1. Introduction

1.1 Purpose

The primary purpose of this document is to provide technically sound and nationally acceptable guidelines for the seismic rehabilitation of buildings. The *Guidelines for the Seismic Rehabilitation of Buildings* are intended to serve as a ready tool for design professionals, a reference document for building regulatory officials, and a foundation for the future development and implementation of building code provisions and standards.

This document consists of two volumes. The *Guidelines* volume details requirements and procedures, which the *Commentary* volume explains. A companion volume titled *Example Applications* contains information on typical deficiencies, rehabilitation costs, and other useful explanatory information.

This document is intended for a primary user group of architects, engineers, and building officials, specifically those in the technical community responsible for developing and using building codes and standards, and for carrying out the design and analysis of buildings. Parts of the document will also be useful and informative to such secondary audiences beyond the technical community as building owners, government agencies, and policy makers.

The engineering expertise of a design professional is a prerequisite to the appropriate use of the *Guidelines*, and most of the provisions of the following chapters presume the expertise of a professional engineer experienced in building design, as indicated in specific references to “the engineer” found extensively throughout this document.

An engineer can use this document to help a building owner select seismic protection criteria when the owner’s risk reduction efforts are purely voluntary. The engineer can also use the document for the design and analysis of seismic rehabilitation projects. However, this document should not be considered to be a design manual, textbook, or handbook. Notwithstanding the instructional examples and explanations found in the *Commentary* and *Example Applications* volume, other supplementary information and instructional resources may well be required to use this document appropriately.

This document is neither a code nor a standard. It is intended to be suitable both for voluntary use by owners and design professionals as well as for adaptation and adoption into model codes and standards. Conversion of material from the *Guidelines* into a code or standard will require, as a minimum, a) careful study as to the applicability of acceptance criteria to the specific situation and building type, b) reformatting into code language, c) the addition of rules of applicability or “triggering” policies, and d) modification or addition of requirements relating to specific building department operations within a given jurisdiction.

See Section 1.3 for important descriptions of the scope and limitations of this document.

1.2 Significant New Features

This document contains several new features that depart significantly from previous seismic design procedures used to design new buildings.

1.2.1 Seismic Performance Levels and Rehabilitation Objectives

Methods and design criteria to achieve several different levels and ranges of seismic performance are defined. The four Building Performance Levels are Collapse Prevention, Life Safety, Immediate Occupancy, and Operational. (The Operational Level is defined, but specification of complete design criteria is not included in the *Guidelines*. See Chapter 2.) These levels are discrete points on a continuous scale describing the building’s expected performance, or alternatively, how much damage, economic loss, and disruption may occur.

Each Building Performance Level is made up of a Structural Performance Level that describes the limiting damage state of the structural systems and a Nonstructural Performance Level that describes the limiting damage state of the nonstructural systems. Three Structural Performance Levels and four Nonstructural Performance Levels are used to form the four basic Building Performance Levels listed above.

In addition, two ranges of structural performance are defined to provide a designation for unique rehabilitations that may be intended for special purposes and therefore will fall between the rather

Building Performance Levels and Ranges

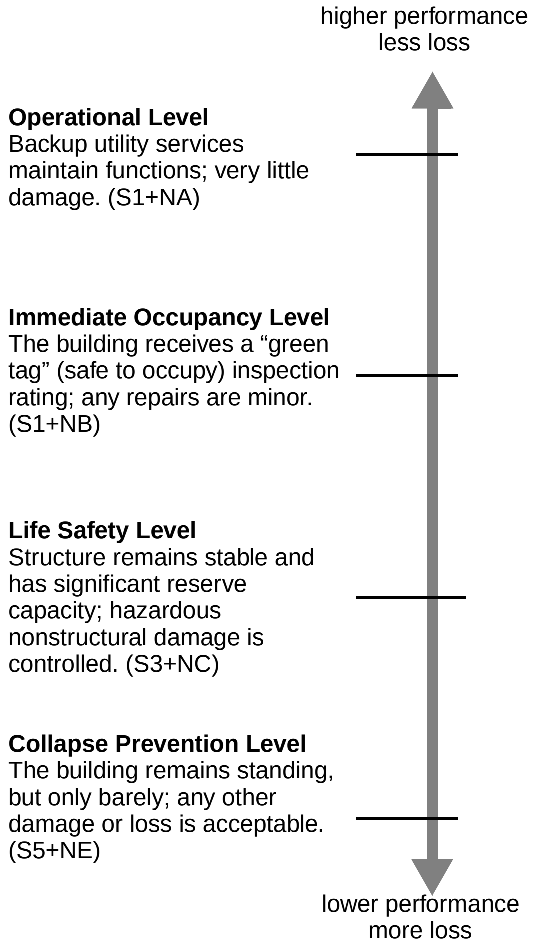
Performance Level: the intended post-earthquake condition of a building; a well-defined point on a scale measuring how much loss is caused by earthquake damage. In addition to casualties, loss may be in terms of property and operational capability.

Performance Range: a range or band of performance, rather than a discrete level.

Designations of Performance Levels and Ranges: Performance is separated into descriptions of damage of structural and nonstructural systems; structural designations are S-1 through S-5 and nonstructural designations are N-A through N-D.

Building Performance Level: The combination of a Structural Performance Level and a Nonstructural Performance Level to form a complete description of an overall damage level.

Rehabilitation Objective: The combination of a Performance Level or Range with Seismic Demand Criteria.



well-defined structural levels. Other structural and nonstructural categories are included to describe a wide range of seismic rehabilitation intentions. In fact, one of the goals of the performance level system employed in this document is to enable description of all performance objectives previously designated in codes and standards and most objectives used in voluntary rehabilitation efforts.

The three Structural Performance Levels and two Structural Performance Ranges consist of:

- S-1: Immediate Occupancy Performance Level
- S-2: Damage Control Performance Range (extends between Life Safety and Immediate Occupancy Performance Levels)
- S-3: Life Safety Performance Level
- S-4: Limited Safety Performance Range (extends between Life Safety and Collapse Prevention Performance Levels)
- S-5: Collapse Prevention Performance Level

In addition, there is the designation of S-6, Structural Performance Not Considered, to cover the situation where only nonstructural improvements are made.

The four Nonstructural Performance Levels are:

- N-A: Operational Performance Level
- N-B: Immediate Occupancy Performance Level
- N-C: Life Safety Performance Level
- N-D: Hazards Reduced Performance Level

In addition, there is the designation of N-E, Nonstructural Performance Not Considered, to cover the situation where only structural improvements are made.

A description of "what the building will look like after the earthquake" raises the questions: Which earthquake? A small one or a large one? A minor-to-moderate degree of ground shaking severity at the site where the building is located, or severe ground motion? Ground shaking criteria must be selected, along with a desired Performance Level or Range, for the *Guidelines* to be applied; this can be done either by reference to standardized regional or national ground shaking hazard maps, or by site-specific studies.

Once a desired Building Performance Level for a particular ground shaking severity (seismic demand) is selected, the result is a Rehabilitation Objective (see Section 1.5.1.3 for a detailed discussion). With the exception of the Basic Safety Objective (BSO), there are no preset combinations of performance and ground shaking hazard. The Basic Safety Objective is met when a building can satisfy two criteria: (1) the Life Safety Building Performance Level, which is the combination of the Structural and Nonstructural Life Safety Performance Levels, for the Basic Safety Earthquake 1 (BSE-1), and (2) the Collapse Prevention Performance Level, which only pertains to structural performance, for the stronger shaking that occurs less frequently as defined in the Basic Safety Earthquake 2 (BSE-2). One or more of these two levels of earthquake motion may be used in the design process to meet other Rehabilitation Objectives as well, but they have been selected as the required ground shaking criteria for the BSO. While the margin against failure may be smaller and the reliability less, the primary goal of the BSO is to provide a level of safety for rehabilitated buildings similar to that of buildings recently designed to US seismic code requirements. In fact, the strongest argument for using similar ground motions to those used for new buildings is to enable a direct comparison of expected performance. It should be remembered, however, that economic losses from damage are not explicitly considered in the BSO, and these losses in rehabilitated existing buildings should be expected to be larger than in the case of a newly constructed building.

Using various combinations of Performance Levels and ground shaking criteria, many other Rehabilitation Objectives can be defined. Those objectives that exceed the requirements for the BSO, either in terms of Performance Level, ground shaking criteria, or both, are termed Enhanced Objectives, and similarly, those that fail to meet some aspect of the BSO are termed Limited Objectives.

1.2.2 Simplified and Systematic Rehabilitation Methods

Simplified Rehabilitation may be applied to certain small buildings specified in the *Guidelines*. The primary intent of Simplified Rehabilitation is to reduce seismic risk efficiently where possible and appropriate by seeking Limited Objectives. Partial rehabilitation measures, which target high-risk building deficiencies such as parapets and other exterior falling hazards, are included as Simplified Rehabilitation techniques. Although limited in scope, Simplified Rehabilitation will be applicable to a large number of buildings throughout the US. The Simplified Rehabilitation Method employs equivalent static force analysis procedures, which are found in most seismic codes for new buildings.

Systematic Rehabilitation may be applied to any building and involves thorough checking of each existing structural element or component (an element such as a moment-resisting frame is composed of beam and column components), the design of new ones, and verification of acceptable overall interaction for expected displacements and internal forces. The Systematic Rehabilitation Method focuses on the nonlinear behavior of structural response, and employs procedures not previously emphasized in seismic codes.

1.2.3 Varying Methods of Analysis

Four distinct analytical procedures can be used in Systematic Rehabilitation: Linear Static, Linear Dynamic, Nonlinear Static, and Nonlinear Dynamic Procedures. The choice of analytical method is subject to limitations based on building characteristics. The linear procedures maintain the traditional use of a linear stress-strain relationship, but incorporate adjustments to overall building deformations and material acceptance criteria to permit better consideration of the probable nonlinear characteristics of seismic response. The Nonlinear Static Procedure, often called “pushover analysis,” uses simplified nonlinear techniques to estimate seismic structural deformations. The Nonlinear Dynamic Procedure, commonly known as nonlinear time history analysis, requires considerable judgment and experience to perform, and may only be used within the limitations described in Section 2.9.2.2 of the *Guidelines*.

1.2.4 Quantitative Specifications of Component Behavior

Inherent in the concept of Performance Levels and Ranges is the assumption that performance can be measured using analytical results such as story drift ratios or strength and ductility demands on individual components or elements. To enable structural verification at the selected Performance Level, stiffness, strength, and ductility characteristics of many common elements and components have been derived from laboratory tests and analytical studies and put in a standard format in the *Guidelines*.

1.2.5 Procedures for Incorporating New Information and Technologies into Rehabilitation

It is expected that testing of existing materials and elements will continue and that additional corrective measures and products will be developed. It is also expected that systems and products intended to modify structural response beneficially will be advanced. The format of the analysis techniques and acceptability criteria of the *Guidelines* allows rapid incorporation of such technology. Section 2.13 gives specific guidance in this regard. It is expected that the *Guidelines* will have a significant impact on testing and documentation of existing materials and systems as well as new products. In addition, an entire chapter (Chapter 9) has been devoted to two such new technologies, seismic isolation and energy dissipation.

1.3 Scope, Contents, and Limitations

This section describes the scope and limitations of the contents of this document pertaining to the following:

- buildings and loadings
- activities and policies associated with seismic rehabilitation
- seismic mapping
- technical content

1.3.1 Buildings and Loadings

This document is intended to be applied to all buildings—regardless of importance, occupancy, historic features, size, or other characteristics—that by some criteria are deficient in their ability to resist the effects of earthquakes. In addition to the direct effects of ground shaking, this document also considers the effects on buildings of local ground failure such as liquefaction. With careful extrapolation, the procedures herein can also be applied to many nonbuilding structures such as pipe racks, steel storage racks, structural towers for tanks and vessels, piers, wharves, and electrical power generating facilities. The applicability of the procedures has not been examined for each and every structural type, particularly those that have generally been covered by their own codes or standards, such as bridges and nuclear power plants. It is important to note that, as written, the provisions are not intended to be mandatory. Careful consideration of the applicability to any given group of buildings or structures should be made prior to adoption of any portion of these procedures for mandatory use.

This document applies to the seismic resistance of both the overall structural system of a building and its elements—such as shear walls or frames—and the constituent components of elements, such as a column in a frame or a boundary member in a wall. It also applies to nonstructural components of existing buildings—ceilings, partitions, and mechanical/ electrical systems. In addition to techniques for increasing strength and ductility of systems, this document provides rehabilitation techniques for reducing seismic demand, such as the introduction of isolation or damping devices. And, although this document is not intended to address the design of new buildings, it does cover new components or elements to be added to existing buildings. Evaluation of components for gravity and wind forces in the absence of earthquake demands is beyond the scope of the document.

1.3.2 Activities and Policies Associated with Seismic Rehabilitation

There are several significant steps in the process of reducing seismic risk in buildings that this document does not encompass. The first step, deciding whether or not to undertake a rehabilitation project for a particular building, is beyond the scope of the *Guidelines*. Once the decision to rehabilitate a building has been made, the *Guidelines'* detailed engineering guidance on how to conduct seismic rehabilitation analysis can be applied.

Another step, determining when the *Guidelines* should be applicable in a mandatory way to a remodeling or structural alteration project (the decision as to when the provisions are "triggered"), is also beyond the scope of this document. Finally, methods of reducing seismic risk that do not physically change the building—such as reducing the number of occupants—are not covered here.

Recommendations regarding the selection of a Rehabilitation Objective for any building are also beyond the scope of this document. As noted above, a life safety risk often considered acceptable, is defined by a specific objective, termed the Basic Safety Objective (BSO). Higher and lower objectives can also be defined by the user. The *Commentary* discusses issues to consider when combining various performance and seismic hazard levels; it should be noted that not all combinations constitute reasonable or cost-effective Rehabilitation Objectives. The *Guidelines* were written under the premise that greater flexibility is required in seismic rehabilitation than in the design of new buildings. However, even with the flexibility provided by various Rehabilitation Objectives, once a Rehabilitation Objective is decided upon, the *Guidelines* provide internally consistent procedures that include the necessary analysis and construction specifications.

Featured in the *Guidelines* are descriptions of damage states with relation to specific Performance Levels. These descriptions are intended to aid design professionals and owners when selecting appropriate Performance Levels for rehabilitation design. They are not intended to be used directly for condition assessment of earthquake-damaged buildings. Although there are similarities in damage descriptions that are used for selection of rehabilitation design criteria and descriptions used for post-earthquake damage assessment, many factors enter into the design and assessment processes. No single parameter should be cited as defining either a Performance Level or the safety or usefulness of an earthquake-damaged building.

Techniques of repair for earthquake-damaged buildings are not included in the *Guidelines*. However, if the mechanical properties of repaired components are known, acceptability criteria for use in this document can be either deduced by comparison with other similar components, or derived. Any combination of repaired elements, undamaged existing elements, and new elements can be modeled using this document, and each checked against Performance Level acceptance criteria.

Although the *Guidelines* were not written for the purpose of evaluating the expected performance of an unrehabilitated existing building, they may be used as a reference for evaluation purposes in deciding whether a building requires rehabilitation, similarly to the way code provisions for new buildings are sometimes used as an evaluation tool.

1.3.3 Seismic Mapping

Special or new mapping of expected seismic ground shaking for the country has not been developed for the *Guidelines*. However, new national earthquake hazard maps were developed in 1996 by the United States Geological Survey (USGS) as part of a joint project (known as Project ’97) with the Building Seismic Safety Council to update the 1997 *NEHRP Recommended Provisions* for new buildings. National probabilistic maps were developed for ground motions with a 10% chance of exceedance in 50 years, a 10% chance of exceedance in 100 years (which can also be expressed as a 5% chance of exceedance in 50 years) and a 10% chance of exceedance in 250 years (which also can be expressed as a 2% chance of exceedance in 50 years). These probabilities correspond to motions that are expected to occur, on average, about once every 500, 1000, and 2500 years. In addition, in certain locations with well-defined earthquake sources, local ground motions for specific earthquakes were developed, known as deterministic motions. Key ordinates of a ground motion response spectrum for these various cases allow the user to develop a complete spectrum at any site. The *Guidelines* are written to use such a response spectrum as the seismic demand input for the various analysis techniques.

The responsibility of the Building Seismic Safety Council in Project ’97 was to develop a national map and/or analytical procedure to best utilize the new seismic hazard information for the design of new buildings. As part of that process, rules were developed to combine portions of both the USGS probabilistic and deterministic maps to create a map of ground motions representing the effects of large, rare events in all parts of the country. This event is called the Maximum Considered Earthquake (MCE). New buildings are to be designed, with traditional design rules, for two-thirds of these ground motion values with the purpose of providing an equal margin against collapse for the varied seismicity across the country.

For consistency in this document, ground motion probabilities will be expressed with relationship to 50-year exposure times, and in a shorthand format; i.e., 10%/50 years is a 10% chance of exceedance in 50 years, 5%/50 years is a 5% chance of exceedance in 50 years, and 2%/50 years is a 2% chance of exceedance in 50 years.

The variable Rehabilitation Objectives featured in the *Guidelines* allows consideration of any ground motion that may be of interest, the characteristics of which can be determined specifically for the site, or taken from a national or local map. However, specifically for use with the BSO, and generally for convenience in defining the ground motion for other Rehabilitation Objectives, the 10%/50 year probabilistic maps and the MCE maps developed in Project 97 are in the map package distributed with the *Guidelines*. For additional map packages, call FEMA at 1-800-480-2520.

New ground motion maps specifically related to the seismic design procedures of the 1997 *NEHRP Recommended Provisions* are expected to be available. These maps plot key ordinates of a ground motion response spectrum, allowing development by the user of a complete spectrum at any site. The *Guidelines* are written to use such a response spectrum as the seismic demand input for the various analysis techniques. While the NEHRP maps provide a ready source for this type of information, the *Guidelines* may be used with seismic hazard data from any source as long as it is expressed as a response spectrum.

1.3.4 Technical Content

The *Guidelines* have been developed by a large team of specialists in earthquake engineering and seismic rehabilitation. The most advanced analytical techniques that were considered practical for production use have been incorporated, and seismic Performance Level criteria have been specified using actual laboratory test results, where available, supplemented by the engineering judgment of the various development teams. Certain buildings damaged in the 1994 Northridge earthquake and a limited number of designs using codes for new buildings have been checked with the procedures of this document. There has not yet been the opportunity, however, for comprehensive comparisons with other codes and standards, nor for evaluation of the accuracy in predicting the damage level under actual earthquake ground motions. As of this writing (1997), significant case studies are already underway to test more thoroughly the various analysis techniques and acceptability criteria. There undoubtedly will also be lessons learned from future damaging earthquakes by studying performance of both unrehabilitated buildings and buildings rehabilitated to these or other standards. A structured program will also be instituted to gather and assess the new knowledge relevant to the data, procedures, and criteria contained in the *Guidelines*, and make recommendations for future refinements. Engineering judgment should be exercised in determining the applicability of various analysis techniques and material acceptability criteria in each situation. It is suggested that results obtained for any individual building be validated by additional checks using alternative methodologies and careful analysis of any differences. Information contained in the *Commentary* will be valuable for such individual validation studies.

The concepts and terminology of performance-based design are new and should be carefully studied and discussed with building owners before use. The terminology used for Performance Levels is intended to represent *goals* of design. The actual ground motion will seldom be comparable to that specified in the Rehabilitation Objective, so in most events, designs targeted at various damage states may only determine relative performance. Even given a ground motion similar to that specified in the Rehabilitation Objective and used in design, variations from stated performances should be expected. These could be associated with unknown geometry and member sizes in existing buildings, deterioration of materials, incomplete site data, variation of ground motion that can occur within a small area, and incomplete knowledge and simplifications related to modeling and analysis. Compliance with the *Guidelines* should therefore not be considered a guarantee of the specified performance. Determination of statistical reliability of the recommendations in the *Guidelines* was not a part of the development project. Such a study would require development of and consensus acceptance of a new methodology to determine reliability. However, the expected reliability of achieving various Performance Levels when the requirements of a given Level are followed is discussed in the *Commentary* for Chapter 2.

1.4 Relationship to Other Documents and Procedures

The *Guidelines* contain specific references to many other documents; however, the *Guidelines* are also related generically to the following publications.

- FEMA 222A and 223A, *NEHRP Recommended Provisions for Seismic Regulations for New Buildings* (BSSC, 1995): For the purposes of the design of new components, the *Guidelines* have been designed to be as compatible as possible with the companion *Provisions* for new buildings and its reference design documents. Detailed references to the use of specific sections of the *Provisions* document will be found in subsequent sections of the *Guidelines*.

- FEMA 302 and 303, 1997 *NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures* (BSSC, 1997), referred to herein as the 1997 *NEHRP Recommended Provisions*, have been in preparation for the same time as the later versions of the *Guidelines*. Most references are to the 1994 *NEHRP Recommended Provisions.*

- FEMA 237, *Development of Guidelines for Seismic Rehabilitation of Buildings, Phase I: Issues Identification and Resolution* (ATC, 1992), which underwent an American Society of Civil Engineers (ASCE) consensus approval process, provided policy direction for this document.

- *Proceedings of the Workshop To Resolve Seismic Rehabilitation Sub-issues* (ATC, 1993) provided recommendations to the writers of the *Guidelines* on more detailed sub-issues.

- FEMA 172, *NEHRP Handbook of Techniques for the Seismic Rehabilitation of Existing Buildings* (BSSC, 1992a), originally produced by URS/Blume and reviewed by the BSSC, contains construction techniques for implementing engineering solutions to the seismic deficiencies of existing buildings.

- FEMA 178, *NEHRP Handbook for the Seismic Evaluation of Existing Buildings* (BSSC, 1992b), which was originally developed by ATC and underwent the consensus approval process of the BSSC, covers the subject of evaluating existing buildings to decide if they are seismically deficient in terms of life safety. The model building types and other information from that publication are used or referred to extensively in the *Guidelines* in Chapter 10 and in the *Example Applications* document (ATC, 1997). FEMA 178, 1992 edition, is being updated to include additional performance objectives as well as to be more compatible with the *Guidelines*.

- FEMA 156 and 157, Second Edition, *Typical Costs for Seismic Rehabilitation of Existing Buildings* (Hart, 1994 and 1995), reports statistical analysis of the costs of rehabilitation of over 2000 buildings, based on construction costs or detailed studies. Several different seismic zones and performance levels are included in the data. Since the data were developed in 1994, none of the data is based on buildings rehabilitated specifically in accordance with the current *Guidelines* document. Performance Levels defined in the *Guidelines* are not intended to be significantly different from parallel levels used previously, and costs should still be reasonably representative.

- FEMA 275, *Planning for Seismic Rehabilitation: Societal Issues (VSP, 1996),* discusses societal and implementation issues associated with rehabilitation, and describes several case histories.

- FEMA 276, *Guidelines for the Seismic Rehabilitation of Buildings*: *Example Applications* (ATC, 1997), intended as a companion document to the *Guidelines* and *Commentary,* describes examples of buildings that have been seismically rehabilitated in various seismic regions and for different Rehabilitation Objectives. Costs of the work are given and references made to FEMA 156 and 157. Since the document is based on previous case histories, none of the examples were rehabilitated specifically in accordance with the current Guidelines document. However, Performance Levels defined in the *Guidelines* are not intended to be significantly different than parallel levels used previously, and the case studies are therefore considered representative.

- ATC 40, *Seismic Evaluation and Retrofit of Concrete Buildings*, (ATC, 1996), incorporates performance levels almost identical to those shown in Table 2-9 and employs “pushover” nonlinear analysis techniques. The capacity spectrum method for determining the displacement demand is treated in detail. This document covers only concrete buildings.

1.5 Use of the *Guidelines* in the Seismic Rehabilitation Process

Figure 1-1 is an overview of the flow of procedures contained in this document as well as an indication of the broader scope of the overall seismic rehabilitation process for individual buildings. In addition to showing a simplified flow diagram of the overall process, Figure 1-1 indicates points at which input from this document is likely, as well as potential steps outside the scope of the *Guidelines*. Specific chapter references are noted at points in the flow diagram where input from the *Guidelines* is to be obtained. This is a very general depiction of this process, which can take many forms and may include steps more numerous and in different order than shown.

As indicated in Section 1.3, the *Guidelines* are written with the assumption that the user has already concluded that a building needs to be seismically improved; evaluation techniques for reaching this decision are not specifically prescribed. However, the use of the detailed analysis and verification techniques associated with Systematic Rehabilitation (Section 1.5.4) may indicate that some buildings determined to be deficient by other evaluation or classification systems are actually acceptable without modification. This might occur, for example, if a *Guidelines* analysis method reveals that an existing building has greater capacity than was determined by use of a less exact evaluation method.

1.5.1 Initial Considerations for Individual Buildings

The use of the *Guidelines* will be simplified and made more efficient if certain base information is obtained and considered prior to beginning the process.

The building owner should be aware of the range of costs and impacts of rehabilitation, including both the variation associated with different Rehabilitation Objectives and the potential add-on costs often associated with seismic rehabilitation, such as other life safety upgrades, hazardous material removal, work associated with the Americans with Disabilities Act, and nonseismic building remodeling. Also to be considered are potential federal tax incentives for the rehabilitation for historic buildings and for some other older nonresidential buildings.

The use of the building must be considered in weighing the significance of potential temporary or permanent disruptions associated with various risk mitigation schemes. Other limitations on modifications to the building due to historic or aesthetic features must also be understood. The historic status of every building at least 50 years old should be determined (see the sidebar, *Considerations for Historic Buildings,* later in this chapter). This determination should be made early, because it could influence the choices of rehabilitation approaches and techniques.

This document is focused primarily on the technical aspects of rehabilitation. Basic information specifically included in the *Guidelines* is discussed below.

1.5.1.1 Site Hazards Other than Seismic Ground Shaking

The analysis and design procedures of the *Guidelines* are primarily aimed at improving the performance of buildings under the loads and deformations imposed by seismic shaking. However, other seismic hazards could exist at the building site that could damage the building regardless of its ability to resist ground shaking. These hazards include fault rupture, liquefaction or other shaking-induced soil failures, landslides, and inundation from offsite effects such as dam failure or tsunami.

The risk and possible extent of damage from such site hazards should be considered before undertaking rehabilitation aimed solely at reducing shaking damage. In some situations, it may be feasible to mitigate the site hazard. In many cases, the likelihood of the site hazard occurring will be sufficiently small that rehabilitating the building for shaking alone is appropriate. Where a site hazard exists, it may be feasible to mitigate it, either by itself or in connection with the building rehabilitation project. It is also possible that the risk from a site hazard is so extreme and difficult to control that rehabilitation will not be cost-effective.

Chapter 2 describes the applicability of seismic ground failure hazards to this document's seismic rehabilitation requirements, and Chapter 4 describes corresponding analysis procedures and mitigation measures.

1.5.1.2 Characteristics of the Existing Building

Chapter 2 discusses investigation of as-built conditions. Efficient use of the *Guidelines* requires basic knowledge of the configuration, structural characteristics, and seismic deficiencies of the building. Much of this information will normally be available from a seismic evaluation of the building. For situations where seismic rehabilitation has been mandated by local government according to building construction classification, familiarity with the building type and its typical seismic deficiencies is recommended. Such information is available from several sources, including FEMA 178 (BSSC, 1992b) and the companion *Example Applications* document.

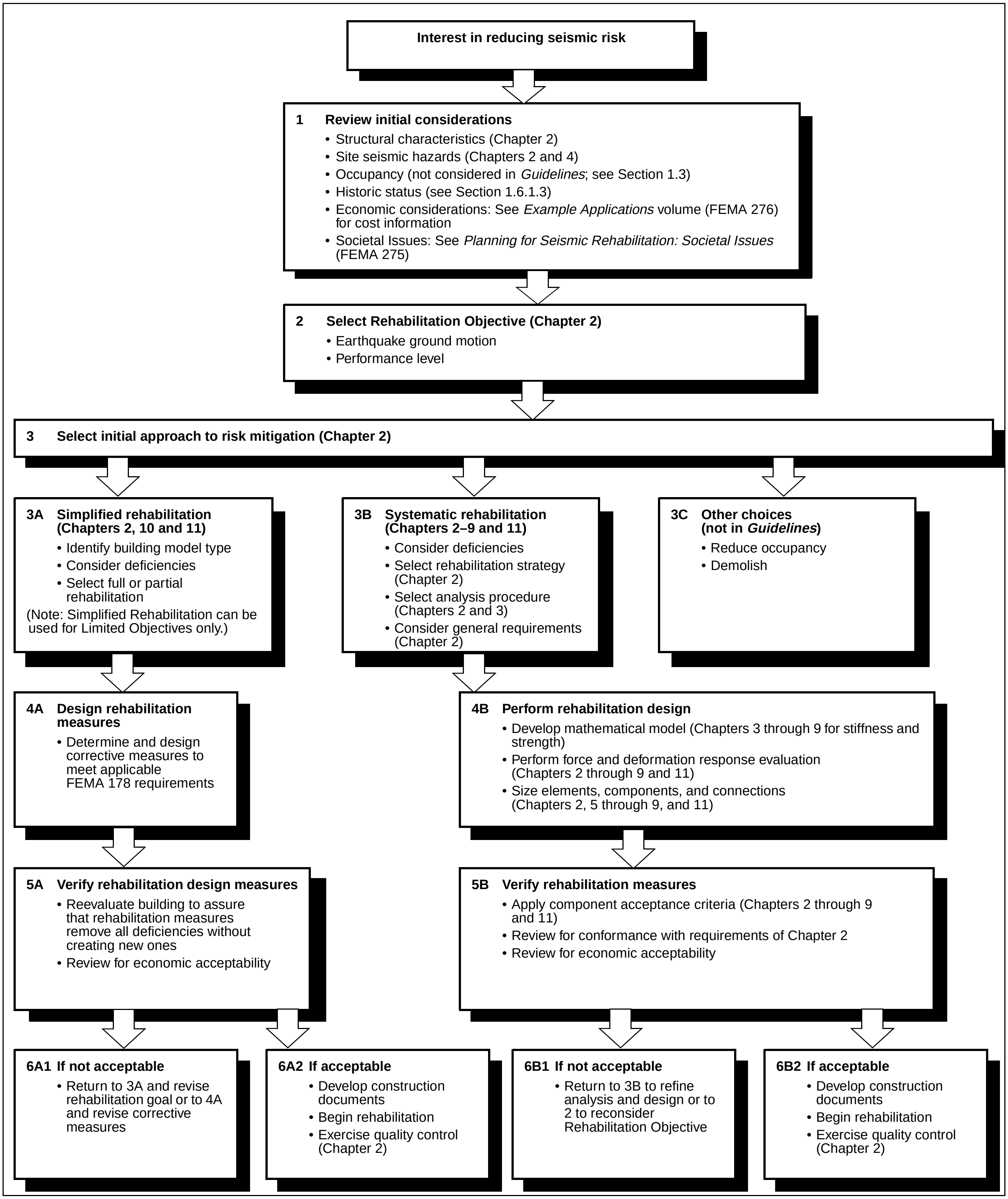


Figure 1-1 Rehabilitation Process Flowchart

Basic information about the building is needed to determine eligibility for Simplified Rehabilitation (Step 3 in Figure 1-1), if its use is desired, or to develop a preliminary design (Step 4 in Figure 1-1). It is prudent to perform preliminary calculations to select key locations or parameters prior to establishing a detailed testing program, in order to obtain knowledge cost-effectively and with as little disruption as possible of construction features and materials properties at concealed locations.

If the building is historic, additional as-built conditions should be more thoroughly investigated and analyzed. Publications dealing with the specialized subject of the character-defining spaces, features, and details of historic buildings should be consulted, and the services of a historic preservation expert may be required.

1.5.1.3 Rehabilitation Objective

A Rehabilitation Objective must be selected, at least on a preliminary basis, before beginning to use the procedures of the *Guidelines*. A Rehabilitation Objective is a statement of the desired limits of damage or loss (Performance Level) for a given seismic demand. The selection of a Rehabilitation Objective will be made by the owner and engineer in voluntary rehabilitation cases, or by relevant public agencies in mandatory programs. If the building is historic, there should be an additional goal to preserve its historic fabric and character in conformance with the Secretary of the Interior's *Standards for Rehabilitation*.

Whenever possible, the Rehabilitation Objective should meet the requirements of the BSO, which consists of two parts: 1, the Life Safety Building Performance Level for BSE-1 (the earthquake ground motion with a 10% chance of exceedance in 50 years (10%/50 year), but in no case exceeding two-thirds of the ground response expressed for the Maximum Considered Earthquake) and 2, the Collapse Prevention Building Performance Level for the earthquake ground motion representing the large, rare event, called the Maximum Considered Earthquake (described in the *Guidelines* as BSE-2). Throughout this document, the BSO provides a national benchmark with which lower or higher Rehabilitation Objectives can be compared.

Due to the variation in performance associated with unknown conditions in existing buildings, deterioration of materials, incomplete site data, and large variation expected in ground shaking, compliance with the *Guidelines* should not be considered a guarantee of the specified performance. The expected reliability of achieving various Performance Levels when the requirements of a given Level are followed is discussed in the *Commentary* to Chapter 2.

1.5.2 Initial Risk Mitigation Strategies

There are many ways to reduce seismic risk, whether the risk is to property, life safety, or post-earthquake use of the building. The occupancy of vulnerable buildings can be reduced, redundant facilities can be provided, and nonhistoric buildings can be demolished and replaced. The risks posed by nonstructural components and contents can be reduced. Seismic site hazards other than shaking can be mitigated.

Most often, however, when all alternatives are considered, the options of modifying the building to reduce the risk of damage must be studied. Such corrective measures include stiffening or strengthening the structure, adding local elements to eliminate irregularities or tie the structure together, reducing the demand on the structure through the use of seismic isolation or energy dissipation devices, and reducing the height or mass of the structure. These modification strategies are discussed in Chapter 2.

Modifications appropriate to the building can be determined using either the Simplified Rehabilitation Method or Systematic Rehabilitation Method.

1.5.3 Simplified Rehabilitation

Simplified Rehabilitation will apply to many small buildings of regular configuration, particularly in moderate or low seismic zones. Simplified Rehabilitation requires less complicated analysis and in some cases less design than the complete analytical rehabilitation design procedures found under Systematic Rehabilitation. In many cases, Simplified Rehabilitation represents a cost-effective improvement in seismic performance, but often does not require sufficiently detailed or complete analysis and evaluation to qualify for a specific Performance Level. Simplified Rehabilitation techniques are described for components (e.g., parapets, wall ties), as well as entire systems. Simplified Rehabilitation of structural systems is covered in Chapter 10, and the combinations of seismicity, Model Building, and other considerations for which it is allowed are provided in Section 2.8 and in Table 10-1. Simplified rehabilitation of nonstructural components is covered in Chapter 11.

1.5.4 Systematic Rehabilitation

The Systematic Rehabilitation Method is intended to be complete and contains all requirements to reach any specified Performance Level. Systematic Rehabilitation is an iterative process, similar to the design of new buildings, in which modifications of the existing structure are assumed for the purposes of a preliminary design and analysis, and the results of the analysis are verified as acceptable on an element and component basis. If either new or existing components or elements still prove to be inadequate, the modifications are adjusted and, if necessary, a new analysis and verification cycle is performed. Systematic Rehabilitation is covered in Chapters 2 through 9, and 11.

1.5.4.1 Preliminary Design

A preliminary design is needed to define the extent and configuration of corrective measures in sufficient detail to estimate the interaction of the stiffness, strength, and post-yield behavior of all new, modified, or existing elements to be used for lateral force resistance. The designer is encouraged to include all elements with significant lateral stiffness in a mathematical model to assure deformation capability under realistic seismic drifts. However, just as in the design of new buildings, it may be determined that certain components or elements will not be considered part of the lateral-force-resisting system, as long as deformation compatibility checks are made on these components or elements to assure their adequacy. In Figure 1-1, the preliminary design is in Steps 3 and 4.

1.5.4.2 Analysis

A mathematical model, developed for the preliminary design, must be constructed in connection with one of the analysis procedures defined in Chapter 3. These are the linear procedures (Linear Static and Linear Dynamic) and the nonlinear procedures (Nonlinear Static and Nonlinear Dynamic). With the exception of the Nonlinear Dynamic Procedure, the *Guidelines* define the analysis and rehabilitation design procedures sufficiently that compliance can be checked by a building department in a manner similar to design reviews for new buildings. Modeling assumptions to be used in various situations are given in Chapters 4 through 9, and Chapter 11 for nonstructural components, and guidance on required seismic demand is given in Chapter 2. Guidance is given for the use of the Nonlinear Dynamic Procedure; however, considerable judgment is required in its application. Criteria for applying ground motion for various analysis procedures is given, but definitive rules for developing ground motion input are not included in the *Guidelines*.

1.5.5 Verification and Economic Acceptance

For systematic rehabilitation, the effects of forces and displacements imposed on various elements by the seismic demand must be checked for acceptability for the selected Performance Level. These acceptability criteria, generally categorized by material, are given in Chapters 4 through 9. In addition, certain overall detailing, configuration, and connectivity requirements, covered in Chapter 2 and in Chapter 10 for simplified rehabilitation, must be satisfied prior to complete acceptance of the rehabilitation design. Nonstructural components are covered in Chapter 11. At this stage a cost estimate can be made to review the design's economic acceptability.

If the design proves uneconomical or otherwise unfeasible, different Rehabilitation Objectives or risk mitigation strategies may have to be considered, and the process would begin anew at Step 2 or 3 in Figure 1-1. The process would return to Step 3 or 4 if only refinements were needed in the design, or if a different scheme were to be tested.

1.5.6 Implementation of the Design

When a satisfactory design is completed, the important implementation phase may begin. Chapter 2 contains provisions for a quality assurance program during construction. While detailed analysis of construction costs and scheduling is not covered by the procedures in the *Guidelines*, these important issues are discussed in the *Example Applications* volume (ATC, 1997). Other significant aspects of the implementation process—including details of the preparation of construction documents by the architectural and engineering design professionals, obtaining a building permit, selection of a contractor, details of historic preservation techniques for particular kinds of materials, and financing—are not part of the *Guidelines*.

Social, Economic, and Political Considerations

The scope of the *Guidelines* is limited to the engineering basis for seismically rehabilitating a building, but the user should also be aware of significant nonengineering issues and social and economic impacts. These problems and opportunities, which vary with each situation, are discussed in a separate publication, *Planning for Seismic Rehabilitation: Societal Issues* (FEMA 275).

Construction Cost
If seismic rehabilitation were always inexpensive, the social and political costs and controversies would largely disappear. Unfortunately, seismic rehabilitation often requires removal of architectural materials to access the vulnerable portions of the structure, and nonseismic upgrading (e.g., electrical, handicapped access, historic restoration) is frequently "triggered" by a building code's remodeling permit requirements or is desirable to undertake at the same time.

Housing
While seismic rehabilitation ultimately improves the housing stock, units can be temporarily lost during the construction phase, which may last more than a year. This can require relocation of tenants.

Impacts on Lower-Income Groups
Lower-income residents and commercial tenants can be displaced by seismic rehabilitation. Often caused by upgrading unrelated to earthquake concerns, seismic upgrading also tends to raise rents and real estate prices, because of the need to recover the costs of the investment.

Regulations
As with efforts to impose safety regulations in other fields, mandating seismic rehabilitation is often controversial. The *Guidelines* are not written as mandatory code provisions, but one possible application is to adapt them for that use. In such cases political controversy should be expected, and nonengineering issues of all kinds should be carefully considered.

Architecture
Even if a building is not historic, there are often significant architectural impacts. The exterior and interior appearance may change, and the division of spaces and arrangement of circulation routes may be altered.

Community Revitalization
Seismic rehabilitation not only poses issues and implies costs, it also confers benefits. In addition to enhanced public safety and economic protection from earthquake loss, seismic rehabilitation can play a leading role in the revitalization of older commercial and industrial areas as well as residential neighborhoods.

1.6 Use of the *Guidelines* for Local or Directed Risk Mitigation Programs

The *Guidelines* have been written to accommodate use in a wide variety of situations, including both local risk mitigation programs and directed programs created by broadly based organizations or governmental agencies that have jurisdiction over many buildings. These programs may target certain building types for rehabilitation or require complete rehabilitation coupled with other remodeling work. The incorporation of variable Rehabilitation Objectives and use of Model Building Types in the *Guidelines* allows creation of subsets of rehabilitation requirements to suit local conditions of seismicity, building inventory, social and economic considerations, and other factors. Provisions appropriate for local situations can be extracted, put into regulatory language, and adopted into appropriate codes, standards, or local ordinances.

1.6.1 Initial Considerations for Mitigation Programs

Local or directed programs can either target high-risk building types or set overall priorities. These decisions should be made with full consideration of physical, social, historic, and economic characteristics of the building inventory. Although financial incentives can induce voluntary risk mitigation, carefully planned mandatory or directed programs, developed in cooperation with those whose interests are affected, are generally more effective. Potential benefits of such programs include reduction of direct earthquake losses—such as casualties, costs to repair damage, and loss of use of buildings—as well as more rapid overall recovery. Rehabilitated buildings may also increase in value and be assigned lower insurance rates. Additional issues that should be considered for positive or negative effects include the interaction of rehabilitation with overall planning goals, historic preservation, and the local economy. These issues are discussed in *Planning for Seismic Rehabilitation: Societal Issues* (VSP, 1996).

1.6.1.1 Potential Costs of Local or Directed Programs

The primary costs of seismic rehabilitation—the construction work itself, including design, inspection, and administration—are normally paid by the owner. Additional costs that should be weighed when creating seismic risk reduction programs are those associated with developing and administering the program, such as the costs of identification of high-risk buildings, environmental or socioeconomic impact reports, training programs, plan checking and construction inspection.

The construction costs include not only the cost of the pure structural rehabilitation but also the costs associated with new or replaced finishes that may be required. In some cases, seismic rehabilitation work will trigger other local jurisdictional requirements, such as hazardous material removal or partial or full compliance with the Americans with Disabilities Act. The costs of seismic or functional improvements to nonstructural systems should also be considered. There may also be costs to the owner associated with temporary disruption or loss of use of the building during construction. To offset these costs, there may be low-interest earthquake rehabilitation loans available from state or local government, or historic building tax credits.

If seismic rehabilitation is the primary purpose of construction, the costs of the various nonseismic work that may be required should be included as direct consequences. On the other hand, if the seismic work is an added feature of a major remodel, the nonseismic improvements probably would have been required anyway, and therefore should not be attributed to seismic rehabilitation.

A discussion of these issues, as well as guidance on the range of costs of seismic rehabilitation, is included in FEMA 156 and 157, Second Edition, *Typical Costs for Seismic Rehabilitation of Buildings* (Hart, 1994 and 1995) and in FEMA 276, *Guidelines for the Seismic Rehabilitation of Buildings: Example Applications* (ATC, 1997). Since the data for these documents were developed prior to the Guidelines, the information is not based on buildings rehabilitated specifically in accordance with the current document. However, Performance Levels defined in the *Guidelines* are not intended to be significantly different than parallel levels used previously, and costs should still be reasonably representative.

1.6.1.2 Timetables and Effectiveness

Presuming that new buildings are being constructed with adequate seismic protection and that older buildings are occasionally demolished or replaced, the inventory of seismically hazardous buildings in any community will be gradually reduced. This attrition rate is normally small, since the structures of many buildings have useful lives of 100 years or more and very few buildings are actually demolished. If buildings or districts become historically significant, they may not be subject to attrition at all. In many cases, then, doing nothing (or waiting for an outside influence to force action) may present a large cumulative risk to the inventory.

It has often been pointed out that exposure time is a significant element of risk. The time aspect of risk reduction is so compelling that it often appears as part of book and workshop titles; for example, *Between Two Earthquakes: Cultural Property in Seismic Zones* (Feilden, 1987); *Competing Against Time* (California Governor’s Board of Inquiry, 1990); and “In Wait for the Next One” (EERI, 1995). Therefore, an important consideration in the development of programs is the time allotted to reach a certain risk reduction goal. It is generally assumed that longer programs create less hardship than short ones by allowing more flexibility in planning for the cost and possible disruption of rehabilitation, as well as by allowing natural or accelerated attrition to reduce undesirable impacts. On the other hand, the net reduction of risk is smaller due to the increased exposure time of the seismically deficient building stock.

Given a high perceived danger and certain advantageous characteristics of ownership, size, and occupancy of the target buildings, mandatory programs have been completed in as little as five to ten years. More extensive programs—involving complex buildings such as hospitals, or with significant funding limitations—may have completion goals of 30 to 50 years. Deadlines for individual buildings are also often determined by the risk presented by building type, occupancy, location, soil type, funding availability, or other factors.

1.6.1.3 Historic Preservation

Seismic rehabilitation of buildings can affect historic preservation in two ways. First, the introduction of new elements that will be associated with the rehabilitation may in some way impact the historic fabric of the

Considerations for Historic Buildings

It must be determined early in the process whether a building is “historic.” A building is historic if it is at least 50 years old and is listed in or potentially eligible for the National Register of Historic Places and/or a state or local register as an individual structure or as a contributing structure in a district. Structures less than 50 years old may also be historic if they possess exceptional significance. For historic buildings, users should develop and evaluate alternative solutions with regard to their effect on the loss of historic character and fabric, using the Secretary of the Interior’s *Standards for Rehabilitation* (Secretary of the Interior, 1990).

In addition to rehabilitation, the Secretary of the Interior also has standards for preservation, restoration, and reconstruction. These are published in the *Standards for the Treatment of Historic Properties* (Secretary of the Interior, 1992). A seismic rehabilitation project may include work that falls under the *Rehabilitation Standards,* the *Treatment Standards*, or both.

For historic buildings as well as for other structures of architectural interest, it is important to note that the Secretary of the Interior’s *Standards* define rehabilitation as “the process of returning a property to a state of utility, through repair or alteration, which makes possible an efficient contemporary use while preserving those portions and features of the property which are significant to its historic, architectural and cultural values.” The Secretary has also published standards for “preservation,” “restoration,” and “reconstruction.” Further guidance on the treatment of historic properties is contained in the publications in the *Catalog of Historic Preservation Publications* (NPS, 1995).

Rehabilitation Objectives

If seismic rehabilitation is required by the governing building jurisdiction, the minimum seismic requirements should be matched with a Rehabilitation Objective defined in the *Guidelines.* It should be noted that many codes covering historic buildings allow some amount of flexibility in required performance, depending on the effect of rehabilitation on important historic features.

If a building contains items of unusual architectural interest, consideration should be given to the value of these items. It may be desirable to rehabilitate the building to the Damage Control Performance Range to ensure that the architectural fabric survives certain earthquakes.

Rehabilitation Strategies

In development of initial risk mitigation strategies, consideration must be given to the architectural and historic value of the building and its fabric. Development of a Historic Structure Report identifying the primary historic fabric may be essential in the preliminary planning stages for certain buildings. Some structurally adequate solutions may nevertheless be unacceptable because they involve destruction of historic fabric or character. Alternate rehabilitation methods that lessen the impact on the historic fabric should be developed for consideration. Partial demolition may be inappropriate for historic structures. Elements that create irregularities may be essential to the historic character of the structure. The advice of historic preservation experts may be necessary.

Structural rehabilitation of historic buildings may be accomplished by hiding the new structural members or by exposing them as admittedly new elements in the building’s history. Often, the exposure of new structural members is preferred, because alterations of this kind are “reversible”; that is, they could conceivably be undone at a future time with no loss of historic fabric to the building. The decision to hide or expose structural members is a complex one, best made by a preservation professional.

building. Second, the seismic rehabilitation work can serve to better protect the building from possibly unrepairable future earthquake damage. The effects of any seismic risk reduction program on historic buildings or preservation districts should be carefully considered during program development, and subsequent work should be carefully monitored to assure compliance with previously mentioned national preservation guidelines. (See the sidebar, “Considerations for Historic Buildings.”)

1.6.2 Use in Passive Programs

Programs that only require seismic rehabilitation in association with other activity on the building are often classified as "passive." "Active" programs, on the other hand, are those that mandate seismic rehabilitation for targeted buildings in a certain time frame, regardless of other activity associated with the building (see Section 1.6.3). Activities in a building that may passively generate a requirement to seismically rehabilitate—such as an increase in occupancy, structural modification, or a major remodeling that would significantly extend the life of the building—are called "triggers." The concept of certain activities triggering compliance with current standards is well established in building codes. However, the details of the requirements have varied widely. These issues have been documented with respect to seismic rehabilitation in California (Hoover, 1992). Passive programs reduce risk more slowly than active programs.

1.6.2.1 Selection of Seismic Rehabilitation Triggers

The *Guidelines* do not cover triggers for seismic rehabilitation. The extent and detail of seismic triggers will greatly affect the speed, effectiveness, and impacts of seismic risk reduction, and the selection of triggers is a policy decision expected to be done locally, by the person or agency responsible for the inventory. Triggers that have been used or considered in the past include revision of specified proportions of the structure, remodeling of specified percentages of the building area, work on the building that costs over a specified percentage of the building value, change in use that increases the occupancy or importance of the building, and changes of ownership.

1.6.2.2 Selection of Passive Seismic Rehabilitation Standards

The *Guidelines* purposely afford a wide variety of options that can be adopted into standards for seismic rehabilitation to facilitate risk reduction. Standards can be selected with varying degrees of risk reduction and varying costs by designating different Rehabilitation Objectives. As described previously, a Rehabilitation Objective is created by specifying a desired Building Performance Level for specified earthquake ground motion criteria. A jurisdiction can thus specify appropriate standards by extracting applicable requirements and incorporating them into its own code or standard, or by reference.

A single Rehabilitation Objective could be selected under all triggering situations (the BSO, for example), or more stringent objectives can be used for important changes to the building, less stringent objectives for minor changes. For example, it is sometimes necessary for design professionals, owners, and building officials to negotiate the extent of seismic improvements done in association with building alterations. Complete rehabilitation is often required by local regulation for complete remodels or major structural alterations. It is the intent of the *Guidelines* to provide a common framework for all of these various uses.

1.6.3 Use in Active or Mandated Programs

Active programs are most often targeted at high-risk building types or occupancies. Active seismic risk reduction programs are those that require owners to rehabilitate their buildings in a certain time frame or, in the case of government agencies or other owners of large inventories, to set self-imposed deadlines for completion.

1.6.3.1 Selection of Buildings to be Included

Programs would logically target only the highest-risk buildings or at least create priorities based on risk. Risk can be based on the likelihood of building failure, the occupancy or importance of buildings, soil types, or other factors. The *Guidelines* are primarily written to be used in the process of rehabilitation and do not directly address the comparative risk level of various building types or other risk factors. Certain building types, such as unreinforced masonry bearing wall buildings and older improperly detailed reinforced concrete frame buildings, have historically presented a high risk, depending on local seismicity and building practice. Therefore, these building types have sometimes been targeted in active programs.

A more pragmatic consideration is the ease of locating targeted buildings. If certain building types cannot be easily identified, either by the local jurisdiction or by the owners and their engineers, enforcement could become difficult and costly. In the extreme, every building designed prior to a given acceptable code cycle would require a seismic evaluation to determine whether targeted characteristics or other risk factors are present, the cost of which may be significant. An alternate procedure might be to select easily identifiable building characteristics to set timelines, even if more accurate building-by-building priorities are somewhat compromised.

1.6.3.2 Selection of Active Seismic Rehabilitation Standards

As discussed for passive programs (Section 1.6.2.2), the *Guidelines* are written to facilitate a wide variation in risk reduction. Factors used to determine an appropriate Rehabilitation Objective include local seismicity, the costs of rehabilitation, and local socioeconomic conditions.

It may be desirable to use Simplified Rehabilitation Methods for active or mandated programs. Only Limited Performance Objectives are included in the *Guidelines* for this method. However, if a program has identified a local building type with few variations in material and configuration, a study of a sample of typical buildings using Systematic Methods may establish that compliance with the requirements of Simplified Rehabilitation meets the BSO, or better, for this building type in this location. Such risk and performance decisions can only be made at the local level.

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