For Superintendents, Business Managers, Board Members & Principals

Part A

Critical Decisions for Earthquake Safety in Schools

A.1 Is There an Earthquake Hazard for Your Schools?

Earthquakes are one of the most serious natural hazards to which school districts may be exposed. Although school administrators face a variety of risks to occupant safety and operations that may appear more immediate, the consequences of earthquakes can be catastrophic. Therefore, in spite of their rare occurrence, earthquake safety should be given full consideration in design and investment for risk management and safety.

The first step to understanding earthquake risk:

RISK = HAZARD x 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, which 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

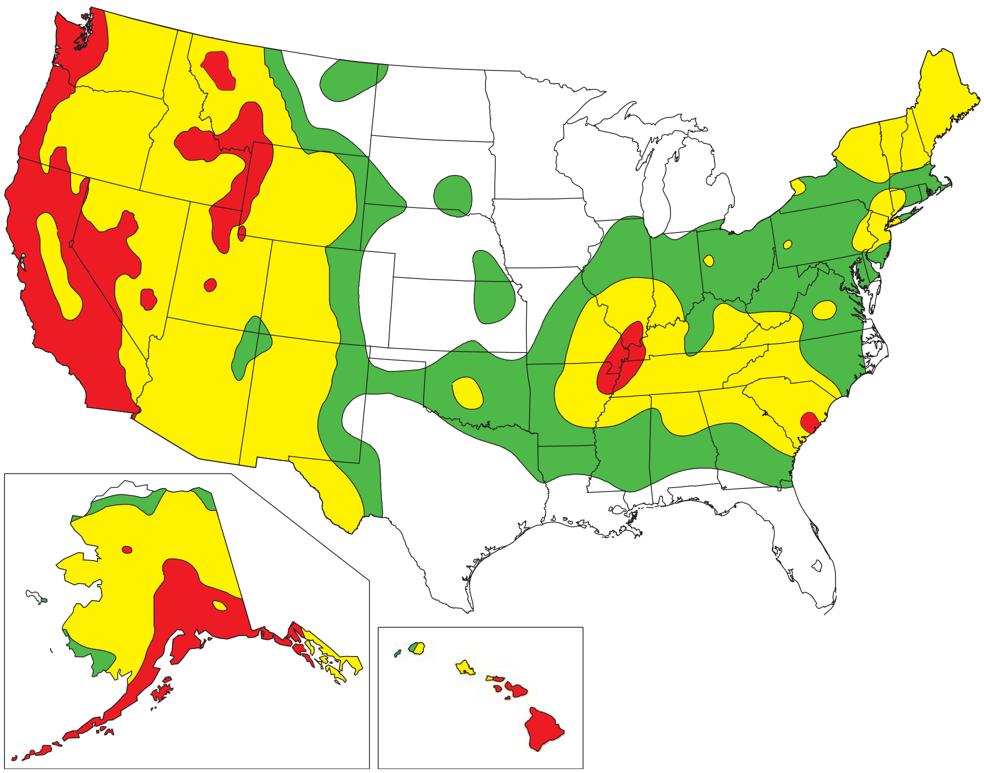
In Brief

- Geographic location is the most significant factor of seismic hazard.
- Soil conditions at a particular site also influence the seismic hazard.

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



School administrators responsible for the safety of students, teachers, and staff need to know whether to be concerned about earthquakes. Some guidelines for determining earthquake risk in your location are:

If your school district 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 school district is located in a yellow zone

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

- Assign responsibility for investigation to the risk managers and facility managers within the district. 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 non-structural hazards, such as securing bookshelves and suspended lighting that could injure building occupants in an earthquake.

If your school district is located in a green zone

While earthquake occurrence is less likely, low-cost mitigation strategies that protect building occupants and the community investment in facilities and systems should be considered.

- Pay particular attention to school buildings designated as emergency shelters.

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.

A.2 Are Your School Buildings Safe?

The second step to understanding earthquake risk:

RISK = HAZARD x VULNERABILITY

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

What Happens to School 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 not designed to adequately resist or accom-

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

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

Earthquake-induced landslides near the building.

Earthquake-induced waves in bodies of water near the building (tsunami, on the ocean and seismic seiche[1] on lakes).

[1] A wave on the surface of a lake or landlocked bay caused by atmospheric or seismic disturbances.

In Brief

- Seismic vulnerability depends on structural type, age, condition, contents, and use of school buildings.
- Hazard exposure and building vulnerability may result in substantial death, injury, building and content damage, and serious disruption of educational programs.

modate 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:

Building Age and Earthquake Vulnerability

The first earthquake design legislation for schools (the Field Act) was enacted in California in 1933. 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 schools in the United States have been constructed in accordance with modern codes and meet societal standards for safety. However, older school buildings should be reexamined in light of current knowledge. Some seismically active parts of the country have only recently adopted appropriate seismic design standards (the Midwest), and in other parts of the country, estimates of seismic risk have been revised upward (the Northwest). The serious problem resides in existing vulnerable school buildings constructed without seismic requirements or designed to obsolete standards. The building code is not retroactive so there is no automatic requirement to bring existing buildings up to current standards. Safety in existing buildings is the responsibility of the owner/operator. That means you!

Estimating Building Vulnerability

It is possible to estimate roughly the vulnerability of a school district's portfolio of buildings and to identify problem buildings with a technique called "rapid visual screening." School districts can produce generalized estimates of expected damage in the initial seismic risk assessment of its buildings.

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. Schools suffering from deferred maintenance will experience greater damage than well-maintained schools. For example, failure to maintain masonry parapets significantly increases the possibility of life threatening failure in even a moderate earthquake.

After initial rapid screening, specific seismic risk assessment for individual school 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 students, teachers, and staff
- Destruction of school contents and equipment
- Disruption of the delivery of all school services, including the capability to provide shelter, which is frequently assigned to schools in a disaster

The expected extent of these losses can also be estimated based on hazard and vulnerability assessments.

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

Failure to address earthquake risk leaves the school district exposed to potential losses, disruption, and liability for deaths and injuries.

While purchasing insurance may protect the school district from financial losses and liability, it still leaves the district exposed to disruption as well as deaths and injuries. Only building rehabilitation can reduce losses, deaths, and injuries and control liability and disruption.

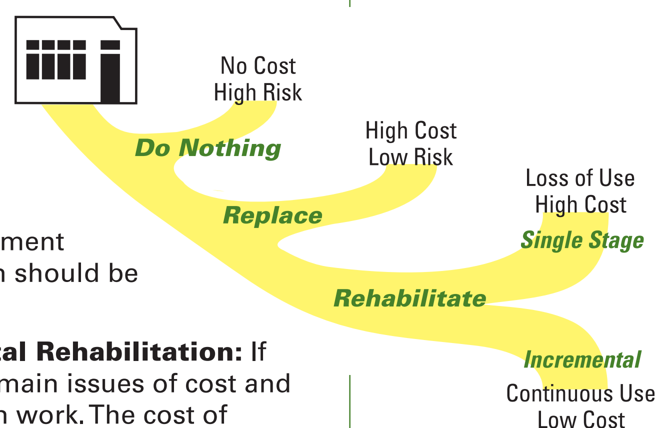
The implementation of seismic risk reduction through building rehabilitation will primarily involve the facility manager. However, to be effective it will require coordination among the facility managers, risk managers, and financial managers. This is further discussed in Part B (for Facility Managers,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

In Brief

- **Seismic rehabilitation of existing vulnerable school buildings can reduce future earthquake damage.**
- **Incremental seismic rehabilitation is a strategy to reduce the cost of rehabilitation and related disruption of educational programs.**

Options for Seismic Risk Reduction

The most important consideration for earthquake safety in school 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[2] or Incremental Rehabilitation: If the rehabilitation option is chosen, there remain 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 in many school districts. 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 School Buildings

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

- Engineering and design services
- Construction
- Disruption of building operations during construction

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

The benefits of seismic rehabilitation of a building are:

- Reduced risk of death and injury of students, teachers, and staff
- Reduced building damage
- Reduced damage of school contents and equipment
- Reduced disruption of the delivery of school services

Engineers have developed estimates of the reduction of earthquake damage that can be achieved with seismic rehabilitation following the Federal Emergency Management Agency's (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 school functions avoided.

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

A.4 Incremental Seismic Rehabilitation of Existing Schools

In Brief

- **Whereas single-stage seismic rehabilitation of an existing school 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.**

Approach

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 schools, a key distinction between the incremental and single-stage rehabilitation approach is that the incremental approach can effectively eliminate or drastically reduce disruption costs if activities are organized so that all rehabilitation occurs during the traditional 10-week summer breaks. 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 school 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 school district's building inventory. Facility managers can implement such an assessment using district 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.

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:

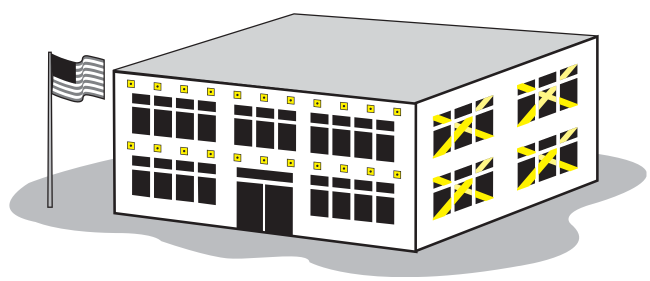
Structural Priority: An initial prioritization of seismic rehabilitation increments should be established primarily in terms of their respective impact on the overall earthquake resistance of the structure. Facility managers will begin with these priorities when determining the order of seismic rehabilitation 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: School districts should consider planning alternative future uses of their existing buildings. Some vulnerable schools may be scheduled for demolition or changed to non-educational 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.

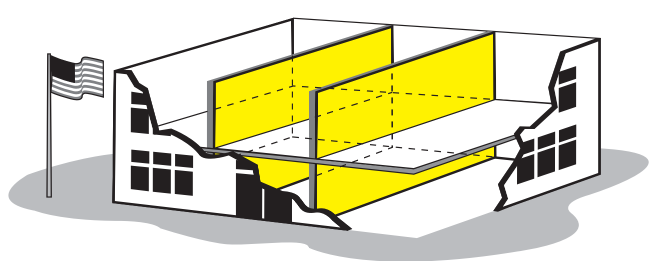
Integration: A major advantage of the incremental seismic rehabilitation approach is that specific work items can be integrated with other building maintenance or capital improvement projects undertaken routinely, as depicted in the illustrations on this page. Such integration will reduce the cost of the seismic rehabilitation action by sharing engineering costs, design cost, 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.

SCHEMATIC INTEGRATION OPPORTUNITIES

Roof Work



Exterior Wall Work



Interior Work

Incremental Seismic Rehabilitation Plan

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

Recommended Actions

1. Communicate the importance of assessing your district'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 the district's 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 students, teachers, and staff, because it is a technically and financially manageable strategy that minimizes disruption of school activities.