For Facility Managers

Part C

Tools for Implementing Incremental Seismic Rehabilitation in Existing School Buildings

Introduction

A school district facility manager charged with the responsibility of implementing a program of incremental seismic rehabilitation may be entering unfamiliar territory. Part C of this manual is intended to provide the facility manager with information and tools regarding building systems, maintenance, repair, and rehabilitation that should help implement such a program.

A program of incremental seismic rehabilitation is likely to be more affordable and less disruptive if specific increments of seismic rehabilitation are integrated with other maintenance and capital improvement projects that would be undertaken regardless of whether or not seismic issues were being addressed.

Guide to Sections C.1 and C.2

Section C.1, How to Use Engineering Services, provides the facility manager with practical information on the special services offered by seismic rehabilitation professionals. There are several essential activities that must be carried out by the facility manager to implement a program of incremental seismic rehabilitation successfully. (These activities are identified and discussed in Part B of this manual.) Some of these activities may require professional architectural and engineering services that differ from or exceed the traditional services usually retained by school districts.

Section C.2, Discovering Integration Opportunities for Incremental Seismic Rehabilitation, provides the facility manager with a set of tools to link specific increments of seismic rehabilitation with specific maintenance and capital improvement projects. These tools will assist the facility manager in defining appropriate scopes of work for projects that will include incremental seismic rehabilitation actions.

A companion document, *Engineering Guideline for Incremental Seismic Rehabilitation*, FEMA 420, provides design professionals with additional technical guidance for the detailed design of specific rehabilitation projects.

In Brief

- **Engineering services should be retained for three specific phases: seismic screening and evaluation, incremental seismic rehabilitation planning and design, and construction period support.**
- **Continuity of building documentation is of special importance.**

C.1 How To Use Engineering Services

To successfully implement integrated incremental seismic rehabilitation, a school district should retain engineering services for three specific phases:

- Seismic screening and evaluation
- Incremental seismic rehabilitation planning and design
- Construction period support

Seismic Screening and Evaluation

Seismic screening and evaluation of the district's building inventory begins with a review of archival drawings and specifications to determine the types of construction used. This determination is essential for all subsequent phases.

Following this review, building inventories should be screened in a process based on FEMA 154, *Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook*, Second Edition. The goal of the screening is to identify vulnerabilities in the inventory. Buildings that have little or no vulnerability are separated out.

For the buildings identified as vulnerable, the next category of service is a detailed seismic evaluation using ASCE 31, *Seismic Evaluation of Existing Buildings*, which is based on FEMA 310, *Handbook for the Seismic Evaluation of Existing Buildings: A Prestandard*. Smaller districts with few buildings may begin with this evaluation, which addresses individual buildings, and identifies both structural and nonstructural deficiencies that require rehabilitation. The output of each building evaluation is a list, possibly prioritized, of needed specific rehabilitation actions.

A school district may retain the services of a single engineering firm to perform both the screening and evaluation, or it can retain a firm for screening, and one or more firms for building evaluation.

Incremental Seismic Rehabilitation Planning and Design

A complete seismic rehabilitation plan covering all the deficiencies identified in the evaluation should be prepared for each building that has been evaluated. This can be done using ASCE 31 and FEMA 356, *Seismic Rehabilitation of Buildings*. However, in incremental seismic rehabilitation the correction of all the deficiencies is not implemented at once, but rather in discrete increments over a period of time. In order to accomplish this, it is necessary to carry out four specific steps:

- Establish target seismic performance levels
- Prioritize seismic rehabilitation opportunities
- Define increments
- Integrate seismic rehabilitation into maintenance and capital improvement programs

Each of these steps is amplified in the discussion of the school facility planning phase in Section B.2.

The potential for unintentional weakening of the building as the result of a particular increment should be analyzed carefully and must be avoided. This subject is discussed in more detail in the companion document, *Engineering Guideline for Incremental Seismic Rehabilitation*, FEMA 420.

Seismic rehabilitation planning and design may be carried out by the same engineering firm that performed the evaluation, or by a separate firm. Close coordination with the school risk management functions is a prerequisite for the successful implementation of performance objectives and prioritization steps. The definition of increments and integration of activities will also require close coordination with financial managers so as to be consistent with budgeting and funding processes, as discussed in Part B. The contractual agreement covering this work should reflect the fact that some of the work is implemented immediately and some of the work is left to the future.

Construction Period Support

Construction period support for incremental seismic rehabilitation is much the same as for any other construction project. The plans and specifications should be implemented correctly, and all specified quality control measures should be followed. All substitutions or changes should be carefully analyzed by the design professionals in terms of their seismic implications. Particular attention should be paid to the proper bracing and anchorage of nonstructural elements undergoing rehabilitation.

Continuity of Building Documentation

Assuring the continuity of building documentation is of particular importance for incremental seismic rehabilitation. The rehabilitation of each individual building may be staged over a period of several years or decades as discussed in Section B.2. The screening, evaluation, planning, and design may be split among several engineering firms. Institutional memory may disappear as district personnel, and even building ownership, may change. It is therefore essential that the school facility manager document all aspects and requirements of seismic rehabilitation from the earliest building screening, through evaluation, seismic rehabilitation planning, and completion of each increment of seismic rehabilitation, paying special attention to the scheduling of follow-up requirements and actions over time.

Fees for Professional Services

The professional services required to implement incremental seismic rehabilitation, as discussed above, clearly exceed the scope of traditional architectural/engineering design services. An appropriate fee structure for these new services will need to be developed and integrated into the budgeting process.

In Brief

- Opportunities to add seismic rehabilitation increments exist within most major maintenance and capital improvement activities.
- This section identifies these opportunities.

C.2 Discovering Integration Opportunities for Incremental Seismic Rehabilitation

Introduction

In order to benefit from opportunities to integrate incremental seismic rehabilitation with other maintenance and capital improvement activities, it is useful to discuss these activities as they are typically undertaken in schools and school districts. Most school districts are familiar with their particular building inventories and the related patterns of maintenance and capital improvement. Aggregate national data are of no particular relevance to a given district, but may be of general interest and is summarized in the sidebar opposite.

Categories of Maintenance and Capital Improvement Projects

School districts often categorize maintenance and capital improvement projects in the following eight categories:

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

These categories reflect groupings of building elements, administrative and funding categories, or other parameters. Some school districts may use other categorizations of maintenance and capital improvement work. The purpose of this discussion is not to impose any particular categorization of work, but simply to demonstrate that planned work items may be particularly suitable opportunities to integrate particular incremental seismic rehabilitation measures. These pairings, of seismic rehabilitation measures with other maintenance tasks or categories, are referred to in this section as "integration opportunities." Facility managers using this manual are encouraged to modify the work categories to suit their own practices.

Work Descriptions and Matrices of Seismic Performance Improvement Opportunities

The eight sections, C.2.1 through C.2.8, provide the facility manager with information used to identify incremental seismic rehabilitation opportunities that can be combined. The information becomes a tool, a technical framework or basis for action, that can be communicated to the architect or engineer selected to work on any project resulting from an integration opportunity.

These sections present the expanded descriptions of each of the work categories defined above in a consistent format. Each category is described in terms of:

- General description
- Physical description
- Associated incremental rehabilitation work
- Performance of the work
- Special equipment
- Impact on building use

Matrices of possible specific seismic performance improvements, one matrix for each work category (Tables C-1 through C-5), accompany the descriptions of the first five categories of maintenance and capital improvement projects. These include:

- Roofing maintenance and repair/re-roofing
- Exterior wall and window maintenance
- Fire and life safety improvements
- Modernization/remodeling/new technology accommodation
- Underfloor and basement maintenance and repair

The integration opportunities for the last three categories of work are defined by reference to one or more of the five matrices.

The seismic performance improvements shown in the matrices fall into three categories:

■ Indicates improvements that can be implemented when the integration opportunity arises, with little or no engineering. 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 but require substantial 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 because of the possibility of unintentionally increasing the seismic vulnerability by redistributing loads to weaker elements of the structural system (sequencing requirements).

Incremental seismic rehabilitation integration opportunities are a function of three levels of seismicity: low, moderate, and high. The definitions of these levels are those used in ASCE 31, *Seismic Evaluation of Existing Buildings*, and FEMA 356, *Seismic Rehabilitation of Buildings*. They include both seismic zonation and soil conditions. The soil conditions at the site may affect the level of seismicity and must be taken into account. For example, soft soil may amplify seismic forces on some buildings. The method for determining the level of seismicity is given in Section 2.5 of ASCE 31. The seismic improvements recommended for low levels of seismicity are significantly fewer than for the higher levels, because seismic vulnerability is lower. The seismic improvements recommended for moderate and high levels of seismicity are the same in number, but differ in the details of the improvements to reflect the different magnitudes of seismic loads encountered in the two levels.

Incremental seismic rehabilitation integration opportunities for each category of work are a function of building structure type. This manual uses five broad structural types, selected to be meaningful to school facility managers. The materials used for the building's vertical load-resisting system can be used to categorize the following structural types:

- Wood
- Unreinforced masonry
- Reinforced masonry
- Concrete
- Steel

The latter two structural types, concrete and steel, are broken down further into those with wood floors (flexible diaphragms) and concrete floors (rigid diaphragms). This breakdown covers an important parameter of seismic performance of the structures.

Generalized Maintenance and Capital Improvement Data

Whitestone Research (a private market research organization) indicates that expenditures for maintenance and repairs over a building's life exceed replacement costs for most building types and configurations, including schools.

The predominant categories of maintenance and repair activities for schools are, first, interior finishes, followed by electrical, mechanical, and plumbing systems. The only other significant cost repair category is roofing. All these activities offer opportunities for integration with incremental seismic rehabilitation work.

The timing of the work is also highly predictable. About 60% of building replacement costs are typically spent in years 20, 25, 30, 40, 45 and 50. These are the highest expense years, in roughly increasing order, with year 50 incurring about 12% of replacement costs for outsourced repair and renovation expenses.

These patterns suggest significant opportunity (and tendency) to implement strategies like incremental rehabilitation at specific points over the service life of a school building. They also imply specific target periods when the strategies could most likely be considered and implemented. Building age is an important characteristic for incremental seismic rehabilitation.

The facility manager using this section to identify incremental seismic rehabilitation integration opportunities in a particular building should use Sections C.2.1 through C.2.8 and the matrices therein as follows:

- Determine the category of maintenance or capital improvement under consideration, and go to the section that corresponds most closely to that category.
- Determine the level of seismicity applicable to the building by considering the seismic map and the soil conditions, and identify the applicable rows of the matrix.
- Determine which of the seven structural categories most closely fits the building, and identify the applicable column of the matrix.
- List all the nonstructural and structural seismic improvements identified in the matrix column and rows.
- Note the category of each improvement (■, □, or ☒).

The facility manager should present to the architect or engineer the annotated list of all the nonstructural and structural seismic improvements identified for consideration and inclusion in the respective scope of design work. The architect or engineer should design the project using the companion document, *Engineering Guideline for Incremental Seismic Rehabilitation*, FEMA 420, which includes more detailed guidance on incremental seismic design. The architect or engineer designing the incremental seismic rehabilitation program will most likely break down the seven structural type categories into further subcategories, as used in ASCE 31 or FEMA 356. These categories and subcategories are discussed in detail in FEMA 420.

Note that 'school building additions' are a category of typical capital improvement that is not included among the eight categories listed at the beginning of this section. Additions have been constructed on many schools over the course of their useful lives. Current additions will be designed to meet the seismic requirements of the building code. Additions may also offer opportunities to strengthen an adjacent building or buildings. These opportunities require careful design and analysis, and they are not specifically identified in the integration opportunities matrices (Tables C-1 through C-5). Furthermore, inadequately designed additions, without proper joints or connections to the existing building, could actually cause damage in an earthquake, as different sections of the building pound against each other.

Definitions of Seismic Performance Improvements

The seismic performance improvements, both nonstructural and structural, that are included in the matrices of integration opportunities described in the preceding paragraphs and included in Sections C.2.1 through C.2.5 are all extracted from a generic list of seismic performance improvements. The generic list is presented in Section C.2.9, which includes brief related explanations for each item on the list. The user of this manual can identify specific seismic performance improvements in the respective project category matrices, and may then refer to these definitions for additional explanation of the involved activities.

The generic nonstructural improvements in C.2.9 are ranked and numbered from highest to lowest priority, in terms of engineering judgment of improvement of life safety in schools. The improvements selected from this list for inclusion in each of the matrices in C.2.1 through C.2.5 are presented in the same order of ranking and retain their respective number. This explains the occasional skipping of a number when a specific nonstructural improvement is omitted because it is not applicable in the particular matrix.

The generic structural improvements in C.2.9 are arranged in the order of structural subsystems and elements, and are not ranked in terms of impact on life safety. The improvements selected from this list for inclusion in each of the matrices in C.2.1 through C.2.5 are presented in the same order.

C.2.1 Roofing Maintenance and Repair/Re-Roofing

General Description of the Work: This category of work includes repair or replacement of any or all of the following elements:

- Roof drainage system
- Eaves and fascias
- Flashing and vents
- Roofing membrane
- Insulation
- Walking surface and ballast
- Parapets and caps
- Roof-mounted equipment
- Roof deck

Most roof maintenance and repair work is done either in response to a failure, or as scheduled periodic maintenance or preventive maintenance work. Most seismic rehabilitation integration opportunities for this work category will relate to either scheduled or preventive maintenance. Placement of roof-mounted equipment usually relates to other work categories such as modernization.

In some jurisdictions, an application for a re-roofing permit triggers a code requirement to implement specific seismic rehabilitation such as parapet bracing.

Physical Description of the Work: Work on the roof can be localized to specific areas, can extend to the entire perimeter of the roof, or may involve the complete roof surface or large portions of it. Work may be limited to the roofing membrane or may include work on the substrate, deck, and supporting system.

Associated Incremental Seismic Rehabilitation Work: Incremental seismic rehabilitation associated with roofing maintenance and repair may include strengthening diaphragms, diaphragm/wall connections, parapets, chimneys, equipment attachment and bracing.

Performance of the Work: Repair work on the roof is often performed by district maintenance staff. Outside contractors may be used for more extensive work.

An architecture/engineering (A/E) firm is typically used in connection with the installation of mechanical, electrical, telecommunication or similar equipment. Also, districts often use the services of an A/E for preparation of re-roofing specifications and bid documents.

Special Equipment: Scaffolding is sometimes used in connection with roof work. Cranes or hoists may be used to lift materials or equipment.

Impact of Work on Building Use: Work on the roof generally does not interrupt building use, except for complete re-roofing including the deck.

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

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													
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.

C.2.2 Exterior Wall and Window Maintenance

General Description of the Work: Exterior wall and window maintenance may involve the following activities:

- Pointing
- Patching
- Painting
- Caulking

This category of work may also include major projects such as:

- Window repair and replacement
- Refinishing with new cladding or material

Most exterior wall maintenance and repair work is done in response to failure or as scheduled periodic maintenance or preventive maintenance work. Caulking and window repair and replacement are also often linked to energy conservation/weatherization work.

Federal or state mandates that require energy conservation improvements may lead to window repair or replacement.

Physical Description of the Work: Work is usually carried out throughout an entire school as a scheduled maintenance activity, although localized patching work is possible. Work may include repainting of brick exterior walls, window replacement, and energy conservation improvements.

Associated Incremental Seismic Rehabilitation Work: Strengthening of shear walls and diaphragm/wall connections.

Performance of the Work: Exterior wall and window work may be performed by skilled construction personnel on the district staff or by an outside contractor. In many cases, there may be an A/E involved to provide design, specifications, and bid process and construction administration services.

Special Equipment: Access to higher exterior areas may require scaffolding or swing stages. This access may provide economical opportunities for the integration of seismic rehabilitation measures.

Impact on Building Use: Since most of the work is being performed from the building exterior, it may be possible to accomplish it throughout the school year. However, some of the seismic rehabilitation measures may be noisy or require access from the interior, so this work may have to be done when the building is vacant.

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.

C.2.3 Fire and Life Safety Improvements

General Description of the Work: Fire and life safety improvements may involve the following building elements:

- Corridors and doors
- Stairs
- Lobbies
- Exits
- Alarms
- Standpipes
- Automatic fire sprinkler systems

Districts will usually schedule this work as part of the normal planning process. Only if the work is in response to a disaster, such as a fire, will the work be unplanned. However, a building disaster that requires some construction may provide an opportunity to integrate seismic safety improvements.

This category of work is usually mandated rather than routine. It may be in response to a building or fire code requirement, or as part of the long-range safety improvement plan of the district. It may also be part of a general modernization program. Some codes may also require seismic rehabilitation when a building experiences a significant amount of damage in a disaster such as fire, flood, or earthquake.

Physical Description of the Work: Fire and life safety improvements usually involve the building's means of egress, which will affect specific internal spaces. Often the work is near the center of the building, such as in the corridors and stairwells. In some cases, it may affect spaces on the building perimeter, such as lobbies, entrances, and stairways. Items include:

- The removal and replacement of corridor wall finishes, doors, transoms and equipment (e.g., lockers and cabinets) will provide access to walls and ceilings;
- The installation of new walls or alteration to existing walls at fire separations and stairway enclosures;
- New stairways may be installed either within the building or on the exterior. If stairways are added, the work may require removal of part of a floor and the construction of new walls; and
- The installation of alarms, standpipes, or sprinklers will provide access to concealed spaces.

Associated Incremental Seismic Rehabilitation Work: Incremental seismic rehabilitation work associated with fire and life safety improvements may include shear walls, bracing, beam/column connections, diaphragm to wall anchors, and bracing of equipment.

Performance of the Work: Typically this work involves skilled construction personnel. These may be district personnel or contractors. In some cases an A/E is involved.

Special Equipment: No special equipment is required for this task except for scaffolding to provide access to the work areas.

Impact on Building Use: Typically this work will be performed when the building is vacant.

Table C-3: Fire and Life Safety Improvements

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													
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.

C.2.4 Modernization/Remodeling/New Technology Accommodation

General Description of the Work: Facility modernization and remodeling work has the potential to involve any interior or exterior wall or element. This category may involve simple work on a single wall or the entire space reconfiguration of the building. The installation of conduits, cables, and wiring to accommodate new technology may involve the reconfiguration of concealed spaces under floors, above ceilings, and inside wall cavities and chases located throughout the building.

Interior remodeling and modernization are usually major activities and are included in the long-range educational plans of the district. Often this includes the conversion of open classroom plans (that were popular in the '60s and '70s) to more traditional classroom configuration. Thus, it is a common capital improvement activity.

Frequently this work is in response to changing educational requirements or major technological advances. It may also be triggered by federal or state mandates. Some codes may also require seismic rehabilitation when a building experiences a significant amount of damage in a disaster such as fire, flood, or earthquake.

Physical Description of the Work: This work may include reconfiguration of spaces and creation of new spaces, removal of walls and ceilings, construction of new partitions, installation of replacement finishes, and installation of communications networks for new technology. This access to spaces behind finishes and the new wall construction provide various opportunities for seismic rehabilitation work.

Associated Incremental Seismic Rehabilitation Work: Incremental seismic rehabilitation associated with this work may include shear walls, bracing, beam/column connections, diaphragm to wall anchors, and bracing of equipment.

Performance of the Work: This work will usually be performed by skilled construction personnel, either district staff or contractor personnel. Usually architectural/engineering design is used for major remodeling.

Special Equipment: Special equipment required for access to work areas for any seismic rehabilitation construction will typically be available during any remodeling work.

Impact on Building Use: Major remodeling will require the space to be vacated during the course of construction.

Table C-4: Modernization/Remodeling/New Technology

Rank*	Level of Seimicity			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													
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.

C.2.5 Underfloor and Basement Maintenance and Repair

General Description of the Work: Underfloor and basement maintenance may involve the following activities:

- Repair of deterioration
- Termite repair
- Equipment replacement

Most underfloor repair activities will be in response to a problem. The solution may be immediate or assigned to the capital improvements budget. For example, settlement and resulting underpinning repair may be the result of a floor problem and require major immediate intervention.

Usually there are no mandates or code issues involved with underfloor repair work. Safety is the usual driving force.

Physical Description of the Work: Work includes replacement of deteriorated wood elements, repair of cracked or bowed walls, underpinning where buildings have settled, and replacement of basement equipment.

Associated Incremental Seismic Rehabilitation Work: Incremental seismic rehabilitation work associated with underfloor and basement work may include cripple stud bracing, foundation anchorage, new foundation, and floor to wall anchoring.

Performance of the Work: The work is often performed by school district staff or by outside contractors.

Special Equipment: Special equipment is usually not required for underfloor work. However access is usually all that is necessary. Major design work will often require A/E services.

Impact on Building Use: Except for equipment replacement, the work may be done at any time, independent of building use.

Table C-5: Underfloor and Basement Work

Rank*	Level of Seimicity			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													
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.

C.2.6 Energy Conservation/Weatherization/Air-Conditioning

General Description of the Work: Energy conservation/weatherization and air-conditioning projects may include the following items:

- Exterior envelope work
- Insulation
- Windows
- Electrical and HVAC equipment
- Ducts and piping

Building elements affected may include exterior walls, ceilings, attic spaces, roofs, and basements.

These improvements may be in response to a long-term school district policy, special state or federal funding, or as part of other routine equipment replacement. In all cases, the intent is not only to save energy but also to reduce operating costs and improve occupant comfort.

Federal or state mandates may be factors leading to energy conservation improvements. If special grants are available, they can be made part of the capital improvement program. Local building code requirements may also encourage energy conservation improvements.

Physical Description of the Work: The physical work involved in energy conservation improvements may be localized or involve the entire building. Items include:

- Window improvements or replacement
- New insulation in exterior walls
- New insulation in the attic, which may permit access to the ceiling space
- New insulation installed on the roof deck, which can be coordinated with other roof-top work
- HVAC equipment installation, which should meet the anchorage requirements for seismic forces and may provide access to areas for other work
- The addition of air-conditioning, which may include the installation of ducts or piping to spaces throughout the building

Associated Incremental Seismic Rehabilitation Work: This work may include the incremental seismic rehabilitation work associated with the following other project categories discussed earlier:

- C.2.1, Roofing Maintenance and Repair/Re-Roofing
- C.2.2, Exterior Wall and Window Maintenance
- C.2.4, Modernization/Remodeling/New Technology Accommodation

See Tables C-1, C-2, and C-4 for integration opportunities.

Performance of the Work: The work may be performed by school district personnel or by outside contractors depending on the project size or complexity. Whether the services of an A/E are required will depend on the nature of the work.

Special Equipment: Special equipment may be required to provide access to the work. This may include scaffolding or a crane or lift.

Impact on Building Use: Some of this work may be done at any time of year from the roof. Most window or interior work must be accomplished when school is not in session. Typically this work cannot be done around occupants and may require the building to be vacant.

C.2.7 Hazardous Materials Abatement

General Description of the Work: The presence of hazardous materials may involve abatement of:

- Asbestos
- Lead paint
- Radon

Most districts have had asbestos abatement programs for some time and radon programs more recently. Lead paint has also been recognized as a hazard for some time, but only recently has it been included in government programs for abatement.

Hazardous materials abatement programs may be triggered by federal requirements or mandates, state regulations or school district policies.

Physical Description of the Work: Hazardous materials abatement may include the removal of finishes such as plaster, ceiling materials, and flooring. It may include removal of the adhesives used. Asbestos abatement may include the removal or encapsulation of insulation on pipes and ducts. Lead paint abatement may include removal of the paint and finishes or encapsulation of the component containing the lead paint. Radon abatement may require installation of ventilation systems or other work in the basement.

Associated Incremental Seismic Rehabilitation Work: In some cases, the extent of the work may provide access to interior spaces that will provide a seismic rehabilitation opportunity. Seismic rehabilitation work could follow the hazard mitigation work before the finishes are reinstalled. This work may include the incremental seismic rehabilitation work associated with C.2.4, Modernization/Remodeling/New Technology Accommodation, discussed earlier.

See Table C-4 for integration opportunities.

Performance of the Work: The work is typically performed by specialty contractors or specially trained school district staff.

Special Equipment: Special equipment such as scaffolding would often be on the job as part of the abatement work. Other special equipment such as fans and enclosures are irrelevant to seismic work.

Impact on Building Use: Building use will be curtailed during any hazardous materials abatement work. The work cannot be done around occupants. It requires a vacant building.

C.2.8 Accessibility Improvements

General Description of the Work: Typically such work is done in response to a complaint, or a federal or state mandate. It is often included as part of the long-range plans of the district.

Physical Description of the Work: Most work involves revisions to walks and doors. Ramps are constructed, and in some cases elevators or lifts installed.

Toilet room improvements may require the removal of finishes and possibly construction of new walls.

Associated Incremental Seismic Rehabilitation Work: Accessibility improvements usually do not lead to seismic rehabilitation opportunities because of their relatively limited spatial applicability. Interior work relating to corridors and circulation routes may share some seismic rehabilitation opportunities with C.2.3, Fire and Life Safety Improvements.

See Table C-3 for integration opportunities.

Other interior work may lead to localized seismic rehabilitation opportunities but no major mitigation. Installation of an elevator may provide an opportunity to use the new shaft walls as shear walls, thereby adding shear capacity.

Performance of the Work: Accessibility improvements may be accomplished by school district staff or by outside contractors. Often the services of an A/E are utilized.

Special Equipment: No special equipment is used in this work that might be of assistance in seismic rehabilitation. However, any scaffolding used for interior finish work can provide access for seismic rehabilitation.

Impact on Building Use: Usually this work can be done around occupants of the building. It does not require a vacant building.

C.2.9 Definitions of Seismic Performance Improvements

The seismic performance improvements included in the matrices of integration opportunities in Sections C.2.1 through C.2.8 are all extracted from the generic list in the following tables. The table contains additional information (description and purpose) that should be useful to school facility managers using this section.

Note that the nonstructural improvements are ranked and numbered from highest to lowest priority, in terms of their impact on improving life safety in schools. The facility manager and risk manager may revise the ranking based on local considerations.

Nonstructural Seismic Performance Improvements

Rank *	Level of Seismicity			Definitions and Purpose		
	L	M	H	Seismic Performance Improvement	Description	Purpose
1	✓	✓	✓	Bracing of Parapets, Gables, Ornamentation & 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.	Prevents parapets, gables and ornamentation from falling outward
2	✓	✓	✓	Anchorage of Canopies at Exits	Canopies or roofs over exits	Prevents collapse of canopies which would block exits and possibly injure persons
3		✓	✓	Bracing or Removal of Chimneys	Chimneys should be braced to the structure	Chimneys may topple onto yards or through roofs
4	✓	✓	✓	Bracing or Reinforcing Masonry Walls at Interior Stairs	Interior exit stairs may have unreinforced masonry enclosure walls that could collapse	Prevents collapse of walls blocking stairways
5		✓	✓	Suspension and Bracing of Lights	Lights may swing or otherwise fall in an earthquake	Falling lights could injure occupants. Lights should not be supported by a suspended ceiling in a high and moderate seismic zone. Pendent lights should have their sway limited.
6	✓	✓	✓	Anchorage and Bracing of Emergency Lighting	Positive attachment of emergency lights	Battery packs are heavy and could fall
7		✓	✓	Fastening and Bracing of Ceilings	Diagonal bracing of ceiling	Suspended ceilings should be braced against sidesway to reduce the chance of elements falling
8		✓	✓	Restraint of Hazardous Materials Containers	Chemical labs, shops, etc may have materials that could, when combined, create a fire or chemical hazard	Reduces danger of breakage and mixing of chemical
9		✓	✓	Bracing and Detailing of Sprinkler and Piping	Sprinkler pipes should be braced in each direction	Sprinkler lines could break and flood the building
10		✓	✓	Anchorage and Detailing of Rooftop Equipment	Equipment should be properly attached, and restrained if isolation-mounted	Equipment could slide or fall off platforms
11		✓	✓	Fastening and Bracing of Equipment – Mechanical and Electrical	Equipment above ceilings	Fans and other equipment could sway and fall on occupants
12	✓	✓	✓	Cladding Anchorage	Heavy cladding (concrete) must be connected to the structure	Prevents cladding from falling. Careful design is required so the cladding does not limit the structures type of lateral movement.
13		✓	✓	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	Inadequately anchored veneer could fall outward
14		✓	✓	Anchorage of Exterior Wythe in Cavity Walls	A masonry wall separated from the veneer by a hollow space	Veneer could fall outward. Existing anchorage should be checked for rust damage and loss of strength.
15	✓	✓	✓	Glazing Selection and Detailing	Glass above a walking surface	Prevents it from falling onto the walking surface and injuring persons
16		✓	✓	Bracing of Interior Partitions – Masonry & Wood	Bracing may be vertical or diagonal braces	Interior partitions must be braced to prevent falling/collapse
17		✓	✓	Anchorage of Steel Stud Backup	Steel studs behind veneer or other cladding	Steel studs are used as a backup to support veneer or other cladding and could become detached and fall
18		✓	✓	Attachment and Bracing of Cabinets and Furnishings	Anchorage to structural walls or other elements	Cabinets and other furnishings could topple. Cabinets have moved caused damage. Fallen file cabinets may block exit doors.
19		✓	✓	Attachment and Bracing of Large Ductwork	Large ducts	Ducts could fall on occupants
20		✓	✓	Shut-Off Valves	Installation of a shut-off device	Gas and water lines could break and should have a means of turning them off
21		✓	✓	Support and Detailing of Elevators	Elevator guides have become dislodged in earthquakes. Applies to cable lift elevators	Keeps elevators functioning
22		✓	✓	Underfloor Bracing of Computer Access Floor	Raised floors for cabling	Floors could collapse damaging equipment

* Rank in terms of 'life safety effectiveness'

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	Improves load path. Provides adequate connection between the building and the foundation.
	✓	✓	Foundation		Cripple Stud Bracing	Short wood studs between the foundation and the first floor	Cripple studs are usually not braced. They may topple 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.
	✓	✓	Foundation		Uplift	Under overturning type loads foundations may be pulled upward	Reduces the uplift chance by improving foundation system.
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	Controls 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	Reduces 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	Strengthens the roof to act as a lateral force element. Controls drift of the roof or floor.
Definition			Vertical Elements	Braced Frames		Steel or concrete beams and columns with diagonal bracing	Act as a lateral force resisting element and brace the structure
	✓	✓	Vertical Elements	Braced Frames	Capacity/Stiffness	Frame capacity improvements for adequate load resistance	Frames are often used as the lateral force resisting element on open sides of buildings. They must be connected to the horizontal elements.
	✓	✓	Vertical Elements	Braced Frames	Continuity	Braced frames should be continuous from the foundation to the roof	Discontinuities of lateral 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 result in unintentional increase in seismic vulnerability.	This assures 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	Permits earthquake loads to be conveyed to the foundation. Develops a load path.

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	Act as a lateral force resisting element and braces the structure
	✓	✓	Vertical Elements	Moment Frames	Beam Column Capacity/Stiffness	Frame capacity improvements for adequate load resistance	Frames are often used as the lateral force resisting element on open sides of buildings. They must be connected to the horizontal elements.
	✓	✓	Vertical Elements	Moment Frames	Beam Column Connection	Steel or concrete with improved connections to increase strength. Improvements will not result in unintentional increase in seismic vulnerability.	This assures 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	Brace the structure
	✓	✓	Vertical Elements	Shear Walls	Capacity	Capacity equals strength	Building walls can act as lateral load resisting elements. They must be connected to the horizontal elements.
	✓	✓	Vertical Elements	Shear Walls	Continuity	Shear walls should be continuous from the foundation to the roof	Discontinuities of lateral 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 URM and other buildings	Permits 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	Prevents 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	Prevents 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 elements that resist lateral force	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.