. This work involves improving existing guidelines, developing standards for classifying such hazards, and supporting other activities to evaluate the effects of such hazards on the expected seismic performance of existing structures.

Objective 4: Consider new program directions

Task 20: Create and disseminate information about effective partial and incremental structural and nonstructural rehabilitation strategies and techniques.

Recognizing that buildings need maintenance and often are remodeled to suit newer uses, there is an opportunity to introduce seismic improvements during the planning of such work. Guidance on partial and incremental rehabilitation strategies and techniques could provide users, such as facility managers, for example, with information about strengthening measures that can be budgeted for and implemented over time via normal building maintenance, repair, or remodeling activities.

Task 21: Develop a standard and uniformly acceptable building performance rating system.

There is a need to extend the building evaluation methods done to date so that they include more factors and are useful to more stakeholders, portray relative risk, are better able to help set rehabilitation priorities and support decision making, and provide consistent results nationwide. This task would combine engineering concepts of building performance with site conditions, occupancy, and other information to provide comparable results for understanding relative risk, deciding appropriate rehabilitation priorities and measures, establishing more accurate risk-based insurance rates, and assisting the financial community with making rehabilitation investment decisions.

Task 22: Systematically collect, analyze, and apply more and better data about building performance in earthquakes (the "best laboratory").

Learning from earthquakes, coupled with research, remains the best way to evaluate building performance. Historically, the results lead to improved codes, designs, and practices. There is a strong need to focus more effort on defining specific data needs, developing standard collection methods, and improving other measures to build a common database systematically. Funds must be available after earthquakes to sustain analytically rigorous, and statistically valid and exhaustive, performance data collection efforts on both damaged and undamaged buildings. Accumulated over time, the results will help validate and modify existing rehabilitation methods and techniques, or support the development of new and improved methods.

Task 23: Provide guidance on implementing seismic rehabilitation in multihazard environments.

Risk analyses, loss estimates, and disaster experience clearly shows that the hazard exposure varies significantly across the United States. Greater emphasis is being placed on defining relative risks and appropriate techniques for preventing future losses (mitigation) from multiple hazards. There is a need to provide a broad range of users with information on how to integrate seismic rehabilitation procedures with those addressing other hazards. There is a corresponding need to share information about, and experiences with, mitigation marketing techniques, financial incentives, and policy actions for the mutual benefit of all, and the development of more integrated approaches.

Task 24: Develop seismic rehabilitation guidelines for non-engineered buildings.

The vast majority of smaller and simpler buildings in the United States have been designed and built without the involvement of design professionals. Collectively, these represent the largest pool of candidate buildings for seismic rehabilitation. Because of the complexities of rehabilitation, however, there is a need to provide design professionals and other users with guidance on cost-effective rehabilitation of these smaller and simpler buildings. There is substantial experience that could be marshaled to prepare such guidelines. This work needs to be coordinated with that contained in Task 15.

Task 25: Develop improved building inventory methods.

Accurate and comparable building inventory data is crucial to every dimension of seismic safety, including rehabilitation. Many techniques exist for collecting inventory data, and they vary greatly in complexity and cost. Moreover, the uses of such information can also vary from quite general (e.g., scope of the problem) to very specific (e.g., loss estimation). For purposes of seismic rehabilitation, there is a broader and critical need to develop improved and standard building inventory methods that can be used consistently across the United States.

Other Tasks:

In addition to the above tasks of the *2005 Plan*, three items were defined for further consideration. They include the following items:

Design and support comprehensive seismic rehabilitation pilot projects.

Though the Existing Buildings Program traditionally has not undertaken specific pilot projects, this proposal would establish three to five geographically dispersed seismic rehabilitation planning and priority-setting projects. Each would focus on (1) developing risk information, (2) presenting this information to support community decision making, and (3) providing assistance to help initiate and implement seismic-specific rehabilitation actions.

Develop a method to determine the behavior of modern unreinforced masonry buildings.

The current strategies for rehabilitating unreinforced masonry buildings (URMs) assume that they are composed of older, soft bricks and weak lime mortar. Especially outside California, many more recent and stronger URMs were built since the 1950s, and may still be constructed in some areas. There is a need, therefore, especially in the eastern and central parts of the United States, to develop improved analytical methods to determine the resistance of these newer URMs and the extent of rehabilitation that might be required to resist expected earthquake forces.

Develop methods to understand the fundamental force-displacement behavior of building components to support modeling and analytical methods.

There is a fundamental lack of experiential and research data to describe adequately the force-displacement behavior of building components. Though further research on this subject is needed, short-term improvements can be made by improving both testing protocols and reporting formats, and preparing other technical material that will support modeling and acceptance criteria for current analytical methods.

Appendix D
Contributors in Project Interviews

The following individuals provided opinions to the project team through their participation in interview sessions.

Building Regulatory Officials

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Acronyms

ABE Joint Venture	ATC, BSSC, and EERI Joint Venture
ACI	American Concrete Institute
AISC	American Institute for Steel Construction
ASCE	American Society of Civil Engineers
ATC	Applied Technology Council
BSSC	Building Seismic Safety Council
CBC	*California Building Code*
EERI	Earthquake Engineering Research Institute
FEMA	Federal Emergency Management Agency
GSREB	*Guidelines for the Seismic Retrofit of Existing Buildings* (Appendix A of *IEBC*)
HAZUS	FEMA's U.S. Hazards loss-estimation software
IBC	*International Building Code*
ICBO	International Conference of Building Officials
ICC	International Code Council
IEBC	*International Existing Building Code*
LEED	Leadership in Energy and Environmental Design, a rating system
NCSEA	National Council of Structural Engineers Associations
NEHRP	National Earthquake Hazards Reduction Program
NFPA	National Fire Protection Association
PEER	Pacific Earthquake Engineering Research Center
PIMS	NEHRP's Postearthquake Information Management System
PML	probable maximum loss
SEAOC	Structural Engineers Association of California
UCBC	*Uniform Code for Building Conservation*

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ATC, 2008b. *NEHRP Workshop on Meeting the Challenges of Existing Buildings, Prioritized Research for Reducing the Seismic Hazards of Existing Buildings,* ATC-73 Report, Applied Technology Council, Redwood City, California.

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Applied Technology Council Projects and Report Information

One of the primary purposes of the Applied Technology Council is to develop resource documents that translate and summarize useful information to practicing engineers. This includes the development of guidelines and manuals, as well as the development of research recommendations for specific areas determined by the profession. ATC is not a code development organization, although ATC project reports often serve as resource documents for the development of codes, standards and specifications.

Applied Technology Council conducts projects that meet the following criteria:

1. The primary audience or benefactor is the design practitioner in structural engineering.
2. A cross section or consensus of engineering opinion is required to be obtained and presented by a neutral source.
3. The project fosters the advancement of structural engineering practice.

Brief descriptions of completed ATC projects and reports are provided below. Funding for projects is obtained from government agencies and tax-deductible contributions from the private sector.

ATC-1: This project resulted in five papers that were published as part of *Building Practices for Disaster Mitigation, Building Science Series 46*, proceedings of a workshop sponsored by the National Science Foundation (NSF) and the National Bureau of Standards (NBS). Available through the National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, VA 22151, as NTIS report No. COM-73-50188.

ATC-2: The report, *An Evaluation of a Response Spectrum Approach to Seismic Design of Buildings*, was funded by NSF and NBS and was conducted as part of the Cooperative Federal Program in Building Practices for Disaster Mitigation. Available through the ATC office. (Published 1974, 270 Pages)

> ABSTRACT: This study evaluated the applicability and cost of the response spectrum approach to seismic analysis and design that was proposed by various segments of the engineering profession. Specific building designs, design procedures and parameter values were evaluated for future application. Eleven existing buildings of varying dimensions were redesigned according to the procedures.

ATC-3: The report, *Tentative Provisions for the Development of Seismic Regulations for Buildings* (ATC-3-06), was funded by NSF and NBS. The second printing of this report, which includes proposed amendments, is available through the ATC office. (Published 1978, amended 1982, 505 pages plus proposed amendments)

ABSTRACT: The tentative provisions in this document represent the results of a concerted effort by a multi-disciplinary team of 85 nationally recognized experts in earthquake engineering. The provisions serve as the basis for the seismic provisions of the 1988 and subsequent issues of the *Uniform Building Code* and the *NEHRP Recommended Provisions for the Development of Seismic Regulation for New Building and Other Structures*. The second printing of this document contains proposed amendments prepared by a joint committee of the Building Seismic Safety Council (BSSC) and the NBS.

ATC-3-2: The project, "Comparative Test Designs of Buildings Using ATC-3-06 Tentative Provisions", was funded by NSF. The project consisted of a study to develop and plan a program for making comparative test designs of the ATC-3-06 Tentative Provisions. The project report was written to be used by the Building Seismic Safety Council in its refinement of the ATC-3-06 Tentative Provisions.

ATC-3-4: The report, *Redesign of Three Multistory Buildings: A Comparison Using ATC-3-06 and 1982 Uniform Building Code Design Provisions*, was published under a grant from NSF. Available through the ATC office. (Published 1984, 112 pages)

ABSTRACT: This report evaluates the cost and technical impact of using the 1978 ATC-3-06 report, *Tentative Provisions for the Development of Seismic Regulations for Buildings*, as amended by a joint committee of the Building Seismic Safety Council and the National Bureau of Standards in 1982. The evaluations are based on studies of three existing California buildings redesigned in accordance with the ATC-3-06 Tentative Provisions and the 1982 *Uniform Building Code*. Included in the report are recommendations to code implementing bodies.

ATC-3-5: This project, "Assistance for First Phase of ATC-3-06 Trial Design Program Being Conducted by the Building Seismic Safety Council", was funded by the Building Seismic Safety Council to provide the services of the ATC Senior Consultant and other ATC personnel to assist the BSSC in the conduct of the first phase of its Trial Design Program. The first phase provided for trial designs conducted for buildings in Los Angeles, Seattle, Phoenix, and Memphis.

ATC-3-6: This project, "Assistance for Second Phase of ATC-3-06 Trial Design Program Being Conducted by the Building Seismic Safety Council", was funded by the Building Seismic Safety Council to provide the services of the ATC Senior Consultant and other ATC personnel to assist the BSSC in the conduct of the second phase of its Trial Design Program. The second phase provided for trial designs conducted for buildings in New York, Chicago, St. Louis, Charleston, and Fort Worth.

ATC-4: The report, *A Methodology for Seismic Design and Construction of Single-Family Dwelling*s, was published under a contract with the Department of Housing and Urban Development (HUD). Available through the ATC office. (Published 1976, 576 pages)

ABSTRACT: This report presents the results of an in-depth effort to develop design and construction details for single-family residences that minimize the potential economic loss and life-loss risk associated with earthquakes. The report: (1) discusses the ways structures behave when subjected to seismic forces, (2) sets forth suggested design criteria for conventional layouts of dwellings constructed with conventional materials, (3) presents construction details that do not require the designer to perform analytical calculations, (4) suggests procedures for efficient plan-checking, and (5) presents recommendations including details and schedules for use in the field by construction personnel and building inspectors.

ATC-4-1: The report, *The Home Builders Guide for Earthquake Design*, was published under a contract with HUD. Available through the ATC office. (Published 1980, 57 pages)

ABSTRACT: This report is an abridged version of the ATC-4 report. The concise, easily understood text of the Guide is supplemented with illustrations and 46 construction details. The details are provided to ensure that houses contain structural features that are properly positioned, dimensioned and constructed to resist earthquake forces. A brief description is included on how earthquake forces impact on houses and some precautionary constraints are given with respect to site selection and architectural designs.

ATC-5: The report, *Guidelines for Seismic Design and Construction of Single-Story Masonry Dwellings in Seismic Zone 2*, was developed under a contract with HUD. Available through the ATC office. (Published 1986, 38 pages)

ABSTRACT: The report offers a concise methodology for the earthquake design and construction of single-story masonry dwellings in Seismic Zone 2 of the United States, as defined by the 1973 *Uniform Building Code*. The Guidelines are based in part on shaking table tests of masonry construction conducted at the University of California at Berkeley Earthquake Engineering Research Center. The report is written in simple language and includes basic house plans, wall evaluations, detail drawings, and material specifications.

ATC-6: The report, *Seismic Design Guidelines for Highway Bridges*, was published under a contract with the Federal Highway Administration (FHWA). Available through the ATC office. (Published 1981, 210 pages)

ABSTRACT: The Guidelines are the recommendations of a team of sixteen nationally recognized experts that included consulting engineers, academics, state and federal agency representatives from throughout the United States. The Guidelines embody several new concepts that were significant departures from then existing design provisions. Included in the Guidelines are an extensive commentary, an example demonstrating the use of the Guidelines, and summary reports on 21 bridges redesigned in accordance with the Guidelines. In 1991 the guidelines were adopted by the American Association of Highway and Transportation Officials as a standard specification.

ATC-6-1: The report, *Proceedings of a Workshop on Earthquake Resistance of Highway Bridges*, was published under a grant from NSF. Available through the ATC office. (Published 1979, 625 pages)

ABSTRACT: The report includes 23 state-of-the-art and state-of-practice papers on earthquake resistance of highway bridges. Seven of the twenty-three papers were authored by participants from Japan, New Zealand and Portugal. The Proceedings also contain recommendations for future research that were developed by the 45 workshop participants.

ATC-6-2: The report, *Seismic Retrofitting Guidelines for Highway Bridges*, was published under a contract with FHWA. Available through the ATC office. (Published 1983, 220 pages)

ABSTRACT: The Guidelines are the recommendations of a team of thirteen nationally recognized experts that included consulting engineers, academics, state highway engineers, and federal agency representatives. The Guidelines, applicable for use in all parts of the United States, include a preliminary screening procedure, methods for evaluating an existing bridge in detail, and potential retrofitting measures for the most common seismic deficiencies. Also included are special design requirements for various retrofitting measures.

ATC-7: The report, *Guidelines for the Design of Horizontal Wood Diaphragms*, was published under a grant from NSF. Available through the ATC office. (Published 1981, 190 pages)

ABSTRACT: Guidelines are presented for designing roof and floor systems so these can function as horizontal diaphragms in a lateral force resisting system. Analytical procedures, connection details and design examples are included in the Guidelines.

ATC-7-1: The report, *Proceedings of a Workshop on Design of Horizontal Wood Diaphragms*, was published under a grant from NSF. Available through the ATC office. (Published 1980, 302 pages)

ABSTRACT: The report includes seven papers on state-of-the-practice and two papers on recent research. Also included are recommendations for future research that were developed by the 35 workshop participants.

ATC-8: This report, *Proceedings of a Workshop on the Design of Prefabricated Concrete Buildings for Earthquake Loads*, was funded by NSF. Available through the ATC office. (Published 1981, 400 pages)

ABSTRACT: The report includes eighteen state-of-the-art papers and six summary papers. Also included are recommendations for future research that were developed by the 43 workshop participants.

ATC-9: The report, *An Evaluation of the Imperial County Services Building Earthquake Response and Associated Damage*, was published under a grant from NSF. Available through the ATC office. (Published 1984, 231 pages)

ABSTRACT: The report presents the results of an in-depth evaluation of the Imperial County Services Building, a 6-story reinforced concrete frame and shear wall building severely damaged by the October 15, 1979 Imperial Valley, California, earthquake. The report contains a review and evaluation of earthquake damage to the building; a review and evaluation of the seismic design; a comparison of the requirements of various building codes as they relate to the building; and conclusions and recommendations pertaining to future building code provisions and future research needs.

ATC-10: This report, *An Investigation of the Correlation Between Earthquake Ground Motion and Building Performance*, was funded by the U.S. Geological Survey (USGS). Available through the ATC office. (Published 1982, 114 pages)

ABSTRACT: The report contains an in-depth analytical evaluation of the ultimate or limit capacity of selected representative building framing types, a discussion of the factors affecting the seismic performance of buildings, and a summary and comparison of seismic design and seismic risk parameters currently in widespread use.

ATC-10-1: This report, *Critical Aspects of Earthquake Ground Motion and Building Damage Potential*, was co-funded by the USGS and the NSF. Available through the ATC office. (Published 1984, 259 pages)

ABSTRACT: This document contains 19 state-of-the-art papers on ground motion, structural response, and structural design issues presented by prominent engineers and earth scientists in an ATC seminar. The main theme of the papers is to identify the critical aspects of ground motion and building performance that currently are not being considered in building design. The report also contains conclusions and recommendations of working groups convened after the Seminar.

ATC-11: The report, *Seismic Resistance of Reinforced Concrete Shear Walls and Frame Joints: Implications of Recent Research for Design Engineers*, was published under a grant from NSF. Available through the ATC office. (Published 1983, 184 pages)

ABSTRACT: This document presents the results of an in-depth review and synthesis of research reports pertaining to cyclic loading of reinforced concrete shear walls and cyclic loading of joints in reinforced concrete frames. More than 125 research reports published since 1971 are reviewed and evaluated in this report. The preparation of the report included a consensus process involving numerous experienced design professionals from throughout the United States. The report contains reviews of current and past design practices, summaries of research developments, and in-depth discussions of design implications of recent research results.

ATC-12: This report, *Comparison of United States and New Zealand Seismic Design Practices for Highway Bridges*, was published under a grant from NSF. Available through the ATC office. (Published 1982, 270 pages)

ABSTRACT: The report contains summaries of all aspects and innovative design procedures used in New Zealand as well as comparison of United States and New Zealand design practice. Also included are research recommendations developed at a 3-day workshop in New Zealand attended by 16 U.S. and 35 New Zealand bridge design engineers and researchers.

ATC-12-1: This report, *Proceedings of Second Joint U.S.-New Zealand Workshop on Seismic Resistance of Highway Bridges*, was published under a grant from NSF. Available through the ATC office. (Published 1986, 272 pages)

ABSTRACT: This report contains written versions of the papers presented at this 1985 workshop as well as a list and prioritization of workshop recommendations. Included are summaries of research projects being conducted in both countries as well as state-of-the-practice papers on various aspects of design practice. Topics discussed include bridge design philosophy and loadings; design of columns, footings, piles, abutments and retaining structures; geotechnical aspects of foundation design; seismic analysis techniques; seismic retrofitting; case studies using base isolation; strong-motion data acquisition and interpretation; and testing of bridge components and bridge systems.

ATC-13: The report, *Earthquake Damage Evaluation Data for California*, was developed under a contract with the Federal Emergency Management Agency (FEMA). Available through the ATC office. (Published 1985, 492 pages)

ABSTRACT: This report presents expert-opinion earthquake damage and loss estimates for industrial, commercial, residential, utility and transportation facilities in California. Included are damage probability matrices for 78 classes of structures and estimates of time required to restore damaged facilities to pre-earthquake usability. The report also describes the inventory information essential for estimating economic losses and the methodology used to develop loss estimates on a regional basis.

ATC-13-1: The report, *Commentary on the Use of ATC-13 Earthquake Damage Evaluation Data for Probable Maximum Loss Studies of California Buildings*, was developed with funding from ATC's Henry J. Degenkolb Memorial Endowment Fund. Available through the ATC office. (Published 2002, 66 pages)

ABSTRACT: This report provides guidance to consulting firms who are using ATC-13 expert-opinion data for probable maximum loss (PML) studies of California buildings. Included are discussions of the limitations of the ATC-13 expert-opinion data, and the issues associated with using the data for PML studies. Also included are three appendices containing information and data not included in the original ATC-13 report: (1) ATC-13 model building type descriptions, including methodology for estimating the expected performance of standard, nonstandard, and special construction; (2) ATC-13 Beta damage distribution parameters for model building types; and (3) PML values for ATC-13 model building types.

ATC-14: The report, *Evaluating the Seismic Resistance of Existing Buildings*, was developed under a grant from the NSF. Available through the ATC office. (Published 1987, 370 pages)

ABSTRACT: This report, written for practicing structural engineers, describes a methodology for performing preliminary and detailed building seismic evaluations. The report contains a state-of-practice review; seismic loading criteria; data collection procedures; a detailed description of the building classification system; preliminary and detailed analysis procedures; and example case studies, including nonstructural considerations.

ATC-15: The report, *Comparison of Seismic Design Practices in the United States and Japan*, was published under a grant from NSF. Available through the ATC office. (Published 1984, 317 pages)

ABSTRACT: The report contains detailed technical papers describing design practices in the United States and Japan as well as recommendations emanating from a joint U.S.-Japan workshop held in Hawaii in March, 1984. Included are detailed descriptions of new seismic design methods for buildings in Japan and case studies of the design of specific buildings (in both countries). The report also contains an overview of the history and objectives of the Japan Structural Consultants Association.

ATC-15-1: The report, *Proceedings of Second U.S.-Japan Workshop on Improvement of Building Seismic Design and Construction Practices*, was published under a grant from NSF. Available through the ATC office. (Published 1987, 412 pages)

ABSTRACT: This report contains 23 technical papers presented at this San Francisco workshop in August, 1986, by practitioners and researchers from the U.S. and Japan. Included are state-of-the-practice papers and case studies of actual building designs and information on regulatory, contractual, and licensing issues.

ATC-15-2: The report, *Proceedings of Third U.S.-Japan Workshop on Improvement of Building Structural Design and Construction Practices*, was published jointly by ATC and the Japan Structural Consultants Association. Available through the ATC office. (Published 1989, 358 pages)

ABSTRACT: This report contains 21 technical papers presented at this Tokyo, Japan, workshop in July, 1988, by practitioners and researchers from the U.S., Japan, China, and New Zealand. Included are state-of-the-practice papers on various topics, including braced steel frame buildings, beam-column joints in reinforced concrete buildings, summaries of comparative U. S. and Japanese design, and base isolation and passive energy dissipation devices.

ATC-15-3: The report, *Proceedings of Fourth U.S.-Japan Workshop on Improvement of Building Structural Design and Construction Practices*, was published jointly by ATC and the Japan Structural Consultants Association. Available through the ATC office. (Published 1992, 484 pages)

ABSTRACT: This report contains 22 technical papers presented at this Kailua-Kona, Hawaii, workshop in August, 1990, by practitioners and researchers from the United States, Japan, and Peru. Included are papers on postearthquake building damage assessment; acceptable earth-quake damage; repair and retrofit of earthquake damaged buildings; base-isolated buildings, including Architectural Institute of Japan recommendations for design; active damping systems; wind-resistant design; and summaries of working group conclusions and recommendations.

ATC-15-4: The report, *Proceedings of Fifth U.S.-Japan Workshop on Improvement of Building Structural Design and Construction Practices*, was published jointly by ATC and the Japan Structural Consultants Association. Available through the ATC office. (Published 1994, 360 pages)

ABSTRACT: This report contains 20 technical papers presented at this San Diego, California workshop in September, 1992. Included are papers on performance goals/acceptable damage in seismic design; seismic design procedures and case studies; construction influences on design; seismic isolation and passive energy dissipation; design of irregular structures; seismic evaluation, repair and upgrading; quality control for design and construction; and summaries of working group discussions and recommendations.

ATC-16: This project, "Development of a 5-Year Plan for Reducing the Earthquake Hazards Posed by Existing Nonfederal Buildings", was funded by FEMA and was conducted by a joint venture of ATC, the Building Seismic Safety Council and the Earthquake Engineering Research Institute. The project involved a workshop in Phoenix, Arizona, where approximately

50 earthquake specialists met to identify the major tasks and goals for reducing the earthquake hazards posed by existing nonfederal buildings nationwide. The plan was developed on the basis of nine issue papers presented at the workshop and workshop working group discussions. The Workshop Proceedings and Five-Year Plan are available through the Federal Emergency Management Agency, 500 "C" Street, S.W., Washington, DC 20472.

ATC-17: This report, *Proceedings of a Seminar and Workshop on Base Isolation and Passive Energy Dissipation*, was published under a grant from NSF. Available through the ATC office. (Published 1986, 478 pages)

ABSTRACT: The report contains 42 papers describing the state-of-the-art and state-of-the-practice in base-isolation and passive energy-dissipation technology. Included are papers describing case studies in the United States, applications and developments worldwide, recent innovations in technology development, and structural and ground motion issues. Also included is a proposed 5-year research agenda that addresses the following specific issues: (1) strong ground motion; (2) design criteria; (3) materials, quality control, and long-term reliability; (4) life cycle cost methodology; and (5) system response.

ATC-17-1: This report, *Proceedings of a Seminar on Seismic Isolation, Passive Energy Dissipation and Active Control,* was published under a grant from NCEER and NSF. Available through the ATC office. (Published 1993, 841 pages)

ABSTRACT: The 2-volume report documents 70 technical papers presented during a two-day seminar in San Francisco in early 1993. Included are invited theme papers and competitively selected papers on issues related to seismic isolation systems, passive energy dissipation systems, active control systems and hybrid systems.

ATC-18: The report, *Seismic Design Criteria for Bridges and Other Highway Structures: Current and Future***,** was developed under a grant from NCEER and FHWA. Available through the ATC office. (Published, 1997, 151 pages)

ABSTRACT: Prepared as part of NCEER Project 112 on new highway construction, this report reviews current domestic and foreign design practice, philosophy and criteria, and recommends future directions for code development. The project considered bridges, tunnels, abutments, retaining wall structures, and foundations.

ATC-18-1: The report, *Impact Assessment of Selected MCEER Highway Project Research on the Seismic Design of Highway Structures***,** was developed under a contract from the Multidisciplinary Center for Earthquake Engineering Research (MCEER, formerly NCEER) and FHWA. Available through the ATC office. (Published, 1999, 136 pages)

ABSTRACT: The report provides an in-depth review and assessment of 32 research reports emanating from the MCEER Project 112 on new highway construction, as well as recommendations for future bridge seismic design guidelines. Topics covered include: ground motion issues; determining structural importance; foundations and soils; liquefaction mitigation methodologies; modeling of pile footings and drilled shafts; damage-avoidance design of bridge piers, column design, modeling, and analysis; structural steel and steel-concrete interface details; abutment design, modeling, and analysis; and detailing for structural movements in tunnels.

ATC-19: The report, *Structural Response Modification Factors* was funded by NSF and NCEER. Available through the ATC office. (Published 1995, 70 pages)

ABSTRACT: This report addresses structural response modification factors (R factors), which are used to reduce the seismic forces associated with elastic response to obtain design forces. The report documents the basis for current R values, how R factors are used for seismic design in other countries, a rational means for decomposing R into key components, a framework (and methods) for evaluating the key components of R, and the research necessary to improve the reliability of engineered construction designed using R factors.

ATC-20: The report, *Procedures for Postearthquake Safety Evaluation of Buildings*, was developed under a contract from the California Office of Emergency Services (OES), California Office of Statewide Health Planning and Development (OSHPD) and FEMA. Available through the ATC office (Published 1989, 152 pages)

ABSTRACT: This report provides procedures and guidelines for making on-the-spot evaluations and decisions regarding continued use and occupancy of earthquake damaged buildings. Written specifically for volunteer structural engineers and building inspectors, the report includes rapid and detailed evaluation procedures for inspecting buildings and posting them as "inspected" (apparently safe, green placard), "limited entry" (yellow) or "unsafe" (red). Also included are special procedures for evaluation of essential buildings (e.g., hospitals), and evaluation procedures for nonstructural elements, and geotechnical hazards.

ATC-20-1: The report, *Field Manual: Postearthquake Safety Evaluation of Buildings*, *Second Edition*, was funded by Applied Technology Council. Available through the ATC office (Published 2004, 143 pages)

ABSTRACT: This report, a companion Field Manual for the ATC-20 report, summarizes the postearthquake safety evaluation procedures in a brief concise format designed for ease of use in the field. The Second Edition has been updated to include improved versions of the posting placards and evaluation forms, as well as more detailed information on steel moment-frame buildings, mobile homes, and manufactured housing. It also includes new information on barricading and provides a list of internet resources pertaining to postearthquake safety evaluation.

ATC-20-2: The report, *Addendum to the ATC-20 Postearthquake Building Safety Procedures* was published under a grant from the NSF and funded by the USGS. Available through the ATC office. (Published 1995, 94 pages)

ABSTRACT: This report provides updated assessment forms, placards, including a revised yellow placard ("restricted use") and procedures that are based on an in-depth review and evaluation of the widespread application of the ATC-20 procedures following five earthquakes occurring since the initial release of the ATC-20 report in 1989.

ATC-20-3: The report, *Case Studies in Rapid Postearthquake Safety Evaluation of Buildings,* was funded by ATC and R. P. Gallagher Associates. Available through the ATC office. (Published 1996, 295 pages)

ABSTRACT: This report contains 53 case studies using the ATC-20 Rapid Evaluation procedure. Each case study is illustrated with photos and describes how a building was inspected and evaluated for life safety, and includes a completed safety assessment form and placard. The report is intended to be used as a training and reference manual for building officials, building inspectors, civil and structural engineers, architects, disaster workers, and others who may be asked to perform safety evaluations after an earthquake.

ATC-20-T: The *Postearthquake Safety Evaluation of Buildings Training CD* was developed by FEMA to replace the 1993 ATC-20-T Training Manual that included 160 35-mm slides. Available through the ATC office. (Published 2002, 230 PowerPoint slides with Speakers Notes)

ABSTRACT: This Training CD is intended to facilitate the presentation of the contents of the ATC-20 and ATC-20-2 reports in a 4½-hour training seminar. The Training CD contains 230 slides of photographs, schematic drawings and textual information. Topics covered include: posting system; evaluation procedures; structural basics; wood frame, masonry, concrete, and steel frame structures; nonstructural elements; geotechnical hazards; hazardous materials; and field safety.

ATC-21: The report, *Second Edition, Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook*, was developed under a contract from FEMA. Available through the ATC office, or from FEMA by contacting 1-800-480-2520, as *FEMA 154 Second Edition*. (Published 2002, 161 pages)

ABSTRACT: This report describes a rapid visual screening procedure for identifying those buildings that might pose serious risk of loss of life and injury, or of severe curtailment of community services, in case of a damaging earthquake. The screening procedure utilizes a methodology based on a "sidewalk survey" approach that involves identification of the primary structural load-resisting system and its building material, and assignment of a basic structural hazards score and performance modifiers based on the observed building characteristics. Application of the methodology identifies those buildings that are potentially hazardous and should be analyzed in more detail by a professional engineer experienced in seismic design. In the Second Edition, the scoring system has been revised and the *Handbook* has been shortened and focused to ease its use.

ATC-21-1: The report, *Rapid Visual Screening of Buildings for Potential Seismic Hazards: Supporting Documentation*, *Second Edition*, was developed under a contract from FEMA. Available through the ATC office, or from FEMA by contacting 1-800-480-2520, as *FEMA 155 Second Edition*. (Published 2002, 117 pages)

ABSTRACT: Included in this report is the technical basis for the updated rapid visual screening procedure of ATC-21, including (1) a summary of the results from the efforts to solicit user feedback, and (2) a detailed description of the development effort leading to the basic structural hazard scores and the score modifiers.

ATC-21-2: The report, *Earthquake Damaged Buildings: An Overview of Heavy Debris and Victim Extrication*, was developed under a contract from FEMA. (Published 1988, 95 pages)

ABSTRACT: Included in this report, a companion volume to the first edition of the ATC-21 and ATC-21-1 reports, is state-of-the-art information on (1) the identification of those buildings that might collapse and trap victims in debris or generate debris of such a size that its handling would require special or heavy lifting equipment; (2) guidance in identifying these types of buildings, on the basis of their major exterior features, and (3) the types and life capacities of equipment required to remove the heavy portion of the debris that might result from the collapse of such buildings.

ATC-21-T: The report, *Rapid Visual Screening of Buildings for Potential Seismic Hazards Training Manual Second Edition,* was developed under a contract with FEMA. Available through the ATC office. (Published 2004, 148 pages and PowerPoint presentation on companion CD)

ABSTRACT: This training manual and CD is intended to facilitate the presentation of the contents of the FEMA 154 report (*Second Edition*). The training materials consist of 120 slides in PowerPoint™ format and a companion training presentation narrative coordinated with the presentation. Topics covered include: description of procedure, building behavior, building types, building scores, occupancy and falling hazards, and implementation.

ATC-22: The report, *A Handbook for Seismic Evaluation of Existing Buildings (Preliminary)*, was developed under a contract from FEMA. (Originally published in 1989; revised by BSSC and published as FEMA 178: *NEHRP Handbook for the Seismic Evaluation of Existing Buildings* in 1992, 211 pages; revised by ASCE for FEMA and published as FEMA 310: *Handbook for the Seismic Evaluation of Buildings – a Prestandard* in 1998, 362 pages; revised and published as ASCE 31-03, a standard of the American Society of Civil Engineers, in 2003). Available through ASCE, Reston, Virginia.

ABSTRACT: The ATC-22 handbook provides a methodology for seismic evaluation of existing buildings of different types and occupancies in areas of different seismicity throughout the United States. The methodology, which has been field tested in several programs nationwide, utilizes the information and procedures developed for the ATC-14 report and documented therein. The handbook includes checklists, diagrams, and sketches designed to assist the user.

ATC-22-1: The report, *Seismic Evaluation of Existing Buildings: Supporting Documentation*, was developed under a contract from FEMA. (Published 1989, 160 pages)

ABSTRACT: Included in this report, a companion volume to the ATC-22 report, are (1) a review and evaluation of existing buildings seismic evaluation methodologies; (2) results from field tests of the ATC-14 methodology; and (3) summaries of evaluations of ATC-14 conducted by the National Center for Earthquake Engineering Research (State University of New York at Buffalo) and the City of San Francisco.

ATC-23A: The report, *General Acute Care Hospital Earthquake Survivability Inventory for California, Part A: Survey Description, Summary of Results, Data Analysis and Interpretation*, was developed under a contract from the Office of Statewide Health Planning and Development (OSHPD), State of California. Available through the ATC office. (Published 1991, 58 pages)

ABSTRACT: This report summarizes results from a seismic survey of 490 California acute care hospitals. Included are a description of the survey procedures and data collected, a summary of the data, and an illustrative discussion of data analysis and interpretation that has been provided to demonstrate potential applications of the ATC-23 database.

ATC-23B: The report, *General Acute Care Hospital Earthquake Survivability Inventory for California, Part B: Raw Data*, is a companion document to the ATC-23A Report and was developed under the above-mentioned contract from OSHPD. Available through the ATC office. (Published 1991, 377 pages)

ABSTRACT: Included in this report are tabulations of raw general site and building data for 490 acute care hospitals in California.

ATC-24: The report, *Guidelines for Seismic Testing of Components of Steel Structures*, was jointly funded by the American Iron and Steel Institute (AISI), American Institute of Steel Construction (AISC), National Center for Earthquake Engineering Research (NCEER), and NSF. Available through the ATC office. (Published 1992, 57 pages)

ABSTRACT: This report provides guidance for most cyclic experiments on components of steel structures for the purpose of consistency in experimental procedures. The report contains recommendations and companion commentary pertaining to loading histories, presentation of test results, and other aspects of experimentation. The recommendations are written specifically for experiments with slow cyclic load application.

ATC-25: The report, *Seismic Vulnerability and Impact of Disruption of Lifelines in the Conterminous United States*, was developed under a contract from FEMA. Available through the ATC office. (Published 1991, 440 pages)

ABSTRACT: Documented in this report is a national overview of lifeline seismic vulnerability and impact of disruption. Lifelines considered include electric systems, water systems, transportation systems, gas and liquid fuel supply systems, and emergency service facilities (hospitals, fire and police stations). Vulnerability estimates and impacts developed are presented in terms of estimated first approximation direct damage losses and indirect economic losses.

ATC-25-1: The report, *A Model Methodology for Assessment of Seismic Vulnerability and Impact of Disruption of Water Supply Systems*, was developed under a contract from FEMA. Available through the ATC office. (Published 1992, 147 pages)

ABSTRACT: This report contains a practical methodology for the detailed assessment of seismic vulnerability and impact of disruption of water supply systems. The methodology has been designed for use by water system operators. Application of the methodology enables the user to develop estimates of direct damage to system components and the time required to restore damaged facilities to pre-earthquake usability. Suggested measures for mitigation of seismic hazards are also provided.

ATC-26: This project, U.S. Postal Service National Seismic Program, was funded under a contract with the U.S. Postal Service (USPS). Under this project, ATC developed and submitted to the USPS the following interim documents, most of which pertain to the seismic evaluation and rehabilitation of USPS facilities:

ATC-26 Report, *Cost Projections for the U. S. Postal Service Seismic Program* (completed 1990)

ATC-26-1 Report, *United States Postal Service Procedures for Seismic Evaluation of Existing Buildings (Interim)* (Completed 1991)

ATC-26-2 Report, *Procedures for Post-disaster Safety Evaluation of Postal Service Facilities (Interim)* (Published 1991, 221 pages, available through the ATC office)

ATC-26-3 Report, *Field Manual: Post-earthquake Safety Evaluation of Postal Buildings (Interim)* (Published 1992, 133 pages, available through the ATC office)

ATC-26-3A Report, *Field Manual: Post Flood and Wind Storm Safety Evaluation of Postal Buildings (Interim)* (Published 1992, 114 pages, available through the ATC office)

ATC-26-4 Report, *United States Postal Service Procedures for Building Seismic Rehabilitation (Interim)* (Completed 1992)

ATC-26-5 Report, *United States Postal Service Guidelines for Building and Site Selection in Seismic Areas (Interim)* (Completed 1992)

ATC-28: The report, *Development of Recommended Guidelines for Seismic Strengthening of Existing Buildings, Phase I: Issues Identification and Resolution*, was developed under a contract with FEMA. Available through the ATC office. (Published 1992, 150 pages)

ABSTRACT: This report identifies and provides resolutions for issues that will affect the development of guidelines for the seismic strengthening of existing buildings. Issues addressed include: implementation and format, coordination with other efforts, legal and political, social, economic, historic buildings, research and technology, seismicity and mapping, engineering philosophy and goals, issues related to the development of specific provisions, and nonstructural element issues.

ATC-29: The report, *Proceedings of a Seminar and Workshop on Seismic Design and Performance of Equipment and Nonstructural Elements in Buildings and Industrial Structures*, was developed under a grant from NCEER and NSF. Available through the ATC office. (Published 1992, 470 pages)

ABSTRACT: These Proceedings contain 35 papers describing state-of-the-art technical information pertaining to the seismic design and performance of equipment and nonstructural elements in buildings and industrial structures. The papers were presented at a seminar in Irvine, California in 1990. Included are papers describing current practice, codes and regulations; earthquake performance; analytical and experimental investigations; development of new seismic qualification methods; and research, practice, and code development needs for specific elements and systems. The report also includes a summary of a proposed 5-year research agenda for NCEER.

ATC-29-1: The report, *Proceedings of a Seminar on Seismic Design, Retrofit, and Performance of Nonstructural Components*, was developed under a grant from NCEER and NSF. Available through the ATC office. (Published 1998, 518 pages)

> ABSTRACT: These Proceedings contain 38 technical papers presented at a seminar in San Francisco, California in 1998. The paper topics include: observed performance in recent earthquakes; seismic design codes, standards, and procedures for commercial and institutional buildings; seismic design issues relating to industrial and hazardous material facilities; design analysis, and testing; and seismic evaluation and rehabilitation of conventional and essential facilities, including hospitals.

ATC-29-2: The report, *Proceedings of Seminar on Seismic Design, Performance, and Retrofit of Nonstructural Components in Critical Facilities*, was developed under a grant from MCEER and NSF. Available through the ATC office. (Published 2003, 574 pages)

> ABSTRACT: These Proceedings contain 43 papers presented at a seminar in Newport Beach, California, in 2003. The purpose of the Seminar was to present state-of-the-art technical information pertaining to the seismic design, performance, and retrofit of nonstructural components in critical facilities (e.g., computer centers, hospitals, manufacturing plants with especially hazardous materials, and museums with fragile/valuable collection items). The technical papers address the following topics: current practices and emerging codes; seismic design and retrofit; risk and performance evaluation; system qualification and testing; and advanced technologies.

ATC-30: The report, *Proceedings of Workshop for Utilization of Research on Engineering and Socioeconomic Aspects of 1985 Chile and Mexico Earthquakes*, was developed under a grant from the NSF. Available through the ATC office. (Published 1991, 113 pages)

> ABSTRACT: This report documents the findings of a 1990 technology transfer workshop in San Diego, California, co-sponsored by ATC and the Earthquake Engineering Research Institute. Included in the report are invited papers and working group recommendations on geotechnical issues, structural response issues, architectural and urban design considerations, emergency response planning, search and rescue, and reconstruction policy issues.

ATC-31: The report, *Evaluation of the Performance of Seismically Retrofitted Buildings*, was developed under a contract from the National Institute of Standards and Technology (NIST, formerly NBS) and funded by the USGS. Available through the ATC office. (Published 1992, 75 pages)

> ABSTRACT: This report summarizes the results from an investigation of the effectiveness of 229 seismically retrofitted buildings, primarily unreinforced masonry and concrete tilt-up buildings. All buildings were located in the areas affected by the 1987 Whittier Narrows, California, and 1989 Loma Prieta, California, earthquakes.

ATC-32: The report, *Improved Seismic Design Criteria for California Bridges: Provisional Recommendations,* was funded by the California Department of Transportation (Caltrans). Available through the ATC office. (Published 1996, 215 pages)

> ABSTRACT: This report provides recommended revisions to the then-current *Caltrans Bridge Design Specifications* (BDS) pertaining to

seismic loading, structural response analysis, and component design. Special attention is given to design issues related to reinforced concrete components, steel components, foundations, and conventional bearings. The recommendations are based on recent research in the field of bridge seismic design and the performance of Caltrans-designed bridges in the 1989 Loma Prieta and other recent California earthquakes.

ATC-32-1: The report, *Improved Seismic Design Criteria for California Bridges: Resource Document,* was funded by Caltrans. Available through the ATC office. (Published 1996, 365 pages; also available on CD-ROM)

ABSTRACT: This report, a companion to the ATC-32 Report, documents pertinent background material and the technical basis for the recommendations provided in ATC-32, including potential recommendations that showed some promise but were not adopted. Topics include: design concepts; seismic loading, including ARS design spectra; dynamic analysis; foundation design; ductile component design; capacity protected design; reinforcing details; and steel bridges.

ATC-33: The reports, *NEHRP Guidelines for the Seismic Rehabilitation of Buildings* (FEMA 273), *NEHRP Commentary on the Guidelines for the Seismic Rehabilitation of Buildings* (FEMA 274), and *Example Applications of the NEHRP Guidelines for the Seismic Rehabilitation of Buildings* (FEMA 276), were developed under a contract with the Building Seismic Safety Council, for FEMA. (Published 1997, *Guidelines*, 440 pages; *Commentary*, 492 pages; *Example Applications*, 295 pages.) FEMA 273 and portions of FEMA 274 have been revised by ASCE for FEMA as FEMA 356 *Prestandard and Commentary for the Seismic Rehabilitation of Buildings*. Available through FEMA by contacting 1-800-480-2520 (Published 2000, 509 pages)

ABSTRACT: Developed over a 5-year period through the efforts of more than 60 paid consultants and several hundred volunteer reviewers, these documents provide nationally applicable, state-of-the-art guidance for the seismic rehabilitation of buildings. The FEMA 273 *Guidelines* contain several new features that depart significantly from previous seismic design procedures used to design new buildings: seismic performance levels and rehabilitation objectives; simplified and systematic rehabilitation methods; new linear static and nonlinear static analysis procedures; quantitative specifications of component behavior; and procedures for incorporating new information and technologies, such as seismic isolation and energy dissipation systems, into rehabilitation.

ATC-34: The report, *A Critical Review of Current Approaches to Earthquake Resistant Design***,** was developed under a grant from NCEER and NSF. Available through the ATC office. (Published, 1995, 94 pages)

ABSTRACT: This report documents the history of U. S. codes and standards of practice, focusing primarily on the strengths and deficiencies of current code approaches. Issues addressed include: seismic hazard analysis, earthquake collateral hazards, performance objectives, redundancy and configuration, response modification factors (*R* factors), simplified analysis procedures, modeling of structural components, foundation design, nonstructural component design, and risk and reliability. The report also identifies goals that a new seismic code should achieve.

ATC-35: This report, *Enhancing the Transfer of U.S. Geological Survey Research Results into Engineering Practice* was developed under a cooperative agreement with the USGS. Available through the ATC office. (Published 1994, 120 pages)

ABSTRACT: The report provides a program of recommended "technology transfer" activities for the USGS; included are recommendations pertaining to management actions, communications with practicing engineers, and research activities to enhance development and transfer of information that is vital to engineering practice.

ATC-35-1: The report, *Proceedings of Seminar on New Developments in Earthquake Ground Motion Estimation and Implications for Engineering Design Practice*, was developed under a cooperative agreement with USGS. Available through the ATC office. (Published 1994, 478 pages)

ABSTRACT: These Proceedings contain 22 technical papers describing state-of-the-art information on regional earthquake risk (focused on five specific regions—Northern and Southern California, Pacific Northwest, Central United States, and northeastern North America); new techniques for estimating strong ground motions as a function of earthquake source, travel path, and site parameters; and new developments specifically applicable to geotechnical engineering and the seismic design of buildings and bridges.

ATC-35-2: The report, *Proceedings: National Earthquake Ground Motion Mapping Workshop*, was developed under a cooperative agreement with USGS. Available through the ATC office. (Published 1997, 154 pages)

ABSTRACT: These Proceedings document the technical presentations and findings of a workshop in Los Angeles in 1995 on several key issues that affect the preparation and use of national earthquake ground motion maps for design. The following four key issues were the focus of the workshop: ground motion parameters; reference site conditions; probabilistic versus deterministic basis, and the treatment of uncertainty in seismic source characterization and ground motion attenuation.

ATC-35-3: The report, *Proceedings: Workshop on Improved Characterization of Strong Ground Shaking for Seismic Design,* was developed under a cooperative agreement with USGS. Available through the ATC office. (Published 1999, 75 pages)

ABSTRACT: These Proceedings document the technical presentations and findings of a workshop in Rancho Bernardo, California in 1997 on the Ground Motion Initiative (GMI) component of the ATC-35 Project. The workshop focused on identifying needs and developing improved representations of earthquake ground motion for use in seismic design practice, including codes.

ATC-37: The report, *Review of Seismic Research Results on Existing Buildings***,** was developed in conjunction with the Structural Engineers Association of California and California Universities for Research in Earthquake Engineering under a contract from the California Seismic Safety Commission (SSC). Available through the Seismic Safety Commission as Report SSC 94-03. (Published, 1994, 492 pages)

ABSTRACT: This report describes the state of knowledge of the earthquake performance of nonductile concrete frame, shear wall, and infilled buildings. Included are summaries of 90 recent research efforts with key results and conclusions in a simple, easy-to-access format written for practicing design professionals.

ATC-38: This report, *Database on the Performance of Structures near Strong-Motion Recordings: 1994 Northridge, California, Earthquake*, was developed with funding from the USGS, the Southern California Earthquake Center (SCEC), OES, and the Institute for Business and Home Safety (IBHS). Available through the ATC office. (Published 2000, 260 pages, with CD-ROM containing complete database).

ABSTRACT: The report documents the earthquake performance of 530 buildings within 1000 feet of sites where strong ground motion was recorded during the 1994 Northridge, California, earthquake (31 recording sites in total). The project required the development of a suitable survey form, the training of licensed engineers for the survey, the selection of the surveyed areas, and the entry of the survey data into an electronic relational database. The full database is contained in the ATC-38 CD-ROM. The ATC-38 database includes information on the structure size, age and location; the structural framing system and other important structural characteristics; nonstructural characteristics; geotechnical effects, such as liquefaction; performance characteristics (damage); fatalities and injuries; and estimated time to restore the facility to its pre-earthquake usability. The report and CD also contain strong-motion data, including acceleration, velocity, and displacement time histories, and acceleration response spectra.

ATC-40: The report, *Seismic Evaluation and Retrofit of Concrete Buildings***,** was developed under a contract from the California Seismic Safety Commission. Available through the ATC office. (Published, 1996, 612 pages)

ABSTRACT: This 2-volume report provides a state-of-the-art methodology for the seismic evaluation and retrofit of concrete buildings. Specific guidance is provided on the following topics: performance objectives; seismic hazard; determination of deficiencies; retrofit strategies; quality assurance procedures; nonlinear static analysis procedures; modeling rules; foundation effects; response limits; and nonstructural components. In 1997 this report received the Western States Seismic Policy Council "Overall Excellence and New Technology Award."

ATC-41 (SAC Joint Venture, Phase 1): This project, Program to Reduce the Earthquake Hazards of Steel Moment-Resisting Frame Structures, Phase 1, was funded by FEMA and OES and conducted by a Joint Venture partnership of SEAOC, ATC, and CUREe. Under this Phase 1 program SAC prepared the following documents:

SAC-94-01, *Proceedings of the Invitational Workshop on Steel Seismic Issues, Los Angeles, September 1994* (Published 1994, 155 pages, available through the ATC office)

SAC-95-01, *Steel Moment-Frame Connection Advisory No. 3* (Published 1995, 310 pages, available through the ATC office)

SAC-95-02, *Interim Guidelines: Evaluation, Repair, Modification and Design of Welded Steel Moment-Frame Structures* (FEMA 267 report)

(Published 1995, 215 pages, available through ATC and by calling FEMA: 1-800-480-2520)

SAC-95-03, *Characterization of Ground Motions During the Northridge Earthquake of January 17, 1994* (Published 1995, 179 pages, available through the ATC office)

SAC-95-04, *Analytical and Field Investigations of Buildings Affected by the Northridge Earthquake of January 17, 1994* (Published 1995, 2 volumes, 900 pages, available through the ATC office)

SAC-95-05, *Parametric Analytical Investigations of Ground Motion and Structural Response, Northridge Earthquake of January 17, 1994* (Published 1995, 274 pages, available through the ATC office)

SAC-95-06, *Surveys and Assessment of Damage to Buildings Affected by the Northridge Earthquake of January 17, 1994* (Published 1995, 315 pages, available through the ATC office)

SAC-95-07, *Case Studies of Steel Moment Frame Building Performance in the Northridge Earthquake of January 17, 1994* (Published 1995, 260 pages, available through the ATC office)

SAC-95-08, *Experimental Investigations of Materials, Weldments and Nondestructive Examination Techniques* (Published 1995, 144 pages, available through the ATC office)

SAC-95-09, *Background Reports: Metallurgy, Fracture Mechanics, Welding, Moment Connections and Frame systems, Behavior* (FEMA 288 report) (Published 1995, 361 pages, available through ATC and by calling FEMA: 1-800-480-2520)

SAC-96-01, *Experimental Investigations of Beam-Column Subassemblages, Part 1 and 2* (Published 1996, 2 volumes, 924 pages, available through the ATC office)

SAC-96-02, *Connection Test Summaries* (FEMA 289 report) (Published 1996, available through ATC and by calling FEMA: 1-800-480-2520)

ATC-41-1 (SAC Joint Venture, Phase 2): This project, Program to Reduce the Earthquake Hazards of Steel Moment-Resisting Frame Structures, Phase 2, was funded by FEMA and conducted by a Joint Venture partnership of SEAOC, ATC, and CUREe. Under this Phase 2 program SAC prepared the following documents:

SAC-96-03, *Interim Guidelines Advisory No. 1 Supplement to FEMA 267 Interim Guidelines* (FEMA 267A Report) (Published 1997, 100 pages, and superseded by FEMA-350 to 353.)

SAC-99-01, *Interim Guidelines Advisory No. 2 Supplement to FEMA-267 Interim Guidelines* (FEMA 267B Report, superseding FEMA-267A). (Published 1999, 150 pages, and superseded by FEMA-350 to 353.)

FEMA-350, *Recommended Seismic Design Criteria for New Steel Moment-Frame Buildings*. (Published 2000, 190 pages, available through ATC and by calling FEMA: 1-800-480-2520)

FEMA-351, *Recommended Seismic Evaluation and Upgrade Criteria for Existing Welded Steel Moment-Frame Buildings*. (Published 2000, 210 pages, available through ATC and by calling FEMA: 1-800-480-2520)

FEMA-352, *Recommended Postearthquake Evaluation and Repair Criteria for Welded Steel Moment-Frame Buildings*. (Published 2000, 180 pages, available through ATC and by calling FEMA: 1-800-480-2520)

FEMA-353, *Recommended Specifications and Quality Assurance Guidelines for Steel Moment-Frame Construction for Seismic Applications*. (Published 2000, 180 pages, available through ATC and by calling FEMA: 1-800-480-2520)

FEMA-354, *A Policy Guide to Steel Moment-Frame Construction*. (Published 2000, 27 pages, available through ATC and by calling FEMA: 1-800-480-2520)

FEMA-355A, *State of the Art Report on Base Materials and Fracture*. (Published 2000, 107 pages; available on CD-ROM through ATC and by calling FEMA: 1-800-480-2520. Printed version also available through ATC).

FEMA-355B, *State of the Art Report on Welding and Inspection*. (Published 2000, 185 pages; available on CD-ROM through ATC and by calling FEMA: 1-800-480-2520. Printed version also available through ATC).

FEMA-355C, *State of the Art Report on Systems Performance of Steel Moment Frames Subject to Earthquake Ground Shaking*. (Published 2000, 322 pages; available on CD-ROM through ATC and by calling FEMA:
1-800-480-2520. Printed version also available through ATC).

FEMA-355D, *State of the Art Report on Connection Performance*. (Published 2000, 292 pages; available on CD-ROM through ATC and by calling FEMA: 1-800-480-2520. Printed version also available through ATC).

FEMA-355E, *State of the Art Report on Past Performance of Steel Moment-Frame Buildings in Earthquakes*. (Published 2000, 190 pages; available on CD-ROM through ATC and by calling FEMA: 1-800-480-2520. Printed version also available through ATC).

FEMA-355F, *State of the Art Report on Performance Prediction and Evaluation of Steel Moment-Frame Structures*. (Published 2000, 347 pages; available on CD-ROM through ATC and by calling FEMA: 1-800-480-2520. Printed version also available through ATC).

ATC-43: The reports, *Evaluation of Earthquake-Damaged Concrete and Masonry Wall Buildings, Basic Procedures Manual* (FEMA 306), *Evaluation of Earthquake-Damaged Concrete and Masonry Wall Buildings, Technical Resources* (FEMA 307), and *The Repair of Earthquake Damaged Concrete and Masonry Wall Buildings* (FEMA 308)**,** were developed for FEMA under a contract with the Partnership for Response and Recovery, a Joint Venture of Dewberry & Davis and Woodward-Clyde. Available on CD-ROM through ATC; printed versions available through FEMA by contacting 1-800-480-2520 (Published, 1998, *Evaluation Procedures Manual*, 270 pages; *Technical Resources*, 271 pages, *Repair Document*, 81 pages)

ABSTRACT: Developed by 26 nationally recognized specialists in earthquake engineering, these documents provide field investigation techniques, damage evaluation procedures, methods for performance loss determination, repair guides and recommended repair techniques, and an in-depth discussion of policy issues pertaining to the repair and upgrade of earthquake damaged buildings. The documents have been developed specifically for buildings with primary lateral-force-resisting systems consisting of concrete bearing walls or masonry bearing walls, and vertical-load-bearing concrete frames or steel frames with concrete or masonry infill panels. The intended audience includes design engineers, building owners, building regulatory officials, and government agencies.

ATC-44: The report, *Hurricane Fran, North Carolina, September 5, 1996: Reconnaissance Report*, was funded by the Applied Technology Council. Available through the ATC office. (Published 1997, 36 pages)

ABSTRACT: Written for an intended audience of design professionals and regulators, this report contains information on hurricane size, path, and rainfall amounts; coastal impacts, including storm surges and waves, forces on structures, and the role of erosion; the role of beach nourishment in reducing wave energy and crest height; building code requirements; observations and interpretations of damage to buildings, including the effect of debris acting as missiles; and lifeline performance.

ATC-45: The *Field Manual*, *Safety Evaluation of Buildings After Wind Storms and Floods* was developed with funding from ATC, the ATC Endowment Fund, and the Institute for Business and Home Safety. Available through the ATC office. (Published 2004, 132 pages)

ABSTRACT: The Field Manual provides guidelines and procedures to determine whether damaged or potentially damaged buildings are safe for use after wind storms or floods, or if entry should be restricted or prohibited. Formatted as an easy-to-use pocket guide, the Manual is intended to be used by structural engineers, building inspectors, and others involved in postdisaster building safety assessments. Advice is provided on evaluating structural, geotechnical, and nonstructural risks. Also included are procedures for Rapid Safety Evaluation, procedures for Detailed Safety Evaluation, information on how to deal with owners and occupants of damaged buildings, information on field safety for those making damage assessments, and example applications of the procedures.

ATC-48 (ATC/SEAOC Joint Venture Training Curriculum): The training curriculum, *Built to Resist Earthquakes, The Path to Quality Seismic Design and Construction for Architects, Engineers, and Inspectors*, was developed under a contract with the California Seismic Safety Commission and prepared by a Joint Venture partnership of ATC and SEAOC. Available through the ATC office. (Published 1999, 314 pages)

ABSTRACT: Bound in a three-ring notebook, the curriculum contains training materials pertaining to the seismic design and retrofit of wood-frame buildings, concrete and masonry construction, and nonstructural components. Included are detailed, illustrated, instructional material (lessons) and a series of multi-part Briefing Papers and Job Aids to facilitate improvement in the quality of seismic design, inspection, and construction.

ATC-49: The 2-volume report, *Recommended LRFD Guidelines for the Seismic Design of Highway Bridges; Part I: Specifications* and *Part II: Commentary and Appendices*, were developed under the ATC/MCEER Joint

Venture partnership with funding from the Federal Highway Administration. Available through the ATC office. (Published 2003, *Part I*, 164 pages and *Part II*, 294 pages)

ABSTRACT: The Recommended Guidelines are based on significant enhancements in the state of knowledge and state of practice resulting from research investigations and lessons learned from earthquakes over the last 15 years. The Guidelines consist of specifications, commentary, and appendices developed to be compatible with the existing load-and-resistance-factor design (LRFD) provisions for highway bridges published by the American Association of State Highway and Transportation Officials (AASHTO). The new, updated, provisions are nationally applicable and cover all seismic zones, as well as all bridge construction types and materials. They reflect the latest design philosophies and design approaches that will result in highway bridges with a high level of seismic performance.

ATC-49-1: The document, *Liquefaction Study Report, Recommended LRFD Guidelines for the Seismic Design of Highway Bridges,* was developed under the ATC/MCEER Joint Venture partnership with funding from the Federal Highway Administration. Available through the ATC office. (Published 2003, 208 pages)

ABSTRACT: This report documents a comprehensive study of the effects of liquefaction and the associated hazards — lateral spreading and flow. It contains detailed discussions on: (1) recommended procedures to evaluate liquefaction potential and lateral spread effects; (2) ground mitigation design approaches and procedures to evaluate the beneficial effects of pile pinning in straining lateral spread; (3) study results from two bridge sites (one in the western U. S. and one in the central U. S.) that provide an assessment of liquefaction effects based on several types of analyses; an assessment of implications of predicted lateral spread/flow using a pushover-type analysis; and development and evaluation of structural and/or geotechnical mitigation alternatives; and (4) study conclusions, including cost implications.

ATC-49-2: The report, *Design Examples, Recommended LRFD Guidelines for the Seismic Design of Highway Bridges*, was developed under the ATC/MCEER Joint Venture partnership with funding from the Federal Highway Administration. Available through the ATC office. (Published 2003, 316 pages)

ABSTRACT: The report contains two design examples that illustrate use of the *Recommended LRFD Guidelines for the Seismic Design of Highway Bridges*. These design examples are the eighth and ninth in a series originally developed for the Federal Highway Administration (FHWA) to illustrate the use of the American Association of State Highway and Transportation Officials (AASHTO) Division 1-A Standard Specifications for Highway Bridges. The design examples contain flow charts and detailed step-by-step procedures, including: preliminary design; basic requirements; determination of seismic design and analysis procedure; determination of elastic seismic forces and displacements; determination of design forces; design displacements and checks; design of structural components; design of foundations; design of abutments; and consideration of liquefaction.

ATC-51: The report, *U.S.-Italy Collaborative Recommendations for Improved Seismic Safety of Hospitals in Italy*, was developed under a contract with Servizio Sismico Nazionale of Italy (Italian National Seismic Survey). Available through the ATC office. (Published 2000, 154 pages)

ABSTRACT: Developed by a 14-person team of hospital seismic safety specialists and regulators from the United States and Italy, the report provides an overview of hospital seismic risk in Italy; six recommended short-term actions and four recommended long-term actions for improving hospital seismic safety in Italy; and supplemental information on (a) hospital seismic safety regulation in California, (b) requirements for nonstructural components in California and for buildings regulated by the Office of U. S. Foreign Buildings, and (c) current seismic evaluation standards in the United States.

ATC-51-1: The report, *Recommended U.S.-Italy Collaborative Procedures for Earthquake Emergency Response Planning for Hospitals in Italy*, was developed under a contract with Servizio Sismico Nazionale of Italy (Italian National Seismic Survey, NSS). Available in English and Italian through the ATC office. (Published 2002, 120 pages)

ABSTRACT: The report addresses one of the short-term recommendations — planning for emergency response and postearthquake inspection — made in the first phase of the ATC-51 project. The report contains: (1) descriptions of current procedures and concepts for emergency response planning in the United States and Italy, (2) an overview of relevant procedures for both countries for evaluating and predicting the seismic vulnerability of buildings, including procedures for postearthquake inspection, (3) recommended procedures for earthquake emergency response planning and postearthquake assessment of hospitals, to be implemented through the use of a Postearthquake Inspection Notebook and demonstrated through the application on two representative hospital facilities; and (4) recommendations for emergency response training, postearthquake inspection training, and the mitigation of seismic hazards.

ATC-51-2: The report, *Recommended U.S.-Italy Collaborative Guidelines for Bracing and Anchoring Nonstructural Components in Italian Hospitals*, was developed under a contract with the Department of Civil Protection, Italy. Available in English and Italian through the ATC office. (Published 2003, 164 pages)

ABSTRACT: The report supports one of the short-term recommendations — implement bracing and anchorage for new installations of nonstructural components — made in the first phase of the ATC-51 project. The report contains: (1) technical background information, including an overview of nonstructural component damage in prior earthquakes;(2) generalized recommendations for assessment of nonstructural components and recommended performance objectives and requirements; (3) specific recommendations pertaining to twenty-seven different types of nonstructural components; (4) design examples that illustrate in detail how a structural engineer evaluates and designs the retrofit of a nonstructural component; (5) additional seismic design considerations for nonstructural components; and (6) guidance pertaining to the design and selection of devices for seismic anchorage.

ATC-52: The project, "Development of a Community Action Plan for Seismic Safety (CAPSS), City and County of San Francisco", was conducted under a contract with the San Francisco Department of Building Inspection. Under Phase I, completed in 2000, ATC defined the tasks to be conducted under Phase II, a multi-year ATC effort that commenced in 2001. The Phase II tasks include: (1) development of a reliable estimate of the size and nature of the impacts a large earthquake will have on San Francisco; (2) development of technically sound consensus-based guidelines for the evaluation and repair of San Francisco's most vulnerable building types; and (3) identification, definition, and ranking of other activities to reduce the seismic risks in the City and County of San Francisco.

ATC-53: The report, *Assessment of the NIST 12-Million-Pound (53 MN) Large-Scale Testing Facility*, was developed under a contract with NIST. Available through the ATC office. (Published 2000, 44 pages)

> ABSTRACT: This report documents the findings of an ATC Technical Panel engaged to assess the utility and viability of a 30-year-old, 12-million pound (53 MN) Universal Testing Machine located at NIST headquarters in Gaithersburg, Maryland. Issues addressed include: (a) the merits of continuing operation of the facility; (b) possible improvements or modifications that would render it more useful to the earthquake engineering community and other potential large-scale structural research communities; and (c) identification of specific research (seismic and non-seismic) that might require the use of this facility in the future.

ATC-54: The report, *Guidelines for Using Strong-Motion Data and ShakeMaps in Postearthquake Response*, was developed under a contract with the California Geological Survey. Available through the ATC office. (Published 2005, 222 pages)

> ABSTRACT: The report addresses two main topics: (1) effective means for using computer-generated ground motion maps (ShakeMaps) in postearthquake emergency response; and (2) procedures for rapidly evaluating (on a near-real-time basis) strong-motion data from ground sites and instrumented buildings, bridges, and dams to determine the potential for earthquake-induced damage in those structures. The document also provides guidance on the form, type, and extent of data to be collected from structures in the vicinity of strong-motion recordings, and pertinent supplemental information, including guidance on replacement of strong-motion instruments in/on and near buildings, bridges, and dams.

ATC-55: The report, FEMA 440, *Improvement of Nonlinear Static Seismic Analysis Procedures*, was developed under a contract with FEMA. Available through FEMA or the ATC office. (Published 2005, 152 pages)

> ABSTRACT: The report presents the results of a four year study carried out to develop guidelines for improved application of the Coefficient Method, as detailed in the FEMA-356 *Prestandard and Commentary for the Seismic Rehabilitation of Buildings,* and the Capacity Spectrum Method, as detailed in the ATC-40 Report, *Seismic Evaluation and Retrofit of Concrete Buildings*. The report also addresses improved application of nonlinear static analysis procedures in general, including new procedures for incorporating soil-structure interaction effects, and options for addressing multiple-degree-of-freedom effects. An example application of the recommended nonlinear static analysis procedures is

included to illustrate use of the procedures in estimating the maximum displacement of a model building.

ATC-56: The report, FEMA 389, *Primer for Design Professionals: Communicating with Owners and Managers of New Buildings on Earthquake Risk*, was developed under a contract with FEMA. Available through FEMA or the ATC office. (Published 2004, 194 pages)

ABSTRACT: The report has been developed to facilitate the process of educating building owners and managers about seismic risk management tools that can be effectively and economically employed by them during the building development phase—from site selection through design and construction—as well as the operational phase. Written principally for design professionals (architects and structural engineers), the document introduces and discusses (1) seismic risk management and the means to develop a risk management plan; (2) guidance for identifying and assessing earthquake-related hazards during the site selection process; (3) emerging concepts in performance-based seismic design; and (4) seismic design and performance issues related to six specific building occupancies—commercial office facilities, commercial retail facilities, light manufacturing facilities, healthcare facilities, local schools (kindergarten through grade 12), and higher education facilities (universities).

ATC-56-1: The report, FEMA 427, *Primer for Design of Commercial Buildings to Mitigate Terrorist Attacks – Providing Protection to People and Buildings*, was developed under a contract with FEMA. Available through FEMA or the ATC office. (Published 2003, 106 pages)

ABSTRACT: The report provides guidance to building designers, owners and state and local governments to mitigate the effects of hazards resulting from terrorist attacks on new buildings. While the guidance provided focuses principally on explosive attacks and design strategies to mitigate the effects of explosions, the document also addresses design strategies to mitigate the effects of chemical, biological and radiological attacks. Qualitative discussions are provided on the following topics: terrorist threats; weapons effects, building damage, design approach, design guidance, occupancy types, and cost considerations.

ATC-57: The report, *The Missing Piece: Improving Seismic Design and Construction Practices*, was developed under a contract with NIST. Available through the ATC office. (Published 2003, 102 pages)

ABSTRACT: The report was developed to provide a framework for eliminating the technology transfer gap that has emerged within the National Earthquake Hazards Reduction Program (NEHRP) that limits the adaptation of basic research knowledge into practice. The report defines a much-expanded problem-focused knowledge development, synthesis and transfer program to improve seismic design and construction practices. Two subject areas, with a total of five Program Elements, are proposed: (1) systematic support of the seismic code development process; and (2) improve seismic design and construction productivity.

ATC-58: This project, *Development of Next-Generation Performance-Based Seismic Design Guidelines for New and Existing Buildings*, is a multi-year, multi-phase effort funded by FEMA. Reports prepared under this project include:

FEMA 445, *Next-Generation Performance-Based Seismic Design Guidelines, Program Plan for New and Existing Buildings*. (Published 2006, 131 pages, available through FEMA or the ATC office). This Program Plan offers background on current code design procedures, introduces performance-based seismic design concepts, identifies improvements needed in current seismic design practice, and outlines the tasks and projected costs for a two-phase program to develop next-generation performance-based seismic design procedures and guidelines.

FEMA 461, *Interim Testing Protocols for Determining the Seismic Performance Characteristics of Structural and Nonstructural Components* (Published 2007, 113 pages, available through FEMA or the ATC office). Two interim protocol types are provided in this document: Interim Protocol I, Quasi-Static Cyclic Testing, which should be used for the determination of performance characteristics of components whose behavior is primarily controlled by the application of seismic forces or seismic-induced displacements; and Interim Protocol II, Shake Table Testing, which should be used to assess performance characteristics of components whose behavior is affected by the dynamic response of the component itself, or whose behavior is velocity sensitive, or sensitive to strain-rate effects.

ATC-60: The 2-volume report, *SEAW Commentary on Wind Code Provisions, Volume 1* and *Volume 2 - Example Problems,* was developed by the Structural Engineers Association of Washington (SEAW) and edited and published by the Applied Technology Council. (ATC). Available through the ATC office. (Published 2004; *Volume 1*, 238 pages; *Volume 2*, 245 pages)

ABSTRACT: Written for designers, building code officials, instructors and anyone who designs and/or analyzes structures for wind, this report provides commentary on the wind provisions in the 2000 and 2003 editions of the *International Building Code* (IBC), and the 1998 and 2002 editions of ASCE Standard No. 7, *Minimum Design Loads for Buildings and Other Structures*. Volume 1 contains the main body of the commentary, including a technical and historic overview of wind codes and discussions on a broad range of topics: basic wind speed; importance factors; exposure and topographic effects; gust response; design for wind pressures on main wind-force-resisting systems; wind pressures on components and cladding of structures; glass and glazing; prescriptive provisions; miscellaneous and non-building structures; unusual wind loading configurations; high winds, hurricanes, and tornadoes; serviceability; wind tunnel tests applied to design practice; and wind design of equipment and non-building systems. Volume 2 consists of appendices containing over a dozen example problems with solutions.

ATC-74: The report, *Collaborative Recommended Requirements for Automatic Natural Gas Shutoff Valves in Italy*, was developed under a contract with the Department of Civil Protection, Italy. Available through the ATC office and web site. (Published 2007, 76 pages)

ABSTRACT: The report addresses issues related to the use in Italy of earthquake actuated automatic gas shutoff devices meeting U. S. standards. The report describes (1) the specific requirements in the then current Italian seismic code related to natural gas installations; (2) the development of requirements in the ASCE 25-97 Standard, *Earthquake-Actuated Automatic Gas Shutoff Devices*; (3) U. S. approaches to assuring adequate natural gas safety in earthquakes; (4) background information for assessing issues related to the adoption of ASCE 25-97 as a standard for earthquake actuated automatic gas shutoff devices in Italy; and (5) recommendations pertaining to new Italian seismic code provisions; reducing existing post-earthquake fire risk; valve qualification procedures; multi-story buildings (higher than three stories); and existing seismically vulnerable buildings.

ATC-R-1: The report, *Cyclic Testing of Narrow Plywood Shear Walls,* was developed with funding from the Henry J. Degenkolb Memorial Endowment Fund of the Applied Technology Council. Available through the ATC office. (Published 1995, 64 pages)

ABSTRACT: This report documents ATC's first self-directed research program: a series of static and dynamic tests of narrow plywood wall panels having the standard 3.5-to-1 height-to-width ratio and anchored to the sill plate using typical bolted, 9-inch, 5000-lb. capacity hold-down devices. The report provides a description of the testing program and a summary of results, including comparisons of drift ratios found during testing with those specified in the seismic provisions of the 1991 *Uniform Building Code*. The report served as a catalyst for changes in code-specified aspect ratios for narrow plywood wall panels and for new thinking in the design of hold-down devices. It also stimulated widespread interest in laboratory testing of wood-frame structures.

ATC Design Guide 1: The report, *Minimizing Floor Vibration***,** was developed with funding from ATC's Henry J. Degenkolb Memorial Endowment Fund. Available through the ATC office. (Published, 1999, 64 pages)

ABSTRACT: Design Guide 1 provides guidance on design and retrofit of floor structures to limit transient vibrations to acceptable levels. The document includes guidance for estimating floor vibration properties and example calculations for a variety of currently used floor types and designs. The criteria for acceptable levels of floor vibration are based on human sensitivity to the vibration, whether it is caused by human behavior or machinery in the structure.

ATC TechBrief 1: The ATC TechBrief 1, *Liquefaction Maps*, was developed under a contract with the United States Geological Survey. Available through the ATC office. (Published 1996, 12 pages)

ABSTRACT: The technical brief inventories and describes the available regional liquefaction hazard maps in the United States and gives information on how to obtain them.

ATC TechBrief 2: The ATC TechBrief 2, *Earthquake Aftershocks − Entering Damaged Buildings*, was developed under a contract with the United States Geological Survey. Available through the ATC office. (Published 1996, 12 pages)

ABSTRACT: The technical brief offers guidelines for entering damaged buildings under emergency conditions during the first hours and days after the initial damaging event.

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