(DRAFT) ENGINEERING GUIDANCE FOR INCREMENTAL SEISMIC REHABILITATION

PREPARED
BY
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AND
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FOREWORD and SCOPE

Earthquakes are a serious threat to safety in institutional and commercial buildings and pose a significant potential liability to building owners. Buildings in 39 states are vulnerable to earthquake damage. Unsafe existing buildings expose their owners and occupants to the following risks:

- ***Death and injury of tenants, occupants, and visitors***
- ***Damage to or collapse of buildings***
- ***Damage to and loss of furnishings, equipment, and other building contents***
- ***Disruption of rental and occupancy functions and other building operations***

The greatest earthquake risk is associated with existing buildings that were designed and constructed before the use of modern building codes. For many parts of the United States, this includes buildings built as recently as the early 1990s.

Although vulnerable buildings need to be replaced with safe, new construction or rehabilitated to correct deficiencies, for many building owners new construction is limited, at times severely, by budgetary constraints, and seismic rehabilitation is expensive and disruptive. However, **incremental seismic rehabilitation** described in this manual, an innovative approach that phases in a series of discrete rehabilitation actions over a period of several years, is an effective, affordable, and non-disruptive strategy for responsible mitigation action. It can be integrated efficiently into ongoing facility maintenance and capital improvement operations to minimize cost and disruption.

This manual and its companion documents are the products of a Federal Emergency Management Agency (FEMA) project to develop the concept of incremental seismic rehabilitation.

This manual is intended to assist architects and engineers who provide services to building owners and contains the information necessary for providing consulting services to owners for implementing incremental seismic rehabilitation. Architects and engineers using this handbook will be effective consultants serving a knowledgeable owner. Together they will be in a position to implement an effective incremental seismic rehabilitation program.

In addition to this manual there is a set of manuals intended for building owners, managers, and their staff:

- *Incremental Seismic Rehabilitation of School Buildings (K-12)*, FEMA 395
- *Incremental Seismic Rehabilitation of Hospital Buildings*, FEMA 396
- *Incremental Seismic Rehabilitation of Office Buildings*, FEMA 397

- *Incremental Seismic Rehabilitation of Multifamily Apartment Buildings*, FEMA 398
- *Incremental Seismic Rehabilitation of Retail Buildings*, FEMA 399
- *Incremental Seismic Rehabilitation of Hotel and Motel Buildings*, FEMA 400
- *Incremental Seismic Rehabilitation of Storage Buildings*, FEMA 401
- *Incremental Seismic Rehabilitation of Emergency Buildings*, FEMA 402

Each manual in this set addresses the specific needs and practices of a particular category of buildings and owners, and guides building owners and managers through a process that will reduce earthquake risk in their building inventory. The manuals answer the question, as specifically as possible: “What is the most affordable, least disruptive, and most effective way to reduce seismic risk in existing buildings?” By using the process outlined in these manuals, building owners and managers will become knowledgeable clients for implementing incremental seismic rehabilitation specifically geared to their building use category.

HOW TO USE THIS MANUAL

This manual consists of six chapters. The first three chapters introduce the concept of incremental seismic rehabilitation, discuss it from the owners' perspective, and explain its relationship to building codes and related regulations. The next two chapters provide guidance on the engineering implementation of incremental seismic rehabilitation. The sixth chapter describes the product of this engineering: an incremental seismic rehabilitation plan.

The engineering implementation of incremental seismic rehabilitation relies on the use of the following three documents, which are referenced extensively in the text:

- *Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook, Second Edition*, FEMA 154
- *Seismic Evaluation of Existing Buildings*, ASCE 31 (based on FEMA 310, *Handbook for the Seismic Evaluation of Existing Buildings—A Prestandard*)
- *Prestandard and Commentary for the Seismic Rehabilitation of Buildings*, FEMA 356

Architects and engineers should obtain these three documents for use in conjunction with this manual.

1. Incremental Seismic Rehabilitation—An Overview

In Brief

This chapter describes the concept of incremental seismic rehabilitation by answering the following questions:

- What is Incremental Seismic Rehabilitation?
- How Does Incremental Seismic Rehabilitation Relate To The FEMA Existing Buildings Program?
- How do the Benefits of Incremental Seismic Rehabilitation and Single-Stage Rehabilitation Compare?
- Has Incremental Seismic Rehabilitation Been Implemented and How?
- What New Forms of Professional Service Will Be Required?
- Does the Incremental Seismic Rehabilitation Process Constitute Responsible Professional Practice?

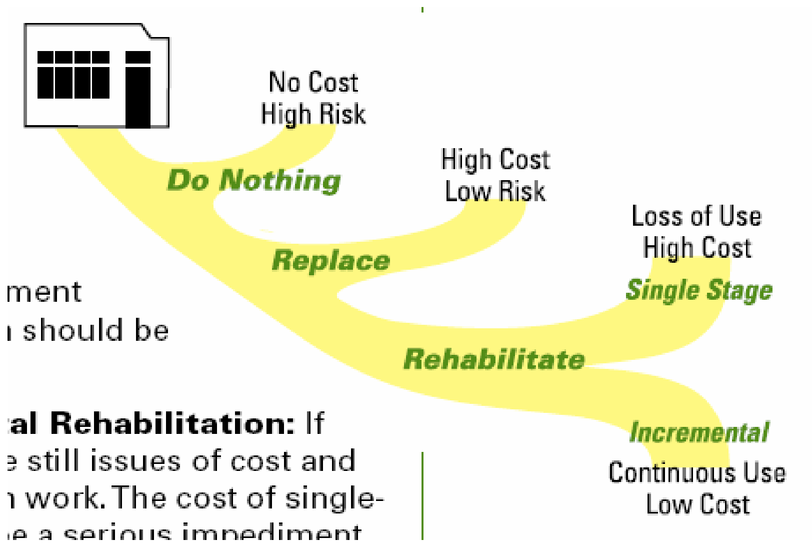
1.1 What is Incremental Seismic Rehabilitation?

Options for Seismic Risk Reduction

The most important consideration for earthquake safety in existing buildings is to reduce the risk of catastrophic structural collapse. Most likely in existing vulnerable buildings, structural collapse poses the greatest threat to life in a major earthquake. Beyond structural collapse, additional considerations may be partial collapse and damage to primary load carrying elements. Nonstructural damage and failures may also pose a risk of death and injury to occupants and property loss to owners. Choosing the method of reducing these risks in a deficient building requires two critical decisions:

- **Replace or Rehabilitate:** If the owner decides to replace a building, new construction is carried out according to modern codes and can be assumed to meet current safety standards. However, financial constraints, historic preservation concerns, and other community interests may make the replacement option infeasible. In that case, rehabilitation should be considered.

- **Single-Stage Rehabilitation[1] or Incremental Rehabilitation:** If the rehabilitation option is chosen, there are still issues of cost and disruption associated with the rehabilitation work. The cost and extensive disruption of use entailed by single-stage seismic rehabilitation has proved to be a serious impediment to its implementation by many building owners. Incremental seismic rehabilitation is specifically designed to address and reduce the problems of cost and disruption.



Approach to Incremental Seismic Rehabilitation

Incremental rehabilitation phases seismic rehabilitation into an ordered series of discrete actions implemented over a period of time, in some cases, several years, and whenever feasible, these actions are planned to coincide with regularly scheduled repairs, maintenance, or capital improvements. Such an approach, if carefully planned, engineered, and implemented, will ultimately achieve the full damage reduction benefits of a more disruptive single-stage rehabilitation. In fact, for many institutional and commercial buildings, a key distinction between the incremental and single-stage rehabilitation approaches is that the incremental approach can effectively eliminate or drastically reduce disruption costs if it can be organized so that most rehabilitation increments occur during periods of reduced occupancy, such as summer vacation in schools or tenant turnover in commercial buildings. Incremental seismic rehabilitation can be initiated in the near- term as a component of planned maintenance and capital improvement with only marginal added cost. Getting started as soon as possible on a program of incremental seismic rehabilitation will improve building

[1] Single-stage rehabilitation refers to completing the rehabilitation in a single continuous project.

performance and demonstrates recognition of responsibility for building safety on the parts of the owner and the design professional.

Assessment of Deficiencies

A necessary activity that must precede a seismic rehabilitation program, be it single-stage or incremental, is an assessment of the seismic vulnerability of an owner's building inventory. The assessment should rank the building inventory in terms of seismic vulnerability and identify specific deficiencies. The Federal Emergency Management Agency (FEMA) publishes a number of documents on the assessment process. Facility assessments and the FEMA publications available to help conduct them are discussed in more detail in Chapter 5.

Prioritization and Scheduling of Rehabilitation Increments

The incremental seismic rehabilitation program will correct the deficiencies identified by the assessment. The order in which seismic rehabilitation increments are undertaken can be important to their ultimate effectiveness. There are four aspects to prioritizing and scheduling seismic rehabilitation increments, which are discussed in more detail in Chapter 5:

- **Structural Priority**--An initial prioritization of seismic rehabilitation increments based on their respective impact on the overall earthquake resistance of the structure.
- **Use Priority**—Prioritization influenced by owners' considerations of alternative future uses of their existing buildings.
- **Construction Priority**—Prioritization influenced by construction characteristics of rehabilitation increments such as work on elements of the building envelope, work on elements of interior spaces, and work on concealed elements.
- **Integration Opportunities**—Prioritization and scheduling influenced by the potential for integrating rehabilitation increments with other building maintenance or capital improvement projects that are undertaken routinely.

Incremental Seismic Rehabilitation Plan

An essential feature of implementing incremental seismic rehabilitation in specific buildings is the development and documentation of a seismic rehabilitation plan. The seismic rehabilitation plan will include all the anticipated rehabilitation increments and their prioritization. The documentation will guide the implementation of the incremental seismic rehabilitation program and should ensure that the building owner does not lose sight of overall rehabilitation goals during implementation of individual increments. The incremental seismic rehabilitation plan is discussed in more detail in Chapter 6.

1.2 How Does Incremental Seismic Rehabilitation Relate To The FEMA Existing Buildings Program?

FEMA's Existing Building Program is part of the National Earthquake Hazard Reduction Program (NEHRP). Under this program FEMA has developed a series of documents that include:

FEMA 154, *Rapid Visual Screening of Buildings for Potential Seismically Hazards and Supporting Documentation—Second Edition*
FEMA 310, *Handbook for the Seismic Evaluation of Existing Buildings—A Prestandard,* which has subsequently become an ASCE standard, ASCE 31, *Seismic Evaluation of Existing Buildings*
FEMA 356 – *Prestandard and Commentary for the Seismic Rehabilitation of Buildings*
FEMA 172 – *Techniques for Seismically Rehabilitating Existing Buildings*
FEMA 156,157 – *Typical Costs for Seismically Rehabilitating Existing Buildings*
FEMA 227 – *A Benefit-Cost Model for the Seismic Rehabilitation of Buildings*
FEMA 255 – *Seismic Rehabilitation of Federal Buildings: a Benefit/Cost Model*.

Additional applicable documents have been developed by others, and include:

ATC 40 – *Seismic Evaluation and Retrofit of Concrete Buildings*
SAC 95-02 -- *Interim Guidelines: Repair, Modification and Design of Welded Moment Resisting Frame Structures*.

These documents, when used together or individually, can effectively guide the design professional through the process of identifying potentially hazardous buildings, evaluating those buildings to determine any needed mitigation of seismic vulnerability, and designing the necessary seismic rehabilitation for the building, be it incremental or single-stage rehabilitation.

While these documents do not explicitly address incremental seismic rehabilitation, they should be used in developing and implementing an incremental seismic rehabilitation plan. The use of these documents is discussed in detail in Chapter 5.

1.3 How Do the Benefits of Incremental Seismic Rehabilitation and Single-Stage Rehabilitation Compare?

FEMA has developed an approach to performing benefit/cost analyses of seismic rehabilitation. The procedures and methodology of the approach is published in the FEMA 227 and FEMA 255, as listed previously. Using this approach it is possible to develop a life-cycle benefit analysis that compares incremental to single-stage rehabilitation.

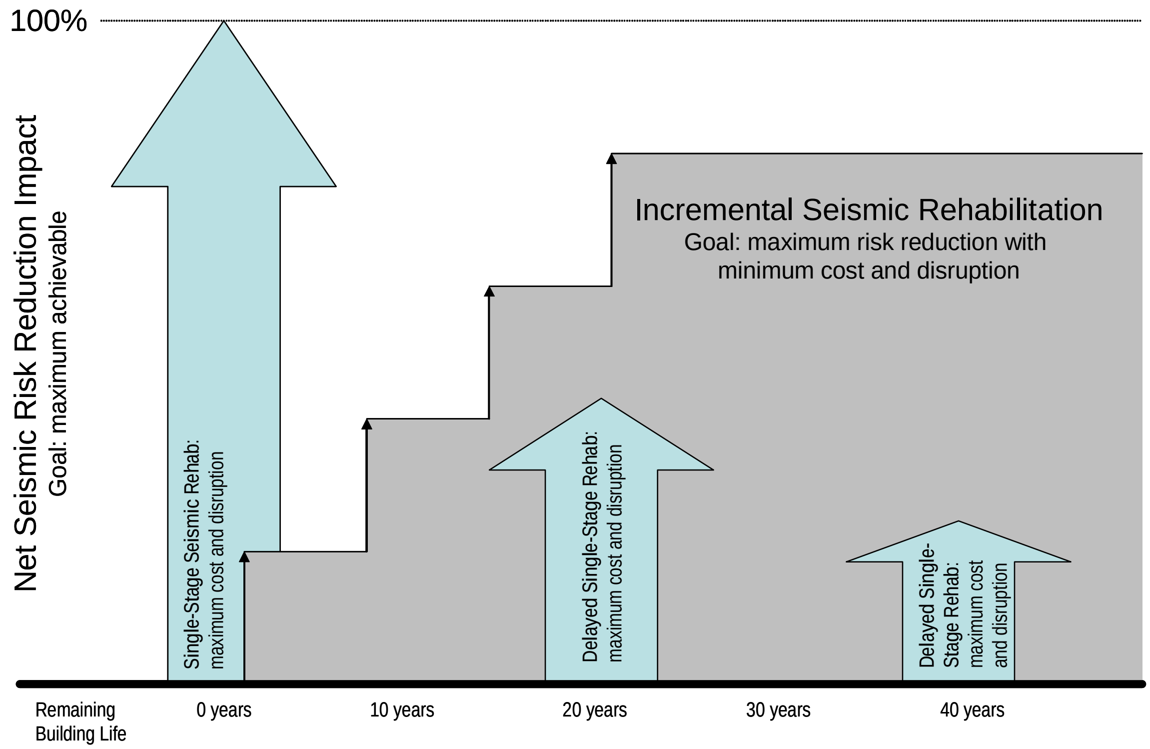
Estimates of seismic damage can be quantified in terms of percentage of building value damaged. Annual seismic damage is calculated as the probable damage that can result in any year from all possible earthquakes. The benefits of seismic rehabilitation are quantified as the reduction in annual seismic damage resulting from specific rehabilitation actions (also quantified in terms of percentage of building value). A generalized life-cycle benefit analysis shows that incremental approaches can return a substantial portion of the expected benefits of single-stage seismic rehabilitation carried out now.

The schematic diagram below illustrates such a life-cycle benefit analysis. The three wide arrows represent the benefits of single-stage rehabilitation occurring at three points in time: now, in 20 years, and in 40 years. Clearly, the largest benefit derives from a single-stage rehabilitation done now, and it is designated as 100%. The benefits of single-stage rehabilitation done in the future must be discounted and expressed as some percentage lower than 100%, as represented by the decreased arrows. The stepped portion of the diagram represents incremental rehabilitation starting soon and completed in four increments over 20 years. The benefits of the future increments must also be discounted, and the benefit of the completed incremental rehabilitation is therefore expressed as a percentage lower than 100%, but higher than the single-stage rehabilitation in year 20. Reducing the overall duration of the incremental rehabilitation will increase its benefit, and extending the duration will decrease it.

Incremental seismic rehabilitation affords great flexibility in the sequence and timing of actions when the following precautions are kept in mind:

- It is important to get started as soon as possible. Any early reduction of risk will provide benefit over the remaining life of the building. Delaying action extends risk exposure. The incremental approach can be more effective than a delayed, single-stage rehabilitation, as long as one gets started soon.
- Even if the completion of the incremental program takes 10 or 20 years, most of the risk reduction benefit is realized.

- There is a wide margin of error. For example, you may unintentionally increase the probability of damage in the first few years due to an initial rehabilitation increment that makes the building more vulnerable to damage, and still realize the benefit of risk reduction if you complete the incremental rehabilitation over a reasonable period.



1.4 Has Incremental Seismic Rehabilitation Been Implemented and How?

Incremental seismic rehabilitation has been practiced by organizations such as Seattle Public Schools and Jordan School District in Utah, where increments that can be accomplished over the summer vacation have been implemented in many older school buildings. [See case study in Appendix A].

The approach has been practiced by innovative owners and engineers on an ad hoc basis in various parts of the country. However, to date, this has required the independent insight and flexibility of particularly creative individuals. The practice has not necessarily had the explicit support of building officials, insurers or lenders.

Because improvement of existing structures is for the most part a voluntary activity initiated by the building owner, it is necessary to make clear the business case for investment in seismic rehabilitation. Seismic risk must be appropriately represented in financial decisions related to facility management. The design professional has a key role in the education of clients about the range of options available for the reduction of seismic risk. This role includes providing value for money in maximizing risk reduction for available investment.

1.5 What New Forms of Professional Service Will Be Required?

There is a sequence of engineering services that may be required in order to implement incremental seismic rehabilitation:

- Acquisition due diligence
- Building assessment and evaluation
  - Identifying buildings needing seismic rehab
  - Identifying deficiencies in buildings
- Designing building rehabilitation program
- Prioritization of rehabilitation increments (taking care to not inadvertently increase the building's vulnerability)
- Integration of increments with maintenance and capital improvements.

Some of these services may represent a departure from standard practice in seismic rehabilitation for existing buildings.

Successfully carrying out these services requires a clear understanding of the owner's organizational structure and facility management practices. The design of an incremental seismic rehabilitation strategy must be developed in cooperation with the owner's facility manager, risk manager and financial manager. The strategy must take advantage of opportunities provided by the normal facility maintenance routines and should be accepted as an integral part to the organization's risk management program.

The design professional benefits from an understanding of the risk management process and the terms of executive level decision-making regarding seismic risk. Understanding the broader functional and financial objectives of the client strengthens the argument for seismic rehabilitation and improves the quality and cost effectiveness of the engineering services offered.

Facility management processes vary by building occupancy type as well as ownership category. Public and institutional building facility management is subject to different pressures and constraints than that of commercial buildings. Appendix B provides analysis of the facility management processes used by representative building occupancies including:

- School Buildings
- Hospital Buildings
- Office Buildings
- Retail Buildings
- Multifamily Apartment Buildings
- Hotel and Motel Buildings
- Storage Buildings
- Emergency Buildings

This insight to client decision processes related to seismic risk should assist in the development of effective marketing strategies for the design professional. Well-prepared marketing of engineering services can provide a valuable educational function and serve as and aggressive, self-motivated form of dissemination.

1.6 Does the Incremental Seismic Rehabilitation Process Constitute Responsible Professional Practice?

Both owners and engineers should understand that responsible action taken to reduce seismic risk does not create or increase liability. The building codes encourage any improvement to building safety, as discussed in Chapter 3. The creation of a strategy for incremental seismic rehabilitation and the following of that strategy represent responsible action and best professional practice.

2. Owner/Occupant Perspective on Incremental Seismic Rehabilitation

2.1 Owner/Occupant Objectives: Revenue Generation and Service Delivery

Existing buildings are owned, occupied, and operated for the purpose of generating revenue or delivering a service. Revenue is generated for building owners in the form of rents collected from tenants/occupants, such as in multifamily apartment buildings, office buildings, and retail malls. Revenue is also generated by the building through the sale of merchandise in retail buildings or of manufactured products in industrial buildings. Services are delivered in buildings such as schools and hospitals. In all cases, the revenue generation or the service delivery are a direct function of the continuous occupancy and use of the building.

Owners and occupants of buildings incur costs in the operations and use of buildings to generate revenue or deliver services. These costs consist of labor, energy, and maintenance. Many building owners also invest from time to time in building improvements that serve to maintain or enhance the revenue generation or the quality of service provided.

At some point in their life cycle buildings may become obsolete in terms of performing the functions of revenue generation or service delivery. At this point the owner has the option of disposing of the building (selling it or demolishing it) and constructing or acquiring a new building, or the owner may determine that rehabbing the building is more economical. The former option, demolishing and constructing new, is not always available. A department store in a mall may lose its customer base if it moves to a different location. A historic building may be difficult to dispose of or demolish. Where down-zoning has occurred, an older, larger, nonconforming building will not be permitted to be replaced if demolished. In these cases, a major rehabilitation may be the owner's only option.

2.2 Uncertainty and Risk

The continuity of building owners' revenue generation and service delivery is subject to uncertainty and risk from a variety of causes. Natural disasters, including earthquakes, are a significant source of risk to many building owners. Earthquakes can have the following effects on building owners:

- Deaths and injuries to building occupants, and related liability.
- Building collapse or damage to building elements, and related costs of repair or replacement.
- Damage to building contents, and related costs or liabilities.

- Disruption of building operation, and related costs or liabilities.

These effects are more likely in older existing buildings, those built before earthquake engineering was well understood and before this knowledge was incorporated into building codes.

Building owners can manage these risks, including earthquake risk, by undertaking a combination of the following measures:

- Provide backup or redundant facilities to reduce the effect of disruption of operation.
- Purchase insurance or establish a self-insurance reserve.
- Reduce building vulnerability by investing in seismic rehabilitation.

2.3 Facility Management

Building owners are always planning ahead, trying to schedule maintenance and capital improvements of buildings. The time horizons of such plans may differ from one owner to the next; some may have a one-year time frame, many use five years, and others may have a longer horizon of 15 years. These facility maintenance and capital improvement plans are usually carried out in the context of strategic planning, which seeks answers to questions such as the following:

- What will be the nature of future education delivered at this school?
- What healthcare technology must be acquired to remain competitive?
- What will the residential market look like in this city or neighborhood?
- How do I maintain or grow my market share?

A key factor in planning maintenance and capital improvement projects in a building is to accomplish them with the least possible disruption to the building operations. Disruption of operations is a major cost to any building occupant.

2.4 Incremental Seismic Rehabilitation Services, and Their Integration into Owners' Facility Management Processes

Incremental seismic rehabilitation is a tool to reduce the seismic vulnerability of existing buildings. The basic technical issues of seismic evaluation and strengthening of existing buildings have been dealt with in FEMA reference documents. Incremental seismic rehabilitation provides the strategy for application of these technical principles by integrating the process of seismic rehabilitation with the owner's normal processes of facility management and risk management. It also provides guidance for the integration of appropriate information on seismic risk in organizational resource allocation decision processes.

Facility management processes vary by building occupancy type as well as ownership category. Public and institutional building facility management is subject to different pressures and constraints than that of commercial buildings. Appendix B provides analysis of the facility management processes used by representative building occupancies including:

- School Buildings
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- Storage Buildings
- Emergency Buildings

3. Seismic Rehabilitation in Building Codes

IN BRIEF:
- **Most older buildings violate current seismic provisions**
- **The regulation of voluntary rehabilitation is in general less strict in its requirements than new construction**
- **Rehabilitation is sometimes mandated in retroactive ordinances and in the model codes**
- **The codes provide a basis for implementing incremental rehabilitation by design professionals**

3.1 Overview

Building codes are constantly revised, and the model codes are systematically revised on a regular schedule. In general, these revisions entail additional requirements and increasingly stringent requirement. An existing building built in compliance with the code at the time it was constructed is likely to be in violation of current codes. This increase in quantity and stringency has been specifically applicable to the codes' seismic requirements, and most older buildings violate current seismic provisions.

What are the implications for seismic rehabilitation?

The governing principle is that building codes contain provisions permitting a structure to remain and continue in use without change. This is generally referred to as "nonconforming rights". The traditional language, which is still used in the 2003 International Building Code (IBC) is:

> "The legal occupancy of any structure existing on the date of adoption of this code shall be permitted to continue without change, …."

Jurisdictions may create an exception to this principle by enacting retroactive ordinances that require existing buildings to mitigate an identified hazard. These are discussed in the next section.

With the exception of retroactive ordinances, code requirements are often triggered by voluntary actions carried out in buildings by their owners. These actions, discussed in the following sections, are:
- Repairs
- Alterations
- Additions

- Change of use

3.2 Regulation of Voluntary Rehabilitation (Repairs, Alterations, Additions, and Change of Use)

Typically, voluntary repairs have always been allowed to be made with the same material as the original construction.

Originally building codes had rules requiring buildings being altered more than a certain proportion of their value, usually 50%, to fully meet the code for new construction. An unintended result was to discourage improvements to existing buildings. By the mid-1970's all model codes had deleted such provisions. In their place, provisions were introduced to encourage rehabilitation of buildings. The general approach was to encourage any improvement in a building without specific mandates or rules. The codes allow buildings to be altered and improved without the entire building being required to meet the requirements of the code for new construction, provided the new work complies with the applicable provisions.

Additions must comply with the code for new construction. The design of additions that increase loads on an existing building must consider the effect of the increased load.

Originally building codes required that in a change of occupancy group or character of use, the building be made to comply with all the requirements of the code for new construction applicable to the new occupancy. More recently exceptions have been introduced that allow the Building Official to permit a building to be used for another occupancy group without full compliance if the fire and life risk are not increased.

Pre-2000 Model Code Approach

BOCA National Building Code (NBC)--The 1996 edition includes Section 3404, which permits alterations to structures without requiring the entire structure to be brought up to the current code. Section 3405 requires that a change of occupancy comply with the intent of the code for new construction, and not result in greater hazard. Chapter 16 of the code requires compliance with the seismic provisions of the code in additions and changes of occupancy that reclassify the building to a higher Seismic Hazard Exposure Group. There are special exceptions to the latter case for change of group regions of low seismicity.

SBCCI Standard Building Code (SBC)--The 1999 edition includes Section 3401.2.1, which permits alterations, repairs or rehabilitation work to be made to any existing structure without requiring the structure to comply with the code as long as the new work is in accordance with the current code. Section 1607.1 contains requirements for seismic design with exceptions for wood frame structures and the regions of low seismicity.

ICBO Uniform Building Code (UBC)—The 1997 edition includes provisions similar to BOCA and SBCCI plus additional specific provisions permitting seismic improvements without designing to current building code seismic force levels. Within these provisions are certain requirements such as not reducing the strength of the existing systems but any improvement is encouraged.

The International Conference of Building Officials (ICBO) also published the Uniform Code for Building Conservation (UCBC). This document contains appendix chapters for seismic rehabilitation of Unreinforced Masonry Bearing Wall Buildings, Tilt-up Concrete Wall Buildings, and Wood Frame Buildings with Cripple Walls. The UCBC also contains the trigger for wall anchors and parapet bracing in unreinforced masonry buildings. The provisions of the UCBC are used by many jurisdictions throughout the country for seismic rehabilitation of unreinforced masonry buildings.

Current Building Code Provisions

ICC International Building Code (IBC)—The 2000 edition includes language similar to the earlier model codes regarding non-conforming rights, repairs, alterations, additions, and change of use. There is also permissive language encouraging improvements, but not as detailed as the seismic improvement provisions of the UBC.

The current 2003 editions has continued these provisions. Chapter 1 allows existing buildings to continue to serve (non-conforming rights), Chapter 16 – Seismic Provisions, permits voluntary seismic rehabilitation without full compliance and provides more detail similar to the UBC. Chapter 34 contains provisions for repairs, alterations, additions, and change of use in existing buildings. Chapter 34 of the IBC permits a building to be used for other occupancies without conforming to all the requirements of the code if the life risk is less hazardous that the existing. Many jurisdictions have permitted the UCBC provisions to be used for strengthening buildings when a change of occupancy is requested.

ICC International Existing Building Code (IEBC)--The IEBC represents a new approach to the regulation of existing buildings, one that specifically encourages their continued use. The 2003 edition has provisions similar to those in the 2003 IBC relative to non-conforming rights, repairs, and additions. For alterations it defines three levels—Level 1, Level 2, and Level 3—which attempt to establish proportionality between the voluntary work and the mandated work, keeping the latter to a predictable minimum. Alterations that strengthen the building may be made without full compliance with the current code force levels. For change of use the IEBC establishes three hazard scales, and mandate compliance with selected code provisions for new construction only when a defined hazard is increased. Its seismic requirements in a change of use are similar to those in the IBC (triggered by a higher hazard classifications), with a number of additional exceptions based on the use group and number of stories; different analysis methods are permitted as well.

The IEBC includes a provision that mandates the addition of parapet bracing and wall anchors in unreinforced masonry buildings in a region of high seismicity when the building is reroofed.

Repairs to a structural elements require that a seismic evaluation be done. The seismic evaluation is to be based on ASCE 31, FEMA 356, or the Guidelines for Seismic Rehabilitation of Buildings (GSREB), published by ICBO and included in the IEBC as an Appendix. The code describes the basis for design, the performance level and when reduced design forces may be used. When repairs are made to buildings damaged in a disaster, special seismic provisions apply, which are discussed in the next section.

NFPA Building Construction and Safety Code (NFPA 5000)--The 2003 edition adopts by reference the ASCE 7 Standard, Minimum Design Loads for Buildings and Other Structures for structural loads, including seismic. ASCE 7 contains specific criteria for additions in that the addition must comply with current loads and if the addition increases the seismic load on, or reduces the seismic resistance of, the existing structure, additional design is required.

ASCE 7 also contains provisions triggered by change of use. In the case of change of use that reclassifies the building to a higher Seismic Use Group (SUG), it must comply with the current code provisions. There are two exceptions:

1. Compliance is not required for buildings reclassified for SUG I to SUG II (an increase in occupant load), where the $S_{ds} < 0.33$.
2. Specific seismic detailing requirements of the Appendix, required for new structures of steel or concrete are not required to be met when it can be shown the performance and seismic safety is equivalent to that of a new structure.

Chapter 15 of NFPA 5000 is entitled Building Rehabilitation, and like the IEBC, it represents a new approach to the regulation of existing buildings, one that specifically encourages their continued use. It is quite similar to the IEBC, but does not include the various seismic provisions of the IEBC. It is silent on structural requirements in alterations, reserving those sections for future development. There is no direction in ASCE 7 for alterations to existing structures.

3.3 Mandatory Rehabilitation (Damage Repair and Retroactive Ordinances)

Retroactive Ordinances

As described above, typical code provisions permit repairs to be made using the same materials as the original. The IEBC has additional provisions relating to repairs to structural elements and repairs to damaged buildings.

Some jurisdictions around the country have limited the non-conforming rights of existing buildings by enacting retroactive ordinances. Some of these mandate seismic strengthening for certain building construction types. Typical of these would be mandated strengthening of unreinforced masonry buildings, such as Division 88 of the Los Angeles Building Code, the unreinforced masonry ordinance. These have been adopted by most cities in California's seismic zone 4, and by some jurisdictions in California's seismic zone 3 and Nevada's seismic zones 3 and 4. Many of these permit incremental rehabilitation. Other jurisdictions have adopted seismic rehabilitation provisions for tilt-up concrete wall buildings.

IEBC Provisions

As stated above, the IEBC contains provisions that may trigger a seismic evaluation when a building has been damaged or is undergoing repair.

The IEBC defines the term "substantial structural damage", which is based on the percent of strength loss in vertical elements of the lateral load resisting system and to vertical load carrying components that are damaged to a level less than 75 percent of the current code requirements. Buildings that have sustained "substantial structural damage" and are repaired are required to demonstrate that the repaired building complies with the wind and seismic provisions of the IBC. Buildings that have sustained less damage then "substantial structural damage" are permitted to be repaired using materials the same as the original.

3.4 Code Basis for Incremental Rehabilitation

Goal

The goal of incremental seismic rehabilitation is to ultimately comply with the intent of the building code when all the increments are completed. Incremental seismic rehabilitation is intended to bring a building into full compliance with current seismic rehabilitation provisions as described in the referenced ASCE 31 and FEMA 356 and as adopted by the model building codes. The only difference is that the work is done over time rather than as a single project.

From the perspective of the building code, each increment of seismic rehabilitation is an alteration that improves the building. Thus, it is fully consistent with code provisions permitting voluntary improvements without requiring total building upgrading.

With the possible exceptions of specific IEBC triggers for repair of damaged building, change of occupancy, or retroactively mandated strengthening, the design professional may design and implement incremental seismic rehabilitation without full compliance with current code provisions.

Liability

Many design professionals have been reluctant to undertake any rehabilitation that is not in full compliance with current building code provisions. Some believe that there is a potential exposure to professional liability risk when undertaking incremental or partial seismic rehabilitation. This chapter suggests that this concern for liability is misplaced, and that code intent is to permit alterations to buildings without the entire structure being made to comply with the requirements of the code. It also suggests that the codes permit any improvement.

While the design professional must make the decision on the character and extent of work, the information provided above is to note that the code, as the law, permits the designer leeway and discretion in phasing incremental seismic rehabilitation projects.

4. Incremental Seismic Rehabilitation Engineering/Basic Information Requirements

4.1 Overview

The concept of Incremental seismic rehabilitation is presented to building owners in the companion set of documents *Incremental Seismic Rehabilitation for _____ Buildings*, FEMA 395 through FEMA 402 (referred to herein as occupancy manuals).

The engineering implementation of incremental seismic rehabilitation relies on the use of the following three documents, which are referenced extensively in the text:

- *Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook, Second Edition*, FEMA 154
- *Seismic Evaluation of Existing Buildings*, ASCE 31 (based on FEMA 310, *Handbook for the Seismic Evaluation of Existing Buildings—A Prestandard*)
- *Prestandard and Commentary for the Seismic Rehabilitation of Buildings*, FEMA 356

Each of these documents requires the application of basic information in the following three categories:

- level of seismicity
- building structural classification
- performance level goal

While the information in each of these categories used in documents noted above is consistent, it is presented in different degrees of detail as a function of the specific application of each document. This chapter discusses each of the three categories of information, and compares their use in each of the documents. Chapter 5 discusses the use of each of these documents in the context of incremental seismic rehabilitation engineering.

4.2 Levels of Seismicity

Extensive studies by the U.S. Geological Survey (USGS) have developed maps of the earthquake potential throughout the nation. Maps show the anticipated level of ground acceleration. Knowing the location of the building, one can determine the expected ground shaking. There are two maps for the United States: a short (S_s) period map and a one second (S_1) map. The specific map data is necessary to determine the Level of Seismicity, a factor used throughout the several reference FEMA and building code documents described later in this manual.

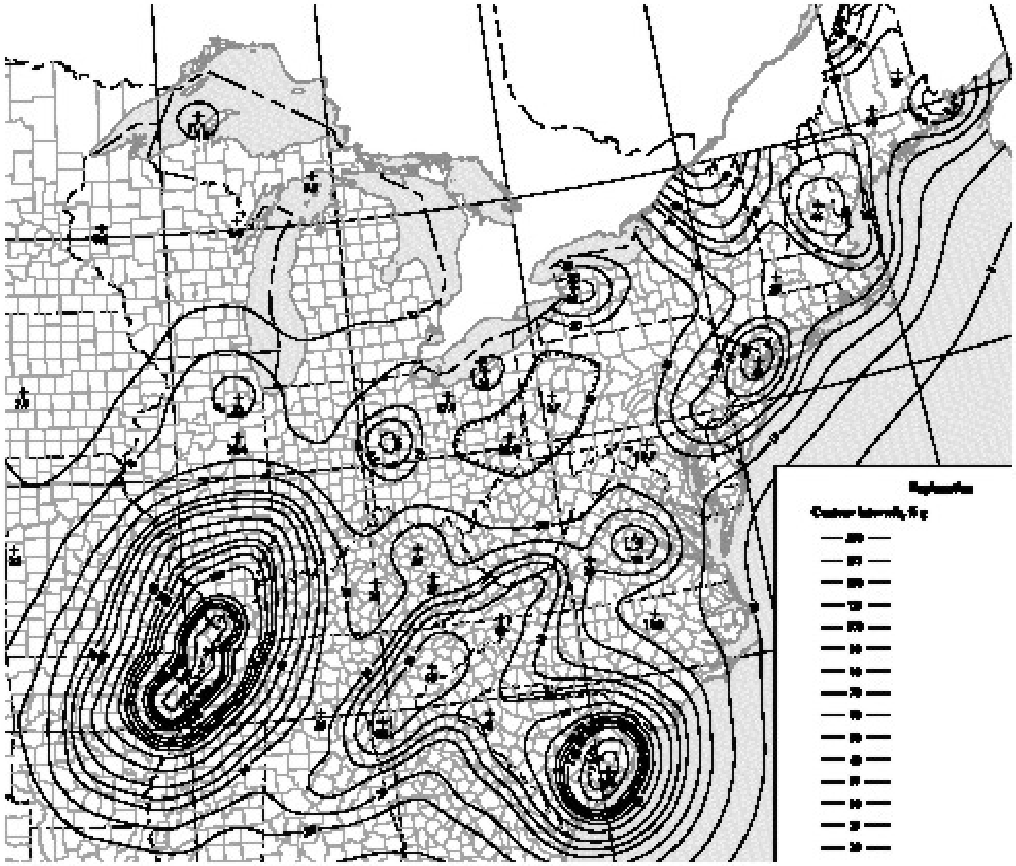


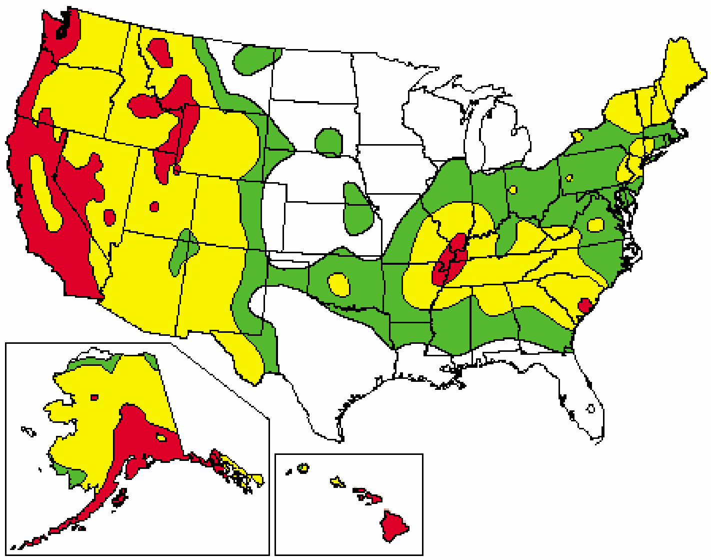
Figure: Sample Seismicity Map

In addition to the expected ground shaking, the engineer must also know the soil type at the specific building site. The soil type will determine whether the ground shaking will amplify or decrease at that particular site. The S_s and S_1 values found on the maps and the soil type will permit determination of the level of seismicity.

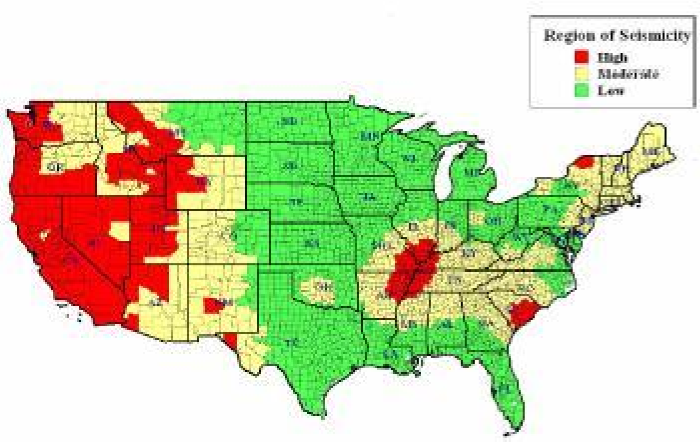
In some cases, depending on site-specific soil information, a building appearing to be in one level of seismicity may turn out to have a different level of seismicity. Possibly higher or lower.

Use of a default soil value is possible and depending on the building may simplify the evaluation process. It may result in more conservative analysis criteria (and, potentially, a more expensive rehabilitation cost).

The Seismic Hazard Map included in the occupancy manuals is based on the USGS maps. It is intended to explain levels of seismicity to building owners. The map is a simplified presentation of seismic potential. It shows three zones from the lowest (green) to the highest (red). White areas on the map have low seismic hazard.



FEMA 154 uses a similar map to define three levels of seismicity: low, moderate and high. The map is based on the USGS maps, but aggregates the levels more conservatively than the occupancy manual map.



Note: Seismicity regions are based on ground motions having a 2% probability of exceedance in 50 years.

ASCE 31 establishes three levels of seismicity that are defined in terms of the USGS maps S_s and S_1 values modified by soil factors as S_{DS} and S_{D1} respectively. The following Table defines the three levels of seismicity, low, moderate, and high:

Region of Seismicity[1]	S_{DS}	S_{D1}
Low	<0.167g	<0.067g
Moderate	<0.500g ≥0.167g	<0.200g ≥0.067g
High	≥0.500g	≥0.200g

[1] The highest region of seismicity defined by S_{DS} or S_{D1} shall govern.

FEMA 356 employs three zones of seismicity that are defined in terms of the USGS maps S_s and S_1 values modified by soil factors and seismic probabilities as S_{XS} and S_{X1} respectively. The three zones of seismicity, low, moderate, and high are defined by ranges of values of S_{XS} and S_{X1} that are identical to the ranges of values of S_{DS} and S_{D1} used in ASCE 31.

4.3 Building Structural Classification

While every building is unique in terms of its potential seismic vulnerabilities, it is useful for planning, screening, and evaluation purposes to categorize buildings into a limited number of categories.

The occupancy manuals categorize buildings into seven structural types based on the vertical load carrying structure and the diaphragm type. These categories are intended for use by building owners and their facility managers to initiate an incremental seismic rehabilitation program. The categories are used in matrices to identify mitigation opportunities and the respective complexity of engineering required to implement them (see Appendix B). The seven categories are:

- wood
- unreinforced masonry
- reinforced masonry
- concrete with flexible diaphragms
- concrete with rigid diaphragms
- steel with flexible diaphragms
- steel with rigid diaphragms

FEMA 154 considers fifteen building types, categorized by their primary structural lateral-load-resisting system. These categories are used to established Basic Scores, which define initial relative vulnerabilities, in the rapid visual screening procedure. The information used to classify buildings is obtained from a sidewalk survey. The surveyor may not be able to readily determine the structural system as it may be covered with finishes. In this case the surveyor must make an estimate of the lateral-load-resisting system including evaluation for more than one category. Furthermore, the lateral-load-resisting system may be different in different directions of the building, which is considered in a FEMA 154 survey.

ASCE 31 uses 24 building types, called common building types, categorized by their lateral-load-resisting system. These form the basis for specific checklists that are used in specific building evaluations. They are an expansion of the FEMA 154 building types, made possible by the more detailed information available to the engineer about each building. Some of distinctions of structure are based on the type of diaphragm in the building. The diaphragm type will affect the distribution of loads to shear resisting elements and the effects of torsion. The common building types represent most of the building stock, however ASCE 31 contains a checklist for buildings that may not fit into one of these common types.

FEMA 356 uses the 24 building types of ASCE 31 in a rehabilitation design procedure called Simplified Rehabilitation.

Table ____, shows the relationship between the building types, across the various FEMA documents.

OCCUPANCY MANUALS	FEMA 154, second edition	ASCE 31	Diaphragm Type
Wood Structure	W-1	W-1 (Light Frame)	
		W-1A (Frame w. Soft Story)	
	W-2	W-2 (Commercial and Industrial Buildings)	
Masonry Structure			
Unreinforced Masonry*	URM	URM	Flexible
		URMA	Rigid
Reinforced Masonry*	RM-1	RM-1	Flexible
	RM-2	RM-2	Rigid
Concrete Structure			
Wood Diaphragms	PC-1	C-2A	Flexible
		C-3A	
		PC-1	
Concrete Diaphragms	C-1	C-1	Rigid
	C-2	C-2	
	C-3	C-3	
	PC-2	PC-1A	
		PC-2	
		PC-2A	
Steel Structure			
	S-1	S-1A	

Wood Diaphragm		S-2A	Flexible
	S-2	S-3 (Light Gauge Metal)	
		S-5A	
Concrete Diaphragm	S-3	S-1	Rigid
		S-2	
	S-4	S-4	
	S-5	S-5	

* Masonry Structures with concrete diaphragms are treated like Concrete Structures with concrete diaphragms.

Figure ___: Comparison of FEMA Building Types

4.4 Level of Performance

Traditional Seismic Design

Seismic design of buildings, as required in building codes, is based on the criteria developed by the Structural Engineers Association of California (SEAOC).
The loading, or base shear, has changed over the years based on earthquake experience. Observing damage to buildings in earthquakes, as with methods in place to measure ground shaking, the engineers defined levels of ground shaking and characteristics of buildings with different lateral load resisting systems.

The expected building performance is not stated in the building code but contained in the SEAOC Recommended Lateral Force Requirements and Commentary, 1999 edition, which states:

> "These requirements provide minimum standards for use in building design regulation to maintain public safety in the extreme ground shaking likely to occur during an earthquake. These Requirements are primarily intended to safeguard against major failures and loss of life, not to limit damage, maintain function, or provide for easy repair."

Thus current seismic design criteria are intended to preserve life safety and assume there may be damage to a building as a result of an earthquake.

The SEAOC Requirements also contain a general set of performance statements to qualify the nature of expected damage. These are:

> "Structures designed in accordance with these requirements should, in general, be able to:
> Resist a minor level of earthquake ground motion without damage

Resist a moderate level of earthquake ground motion without structural damage, but possibly experience some non-structural damage
Resist a major level of earthquake ground motion having an intensity equal to the strongest either experienced or forecast for the building site without collapse, but possibly with some structural as well as non-structural damage."

Thus under current building codes, it is expected that structural damage, even in a design level earthquake, will be limited to a repairable level for most structures that meet the SEAOC Requirements. It should be noted that buildings constructed to earlier editions of the building code may have been designed to lower levels of ground shaking and thus may experience more damage than described in the current SEAOC Requirements.

Expected Structural Performance Under Current Codes

As mentioned above the intent of the building code, for non-essential building, is to provide life safety, in other words, no damage in a minor earthquake, limited structural damage in a moderate earthquake, and resistance to collapse in a major earthquake. Such a structure may lose much of its lateral load resisting system but the gravity load bearing elements will still function and provide some margin of safety against collapse. Such a structure may not be safe for continued occupancy or use until repairs are done. The economics of the repair of such damaged structures will vary on a case by case basis.

Expected Performance of Non-structural Components Under Current Codes

While current seismic design provisions typically require that nonstructural elements, such as partitions, lights and ceilings, mechanical and plumbing systems, cladding, canopies, etc., be secured so as not to present a falling hazard, they do not address the expected performance of these components. Much of the damage observed in recent earthquakes has been nonstructural, leaving buildings unoccupiable for extended periods of time.

Performance Approach to Seismic Design

Performance-based design, a relatively new concept in seismic design, is intended to give the design professional the ability to achieve, through analytical means, a building design that will reliably perform in a prescribed manner under one or more seismic hazard conditions. Alternative levels of seismic performance can be defined and performance objectives selected. This concept is attributable, at least in part, to studies of recent earthquakes in which buildings suffered substantial dollar damage but owners were surprised to find that the building performed as expected under the building code life safety requirements. Thus designers realized they need to be more specific about what "design to code" represents and what seismic design can and cannot accomplish. The concept is achievable with the development of analytical tools that enhance the understanding of building response under the range of earthquake ground motion that can be expected. Performance-based seismic design is articulated extensively in FEMA 356.

Specific levels of building performance can be selected as performance objectives, which describe the intended performance of the building (e.g., in terms of life safety, levels of acceptable damage, and post-earthquake functionality) when subjected to an earthquake hazard of a defined intensity (e.g., a maximum credible event or an event with a certain return period). FEMA 356 defines Rehabilitation Objectives as a function of four Target Building Performance Levels and four Earthquake Hazard Levels, resulting in 16 discrete Rehabilitation Objectives, as follows:

- Target Building Performance Levels (points on a continuous scale of increasing performance):
  - Collapse Prevention
  - Life Safety
  - Immediate Occupancy
  - Operational

- Earthquake Hazard Levels (in mean return period):
  - 72 years (typically rounded to 75)
  - 225 years
  - 474 years (typically rounded to 500)
  - 2,475 years (typically rounded to 2,500)

Current codes require that buildings be designed for two earthquake hazard levels without specifying a performance level:

- An earthquake with a 475 year return period, ground motions having a 10% probability of being exceeded in 50 years, called Basic Safety Earthquake 1 (BSE-1).
- An earthquake with a 2475 year return period, ground motions with a 2% probability of being exceeded in 50 years, Basic Safety Earthquake 2 (BSE-2).

FEMA 356 categorizes the 16 Rehabilitation Objectives into three categories:

- Basic Safety Objective
- Enhanced Objectives
- Limited Objectives

The Basic Safety Objective (BSO) is defined as buildings meeting the target building performance level of Life Safety for BSE-1, and the target building performance level of Collapse Prevention for BSE-2. The BSO is intended to approximate the earthquake risk to life safety traditionally considered acceptable in the United States, and implied in current codes for new construction. Buildings meeting the BSO are expected to experience little damage from relatively frequent, moderate earthquakes, but significantly more damage and potential economic loss from the most severe and infrequent earthquake that could affect them.

The Enhanced Objectives are those combinations of objectives higher than the BSO (greater than mandated in most current building codes for new construction), which fall into two categories:

- BSO plus meeting either Immediate Occupancy or Operational target building performance levels for any return period earthquake
- Meeting either Life Safety, Immediate Occupancy, or Operational target building performance levels for the 2,745 year earthquake.

The Limited Objectives are those combinations of objectives lower than the BSO (lower than mandated in most current building codes for new construction) that may be acceptable for existing buildings rehabilitation. Limited Objectives fall into two categories:

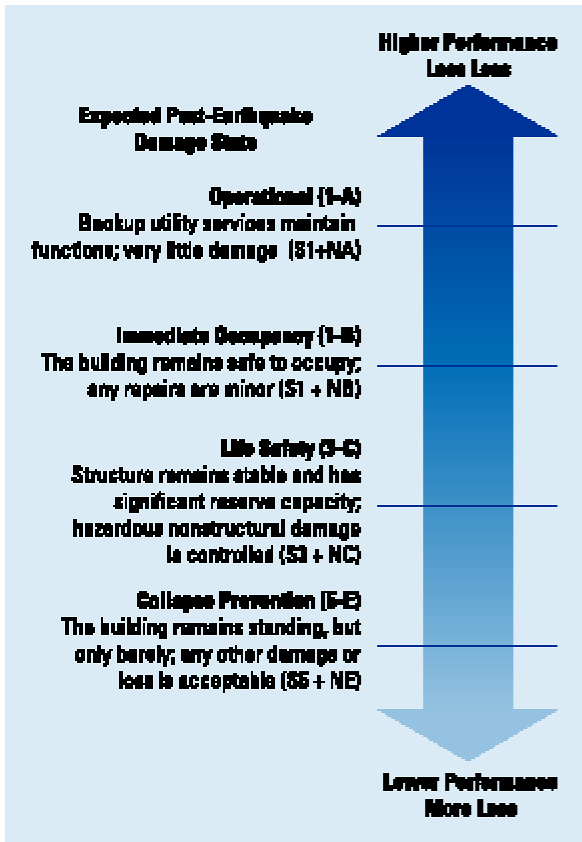
- Meeting either the target building performance level of Life Safety for BSE-1, or the target building performance level of Collapse Prevention for BSE-2, but not both.
- Meeting the target building performance level of Life Safety for earthquakes with a shorter return period than 475 years, or the building performance level of Collapse Prevention for earthquakes with a shorter return period than 2,745 years.

Building performance levels may described qualitatively in terms of the:

- Safety afforded building occupants during and after an earthquake
- Cost and feasibility of restoring the building to pre-earthquake conditions
- Length of time the building is removed from service to conduct repairs
- Economic, architectural, or, historic impacts on the community at large

The four Target Building Performance Levels discussed above can be directly related to the extent of damage sustained by the building during an earthquake. These damage states are elaborated in FEMA 356 as various combinations of Structural Performance Levels (of which five are defined in FEMA 356: S-1 through S-5) and Nonstructural Performance Levels (of which four are defined in FEMA 356: N-A through N-D). The most commonly used Structural Performance Levels are Immediate Occupancy (S-1), Life Safety S-3), and Collapse Prevention (S-5).

The occupancy manuals discuss the various levels of performance using the terminology of FEMA 356. Owners' facility managers are encouraged to define performance levels early in their seismic rehabilitation planning process, and to revisit these definitions in an iterative manner as they develop detailed plans and cost estimates. They are told that the design professionals that they employ will most likely make use of FEMA 356. The concept is explained with the help of the following two graphics adapted from FEMA 356.



Adapted from FEMA 356, Figure C1-2

This figure defines and illustrates the Target Building Performance Levels.

Damage Control and Building Performance Levels

	Target Building Performance Levels Lower Performance / More Loss → Higher Performance / Less Loss			
	Collapse Prevention Level (5-E)	Life Safety Level (3-C)	Immediate Occupancy Level (1-B)	Operational Level (1-A)
Overall Damage	**Severe**	**Moderate**	**Light**	**Very Light**
General	Little residual stiffness and strength, but load-bearing columns and walls function. Large permanent drifts. Some exits blocked. Infills and unbraced parapets failed or at incipient failure. Building is near collapse.	Some residual strength and stiffness left in all stories. Gravity-load-bearing elements function. No out-of-plane failure of walls or tipping of parapets. Some permanent drift. Damage to partitions. Building may be beyond economical repair	No permanent drift. Structure substantially retains original strength and stiffness. Minor cracking of facades, partitions, and ceilings as well as structural elements. Elevators can be restarted. Fire protection operable.	No permanent drift. Structure substantially retains original strength and stiffness. Minor cracking of facades, partitions, and ceilings as well as structural elements. All systems important to normal operations are functional.
Nonstructural Components	Extensive damage.	Falling hazards mitigated but many architectural, mechanical, and electrical systems are damaged	Equipment and contents are generally secure, but may not be operable due to mechanical failure or lack of utilities.	Negligible damage occurs. Power and other utilities are available, possibly from standby sources.
Comparison with performance intended for buildings designed under the *NEHRP Provisions* for the Design Earthquake	Significantly more damage and greater risk.	Somewhat more damage and slightly higher risk.	Less damage and lower risk.	Much less damage and lower risk.

Adapted from FEMA 356, Table C1-2

This table describes the approximate limiting levels of structural and nonstructural damage that may be expected of buildings rehabilitated to the levels defined in FEMA 356.

FEMA 154 is used to identify potentially hazardous buildings. It does not involve performance levels, but the term “hazardous” implies a basis in life safety.

In ASCE 31, the concept of performance level in introduced into the evaluation process. ASCE 31 uses two levels of performance, Life Safety (LS) and Immediate Occupancy (IO). The checklists in ASCE 31 contain criteria and evaluation methods for both performance levels. The performance levels of ASCE 31 and FEMA 356 are consistent in concept and terminology. Higher performance levels may be evaluated using ASCE 31 but will require a Tier 3 analysis.

As stated above, FEMA 356 is where the concept of performance levels has been most completely articulated to date. In addition to the general graphics presented above, FEMA 356 includes tables that contain detailed descriptions of damage states for the three most commonly used Structural Performance Levels

(Table C1-3) and the four Nonstructural Performance Levels (Table C1-4). Damage states are defined for specific structural components and specific nonstructural elements. The design professional should use FEMA 356 and should work closely with the owner in determining the appropriate performance level. This may be an iterative process to determine the best cost/benefit ratio for a specific building project.

5. Incremental Seismic Rehabilitation Engineering / Process Tasks

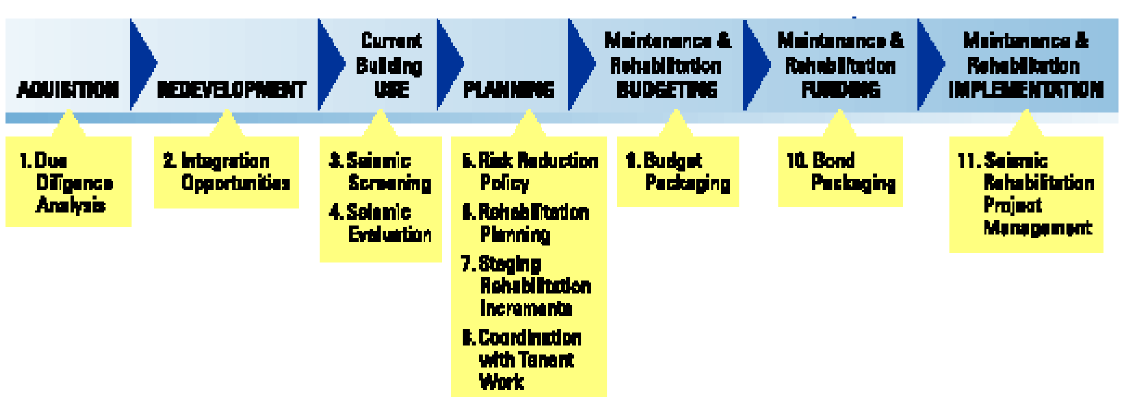
5.1 Overview

The typical facility management process used by owners of commercial buildings consists of seven phases of activities:

- Acquisition
- Redevelopment
- Current Building Use
- Planning
- Maintenance & Rehabilitation Budgeting
- Maintenance & Rehabilitation Funding
- Maintenance & Rehabilitation Implementation.

(For institutional owners such as school districts, the process may exclude the first two phases, and begin with Current Building Use.) This process is sequential, progressing from acquisition through implementation of rehabilitation in any given building. An owner who has a large inventory of buildings is likely to have ongoing activities in all of these phases in different buildings. The process is illustrated in the following diagram. (See Appendix C for more detailed diagrams).

Design professionals can perform seismic rehabilitation engineering services for owners in five of these phases, as illustrated in the following diagram.



[Delete 5, 8, 9,and 10; consider changing the numbers to bullets.]

These engineering services consist of six distinct tasks, the first five of which are discussed in the following sections of this chapter:

1. Due diligence analysis and identification of initial integration opportunities (performed in the acquisition and redevelopment phases).
2. Seismic screening of the building inventory (performed in the current building use phase).
3. Seismic evaluation of individual buildings (performed in the current building use phase).
4. Seismic rehabilitation planning and design (performed in the planning phase).
5. Staging of rehabilitation increments/prioritization and integration of seismic rehabilitation increments (performed in the planning phase).
6. Construction period support (performed in the maintenance & rehabilitation implementation phase).

There are resource documents to assist the design professional in most of these tasks.

ASTM has developed and published E 2026, *Standard Guide for the Estimation of Building Damageability in Earthquakes*. It is intended for use in the due diligence process of building acquisition, and can assist in the performance of task 1. It defines and establishes good commercial, customary practice, and standard-of-care for conducting a probabilistic study of expected loss to buildings from damage associated with earthquakes.

FEMA has developed the following resource documents, which can assist in the performance of tasks 2-4:

- *Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook, Second Edition*, FEMA 154
- *Seismic Evaluation of Existing Buildings*, ASCE 31 (based on FEMA 310, *Handbook for the Seismic Evaluation of Existing Buildings—A Prestandard*)
- *Prestandard and Commentary for the Seismic Rehabilitation of Buildings*, FEMA 356

These resource documents are discussed in detail later in this chapter.

Two additional FEMA resource documents that are not discussed in this manual may provide useful information to the design professional:

FEMA 172 – *Techniques for Seismically Rehabilitating Existing Buildings*
FEMA 156,157 – *Typical Costs for Seismically Rehabilitating Existing Buildings*

5.2 Task 1. Due diligence analysis and identification of initial integration opportunities

Due diligence is performed on behalf of owners considering the acquisition of an existing building. Separate due diligence is also usually performed by lenders and insurers involved in the real estate transaction. The purpose of due diligence is to identify and quantify all the risks that may accompany the building being acquired.

Seismic risks have traditionally been identified and quantified in the due diligence process by means of Probable Maximum Loss (PML) analyses, which are routinely performed in real estate transactions in California and the Pacific Northwest. PML analyses consist of estimating the damage that the building would experience in a major rare earthquake, expressed as a percentage of the value of the building. Owners, lenders, and insurers all establish their own criteria for acceptable PML values, based on their respective risk-tolerances.

An alternative method of analysis would estimate the damage that the building would experience from all earthquakes that could affect the site, from lower intensity more frequent earthquakes to the major rare earthquakes. Such an analysis accounts for the probabilities of each earthquake being considered, and may express the results as an annual loss rate.

ASTM E 2026, *Standard Guide for the Estimation of Building Damageability in Earthquakes,* is intended for use in the due diligence process of building acquisition. It specifically encourages the use of alternative methods of analysis discussed in the preceding paragraph.

The guide is intended for use, on a voluntary basis, by parties who wish to estimate damageability from earthquakes to real estate. It outlines procedures for conducting an estimate of earthquake loss study for a specific user considering the user's due-diligence requirements and risk tolerance level. The specific purpose of the estimate of earthquake loss study is to provide the user with an adequate measure of possible earthquake losses that may be expected during the anticipated term for holding either the mortgage or the deed.

It is designed to assist the user in developing information about the earthquake-related damage potential of a building, or groups of buildings, and as such has utility for a wide range of persons, including, but not limited to, building owners, building tenants, lenders, insurers, occupants, and potential investors/owners and mortgages.

The guide provides requirements for the performance of five different types of earthquake loss studies intended to serve different financial and management needs of the user:

- Building stability
- Site Stability
- Damageability
- Contents Damageability
- Business Interruption

Several of these types of assessment depend on earthquake ground motion characterization.

The estimate of earthquake loss may consider any level of investigation from 0 to 3 that serves the particular purposes for which the results are desired. Level 0 is termed a screening level of investigation while Level 3 is an exhaustive investigation. Each level is defined in the guide.

The guide is site-specific in that it relates to estimation of earthquake loss to building(s) located at a specific site.

5.3 Task 2. Seismic screening of the building inventory

FEMA 154, *Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook, Second Edition* provides a simple procedure for surveying an inventory of buildings that enables users to classify surveyed buildings into two categories: those acceptable as to risk to life safety or those that may be seismically hazardous and should be evaluated in more detail.

Briefly, the rapid visual screening (RVS) procedure consists of inspecting a building from the exterior, identifying its probable lateral-load-resisting system, identifying building attributes that modify the seismic performance expected of this lateral-load-resisting system, and assigning a score to quickly determine if the building has a lateral-load-resisting system or features that are potentially hazardous. This procedure is carried out on pre-printed data collection forms. If a building receives a high score it is considered to have adequate seismic resistance. If a building receives a low score it should be evaluated by a design professional. Buildings identified as needing more detailed evaluation should not be considered hazardous without additional evaluation.

A basic concept of the RVS is to identify, for the building under review, which of 15 building types it corresponds to. These 15 types, and their relationship to the seven categories used in occupancy manuals and to the 24 types used in ASCE 31, are discussed in Chapter 4. In many cases an experienced building inspector or other person knowledgeable in building practices will be able to determine easily which of the categories most accurately describes a particular building.

This often involves not only general knowledge of building practices, but familiarity with specific regional patterns of construction.

The 15 categories are sufficiently broad yet distinguishable so that the experts who developed FEMA 154 could estimate their seismic performance based on past experience. Based on this expert opinion, a Basic Structural Hazard (BSH) score is assigned to a typical building in each category, depending on the earthquake forces it is likely to experience. BSH scores are given for regions of low, moderate, and high levels of seismicity. (These levels of seismicity and their relationship to levels of seismicity used in the occupancy manuals, ASCE 31, and FEMA 356 are discussed in Chapter 4.) For each level of seismicity, the score reflects the estimated likelihood of a typical building of that category sustaining major damage, defined as damage requiring repairs that would approximate 60% of the building value. This level of damage is about the threshold where life-safety begins to become a serious hazard.

The BSH scores range from 1.6 (concrete frame with unreinforced masonry infill in region of high seismicity) to 7.4 (light wood frame, less than or equal to 5,000 square feet, in region of low seismicity), where a higher score signifies better seismic performance. The BSH scores are next increased or decreased by nine Score Modifiers that account for building or site features that increase or decrease a building's seismic vulnerability (such as number of stories, building condition, and irregularities). The Score Modifiers are the following:

- mid-rise (4-7 stories)
- high-rise (8 or more stories)
- vertical irregularity
- horizontal irregularity
- pre-code (buildings designed and constructed prior to the adoption of a seismic code)
- post-benchmark (buildings designed and constructed after significant improvements in seismic codes)
- soil type C (soft rock or very dense soil)
- soil type D (stiff soil)
- soil type E (soft soil)

When the Score Modifiers are subtracted from or added to the BSH, the result is the final Structural Score (S) for the building under review.

The S-score is the basic measure of the degree of adequacy of the building. Final S-scores typically range from 0 to 7 with higher scores corresponding to better expected seismic performance. An S-score of 2 is suggested as a "cut-off", based on present seismic design criteria. At this level and below the building may sustain major life-threatening damage in an earthquake that it is reasonable to expect. Using this cut-off level, buildings having an S-score of 2 or less should be investigated by a design professional. For a large group of buildings, priorities for seismic evaluation can be based on these scores (the lower the score, the higher the priority). (The S-score of 2 is only a recommendation. Some agencies and engineers suggest that a building with an S-score of less than 3 should be evaluated.)

This information is summarized in a quick reference guide form (see Figure__).

Rapid Visual Screening of Buildings for Potential Seismic Hazards (FEMA 154)
Quick Reference Guide (for use with Data Collection Form)

1. Model Building Types and Critical Code Adoption and Enforcement Dates

Structural Types		Year Seismic Codes Initially Adopted and Enforced*	Benchmark Year when Codes Improved
W1	Light wood frame, residential or commercial, ≤ 5000 square feet	______	______
W2	Wood frame buildings, > 5000 square feet.	______	______
S1	Steel moment-resisting frame	______	______
S2	Steel braced frame	______	______
S3	Light metal frame	______	______
S4	Steel frame with cast-in-place concrete shear walls	______	______
S5	Steel frame with unreinforced masonry infill	______	______
C1	Concrete moment-resisting frame	______	______
C2	Concrete shear wall	______	______
C3	Concrete frame with unreinforced masonry infill	______	______
PC1	Tilt-up construction	______	______
PC2	Precast concrete frame	______	______
RM1	Reinforced masonry with flexible floor and roof diaphragms	______	______
RM2	Reinforced masonry with rigid diaphragms	______	______
URM	Unreinforced masonry bearing-wall buildings	______	______

*Not applicable in regions of low seismicity

2. Anchorage of Heavy Cladding
Year in which seismic anchorage requirements were adopted: ______

3. Occupancy Loads

Use	Square Feet, Per Person	Use	Square Feet, Per Person
Assembly	varies, 10 minimum	Industrial	200-500
Commercial	50-200	Office	100-200
Emergency Services	100	Residential	100-300
Government	100-200	School	50-100

4. Score Modifier Definitions

Mid-Rise:	4 to 7 stories
High-Rise:	8 or more stories
Vertical Irregularity:	Steps in elevation view; inclined walls; building on hill; soft story (e.g., house over garage); building with short columns; unbraced cripple walls.
Plan Irregularity	Buildings with re-entrant corners (L, T, U, E, + or other irregular building plan); buildings with good lateral resistance in one direction but not in the other direction; eccentric stiffness in plan, (e.g. corner building, or wedge-shaped building, with one or two solid walls and all other walls open).
Pre-Code:	Building designed and constructed prior to the year in which seismic codes were first adopted and enforced in the jurisdiction; use years specified above in Item 1; default is 1941, except for PC1, which is 1973.
Post-Benchmark:	Building designed and constructed after significant improvements in seismic code requirements (e.g., ductile detailing) were adopted and enforced; the benchmark year when codes improved may be different for each building type and jurisdiction; use years specified above in Item 1 (see Table 2-2 of FEMA 154 *Handbook* for additional information).
Soil Type C:	Soft rock or very dense soil; S-wave velocity: 1200 – 2500 ft/s; blow count > 50; or undrained shear strength > 2000 psf.
Soil Type D:	Stiff soil; S-wave velocity: 600 – 1200 ft/s; blow count: 15 – 50; or undrained shear strength: 1000 – 2000 psf.
Soil Type E:	Soft soil; S-wave velocity < 600 ft/s; or more than 100 ft of soil with plasticity index > 20, water content > 40%, and undrained shear strength < 500 psf.

All the scoring is carried out on pre-printed data collection forms (see Figure__). These forms also record other features that may be important for risk assessment:

- occupancy category and number of occupants
- soil type
- falling hazards (unreinforced chimneys, parapets, cladding, and other)

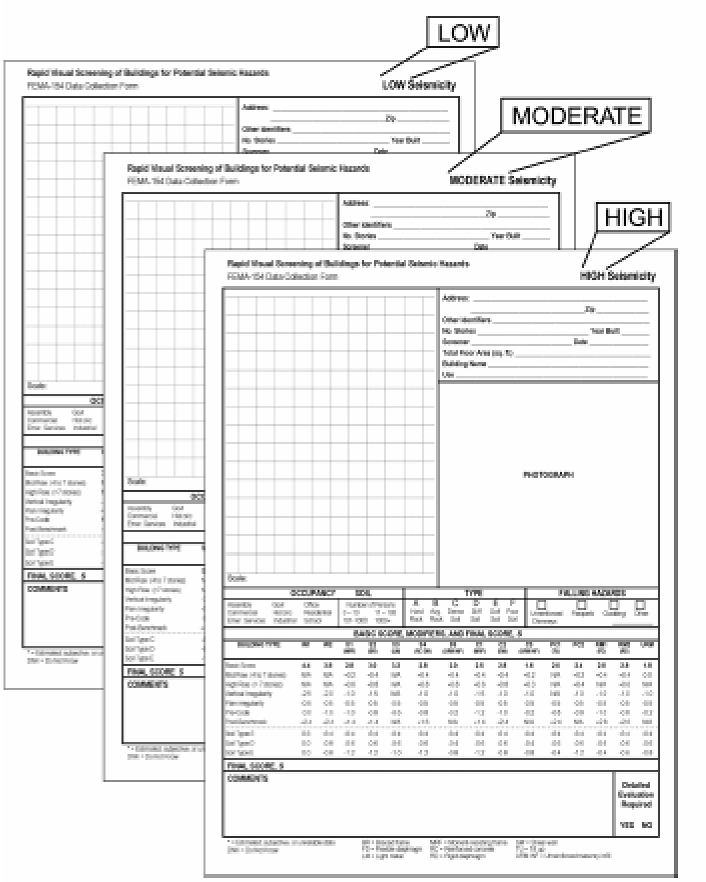


Figure 1-2 Data Collection Forms for the three designated seismicity regions (low, moderate, and high). [change figure number]

An example of a complete FEMA 154 data collection form is shown in Figure __.

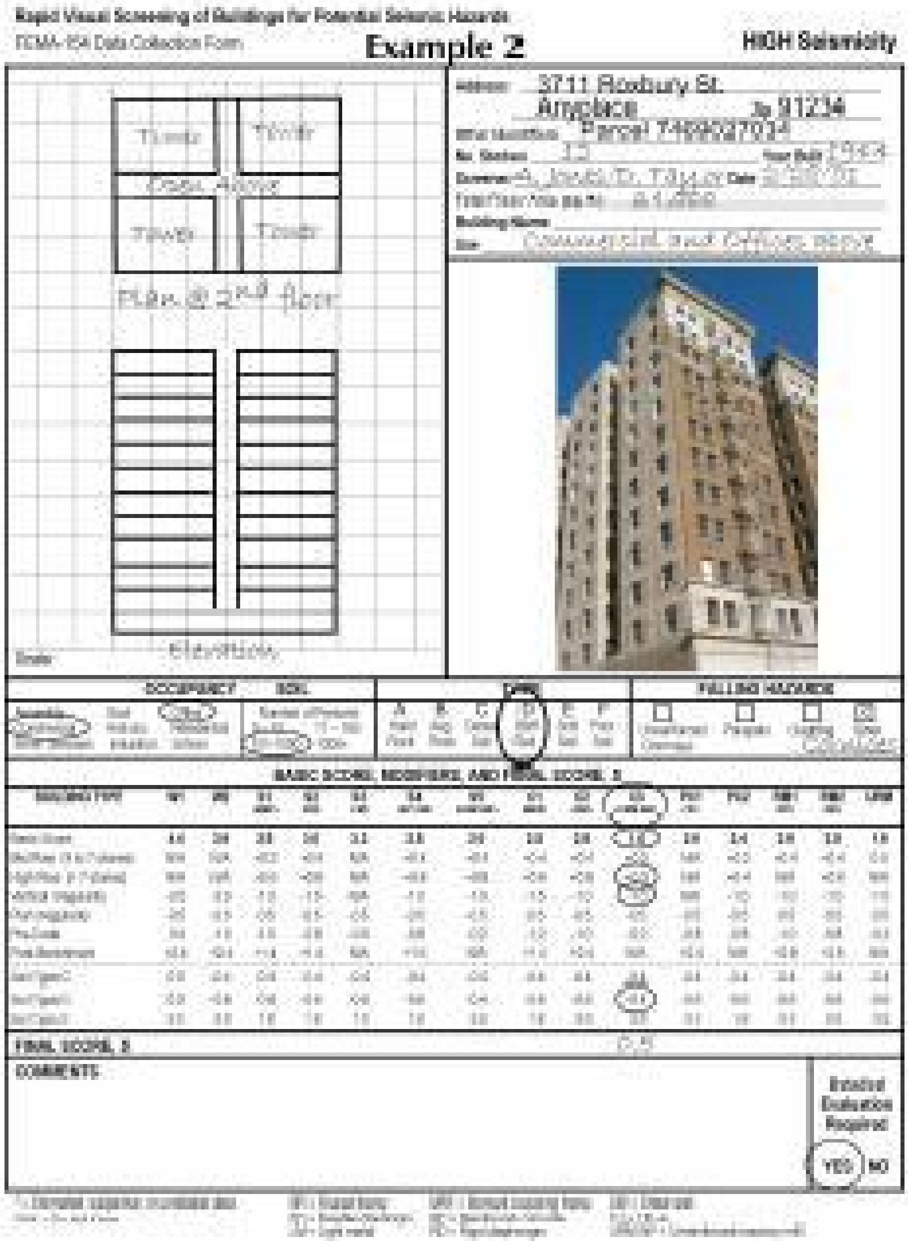


Figure 5-11 Completed Data Collection Form for Example 2, 3711 Roxbury Street.

[change figure number]

In order to carry out a RVS survey, the design professional should obtain the following information, if available, from the owner or from other sources:

- o Address(es) and/or other identifying information
- o Structural system
- o Building age
- o Building occupancy

- Soil conditions
- Building plans if available

The design professional should deliver to the owner a prioritized list of all the buildings in the inventory that may require more detailed seismic evaluation.

5.4 Task 3. Seismic evaluation of individual buildings

Once it has been determined that a building should be evaluated, either based on a FEMA 154 survey, prior knowledge of a building's vulnerability, or for any other reason, the seismic evaluation is initiated. The methodology contained in ASCE 31, *Seismic Evaluation of Existing Buildings*, provides the engineer with a straightforward and logical set of tools. Other established procedures may be used for evaluation if the engineer so desires. Note that ASCE 31 is based on a prior FEMA publication, FEMA 310, which in turn was first published as FEMA 178. FEMA 178 has been used to evaluate many buildings and may be the basis for regulation in a number of jurisdictions. Engineers involved in building evaluation, should be familiar with FEMA 178.

The intent of ASCE 31 is to screen out the acceptable buildings and identify mitigation needs for the remainder. It uses a three-tiered process applicable to any level of seismicity. Using this process, buildings may be evaluated to either the life safety or immediate occupancy performance level (see Chapter 4 for a discussion of performance levels). A graphic illustration of the process is shown herein as Figure__.

Chapter 1.0 - General Provisions

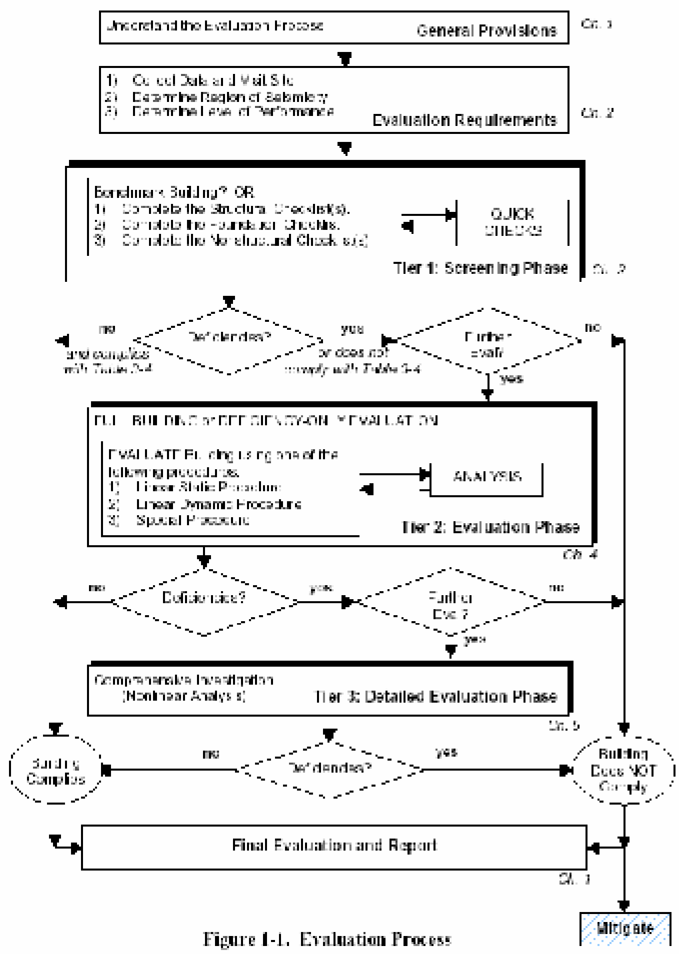


Figure 1-1. Evaluation Process

ASCE xx-xx Seismic Evaluation Draft Standard 1 - 7

[provide #]

Users should note that the ASCE 31 process provides flexibility for the engineer to make judgments on whether additional evaluation is desirable or necessary or when it may be most desirable to mitigate the identified hazards. One can complete a Tier 1 screening, and proceed directly to the mitigation of identified deficiencies. Alternatively, one can proceed to a more detailed analysis.

A Tier 1 evaluation is required for all buildings so that potential deficiencies may be quickly identified. Further evaluation using a Tier 2 or Tier 3 evaluation will then focus, as a minimum, on the potential deficiencies identified in Tier 1, unless the latter are mitigated.

ASCE 31 provides guidance for the level of investigation required. A site visit is required to verify existing data or collect additional data, determine the general condition of the building, and verify or assess the site conditions including potential impact of adjacent buildings.

Tier 1: A Tier 1 evaluation is intended to screen, or filter out, those buildings that do not need further seismic rehabilitation. The Tier 1 process is shown in Figure__.

Chapter 3.0 - Screening Phase (Tier 1)

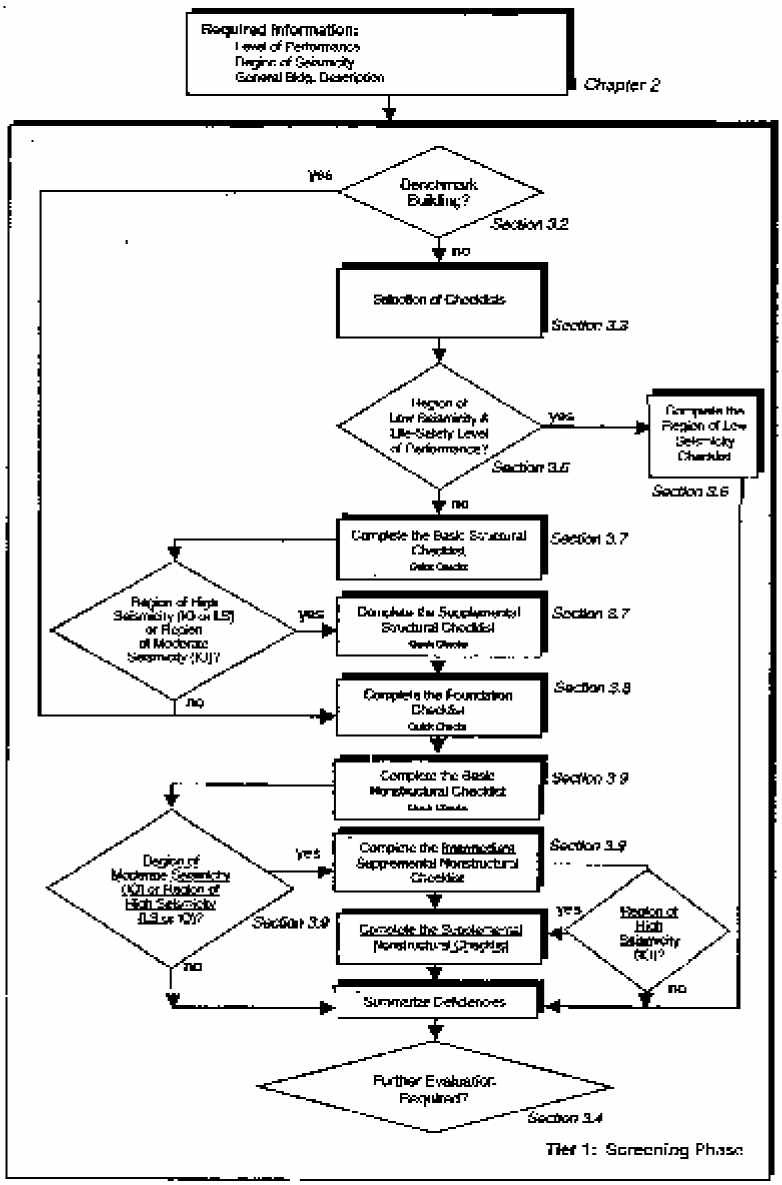


Figure 3-1. Tier 1 Evaluation Process

3 - 2 Seismic Evaluation Draft Standard ASCE 31-xx

The Tier 1 evaluation begins with the determination whether the building is a “Benchmark Building.” Benchmark buildings are those structures constructed under a modern building code, developed in recent years, that required seismic design. While Benchmark Buildings need not proceed with further evaluation, it should be noted that they are not simply exempt from the criteria. The design professional must determine that the building is compliant with the benchmark provisions. This will entail a site visit, an examination of existing documentation, and other requirements specified in the chapter. Even for benchmark buildings, the nonstructural and foundation elements checklists must be completed. Users are cautioned that even though a model building code may have contained the seismic provisions in the period of construction, the local jurisdictions may have deleted or exempted a building from such requirements.

In order to conduct a Tier 1 evaluation the engineer will have to determine the level of seismicity (see Chapter 4 for discussion), as shown in Figure__. The engineer will also need to review plans and other information concerning the building or develop that information. This may require development of as-built drawings and physical testing to determine the presence of reinforcing steel or connections. Removals of finishes may be necessary for testing or inspection.

Region of Seismicity[1]	S_{DS}	S_{D1}
Low	<0.167g	<0.067g
Moderate	<0.500g ≥0.167g	<0.200g ≥0.067g
High	≥0.500g	≥0.200g

[1] The highest region of seismicity defined by S_{DS} or S_{D1} shall govern.

[change “region” to level”]

For Tier 1, ASCE 31 categorizes building into 24 Common Building Types (see Chapter 4 for discussion) based on their lateral force resisting system. Structural checklists are included for each building type. Most buildings will fall into one of these categories. A procedure is included for structures that may not fit in one of these building types.

In additional to the structural checklists, there are nonstructural checklists covering architectural, mechanical, electrical, and plumbing elements of the building, and a foundation-geologic hazard checklist. Figure__ arrays the checklists required for a Tier 1 evaluation by level of seismicity and performance level. In some cases, ”quick check” calculation may be required. However, the level of analysis necessary in Tier 1 is minimal. A Tier 1 evaluation is necessarily conservative, which should be kept in mind by the engineer.

Table 3-2. Checklists Required for a Tier 1 Evaluation

Region Level of Seismicity[2]	Level of Performance[2]	Required Checklists[1]: Region Level of Low Seismicity (Sec. 3.6)	Basic Structural (Sec. 3.7)	Supplemental Structural (Sec. 3.7)	Geologic Site Hazard and Foundation (Sec. 3.8)	Basic Nonstructural (Sec. 3.9.1)	Intermediate Supplemental Nonstructural (Sec. 3.9.2)	Supplemental Nonstructural (Sec. 3.9.3)
Low	LS	✓						
	IO		✓		✓	✓		
Moderate	LS		✓		✓	✓		
	IO		✓	✓	✓	✓	✓	
High	LS		✓	✓	✓	✓	✓	
	IO		✓	✓	✓	✓	✓	✓

[1]A checkmark (✓) designates the checklist that must be completed for a Tier 1 evaluation as a function of the region level of seismicity and level of performance.

[2]LS = Life-Safety; IO = Immediate Occupancy; defined in Section 2.4.3.

[3]Defined in Section 2.5.

3-6 Seismic Evaluation Draft Standard ASCE 31-xx

[Figure number]

Figures__ and __ present basic and supplemental structural checklists, respectively, for an example building type.

Screening Phase (Tier 1)

3.7.9 Basic Structural Checklist for Building Type C2: Concrete Shear Walls with Stiff Diaphragms

This Basic Structural Checklist shall be completed where required by Table 3-2.

Each of the evaluation statements on this checklist shall be marked Compliant (C), Non-compliant (NC), or Not Applicable (N/A) for a Tier 1 Evaluation. Compliant statements identify issues that are acceptable according to the criteria of this standard, while non-compliant statements identify issues that require further investigation. Certain statements may not apply to the buildings being evaluated. For non-compliant evaluation statements, the design professional may choose to conduct further investigation using the corresponding Tier 2 Evaluation procedure; corresponding section numbers are in parentheses following each evaluation statement.

C3.7.9 Basic Structural Checklist for Building Type C2

These buildings have floor and roof framing that consists of cast-in-place concrete slabs, concrete beams, one-way joists, two-way waffle joists, or flat slabs. Floors are supported on concrete columns or bearing walls. Lateral forces are resisted by cast-in-place concrete shear walls. In older construction, shear walls are lightly reinforced but often extend throughout the building. In more recent construction, shear walls occur in isolated locations and are more heavily reinforced with boundary elements and closely spaced ties to provide ductile performance. The diaphragms consist of concrete slabs and are stiff relative to the walls. Foundations consist of concrete spread footings, mat foundations, or deep foundations.

Building System

C NC N/A LOAD PATH: The structure shall contain a minimum of one complete load path for Life Safety and Immediate Occupancy for seismic force effects from any horizontal direction that serves to transfer the inertial forces from the mass to the foundation. (Tier 2: Sec. 4.3.1.1)

C NC N/A MEZZANINES: Interior mezzanine levels shall be braced independently from the main structure, or shall be anchored to the lateral-force-resisting elements of the main structure. (Tier 2: Sec. 4.3.1.3)

C NC N/A WEAK STORY: The strength of the lateral-force-resisting system in any story shall not be less than 80 percent of the strength in an adjacent story, above or below, for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.1)

C NC N/A SOFT STORY: The stiffness of the lateral-force-resisting system in any story shall not be less than 70 percent of the lateral-force-resisting system stiffness in an adjacent story above or below, or less than 80 percent of the average lateral-force-resisting system stiffness of the three stories above or below for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.2)

C NC N/A GEOMETRY: There shall be no changes in horizontal dimension of the lateral-force-resisting system of more than 30 percent in a story relative to adjacent stories for Life Safety and Immediate Occupancy, excluding one-story penthouses and mezzanines. (Tier 2: Sec. 4.3.2.3)

C NC N/A VERTICAL DISCONTINUITIES: All vertical elements in the lateral-force-resisting system shall be continuous to the foundation. (Tier 2: Sec. 4.3.2.4)

C NC N/A MASS: There shall be no change in effective mass more than 50 percent from one story to the next for Life Safety and Immediate Occupancy. Light roofs, penthouses, and mezzanines need not be considered. (Tier 2: Sec. 4.3.2.5)

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C NC N/A TORSION: The estimated distance between the story center of mass and the story center of rigidity shall be less than 20 percent of the building width in either plan dimension for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.6)

C NC N/A DETERIORATION OF CONCRETE: There shall be no visible deterioration of concrete or reinforcing steel in any of the vertical- or lateral-force-resisting elements. (Tier 2: Sec. 4.3.3.4)

C NC N/A POST-TENSIONING ANCHORS: There shall be no evidence of corrosion or spalling in the vicinity of post-tensioning or end fittings. Coil anchors shall not have been used. (Tier 2: Sec. 4.3.3.5)

C NC N/A CONCRETE WALL CRACKS: All existing diagonal cracks in wall elements shall be less than 1/8 inch for Life Safety and 1/16 inch for Immediate Occupancy, shall not be concentrated in one location, and shall not form an X pattern. (Tier 2: Sec. 4.3.3.9)

Lateral-Force-Resisting System

C NC N/A COMPLETE FRAMES: Steel or concrete frames classified as secondary components shall form a complete vertical-load-carrying system. (Tier 2: Sec. 4.4.1.6.1)

C NC N/A REDUNDANCY: The number of lines of shear walls in each principal direction shall be greater than or equal to 2 for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.4.2.1.1)

C NC N/A SHEAR STRESS CHECK: The shear stress in the concrete shear walls, calculated using the Quick Check procedure of Section 3.5.3.3, shall be less than the greater of 100 psi or $2\sqrt{f'_c}$ for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.4.2.2.1)

C NC N/A REINFORCING STEEL: The ratio of reinforcing steel area to gross concrete area shall be not less than 0.0015 in the vertical direction and 0.0025 in the horizontal direction for Life Safety and Immediate Occupancy. The spacing of reinforcing steel shall be equal to or less than 18 inches for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.4.2.2.2)

Connections

C NC N/A TRANSFER TO SHEAR WALLS: Diaphragms shall be connected for transfer of loads to the shear walls for Life Safety and the connections shall be able to develop the lesser of the shear strength of the walls or diaphragms for Immediate Occupancy. (Tier 2: Sec. 4.6.2.1)

C NC N/A FOUNDATION DOWELS: Wall reinforcement shall be doweled into the foundation for Life Safety, and the dowels shall be able to develop the lesser of the strength of the walls or the uplift capacity of the foundation for Immediate Occupancy. (Tier 2: Sec. 4.6.3.5)

3.7.8S Supplemental Structural Checklist for Building Type C2: Concrete Shear Walls with Stiff Diaphragms

This Supplemental Structural Checklist shall be completed where required by Table 3-2. The Basic Structural Checklist shall be completed prior to completing this Supplemental Structural Checklist.

Lateral-Force-Resisting System

C NC N/A DEFLECTION COMPATIBILITY: Secondary components shall have the shear capacity to develop the flexural strength of the components for Life Safety and shall meet the requirements of Sections 4.4.1.4.9, 4.4.1.4.10, 4.4.1.4.11, 4.4.1.4.12, and 4.4.1.4.15 for Immediate Occupancy. (Tier 2: Sec. 4.4.1.6.2)

C NC N/A FLAT SLABS: Flat slabs/plates not part of lateral-force-resisting system shall have continuous bottom steel through the column joints for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.4.1.6.3)

C NC N/A COUPLING BEAMS: The stirrups in coupling beams over means of egress shall be spaced at or less than d/2 and shall be anchored into the confined core of the beam with hooks of 135° or more for Life Safety. All coupling beams shall comply with the requirements above and shall have the capacity in shear to develop the uplift capacity of the adjacent wall for Immediate Occupancy. (Tier 2: Sec. 4.4.2.2.3)

C NC N/A OVERTURNING: All shear walls shall have aspect ratios less than 4-to-1. Wall piers need not be considered. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.2.2.4)

C NC N/A CONFINEMENT REINFORCING: For shear walls with aspect ratios greater than 2-to-1, the boundary elements shall be confined with spirals or ties with spacing less than 8d_b. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.2.2.5)

C NC N/A REINFORCING AT OPENINGS: There shall be added trim reinforcement around all wall openings with a dimension greater than three times the thickness of the wall. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.2.2.6)

C NC N/A WALL THICKNESS: Thickness of bearing walls shall not be less than 1/25 the unsupported height or length, whichever is shorter, nor less than 4 inches. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.2.2.7)

Diaphragms

C NC N/A DIAPHRAGM CONTINUITY: The diaphragms shall not be composed of split-level floors and shall not have expansion joints. (Tier 2: Sec. 4.5.1.1)

C NC N/A OPENINGS AT SHEAR WALLS: Diaphragm openings immediately adjacent to the shear walls shall be less than 25 percent of the wall length for Life Safety and 15 percent of the wall length for Immediate Occupancy. (Tier 2: Sec. 4.5.1.4)

C NC N/A PLAN IRREGULARITIES: There shall be tensile capacity to develop the strength of the diaphragm at re-entrant corners or other locations of plan irregularities. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.5.1.7)

C NC N/A DIAPHRAGM REINFORCEMENT AT OPENINGS: There shall be reinforcing around all diaphragm openings larger than 50 percent of the building width in either major plan dimension. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.5.1.8)

Screening Phase (Tier 1)

Connections

C NC N/A UPLIFT AT PILE CAPS: Pile caps shall have top reinforcement and piles shall be anchored to the pile caps for Life Safety, and the pile cap reinforcement and pile anchorage shall be able to develop the tensile capacity of the piles for Immediate Occupancy. (Tier 2: Sec. 4.6.3.10)

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If deficiencies are identified for a building using the checklists, the design professional may proceed to Tier 2 and conduct a more detailed evaluation of the building or choose to recommend mitigation after the Tier 1 analysis. Alternatively, the design professional may conclude the evaluation and state that potential deficiencies were identified. In some cases, a Tier 2 or Tier 3 evaluation may be required because of the building type, even if no deficiencies are noted in Tier 1. This is specified in the Tier 1 chapter of ASCE 31.

Tier 2: A Tier 2 evaluation is a more detailed and rigorous evaluation of the building. A Tier 1 evaluation must be performed before undertaking a Tier 2 evaluation. A Tier 2 evaluation may be required in all cases for certain building types specifically identified in ASCE 31. For other buildings evaluated under Tier 1 the engineer may choose to perform a Tier 2 evaluation to determine if the conservative approach of Tier 1 may have identified deficiencies that may be eliminated by a more rigorous and detailed evaluation. As a minimum, the engineer need only evaluate those items found deficient under the Tier 1 analysis.

Four analysis procedures are provided for a Tier 2 analysis:

- Linear Static Procedure (LSP)
- Linear Dynamic Procedure (LDP)
- Special Procedure for unreinforced masonry buildings with flexible diaphragms
- Procedure for nonstructural components.

A Tier 2 Evaluation may require more information about the building than in a Tier 1 Evaluation. This may include determination of concrete strength for example.

At the conclusion of a Tier 2 evaluation, the deficiencies may be mitigated or a plan for mitigation developed. For certain building types further investigation may be warranted. This would entail a Tier 3 evaluation.

Tier 3: For buildings requiring further investigation, a Tier 3 evaluation may be conducted. Certain building types in some regions of seismicity may require a Tier 3 evaluation. A Tier 3 evaluation is based on the FEMA 356 methodology, or on provisions for the design of new buildings. Because a Tier 2 evaluation is more conservative than a Tier 3, some elements previously thought to be deficient may prove to be acceptable. In general a Tier 3 analysis refers the user to FEMA 356 for the component-based evaluation. However for a Tier 3 evaluation a lower demand level may be used.

Moving from a Tier 2 to a Tier 3 evaluations using FEMA 356 may provide the design professional with the opportunity to consider more levels of performance, as discussed in Chapter 4.

The Tier 3 evaluation will require simulation of the building using nonlinear analysis procedures that may be complex and expensive to carry out. However, they often result in construction savings many times the engineering costs.

Outline of the Report to Owner

At the completion of an ASCE 31 evaluation, the building's deficiencies and mitigation needs have been identified. The actual rehabilitation design now may be started.

The final report serves to communicate the results to the owner and record the process and assumptions used to complete the evaluation. As a minimum the report should include the following items:

- Introduction
- Scope and Intent
- Limitations
- Investigation, assessment, and analysis methods
- General description of the building
- Structural system description
- Nonstructural systems description
- Building type
- Performance level
- Level of Seismicity
- Soil type
- List of assumptions
- Findings (list of deficiencies)
- Checklists and other documents
- Recommendations for Mitigation
- Appendices
- Calculations
- Photographs
- Examples of the Type of Work Needed

5.5 Task 4. Seismic rehabilitation planning and design

Once the evaluation has been completed and the mitigation needs known, the design professional, in cooperation with the owner, is ready to begin planning and designing the seismic rehabilitation that will mitigate the deficiencies. FEMA 356, *Prestandard and Commentary for the Seismic Rehabilitation of Buildings*, provides a methodology and design approach.

The FEMA 356 Approach

FEMA 356 provides appropriate guidelines and design procedures to comply with the basic safety objective and the desired performance level. This is a unique approach, distinctly different from that presently adopted by building codes for new construction.

In the building codes for new construction, building performance is implicitly set in a manner that is not transparent to the user. Therefore, the user frequently does not understand the level of performance to be expected of buildings designed to the code, should they experience the design earthquake. Further, the user is not given a clear understanding of what design changes should be made in order to obtain performance different from that implicit in the codes.

Figure__ illustrates the general process for building rehabilitation under FEMA 356, which at its core consists of selection of a rehabilitation objective, selection of a rehabilitation method, performance and verification of a rehabilitation design, and preparation of construction documents.

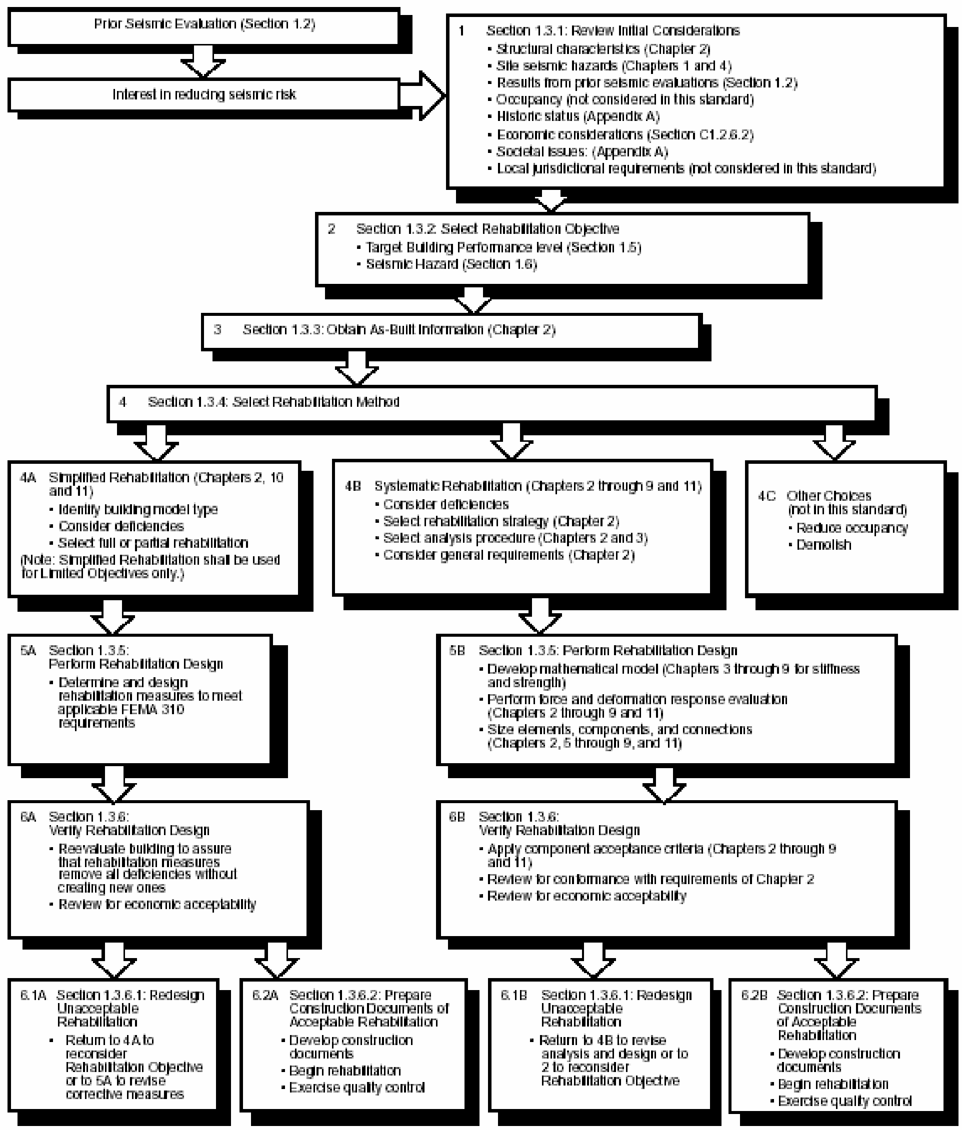


Figure C1-1 Rehabilitation Process

Set the Performance Objective: FEMA 356 starts by requiring the user to select specific performance goals, termed rehabilitation objectives, as a basis for design. In this way, users can directly determine the effect of different performance goals on the design requirements. But it is the intent of FEMA 356 that most, although not necessarily all, structures designed to obtain a given performance at the specific earthquake demand would exhibit behavior superior to that predicted

As discussed in Chapter 4 and illustrated in Figure___, FEMA 356 defines a continuum of rehabilitation objectives that are a function of Target Building Performance Levels and Earthquake Hazard Levels, of which 16 are explicitly identified. These 16 objectives are categorized in FEMA 356 into three categories:

- Basic Safety Objective (similar to the implied design criteria for new buildings)
- Enhanced Objectives
- Limited Objectives

The Rehabilitation Objective selected as a basis for design will determine, to a great extent, the cost and feasibility of any rehabilitation project, as well as the benefit to be obtained in terms of improved safety, reduction in property damage, and interruption of use in the event of future earthquakes. Table C1-1 indicates the range of Rehabilitation Objectives that may be used in this standard.

Table C1-1 Rehabilitation Objectives

		Target Building Performance Levels			
		Operational Performance Level (1-A)	Immediate Occupancy Performance Level (1-B)	Life Safety Performance Level (3-C)	Collapse Prevention Performance Level (5-E)
Earthquake Hazard Level	50%/50 year	a	b	c	d
	20%/50 year	e	f	g	h
	BSE-1 (~10%/50 year)	i	j	k	l
	BSE-2 (~2%/50 year)	m	n	o	p

Notes:

1. Each cell in the above matrix represents a discrete Rehabilitation Objective.
2. The Rehabilitation Objectives in the matrix above may be used to represent the three specific Rehabilitation Objectives defined in Sections 1.4.1, 1.4.2, and 1.4.3, as follows:

   k + p = Basic Safety Objective (BSO)
   k + p + any of a, e, i, b, f, j, or n = Enhanced Objectives
   o alone or n alone or m alone = Enhanced Objective
   k alone or p alone = Limited Objectives
   c, g, d, h, l = Limited Objectives

Selection of a rehabilitation objective will be a significant factor in determining the cost and feasibility of the project. The design professional should understand the various rehabilitation objectives, the underlying parameters of building performance levels and seismic hazard levels, the resultant requirements, and associated design and construction costs. The design professional should establish the rehabilitation objectives in close coordination with the owner's facility, risk, and financial managers. Owners may initially suggest higher performance levels, but later find that the associated construction cost is beyond their budget. The design is likely to be an iterative process, to obtain a performance level and a rehabilitation objective that meets the budget and project needs.

The target building performance levels—collapse prevention, life safety, immediate occupancy, or operational—will establish the desired level of damage control for the rehabilitation project. Figures__ and __ provide a side by side comparison of the various performance levels compared to the expected damage, and will assist the design professional in communicating with the owner. The chart, along with the graphic, provides information for the engineer in assisting the client with selection of the appropriate performance level.

[select additional graphics from 356]

Damage Control and Building Performance Levels

	Target Building Performance Levels (Lower Performance, More Loss → Higher Performance, Less Loss)			
	Collapse Pervention Level (5-E)	Life Safety Level (3-C)	Immediate Occupancy Level (1-B)	Operational Level (1-A)
Overall Damage	**Severe**	**Moderate**	**Light**	**Very Light**
General	Little residual stiffness and strength, but load-bearing columns and walls function. Large permanent drifts. Some exits blocked. Infills and unbraced parapets failed or at incipient failure. Building is near collapse.	Some residual strength and stiffness left in all stories. Gravity-load-bearing elements function. No out-of-plane failure of walls or tipping of parapets. Some permanent drift. Damage to partitions. Building may be beyond economical repair	No permanent drift. Structure substantially retains original strength and stiffness. Minor cracking of facades, partitions, and ceilings as well as structural elements. Elevators can be restarted. Fire protection operable.	No permanent drift. Structure substantially retains original strength and stiffness. Minor cracking of facades, partitions, and ceilings as well as structural elements. All systems important to normal operations are functional.
Nonstructural Components	Extensive damage.	Falling hazards mitigated but many architectural, mechanical, and electrical systems are damaged	Equipment and contents are generally secure, but may not be operable due to mechanical failure or lack of utilities.	Negligible damage occurs. Power and other utilities are available, possibly from standby sources.
Comparison with performance intended for buildings designed under the *NEHRP Provisions* for the Design Earthquake	Significantly more damage and greater risk.	Somewhat more damage and slightly higher risk.	Less damage and lower risk.	Much less damage and lower risk.

Adapted from FEMA 356, Table C1-2

Data collection: Data collection is an important factor in design using FEMA 356. The extent of the design professional's knowledge about the material strengths of the building will have a significant effect on the analysis and the confidence level provided. This will impact on the ultimate work and construction costs. Table 2-1 of FEMA 356 arrays the level of knowledge needed for the various types of data collection that must occur in any rehabilitation project as a function of the Rehabilitation Objective and analysis procedure used.

Rehabilitation methods: FEMA 356 provides two rehabilitation methods:
- Systematic rehabilitation
- Simplified rehabilitation

Systematic rehabilitation is a methodology for the detailed design necessary to meet the rehabilitation objective. It provides uniform criteria by which existing buildings may be evaluated and upgraded to attain a wide range of different objectives. Systematic rehabilitation for structural systems is covered in Chapters 2-9 of FEMA 356.

Simplified rehabilitation is explained in Chapter 10 of FEMA 356. The chapter limits the use of simplified rehabilitation as a function of the 24 Model Building Types and the three levels of seismicity. The chapter contains extensive guidance on building elements to consider for analysis. It also contains a description of each of the building types with a ranking of importance for mitigation items. Table10-1 of FEMA 356 summarizes the limitations on the use of the simplified rehabilitation method for each of 24 model building types. Buildings using the simplified rehabilitation may not meet the specified performance objective.

FEMA 356 may not be the appropriate methodology for smaller buildings with flexible diaphragms. The alternate guidelines may provide a more economical solution, however they will not meet the objective of FEMA 356 BSO.

Other resources available to the engineer to mitigate seismic deficiencies in buildings include:
- ASCE 31 – When seismic deficiencies are identified in an ASCE 31 analysis, correcting the deficiencies will achieve an improved level of safety. ASCE 31 uses a factor of approximately 75% of the design level of the code for new construction and FEMA 356. Compliance will provide for safety to life but the building may not meet the Collapse Prevention level required for the BSE-2 earthquake. The building will also have greater damage than a building meeting the FEMA 356 BSO. It may provide an economical solution for many owners.
- International Building Code (IBC) – A design to meet the force levels of the IBC, with some compromises on detailing, would be a valid approach and provide a building that essentially meets the intent of FEMA 356.
- International Existing Building Code (IEBC) – The IEBC includes triggers for certain seismic rehabilitation, and repair of damaged buildings. There

are also triggers for partial strengthening of unreinforced masonry buildings. IEBC directs designers to use FEMA 356, or the GSREB (see below), which is included in the Appendix with an analysis using ASCE 31.

- NFPA 5000 Building Code – The NFPA 5000 code adopts ASCE 7. The criterion in ASCE 7 does not provide criteria for rehabilitation. Meeting the design levels of ASCE 7 for a rehabilitation project would be the same as meeting the levels of the code for new construction.
- Guidelines for the Structural Retrofit of Existing Buildings (GSREB) ICBO, 2001 (contained in the 2003 IEBC) – The document provides rehabilitation provisions for specific building types. Compliance with this document will meet the Collapse Prevention level or higher. Its use will not meet the Life Safety criteria of FEMA 356.
- Los Angeles Division 91 and Los Angeles Division 95, provisions of the Los Angeles Building Code – These provisions are similar to the approaches of FEMA 356 but compliance with these criteria may not meet the BSO.
- Seismic Evaluation and Retrofit of Concrete Buildings, ATC-40, 1996. – These documents provide guidance on the repair of concrete frame buildings.

5.6 Task 5. Staging of rehabilitation increments/prioritization and integration of seismic rehabilitation increments

In the absence of the reality of building occupancy and use, the preferred path for building seismic rehabilitation is to complete the work in one continuous phase. However this may not be possible for a variety of reasons described earlier in this document. The owner's needs and available resources as well as the continued occupancy of the building are often determining factors in deciding whether the rehabilitation will be single-phase or incremental.

Accepting this reality requires that the owner and design professional think of the seismic rehabilitation program in increments and prioritize and schedule the implementation of these increments. There are four distinct aspects to this task.

Structural Priority (Seismic Engineering)

After completing an ASCE 31 or FEMA 356 analysis, the engineer needs to rank the deficiencies. Such a ranking might consider whether a deficiency is a threat to life, whether it will cause building collapse or might simply result in a localized, repairable failure. Generally, it is recommended that a "worst first" approach should be applied, attending to heavily used sections of the most vulnerable buildings, those with the largest occupant loads or housing critical functions or equipment, areas that facilitate evacuation of the building including corridors, stairs, lobbies, and other elements of the egress system. Canopies over exits, though considered "nonstructural", should not be ignored in the prioritization.

The Commentary to Chapter 10 (Simplified Rehabilitation) of FEMA 356 provides lists of deficiency rankings by building types. These rankings are described as follows:

> "Potential deficiencies are ranked in Tables C10-1 through C10-19; items in these tables are ordered roughly from highest priority at the top to lowest at t he bottom, although this can vary widely in individual cases."

See Figure__ for two example tables:

Table C10-10 C2, C2A: Concrete Shear Walls with Stiff or Flexible Diaphragms

Typical Deficiencies
Load Path Redundancy Vertical Irregularities Plan Irregularities Lateral Load Path at Pile Caps Deflection Compatibility
Frames Not Part of the Lateral Force Resisting System Short "Captive" Columns
Cast-in-Place Concrete Shear Walls Shear Stress Overturning Coupling Beams Boundary Component Detailing Wall Reinforcement
Re-entrant Corners Diaphragm Openings Diaphragm Stiffness/Strength Sheathing
Diaphragm/Wall Shear Transfer
Anchorage to Foundations Condition of Foundations Overturning Lateral Loads Geologic Site Hazards
Condition of Concrete

Table C10-11 C3, C3A: Concrete Frames with Infill Masonry Shear Walls and Stiff or Flexible Diaphragms

Typical Deficiencies
Load Path Redundancy Vertical Irregularities Plan Irregularities Lateral Load Path at Pile Caps Deflection Compatibility
Frames Not Part of the Lateral Force Resisting System Complete Frames
Masonry Shear Walls Reinforcing in Masonry Walls Shear Stress Reinforcing at Openings Unreinforced Masonry Shear Walls Proportions, Solid Walls Infill Walls
Re-entrant Corners Diaphragm Openings Diaphragm Stiffness/Strength Span/Depth Ratio
Diaphragm/Wall Shear Transfer Anchorage for Normal Forces
Anchorage to Foundations Condition of Foundations Overturning Lateral Loads Geologic Site Hazards
Condition of Concrete Quality of Masonry

Owners' facility managers and their design professionals will likely begin with these initial prioritizations when determining the order of seismic rehabilitation increments to be undertaken.

The owners manuals include tables that list typical rehabilitation work elements, simple descriptions of the improvements, and their intent. The tables are reproduced below. The design professionals may consider their structural priority with the help of FEMA 356 Chapter 10 or their own analysis.

However, one may not necessarily be able to accomplish the necessary mitigation in the order of their structural priorities. The final order of increments may deviate from their structural priority, based on other planning parameters. Additional engineering analysis may be required for certain building types when deviating from the structural priority, as discussed later in this Section.

Nonstructural Seismic Performance Improvements

Office Number*	Level of Seismicity			Definitions and Purpose		
	L	M	H	Seismic Performance Improvement	Description	Purpose
1	✓	✓	✓	Anchorage of Canopies at Exits	Canopies or roofs over exits.	Prevent collapse of canopies that would block exits and possibly cause injuries.
2		✓	✓	Anchorage and Detailing of Rooftop Equipment	Equipment should be properly attached, and restrained if isolation-mounted.	Prevent equipment from sliding or falling off platforms due to connection failure or nonfunction.
3		✓	✓	Bracing and Detailing of Sprinkler and Piping	Sprinkler pipes should be braced in each direction.	Prevent sprinkler lines from breaking and flooding the building.
4		✓	✓	Suspension and Bracing of Lights	Lights may swing or otherwise fall in an earthquake.	Prevent lights from falling and injuring occupants. Lights should not be supported by a suspended ceiling in a high or moderate seismic zone. Pendent lights should have their sway limited.
5		✓	✓	Fastening and Bracing of Ceilings	Diagonal bracing of ceiling.	Suspended ceilings should be braced against sidesway to reduce the chance of elements falling.
6		✓	✓	Fastening and Bracing of Equipment (Mechanical and Electrical)	Equipment above ceilings.	Prevent fans and other equipment from swaying and falling on occupants; connections could fail resulting in equipment no longer functioning.
7	✓	✓	✓	Bracing of Parapets, Gables, Ornamentation, and Appendages	Construct parapet bracing on the roof side of the parapet. Gables are braced in the attic space. Other elements are anchored in a positive manner.	Prevent parapets, gables, and ornamentation from falling outward.
8	✓	✓	✓	Glazing Selection and Detailing	Glass above a walking surface.	Prevent exterior or interior glass from falling onto the walking surface and causing injuries.
9		✓	✓	Attachment and Bracing of Large Ductwork	Large ducts.	Prevent ducts from falling on occupants.
10	✓	✓	✓	Bracing or Reinforcing Masonry Walls at Interior Stairs	Interior exit stairs may have unreinforced masonry enclosure walls that could collapse.	Prevent collapse of walls that could block stairways.
11		✓	✓	Bracing of Interior Partitions (Masonry and Wood)	Bracing may be vertical or diagonal braces.	Interior partitions must be braced to prevent falling/collapse.
12		✓	✓	Support and Detailing of Elevators	Elevator guides have become dislodged in earthquakes. Applies to cable lift elevators.	Keep elevators functioning.
13	✓	✓	✓	Anchorage and Bracing of Emergency Lighting	Positive attachment of emergency lights.	Prevent heavy battery packs from falling.
14	✓	✓	✓	Cladding Anchorage	Heavy cladding (concrete) must be connected to the structure.	Prevent cladding from falling. Careful design is required so the cladding does not limit the structure's lateral movement.
15		✓	✓	Anchorage of Masonry Veneer	Veneer over exterior wood or masonry walls or over other materials in steel or concrete structure. Materials may be brick, terra cotta, stone, or similar materials.	Prevent inadequately anchored veneer from falling outward onto pedestrians.
16		✓	✓	Shut-Off Valves	Installation of a shut-off device.	Gas and water lines could break and should have a means of turning them off.
17		✓	✓	Anchorage of Exterior Wythe in Cavity Walls	A masonry wall separated from the veneer by a hollow space.	Prevent veneer from falling outward. Existing anchorage should be checked for rust damage and loss of strength.
18		✓	✓	Bracing or Removal of Chimneys	Chimneys should be braced to the structure.	Prevent chimneys from toppling into yards or through roofs.
19		✓	✓	Attachment and Bracing of Cabinets and Furnishings	Anchorage to structural walls or other elements.	Prevent cabinets and other furnishings form toppling or moving and causing damage. Fallen file cabinets may block exit doors.
20		✓	✓	Anchorage of Steel Stud Backup	Steel studs behind veneer or other cladding.	Prevent steel studs used as a backup to support veneer or other cladding from becoming detached or falling.
21		✓	✓	Restraint of Hazardous Materials Containers	Chemical labs, shops, etc. may have materials that could, when combined, create a fire or chemical hazard.	Reduce danger of breakage and mixing of chemicals.
22		✓	✓	Underfloor Bracing of Computer Access Floor	Raised floors for cabling.	Prevent floors from collapsing and damaging equipment.

* Items numbered for ease of reference.

Structural Seismic Performance Improvements

Level of Seismicity			Building Element	Structural Sub-System	Definitions and Purpose		
L	M	H			Seismic Performance Improvement	Description	Purpose
	✔	✔	Foundation		Anchor Bolts	Connection between the foundation and the building.	Improve load path. Prevent building from sliding off foundation.
	✔	✔	Foundation		Anchorage	Connection between the foundation and the building for larger buildings.	Improve load path. Provide adequate connection between building and foundation.
	✔	✔	Foundation		Cripple Stud Bracing	Short wood studs between the foundation and the first floor.	Cripple studs are usually not braced. Prevent them from toppling and causing the building to fall off the foundation.
	✔	✔	Foundation		New Foundations	New foundations to convey loads.	Additional foundations may be the preferred solution in some cases.
	✔	✔	Foundation		Pile Cap Lateral Load	Piles supporting buildings may try to move laterally from building loads during earthquakes.	Brace piles at their top to eliminate the chance of lateral movement and reduce chance of foundation failure.
	✔	✔	Foundation		Uplift	Under overturning type loads foundations may be pulled upward.	Reduce the uplift chance by improving foundation system; engineer should evaluate the effects of uplift.
Definition			Horizontal Elements			Floors, mezzanines, and roofs.	
Definition			Horizontal Elements	Diaphragms		Floors and roofs connecting walls and lateral force-resisting elements.	Diaphragms are the roof and floors of a building. They must be of adequate strength to transfer the earthquake loads to the walls and other elements. The connection from the diaphragm to the wall or other lateral force-resisting element is part of the load path.
	✔	✔	Horizontal Elements	Diaphragms	Attachment and Strengthening at Boundaries	Improving the connection of the diaphragm to the edge/boundary elements with nails, bolts, or welding.	This is part of the load path and conveys the diaphragm forces into the walls or other lateral force-resisting elements.
	✔	✔	Horizontal Elements	Diaphragms	Mezzanine Anchorage and Bracing	Anchor the mezzanine to the wall. Where there is an open side of the mezzanine, bracing may be necessary.	Make sure the mezzanine is attached to the building to provide for a load path for the mezzanine diaphragm and to reduce any pounding of the mezzanine against the building's walls or columns. A large mezzanine may require bracing on the open sides.
	✔	✔	Horizontal Elements	Diaphragms	Strength/Stiffness	Strengthen the diaphragm to limit its lateral deflection.	Control the movement of the diaphragm to reduce the damage due to drift and to control the out-of-plane loads on vertical elements.
	✔	✔	Horizontal Elements	Diaphragms	Strengthening at Openings	Strapping around diaphragm openings.	Openings may create a weak point in the diaphragm. Straps will provide additional strength to wood diaphragms.
	✔	✔	Horizontal Elements	Diaphragms	Strengthening at Re-entrant Corners	"L" and "U" shaped buildings have stress concentrations at the interior corners.	Reduce damage from cracking and failures caused by stress concentration.
	✔	✔	Horizontal Elements	Diaphragms	Topping Slab for Precast Concrete	Concrete slab over precast concrete roof to create a continuous diaphragm. Connect to the vertical elements as part of a load path.	Strengthen the roof to act as a lateral force element. Control drift of the roof or floor.
Definition			Vertical Elements	Braced Frames		Steel or concrete beams and columns with diagonal bracing.	Braced frames act as a lateral force-resisting element. They are often used as the lateral force-resisting element on open sides of buildings. They must be connected to the horizontal element as part of the load path.
	✔	✔	Vertical Elements	Braced Frames	Capacity/Stiffness	Frame capacity improvements for adequate load resistance.	Capacity and stiffness assure the adequacy of the frame elements to resist loads.
	✔	✔	Vertical Elements	Braced Frames	Continuity	Braced frames should be continuous from the foundation to the roof.	Discontinuities of lateral force-resisting elements create load transfer demands. Design standards may impose higher loads for this condition.
	✔	✔	Vertical Elements	Braced Frames	Connections	The details of the connections (bolts or welds) must be adequate. Improvements to strength will not have a negative effect on the phased construction.	Braced frame connections assure the adequacy of the frame elements to resist loads. Improvements may be made by the addition of steel plates with bolting or welding.
✔	✔	✔	Vertical Elements	Load Path	Lateral Resisting System to Diaphragm Connection	Connections between roof/floor and wall or other element.	Permit earthquake loads to be conveyed to the foundation—develop a load path. This is the key element in seismic safety.

Structural Seismic Performance Improvements (continued)

Level of Seismicity			Building Element	Structural Sub-System	Definitions and Purpose of Structural Performance Improvements		
L	M	H			Seismic Performance Improvement	Description	Purpose
Definition			Vertical Elements	Moment Frames		A steel or concrete system of beams and columns.	Moment frames act as a lateral force-resisting element and brace the structure. They are often used as the lateral force-resisting element on open sides of buildings. They must be connected to the horizontal element as part of the load path.
	✓	✓	Vertical Elements	Moment Frames	Beam Column Capacity/Stiffness	Frame capacity improvements for adequate load resistance.	Capacity and stiffness assure the adequacy of the frame elements to resist loads.
	✓	✓	Vertical Elements	Moment Frames	Beam Column Connection	Steel or concrete with improved connections to increase strength. Improvements will not have a negative effect on the phased construction.	Beam column connections assure the adequacy of the frame elements to resist loads. Improvements may be made by the addition of steel plates with bolting or welding.
Definition			Vertical Elements	Shear Walls		Walls that brace the building against earthquakes.	Shear walls brace the structure. Building walls can act as lateral load-resisting elements. They must be connected to the horizontal elements as part of the load path.
	✓	✓	Vertical Elements	Shear Walls	Capacity	Capacity equals strength.	Capacity assures the adequacy of walls to resist loads.
	✓	✓	Vertical Elements	Shear Walls	Continuity	Shear walls should be continuous from the foundation to the roof.	Discontinuities of lateral force-resisting elements create load transfer demands. Design standards may impose higher loads for this condition. This is one of the most cost-effective improvements in buildings.
	✓	✓	Vertical Elements	Shear Walls	Extension of Wood Interior Walls to Roof	Extending interior wood walls to diaphragms in unreinforced masonry and other buildings.	Permit walls that were not constructed full height to be used as shear walls in buildings with wood interior walls.
	✓	✓	Vertical Elements	Shear Walls	Lateral Stability	Tall walls may buckle and need bracing.	Prevent buckling and possible wall collapse. Walls must be anchored at the top or may have other bracing elements such as diagonal or vertical braces.
✓	✓	✓	Vertical Elements		Out-of-Plane Anchorage of Concrete or Masonry Wall	Connections from the walls to the floors and roof.	Prevent walls from falling outward due to inadequate connections between the wall and the diaphragms. A cost-effective mitigation measure for bearing wall buildings.
✓	✓	✓	All Elements		Load Path and Collectors	Distribute loads from diaphragms into lateral force-resisting elements.	These are straps of steel or wood that "collect" load and distribute it into the vertical lateral force-resisting elements. Connections may be with bolts, nails, or welding, depending on the material and location.

An example code-developed approach to staging rehabilitation based on structural priority is presented in "Guidelines for Seismic Retrofit of Existing Buildings (GSREB)." These apply wood frame apartment or commercial structures with an open, soft story, side. These provisions offer suggestions for phasing the work.

SECTION 404
GENERAL REQUIREMENTS
FOR PHASED CONSTRUCTION

When the building contains three or more levels, the work specified in this chapter shall be permitted to be done in the following phases. Work shall start with Phase I unless otherwise approved by the building official. When the building does not contain the conditions shown in any phase, the sequence of retrofit work shall proceed to the next phase in numerical order.

Phase 1 Work. The first phase of the retrofit work shall include the ground floor portion of the wood structure that contains parking or other similar open floor space.

Phase 2 Work. The second phase of the retrofit work shall include walls of any level of wood construction with two or more levels above that are laterally braced with nonconforming structural materials.

Phase 3 Work. The third and final phase of the retrofit work shall include the remaining portions of the building up to, but not including, the top story as specified in Section 403.2.

Use Priority

The occupancy of a building is critical in evaluating safety, and owners may consider planning alternative uses for their seismically vulnerable buildings. Some vulnerable buildings may be scheduled for early demolition, or for conversion to a lower risk category such as storage. Other buildings in the owner's inventory may be scheduled for expansion or intensification of use. Considerations such as these will influence the prioritization of seismic rehabilitation increments.

Disruption Priority

Rehabilitation increments of various structural priorities can be categorized by the location and extent of the work involved. In general these can be:

- Work that can be accomplished from the exterior (roofs, exterior walls, and basements) with little or no effect on interior space use.
- Work that can be accomplished in localized spaces in the interior of the building (e.g., corridors).
- Work that must be accomplished in spaces spread throughout the building (these may be tenant spaces and/or common spaces).
- Work that requires access to concealed spaces.
- Work that involves mechanical, electrical, and plumbing systems.

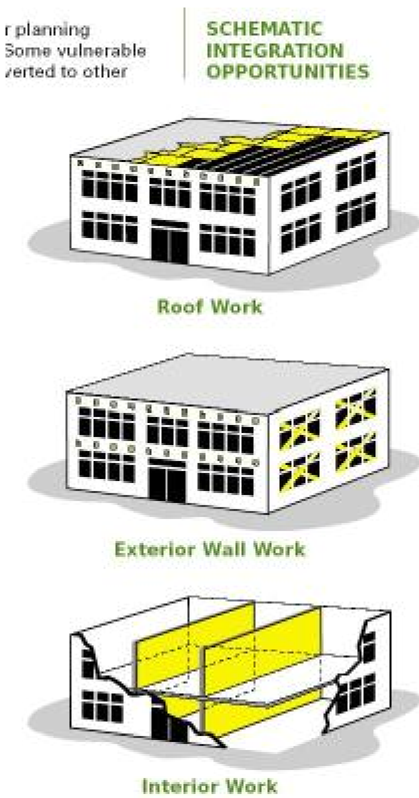
Each of these categories of work entails specific disruptions of the occupancy and use of the building. These disruptions may entail costs to the owner that equal or exceed the actual construction costs, such as moving employees or losing tenants. The extent of these disruptions may have a time-dimension. For example, the summer vacation may be the least disruptive period for school buildings, and periods of tenant turnover may be the least disruptive in rental commercial buildings.

Considerations such as these will also influence the prioritization of seismic rehabilitation increments.

Integration Opportunities with Other Maintenance and Capital Improvement Work

A characteristic of the incremental seismic rehabilitation approach is that specific work items can be integrated with other building maintenance or capital improvement projects undertaken routinely by the owner. Such integration will reduce the cost of the seismic rehabilitation action by sharing engineering costs, design costs, and some aspects of construction costs. It also manages the disruption costs. Integration opportunities are a key consideration in adapting the sequence of actions suggested by the preceding discussion of priorities.

Often the work is opportunistic, in that some seismic rehabilitation increments may be accomplished when specific other building work is being undertaken. Figure ___illustrates these integration opportunities schematically.



Every building owner has a particular pattern of scheduling maintenance and capital improvement work, and the design professional should consider this pattern when identifying the integration opportunities for specific seismic rehabilitation increments. However, there are typical maintenance and capital improvement categories found in specific building occupancies, as follows:

Schools:

1. Roofing maintenance and repair/re-roofing
2. Exterior wall and window maintenance
3. Fire and life safety improvements
4. Modernization/remodeling/new technology accommodation
5. Underfloor and basement maintenance and repair
6. Energy conservation/weatherization/air-conditioning
7. Hazardous materials abatement

8. Accessibility improvements

Hospitals:

1. Patient care improvements
2. New technology accommodation
3. Fire and life safety improvements
4. Roofing maintenance and repair/re-roofing
5. Exterior wall and window maintenance/façade modernization
6. Underfloor and basement maintenance and repair
7. Heating, ventilating, and air conditioning (HVAC) improvements
8. Energy conservation/weatherization/air conditioning
9. Hazardous materials abatement

Office Buildings:

1. Roofing maintenance and repair/re-roofing
2. Exterior wall and window maintenance/façade modernization
3. Public area modernization
4. Fire and life safety improvements
5. New technology accommodation
6. Tenant alterations and improvements
7. Underfloor and basement maintenance and repair
8. HVAC upgrade and energy conservation
9. Hazardous materials abatement (usually at acquisition)

Retailing:

1. Roofing maintenance and repair/re-roofing
2. Exterior wall and window maintenance/façade modernization
3. Fire and life safety improvements
4. Mall public area modernization
5. Retail area modernization
6. Underfloor and basement maintenance and repair
7. HVAC upgrade and energy conservation
8. Hazardous materials abatement

Multifamily Housing:

1. Roofing maintenance and repair/re-roofing
2. Exterior wall and window maintenance/façade modernization
3. Public area modernization
4. Kitchen and bathroom modernization (“white work”)
5. Fire and life safety improvements
6. Underfloor and basement maintenance and repair
7. HVAC upgrade and energy conservation
8. Hazardous materials abatement

The owner manuals include matrices showing specific structural and nonstructural seismic improvements that can be integrated with each respective category of maintenance and capital improvement. The following figures illustrate the matrices for the categories of “roofing maintenance and repair/re-roofing” and “fire and life safety improvements”.

Table C-1: Roofing Maintenance and Repair/Re-roofing

Number*	Level of Seismicity: L	Level of Seismicity: M	Level of Seismicity: H	Building Structural Element	Structural Sub-System	Seismic Performance Improvement	Vertical Load Carrying Structure: Wood	Masonry[1]: Unreinforced Masonry	Masonry[1]: Reinforced Masonry	Concrete: Wood Diaphragm	Concrete: Concrete Diaphragm	Steel: Wood Diaphragm	Steel: Concrete Diaphragm
Nonstructural													
1	✓	✓	✓	n/a	n/a	Anchorage of Canopies at Exits	■	■	■	■	■	■	■
2		✓	✓	n/a	n/a	Anchorage and Detailing of Rooftop Equipment	■	■	■	■	■	■	■
7	✓	✓	✓	n/a	n/a	Bracing of Parapets, Gables, Ornamentation, and Appendages	■	■	■	■	■	■	■
9		✓	✓	n/a	n/a	Attachment and Bracing of Large Ductwork	■	■	■	■	■	■	■
18		✓	✓	n/a	n/a	Bracing or Removal of Chimneys	■	■	■	■	■	■	■
Structural													
n/a		✓	✓	All Elements		Load Path and Collectors	□	□	□	□	☒	□	☒
n/a		✓	✓	Horizontal Elements	Diaphragms	Attachment and Strengthening at Boundaries	■	■	■	■	☒	■	☒
n/a		✓	✓	Horizontal Elements	Diaphragms	Strength/Stiffness	■	■	■	■	☒	■	☒
n/a		✓	✓	Horizontal Elements	Diaphragms	Strengthening at Openings	□	□	□	□		□	
n/a		✓	✓	Horizontal Elements	Diaphragms	Strengthening at Re-entrant Corners	□	□	□	□	☒	□	☒
n/a		✓	✓	Horizontal Elements	Diaphragms	Topping Slab for Precast Concrete		□	□		☒		☒
n/a	✓	✓	✓	Vertical Elements	Load Path	Lateral Resisting System to Diaphragm Connection	■	■	■	■	☒	■	☒
n/a	✓	✓	✓	Vertical Elements		Out-of-Plane Anchorage of Concrete or Masonry Wall		■	■	■	□	■	□

* Nonstructural improvements are numbered for ease of use.
Structural improvements are not numbered, but rather, organized by structural element and sub-system.

■ Work that may be included in the building rehabilitation/maintenance/repair project on the basis of a quick evaluation by a design professional.

□ Work requiring engineering design.

☒ Work requiring detailed engineering analysis and evaluation of sequencing requirements. The 'x' designates work that could redistribute loads, overstressing some elements.

Note 1: Masonry buildings with a concrete roof should use the concrete building, concrete diaphragm for options.

Table C-4: Fire and Life Safety Improvements

Number*	Level of Seismicity: L	M	H	Building Structural Element	Structural Sub-System	Seismic Performance Improvement	Vertical Load Carrying Structure: Wood	Masonry[1]: Unreinforced Masonry	Masonry[1]: Reinforced Masonry	Concrete: Wood Diaphragm	Concrete: Concrete Diaphragm	Steel: Wood Diaphragm	Steel: Concrete Diaphragm
Nonstructural													
3		✔	✔	n/a	n/a	Bracing and Detailing of Sprinkler and Piping	■	■	■	■	■	■	■
4		✔	✔	n/a	n/a	Suspension and Bracing of Lights	■	■	■	■	■	■	■
5		✔	✔	n/a	n/a	Fastening and Bracing of Ceilings	■	■	■	■	■	■	■
6		✔	✔	n/a	n/a	Fastening and Bracing of Equipment (Mechanical and Electrical)	■	■	■	■	■	■	■
8	✔	✔	✔	n/a	n/a	Glazing Selection and Detailing	■	■	■	■	■	■	■
9		✔	✔	n/a	n/a	Attachment and Bracing of Large Ductwork	■	■	■	■	■	■	■
10	✔	✔	✔	n/a	n/a	Bracing or Reinforcing Masonry Walls at Interior Stairs		■	■	■	■	■	■
11		✔	✔	n/a	n/a	Bracing of Interior Partitions (Masonry and Wood)	■	■	■	■	■	■	■
12		✔	✔	n/a	n/a	Support and Detailing of Elevators		■	■	■	■	■	■
13	✔	✔	✔	n/a	n/a	Anchorage and Bracing of Emergency Lighting	■	■	■	■	■	■	■
19		✔	✔	n/a	n/a	Attachment and Bracing of Cabinets and Furnishings	■	■	■	■	■	■	■
20		✔	✔	n/a	n/a	Anchorage of Steel Stud Backup		■	■	■	■	■	■
21		✔	✔	n/a	n/a	Restraint of Hazardous Materials Containers	■	■	■	■	■	■	■
Structural													
n/a		✔	✔	All Elements		Collector and Drag Element Improvement	☐	☐	☐	☐	☒	☐	☒
n/a		✔	✔	Horizontal Elements	Diaphragms	Mezzanine Anchorage and Bracing		■	■	■	■	■	■
n/a	✔	✔	✔	Vertical Elements	Load Path	Lateral Resisting System to Diaphragm Connection	■	■	■	■	☒	■	☒
n/a		✔	✔	Vertical Elements	Braced Frames	Capacity/Stiffness			☐	☐	☒	☐	☒
n/a		✔	✔	Vertical Elements	Braced Frames	Continuity			☐	☐	☒	☐	☒
n/a		✔	✔	Vertical Elements	Braced Frames	Connections			☐	☐	☐	☐	☐
n/a		✔	✔	Vertical Elements	Moment Frames	Beam Column Capacity/Stiffness			☐	☐	☒	☐	☒
n/a		✔	✔	Vertical Elements	Moment Frames	Beam Column Connection			☐	☐	☐	☐	☐
n/a		✔	✔	Vertical Elements	Shear Walls	Capacity	■	☐	☐	☐	☒	☐	☒
n/a		✔	✔	Vertical Elements	Shear Walls	Continuity	■	☐	☐	☐	☒	☐	☒
n/a		✔	✔	Vertical Elements	Shear Walls	Extension of Wood Interior Walls to Roof	■	■	■				
n/a		✔	✔	Vertical Elements	Shear Walls	Lateral Stability		■	■	☐	☐	☐	☐
n/a	✔	✔	✔	Vertical Elements		Out-of-Plane Anchorage of Concrete or Masonry Wall		■	■	■	☐	■	☐

* Nonstructural improvements are numbered for ease of use.
Structural improvements are not numbered, but rather, organized by structural element and sub-system.

■ Work that may be included in the building rehabilitation/maintenance/repair project on the basis of a quick evaluation by a design professional.

☐ Work requiring engineering design.

☒ Work requiring detailed engineering analysis and evaluation of sequencing requirements. The "x" designates work that could redistribute loads, overstressing some elements.

Note 1: Masonry buildings with a concrete roof or floors should use the concrete building, concrete diaphragm for options.

Additional Engineering

The matrices in the owner manuals further categorize the integration opportunities with the extent of engineering involved in implementing particular increments by three symbols in the matrix intercepts. These are described as follows:

■ Indicates improvements that can be implemented when the integration opportunity arises, on the basis of a quick evaluation by a design professional. These types of improvements address deficiencies that may be identified in an ASCE 31, *Seismic Evaluation of Existing Buildings,* Tier 1 analysis.

□ Indicates improvements that can be implemented when the integration opportunity arises and that require engineering design. These types of improvements address deficiencies that may be identified in an ASCE 31 Tier 1 or Tier 2 analysis.

☒ Indicates improvements that require engineering analysis to determine if they should be implemented when the integration opportunity arises to avoid unintentionally increasing the seismic vulnerability by redistributing loads to weaker elements of the structural system (sequencing requirements).

Of particular significance is the symbol ☒, which suggests the need for additional engineering analysis for buildings with rigid diaphragms.

Many smaller buildings have wood floors and roofs. These are generally considered flexible diaphragm buildings. Buildings with concrete floors and roofs have rigid diaphragms. The dynamic behavior of the two diaphragm-type buildings is different. This is an important parameter that determines how lateral loads are distributed to load-resisting elements of the structures.

Structures with flexible diaphragms distribute earthquake loads based on proportional or tributary area between shear resisting elements (shear walls or frames). Flexible diaphragms allow a straightforward analysis of loads in each shear element. In buildings with flexible diaphragms, increments of strengthening can usually be accomplished with a modest amount of engineering and such work will almost always, result in strengthening of the building.

Structures with rigid diaphragms distribute earthquake loads based on the relative rigidity of the individual shear-resisting elements. Rotational forces may be introduced that must be resisted by these and other elements imposing loads. Rigid diaphragms require more detailed analysis that may have to be conducted for each increment of the proposed strengthening program. Buildings with rigid diaphragms may require an extensive engineering investigation and consideration as the potential increments are being defined.

It is possible that as the parts of the incremental rehabilitation program are implemented, a structure might have less strength or increased torsion than the current structure. An example might occur in a structure with masonry or concrete walls and a concrete floor and roof. Strengthening one or two walls in a section of a building could affect the building's behavior. If this occurs the engineer should make sure that the reduction in seismic resistance is for a limited period and that the entire rehabilitation program will be completed. While there may be some increased risk for a relatively short period, it is justified by the long-term improvement is safety.

6. Incremental Seismic Rehabilitation Plan

The owner manuals have described the Incremental Seismic Rehabilitation Plan as follows:

> An essential feature of implementing incremental seismic rehabilitation in specific buildings is the development and documentation of a seismic rehabilitation plan. The seismic rehabilitation plan will include all the anticipated rehabilitation increments and their prioritization as previously discussed. The documentation will guide the implementation of the incremental seismic rehabilitation program and should ensure that the building owner does not lose sight of overall rehabilitation goals during implementation of individual increments."

An Incremental Seismic Rehabilitation Plan should be prepared for each building determined to require seismic rehabilitation. It should include discussion of the following:

Level of seismicity—The basis for determining the level of seismicity used in the building seismic evaluation and rehabilitation design should be documented, specifying the maps, geotechnical records and reports, and soil analysis used. Coefficients that are a function of the level of seismicity should be clearly documented. Since USGS maps are updated from time to time, it is important to note the dates of the analysis, and of the information on which it was based. It may be appropriate to place this information on the construction documents.

Current building description— The building and its lateral force resisting system should be described in a report in as much detail as possible. Any records about the building, such as plans, construction details, calculations, and specifications records should be included. If the building was classified according to ASCE 31 or FEMA 356 in the course of its evaluation, the classification as well as any conclusions derived from it should be recorded.

Level of performance—The level of performance used in the building seismic evaluation and rehabilitation design should be documented, using the levels of specificity employed in FEMA 356. The reasons for establishing this level should be recorded. As noted in Chapter 5, the seismic rehabilitation design may follow an iterative process, and the level of performance may be revised over time. Any such evolution should be documented. It may be appropriate to place information on the selected level of performance on the construction documents.

List of deficiencies—A complete list of all the building's seismic deficiencies determined during its evaluation should be prepared.

Rehabilitation measures—The rehabilitation measures required to address all the deficiencies in order to meet the selected level of performance should be listed. The incremental seismic rehabilitation will be implemented over a specified period of time, but the comprehensive list of rehabilitation measures will be the final goal of the process, as long as it might take.

Rehabilitation increments—A complete discussion of the definitions prioritization and staging of the rehabilitation measures into discrete increments. As discussed in Chapter 5, this should include:

- Structural Priority (Seismic Engineering)
- Use priority
- Disruption priority

The reasons for selection of the priorities should be retained in the written records and reports. The basis for the determination of the priorities, such as FEMA 356 or engineering judgment, should also be noted.

Integration opportunities—The prioritized rehabilitation increments should be linked to scheduled or planned building maintenance and capital improvement projects. The design professional preparing the Incremental Seismic Rehabilitation Plan should coordinate this work with the owner's facility management plan. Assumptions regarding the scheduling of future work should be clearly documented. The plan should also note any limitations on future scheduling or sequencing of work. An example may be where a certain increments may reduce the strength in part of a building until a subsequent phase. In such a case the scheduling of the next increment that will eliminate the temporary strength reduction should be scheduled. Increments may also be accomplished by opportunities that occur such as unanticipated use or tenant changes, changes in owner priorities, natural disasters or unanticipated funding opportunities.

Integration Project Schedule—The ultimate goal of the Incremental Seismic Rehabilitation Plan is to develop a schedule for the complete seismic rehabilitation project.

In summary, the Incremental Seismic Rehabilitation Plan needs to be a written record of the goals and decisions on implementation. The work may continue over a period of years and perhaps decades. The plan must also be in a form that will permit changes and the recording of those changes. Since design professionals and other project personnel may change over the course of implementation of the plan, it should be in a form that follow-on users can pick up and continue with the work and accomplish its goals.

The following list includes some of the parameters of the plan that may change over time:

- building codes
- levels of seismicity and seismic coefficients
- target performance levels
- natural disasters affecting the building
- building technology, systems, and materials
- financial climate
- local market conditions
- strategic plans of the owner
- maintenance and capital improvement plans of the owner

The Incremental Seismic Rehabilitation Plan should be capable of accommodating all of these changes.

APPENDIX A

SEATTLE PUBLIC SCHOOLS/CASE STUDY REPORT/2/20-22/01

INTRODUCTION

Seattle Public Schools has carried out, and currently continues to carry out, two programs that include seismic rehabilitation of existing school buildings: the Capital Levy Program, currently called the BTA (Buildings, Technology and Athletics) Levy, and the Capital Improvement Program (CIP). The former consists of many small to medium-sized projects that are generally carried out during the summer months when the schools are out of session. The latter are major projects that involve the demolition and construction of new schools or the major rehabilitation of existing schools.

CAPITAL LEVY PROJECTS

About 103 schools have included Capital Levy Projects from 1982 through 1999. Of these, 51 have had seismic rehabilitation projects starting in 1984, and some have had multiple seismic rehabilitation projects. When seismic rehabilitation is coupled with other work, it is most often roofing, followed by exterior wall improvements, accessibility improvements (ADA), and corridor improvements. The following Table summarizes this data for the 51 schools.

SCHOOL	YEAR & WORK DESCRIPTION	SCHOOL	YEAR & WORK DESCRIPTION
Addams	1991 – Seismic	Madison	1994 – Seismic, Roof, Exterior
Alki	1991 – Seismic, Corridor	Madrona*	1992 – Seismic
Allen	1993 – Seismic	Magnolia	1994 – Seismic, Corridor, ADA
Arbor Heights	1985 – Seismic, Roof	Mann	1993 – Seismic, ADA
Bagley	1991 – Seismic, Exterior	Marshall	1993 – Seismic
Ballard*	1993 – Seismic, Gutters & Downspouts	McDonald	1993 – Seismic 1998 – Seismic, ADA
Blaine	1992 – Seismic, Corridor	McGilvra	1992 – Seismic
Boren*	1999 – Seismic, Roof, Hazmat, Fire Alarms	Meany	1991 – Seismic, Roof
Brighton	1994 – Seismic, Corridor, ADA	Memorial Stad.	1994 – Seismic, Roof
Bryant*	1989 – Seismic	Minor	1993 – Seismic, ADA
Coe*	1993 – Seismic	Monroe	1998 – Seismic, ADA
Columbia	1989 – Seismic, Roof	Northbeach	1989 – Seismic
Concord*	1989 – Seismic 1992 – Seismic	Northgate	1987 – Seismic, Roof
Dearborn Park	1991 – Seismic, Roofing	Pinehurst	1994 – Seismic, Roof, Exterior
Decatur	1989 – Seismic	Rainier Beach*	1992 – Seismic, Roof
Dunlap*	1993 – Seismic		
Garfield	1999 – Seismic, Windows, Arts/Science Improvements.	Rogers	1987 – Seismic, Roof 1993 – Seismic
Genessee Hill	1985 – Seismic, Roof 1997 – Seismic	Roosevelt	1993 – Seismic, Roof
Greenwood*	1987 – Seismic, Structural	Sacajawea	1997 – Seismic
Hamilton	1990 – Seismic, Roof, Exterior	Schmitz Park	1991 – Seismic
Highland Park*	1993 – Seismic, ADA	Seward*	1984 – Seismic, Windows, A/C 1991 – Seismic 1993 – Seismic
Hughes	1998 – Seismic, ADA		
Latona*	1989 – Seismic 1992 – Seismic		
Lowell	1993 – Seismic, ADA	Sharples	1994 – Seismic, Roof, Exterior
Loyal Heights	1991 – Seismic, Exterior	Stevens*	1993 – Seismic, Roofing, ADA

SCHOOL	YEAR & WORK DESCRIPTION	SCHOOL	YEAR & WORK DESCRIPTION
Van Asselt	1992 – Seismic, Exterior	Whitman	1995 – Seismic
West Seattle*	1993 – Seismic, ADA	Wilson	1999 – Seismic, Roof

- These 14 schools are among the 20 schools currently scheduled for replacement or gut rehabilitation in the CIP Program.

THE BTA PROGRAM

The Facilities Development and Construction division of Seattle Public Schools is in the continuing process of implementing the New Capital Levy Program which is concerned with the replacement and/or capital upgrades of existing systems in facilities and to provide students with safe and secure buildings.

The current Capital Levy Program is designated Buildings, Technology and Athletics (BTA) Levy. Voters approved $150 million for this program on February 3, 1998. This is a six-year program to finance more than 465 small and large facility improvement projects, at every school (112 schools) in the District. The Program includes the following (about $138.7 million is budgeted for specific school improvements, and $10.7 million is budgeted for computer equipment):

BUILDINGS: Budget: $59,111,822

- Protect the building envelope:
  Replace the most critical roofs (this work includes seismic upgrading of the diaphragm and improved diaphragm connections, if necessary, but is not classified as seismic work)
  Complete the seismic mitigation program started in the early 1980s
  Replace windows to protect the building and improve energy efficiency

- Provide life safety improvements:
  Upgrade fire alarms
  Provide better ADA access, to include elevators
  Do selected hazards materials abatement to reduce future maintenance costs

- Replace heat pumps that will be at the end of their useful life to improve energy efficiency and reduce repair and maintenance costs

- Improve science and art facilities in all secondary schools

TECHNOLOGY: Budget: $41,213,571

- Provide power upgrades to replace worn out systems and support technology
- Technology upgrades to provide data network infrastructure, telephones/intercoms to all classrooms and offices

ATHLETICS: Budget: $38,389,978

- Upgrade athletic facilities and fields at several high schools
- Gymnasium improvements at all secondary schools

These improvements, beginning with some in 1998, are planned to be implemented through 2004, with the majority of the construction phase occurring in the summer months while the schools are closed. The individual scopes of work are packaged into a variety of small projects to meet these goals.

The following tables provide the budget ranges for seismic work. It is assumed that work classified as roof work in the "roof+seismic" classification consists of no more than 15% seismic. This assumption is based on costs reported in the companion Utah Case Study.

	Total Program	Roof + Seismic	Seismic
$	138,715,371	33,497,404	6,915,841
%	100	24	4.5

Table 1.

	Total BUILDING Program	Roof + Seismic	Seismic
$	59,111,822	33,497,404	6,915,841
%	100	57	12

Table 2.

Assuming that no more than 15% of roof work is seismic, Table 1 shows that budgeted seismic work is between 4.5% and 7% of the total program, and Table 2 shows that budgeted seismic work is between 12% and 19% of the BUILDING program (excluding TECHNOLOGY and ATHLETICS).

Twenty-four of the 112 schools in the Program have seismic work programmed (of which 16 also have roof work), and 33 additional schools have roof work and no seismic work programmed. In analyzing the integration of seismic rehabilitation with other work, it is useful to look more closely at the 24 schools that specifically include seismic work.

	Total Program in Schools with Seismic (24 schools)	Seismic
$	43,150689	6,915,841
%	100	16

Table 3.

Table 3 shows that seismic work is at least 16% of the total budgets of the schools in which it occurs. Roofing work that includes some seismic improvements is not included in this estimate.

	Total BUILDING Program in Schools with Seismic	Seismic	Individual Project Range of Seismic
$	23,185,371	6,915,841	
%	100	30	3.5-74

Table 4.

Table 4. shows that seismic work is at least 30% of the BUILDING Program budgets of the schools in which it occurs. Of the 24 schools with seismic work, the smallest seismic work is 3.5% of the budget and the largest is 74% of the budget. Roofing work that includes some seismic improvements is not included in this estimate.

		BUILDING Program						
School	Earlier Seismic*	Roof	Seismic	Life Safety	Exterior	Haz. Mat.	Heat Pump	Sci & Art Improv.
Marshall	1993	279,120	350,000	273,500		31,500		555,556
Rainier Beach	1992		1,021,020	1,016,272				555,555
Roosevelt	1989/1993	300,000	350,000	450,000	750,000	139,650		555,556
Denny		724,500	265,766	50,836				303,030
Madison	1994		350,000	115,649		31,500		303,030
McClure			556,206			10,500		303,030
Meany	1991		18,018					303,030
Arbor Heights	1985	453,338	423,191	281,381				
Broadview		741,526	105,105	47,953				
Fairmont Park		15,683	85,586	173,895				
King		390,829	79,580	92,753				
Laurelhurst		213,184	230,250	109,209				
Loyal Heights	1991	165,179	230,250	281,521				
North Beach	1989		58,559	101,361				
Rainier View		325,086	67,568	142,120				
Roxhill		482,265	22,523	151,164				
Sacajawea	1997		367,500	127,867				
AE#2 – Decatur	1989	456,058	373,874					
Boren/ Cooper		1,200,000	173,250	237,450		38,850		
Hay NOMS		638,652	290,312	899,701				303,030
Hughes		127,575	420,000	47,548				
Magnolia	1994		215,250	72,349	317,250			
McDonald	1993	190,062	614,114	104,276				
Monroe			247,919	57,953		262,500		

- Not including earlier roofing work

Table 5. BUILDING Budget Breakdown for Schools with Seismic Work

Table 5. shows that of the 24 schools in the BTA Program that include seismic work, 11 had earlier increments of seismic work, and one had two such increments.

INDIVIDUAL SCHOOL ANALYSIS OF INCREMENTAL SEISMIC REHABILITATION

The following 10 schools in the BTA Levy Program, and one additional school from earlier Levy Programs, were analyzed:

High Schools:	Marshall Roosevelt
Middle Schools:	Eckstein Meany Whitman
Elementary Schools:	Arbor Heights Broadview Thomson Sacajawea Genessee Hill (not included in current BTA Program)
Closed/Leased Schools:	McDonald Monroe

In addition, information was obtained about the following two schools in the CIP Program:

High Schools:	West Seattle
Elementary Schools:	Concord

School	Model Building Type	General Description of Building	Incremental Seismic Rehab Work Items		Other Rehab Work Items, if Any (% cost)	One of several Increments?		Efficiencies/ Inefficiencies (Cost Savings/ Overruns) (Added Admin.Costs)	Problems and Disadvantages		Subjected to Earthquake
			Structural (% cost)	Non-Structural (% cost)		Past	Future		Intermediate Weaknesses	Other	
High Schools											
Marshal	URM (1st) C2 (3st)	!927. 1 story shops, gym, aud. & cftria. 3 story classrooms	URM shear walls* Wood diaphragma* Tot: 350,000 (23%)	URM chimney* URM/clay tile walls & partitions*	Roof, Life Safety, Haz. Mat., Sci/Art Improvements 1,139,676 (77%)	1993: Parapet bracing	Not known	See general discussion	See general discussion	See general discussion	
Roosevelt	C2	1922 (3 story) 1928 (2 story) 1961 (1, 2 st.)		URM/clay tile walls & partitions Gas shutoffs, brace aquarium, bolt cabinets Tot: 350,000 (14%)	Roof, Life Safety, Exterior Envelope, Haz. Mat., Sci/Art Improvements 2,195,206 (86%)	1993: Attachment of gym roof to wall	None	Dodd Report estimated work at $1.5 million. Only 350,000 budgeted. Decision to keep the exterior wall (landmark school), and replace school, and allocate to seismic work in other schools.			

* Work item identified in Dodd Report and not confirmed.

School	Model Building Type	General Description of Building	Incremental Seismic Rehab Work Items		Other Rehab Work Items, if Any (% cost)	One of several Increments?		Efficiencies/ Inefficiencies (Cost Savings/ Overruns) (Added Admin.Costs)	Problems and Disadvantages		Subjected to Earthquake
			Structural (% cost)	Non-Structural (% cost)		Past	Future		Intermediate Weaknesses	Other	
Middle Schools											
Eckstein (no seismic work budgeted)	C2	1950 2 story + 1 story gym	Upgrade diaphragm & s(rapping to shear walls (Included in roofing)		Roofing, Life Safety, Sci/Art Improvements $1,423, 570 of which roofing $1,066,563	None	None	Seismic work completely integrated with roofing.			
Meany	C2 PC1 W1	1941 – 1 story 1954 – 1, 2 st. 1961 – 1 story	W1: Replace 1 window bay per classroom with plywood shear wall $30,000 (budg: $18,018)		Sci/Art Improvements, Gym work $185,000 (86%) (budg: $338,030)	1991: Reroofing		Seismic work seems unrelated spatially to other work.			
Whitman (no seismic work budgeted)	S5	1959 1-2 story steel frame with URM infill	Additional bracing of selected shear walls Budget unspecified		Roof, Life Safety, Sci/Art Improvements, Gym work $1,470,890	1995: Tubular colums to brace masonry shear walls				Dodd Report called for “shotcrete walls to one side of selected wood walls” but steel colums used instead	

School	Model Building Type	General Description of Building	Incremental Seismic Rehab Work Items		Other Rehab Work Items, if Any (% cost)	One of several Increments?		Efficiencies/ Inefficiencies (Cost Savings/ Overruns) (Added Admin.Costs)	Problems and Disadvantages		Subjected to Earthquake
			Structural (% cost)	Non-Structural (% cost)		Past	Future		Intermediate Weaknesses	Other	
Elementary Schools											
Arbor Heights* * FEMA 178 used for both evaluation and	URM W1 C3 C2 URM	1948 – 1 story 1951 – 1 story w URM corr. 1953 – 1 story 1958 – 2 story 1958 – 1 story	W1: Wood frame shear walls at exterior & bracing between columns C3: URM corr wall shear transfer &reinforcing framing at exits $ 221,000	Tie back brick veneer at exits $74,000 (6%)	Reroofing (including seismic), Life Safety (fire alarm), Technology Upgrades $905,000 (75%)	1979: Strongback stiffeners 1985: Shear transfer CMU corr. Walls to conc. Roof combined with door upgrades	? Check with engineer	Most hazardous conditions solved in 1979 and 1985. Currently, they are making further corridor improvements and nonstructural veneer. Integration of seismic work to accomplish as much as possible during Summer.		No negative impacts	
Broadview/Thomson* * FEMA 178 not used in	PC2	1963 - 1 & 2 story T-beams, prec. Columns, RM infill walls & URM shear walls	$66,000 budgeted for seismic deemed inadequate.		Reroofing, Life Safety, Technology Upgrades	No		Seismic rehabilitaion abandoned due to inadequate budget.	Engineer felt that minor seismic rehab will weaken buidling.		

School	Model Building Type	General Description of Building	Incremental Seismic Rehab Work Items		Other Rehab Work Items, if Any (% cost)	One of several Increments?		Efficiencies/ Inefficiencies (Cost Savings/ Overruns) (Added Admin.Costs)	Problems and Disadvantages		Subjected to Earthquake
			Structural (% cost)	Non-Structural (% cost)		Past	Future		Intermediate Weaknesses	Other	
Elementary Schools											
Sacajawea	W1 C2	1959 2 story classroms 1 story gym	Additional plywood shear walls. Steel bracing . URM partitions in larger	Brick veneer ties at egress locations. $15,000 (2%)	Life Safety (fire alarm), Technology Upgrades $313,000 (43%)	1997: Plywood shear walls in every classroom; URM walls in corridors; roof replacement	None.	First increment was classrooms and corridors. Less used larger spaces done in second phase.			
Genessee Hill	W1 W1 S4 or S5	1948 1 story with URM corridors 1949 1 story with URM corridors 1953 1 story steel frame with URM infill and concrete shear walls	Not in current BTA Levy Program			1985: Reroofing and seismic repairs 1997: Shotcrete shear walls in auditorium & gym, steel bracing in corridors, roof diaphragm					

School	Model Building Type	General Description of Building	Incremental Seismic Rehab Work Items		Other Rehab Work Items, if Any (% cost)	One of several Increments?		Efficiencies/ Inefficiencies (Cost Savings/ Overruns) (Added Admin.Costs)	Problems and Disadvantages		Subjected to Earthquake
			Structural (% cost)	Non-Structural (% cost)		Past	Future		Intermediate Weaknesses	Other	
Closed/Leased Schools											
McDonald	URM & steel framing, conc floors C2	1914: 3 story 1921: 3 story	1998: Shotcrete exterior walls in on direction only. $614,114 (68%)		Roof, Life Safety. $294,338 (32%)	1979: Anchored cornice; reduced parapet; strongback ro tile partitions, tied to diaphragm. 1993: Ceiling ties		Budget limitation		City code governed because it was a leased building.	
Monroe	URM C1/C2	1929 1 story 3 story	1998: Shotcrete shear walls. Membrane/wall ties. $247,000 (39%)		Life Safety (fire alarms, fire rated doors, stair enclosure), Haz. Mat, ADA, cosmetics $383,000 (61%)	1997: Roof diaphragm and entries.					

School	Model Building Type	General Description of Building	Incremental Seismic* Rehab Work Items		Other Rehab Work Items, if Any (% cost)	One of several Increments?		Efficiencies/ Inefficiencies (Cost Savings/ Overruns) (Added Admin.Costs)	Problems and Disadvantages		Subjected to Earthquake
			Structural (% cost)	Non-Structural (% cost)		Past	Future		Intermediate Weaknesses	Other	
CIP Program Schools (* In CIP Program, any seismic work is no longer incremental)											
West Seattle High School	URM, S5 C2 S5 C1	1917: 2, 3 story 1924: 2 story 1954: 1 story, 3 sections 1961: 1 story	Complete rehabilitation. Façade to be retained. Adding shear walls throughout the building.	Complete rehabilitation	Gut rehab	1993: Added concrete shear wall in auditorium. Gables and parapets (?)	None		Current engineering found the concrete shear wall added in 1993 to be inadequately braced.		
Concord elementary School	URM RM1	1913: 3 story. URM piers and exterior wall, steel interior frames & reinforced concrete floors 1971: 1 story, reinforce masonry shear walls	Gut the interior. Shotcrete exterior walls, interior structure to remain. Roof diaphragm to be upgraded. (Design to lower level than current code.		Gut rehab	1989: Chimney, column bracing in attic. 1992: Steel cols. in ext. wall, shotcrete some walls, diagonal bracing in windows.	None	Incremental work done in 1992 was considered the highest priority.			

SELECTED RESPONSES TO QUESTIONS

Why was partial rather than complete seismic rehabilitation undertaken?

> Work in the Capital Levy Program is implemented in the summer, so the projects are limited in scope by definition. They address the highest priority work, which is often related to classroom safety, and to assuring a safe means of egress (hence, the emphasis of bracing URM corridor walls (which are found in many schools due to their fire resistance).

Was the seismic work part of a planned program, or triggered by some external factor?

> The seismic work is part of a planned program (Dodd Report) that evaluated and prioritized all the schools, and identified the most critical work items. Many of the schools had several increments of seismic rehabilitation. Reportedly, much parapet work was done in the 1980s, and is not included in the data used for this report.

Were there cost or administrative implications to the combination of seismic and non-seismic work?

> Sometimes there are trade conflicts. For example, in reroofing, the upgrading of beams is delayed to a later date. One project manager reported that they try to avoid topics that “can open a can of worms”.

What evaluation methods, if any, were used to determine need for seismic rehabilitation?

> Generally, the School District staff and the project engineers report using FEMA 178 for the evaluation.

What seismic design standards are used for the seismic rehabilitation?

> No specific seismic design standards are specified by the School District. Each engineers reportedly designs to his preferred standard and budget. Some report using FEMA 178, and others report using something less than current code. Some schools that had been closed or leased (Hughes, McDonald, Monroe), and are considered a change of occupancy, and required by the City of Seattle to meet either the 1991 UCBC, FEMA 178, or the Tri-Service Manual.

Were intermediate weaknesses due to the partial nature of the seismic improvement identified and analyzed?

> Reported only in one school (Broadview/Thomson) where the engineer felt the budget was inadequate, and partial rehabilitation would weaken the building. Notably, they applied the current code standard. This was a precast concrete structure.

Were there other technical problems in combining seismic and non-seismic rehabilitation?

> Reroofing often includes a seismic component of upgrading the diaphragm and connections.

APPENDIX B

INTEGRATION OPPORTUNITIES

SCHOOLS

Table C-1: Roofing Maintenance and Repair/Re-Roofing

Rank*	Level of Seimicity: L	M	H	Building Structural Element	Structural Sub-System	Seismic Performance Improvement	Vertical Load Carrying Structure: Wood	Masonry[1]: Unreinforced Masonry	Masonry[1]: Reinforced Masonry	Concrete: Wood Diaphragm	Concrete: Concrete Diaphragm	Steel: Wood Diaphragm	Steel: Concrete Diaphragm
Nonstructural													
1	✓	✓	✓	n/a	n/a	Bracing of Parapets, Gables, Ornamentation & Appendages		■		■	■	■	■
2	✓	✓	✓	n/a	n/a	Anchorage of Canopies at Exits	■	■	■	■	■	■	■
3		✓	✓	n/a	n/a	Bracing or Removal of Chimneys	■	■	■	■	■	■	■
10		✓	✓	n/a	n/a	Anchorage and Detailing of Rooftop Equipment	■	■	■	■	■	■	■
Structural													
n/a		✓	✓	All Elements		Load Path and Collectors	□	□	□	□	□	□	□
n/a		✓	✓	Horizontal Elements	Diaphragms	Attachment and Strengthening at Boundaries	■	■	■	■	□	■	□
n/a		✓	✓	Horizontal Elements	Diaphragms	Strength/Stiffness	■	■	■	■	□	■	□
n/a		✓	✓	Horizontal Elements	Diaphragms	Strengthening at Openings	□	□	□	□		□	
n/a		✓	✓	Horizontal Elements	Diaphragms	Strengthening at Re-entrant Corners	□	□	□	□	□	□	□
n/a		✓	✓	Horizontal Elements	Diaphragms	Topping Slab for Precast Concrete		□	□		□		□
n/a	✓	✓	✓	Vertical Elements	Load Path	Lateral Resisting System to Diaphragm Connection		■	■	■	⊠	■	⊠
n/a	✓	✓	✓	Vertical Elements		Out-of-Plane Anchorage of Concrete or Masonry Wall		■	■	■	□	■	□

* Nonstructural improvements are ranked on the basis of engineering judgment of their relative impact on improving life safety in schools. Structural improvements are not ranked, but rather, organized by structural element and sub-system.

■ Work that may be included in the building rehabilitation/maintenance/repair project using little or no engineering

□ Work requiring detailed engineering design to be included in the project

⊠ Work requiring detailed engineering design and evaluation of sequencing requirements; The "x" designates work that could redistribute loads, overstressing some elements

Note 1: Masonry buildings with a concrete roof should use the concrete building, concrete diaphragm for integration opportunities.

Table C-2: Exterior Wall and Window Maintenance

Rank*	Level of Seismicity: L	Level of Seismicity: M	Level of Seismicity: H	Building Structural Element	Structural Sub-System	Seismic Performance Improvement	Vertical Load Carrying Structure: Wood	Masonry[1]: Unreinforced Masonry	Masonry[1]: Reinforced Masonry	Concrete: Wood Diaphragm	Concrete: Concrete Diaphragm	Steel: Wood Diaphragm	Steel: Concrete Diaphragm
Nonstructural													
1	✓	✓	✓	n/a	n/a	Bracing of Parapets, Gables, Ornamentation & Appendages		■	■	■	■	■	■
2	✓	✓	✓	n/a	n/a	Anchorage of Canopies at Exits	■	■	■	■	■	■	■
12	✓	✓	✓	n/a	n/a	Cladding Anchorage		□	□	□	□	□	□
13		✓	✓	n/a	n/a	Anchorage of Masonry Veneer	■	■	■	■	■	■	■
14		✓	✓	n/a	n/a	Anchorage of Exterior Wythe in Cavity Walls		■	■	■	■	■	■
15	✓	✓	✓	n/a	n/a	Glazing Selection and Detailing	■	■	■	■	■	■	■
17		✓	✓	n/a	n/a	Anchorage of Steel Stud Backup		■	■	■	■	■	■
20		✓	✓	n/a	n/a	Shut-Off Valves	■	■	■	■	■	■	■
Structural													
n/a		✓	✓	All Elements		Collector and Drag Element Improvement	□	□	□	□	□	□	□
n/a		✓	✓	Foundation		Anchor Bolts	■						
n/a		✓	✓	Foundation		Anchorage	■						
n/a		✓	✓	Foundation		Cripple Stud Bracing	■						
n/a		✓	✓	Horizontal Elements	Diaphragms	Attachment and Strengthening at Boundaries	■	■	■	■	□	■	□
n/a	✓	✓	✓	Vertical Elements	Load Path	Lateral Resisting System to Diaphragm Connection	■	■	■	■	☒	■	☒
n/a		✓	✓	Vertical Elements	Braced Frames	Capacity/Stiffness	□	□	□	□	☒	□	☒
n/a		✓	✓	Vertical Elements	Braced Frames	Continuity	□	□	□	□	□	□	□
n/a		✓	✓	Vertical Elements	Braced Frames	Connections	□	□	□	□	□	□	□
n/a		✓	✓	Vertical Elements	Moment Frames	Beam Column Capacity/Stiffness	□	□	□	□	☒	□	☒
n/a		✓	✓	Vertical Elements	Moment Frames	Beam Column Connection	□	□	□	□	□	□	□
n/a		✓	✓	Vertical Elements	Shear Walls	Capacity	■	□	□	□	☒	□	☒
n/a		✓	✓	Vertical Elements	Shear Walls	Continuity	■	□	□	□	□	□	□
n/a		✓	✓	Vertical Elements	Shear Walls	Lateral Stability		■	■	■	□	■	□
n/a	✓	✓	✓	Vertical Elements		Out-of-Plane Anchorage of Concrete or Masonry Wall	■	■	■	■	□	■	□

* Nonstructural improvements are ranked on the basis of engineering judgment of their relative impact on improving life safety in schools. Structural improvements are not ranked, but rather, organized by structural element and sub-system.

■ Work that may be included in the building rehabilitation/maintenance/repair project using little or no engineering

□ Work requiring detailed engineering design to be included in the project

☒ Work requiring detailed engineering design and evaluation of sequencing requirements; The 'x' designates work that could redistribute loads, overstressing some elements

Note 1: Masonry buildings with a concrete roof or floors should use the concrete building, concrete diaphragm for integration opportunities.

Table C-3: Fire and Life Safety Improvements

Rank*	Level of Seismicity: L	Level of Seismicity: M	Level of Seismicity: H	Building Structural Element	Structural Sub-System	Seismic Performance Improvement	Vertical Load Carrying Structure: Wood	Masonry[1]: Unreinforced Masonry	Masonry[1]: Reinforced Masonry	Concrete: Wood Diaphragm	Concrete: Concrete Diaphragm	Steel: Wood Diaphragm	Steel: Concrete Diaphragm
Nonstructural													
4	✔	✔	✔	n/a	n/a	Bracing or Reinforcing Masonry Walls at Interior Stairs		■	■	■	■	■	■
5		✔	✔	n/a	n/a	Suspension and Bracing of Lights	■	■	■	■	■	■	■
6	✔	✔	✔	n/a	n/a	Anchorage and Bracing of Emergency Lighting	■	■	■	■	■	■	■
7		✔	✔	n/a	n/a	Fastening and Bracing of Ceilings	■	■	■	■	■	■	■
8		✔	✔	n/a	n/a	Restraint of Hazardous Materials Containers	■	■	■	■	■	■	■
9		✔	✔	n/a	n/a	Bracing and Detailing of Sprinkler and Piping	■	■	■	■	■	■	■
11		✔	✔	n/a	n/a	Fastening and Bracing of Equipment, Mechanical and Electrical	■	■	■	■	■	■	■
15	✔	✔	✔	n/a	n/a	Glazing Selection and Detailing	■	■	■	■	■	■	■
16		✔	✔	n/a	n/a	Bracing of Interior Partitions, Masonry & Wood	■	■	■	■	■	■	■
17		✔	✔	n/a	n/a	Anchorage of Steel Stud Backup		■	■	■	■	■	■
18		✔	✔	n/a	n/a	Attachment and Bracing of Cabinets and Furnishings	■	■	■	■	■	■	■
19		✔	✔	n/a	n/a	Attachment and Bracing of Large Ductwork	■	■	■	■	■	■	■
21		✔	✔	n/a	n/a	Support and Detailing of Elevators		■	■	■	■	■	■
Structural													
n/a		✔	✔	All Elements		Collector and Drag Element Improvement	□	□	□	□	□	□	□
n/a		✔	✔	Horizontal Elements	Diaphragms	Mezzanine Anchorage and Bracing		■	■	■	■	■	■
n/a	✔	✔	✔	Vertical Elements	Load Path	Lateral Resisting System to Diaphragm Connection	■	■	■	■	☒	■	☒
n/a		✔	✔	Vertical Elements	Braced Frames	Capacity/Stiffness			□	□	☒	□	☒
n/a		✔	✔	Vertical Elements	Braced Frames	Continuity			□	□	□	□	□
n/a		✔	✔	Vertical Elements	Braced Frames	Connections			□	□	□	□	□
n/a		✔	✔	Vertical Elements	Moment Frames	Beam Column Capacity/Stiffness			□	□	☒	□	☒
n/a		✔	✔	Vertical Elements	Moment Frames	Beam Column Connection			□	□	□	□	□
n/a		✔	✔	Vertical Elements	Shear Walls	Capacity	■	□	□	□	☒	□	☒
n/a		✔	✔	Vertical Elements	Shear Walls	Continuity	■	□	□	□	□	□	□
n/a		✔	✔	Vertical Elements	Shear Walls	Extension of Wood Interior Walls to Roof	■	■	■				
n/a		✔	✔	Vertical Elements	Shear Walls	Lateral Stability		■	■	■	□	■	□
n/a	✔	✔	✔	Vertical Elements		Out-of-Plane Anchorage of Concrete or Masonry Wall		■	■	■	□	■	□

* Nonstructural improvements are ranked on the basis of engineering judgment of their relative impact on improving life safety in schools. Structural improvements are not ranked, but rather, organized by structural element and sub-system.

■ Work that may be included in the building rehabilitation/maintenance/repair project using little or no engineering

□ Work requiring detailed engineering design to be included in the project

☒ Work requiring detailed engineering design and evaluation of sequencing requirements; The "x" designates work that could redistribute loads, overstressing some elements

Note 1: Masonry buildings with a concrete roof or floors should use the concrete building, concrete diaphragm for integration opportunities.

Table C-4: Modernization/Remodeling/New Technology

Rank*	Level of Seismicity: L	Level of Seismicity: M	Level of Seismicity: H	Building Structural Element	Structural Sub-System	Seismic Performance Improvement	Vertical Load Carrying Structure: Wood	Masonry[1]: Unreinforced Masonry	Masonry[1]: Reinforced Masonry	Concrete: Wood Diaphragm	Concrete: Concrete Diaphragm	Steel: Wood Diaphragm	Steel: Concrete Diaphragm
Nonstructural													
4	✓	✓	✓	n/a	n/a	Bracing or Reinforcing Masonry Walls at Interior Stairs	■	■	■	■	■	■	■
5		✓	✓	n/a	n/a	Suspension and Bracing of Lights	■	■	■	■	■	■	■
6	✓	✓	✓	n/a	n/a	Anchorage and Bracing of Emergency Lighting	■	■	■	■	■	■	■
7		✓	✓	n/a	n/a	Fastening and Bracing of Ceilings	■	■	■	■	■	■	■
8		✓	✓	n/a	n/a	Restraint of Hazardous Materials Containers	■	■	■	■	■	■	■
9		✓	✓	n/a	n/a	Bracing and Detailing of Sprinkler and Piping	■	■	■	■	■	■	■
11		✓	✓	n/a	n/a	Fastening and Bracing of Equipment, Mechanical and Electrical	■	■	■	■	■	■	■
15	✓	✓	✓	n/a	n/a	Glazing Selection and Detailing	■	■	■	■	■	■	■
16		✓	✓	n/a	n/a	Bracing of Interior Partitions, Masonry & Wood	■	■	■	■	■	■	■
17		✓	✓	n/a	n/a	Anchorage of Steel Stud Backup		■	■	■	■	■	
18		✓	✓	n/a	n/a	Attachment and Bracing of Cabinets and Furnishings	■	■	■	■	■	■	■
19		✓	✓	n/a	n/a	Attachment and Bracing of Large Ductwork	■	■	■	■	■	■	■
21		✓	✓	n/a	n/a	Support and Detailing of Elevators		■	■	■	■	■	■
22		✓	✓	n/a	n/a	Underfloor Bracing of Computer Access Floor	■	■	■	■	■	■	■
Structural													
n/a		✓	✓	All Elements		Collector and Drag Element Improvement	□	□	□	□	□	□	□
n/a		✓	✓	Foundation		Anchor Bolts	■						
n/a		✓	✓	Foundation		Cripple Stud Bracing	■						
n/a		✓	✓	Foundation		New Foundations	■						
n/a		✓	✓	Horizontal Elements	Diaphragms	Mezzanine Anchorage and Bracing		■	■	■	■	■	■
n/a		✓	✓	Horizontal Elements	Diaphragms	Strengthening at Openings	□	□	□	□		□	
n/a		✓	✓	Horizontal Elements	Diaphragms	Strengthening at Re-entrant Corners	□	□	□	□	□	□	□
n/a	✓	✓	✓	Vertical Elements	Load Path	Lateral Resisting System to Diaphragm Connection	■	■	■	■	⊠	■	⊠
n/a		✓	✓	Vertical Elements	Braced Frames	Capacity/Stiffness			□	□	⊠	□	⊠
n/a		✓	✓	Vertical Elements	Braced Frames	Continuity			□	□	□	□	□
n/a		✓	✓	Vertical Elements	Braced Frames	Connections			□	□	□	□	□
n/a		✓	✓	Vertical Elements	Moment Frames	Beam Column Capacity/Stiffness			□	□	⊠	□	⊠
n/a		✓	✓	Vertical Elements	Moment Frames	Beam Column Connection			□	□	□	□	□
n/a		✓	✓	Vertical Elements	Shear Walls	Capacity	■	□	□	□	⊠	□	⊠
n/a		✓	✓	Vertical Elements	Shear Walls	Continuity	■	□	□	□	□	□	□
n/a		✓	✓	Vertical Elements	Shear Walls	Extension of Wood Interior Walls to Roof	■						
n/a		✓	✓	Vertical Elements	Shear Walls	Lateral Stability		■	■	□	□	□	□
n/a	✓	✓	✓	Vertical Elements		Out-of-Plane Anchorage of Concrete or Masonry Wall		■	■	■	□	■	□

* Nonstructural improvements are ranked on the basis of engineering judgment of their relative impact on improving life safety in schools.
Structural improvements are not ranked, but rather, organized by structural element and sub-system.

■ Work that may be included in the building rehabilitation/maintenance/repair project using little or no engineering

□ Work requiring detailed engineering design to be included in the project

⊠ Work requiring detailed engineering design and evaluation of sequencing requirements; The "x" designates work that could redistribute loads, overstressing some elements

Note 1: Masonry buildings with a concrete roof or floors should use the concrete building, concrete diaphragm for integration opportunities.

Table C-5: Underfloor and Basement Work

Rank*	Level of Seimicity L	Level of Seimicity M	Level of Seimicity H	Building Structural Element	Structural Sub-System	Seismic Performance Improvement	Vertical Load Carrying Structure: Wood	Masonry[1]: Unreinforced Masonry	Masonry[1]: Reinforced Masonry	Concrete: Wood Diaphragm	Concrete: Concrete Diaphragm	Steel: Wood Diaphragm	Steel: Concrete Diaphragm
Nonstructural													
8		✔	✔	n/a	n/a	Restraint of Hazardous Materials Containers	■	■	■	■	■	■	■
11		✔	✔	n/a	n/a	Fastening and Bracing of Equipment, Mechanical and Electrical	■	■	■	■	■	■	■
20		✔	✔	n/a	n/a	Shut-Off Valves	■	■	■	■	■	■	■
Structural													
n/a		✔	✔	All Elements		Collector and Drag Element Improvement	□	□	□	□	□	□	□
n/a		✔	✔	Foundation		Anchor Bolts	■						
n/a		✔	✔	Foundation		Anchorage	■	■	■	□	□	□	□
n/a		✔	✔	Foundation		Cripple Stud Bracing	■						
n/a		✔	✔	Foundation		New Foundations	■	□	□	□	□	□	□
n/a		✔	✔	Foundation		Pile Cap Lateral Load		■	■	□	□	□	□
n/a		✔	✔	Foundation		Uplift	■	■	■	□	□	□	□
n/a	✔	✔	✔	Vertical Elements	Load Path	Lateral Resisting System to Diaphragm Connection	■	■	■	■	⊠	■	⊠
n/a		✔	✔	Vertical Elements	Braced Frames	Connections						□	□
n/a		✔	✔	Vertical Elements	Moment Frames	Beam Column Connection						□	□
n/a		✔	✔	Vertical Elements	Shear Walls	Capacity	■	□	□	□	⊠	□	⊠
n/a		✔	✔	Vertical Elements	Shear Walls	Continuity	■	□	□	□	□	□	□
n/a	✔	✔	✔	Vertical Elements		Out-of-Plane Anchorage of Concrete or Masonry Wall		■	■	■	□	■	□

* Nonstructural improvements are ranked on the basis of engineering judgment of their relative impact on improving life safety in schools. Structural improvements are not ranked, but rather, organized by structural element and sub-system.

■ Work that may be included in the building rehabilitation/maintenance/repair project using little or no engineering

□ Work requiring detailed engineering design to be included in the project

⊠ Work requiring detailed engineering design and evaluation of sequencing requirements; The "x" designates work that could redistribute loads, overstressing some elements

Note 1: Masonry buildings with a concrete roof or floors should use the concrete building, concrete diaphragm for integration opportunities.

HOSPITALS

Table C-1: Patient Care Improvements

Number*	Level of Seismicity			Building Structural Element	Structural Sub-System	Seismic Performance Improvement	Vertical Load Carrying Structure: Wood	Masonry[1]		Concrete		Steel	
	L	M	H					Unreinforced Masonry	Reinforced Masonry	Wood Diaphragm	Concrete Diaphragm	Wood Diaphragm	Concrete Diaphragm
Nonstructural													
3		✓	✓	n/a	n/a	Bracing and Detailing of Sprinkler and Piping	■	■	■	■	■	■	■
4		✓	✓	n/a	n/a	Suspension and Bracing of Lights	■	■	■	■	■	■	■
5		✓	✓	n/a	n/a	Fastening and Bracing of Ceilings	■	■	■	■	■	■	■
6	✓	✓	✓	n/a	n/a	Anchorage and Bracing of Emergency Lighting	■	■	■	■	■	■	■
7		✓	✓	n/a	n/a	Attachment and Bracing of Cabinets and Furnishings	■	■	■	■	■	■	■
8		✓	✓	n/a	n/a	Fastening and Bracing of Equipment (Mechanical and Electrical)	■	■	■	■	■	■	■
9		✓	✓	n/a	n/a	Support and Detailing of Elevators		■	■	■	■	■	■
10	✓	✓	✓	n/a	n/a	Bracing or Reinforcing Masonry Walls at Interior Stair	■	■	■	■	■	■	■
11		✓	✓	n/a	n/a	Attachment and Bracing of Large Ductwork	■	■	■	■	■	■	■
13		✓	✓	n/a	n/a	Restraint of Hazardous Materials Containers	■	■	■	■	■	■	■
14		✓	✓	n/a	n/a	Bracing of Interior Partitions (Masonry & Wood)	■	■	■	■	■	■	■
16	✓	✓	✓	n/a	n/a	Glazing Selection and Detailing	■	■	■	■	■	■	■
17		✓	✓	n/a	n/a	Underfloor Bracing of Computer Access Floor	■	■	■	■	■	■	■
20		✓	✓	n/a	n/a	Anchorage of Steel Stud Backup		■	■	■	■	■	■
Structural													
n/a		✓	✓	All		Collector and Drag Element Improvement	□	□	□	□	☒	□	☒
n/a		✓	✓	Foundation		Anchor Bolts	■						
n/a		✓	✓	Foundation		Cripple Stud Bracing	■						
n/a		✓	✓	Foundation		New Foundations	■						
n/a		✓	✓	Horizontal Elements	Diaphragms	Mezzanine Anchorage and Bracing		■	■	■	■	■	■
n/a		✓	✓	Horizontal Elements	Diaphragms	Strengthening at Openings	□	□	□	□		□	
n/a		✓	✓	Horizontal Elements	Diaphragms	Strengthening at Re-entrant Corners	□	□	□	□	☒	□	☒
n/a	✓	✓	✓	Vertical Elements	Load Path	Lateral Resisting System to Diaphragm Connection	■	■	■	■	☒	■	☒
n/a		✓	✓	Vertical Elements	Braced Frames	Capacity/Stiffness				□	☒	□	☒
n/a		✓	✓	Vertical Elements	Braced Frames	Continuity				□	☒	□	☒
n/a		✓	✓	Vertical Elements	Braced Frames	Connections				□	□	□	□
n/a		✓	✓	Vertical Elements	Moment Frames	Beam Column Capacity/Stiffness				□	☒	□	☒
n/a		✓	✓	Vertical Elements	Moment Frames	Beam Column Connection				□	□	□	□
n/a		✓	✓	Vertical Elements	Shear Walls	Capacity	■	□	□	□	☒	□	☒
n/a		✓	✓	Vertical Elements	Shear Walls	Continuity	■	□	□	□	☒	□	☒
n/a		✓	✓	Vertical Elements	Shear Walls	Extension of Wood Interior Walls to Roof	■	■	■				
n/a		✓	✓	Vertical Elements	Shear Walls	Lateral Stability		■	■	□	□	□	□
n/a	✓	✓	✓	Vertical Elements		Out-of-Plane Anchorage of Concrete or Masonry Wall		■	■	■	□	■	□

* Nonstructural improvements are numbered for ease of use.
Structural improvements are not numbered, but rather, organized by structural element and sub-system.

■ Work that may be included in the building rehabilitation/maintenance/repair project on the basis of a quick evaluation by a design professional

□ Work requiring engineering design.

☒ Work requiring detailed engineering analysis and evaluation of sequencing requirements. The "x" designates work that could redistribute loads, overstressing some elements.

Note 1: Masonry buildings with a concrete roof should use the concrete building, concrete diaphragm for options.

Table C-2: New Technology Accommodation

Number*	Level of Seismicity			Building Structural Element	Structural Sub-System	Seismic Performance Improvement	Vertical Load Carrying Structure						
							Wood	Masonry[1]		Concrete		Steel	
	L	M	H					Unreinforced Masonry	Reinforced Masonry	Wood Diaphragm	Concrete Diaphragm	Wood Diaphragm	Concrete Diaphragm
Nonstructural													
3		✓	✓	n/a	n/a	Bracing and Detailing of Sprinkler and Piping	■	■	■	■	■	■	■
4		✓	✓	n/a	n/a	Suspension and Bracing of Lights	■	■	■	■	■	■	■
5		✓	✓	n/a	n/a	Fastening and Bracing of Ceilings	■	■	■	■	■	■	■
6	✓	✓	✓	n/a	n/a	Anchorage and Bracing of Emergency Lighting	■	■	■	■	■	■	■
7		✓	✓	n/a	n/a	Attachment and Bracing of Cabinets and Furnishings	■	■	■	■	■	■	■
8		✓	✓	n/a	n/a	Fastening and Bracing of Equipment (Mechanical and Electrical)	■	■	■	■	■	■	■
9		✓	✓	n/a	n/a	Support and Detailing of Elevators		■	■	■	■	■	■
10	✓	✓	✓	n/a	n/a	Bracing or Reinforcing Masonry Walls at Interior Stairs		■	■	■	■	■	■
11		✓	✓	n/a	n/a	Attachment and Bracing of Large Ductwork	■	■	■	■	■	■	■
13		✓	✓	n/a	n/a	Restraint of Hazardous Materials Containers	■	■	■	■	■	■	■
14		✓	✓	n/a	n/a	Bracing of Interior Partitions (Masonry & Wood)	■	■	■	■	■	■	■
16	✓	✓	✓	n/a	n/a	Glazing Selection and Detailing	■	■	■	■	■	■	■
17		✓	✓	n/a	n/a	Underfloor Bracing of Computer Access Floor	■	■	■	■	■	■	■
20		✓	✓	n/a	n/a	Anchorage of Steel Stud Backup		■	■	■	■	■	■
Structural													
n/a		✓	✓	All		Collector and Drag Element Improvement	□	□	□	□	⊠	□	⊠
n/a		✓	✓	Foundation		Anchor Bolts	■						
n/a		✓	✓	Foundation		Cripple Stud Bracing	■						
n/a		✓	✓	Foundation		New Foundations	■						
n/a		✓	✓	Horizontal Elements	Diaphragms	Mezzanine Anchorage and Bracing		■	■	■	■	■	■
n/a		✓	✓	Horizontal Elements	Diaphragms	Strengthening at Openings	□	□	□	□		□	
n/a		✓	✓	Horizontal Elements	Diaphragms	Strengthening at Re-entrant Corners	□	□	□	□	⊠	□	⊠
n/a	✓	✓	✓	Vertical Elements	Load Path	Lateral Resisting System to Diaphragm Connection	■	■	■	■	⊠	■	⊠
n/a		✓	✓	Vertical Elements	Braced Frames	Capacity/Stiffness			□	□	⊠	□	⊠
n/a		✓	✓	Vertical Elements	Braced Frames	Continuity			□	□	⊠	□	⊠
n/a		✓	✓	Vertical Elements	Braced Frames	Connections			□	□	□	□	□
n/a		✓	✓	Vertical Elements	Moment Frames	Beam Column Capacity/Stiffness			□	□	⊠	□	⊠
n/a		✓	✓	Vertical Elements	Moment Frames	Beam Column Connection			□	□	□	□	□
n/a		✓	✓	Vertical Elements	Shear Walls	Capacity	■	□	□	□	⊠	□	⊠
n/a		✓	✓	Vertical Elements	Shear Walls	Continuity	■	□	□	□	⊠	□	⊠
n/a		✓	✓	Vertical Elements	Shear Walls	Extension of Wood Interior Walls to Roof	■	■	■				
n/a		✓	✓	Vertical Elements	Shear Walls	Lateral Stability		■	■	□	□	□	□
n/a	✓	✓	✓	Vertical Elements		Out-of-Plane Anchorage of Concrete or Masonry Wall		■	■	■	□	■	□

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Structural improvements are not numbered, but rather, organized by structural element and sub-system.

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□ Work requiring engineering design.

⊠ Work requiring detailed engineering analysis and evaluation of sequencing requirements. The 'x' designates work that could redistribute loads, overstressing some elements.

Note 1: Masonry buildings with a concrete roof or floors should use the concrete building, concrete diaphragm for options.

Table C-3: Fire and Life Safety Improvements

Number*	Level of Seimicity: L	M	H	Building Structural Element	Structural Sub-System	Seismic Performance Improvement	Vertical Load Carrying Structure: Wood	Masonry[1]: Unreinforced Masonry	Masonry[1]: Reinforced Masonry	Concrete: Wood Diaphragm	Concrete: Concrete Diaphragm	Steel: Wood Diaphragm	Steel: Concrete Diaphragm
Nonstructural													
3		✓	✓	n/a	n/a	Bracing and Detailing of Sprinkler and Piping	■	■	■	■	■	■	■
4		✓	✓	n/a	n/a	Suspension and Bracing of Lights	■	■	■	■	■	■	■
5		✓	✓	n/a	n/a	Fastening and Bracing of Ceilings	■	■	■	■	■	■	■
6		✓	✓	n/a	n/a	Fastening and Bracing of Equipment (Mechanical and Electrical)	■	■	■	■	■	■	■
8	✓	✓	✓	n/a	n/a	Glazing Selection and Detailing	■	■	■	■	■	■	■
9		✓	✓	n/a	n/a	Attachment and Bracing of Large Ductwork	■	■	■	■	■	■	■
10	✓	✓	✓	n/a	n/a	Bracing or Reinforcing Masonry Walls at Interior Stairs		■	■	■	■	■	■
11		✓	✓	n/a	n/a	Bracing of Interior Partitions (Masonry and Wood)	■	■	■	■	■	■	■
12		✓	✓	n/a	n/a	Support and Detailing of Elevators		■	■	■	■	■	■
13	✓	✓	✓	n/a	n/a	Anchorage and Bracing of Emergency Lighting	■	■	■	■	■	■	■
19		✓	✓	n/a	n/a	Attachment and Bracing of Cabinets and Furnishings	■	■	■	■	■	■	■
20		✓	✓	n/a	n/a	Anchorage of Steel Stud Backup		■	■	■	■	■	■
21		✓	✓	n/a	n/a	Restraint of Hazardous Materials Containers	■	■	■	■	■	■	■
Structural													
n/a		✓	✓	All Elements		Collector and Drag Element Improvement	□	□	□	□	⊠	□	⊠
n/a		✓	✓	Horizontal Elements	Diaphragms	Mezzanine Anchorage and Bracing		■	■	■	■	■	■
n/a	✓	✓	✓	Vertical Elements	Load Path	Lateral Resisting System to Diaphragm Connection	■	■	■	■	⊠	■	⊠
n/a		✓	✓	Vertical Elements	Braced Frames	Capacity/Stiffness			□	□	⊠	□	⊠
n/a		✓	✓	Vertical Elements	Braced Frames	Continuity			□	□	⊠	□	⊠
n/a		✓	✓	Vertical Elements	Braced Frames	Connections			□	□	□	□	□
n/a		✓	✓	Vertical Elements	Moment Frames	Beam Column Capacity/Stiffness			□	□	⊠	□	⊠
n/a		✓	✓	Vertical Elements	Moment Frames	Beam Column Connection			□	□	□	□	□
n/a		✓	✓	Vertical Elements	Shear Walls	Capacity	■	□	□	□	⊠	□	⊠
n/a		✓	✓	Vertical Elements	Shear Walls	Continuity	■	□	□	□	⊠	□	⊠
n/a		✓	✓	Vertical Elements	Shear Walls	Extension of Wood Interior Walls to Roof	■	■	■				
n/a		✓	✓	Vertical Elements	Shear Walls	Lateral Stability		■	■	□	□	□	□
n/a	✓	✓	✓	Vertical Elements		Out-of-Plane Anchorage of Concrete or Masonry Wall		■	■	■	□	■	□

* Nonstructural improvements are numbered for ease of use.
Structural improvements are not numbered, but rather, organized by structural element and sub-system.

■ Work that may be included in the building rehabilitation/maintenance/repair project on the basis of a quick evaluation by a design professional.

□ Work requiring engineering design.

⊠ Work requiring detailed engineering analysis and evaluation of sequencing requirements. The "x" designates work that could redistribute loads, overstressing some elements.

Note 1: Masonry buildings with a concrete roof or floors should use the concrete building, concrete diaphragm for options.

Table C-4: Roofing Maintenance & Repair/Re-roofing

Number*	Level of Seismicity			Building Structural Element	Structural Sub-System	Seismic Performance Improvement	Vertical Load Carrying Structure						
							Wood	Masonry[1]		Concrete		Steel	
	L	M	H					Unreinforced Masonry	Reinforced Masonry	Wood Diaphragm	Concrete Diaphragm	Wood Diaphragm	Concrete Diaphragm
Nonstructural													
1	✓	✓	✓	n/a	n/a	Anchorage of Canopies at Exits	■	■	■	■	■	■	■
2		✓	✓	n/a	n/a	Anchorage and Detailing of Rooftop Equipment	■	■	■	■	■	■	■
11	✓	✓	✓	n/a	n/a	Attachment and Bracing of Large Ductwork	■	■	■	■	■	■	■
12		✓	✓	n/a	n/a	Bracing of Parapets, Gables, Ornamentation, and Appendages	■	■	■	■	■	■	■
22		✓	✓	n/a	n/a	Bracing or Removal of Chimneys	■	■	■	■	■	■	■
Structural													
n/a		✓	✓	All Elements		Load Path and Collectors	□	□	□	□	⊠	□	⊠
n/a		✓	✓	Horizontal Elements	Diaphragms	Attachment and Strengthening at Boundaries	■	■	■	■	⊠	■	⊠
n/a		✓	✓	Horizontal Elements	Diaphragms	Strength/Stiffness	■	■	■	■	⊠	■	⊠
n/a		✓	✓	Horizontal Elements	Diaphragms	Strengthening at Openings	□	□	□	□		□	
n/a		✓	✓	Horizontal Elements	Diaphragms	Strengthening at Re-entrant Corners	□	□	□	□	⊠	□	⊠
n/a		✓	✓	Horizontal Elements	Diaphragms	Topping Slab for Precast Concrete		□	□		⊠		⊠
n/a	✓	✓	✓	Vertical Elements	Load Path	Lateral Resisting System to Diaphragm Connection	■	■	■	■	⊠	■	⊠
n/a	✓	✓	✓	Vertical Elements		Out-of-Plane Anchorage of Concrete or Masonry Wall		■	■	■	□	■	□

* Nonstructural improvements are numbered for ease of use.
Structural improvements are not numbered, but rather, organized by structural element and sub-system.

■ Work that may be included in the building rehabilitation/maintenance/repair project on the basis of a quick evaluation by a design professional.

□ Work requiring engineering design.

⊠ Work requiring detailed engineering analysis and evaluation of sequencing requirements. The "x" designates work that could redistribute loads, overstressing some elements.

Note 1: Masonry buildings with a concrete roof should use the concrete building, concrete diaphragm for options.

Table C-5: Exterior Wall and Window Work

Number*	Level of Seismicity: L	Level of Seismicity: M	Level of Seismicity: H	Building Structural Element	Structural Sub-System	Seismic Performance Improvement	Vertical Load Carrying Structure: Wood	Masonry[1]: Unreinforced Masonry	Masonry[1]: Reinforced Masonry	Concrete: Wood Diaphragm	Concrete: Concrete Diaphragm	Steel: Wood Diaphragm	Steel: Concrete Diaphragm
Nonstructural													
1	✓	✓	✓	n/a	n/a	Anchorage of Canopies at Exits	■	■	■	■	■	■	■
12	✓	✓	✓	n/a	n/a	Bracing of Parapets, Gables, Ornamentation, and Appendages		■	■	■	■	■	■
15		✓	✓	n/a	n/a	Shut-Off Valves	■	■	■	■	■	■	■
16	✓	✓	✓	n/a	n/a	Glazing Selection and Detailing	■	■	■	■	■	■	■
18	✓	✓	✓	n/a	n/a	Cladding Anchorage		□	□	□	□	□	□
19		✓	✓	n/a	n/a	Anchorage of Masonry Veneer	■	■	■	■	■	■	■
20		✓	✓	n/a	n/a	Anchorage of Steel Stud Backup		■	■	■	■	■	■
21		✓	✓	n/a	n/a	Anchorage of Exterior Wythe in Cavity Walls		■	■	■	■	■	■
Structural													
n/a		✓	✓	All Elements		Collector and Drag Element Improvement	□	□	□	□	☒	□	☒
n/a		✓	✓	Foundation		Anchor Bolts	■						
n/a		✓	✓	Foundation		Cripple Stud Bracing	■						
n/a		✓	✓	Horizontal Elements	Diaphragms	Attachment and Strengthening at Boundaries	■	■	■	■	☒	■	☒
n/a	✓	✓	✓	Vertical Elements	Load Path	Lateral Resisting System to Diaphragm Connection	■	■	■	■	☒	■	☒
n/a		✓	✓	Vertical Elements	Braced Frames	Capacity/Stiffness	□	□	□	□	☒	□	☒
n/a		✓	✓	Vertical Elements	Braced Frames	Continuity	□	□	□	□	☒	□	☒
n/a		✓	✓	Vertical Elements	Braced Frames	Connections	□	□	□	□	□	□	□
n/a		✓	✓	Vertical Elements	Moment Frames	Beam Column Capacity/Stiffness	□	□	□	□	☒	□	☒
n/a		✓	✓	Vertical Elements	Moment Frames	Beam Column Connection	□	□	□	□	□	□	□
n/a		✓	✓	Vertical Elements	Shear Walls	Capacity	■	□	□	□	☒	□	☒
n/a		✓	✓	Vertical Elements	Shear Walls	Continuity	■	□	□	□	☒	□	☒
n/a		✓	✓	Vertical Elements	Shear Walls	Lateral Stability		■	■	□	□	□	□
n/a	✓	✓	✓	Vertical Elements		Out-of-Plane Anchorage of Concrete or Masonry Wall		■	■	■	□	■	□

* Nonstructural improvements are numbered for ease of use.
Structural improvements are not numbered, but rather, organized by structural element and sub-system.

■ Work that may be included in the building rehabilitation/maintenance/repair project on the basis of a quick evaluation by a design professional.

□ Work requiring engineering design.

☒ Work requiring detailed engineering analysis and evaluation of sequencing requirements. The "x" designates work that could redistribute loads, overstressing some elements.

Note 1: Masonry buildings with a concrete roof or floors should use the concrete building, concrete diaphragm for options.

Table C-6: Underfloor and Basement Work

Number*	Level of Seismicity: L	Level of Seismicity: M	Level of Seismicity: H	Building Structural Element	Structural Sub-System	Seismic Performance Improvement	Vertical Load Carrying Structure: Wood	Masonry[1]: Unreinforced Masonry	Masonry[1]: Reinforced Masonry	Concrete: Wood Diaphragm	Concrete: Concrete Diaphragm	Steel: Wood Diaphragm	Steel: Concrete Diaphragm
Nonstructural													
8		✓	✓	n/a	n/a	Fastening and Bracing of Equipment (Mechanical and Electrical)	■	■	■	■	■	■	■
13		✓	✓	n/a	n/a	Restraint of Hazardous Materials Containers	■	■	■	■	■	■	■
15		✓	✓	n/a	n/a	Shut-Off Valves	■	■	■	■	■	■	■
Structural													
n/a		✓	✓	All Elements		Collector and Drag Element Improvement	□	□	□	□	☒	□	☒
n/a		✓	✓	Foundation		Anchor Bolts	■						
n/a		✓	✓	Foundation		Anchorage	■	□	□	□	□	□	□
n/a		✓	✓	Foundation		Cripple Stud Bracing	■						
n/a		✓	✓	Foundation		New Foundations	■	□	□	□	□	□	□
n/a		✓	✓	Foundation		Pile Cap Lateral Load		■	■	□	□	□	□
n/a		✓	✓	Foundation		Uplift	■	■	■	□	□	□	□
n/a	✓	✓	✓	Vertical Elements	Load Path	Lateral Resisting System to Diaphragm Connection	■	■	■	■	☒	■	☒
n/a		✓	✓	Vertical Elements	Braced Frames	Connections						□	□
n/a		✓	✓	Vertical Elements	Moment Frames	Beam Column Connection						□	□
n/a		✓	✓	Vertical Elements	Shear Walls	Capacity	■	□	□	□	☒	□	☒
n/a		✓	✓	Vertical Elements	Shear Walls	Continuity	■	□	□	□	☒	□	☒
n/a	✓	✓	✓	Vertical Elements		Out-of-Plane Anchorage of Concrete or Masonry Wall		■	■	■	□	■	□

* Nonstructural improvements are numbered for ease of use.
Structural improvements are not numbered, but rather, organized by structural element and sub-system.

■ Work that may be included in the building rehabilitation/maintenance/repair project on the basis of a quick evaluation by a design professional.

□ Work requiring engineering design.

☒ Work requiring detailed engineering analysis and evaluation of sequencing requirements. The "x" designates work that could redistribute loads, overstressing some elements.

Note 1: Masonry buildings with a concrete roof or floors should use the concrete building, concrete diaphragm for options.

OFFICE BUILDINGS

Table C-1: Roofing Maintenance and Repair/Re-roofing

Number*	Level of Seismicity: L	M	H	Building Structural Element	Structural Sub-System	Seismic Performance Improvement	Vertical Load Carrying Structure: Wood	Masonry[1]: Unreinforced Masonry	Masonry[1]: Reinforced Masonry	Concrete: Wood Diaphragm	Concrete: Concrete Diaphragm	Steel: Wood Diaphragm	Steel: Concrete Diaphragm
Nonstructural													
1	✓	✓	✓	n/a	n/a	Anchorage of Canopies at Exits	■	■	■	■	■	■	■
2		✓	✓	n/a	n/a	Anchorage and Detailing of Rooftop Equipment	■	■	■	■	■	■	■
7	✓	✓	✓	n/a	n/a	Bracing of Parapets, Gables, Ornamentation, and Appendages	■	■	■	■	■	■	■
9		✓	✓	n/a	n/a	Attachment and Bracing of Large Ductwork	■	■	■	■	■	■	■
16		✓	✓	n/a	n/a	Bracing or Removal of Chimneys	■	■	■	■	■	■	■
Structural													
n/a		✓	✓	All Elements		Load Path and Collectors	□	□	□	□	☒	□	☒
n/a		✓	✓	Horizontal Elements	Diaphragms	Attachment and Strengthening at Boundaries	■	■	■	■	☒	■	☒
n/a		✓	✓	Horizontal Elements	Diaphragms	Strength/Stiffness	■	■	■	■	☒	■	☒
n/a		✓	✓	Horizontal Elements	Diaphragms	Strengthening at Openings	□	□	□	□		□	
n/a		✓	✓	Horizontal Elements	Diaphragms	Strengthening at Re-entrant Corners	□	□	□	□	☒	□	☒
n/a		✓	✓	Horizontal Elements	Diaphragms	Topping Slab for Precast Concrete		□	□		☒		☒
n/a	✓	✓	✓	Vertical Elements	Load Path	Lateral Resisting System to Diaphragm Connection	■	■	■	■	☒	■	☒
n/a	✓	✓	✓	Vertical Elements		Out-of-Plane Anchorage of Concrete or Masonry Wall		■	■	■	□	■	□

* Nonstructural improvements are numbered for ease of use.
Structural improvements are not numbered, but rather, organized by structural element and sub-system.

■ Work that may be included in the building rehabilitation/maintenance/repair project on the basis of a quick evaluation by a design professional.

□ Work requiring engineering design.

☒ Work requiring detailed engineering analysis and evaluation of sequencing requirements. The "x" designates work that could redistribute loads, overstressing some elements.

Note 1: Masonry buildings with a concrete roof should use the concrete building, concrete diaphragm for options.

Table C-2: Exterior Wall and Window Work

Number*	Level of Seismicity			Building Structural Element	Structural Sub-System	Seismic Performance Improvement	Vertical Load Carrying Structure						
							Wood	Masonry[1]		Concrete		Steel	
	L	M	H					Unreinforced Masonry	Reinforced Masonry	Wood Diaphragm	Concrete Diaphragm	Wood Diaphragm	Concrete Diaphragm
Nonstructural													
1	✓	✓	✓	n/a	n/a	Anchorage of Canopies at Exits	■	■	■	■	■	■	■
7	✓	✓	✓	n/a	n/a	Bracing of Parapets, Gables, Ornamentation, and Appendages	■	■	■	■	■	■	■
8	✓	✓	✓	n/a	n/a	Glazing Selection and Detailing	■	■	■	■	■	■	■
14	✓	✓	✓	n/a	n/a	Cladding Anchorage		□	□	□	□	□	□
15		✓	✓	n/a	n/a	Anchorage of Masonry Veneer	■	■	■	■	■	■	■
16		✓	✓	n/a	n/a	Shut-Off Valves	■	■	■	■	■	■	■
17		✓	✓	n/a	n/a	Anchorage of Exterior Wythe in Cavity Walls		■	■	■	■	■	■
20		✓	✓	n/a	n/a	Anchorage of Steel Stud Backup		■	■	■	■	■	■
Structural													
n/a		✓	✓	All Elements		Collector and Drag Element Improvement	□	□	□	□	⊠	□	⊠
n/a		✓	✓	Foundation		Anchor Bolts	■						
n/a		✓	✓	Foundation		Cripple Stud Bracing	■						
n/a		✓	✓	Horizontal Elements	Diaphragms	Attachment and Strengthening at Boundaries	■	■	■	■	⊠	■	⊠
n/a	✓	✓	✓	Vertical Elements	Load Path	Lateral Resisting System to Diaphragm Connection	■	■	■	■	⊠	■	⊠
n/a		✓	✓	Vertical Elements	Braced Frames	Capacity/Stiffness	□	□	□	□	⊠	□	⊠
n/a		✓	✓	Vertical Elements	Braced Frames	Continuity	□	□	□	□	⊠	□	⊠
n/a		✓	✓	Vertical Elements	Braced Frames	Connections	□	□	□	□	□	□	□
n/a		✓	✓	Vertical Elements	Moment Frames	Beam Column Capacity/Stiffness	□	□	□	□	⊠	□	⊠
n/a		✓	✓	Vertical Elements	Moment Frames	Beam Column Connection	□	□	□	□	□	□	□
n/a		✓	✓	Vertical Elements	Shear Walls	Capacity	■	□	□	□	⊠	□	⊠
n/a		✓	✓	Vertical Elements	Shear Walls	Continuity	■	□	□	□	⊠	□	⊠
n/a		✓	✓	Vertical Elements	Shear Walls	Lateral Stability		■	■	□	□	□	□
n/a	✓	✓	✓	Vertical Elements		Out-of-Plane Anchorage of Concrete or Masonry Wall		■	■	■	□	■	□

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■ Work that may be included in the building rehabilitation/maintenance/repair project on the basis of a quick evaluation by a design professional.

□ Work requiring engineering design.

⊠ Work requiring detailed engineering analysis and evaluation of sequencing requirements. The "x" designates work that could redistribute loads, overstressing some elements.

Note 1: Masonry buildings with a concrete roof or floors should use the concrete building, concrete diaphragm for options.

Table C-3: Public Area Modernization

Number*	Level of Seismicity: L	Level of Seismicity: M	Level of Seismicity: H	Building Structural Element	Structural Sub-System	Seismic Performance Improvement	Vertical Load Carrying Structure: Wood	Masonry[1]: Unreinforced Masonry	Masonry[1]: Reinforced Masonry	Concrete: Wood Diaphragm	Concrete: Concrete Diaphragm	Steel: Wood Diaphragm	Steel: Concrete Diaphragm
Nonstructural													
3		✓	✓	n/a	n/a	Bracing and Detailing of Sprinkler and Piping	■	■	■	■	■	■	■
4		✓	✓	n/a	n/a	Suspension and Bracing of Lights	■	■	■	■	■	■	■
5		✓	✓	n/a	n/a	Fastening and Bracing of Ceilings	■	■	■	■	■	■	■
6		✓	✓	n/a	n/a	Fastening and Bracing of Equipment (Mechanical and Electrical)	■	■	■	■	■	■	■
8	✓	✓	✓	n/a	n/a	Glazing Selection and Detailing	■	■	■	■	■	■	■
9		✓	✓	n/a	n/a	Attachment and Bracing of Large Ductwork	■	■	■	■	■	■	■
10	✓	✓	✓	n/a	n/a	Bracing or Reinforcing Masonry Walls at Interior Stairs		■	■	■	■	■	■
11		✓	✓	n/a	n/a	Bracing of Interior Partitions (Masonry and Wood)	■	■	■	■	■	■	■
12		✓	✓	n/a	n/a	Support and Detailing of Elevators		■	■	■	■	■	■
13	✓	✓	✓	n/a	n/a	Anchorage and Bracing of Emergency Lighting	■	■	■	■	■	■	■
19		✓	✓	n/a	n/a	Attachment and Bracing of Cabinets and Furnishings	■	■	■	■	■	■	■
20		✓	✓	n/a	n/a	Anchorage of Steel Stud Backup		■	■	■	■	■	■
21		✓	✓	n/a	n/a	Restraint of Hazardous Materials Containers	■	■	■	■	■	■	■
Structural													
n/a		✓	✓	All		Collector and Drag Element Improvement	□	□	□	□	⊠	□	⊠
n/a		✓	✓	Horizontal Elements	Diaphragms	Mezzanine Anchorage and Bracing		■	■	■	■	■	■
n/a		✓	✓	Horizontal Elements	Diaphragms	Strengthening at Openings	□	□	□	□		□	
n/a		✓	✓	Horizontal Elements	Diaphragms	Strengthening at Re-entrant Corners	□	□	□	□	⊠	□	⊠
n/a	✓	✓	✓	Vertical Elements	Load Path	Lateral Resisting System to Diaphragm Connection	■	■	■	■	⊠	■	⊠
n/a		✓	✓	Vertical Elements	Braced Frames	Capacity/Stiffness			□	□	⊠	□	⊠
n/a		✓	✓	Vertical Elements	Braced Frames	Continuity			□	□	⊠	□	⊠
n/a		✓	✓	Vertical Elements	Braced Frames	Connections			□	□	□	□	□
n/a		✓	✓	Vertical Elements	Moment Frames	Beam Column Capacity/Stiffness			□	□	⊠	□	⊠
n/a		✓	✓	Vertical Elements	Moment Frames	Beam Column Connection			□	□	□	□	□
n/a		✓	✓	Vertical Elements	Shear Walls	Capacity	■	□	□	□	⊠	□	⊠
n/a		✓	✓	Vertical Elements	Shear Walls	Continuity	■	□	□	□	⊠	□	⊠
n/a		✓	✓	Vertical Elements	Shear Walls	Extension of Wood Interior Walls to Roof	■	■	■				
n/a		✓	✓	Vertical Elements	Shear Walls	Lateral Stability		■	■	□	□	□	□
n/a	✓	✓	✓	Vertical Elements		Out-of-Plane Anchorage of Concrete or Masonry Wall		■	■	■	□	■	□

* Nonstructural improvements are numbered for ease of use.
Structural improvements are not numbered, but rather, organized by structural element and sub-system.

■ Work that may be included in the building rehabilitation/maintenance/repair project on the basis of a quick evaluation by a design professional.

□ Work requiring engineering design.

⊠ Work requiring detailed engineering analysis and evaluation of sequencing requirements. The "x" designates work that could redistribute loads, overstressing some elements.

Note 1: Masonry buildings with a concrete roof or floors should use the concrete building, concrete diaphragm for options.

Table C-4: Fire and Life Safety Improvements

Number*	Level of Seismicity: L	M	H	Building Structural Element	Structural Sub-System	Seismic Performance Improvement	Vertical Load Carrying Structure: Wood	Masonry[1]: Unreinforced Masonry	Masonry[1]: Reinforced Masonry	Concrete: Wood Diaphragm	Concrete: Concrete Diaphragm	Steel: Wood Diaphragm	Steel: Concrete Diaphragm
Nonstructural													
3		✔	✔	n/a	n/a	Bracing and Detailing of Sprinkler and Piping	■	■	■	■	■	■	■
4		✔	✔	n/a	n/a	Suspension and Bracing of Lights	■	■	■	■	■	■	■
5		✔	✔	n/a	n/a	Fastening and Bracing of Ceilings	■	■	■	■	■	■	■
6		✔	✔	n/a	n/a	Fastening and Bracing of Equipment (Mechanical and Electrical)	■	■	■	■	■	■	■
8	✔	✔	✔	n/a	n/a	Glazing Selection and Detailing	■	■	■	■	■	■	■
9		✔	✔	n/a	n/a	Attachment and Bracing of Large Ductwork	■	■	■	■	■	■	■
10	✔	✔	✔	n/a	n/a	Bracing or Reinforcing Masonry Walls at Interior Stairs		■	■	■	■	■	■
11		✔	✔	n/a	n/a	Bracing of Interior Partitions (Masonry and Wood)	■	■	■	■	■	■	■
12		✔	✔	n/a	n/a	Support and Detailing of Elevators		■	■	■	■	■	■
13	✔	✔	✔	n/a	n/a	Anchorage and Bracing of Emergency Lighting	■	■	■	■	■	■	■
19		✔	✔	n/a	n/a	Attachment and Bracing of Cabinets and Furnishings	■	■	■	■	■	■	■
20		✔	✔	n/a	n/a	Anchorage of Steel Stud Backup		■	■	■	■	■	■
21		✔	✔	n/a	n/a	Restraint of Hazardous Materials Containers	■	■	■	■	■	■	■
Structural													
n/a		✔	✔	All Elements		Collector and Drag Element Improvement	□	□	□	□	⊠	□	⊠
n/a		✔	✔	Horizontal Elements	Diaphragms	Mezzanine Anchorage and Bracing		■	■	■	■	■	■
n/a	✔	✔	✔	Vertical Elements	Load Path	Lateral Resisting System to Diaphragm Connection	■	■	■	■	⊠	■	⊠
n/a		✔	✔	Vertical Elements	Braced Frames	Capacity/Stiffness			□	□	⊠	□	⊠
n/a		✔	✔	Vertical Elements	Braced Frames	Continuity			□	□	⊠	□	⊠
n/a		✔	✔	Vertical Elements	Braced Frames	Connections			□	□	□	□	□
n/a		✔	✔	Vertical Elements	Moment Frames	Beam Column Capacity/Stiffness			□	□	⊠	□	⊠
n/a		✔	✔	Vertical Elements	Moment Frames	Beam Column Connection			□	□	□	□	□
n/a		✔	✔	Vertical Elements	Shear Walls	Capacity	■	□	□	□	⊠	□	⊠
n/a		✔	✔	Vertical Elements	Shear Walls	Continuity	■	□	□	□	⊠	□	⊠
n/a		✔	✔	Vertical Elements	Shear Walls	Extension of Wood Interior Walls to Roof	■	■	■				
n/a		✔	✔	Vertical Elements	Shear Walls	Lateral Stability		■	■	□	□	□	□
n/a	✔	✔	✔	Vertical Elements		Out-of-Plane Anchorage of Concrete or Masonry Wall		■	■	■	□	■	□

* Nonstructural improvements are numbered for ease of use.
Structural improvements are not numbered, but rather, organized by structural element and sub-system.

■ Work that may be included in the building rehabilitation/maintenance/repair project on the basis of a quick evaluation by a design professional.

□ Work requiring engineering design.

⊠ Work requiring detailed engineering analysis and evaluation of sequencing requirements. The "x" designates work that could redistribute loads, overstressing some elements.

Note 1: Masonry buildings with a concrete roof or floors should use the concrete building, concrete diaphragm for options.

Table C-5: New Technology Accomodation

Number*	Level of Seismicity			Building Structural Element	Structural Sub-System	Seismic Performance Improvement	Vertical Load Carrying Structure						
							Wood	Masonry¹		Concrete		Steel	
	L	M	H					Unreinforced Masonry	Reinforced Masonry	Wood Diaphragm	Concrete Diaphragm	Wood Diaphragm	Concrete Diaphragm
Nonstructural													
3		✓	✓	n/a	n/a	Bracing and Detailing of Sprinkler and Piping	■	■	■	■	■	■	■
4		✓	✓	n/a	n/a	Suspension and Bracing of Lights	■	■	■	■	■	■	■
5		✓	✓	n/a	n/a	Fastening and Bracing of Ceilings	■	■	■	■	■	■	■
6		✓	✓	n/a	n/a	Fastening and Bracing of Equipment (Mechanical and Electrical)	■	■	■	■	■	■	■
8	✓	✓	✓	n/a	n/a	Glazing Selection and Detailing	■	■	■	■	■	■	■
9		✓	✓	n/a	n/a	Attachment and Bracing of Large Ductwork	■	■	■	■	■	■	■
10	✓	✓	✓	n/a	n/a	Bracing or Reinforcing Masonry Walls at Interior Stairs		■	■	■	■	■	■
11		✓	✓	n/a	n/a	Bracing of Interior Partitions (Masonry and Wood)	■	■	■	■	■	■	■
12		✓	✓	n/a	n/a	Support and Detailing of Elevators		■	■	■	■	■	■
13	✓	✓	✓	n/a	n/a	Anchorage and Bracing of Emergency Lighting	■	■	■	■	■	■	■
19		✓	✓	n/a	n/a	Attachment and Bracing of Cabinets and Furnishings	■	■	■	■	■	■	■
20		✓	✓	n/a	n/a	Anchorage of Steel Stud Backup		■	■	■	■	■	■
21		✓	✓	n/a	n/a	Restraint of Hazardous Materials Containers	■	■	■	■	■	■	■
22		✓	✓	n/a	n/a	Underfloor Bracing of Computer Access Floor	■	■	■	■	■	■	■
Structural													
n/a		✓	✓	All		Collector and Drag Element Improvement	□	□	□	□	⊠	□	⊠
n/a		✓	✓	Foundation		Anchor Bolts	■						
n/a		✓	✓	Foundation		Cripple Stud Bracing	■						
n/a		✓	✓	Foundation		New Foundations	■						
n/a		✓	✓	Horizontal Elements	Diaphragms	Mezzanine Anchorage and Bracing		■	■	■	■	■	■
n/a		✓	✓	Horizontal Elements	Diaphragms	Strengthening at Openings	□	□	□	□		□	
n/a		✓	✓	Horizontal Elements	Diaphragms	Strengthening at Re-entrant Corners	□	□	□	□	⊠	□	⊠
n/a	✓	✓	✓	Vertical Elements	Load Path	Lateral Resisting System to Diaphragm Connection	■	■	■	■	⊠	■	⊠
n/a		✓	✓	Vertical Elements	Braced Frames	Capacity/Stiffness			□	□	⊠	□	⊠
n/a		✓	✓	Vertical Elements	Braced Frames	Continuity			□	□	⊠	□	⊠
n/a		✓	✓	Vertical Elements	Braced Frames	Connections			□	□	□	□	□
n/a		✓	✓	Vertical Elements	Moment Frames	Beam Column Capacity/Stiffness			□	□	⊠	□	⊠
n/a		✓	✓	Vertical Elements	Moment Frames	Beam Column Connection			□	□	□	□	□
n/a		✓	✓	Vertical Elements	Shear Walls	Capacity	■	□	□	□	⊠	□	⊠
n/a		✓	✓	Vertical Elements	Shear Walls	Continuity	■	□	□	□	⊠	□	⊠
n/a		✓	✓	Vertical Elements	Shear Walls	Extension of Wood Interior Walls to Roof	■	■	■				
n/a		✓	✓	Vertical Elements	Shear Walls	Lateral Stability		■	■	□	□	□	□
n/a	✓	✓	✓	Vertical Elements		Out-of-Plane Anchorage of Concrete or Masonry Wall		■	■	■	□	■	□

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■ Work that may be included in the building rehabilitation/maintenance/repair project on the basis of a quick evaluation by a design professional.

□ Work requiring engineering design.

⊠ Work requiring detailed engineering analysis and evaluation of sequencing requirements. The "x" designates work that could redistribute loads, overstressing some elements.

Note 1: Masonry buildings with a concrete roof or floors should use the concrete building, concrete diaphragm for options.

Table C-6: Tenant Alterations and Improvements

Number*	Level of Seismicity: L	M	H	Building Structural Element	Structural Sub-System	Seismic Performance Improvement	Vertical Load Carrying Structure: Wood	Masonry[1]: Unreinforced Masonry	Reinforced Masonry	Concrete: Wood Diaphragm	Concrete Diaphragm	Steel: Wood Diaphragm	Concrete Diaphragm
Nonstructural													
3		✓	✓	n/a	n/a	Bracing and Detailing of Sprinkler and Piping	■	■	■	■	■	■	■
4		✓	✓	n/a	n/a	Suspension and Bracing of Lights	■	■	■	■	■	■	■
5		✓	✓	n/a	n/a	Fastening and Bracing of Ceilings	■	■	■	■	■	■	■
6		✓	✓	n/a	n/a	Fastening and Bracing of Equipment (Mechanical and Electrical)	■	■	■	■	■	■	■
8	✓	✓	✓	n/a	n/a	Glazing Selection and Detailing	■	■	■	■	■	■	■
9		✓	✓	n/a	n/a	Attachment and Bracing of Large Ductwork	■	■	■	■	■	■	■
10	✓	✓	✓	n/a	n/a	Bracing or Reinforcing Masonry Walls at Interior Stairs		■	■	■	■	■	■
11		✓	✓	n/a	n/a	Bracing of Interior Partitions (Masonry and Wood)	■	■	■	■	■	■	■
12		✓	✓	n/a	n/a	Support and Detailing of Elevators		■	■	■	■	■	■
13	✓	✓	✓	n/a	n/a	Anchorage and Bracing of Emergency Lighting	■	■	■	■	■	■	■
19		✓	✓	n/a	n/a	Attachment and Bracing of Cabinets and Furnishings	■	■	■	■	■	■	■
20		✓	✓	n/a	n/a	Anchorage of Steel Stud Backup		■	■	■	■	■	■
21		✓	✓	n/a	n/a	Restraint of Hazardous Materials Containers	■	■	■	■	■	■	■
22		✓	✓	n/a	n/a	Underfloor Bracing of Computer Access Floor	■	■	■	■	■	■	■
Structural													
n/a		✓	✓	All		Collector and Drag Element Improvement	□	□	□	□	⊠	□	⊠
n/a		✓	✓	Horizontal Elements	Diaphragms	Mezzanine Anchorage and Bracing		■	■	■	■	■	■
n/a		✓	✓	Horizontal Elements	Diaphragms	Strengthening at Openings	□	□	□	□		□	
n/a		✓	✓	Horizontal Elements	Diaphragms	Strengthening at Re-entrant Corners	□	□	□	□	⊠	□	⊠
n/a	✓	✓	✓	Vertical Elements	Load Path	Lateral Resisting System to Diaphragm Connection	■	■	■	■	⊠	■	⊠
n/a		✓	✓	Vertical Elements	Braced Frames	Capacity/Stiffness			□	□	⊠	□	⊠
n/a		✓	✓	Vertical Elements	Braced Frames	Continuity			□	□	⊠	□	⊠
n/a		✓	✓	Vertical Elements	Braced Frames	Connections			□	□	□	□	□
n/a		✓	✓	Vertical Elements	Moment Frames	Beam Column Capacity/Stiffness			□	□	⊠	□	⊠
n/a		✓	✓	Vertical Elements	Moment Frames	Beam Column Connection			□	□	□	□	□
n/a		✓	✓	Vertical Elements	Shear Walls	Capacity	■	□	□	□	⊠	□	⊠
n/a		✓	✓	Vertical Elements	Shear Walls	Continuity	■	□	□	□	⊠	□	⊠
n/a		✓	✓	Vertical Elements	Shear Walls	Extension of Wood Interior Walls to Roof	■	■	■				
n/a		✓	✓	Vertical Elements	Shear Walls	Lateral Stability		■	■	□	□	□	□
n/a	✓	✓	✓	Vertical Elements		Out-of-Plane Anchorage of Concrete or Masonry Wall		■	■	■	□	■	□

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Structural improvements are not numbered, but rather, organized by structural element and sub-system.

■ Work that may be included in the building rehabilitation/maintenance/repair project on the basis of a quick evaluation by a design professional.

□ Work requiring engineering design.

⊠ Work requiring detailed engineering analysis and evaluation of sequencing requirements. The "x" designates work that could redistribute loads, overstressing some elements.

Note 1: Masonry buildings with a concrete roof or floors should use the concrete building, concrete diaphragm for options.

Table C-7: Underfloor and Basement Work

Number*	Level of Seismicity: L	M	H	Building Structural Element	Structural Sub-System	Seismic Performance Improvement	Vertical Load Carrying Structure: Wood	Masonry: Unreinforced Masonry	Masonry: Reinforced Masonry	Concrete: Wood Diaphragm	Concrete: Concrete Diaphragm	Steel: Wood Diaphragm	Steel: Concrete Diaphragm
Nonstructural													
6		✓	✓	n/a	n/a	Fastening and Bracing of Equipment (Mechanical and Electrical)	■	■	■	■	■	■	■
16		✓	✓	n/a	n/a	Shut-Off Valves	■	■	■	■	■	■	■
21		✓	✓	n/a	n/a	Restraint of Hazardous Materials Containers	■	■	■	■	■	■	■
Structural													
n/a		✓	✓	All Elements		Collector and Drag Element Improvement	□	□	□	□	☒	□	☒
n/a		✓	✓	Foundation		Anchor Bolts	■						
n/a		✓	✓	Foundation		Anchorage	■	□	□	□	□	□	□
n/a		✓	✓	Foundation		Cripple Stud Bracing	■						
n/a		✓	✓	Foundation		New Foundations	■	□	□	□	□	□	□
n/a		✓	✓	Foundation		Pile Cap Lateral Load		■	■	□	□	□	□
n/a		✓	✓	Foundation		Uplift	■	■	■	□	□	□	□
n/a	✓	✓	✓	Vertical Elements	Load Path	Lateral Resisting System to Diaphragm Connection	■	■	■	■	☒	■	☒
n/a		✓	✓	Vertical Elements	Braced Frames	Connections						□	□
n/a		✓	✓	Vertical Elements	Moment Frames	Beam Column Connection						□	□
n/a		✓	✓	Vertical Elements	Shear Walls	Capacity	■	□	□	□	☒	□	☒
n/a		✓	✓	Vertical Elements	Shear Walls	Continuity	■	□	□	□	☒	□	☒
n/a	✓	✓	✓	Vertical Elements		Out-of-Plane Anchorage of Concrete or Masonry Wall		■	■	■	□	■	□

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Structural improvements are not numbered, but rather, organized by structural element and sub-system.

■ Work that may be included in the building rehabilitation/maintenance/repair project on the basis of a quick evaluation by a design professional.

□ Work requiring engineering design.

☒ Work requiring detailed engineering analysis and evaluation of sequencing requirements. The "x" designates work that could redistribute loads, overstressing some elements.

Note 1: Masonry buildings with a concrete roof or floors should use the concrete building, concrete diaphragm for options.

MULTIFAMILY APARTMENT BUILDINGS

Table C-1: Roofing Maintenance & Repair / Re-roofing

Number*	Level of Seismicity L	M	H	Building Structural Element	Structural Sub-System	Seismic Performance Improvement	Vertical Load Carrying Structure: Wood	Masonry[1]: *Unreinforced Masonry*	Masonry[1]: *Reinforced Masonry*	Concrete: *Wood Diaphragm*	Concrete: *Concrete Diaphragm*	Steel: *Wood Diaphragm*	Steel: *Concrete Diaphragm*
						NONSTRUCTURAL							
1	X	X	X	n/a	n/a	Anchorage of Canopies at Exits	**n**	**n**	**n**	**n**	**n**	**n**	**n**
2		X	X	n/a	n/a	Anchorage and Detailing of Rooftop Equipment	**n**	**n**	**n**	**n**	**n**	**n**	**n**
5	X	X	X	n/a	n/a	Bracing of Parapets, Gables, Ornamentation & Appendages	**n**	**n**	**n**	**n**	**n**	**n**	**n**
8		X	X	n/a	n/a	Attachment and Bracing of Large Ductwork	**n**	**n**	**n**	**n**	**n**	**n**	**n**
18		X	X	n/a	n/a	Bracing or Removal of Chimneys	**n**	**n**	**n**	**n**	**n**	**n**	**n**
						STRUCTURAL							
n/a		X	X	All Elements		Load Path and Collectors	**o**	**o**	**o**	**o**	**x**	**o**	**x**
n/a		X	X	Horizontal Elements	*Diaphragms*	Attachment and Strengthening at Boundaries	**n**	**n**	**n**	**n**	**x**	**n**	**x**
n/a		X	X	Horizontal Elements	*Diaphragms*	Strength/Stiffness	**n**	**n**	**n**	**n**	**x**	**n**	**x**
n/a		X	X	Horizontal Elements	*Diaphragms*	Strengthening at Openings	**o**	**o**	**o**	**o**		**o**	
n/a		X	X	Horizontal Elements	*Diaphragms*	Strengthening at Re-entrant Corners	**o**	**o**	**o**	**o**	**x**	**o**	**x**
n/a		X	X	Horizontal Elements	*Diaphragms*	Topping Slab for Precast Concrete		**o**	**o**		**x**		**x**
n/a	X	X	X	Vertical Elements	*Load Path*	Lateral Resisting System to Diaphragm Connection	**n**	**n**	**n**	**n**	**x**	**n**	**x**
n/a	X	X	X	Vertical Elements		Out of Plane Anchorage of Concrete or Masonry Wall		**n**	**n**	**n**	**o**	**n**	**o**

* Non-structural improvements are numbered for ease of use

Structural improvements are not numbered, but, rather, organized by structural element and subsystem.

n Work that may be included in the building rehabilitation/maintenance/repair project on the basis of a quick evaluation by a design professional

o Work requiring engineering design

x Work requiring detailed engineering analysis and evaluation of sequencing requirements; the 'x' designates work that could redistribute loads, overstressing some elements

Note 1 - Masonry buildings with a concrete roof should use the concrete building, concrete diaphragm for options.

Table C-2: Exterior Wall and Window Maintenance / Façade Modernization

Number*	Level of Seismicity L	M	H	Building Structural Element	Structural Sub-System	Seismic Performance Improvement	Wood	Masonry[1] Unreinforced Masonry	Masonry[1] Reinforced Masonry	Concrete Wood Diaphragm	Concrete Concrete Diaphragm	Steel Wood Diaphragm	Steel Concrete Diaphragm
						NONSTRUCTURAL							
1	X	X	X	n/a	n/a	Anchorage of Canopies at Exits	n	n	n	n	n	n	n
7	X	X	X	n/a	n/a	Bracing of Parapets, Gables, Ornamentation, and Appendages	n	n	n	n	n	n	n
8	X	X	X	n/a	n/a	Glazing Selection and Detailing	n	n	n	n	n	n	n
14	X	X	X	n/a	n/a	Cladding Anchorage		o	o	o	o	o	o
15		X	X	n/a	n/a	Anchorage of Masonry Veneer	n	n	n	n	n	n	n
16		X	X	n/a	n/a	Shut-off Valves	n	n	n	n	n	n	n
17		X	X	n/a	n/a	Anchorage of Exterior Wythe in Cavity Walls		n	n	n	n	n	n
20		X	X	n/a	n/a	Anchorage of Steel Stud Backup		n	n	n	n	n	n
						STRUCTURAL							
n/a		X	X	All Elements		Collector and Drag Element Improvement	o	o	o	o	x	o	x
n/a		X	X	Foundation		Anchor Bolts	n						
n/a		X	X	Foundation		Cripple Stud Bracing	n						
n/a		X	X	Horizontal Elements	*Diaphragms*	Attachment and Strengthening at Boundaries	n	n	n	n	x	n	x
n/a	X	X	X	Vertical Elements	*Load Path*	Lateral Resisting system to Diaphragm Connection	n	n	n	n	x	n	x
n/a		X	X	Vertical Elements	*Braced Frames*	Capacity/Stiffness	o	o	o	o	x	o	x
n/a		X	X	Vertical Elements	*Braced Frames*	Continuity	o	o	o	o	x	o	x
n/a		X	X	Vertical Elements	*Braced Frames*	Connections	o	o	o	o	o	o	o
n/a		X	X	Vertical Elements	*Moment Frames*	Beam Column Capacity/Stiffness	o	o	o	o	x	o	x
n/a		X	X	Vertical Elements	*Moment Frames*	Beam Column Connection	o	o	o	o	o	o	o
n/a		X	X	Vertical Elements	*Shear Walls*	Capacity	n	o	o	o	x	o	x
n/a		X	X	Vertical Elements	*Shear Walls*	Continuity	n	o	o	o	x	o	x
n/a		X	X	Vertical Elements	*Shear Walls*	Lateral Stability		n	n	o	o	o	o
n/a	X	X	X	Vertical Elements		Out-of-Plane Anchorage of Concrete or Masonry Wall		n	n	n	o	n	o

(Vertical Load Carrying Structure: Wood, Masonry[1], Concrete, Steel)

* Nonstructural improvements are numbered for ease of use

Structural improvements are not numbered, but, rather, organized by structural element and subsystem.

n Work that may be included in the building rehabilitation/maintenance/repair project on the basis of a quick evaluation by a design professional

o Work requiring engineering design

x Work requiring detailed engineering analysis and evaluation of sequencing requirements; the 'x' designates work that could redistribute loads, overstressing some elements

Note 1 - Masonry buildings with a concrete roof or floors should use the concrete building, concrete diaphragm for options.

Table C-3: Pubic Area Modernization

Number*	Level of Seismicity L	M	H	Building Structural Element	Structural Sub-System	Seismic Performance Improvement	Vertical Load Carrying Structure: Wood	Masonry[1]: *Unreinforced Masonry*	Masonry[1]: *Reinforced Masonry*	Concrete: *Wood Diaphragm*	Concrete: *Concrete Diaphragm*	Steel: *Wood Diaphragm*	Steel: *Concrete Diaphragm*
						NONSTRUCTURAL							
3		X	X	n/a	n/a	Bracing and Detailing of Sprinkler and Piping	n	n	n	n	n	n	n
4		X	X	n/a	n/a	Fastening and Bracing of Equipment - Mechanical and Electrical	n	n	n	n	n	n	n
6		X	X	n/a	n/a	Suspension and Bracing of Lights	n	n	n	n	n	n	n
7		X	X	n/a	n/a	Fastening and Bracing of Ceilings	n	n	n	n	n	n	n
8		X	X	n/a	n/a	Attachment and Bracing of Large Ductwork	n	n	n	n	n	n	n
9	X	X	X	n/a	n/a	Anchorage and Bracing of Emergency Lighting	n	n	n	n	n	n	n
11	X	X	X	n/a	n/a	Bracing or Reinforcing Masonry Walls at Interior Stairs		n	n	n	n	n	n
12		X	X	n/a	n/a	Bracing of Interior Partitions-Masonry & Wood	n	n	n	n	n	n	n
13		X	X	n/a	n/a	Support and Detailing of Elevators		n	n	n	n	n	n
16	X	X	X	n/a	n/a	Glazing Selection and Detailing	n	n	n	n	n	n	n
19		X	X	n/a	n/a	Anchorage of Steel Stud Backup		n	n	n	n	n	n
20		X	X	n/a	n/a	Restraint of Hazardous Materials Containers	n	n	n	n	n	n	n
21		X	X	n/a	n/a	Attachment and Bracing of Cabinets and Furnishings	n	n	n	n	n	n	n
						STRUCTURAL							
n/a		X	X	All Elements		Collector and Drag Element Improvement	o	o	o	o	x	o	x
n/a		X	X	Horizontal Elements	*Diaphragms*	Mezzanine Anchorage and Bracing		n	n	n	n	n	n
n/a		X	X	Horizontal Elements	*Diaphragms*	Strengthening at Openings	o	o	o	o		o	
n/a		X	X	Horizontal Elements	*Diaphragms*	Strengthening at Re-entrant Corners	o	o	o	o	x	o	x
n/a	X	X	X	Vertical Elements	*Load Path*	Lateral Resisting System to Diaphragm Connection	n	n	n	n	x	n	x
n/a		X	X	Vertical Elements	*Braced Frames*	Capacity/Stiffness				o	x	o	x
n/a		X	X	Vertical Elements	*Braced Frames*	Continuity				o	x	o	x
n/a		X	X	Vertical Elements	*Braced Frames*	Connections				o	o	o	o
n/a		X	X	Vertical Elements	*Moment Frames*	Beam Column Capacity/Stiffness				o	x	o	x
n/a		X	X	Vertical Elements	*Moment Frames*	Beam Column Connection				o	o	o	o
n/a		X	X	Vertical Elements	*Shear Walls*	Capacity	n	o	o	o	x	o	x
n/a		X	X	Vertical Elements	*Shear Walls*	Continuity	n	o	o	o	x	o	x
n/a		X	X	Vertical Elements	*Shear Walls*	Extension of Wood Interior Walls to Roof	n	n	n				
n/a		X	X	Vertical Elements	*Shear Walls*	Lateral Stability		n	n	o	o	o	o
n/a	X	X	X	Vertical Elements		Out of Plane Anchorage of Concrete or Masonry Wall		n	n	n	o	n	o

* Non-structural improvements are numbered for ease of use

Structural improvements are not numbered, but, rather, organized by structural element and subsystem.

- **n** Work that may be included in the building rehabilitation/maintenance/repair project on the basis of a quick evaluation by a design professional
- **o** Work requiring engineering design
- **x** Work requiring detailed engineering analysis and evaluation of sequencing requirements; the 'x' designates work that could redistribute loads, overstressing some elements

Note 1 - Masonry buildings with a concrete roof should use the concrete building, concrete diaphragm for options.

Table C-4: Kitchen and Bathroom Modernization

Number*	Level of Seismicity L	M	H	Building Structural Element	Structural Sub-System	Seismic Performance Improvement	Vertical Load Carrying Structure: Wood	Masonry[1]: *Unreinforced Masonry*	Masonry[1]: *Reinforced Masonry*	Concrete: *Wood Diaphragm*	Concrete: *Concrete Diaphragm*	Steel: *Wood Diaphragm*	Steel: *Concrete Diaphragm*
						NONSTRUCTURAL							
3		X	X	n/a	n/a	Bracing and Detailing of Sprinkler and Piping	n	n	n	n	n	n	n
4		X	X	n/a	n/a	Fastening and Bracing of Equipment - Mechanical and Electrical	n	n	n	n	n	n	n
7		X	X	n/a	n/a	Fastening and Bracing of Ceilings	n	n	n	n	n	n	n
12		X	X	n/a	n/a	Bracing of Interior Partitions-Masonry & Wood	n	n	n	n	n	n	n
						STRUCTURAL							
n/a		X	X	All Elements		Collector and Drag Element Improvement	o	o	o	o	x	o	x
n/a		X	X	Horizontal Elements	*Diaphragms*	Mezzanine Anchorage and Bracing		n	n	n	n	n	n
n/a		X	X	Horizontal Elements	*Diaphragms*	Strengthening at Re-entrant Corners	o	o	o	o	x	o	x
n/a	X	X	X	Vertical Elements	*Load Path*	Lateral Resisting System to Diaphragm Connection	n	n	n	n	x	n	x
n/a		X	X	Vertical Elements	*Braced Frames*	Capacity/Stiffness				o	x	o	x
n/a		X	X	Vertical Elements	*Braced Frames*	Continuity				o	x	o	x
n/a		X	X	Vertical Elements	*Braced Frames*	Connections				o	o	o	o
n/a		X	X	Vertical Elements	*Moment Frames*	Beam Column Capacity/Stiffness				o	x	o	x
n/a		X	X	Vertical Elements	*Moment Frames*	Beam Column Connection				o	o	o	o
n/a		X	X	Vertical Elements	*Shear Walls*	Capacity	n	o	o	o	x	o	x
n/a		X	X	Vertical Elements	*Shear Walls*	Continuity	n	o	o	o	x	o	x
n/a		X	X	Vertical Elements	*Shear Walls*	Extension of Wood Interior Walls to Roof	n	n	n				
n/a		X	X	Vertical Elements	*Shear Walls*	Lateral Stability		n	n	o	o	o	o
n/a	X	X	X	Vertical Elements		Out of Plane Anchorage of Concrete or Masonry Wall		n	n	n	o	n	o

* Non-structural improvements are numbered for ease of use

Structural improvements are not numbered, but, rather, organized by structural element and subsystem.

n Work that may be included in the building rehabilitation/maintenance/repair project on the basis of a quick evaluation by a design professional

o Work requiring engineering design

x Work requiring detailed engineering analysis and evaluation of sequencing requirements; the 'x' designates work that could redistribute loads, overstressing some elements

Note 1 - Masonry buildings with a concrete roof should use the concrete building, concrete diaphragm for options.

Table C-5: Fire and Life Safety Improvements

							Vertical Load Carrying Structure						
	Level of Seismicity						Wood	Masonry[1]		Concrete		Steel	
Number*	L	M	H	Building Structural Element	Structural Sub-System	Seismic Performance Improvement		*Unreinforced Masonry*	*Reinforced Masonry*	*Wood Diaphragm*	*Concrete Diaphragm*	*Wood Diaphragm*	*Concrete Diaphragm*
						NONSTRUCTURAL							
3		X	X	n/a	n/a	Bracing and Detailing of Sprinkler and Piping	n	n	n	n	n	n	n
4		X	X	n/a	n/a	Fastening and Bracing of Equipment - Mechanical and Electrical	n	n	n	n	n	n	n
6		X	X	n/a	n/a	Suspension and Bracing of Lights	n	n	n	n	n	n	n
7		X	X	n/a	n/a	Fastening and Bracing of Ceilings	n	n	n	n	n	n	n
8		X	X	n/a	n/a	Attachment and Bracing of Large Ductwork	n	n	n	n	n	n	n
9	X	X	X	n/a	n/a	Anchorage and Bracing of Emergency Lighting	n	n	n	n	n	n	n
11	X	X	X	n/a	n/a	Bracing or Reinforcing Masonry Walls at Interior Stairs		n	n	n	n	n	n
12		X	X	n/a	n/a	Bracing of Interior Partitions-Masonry & Wood	n	n	n	n	n	n	n
13		X	X	n/a	n/a	Support and Detailing of Elevators		n	n	n	n	n	n
16	X	X	X	n/a	n/a	Glazing Selection and Detailing	n	n	n	n	n	n	n
19		X	X	n/a	n/a	Anchorage of Steel Stud Backup		n	n	n	n	n	n
20		X	X	n/a	n/a	Restraint of Hazardous Materials Containers	n	n	n	n	n	n	n
21		X	X	n/a	n/a	Attachment and Bracing of Cabinets and Furnishings	n	n	n	n	n	n	n
						STRUCTURAL							
n/a		X	X	All Elements		Collector and Drag Element Improvement	o	o	o	o	x	o	x
n/a		X	X	Horizontal Elements	*Diaphragms*	Mezzanine Anchorage and Bracing		n	n	n	n	n	n
n/a	X	X	X	Vertical Elements	*Load Path*	Lateral Resisting System to Diaphragm Connection	n	n	n	n	x	n	x
n/a		X	X	Vertical Elements	*Braced Frames*	Capacity/Stiffness				o	x	o	x
n/a		X	X	Vertical Elements	*Braced Frames*	Continuity				o	x	o	x
n/a		X	X	Vertical Elements	*Braced Frames*	Connections				o	o	o	o
n/a		X	X	Vertical Elements	*Moment Frames*	Beam Column Capacity/Stiffness				o	x	o	x
n/a		X	X	Vertical Elements	*Moment Frames*	Beam Column Connection				o	o	o	o
n/a		X	X	Vertical Elements	*Shear Walls*	Capacity	n	o	o	o	x	o	x
n/a		X	X	Vertical Elements	*Shear Walls*	Continuity	n	o	o	o	x	o	x
n/a		X	X	Vertical Elements	*Shear Walls*	Extension of Wood Interior Walls to Roof	n	n	n				
n/a		X	X	Vertical Elements	*Shear Walls*	Lateral Stability		n	n	o	o	o	o
n/a	X	X	X	Vertical Elements		Out of Plane Anchorage of Concrete or Masonry Wall		n	n	n	o	n	o

* Non-structural improvements are numbered for ease of use

Structural improvements are not numbered, but, rather, organized by structural element and subsystem.

n Work that may be included in the building rehabilitation/maintenance/repair project on the basis of a quick evaluation by a design professional

o Work requiring engineering design

x Work requiring detailed engineering analysis and evaluation of sequencing requirements; the 'x' designates work that could redistribute loads, overstressing some elements

Note 1 - Masonry buildings with a concrete roof should use the concrete building, concrete diaphragm for options.

Table C-6: Underfloor and Basement Work

Number*	Level of Seismicity L	Level of Seismicity M	Level of Seismicity H	Building Structural Element	Structural Sub-System	Seismic Performance Improvement	Vertical Load Carrying Structure: Wood	Masonry[1]: *Unreinforced Masonry*	Masonry[1]: *Reinforced Masonry*	Concrete: *Wood Diaphragm*	Concrete: *Concrete Diaphragm*	Steel: *Wood Diaphragm*	Steel: *Concrete Diaphragm*
						NONSTRUCTURAL							
4		X	X	n/a	n/a	Fastening and Bracing of Equipment - Mechanical and Electrical	n	n	n	n	n	n	n
10		X	X	n/a	n/a	Shut Off Valves	n	n	n	n	n	n	n
20		X	X	n/a	n/a	Restraint of Hazardous Materials Containers	n	n	n	n	n	n	n
						STRUCTURAL							
n/a		X	X	All Elements		Collector and Drag Element Improvement	o	o	o	o	x	o	x
n/a		X	X	Foundation		Anchor Bolts	n						
n/a		X	X	Foundation		Anchorage	n	o	o	o	o	o	o
n/a		X	X	Foundation		Cripple Stud Bracing	n						
n/a		X	X	Foundation		New Foundations	n	o	o	o	o	o	o
n/a		X	X	Foundation		Pile Cap Lateral Load		n	n	o	o	o	o
n/a		X	X	Foundation		Uplift	n	n	n	o	o	o	o
n/a	X	X	X	Vertical Elements	*Load Path*	Lateral Resisting System to Diaphragm Connection	n	n	n	n	x	n	x
n/a		X	X	Vertical Elements	*Braced Frames*	Connections						o	o
n/a		X	X	Vertical Elements	*Moment Frames*	Beam Column Connection						o	o
n/a		X	X	Vertical Elements	*Shear Walls*	Capacity	n	o	o	o	x	o	x
n/a		X	X	Vertical Elements	*Shear Walls*	Continuity	n	o	o	o	x	o	x
n/a	X	X	X	Vertical Elements		Out of Plane Anchorage of Concrete or Masonry Wall		n	n	n	o	n	o

* Non-structural improvements are numbered for ease of use
Structural improvements are not numbered, but, rather, organized by structural element and subsystem.

n Work that may be included in the building rehabilitation/maintenance/repair project on the basis of a quick evaluation by a design professional

o Work requiring engineering design

x Work requiring detailed engineering analysis and evaluation of sequencing requirements;
the 'x' designates work that could redistribute loads, overstressing some elements

Note 1 - Masonry buildings with a concrete roof should use the concrete building, concrete diaphragm for options.

RETAIL BUILDINGS

APPENDIX C

FACILITY MANAGEMENT PROCESSES

SCHOOLS

The typical facility management process for existing school buildings consists of five phases of activities: Current Building Use, Planning, Maintenance & Rehabilitation Budgeting, Maintenance & Rehabilitation Funding, and Maintenance & Rehabilitation Implementation, as diagrammed in Figure 1. This process is sequential, progressing from left to right in any given building. A school district that has a large inventory of buildings is likely to have ongoing activities in all of these phases.

This process is generic and, while local variations occur, it is generally followed by school administrators, either explicitly or implicitly.

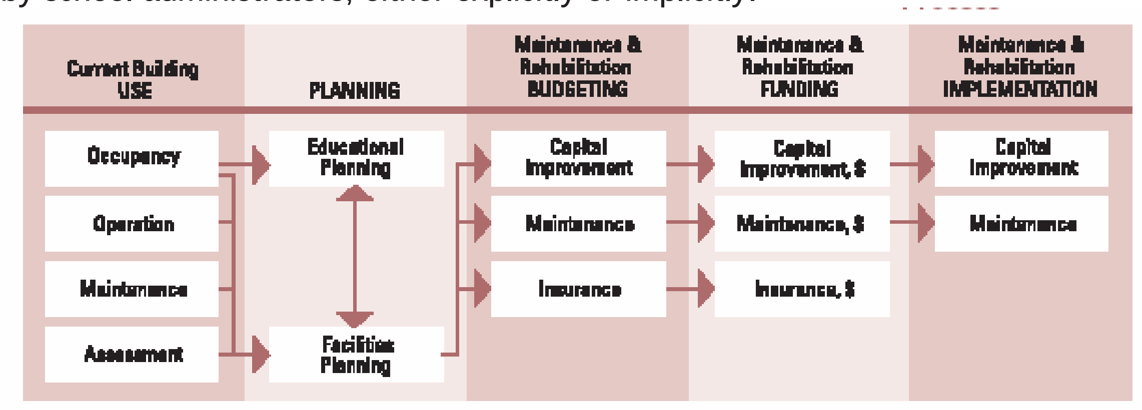

Figure 1. Typical Facility Management Process in Schools

Both internal and external factors typically influence the school facility management process in its various phases. Internal factors (represented by up arrows in Figure 2) are generated within the school district and its administration. External factors (down arrows) are imposed on school districts by outside entities.

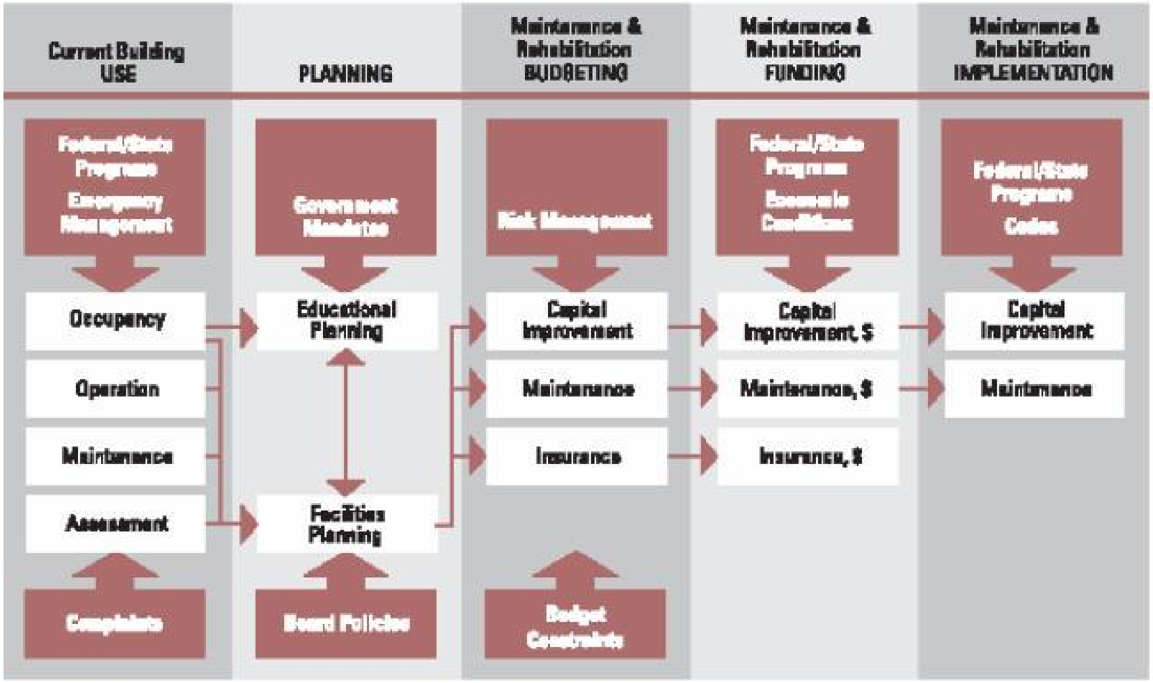

Figure 2. Management Process Influences in Schools

HOSPITALS

The typical facilities management process for existing hospital buildings consists of seven phases of activities: Acquisition, Current Building Use, Accreditation, Planning, Maintenance & Rehabilitation Budgeting, Maintenance & Rehabilitation Funding, Maintenance & Rehabilitation Implementation, as diagrammed in Figure 3. This process is sequential, progressing from left to right in any given building. A healthcare organization that has a large inventory of buildings is likely to have ongoing activities in all of these phases.

This process is generic and, while local variations may occur, it is generally followed by healthcare organizations, either explicitly or implicitly.

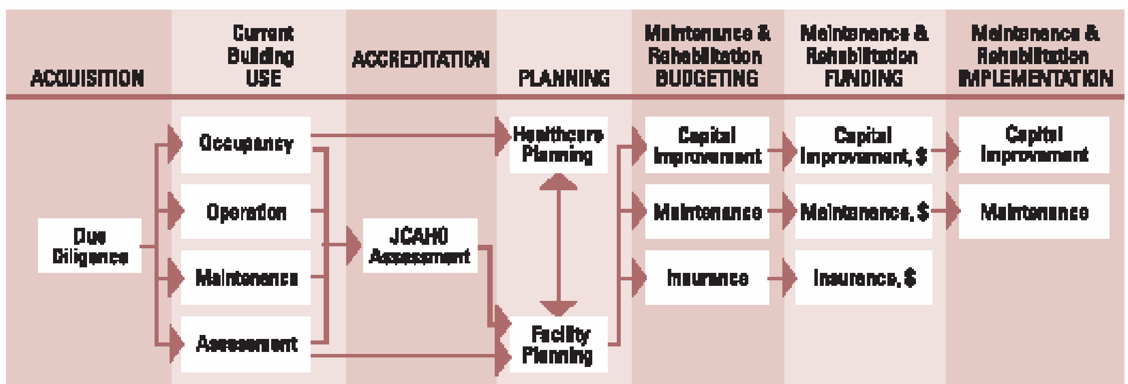

Figure 3. Typical Facility Management Process in Hospitals

Both internal and external factors typically influence the hospital facility management process in its various phases. Internal factors (represented by up arrows in Figure 4) are generated within the healthcare organization and its administration. External factors (down arrows) are imposed on healthcare organizations by outside entities.

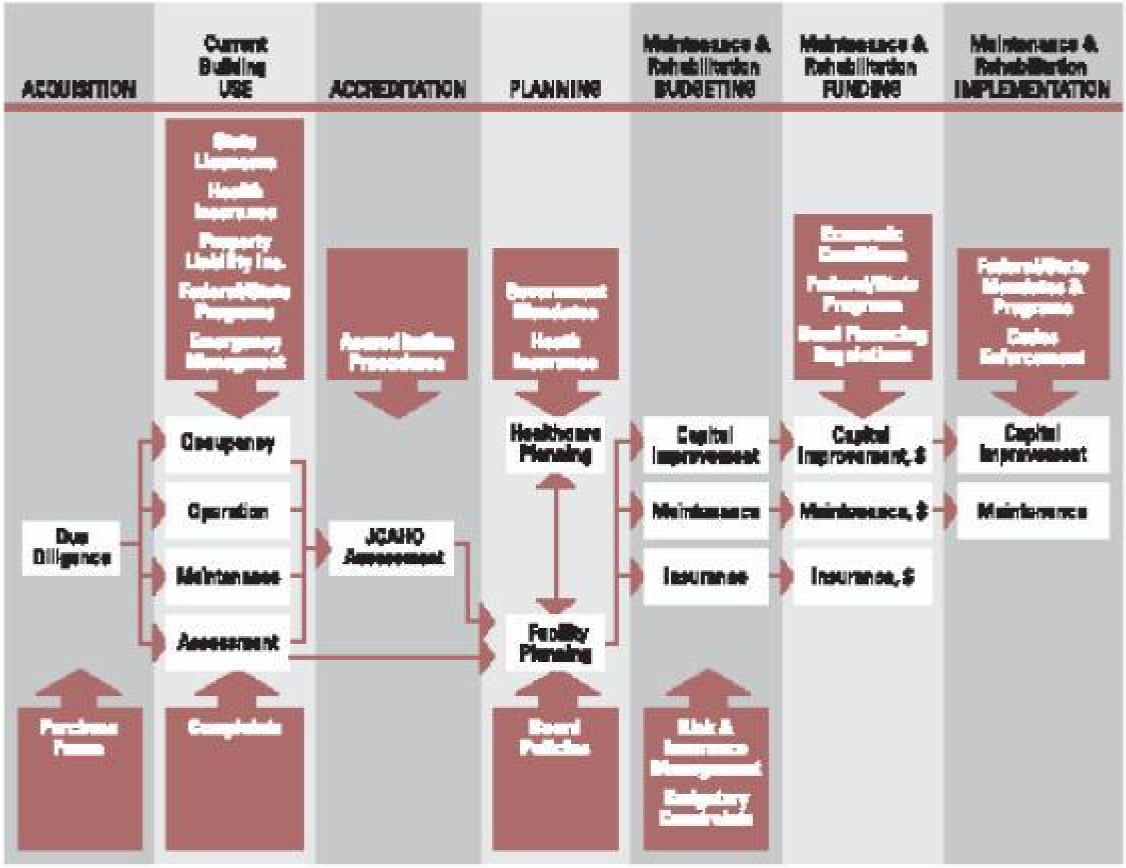

Figure 4. Management Process Influences in Hospitals

COMMERCIAL BUILDINGS

The typical facility management process for existing commercial buildings consists of seven phases of activities: Acquisition, Redevelopment, Current Building Use, Planning, Maintenance & Rehabilitation Budgeting, Maintenance & Rehabilitation Funding, and Maintenance & Rehabilitation Implementation, as diagrammed in Figure 5. This process is sequential, progressing from left to right in any given building. An owner of a large inventory of office buildings is likely to have ongoing activities in all of these phases.

This process is generic, and while variations may occur, it is generally followed by office building owners, either explicitly or implicitly.

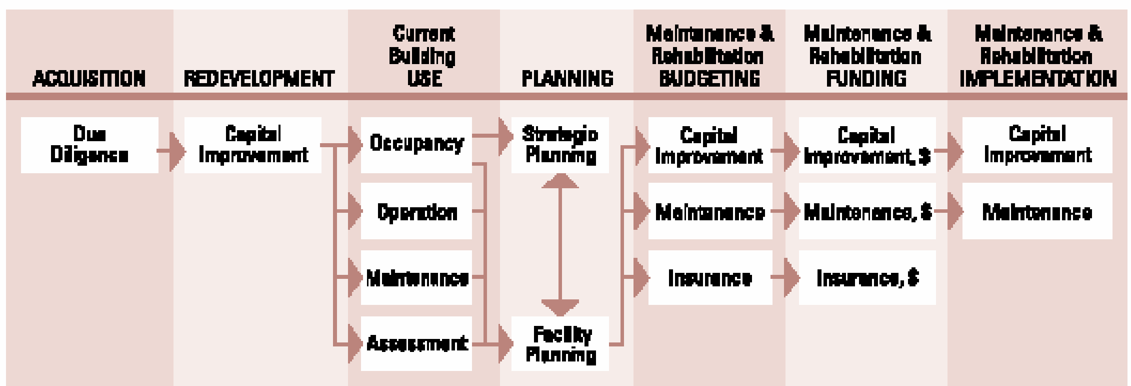

Figure 5. Typical Facility Management Process in Commercial Buildings

Both internal and external factors typically influence the office facility management process in its various phases. Internal factors (represented by up arrows in Figure 6) are generated within the owner organization. External factors (down arrows) are imposed on owners by outside entities.

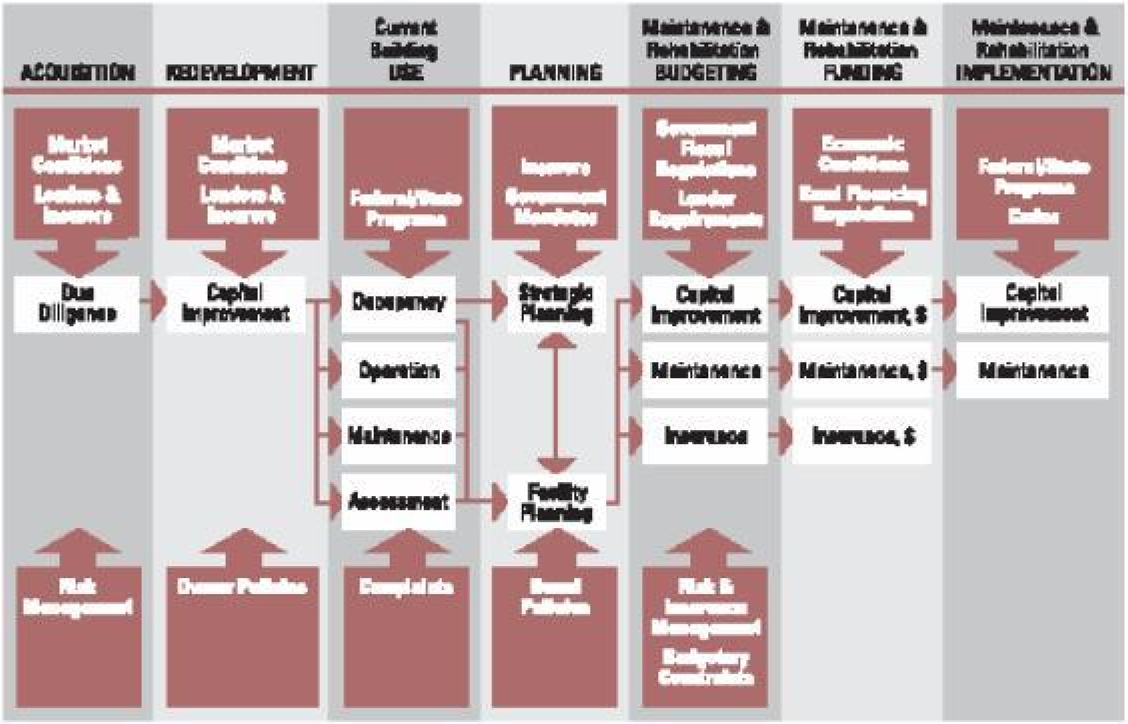

Figure 6. Management Process Influences in Commercial Buildings