

**For Multifamily Building  
Owner Senior Executives,  
Board Members, &  
Similar Policy Makers**

**Part**

# **Critical Decisions for Earthquake Safety in Multifamily Buildings**

## **Introduction**

*This manual is designed to give decision makers the framework and information for making informed decisions about investing in earthquake risk management measures. It is structured to follow the decision-making process of existing planning and management practices and will help you evaluate financial, safety, and strategic planning priorities.*

*Owners of multifamily buildings may vary greatly in size, wealth, and technical capability. Some have comprehensive long-term facility management, maintenance, and development plans. Some have none. The successful implementation of improved earthquake safety should be part of a comprehensive approach to building safety and multi-hazard mitigation.*

*Failure to address earthquake risk leaves the multifamily building owner exposed to potential losses, disruption, and liability for deaths and injuries. While purchasing insurance may protect owners from financial losses and liability, it still leaves them susceptible to disruption as well as deaths and injuries. Only building rehabilitation can reduce losses, deaths, and injuries, as well as control liability and disruption. However, single-stage seismic rehabilitation can be expensive and disruptive. Incremental seismic rehabilitation can reduce that cost and disruption.*

## **Multifamily Buildings, Risk, and Liability**

Earthquakes are low-probability, high-consequence events. Though they may occur only once in the life of a building, they can have devastating, irreversible consequences.

Moderate earthquakes occur more frequently than major earthquakes. Nonetheless, moderate earthquakes can cause serious damage to building contents and nonstructural building systems, serious injury to tenants, visitors, and staff, and disruption of building operations. Major earthquakes can cause catastrophic damage including structural collapse and massive loss of life. Those responsible for multifamily building safety must understand and manage these risks, particularly risks that threaten the lives of tenants, visitors, and staff.

Earthquake risk is the product of hazard exposure and building vulnerability, as shown in the following equation:

$$\text{RISK} = \text{HAZARD} \times \text{VULNERABILITY}$$

To manage earthquake risk in existing multifamily buildings, one must understand the earthquake hazard and reduce building vulnerability.

### **Considering Incremental Seismic Rehabilitation**

The incremental rehabilitation approach to seismic risk mitigation focuses on improvements that will decrease the vulnerability of multifamily buildings to earthquakes at the most appropriate and convenient times in the life cycle of those buildings. The approach clarifies, as specifically as possible, what is the most affordable, least disruptive, and most effective way to reduce seismic risk in your buildings.

Prior to initiating a program of incremental seismic rehabilitation, an owner must first address the following three questions:

- Are your multifamily buildings located in a seismic zone?
- Are these buildings vulnerable to earthquakes?
- What can you do to reduce earthquake risk in existing vulnerable buildings?

This manual will help you find the right answers.

## **In Brief**

- The primary parameters of seismic hazard are the likelihood of occurrence and severity of an earthquake.
- Geographic location is the most significant factor of seismic hazard.
- Soil conditions at a particular site also influence the seismic hazard.

## **A.1 Is There an Earthquake Hazard for Your Multifamily Buildings?**

*Earthquakes are one of the most serious natural hazards to which multifamily building owners may be exposed. Although owners face a variety of risks to their investment, tenant safety, and facility operations that may appear more immediate, the consequences of earthquakes can be catastrophic. Therefore, despite the rare occurrence of earthquakes, earthquake safety should be given full consideration in design and investment for risk management and safety.*

*The first step to understanding earthquake risk:*

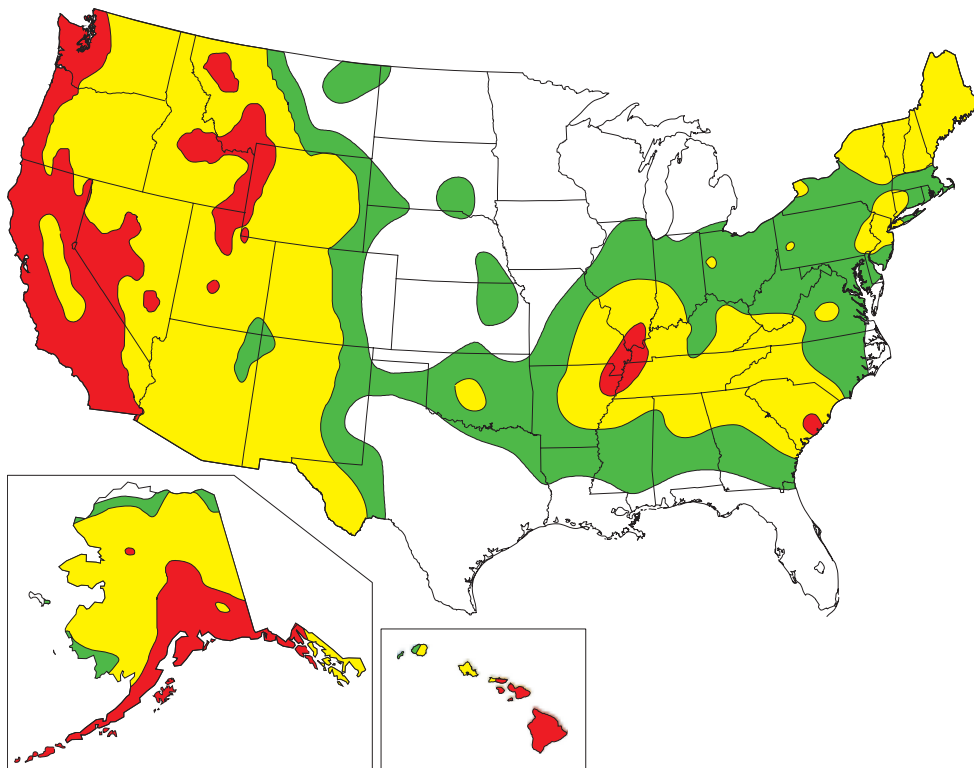
$$\text{RISK} = \text{HAZARD} \times \text{VULNERABILITY}$$

*is to learn the **likelihood and severity** of an earthquake affecting your buildings.*

### **The Earthquake Hazard: Where, When, and How Big**

The surface of the earth consists of solid masses, called tectonic plates, that float on a liquid core. The areas where separate plates meet each other are called faults. Most earthquakes result from the movement of tectonic plates, and seismic hazard is strongly correlated to known faults. A map of zones of seismic hazard for the United States, based on maps provided by the U.S. Geological Survey (USGS), shows three zones from the lowest, green, to the highest, red. The white areas have negligible seismic hazard.

The USGS earthquake hazard map is based on a complex assessment of expected seismic activity associated with recognized faults. The scientific understanding of earthquakes continues to improve and has resulted in increased estimates of seismic hazard in various parts of the country over the last decade.



**Seismic Hazard Map**

Multifamily building owners and managers responsible for the safety of tenants, visitors, and staff need to know whether to be concerned about earthquakes. Some guidelines for determining earthquake risk in your location are:

- If your multifamily building is located in a red zone on the map

Earthquakes are one of the most significant risks facing your facilities.

- Take immediate action to undertake comprehensive vulnerability assessment. Professional structural engineers should perform this assessment.
- Identify and either replace or rehabilitate vulnerable existing buildings as soon as possible.

■ If your multifamily building is located in a yellow zone

The probability of severe earthquake occurrence is sufficiently high to demand systematic investigation of your buildings.

- Assign responsibility for investigation to the risk managers and facility managers within the organization. If they are not available, seek professional engineering assistance from outside.
- Identify vulnerable buildings and schedule them for replacement, rehabilitation, or change of use.
- Also consider mitigation of nonstructural hazards, such as securing equipment and suspended lighting that could injure building occupants in an earthquake.

■ If your multifamily building is located in a green zone

- Consider low-cost mitigation strategies that protect building occupants and the owner’s investment in facilities and systems, even though the probability of an earthquake is low.

Beyond this broad seismic zone designation, expected earthquake ground motion at a particular location is further influenced by local geology and soil conditions. Geotechnical engineering studies should be done to understand fully the earthquake hazard at a particular site in red and yellow zones.

**In Brief**

- Seismic vulnerability consists of expected damages and losses.
- Seismic vulnerability depends on structural type, age, condition, contents, and use of multifamily buildings.
- Hazard exposure and building vulnerability may result in substantial death, injury, building and content damage, and serious disruption of building use and rentals.

**A.2 Are Your Multifamily Buildings Safe?**

*The second step to understanding earthquake risk:*

$$RISK = HAZARD \times VULNERABILITY$$

*is to learn the **expected damage and losses** that could result from an earthquake.*

**What Happens to Multifamily Buildings in Earthquakes**

Earthquake fault rupture causes ground motion over a wide area. This ground motion acts as a powerful force on buildings. Buildings are principally designed to resist the force of gravity, but resistance to earthquake forces requires specialized earthquake engineering. Horizontal earthquake forces cause the rapid movement of the foundation and displacement of upper levels of the structure. When inadequately designed to resist or accommodate these earthquake forces, structures fail, leading to serious structural damage and, in the worst case, total building collapse.

In addition to ground motion, buildings may suffer earthquake damage from the following effects:



Fault rupture under or near the building, often occurring in buildings located close to faults.



Earthquake-induced landslides near the building.



Reduction of the soil bearing capacity under or near the building.



Earthquake-induced waves in bodies of water near the building (tsunami on the ocean and seismic seiche<sup>1</sup> on lakes).

<sup>1</sup> A wave on the surface of a lake or landlocked bay caused by atmospheric or seismic disturbances.

### **Building Age and Earthquake Vulnerability**

The first earthquake design legislation was enacted in 1933 for schools in California (the Field Act). Since that time, awareness of earthquake risk has expanded across the country, and building codes have been improved because of research and experience. Since the early 1990s, most new multifamily buildings in the United States have been constructed in accordance with modern codes and meet societal standards for safety. However, older buildings should be reexamined in light of current knowledge. Some seismically active parts of the country (the Midwest) have only recently adopted appropriate seismic design standards, and in other parts of the country (the Northwest) estimates of seismic risk have been revised upward. The serious problem resides in existing vulnerable multifamily buildings constructed without seismic requirements or designed to obsolete standards. The building code is not retroactive; there is no automatic requirement to bring existing buildings up to current standards. Safety in existing buildings is the responsibility of the owner/operator.

### **Estimating Building Vulnerability**

Engineers have defined levels of the damage that can be expected in particular types of buildings due to varying intensities of earthquake motion. These levels of damage range from minor damage, such as cracks in walls, to total building collapse. In addition to building type, expected damage is also a function of building age and the state of maintenance. Multifamily buildings suffering from deferred maintenance will experience greater damage than well-maintained buildings will. For example, failure to maintain masonry parapets significantly increases the possibility of life-threatening failure in even a moderate earthquake.

It is possible to estimate roughly the vulnerability of an owner's portfolio of buildings and to identify problem buildings with a technique called "rapid visual screening."<sup>2</sup> Multifamily building owners can produce generalized estimates of expected damage in the initial seismic risk assessment of their buildings.

After initial rapid screening, specific seismic risk assessment for individual multifamily buildings requires detailed engineering analysis.

### **Other Earthquake Losses**

While a serious concern in its own right, building failure is the direct cause of even more important earthquake losses:

- Death and injury of tenants, visitors, and staff
- Destruction of apartment contents and building equipment
- Disruption of occupancy and rentals

The expected extent of these losses can also be estimated based on hazard and vulnerability assessments. See Section B.2.2, Elements of an Incremental Seismic Rehabilitation Program, for applicable references.

<sup>2</sup> FEMA 154, *Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook, Second Edition*.

**In Brief**

- Seismic rehabilitation of existing vulnerable multifamily buildings can reduce future earthquake damage.
- Incremental seismic rehabilitation is a strategy to reduce the cost of rehabilitation and related disruption of occupancy and rentals.

## A.3 What Can Be Done to Reduce Earthquake Risk in Existing Vulnerable Multifamily Buildings?

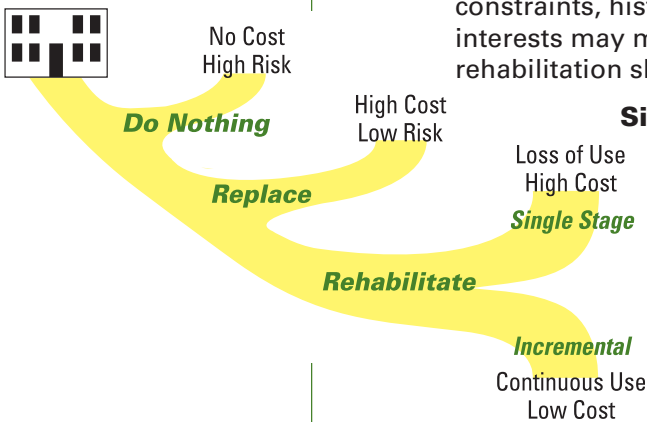
*Failure to address earthquake risk leaves the multifamily building owner exposed to potential losses, disruption, and liability for deaths and injuries. While purchasing insurance may protect owners from financial losses and liability, it still leaves them exposed to disruption as well as deaths and injuries. Only building rehabilitation can reduce losses, deaths, and injuries and control liability and disruption.*

*The implementation of seismic risk reduction through building rehabilitation will primarily involve the facility manager. However, to be effective it will require coordination among the facility managers, risk managers, and financial managers. This is further discussed in Part B (for Facility Managers, Risk Managers, and Financial Managers). In addition, it is the responsibility of the multifamily building owner’s top administrators to make sure that hazards are assessed and risk reduction measures implemented.*

### Options for Seismic Risk Reduction

The most important consideration for earthquake safety in multifamily 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. Choosing the method of protection from structural collapse in a deficient building requires two critical decisions:

**Replace or Rehabilitate:** If you decide 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<sup>3</sup> or Incremental Rehabilitation:

If the rehabilitation option is chosen, there are still issues of cost and disruption associated with the rehabilitation work. The cost of single-stage seismic rehabilitation has proved to be a serious impediment to its implementation by many multifamily building owners. Incremental seismic rehabilitation is specifically designed to address and reduce the problems of cost and disruption.

### Estimating the Costs and Benefits of Seismic Rehabilitation of Existing Multifamily Buildings

The direct and indirect costs of seismic rehabilitation of a building are:

- Engineering and design services
- Construction
- Disruption of building occupancy and rentals during construction

The benefits of seismic rehabilitation of a building are:

- Reduced risk of death and injury of tenants, visitors, and staff
- Reduced building damage

<sup>3</sup> Single-stage rehabilitation refers to completing the rehabilitation in a single continuous project.



- Reduced damage to building contents and equipment
- Reduced disruption of occupancy and rentals

Engineers have developed estimates of the reduction of earthquake damage that can be achieved with seismic rehabilitation following FEMA's current rehabilitation standards. This type of estimate, however, may significantly undervalue the benefit of seismic rehabilitation. In considering the return on seismic rehabilitation investments, it is appropriate to consider the value of damages avoided as well as the difficult-to-quantify values of deaths, injuries, and disruption of occupancy and rental functions avoided.

The primary obstacles to single-stage rehabilitation of vulnerable existing multifamily buildings are the cost of rehabilitation construction work and related disruption of apartment rentals. Incremental seismic rehabilitation offers opportunities to better manage the costs and reduce disruption of rehabilitation. The following section introduces and explains incremental seismic rehabilitation in more detail.

## **A.4 Incremental Seismic Rehabilitation of Existing Multifamily Buildings**

*Incremental rehabilitation phases seismic rehabilitation into an ordered series of discrete actions implemented over a period of several years, and whenever feasible, these actions are timed 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 costly and disruptive single-stage rehabilitation. In fact, for multifamily 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 the incremental approach can be organized so that most rehabilitation increments occur during the period of tenant turnover. 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 earthquake safety demonstrates recognition of responsibility for multifamily building safety and can provide protection from liability.*

### **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 the owner's building inventory. Facility managers can implement such an assessment using owner staff or outside engineering consultants as appropriate. The assessment should rank the building inventory in terms of seismic vulnerability and identify specific deficiencies. FEMA publishes a number of documents that can guide you through the assessment process. Portions of the assessment activities can be integrated with other ongoing facility management activities such as periodic building inspections. Facility assessments and the FEMA publications available to help you conduct them are discussed in more detail in Part B.<sup>4</sup>

<sup>4</sup> To order FEMA publications you may write to FEMA, PO Box 2012, Jessup, MD 20794-2012; or you may call 1-800-480-2520, Monday - Friday, 8:00 a.m. - 5:00 p.m., EASTERN TIME; or you may Fax your request to 301-362-5335.

## **In Brief**

- Whereas single-stage seismic rehabilitation of an existing multifamily building represents a significant cost, rehabilitation actions can be divided into increments and integrated into normal maintenance and capital improvement projects.
- The implementation of incremental seismic rehabilitation requires assessing the buildings, establishing rehabilitation priorities, and planning integration with other projects.

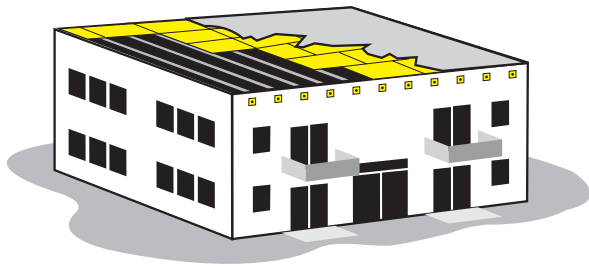
### Rehabilitation Strategy

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 three aspects to prioritizing seismic rehabilitation increments:

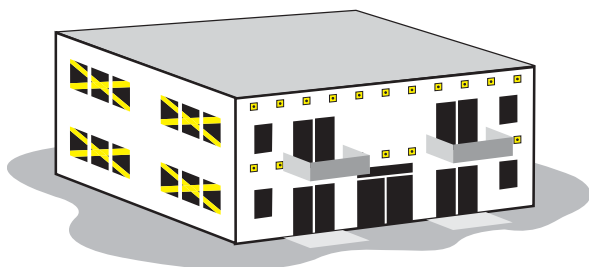
**Structural Priority:** An initial prioritization of seismic rehabilitation increments should be established primarily in terms of their respective impact on the overall earthquake resistance of the structure. Facility managers will begin with these priorities when determining the order of seismic rehabilitation increments to be undertaken. However, the final order of increments may deviate from this priority order depending on other planning parameters. Additional engineering analysis may be required for certain building types when deviating from the structural priority order. This subject is discussed in more detail in Part B, Section B.2, and Part C.

**Use Priority:** Multifamily building owners should consider planning alternative future uses of their existing buildings. Some vulnerable buildings may be scheduled for demolition or converted to other uses (for example, storage). Others may be scheduled for expansion and intensification of use. These considerations, among others, will influence the prioritization of seismic rehabilitation increments.

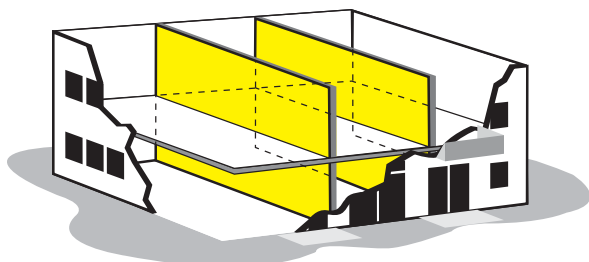
### SCHEMATIC INTEGRATION OPPORTUNITIES



Roof Work



Exterior Wall Work



Interior Work

**Integration:** A major advantage of the incremental seismic rehabilitation approach is that specific work items can be integrated with other building maintenance or capital improvement projects undertaken routinely. Such integration will reduce the cost of the seismic rehabilitation action by sharing engineering costs, design costs, and some aspects of construction costs. Integration opportunities are a key consideration in adapting the sequence of actions suggested by the foregoing discussions of rehabilitation priorities. Integration opportunities are discussed in more detail in Part C, Section C.2.

### Incremental Seismic Rehabilitation Plan

An essential feature of implementing incremental seismic rehabilitation in specific multifamily 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 multifamily building owner does not lose sight of overall rehabilitation goals during implementation of individual increments.



## **Summary of Part A**

- The primary parameters of seismic hazard are the likelihood of occurrence and severity of an earthquake.
- Geographic location is the most significant factor of seismic hazard.
- Soil conditions at a particular site also influence the seismic hazard.
- Seismic vulnerability consists of expected damages and losses.
- Seismic vulnerability depends on structural type, age, condition, contents, and use of multifamily buildings.
- Hazard exposure and building vulnerability may result in substantial death, injury, building and content damage, and serious disruption of building use and rentals.
- Seismic rehabilitation of existing vulnerable multifamily buildings can reduce future earthquake damage.
- Incremental seismic rehabilitation is a strategy to reduce the cost of rehabilitation and related disruption of occupancy and rentals.
- Whereas single-stage seismic rehabilitation of an existing multifamily building represents a significant cost, rehabilitation actions can be divided into increments and integrated into normal maintenance and capital improvement projects.
- The implementation of incremental seismic rehabilitation requires assessing the buildings, establishing rehabilitation priorities, and planning integration with other projects.

## **Recommended Actions**

1. Communicate the importance of assessing your building inventory's risks and pass this manual on to the staff members responsible for facility management, risk management, and financial planning. Specify that they develop an analysis of the current seismic risk of your buildings and a strategy for risk reduction.
2. Promptly initiate a program of earthquake risk reduction in your buildings located in an earthquake-prone zone that were not designed and constructed to meet modern building codes.
3. Consider incremental seismic rehabilitation as a cost-effective means to protect the buildings and, most importantly, the safety of tenants, visitors, and staff, because it is a technically and financially manageable strategy that minimizes disruption of multifamily building operations.

