VOLUME
1

Washington State Department of Natural Resources

SEISMIC ASSESSMENT REPORT

School Seismic Safety Assessments Project

June 2019

PREPARED FOR

SUPERINTENDENT OF PUBLIC INSTRUCTION WASHINGTON

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WASHINGTON STATE SCHOOL SEISMIC SAFETY ASSESSMENTS PROJECT

SEISMIC ASSESSMENT REPORT
VOLUME 1 of 4

June 2019

Prepared for:

State of Washington
Department of Natural Resources and Office of Superintendent of Public Instruction

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EXECUTIVE SUMMARY

This groundbreaking statewide seismic study constitutes a major first step taken by Washington State to improve the understanding of seismic risks to public school buildings. Public school buildings are important to local communities, as they house hundreds or even thousands of students and staff on a typical day, and they are often culturally or societally important to the communities they serve. In urban and rural communities alike, public schools not only educate the next generation of Washington residents but also serve as gathering spaces for communities to come together over interscholastic athletics, meetings, and other events.

The results of the seismic screening evaluations indicate that Washington State has many older school buildings that are vulnerable to earthquakes. Older unreinforced masonry buildings and non-ductile concrete buildings are especially at risk. The average date of construction of the buildings included in the study is 1963, which was well prior to the adoption of modern seismic building codes. These older buildings should receive top priority for further study and seismic improvements. For buildings constructed prior to 1950, almost half of the seismic screening checklist items are identified as non-compliant. Simply put, the seismic screening checklists questions are designed to uncover the seismic safety flaws and weaknesses of a school building. They are in the form of evaluation statements describing building characteristics that are essential if the failures observed in past earthquakes are to be avoided. Compliant statements identify conditions that are acceptable, while non-compliant seismic screening statements identify seismic safety issues or conditions in need of further investigation and evaluation.

For buildings constructed between 1950 and 1990, approximately 30 percent of seismic evaluation checklist items are identified as non-compliant, again signifying additional seismic safety issues even in some relatively newer buildings. Post-benchmark buildings (generally constructed after 1998) possess fewer non-compliant seismic items compared to older buildings. It is important to note that, due to the absence of record drawings and the existence of building finishes, features, and other elements, many of the buildings evaluated were not able to have all of their seismic screening elements positively verified. This means that the estimated numbers of non-compliant seismic screening features are likely to increase as these buildings are examined with more-rigorous field investigations and ASCE 41 Tier 2 and Tier 3 seismic evaluation procedures.

The EPAT spreadsheets estimate that the median building is expected to be 43 percent damaged in a design-level earthquake. EPAT also estimates that the majority of buildings in this study are expected to receive a "Red-Unsafe" post-earthquake building safety placard following a design-level earthquake, meaning that they will likely be unsafe to occupy. In addition, the EPAT spreadsheets estimate that approximately one-fourth of buildings studied will likely not be repairable following a design-level earthquake and will likely require demolition.

Unreinforced masonry buildings and non-ductile concrete buildings located in high seismic hazard areas are especially vulnerable to earthquakes – this is a well-known fact. Many of these school buildings in high seismic hazard areas possess damage estimate ratios in the range of 70 to 80 percent, and generally possess a high life safety risk. As expected, the unreinforced masonry school buildings in lower seismic hazard areas (Eastern Washington, for example) were calculated by EPAT to receive less damage than equivalent buildings in high seismic hazard areas.

Approximately half of the unreinforced masonry school buildings included in the study are located east of the Cascade Mountain Range. While unreinforced masonry buildings and non-ductile concrete buildings are considered to be especially vulnerable, the buildings in high seismic hazard areas are expected to be most at-risk.

The results of the 15 concept-level design case studies indicate that the cost to seismically upgrade vulnerable structures can be less (or much less) than the damage costs the building would incur in an earthquake. The financial benefits of seismically upgrading structures can often far exceed the construction costs when implemented properly. For less vulnerable structures, especially structures in low seismicity areas, however, it may not be cost-effective to implement seismic improvements.

The results presented here are for statewide informational purposes. The goal is that this information can help the governor, state legislators, state agencies, school districts, school administrators, teachers, students, parents, and the public better understand the current level of seismic risk of older Washington state public school buildings. Public schools will need financial and community support to make the necessary changes highlighted in this study.

Solving large and complex statewide seismic safety concerns with thousands of our aging public-school buildings is going to take 21st century problem solving skills that rely on data to guide and inform the best approaches and most-efficient solutions. This statewide study is the first step towards obtaining the data and generating the information and knowledge required to better understand the extent and scope of the problem.

This is a problem that may require a decade or more of action, policy creation, refinement, and funding to successfully complete. The solution will require significant leadership, long-term strategic thinking, public support, and the funding necessary to start a statewide movement toward seismically safer public school buildings.

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Acronyms

ASCE	American Society of Civil Engineers
BPOE	Basic Performance Objective for Existing Buildings
BSE	Basic Safety Earthquake
BU	Built-Up
CMU	Concrete Masonry Unit
CP	Collapse Prevention
DCR	Demand-to-Capacity Ratio
DNR	Department of Natural Resources
EERI	Earthquake Engineering Research Institute
EPAT	Earthquake Performance Assessment Tool
FEMA	Federal Emergency Management Agency
IBC	International Building Code
ICOS	Information and Condition of Schools
IO	Immediate Occupancy
LFRS	Lateral Force-Resisting System
LS	Life Safety
LTD-S	Limited Safety
MCE	Maximum Considered Earthquake
NIST	National Institute of Standards and Technology
OSPI	Office of Superintendent of Public Instruction
OP	Operational
PBEE	Performance-Based Earthquake Engineering
PGA	peak ground acceleration
PR	Position Retention
RM	Reinforced Masonry
SSSSC	Washington State School Seismic Safety Steering Committee
UBC	Uniform Building Code
URM	Unreinforced Masonry
WF	Wide Flange
WGS	Washington Geological Survey

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Acknowledgements

Reid Middleton would like to acknowledge and thank the school districts who participated in this study and the entire project team for their efforts in completing this work.

The Washington State Department of Natural Resources Washington Geological Survey and the State of Washington Office of Superintendent of Public Instruction were instrumental in managing this project and providing valuable information and insight to the seismic engineering team.

We would also like to acknowledge the structural engineering consultant team consisting of Reid Middleton, WRK Engineers, BergerABAM/WSP, and DCI Engineers.

We would also like to acknowledge the architectural consultant team consisting of Rolluda Architects and Dykeman Architects.

We would also like to acknowledge the cost estimating services provided by ProDims.

It is the project team's sincere hope that this information will be valuable to the governor, state legislators, state agencies, school districts, school administrators, teachers, students, parents, and the public. We hope it will help these groups to better understand the current level of seismic risk to Washington state public school buildings. We hope this information can be helpful in improving school seismic safety and resiliency.

1.0 Introduction

1.1 Project Context

This groundbreaking statewide seismic study constitutes a major first step taken by Washington State to improve the understanding of seismic risks to public school buildings. Public school buildings are important to local communities, as they house hundreds or even thousands of students and staff on a typical day, many are historic structures, and they are often culturally or societally important. In urban and rural communities alike, public schools not only educate the next generation of Washington residents but also serve as gathering spaces for communities to come together over interscholastic athletics, meetings, and other events.

Washington State has stunning landscapes that span from wet coastal regions to tall mountain ranges to arid inland plains. Washington has four major mountain ranges within its borders: the Olympic Mountains, the Cascade Mountains, the Columbia Mountains, and the Blue Mountains. The Cascade Mountain Range includes five major volcanoes. The Columbia River cuts through the central and southern parts of the state and carries enough water to be counted as the fourth heaviest-flowing river in the United States.

Much of this stunning beauty is driven by deep geologic forces. Off the coast of Western Washington, the Juan de Fuca tectonic plate slides underneath the North American plate. This geologic action is responsible for Washington's tall mountains and volcanoes. The tall mountains directly affect Washington's climate, which causes heavy snowfall in the mountains and creates the bountiful agricultural region in central and eastern Washington.

Washington's complex plate tectonics have the additional effect of making it one of the highest seismic risk regions of the United States. When built-up stress, produced from the collision of the Juan de Fuca Plate and the North American Plate, is released in the earth's crust, it causes the crust of the earth to vibrate and move - an earthquake. Unlike other areas of the country that have relatively shallow earthquake faulting (such as parts of California), which generally causes one type of earthquake, Washington State can experience three major types of earthquakes. There is recent history of and historical geologic evidence that Washington State has experienced deep intraplate earthquakes (1949 Olympia, 1956 Seattle, and 2001 Nisqually Earthquakes), powerful earthquakes occurring on shallow surface faults (similar to recent earthquakes in Taiwan, Haiti and California), and long-duration subduction zone earthquakes (similar to recent earthquakes in Chile, Indonesia, and Japan).

Using the results of this statewide study as a starting point, Washington State has the opportunity to dramatically increase student public safety, increase public school resiliency, and help ensure the future economic vitality of Washington State by developing a statewide program to enhance school seismic safety. Previous studies have shown that conducting seismic upgrades on vulnerable buildings has a significant net-positive economic impact.

Without seismically upgrading buildings, earthquakes can be very economically damaging. Not only do earthquakes cause physical damage to school buildings that require significant resources to fix, but there are also negative economic impacts associated with loss of life, injuries, and the prolonged closure of damaged schools. Prolonged closures can lead to increased costs for school districts, and can require parents to find childcare or alternative activities for their children when they would otherwise be attending school. Economic setbacks due to earthquakes (or other natural disasters) can also cause long-term disinvestments in communities that can permanently change the character of those communities. Unlike many other types of risks to schools, earthquakes pose an existential threat to Washington State.

1.2 Project Overview

The Washington Geological Survey (WGS), a division of the Washington State Department of Natural Resources (DNR), conducted a seismic assessment of 222 school buildings and 5 fire stations across Washington State to better understand the current level of seismic risk to our state's public school buildings.

There are 295 K-12 public school districts throughout Washington State, consisting of 4,476 recognized permanent buildings. Representative buildings were selected from the state's permanent building stock to assess the overall vulnerability of Washington State's K-12 schools. The school buildings selected for this statewide seismic assessment are distributed throughout the state; consist of a wide variety of building construction types, sizes, ages, materials, and configurations; and are located within a wide range of seismic hazard areas.

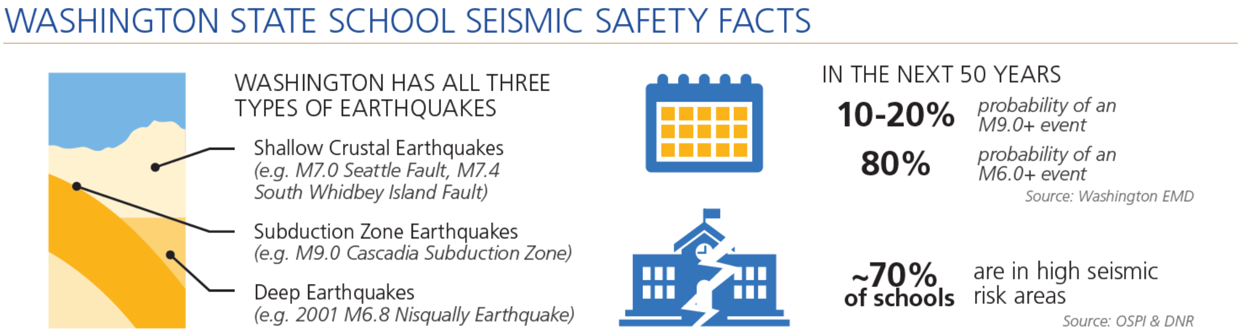


Figure 1.2-1. Washington State School Seismic Safety Facts.

The seismic assessments include ASCE 41-17 Tier 1 seismic screenings of 222 individual school buildings distributed across the state and 5 fire stations within one mile of a public school. Both structural and nonstructural Tier 1 seismic screenings were performed. Additional desktop seismic screenings and risk assessments were performed with the Earthquake Engineering Research Institute's (EERI) Washington Schools Earthquake Performance Assessment Tool (EPAT), Microsoft Excel spreadsheets, and FEMA 154 Rapid Visual Screening forms.

The desktop evaluations were performed to help assess the seismic vulnerability of these buildings, provide a very simplified risk-based prioritization of seismic improvement needs, and collect this data for input into relevant public school facilities databases. Additionally, 15 school buildings were selected for the development of conceptual-level design case studies of seismic retrofit and upgrades for mitigating the identified seismic deficiencies.

1.3 Project Objective

The overall goal of the Washington State School Seismic Safety Assessments project is to continue the statewide school seismic safety initiatives currently being led by the Washington State Department of Natural Resources and the Office of Superintendent of Public Instruction (OSPI). The goal of the ongoing initiative is to provide a better understanding of the current level of seismic risk to K-12 public school buildings throughout the state and help estimate the fiscal needs to improve existing school buildings to meet current seismic safety building code standards.

Figure 1.3-1. Basic Project Steps.

Communication of the project results and information is planned to flow two ways. The first communication objective is to utilize the project information to inform the Washington state legislature and policy makers of the current level of estimated seismic risks in K-12 public school buildings statewide. This information should help guide long-term strategies and policies for improving the seismic safety of our state’s older school buildings. The second communication objective is to provide each participating school district the seismic screening results and related seismic safety improvement recommendations to help inform their long-term capital planning and budgeting efforts.

1.4 Scope of Services

The project was accomplished in several distinct and overlapping phases of work, which included: development of the school building selection for this study; school facilities research and information review; field investigations and data collection; data review and seismic screenings; conceptual-level design and cost estimating for seismic upgrades; data analyses and entry; and reporting and documentation.

1.4.1 Research and Information Review

<u>Project Research</u>: The project team researched available school building records and relevant site data in advance of the field investigations to assist in the planning and scheduling of the field investigation work. This research included, but was not limited to, Google Earth or Google Maps searches of school buildings on school campuses and contacting the school districts and OSPI to obtain building plans, seismic reports, condition reports, or related construction information useful for the project. Some school districts had this information readily available, while other school districts did not have these documents on record.

Data Management: The project team prepared a data-gathering and management plan that included a definition of planned data collection, storage, sharing, and delivery methods. Data collection application software was used during the field investigation phase to streamline data collection procedures while maintaining the field collection data in a searchable and retrievable format. The data management plan included the following elements:

- Collection: The project team employed a data collection application software tool, with password access, to allow the project team to compile, view, and transfer gathered project data and information.
- Storage: Collected data is stored in the data collection/application database, MS Excel spreadsheets, MS Word documents, and PDF file exchange formats. Information from the data collection application is stored in a cloud server and other project data and information is stored on the project team's servers.
- Site Geologic Data: Site geological data was collected, developed, and provided by the WGS and includes site shear wave velocities. This data was used to determine the Site Class, in accordance with ASCE 41, which was then included in the Tier 1 seismic screening checklists and the EPAT spreadsheet inputs.

1.4.2 Field Investigations

Field Investigations: The project team performed site visits at each of the selected school buildings to observe the building's condition, configuration, and structural system for the purposes of the ASCE 41 Tier 1 seismic screening evaluations. This task included confirmation of general information included in building records or layout drawings (when available) and visual observations of the condition of the structure. Engineer notes, photographs, and videos of the facilities were used to record, and document information gathered in the field investigation phase.

Field Investigation Coordination: The project team coordinated the field investigation schedule with the DNR/WGS, OSPI, and the participating school districts to obtain access to the site and minimize disruption to building occupants. Most of the field investigations were performed during the summer months while school was not in session.

Data Collection: ASCE 41 Tier 1 seismic screening checklists and EPAT spreadsheets were used to document the structural framing type, overall condition, relative seismic risk level, and nonstructural and structural seismic deficiencies.

Geotechnical Data Coordination: The project team coordinated the seismic screening work with OSPI and the DNR/WGS to incorporate DNR's analyses and determination of site-specific seismic hazard classification data into the building evaluations and the OSPI Information and Condition of Schools (ICOS) database.

Figure 1.4.2-1. Structural Engineers Performing Field Investigations.

The field observations at each site were performed by an individual Structural Engineer. Observation efforts were limited to areas and building elements that were observable and safely accessible. Observations requiring access to confined spaces, potential hazardous material exposure, use of an unsecured ladder, work around energized electrical equipment or mechanical hazards, areas requiring OSHA fall-protection, steep or unstable slopes, deteriorated structural assemblies, or other field conditions deemed to be potentially unsafe by the engineer were not be performed. Removal of finishes (e.g., gypsum board, lathe and plaster, brick veneer, or roofing materials) for access to concealed conditions or to expose elements that cannot otherwise be visually observed and assessed, along with material sampling and testing, was beyond the scope of this project. The ASCE 41 Tier 1 seismic screening checklist items that are not documented due to access limitations are noted as unknowns.

1.4.3 Seismic Evaluations

Tier 1 Seismic Screening Evaluations: The project team performed ASCE 41-17 Tier 1 structural and nonstructural seismic screening evaluations of the 222 school buildings and five fire stations using the *ASCE 41-17 Seismic Evaluations and Retrofit of Existing Buildings* Tier 1 Seismic Screening Procedures. The fire stations were located within one mile of a school building evaluated as part of this project.

Conceptual-Level Seismic Retrofit/Upgrade Designs: Based on the results of Tier 1 seismic screening evaluations, the project team developed conceptual-level seismic retrofit and upgrade designs for 15 selected school buildings. The designs include narrative descriptions of proposed seismic retrofit or upgrade schemes, concept design sketches depicting the extent and type of recommended structural upgrades, and opinions of probable costs. These designs were summarized in individual reports for each school district's use.

Cost Estimating: The project team prepared opinions of probable costs of the conceptual-level seismic retrofit or upgrade designs for each of the 15 selected school buildings. These school buildings are intended to be representative samples of the state's public school buildings. The intent of the cost estimates is to extrapolate costs developed as part of this study to other similar types of school buildings in the state and use these costs to help estimate the overall capital needs for seismically upgrading Washington State schools.

1.4.4 Data Analyses and Entry

Seismic Screening Evaluation Data: ASCE 41 Tier 1 seismic screening evaluation results and EPAT spreadsheet results are provided for each of the 222 school buildings and 5 fire stations evaluated.

Seismic Screening Evaluation Data Upload: Data from the building seismic screening evaluations were provided to OSPI's ICOS building inventory database for future use and reference with OSPI's Washington Schools EPAT spreadsheets.

1.4.5 Reporting and Documentation

Tier 1 Reports: The project team documented the findings of the building seismic screening assessments in the form of a written report with appendices. Each building is documented by a standard report format that provides a summary of the building's structural system, ASCE 41 Tier 1 seismic screening checklists, EPAT results, and site photographs.

Conceptual-Level Seismic Retrofit/Upgrade Reports: For the school building conceptual-level seismic retrofit and upgrade reports, the project team prepared a stand-alone report that included a summary of each seismic screening evaluation, concept-level seismic retrofit/upgrade sketches, and construction costs estimates. These Tier 1 reports and concept-level seismic retrofit/upgrade documents are compiled by school district.

Project Presentation/Communication Materials: The project team prepared project presentation and communication materials for use by the DNR/WGS, OSPI, and the school districts, as requested. These included electronic presentations, project graphics, animations, presentation boards, flyers, and other project communication and public information materials.

1.5 Report Organization

Due to the voluminous nature of the data and information gathered for this project, this report has been organized into four separate volumes. Volume 1 contains the Seismic Safety Assessment Report, along with information summarizing the work performed by the project team. Volume 2 includes the Washington State Schools EPAT worksheets and summaries. Volume 3 contains the ASCE 41 Tier 1 Seismic Screening Reports for each of the selected school buildings and fire stations. Volume 4 contains the conceptual-level seismic retrofit/upgrade reports for each of the 15 selected school buildings. Please refer to each of these separate report volumes for information that was utilized in the development of this report.

2.0 Earthquake Hazards and Building Selection Process

2.1 Washington State Schools Overview

According to OSPI, approximately 1.1 million students are enrolled in our state's public schools and taught by more than 64,000 classroom teachers. These students and teachers are housed in approximately 4,476 permanent and 5,524 non-permanent buildings across the state within 295 public school districts. Approximately 70 percent of these school buildings are considered to be in high-risk seismic areas, with about 11 percent located in medium-risk seismic areas.

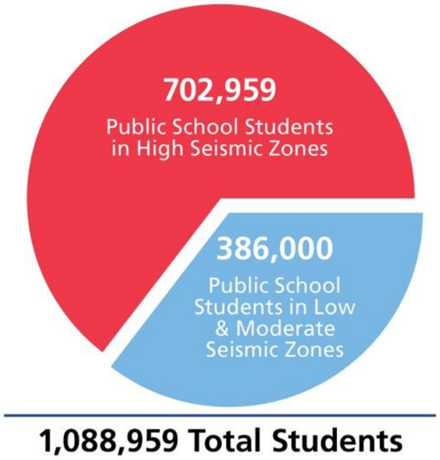


Figure 2.1-1. Distribution of Public School Students in High vs. Moderate/Low Seismic Hazard Areas per OSPI ICOS Database.

As noted previously, the broad purpose of this engineering study is to perform seismic screenings on a statewide sample of public school buildings and to extrapolate that data to better understand the extent of the current seismic risk to the state's public school buildings. Prior to engaging the project's engineering team, the state had shortlisted approximately 350 public school buildings to participate in the seismic screening study based on seismic risk, building age, construction type, and geographic location. From this initial list of 350 buildings, 222 public school buildings representing 75 school districts were subsequently selected to participate in this statewide seismic screening study.

The State of Washington OSPI's ICOS database contains a list of 4,476 recognized permanent school buildings. The 222 selected schools are a subset of the school buildings listed in the current ICOS database. In overall numbers, the 222 school buildings represent a five percent statewide sample of public school buildings and educate approximately 40,000 students within about 6 million square feet of building area. The average area of each school building is 25,000 square feet, with an average student population of approximately 380 students per building. The average year of construction of these buildings is 1963, and 75 percent of these buildings are one-story structures.

The following section summarizes the selection criteria and process that was used by the project team to select the 222 school buildings seismically screened and evaluated by the DNR/WGS School Seismic Safety Assessments project.

2.2 Washington State Seismic Hazards

Washington can experience all three major types of earthquakes: deep intraplate earthquakes, shallow surface fault earthquakes, and subduction zone earthquakes. Each of these types of earthquakes present their own types of hazards and risks.

Figure 2.2-1. Nonstructural Ceiling Tile Earthquake Damage to an Elementary School in Eagle River, Alaska, from the 2018 M7.0 Anchorage Earthquake (Photo by Reid Middleton, Inc.).

Historically, deep intraplate earthquakes have occurred most frequently (1949 Olympia Earthquake, 1965 Puget Sound Earthquake, 2001 Nisqually Earthquake). These earthquakes typically occur within Washington State about every 30 to 50 years. While the death toll from these earthquakes has been relatively small compared to other natural disasters, they have caused substantial infrastructure damage that has required time and money to repair. However, the other types of earthquakes that can occur in Washington have a potential to be much more devastating.

Washington State has many active surface seismic faults (WA DNR, 2019). Most of the known surface faults within Washington State exist on the Olympic Peninsula, in the Puget Sound Region, in areas near Bellingham, Washington, in the Cascade Mountain Range, near Yakima, Washington, near the Tri-Cities area, and in southeastern Washington. There are relatively few known faults in north-central and northeastern Washington. Surface faults within Washington State are expected to cause the largest local ground accelerations out of the three major types of earthquakes. The largest of these earthquakes are expected to possess moment magnitudes varying between 6.8 and 7.4 and peak spectral acceleration are expected to exceed 1.0 g near the epicenter of many of these surface fault earthquakes (USGS, 2019).

WHAT IS A DESIGN-LEVEL EARTHQUAKE?

A "design-level earthquake" is a theoretical earthquake event, here defined as being two-thirds of the magnitude of the maximum considered earthquake (MCE). The MCE is a risk-adjusted probabilistic event with a return period of 2,475 years. While not exact, the magnitude of the design-level earthquake event is similar to the magnitude of an earthquake event with a 475-year return period for many locations on the west coast of the United States. Earth scientists expect the average return period of a Cascadia Subduction Zone (CSZ) earthquake to be approximately 500 years. It is possible that a CSZ earthquake could be approximately the magnitude of the design-level earthquake for many parts of Washington State, depending on the particular earthquake characteristics. Engineers and building officials select a design-level earthquake to either design a new building or to check an existing building to predict its resilience to earthquake shaking. The design-level earthquake is mandated by the building code to represent the earthquake shaking hazards for the region where the building is located. It is used in the design of buildings to ensure that the building behaves in a predictable way if that design-level earthquake event should occur.

In addition to the two types of earthquakes listed above, Washington State can also experience subduction zone earthquakes produced by the Cascadia Subduction Zone (CSZ) off the coast of Western Washington. Subduction zones are known to produce earthquakes with magnitudes around and exceeding 9.0. Scientists have discovered evidence of 19 CSZ earthquakes in the last 10,000 years with an average return period of approximately 500 years (USGS, 2012). From a geologic perspective, these earthquakes occur at quite regular intervals. The most recent CSZ earthquake is believed to have occurred on January 26, 1700 (Satake, et al, 1996). A large magnitude earthquake on the CSZ is expected to affect areas from British Columbia, Canada, all the way to Northern California, with Washington and Oregon being heavily affected in between. While a CSZ earthquake is expected to affect the entirety of the State of Washington, the local ground shaking in locations such as Port Angeles, Seattle, Olympia, or Yakima are expected to be smaller for a CSZ event compared to surface fault ruptures with earthquake epicenters located close to each of those locations.

2.3 Local vs. State-Level Seismic Hazards

The different types of seismic faults and different types of earthquakes that can occur in Washington State affect the ways state and local governments must plan for these different earthquake events. Deep intraplate earthquakes occur the most frequently but tend to be the least damaging type of earthquake. While these earthquakes can cause costly damage that must be repaired, these earthquakes typically do not require significant state-level or national resources in order to recover. The fact that Washington State has experienced three deep intraplate earthquakes since 1949 may lead Washingtonian's to think that the earthquake risk in Washington State is not very high. However, shallow surface fault earthquakes and Cascadia Subduction Zone earthquakes are expected to be different.

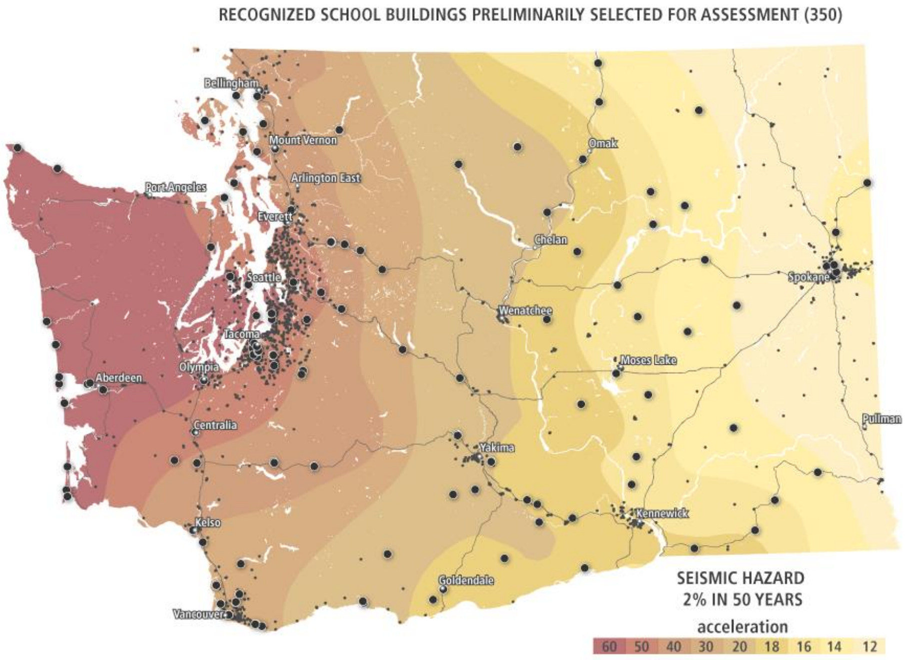
Large-magnitude, shallow-surface fault earthquakes of magnitudes between 6.8 and 7.4 are expected to dramatically affect the local area around the epicenters of these earthquakes. For example, if the Tacoma Fault, Seattle Fault, Southern Whidbey Island Fault, or Wallula Fault were to have a large rupture, this would likely cause the largest possible expected ground shaking close to their epicenters (WA DNR, 2019). For each of these examples, the cities of Tacoma, Seattle, Everett, the Tri-Cities Area, and their surrounding areas would be most greatly affected, respectively. While each of these cities would be devastated in these respective scenarios, areas of the state further than 50 miles away would likely only be minimally affected. While these earthquakes would be locally devastating close to their epicenters, and it is important for local cities and Washington State to prepare for their eventual rupture, the rupture of these faults will not cause high ground shaking that extends across the entire state. In addition to these four example surface faults, there are many other surface faults within Washington State. While it is likely prudent for local city governments to be most concerned about the high ground shaking that can occur from a local surface fault rupture, the state government must be sufficiently prepared to respond to both local surface fault ruptures and also ruptures on the Cascadia Subduction Zone.

In contrast to deep intraplate earthquakes and shallow surface fault earthquakes, a large magnitude earthquake (~9.0) on the Cascadia Subduction Zone fault is expected to greatly affect the entirety of Washington. The earthquake on this fault is expected to cause the largest shaking and a tsunami on Washington’s western coast with decreasingly large shaking in central and eastern Washington (WA DNR, 2013). From a statewide planning perspective, a large magnitude Cascadia Subduction Zone earthquake is likely to utilize the most state and federal resources out of all the known seismic hazards in Washington State.

2.4 School Selection Process

The WGS developed a preliminary list of school buildings that met the requirements in the capital budget and also captured Washington State School Seismic Safety Steering Committee (SSSSC) committee discussions about how to select schools based on seismic risk, year built, tsunami inundation zone, possible unreinforced masonry (URM), liquefaction susceptibility, rural/urban location, geographic distribution, and occupancy.

As noted, OSPI’s ICOS database list of 4,476 recognized permanent school buildings formed the overall statewide inventory of school buildings that were considered in the selection process. The Washington State DNR/WGS provided the project team with a preliminary list of 350 school buildings, and a document explaining how the school buildings were selected, on April 30, 2018.



Note: Preliminary selection of schools as large black dots and all non-assessed schools are small black dots (image courtesy WA DNR/WGS).

Figure 2.4-1. Map of Statewide Distribution of the Initial 350 Selected School Buildings (Courtesy WGS).

The outline below summarizes the school building selection process and criteria:

1. To facilitate and narrow the selection of school buildings to the project budget of 222 buildings, the total list of schools in OSPI's ICOS database was initially shortened by removing the following types of buildings:
    a. Portable buildings.
    b. Buildings constructed after 2010.
    c. Buildings where ASCE 41 assessments and geologic site investigations were known to have already been conducted.

2. The state was categorized into nine seismic hazard zones based on the probabilistic 2%/50-year peak ground acceleration (PGA) values from the 2014 long-term model National Seismic Hazard Map produced by the USGS.

3. Potential URM buildings were crosschecked with the data from the Washington State Department of Archaeology & Historic Preservation.

4. School buildings were selected from each of the nine seismic hazard zones, with selection based on the following process:
    a. Schools were "randomly" (as best possible) selected from north-to-south in each seismic zone.

   b. Possible URM buildings were selected, as they are the most seismically vulnerable building type if left unretrofitted. Where possible URM buildings were selected, other buildings on the same campus were also selected.
   c. Schools were selected, as best possible, to obtain a representative sample of “urban” versus “rural” schools as defined by the ICOS database and as required by the capital budget language.
   d. Schools were selected, as best possible, to obtain a representative sample of buildings of different ages, which also provided a range of different construction types.
   e. The selected schools provide a representative sample of schools in areas of liquefaction susceptibility.
   f. Several schools in tsunami inundation zones were selected. All the schools selected in tsunami inundation zones are also in the seismic hazard zone with the largest probabilistic PGA.

5. OSPI reviewed the list and removed several schools based on their own ICOS information.

6. Upon receipt of the preliminary list of 350 schools from the DNR/WGS, the project team reviewed the information and removed school buildings where seismic studies and/or seismic upgrades had already been conducted, or where school campuses on the list were identified as being in the process of (or had already completed) replacement or renovation.

7. Additional school buildings that were identified as already having been renovated or in the process of being replaced or renovated were removed from the list. Several early learning centers and schools that have already been demolished were also removed from the list.

8. Buildings constructed or seismically upgraded after 2010 were removed from the list, as these buildings are likely at a lower seismic risk than older buildings.

9. Final adjustments were made, based on school districts’ participation and feedback, to narrow the school building study list to 222 school buildings, with approximately 50 alternate buildings identified as substitutes to be used when needed. In some instances, discussions with the school districts concluded that some buildings were scheduled for repurposing or demolition and would not benefit this study.

2.5 Selected Schools

The appendices provide a detailed list of the 222 school buildings that were used in this study. Figure 2.5-1 shows a statewide map of the school district boundaries and with circles representing the study schools and triangles representing the five fire stations.

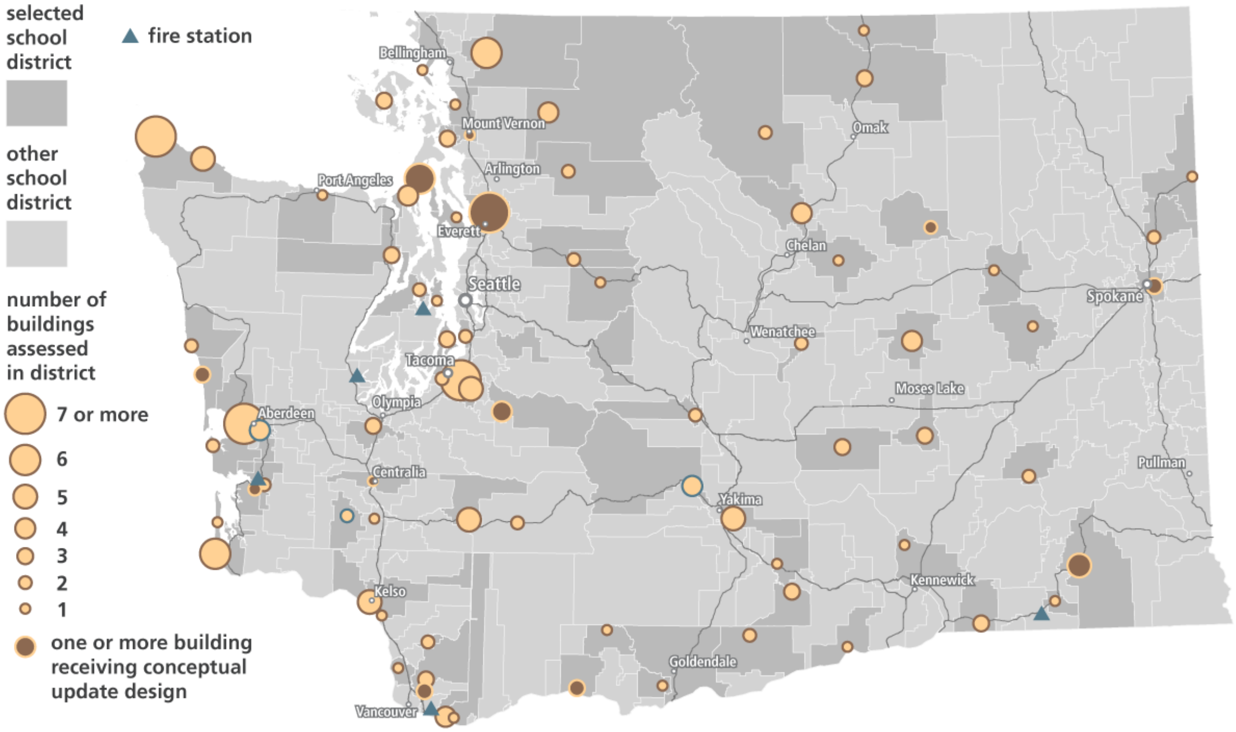


Figure 2.5-1. Statewide Distribution of the 222 Selected Schools and 5 Fire Stations (Courtesy WGS).

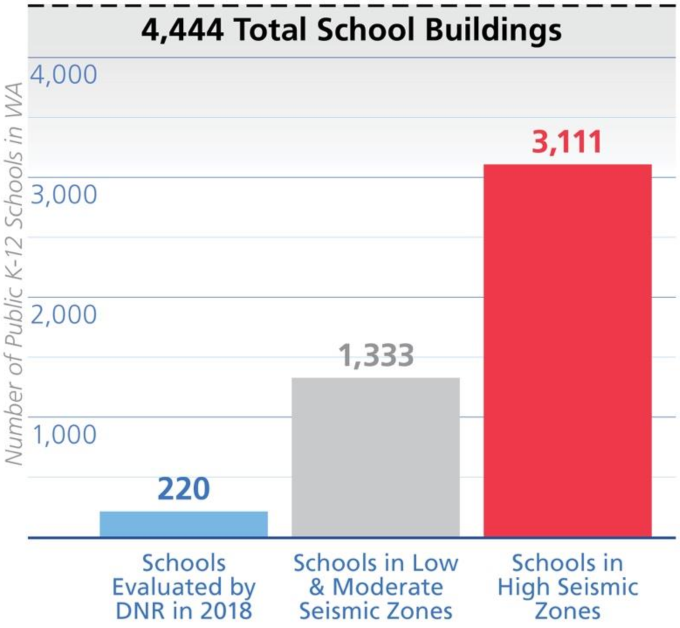


Figure 2.5-2. Breakdown of School Buildings Assessed and School Buildings in High vs. Low/Moderate Seismic Hazard Areas.

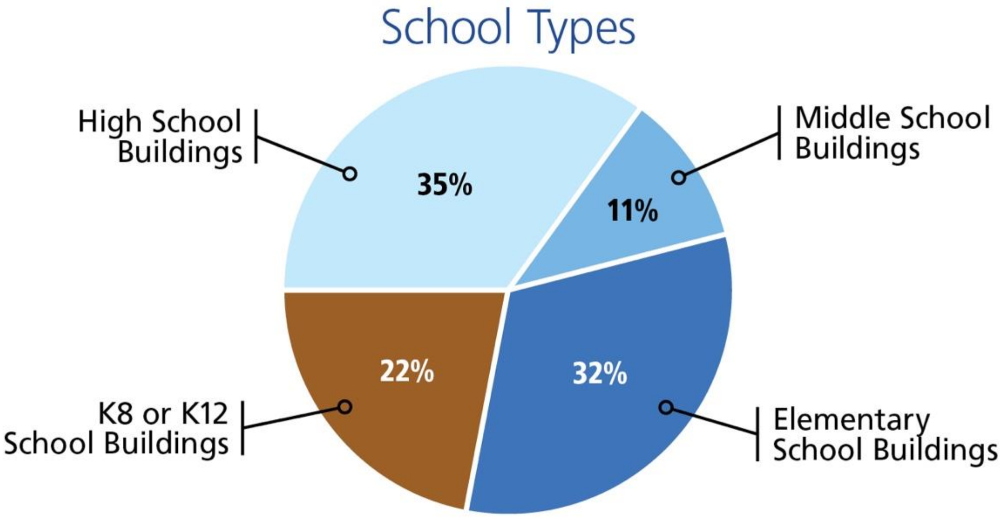


Figure 2.5-3. Distribution of School Building Functional Types of the School Buildings Assessed.

3.0 Seismic Evaluation Procedures

3.1 Performance-Based Earthquake Engineering

The seismic evaluation of building structures is based on performance-based earthquake engineering (PBEE) guidelines presented in ASCE 41-17 *Seismic Evaluation and Retrofit of Existing Buildings* (American Society of Civil Engineers, 2017). A general background of PBEE and an overview of seismic retrofit objectives, seismic hazard levels, seismic performance levels, and seismic evaluation and retrofit procedures are included in this section.

PBEE can be defined as the engineering of a structure to resist earthquake demands while also meeting the needs and objectives of school building owners and other stakeholders. PBEE allows for the design and analysis of building structures for different levels of seismic performance and allows these different levels of seismic performance to be related to the relative seismic hazard.

Historically, the seismic analysis and design of school buildings traditionally focused on one performance level: reducing the risk for loss of life in a design-level earthquake (life safety). The concept of designing essential facilities, such as hospitals, fire stations, and high-occupancy shelters, which are needed immediately after an earthquake, to a higher performance standard evolved after hospitals and other critical facilities were severely damaged in the 1971 San Fernando earthquake in California. That concept of more resilient design is balanced by the recognition that the cost of retrofitting existing buildings to higher levels of seismic performance may be onerous to both stakeholders and policy makers.

3.1.1 Overview of the ASCE 41-17 Seismic Standard

A comprehensive federal program was started in 1991, in cooperation with FEMA, to develop guidelines tailored to address the variation of seismic design performance levels. The first formal applications of performance-based seismic evaluation and design guidelines were the FEMA 310 *Handbook for the Seismic Evaluation of Buildings – A Prestandard (1998)* and FEMA 273 *NEHRP Guidelines for the Seismic Rehabilitation of Buildings (1997).* Following the release of these documents in the 1990s, three additional documents were released in the following years. Another prestandard document, FEMA 356 *Prestandard and Commentary for the Seismic Rehabilitation of Buildings,* was released in the year 2000.

In 2003, the first national standard seismic evaluation document, ASCE 31-03 *Seismic Evaluation of Existing Buildings*, was published. Following the release of ASCE 31-03, the first national standard seismic rehabilitation document, ASCE 41-06 *Seismic Rehabilitation of Existing Buildings*, was released in 2007. ASCE 31-03 and ASCE 41-06 superseded the PBEE documents produced in the previous decade. ASCE 31-03 and ASCE 41-06 used the general framework outlined by previous documents but were updated to incorporate the latest standard of PBEE at the time.

ASCE 31-03 and ASCE 41-06 still had flaws and, soon after the release of ASCE 41-06, an effort was undertaken to combine ASCE 31-03 and ASCE 41-06 into a single national standard document in an attempt to streamline the documents and eliminate discrepancies. ASCE 41 13, *Seismic Evaluation and Retrofit of Existing Buildings*, combines information from all of the previous documents, reflects advancements in technology and analysis techniques, and incorporates case studies and lessons learned from recent earthquakes. The newest version of this national standard is the updated ASCE 41-17, *Seismic Evaluation and Retrofit of Existing Buildings*, published in 2017.

ASCE 41-17 provides criteria by which existing school buildings can be seismically screened, evaluated, and retrofitted to attain a wide range of different performance levels when subjected to earthquakes of varying severity. This is the seismic screening standard that was used as the basis for this project.

3.1.2 Seismic Hazard Levels

Earthquake ground motions are variable and complicated, and every earthquake is different. An earthquake's intensity and energy magnitude depend on fault type, fault movement, depth to epicenter, and soil strata. In earthquake-prone areas, often very small and frequent earthquakes occur every few days or weeks without being noticed by humans, but large earthquakes that occur much less frequently can have a devastating effect on infrastructure and buildings and can result in the temporary displacement of large amounts of people. Earthquakes are unpredictable, and the precise location, intensity, and start time of an earthquake cannot be predicted before an event occurs. However, earthquake hazards for certain geographic areas are well understood based on historical patterns of earthquakes from the geologic record, measured earthquake ground motions, understanding of plate tectonics, and seismological studies.

Geologists, seismologists, and geotechnical engineers have categorized the seismic hazard for particular locations using probabilistic seismic hazard levels. Each seismic hazard level describes a different probabilistic earthquake magnitude based on the probability of a certain magnitude earthquake occurring in a given time period. The table below shows the commonly used seismic hazard levels, their corresponding probabilities of exceedance, and mean return periods.

Table 3.1.2-1. Probabilistic Seismic Hazard Levels and Mean Return Period.

Seismic Hazard Level	Probability of Exceedance in 50 Years	Mean Return Period (Years)
50%/50-year	50%	72
20%/50-year (BSE-1E)	20%	225
10%/50-year	10%	475
5%/50-year (BSE-2E)	5%	975
2%/50-year (BSE-2N)	2%	2,475

Seismic events with longer mean return periods and smaller probabilities of exceedance are associated with stronger seismic motions, larger ground accelerations, and more potential to damage facilities. Consequently, structures designed, retrofitted, or upgraded to a seismic hazard level with a longer return period will generally experience better performance in an earthquake than a structure designed or retrofit to a lower seismic hazard level.

ASCE 41-17 codifies four different Seismic Hazard Levels at which to seismically screen, evaluate, and/or retrofit/upgrade school buildings and other structures. For voluntary seismic evaluations and voluntary seismic upgrades, the owner of a school and the structural engineer can decide the Seismic Hazard Level at which it is appropriate to evaluate or retrofit a structure.

Historically, existing buildings have been seismically evaluated and retrofitted to a lower Seismic Hazard Level than would be typical in new building design. This approach has been historically justified for three primary reasons:

- Ensures that recently constructed structures are not immediately rendered seismically deficient due to minor building code changes.
- Existing buildings often have a shorter remaining life than a new building would; therefore, lower structural resiliency is tempered by a decreased probability of a major seismic event.
- Often the burdensome cost of retrofitting historic structures to a "new building equivalence" performance level is disproportionate to the incremental benefit.

3.1.3 Building Performance Levels and Seismic Retrofit/Upgrade Options

A target building performance level must be selected for the seismic design of a retrofit or upgrade of a school building. The target building performance levels are discrete damage states selected from among the infinite spectrum of possible damage states that a building could experience during an earthquake. The terminology used for target building performance levels is intended to represent goals for design but not necessarily predict building performance during an earthquake.

Since actual ground motions during an earthquake are seldom comparable to that used for design, the target building performance level may only determine relative performance during most events but not predict the actual level of damage following an event. Even given a ground motion similar to that used in design, variations from stated performance objectives should be expected. Variations in actual performance could be associated with differences in the level of workmanship, variations in actual material strengths, deterioration of materials, unknown geometry and sizes of existing members, differences in assumed and actual live loads in the building at the time of the earthquake, influence of nonstructural components, and variations in response of soils beneath the building.

ASCE 41-17 describes performance levels for structural components and nonstructural components of a structure. Historically, much attention was given to the seismic performance of structural components. In more recent years, it has been realized that attention to the seismic performance of nonstructural components can be just as important as, or more important depending on the facility, than the seismic performance of structural components. The ASCE 41-17 standard identifies the following Structural Performance Levels: Immediate Occupancy (IO), Damage Control, Life Safety (LS), Limited Safety (LTD-S), and Collapse Prevention (CP). The nonstructural Performance Levels identified in the standard are: Operational (OP), Position Retention (PR), and Life Safety (LS). Figure 3.1.3-1 is an example of recent earthquake damage to a primary school in central Mexico.

Figure 3.1.3-1. Structural Earthquake Damage to a Primary School in Central Mexico from the 2017 M7.1 Central Mexico Earthquake (Photo by Reid Middleton).

Individual Structural Performance Levels and Nonstructural Performance Levels are aggregated to form a combined Building Performance Level. Structural performance during an earthquake is related to the amount of lateral deformation or drift of the structure and the capacity or ability of the structure to deform. The ASCE 41-17 standard defines four specific common Building Performance Levels, as illustrated in Figure 3.1.3-2.

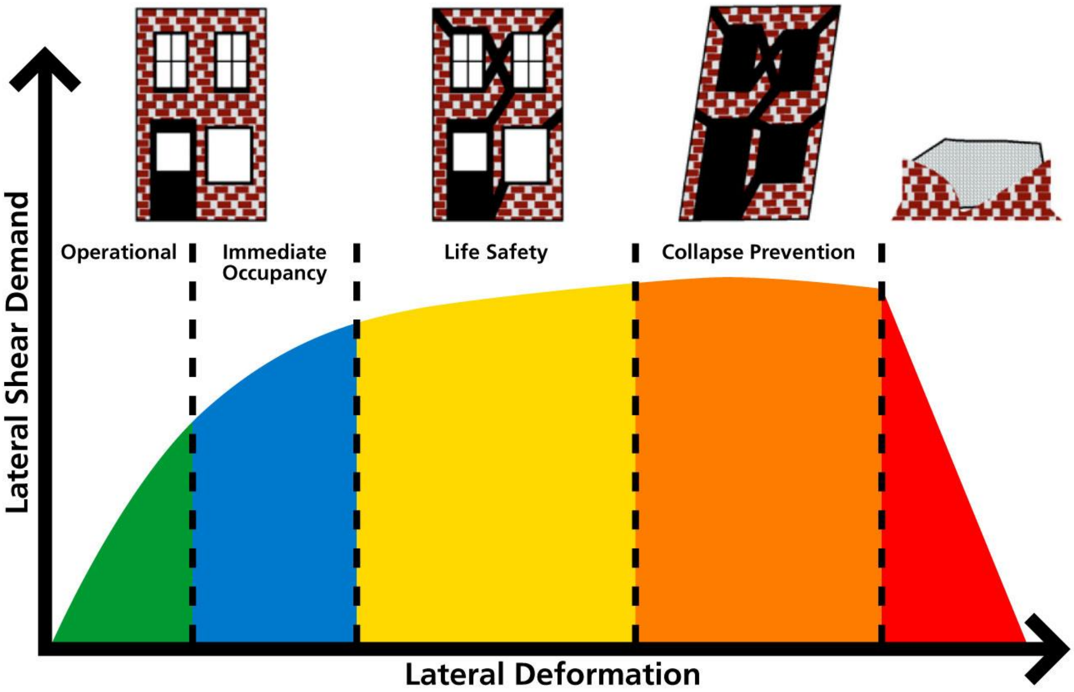


Figure 3.1.3-2. Building Performance Levels (FEMA).

A decision must be made for each building structure as to the acceptable behavior for different levels of seismic hazard, balanced with the construction cost of seismically retrofitting or upgrading a structure to obtain that behavior. ASCE 41-17 defines “baseline” basic performance objectives for structures based on their defined Risk Category. The Risk Category is the same as defined in the International Building Code (IBC) and ASCE 7.

Table 3.1.3-1 summarizes the approximate levels of structural and nonstructural damage that may be expected at the damage states that define the structural performance levels.

Table 3.1.3-1. Expected Damage for Different Building Performance Levels (FEMA 356, 2000).

	Building Performance Levels			
	Collapse Prevention (CP)	**Life Safety (LS)**	**Immediate Occupancy (IO)**	**Operational (OP)**
Overall Damage	Severe.	Moderate.	Light.	Very Light.
Permanent Drift	Large. 1% to 5%.	Some. 0.3% to 1%.	Negligible.	Same as Immediate Occupancy.
Remaining Strength and Stiffness After Earthquake	Little. Gravity system (columns and walls) functions, but building is near collapse.	Some. Gravity system functions, but building may be beyond economical repair.	Significant strength remaining. Minor cracking of structural elements.	Same as Immediate Occupancy.
Examples of Damage to Concrete Framing	Extensive cracking and spalling of concrete members. Crack widths greater than 1/4 inch.	Extensive cracking and spalling of concrete. Crack widths typically less than 1/4 inch and less than	Crack widths typically less than 1/8 inch and less than 1/16 inch in columns and joints.	Same as Immediate Occupancy.

	Building Performance Levels			
	Collapse Prevention (CP)	**Life Safety (LS)**	**Immediate Occupancy (IO)**	**Operational (OP)**
		1/8 inch in columns and joints.		
Examples of Damage to Steel Framing	Extensive yielding and buckling of steel members. Significant connection failures.	Local buckling of steel beams and braces. Moderate amount of connection failures.	Minor deformation of steel members, no connection failures.	Same as Immediate Occupancy.
Other General Description	Structure likely not repairable and not safe for reoccupancy due to potential collapse in aftershock.	Repair may be possible but may not be economically feasible. Repairs may be required prior to reoccupancy.	Minor repairs may be required, but building is safe to occupy.	Same as Immediate Occupancy.
Nonstructural Components	Extensive damage. Some exits blocked. Infills and unbraced parapets failed or at incipient failure.	Falling hazards mitigated, but many architectural, mechanical, and electrical systems are damaged.	Minor cracking of facades, partitions, and ceilings. Equipment and contents are generally secure but may not operate due to lack of utilities.	Negligible damage. All systems important to normal operation are functional. Power and other utilities are available, possibly from standby sources.
Comparison with New Building Design	Significantly more damage and greater risk.	Somewhat more damage and slightly higher risk.	Much less damage and lower risk.	Much less damage and lower risk.

3.1.4 Performance, Safety, Reliability, and Construction Cost

The seismic performance, safety, and reliability of a facility must be weighed against the relative importance and construction costs associated with a facility. It is impractical for the average building to be seismically designed or retrofitted to experience no damage following a major earthquake. However, steps can be taken to mitigate seismic hazards for new and existing structures.

Some facilities have more community importance or pose special risks to a community following an earthquake (for example, hospitals, fire stations, schools, or even facilities housing highly toxic substances). It is reasonable that important facilities be designed or retrofitted to a higher performance standard than the average structure. The relative importance of a facility must be weighed against the relative construction costs associated with facility construction. There are two types of construction costs associated with seismic hazards: the cost of initial construction or seismic retrofit construction and the costs to repair or replace a facility following an earthquake. The better a structure performs during an earthquake, the faster a structure can be returned to service and the less the repair costs will be for a structure following an earthquake. Building expected damage states during a seismic event can be directly linked to:

- Repair/Replacement Costs – Cost of restoring the facility to pre-earthquake condition.
- Public Safety – Number of critical injuries and casualties to building occupants.
- Downtime – Length of time taken to make repairs to return a structure back to service.

The graph in Figure 3.1.4-1 depicts estimated performance-related consequences compared with different increasing post-earthquake structural damage states (which correspond to the design Structural Performance Levels for a given seismic hazard).

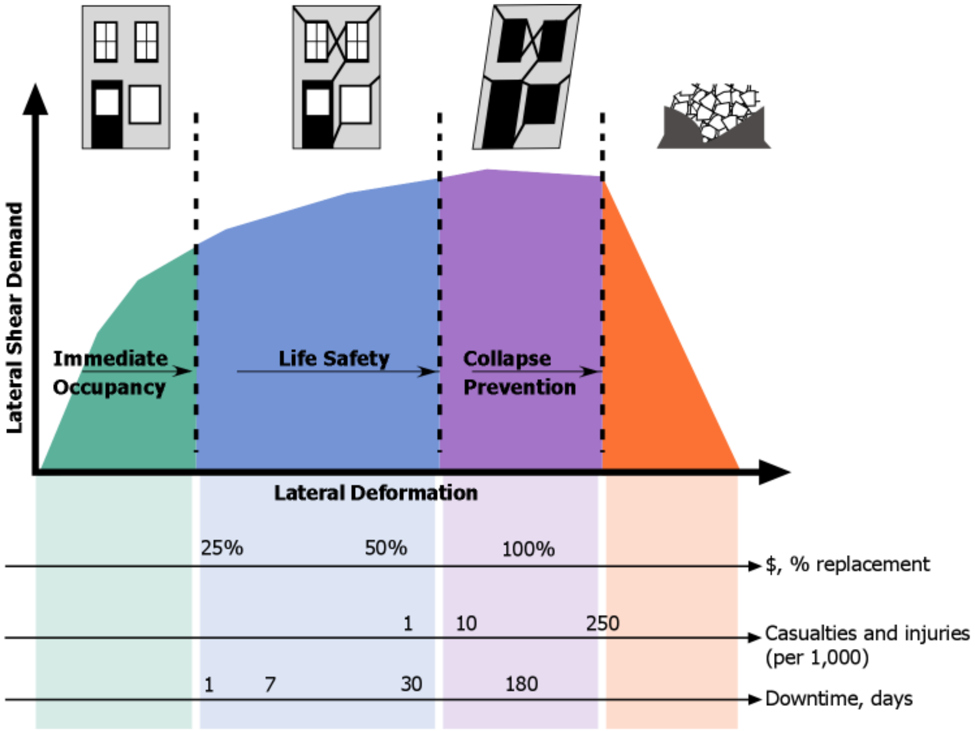


Figure 3.1.4-1. Estimated Seismic Performance-Related Consequences (Moehle, 2003)

Figure 3.1.4-2 presents the schematic relationship between different retrofit building performance objectives and probable seismic retrofit/upgrades program cost.

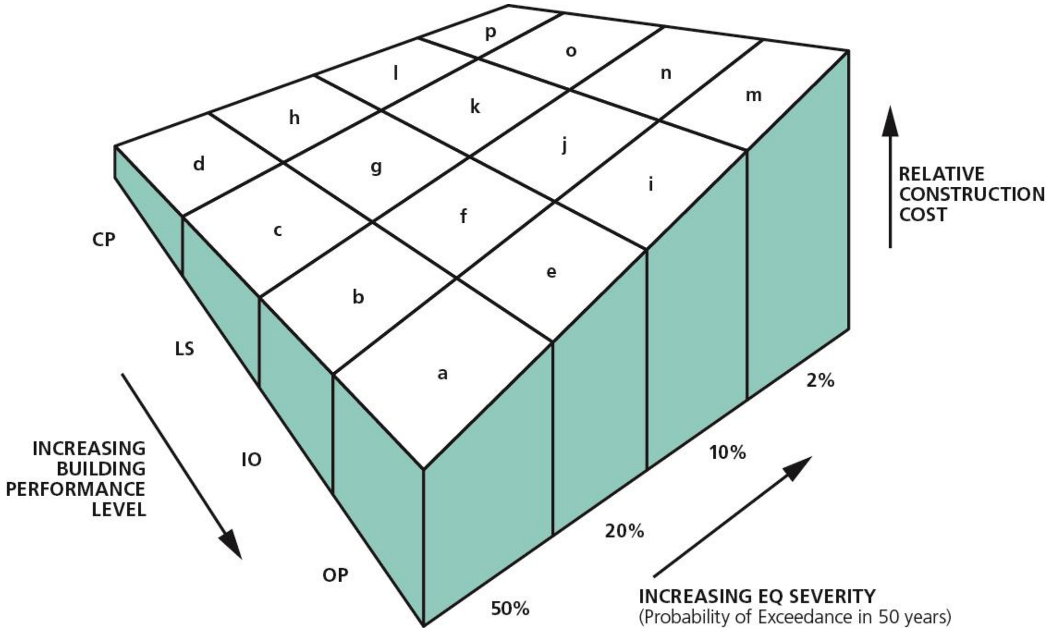


Figure 3.1.4-2. Surface Matrix of ASCE 41 Building Performance Levels Compared with Construction Cost (FEMA 274, 1997).

3.1.5 Seismic Performance of Nonstructural Components

Mitigation of nonstructural seismic hazards is a complex issue that is addressed independently in the ASCE 41-17 seismic evaluation and retrofit/upgrade standards. For much of the 20th century, little attention was given to designing nonstructural components and their anchorage for forces induced by earthquakes. Nonstructural component damage witnessed during earthquakes in more recent decades has demonstrated the importance of nonstructural component performance during earthquakes for life safety, post-earthquake safety, and building function.

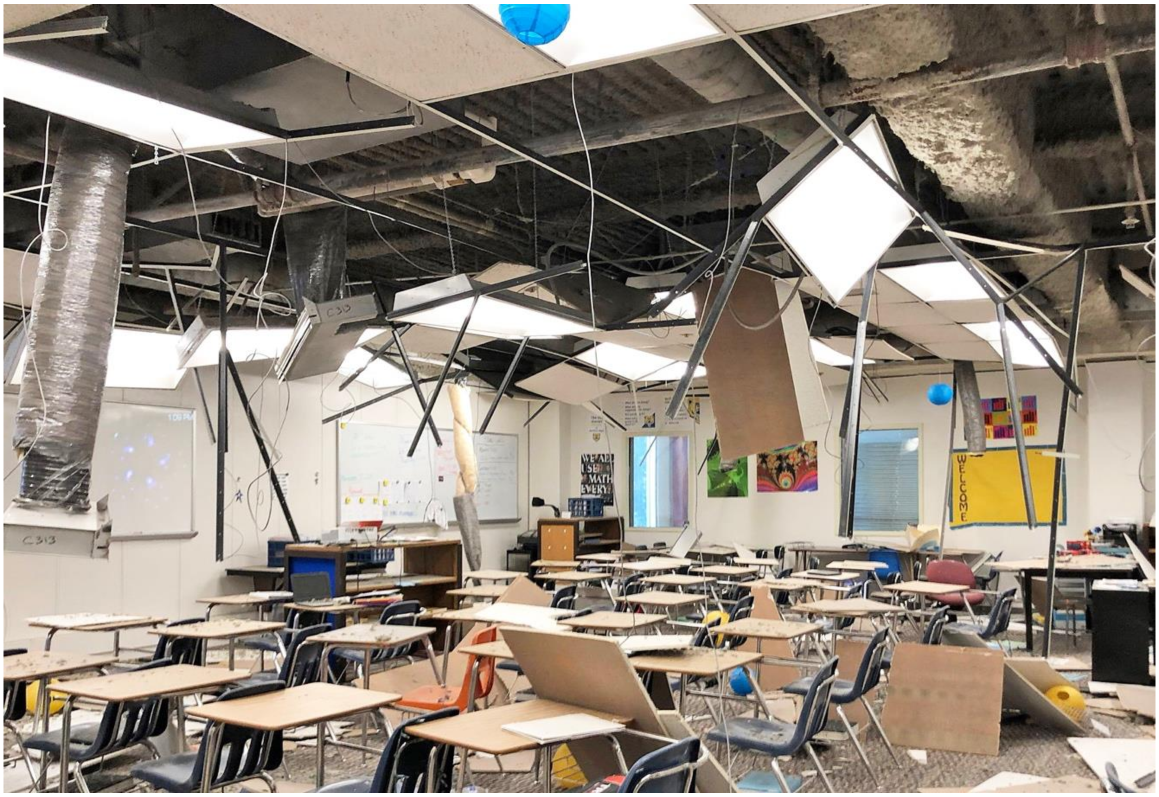


Figure 3.1.5-1. Nonstructural Earthquake Damage to a High School in Anchorage, Alaska, from the 2018 M7.0 Anchorage Earthquake (Photo by Reid Middleton, Inc.).

In addition to the hazards to life safety posed by nonstructural components, the cost to repair nonstructural components following an earthquake can be high and significantly delay the reopening of a school or other facility. In many cases, the cost to repair or replace nonstructural components can be higher than the cost of repairing structural components following an earthquake.

WHAT DOES NON-COMPLIANT MEAN?

"The ASCE 41 Seismic Screening, Evaluation and upgrade Standard is used to evaluate the structural and nonstructural systems and components for any type or size of individual school building. However, the procedure focuses on evaluating whether the building or building components pose a potential earthquake-related risk to human life. The procedure does not address code compliance, damage control, or other aspects of seismic performance not related to life-safety. The methodology involves answering two sets of questions: one set addresses the characteristics of 15 common structural types and the other set deals with structural elements, foundations, geologic site hazards, and nonstructural components and systems. These questions are designed to uncover the flaws and weaknesses of a building and are in the form of positive evaluation statements describing building characteristics that are essential if the failures observed in past earthquakes are to be avoided. Compliant statements identify conditions that are acceptable and non-compliant statements identify conditions in need of further investigation."

FEMA 424 Design Guide for Improving School Safety
in Earthquakes, Flood and High Winds, 2010

The relative monetary importance of nonstructural components can be seen in Figure 3.1.5-2 by comparing the relative construction costs of the contents, nonstructural components, and structural components of three types of typical new buildings. In offices and hotels, the building nonstructural components cost the most to construct, by a significant margin. In hospitals, the costs of constructing the building contents and nonstructural components are similar, but still far exceed the cost of the building structural systems. Nonstructural construction costs for public school buildings would be comparable to office buildings in this particular FEMA E-74 study.

Many nonstructural components, if adequately secured to the structure, are seismically rugged. However, mitigation of some nonstructural hazards (such as bracing for mechanical and electrical components within suspended ceiling systems or the improvement of ceiling systems themselves) can result in extensive disruption of occupancy. Repairing or replacing these components following an earthquake can also be very costly. These costs and benefits need to be taken into consideration when determining desired nonstructural performance levels and the goals of any seismic evaluation or retrofit/upgrade.

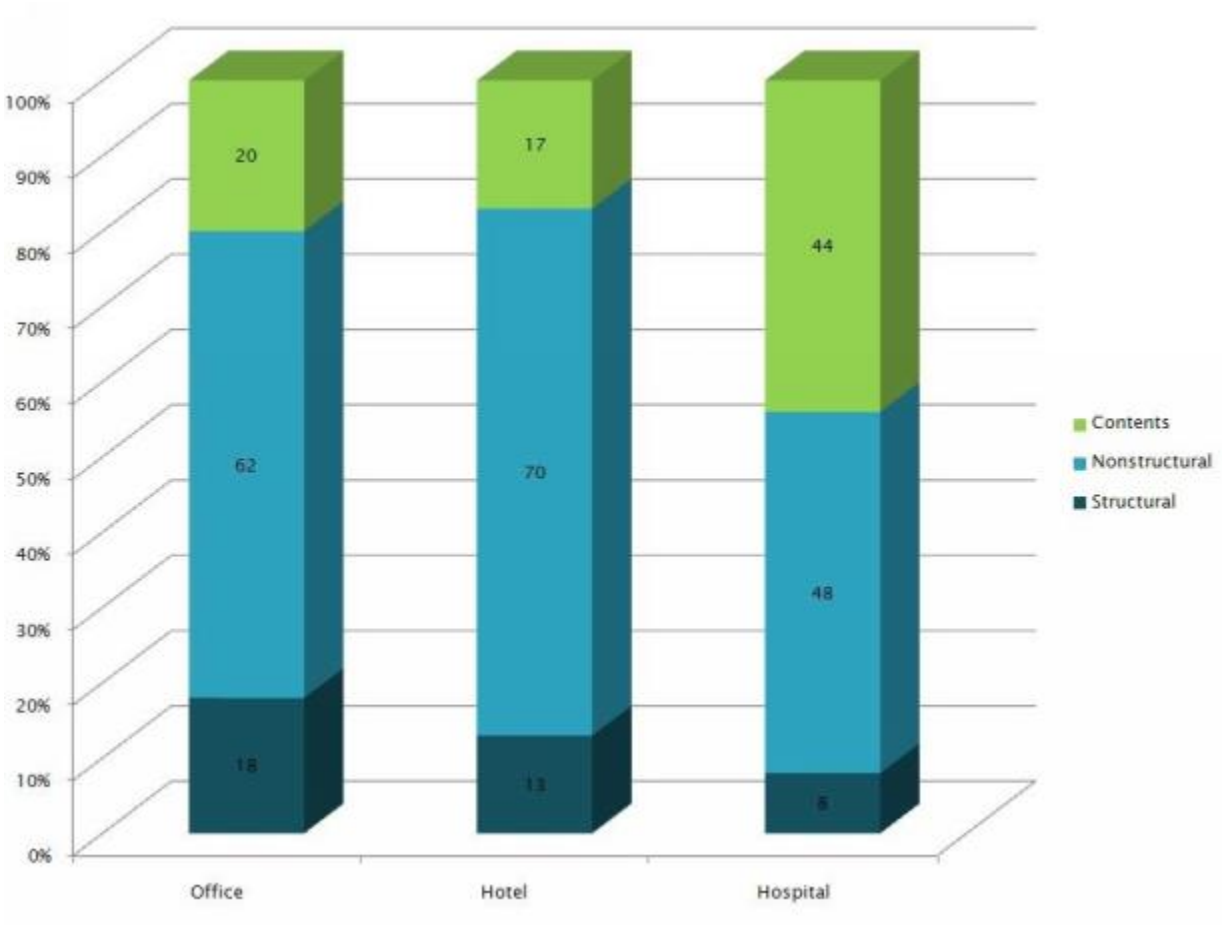


Figure 3.1.5-2. Typical Construction Costs for Different Building Component (FEMA E-74, 2012).

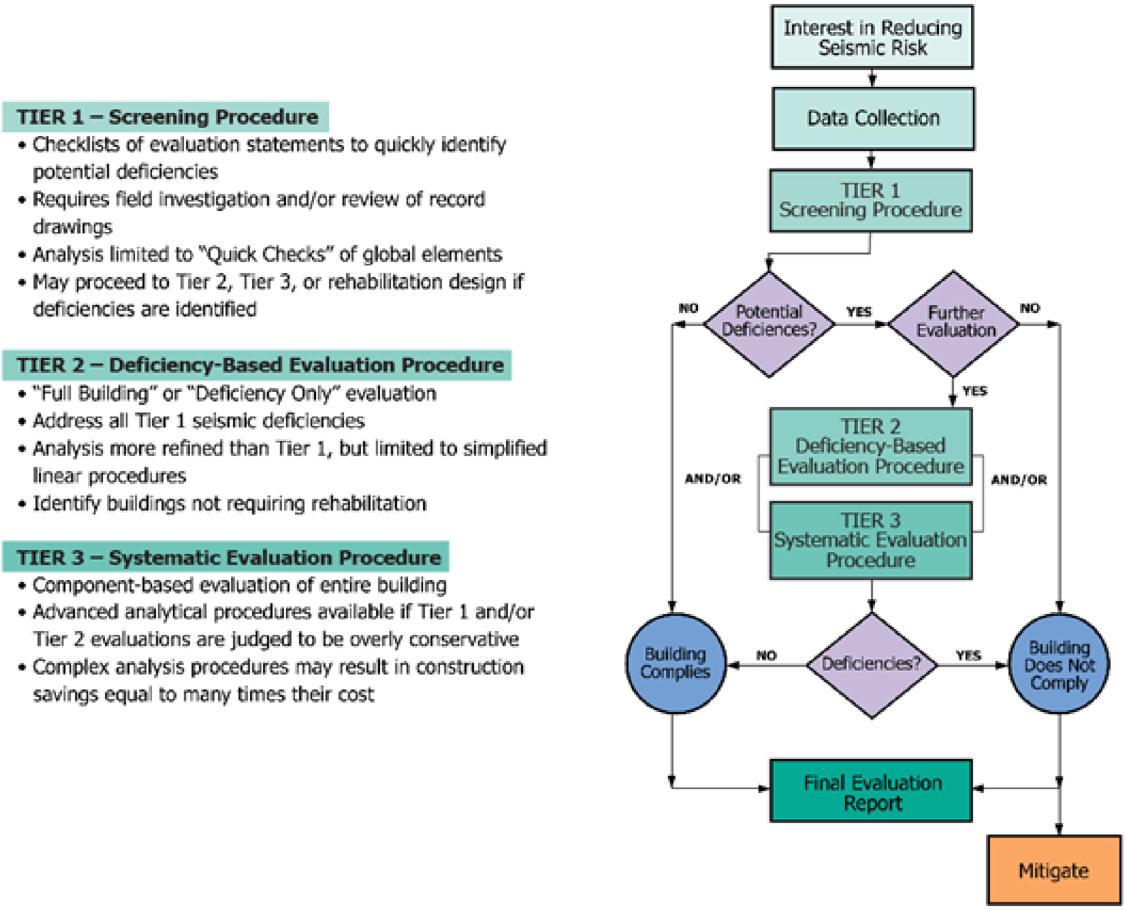
Finally, the use of the structure and required level of building performance need to be taken into consideration. For example, essential facilities that are expected to have minimal structural damage following the design earthquake must have nonstructural components that are designed to match the seismic performance level of the facility.

3.2 Seismic Screening, Evaluation, and Rehabilitation Procedures Overview

3.2.1 Seismic Screening and Evaluation

ASCE 41-17 provides a three-tiered seismic screening and evaluation procedure using performance-based criteria. The process for seismic evaluation is depicted in Figure 3.2.1-1. The evaluation process consists of the following three tiers: Screening Procedure (Tier 1), Deficiency-Based Evaluation Procedure (Tier 2), and Systematic Evaluation Procedure (Tier 3).

The Tier 1 seismic screening procedure was used in this study. The Tier 1 seismic screening checklists questions are designed to uncover the seismic safety flaws and weaknesses of a school building and are in the form of positive evaluation statements describing building characteristics that are essential if the failures observed in past earthquakes are to be avoided. Compliant Tier 1 seismic screening statements identify conditions that are acceptable and non-compliant Tier 1 seismic screening statements identify seismic safety issues or conditions in need of further evaluation.



TIER 1 – Screening Procedure
- Checklists of evaluation statements to quickly identify potential deficiencies
- Requires field investigation and/or review of record drawings
- Analysis limited to "Quick Checks" of global elements
- May proceed to Tier 2, Tier 3, or rehabilitation design if deficiencies are identified

TIER 2 – Deficiency-Based Evaluation Procedure
- "Full Building" or "Deficiency Only" evaluation
- Address all Tier 1 seismic deficiencies
- Analysis more refined than Tier 1, but limited to simplified linear procedures
- Identify buildings not requiring rehabilitation

TIER 3 – Systematic Evaluation Procedure
- Component-based evaluation of entire building
- Advanced analytical procedures available if Tier 1 and/or Tier 2 evaluations are judged to be overly conservative
- Complex analysis procedures may result in construction savings equal to many times their cost

Figure 3.2.1-1. Flow Chart and Description of ASCE 41 Seismic Evaluation Procedures (ASCE 31, 2003).

3.2.2 Seismic Rehabilitation

If seismic deficiencies are identified in the evaluation process, the owner and design team should review all initial conditions before proceeding with the hazard mitigation. Many conditions may affect the retrofit design significantly, such as results of the seismic evaluation and seismic hazard study, building use and occupancy requirements, presence of hazardous materials, and other anticipated future building remodeling, modernization, or replacement. The basic process for performance-based seismic retrofit/upgrades design is illustrated in Figure 3.2.2-1.

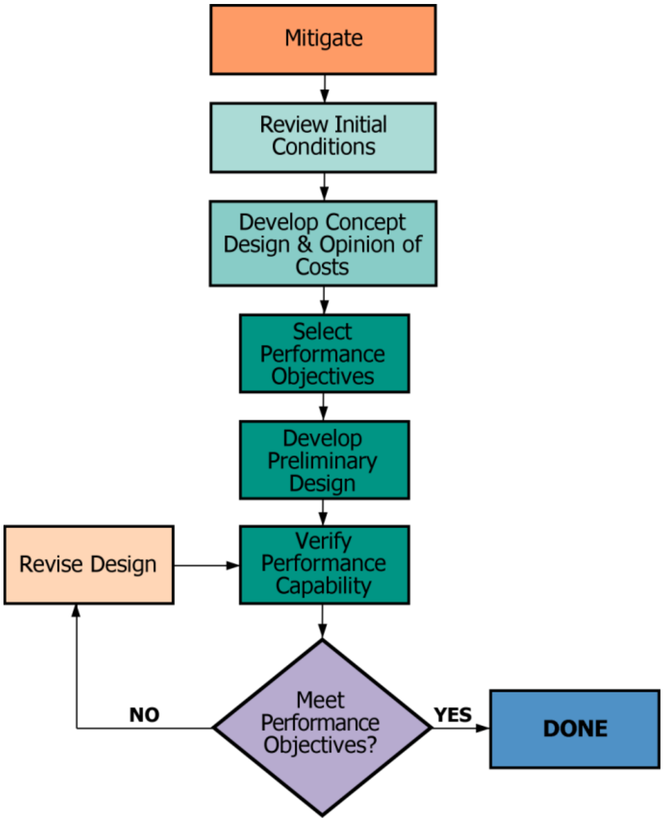


Figure 3.2.2-1. Seismic Rehabilitation Flow Diagram (ASCE 31, 2003).

Following the review of initial conditions, concept-level seismic retrofit/upgrade designs may be developed in order to determine rough opinions of probable construction costs for one or more seismic retrofit/upgrades performance objectives. This is the level of design and cost estimating work that has been performed for the 15 different school buildings included in this statewide school seismic assessments study. The school district (owner) and their design team can then develop a seismic rehabilitation strategy considering the associated costs and feasibility. Schematic and final design can then proceed through an iterative process until verification of acceptable building performance is obtained.

3.3 Field Investigation and Data Collection Processes

To minimize the impacts to schools and their operations, the project team performed the field investigations phase of work during the limited summer break window in the 2017/18 academic calendar. To streamline the data collection and seismic screening process, we developed a mobile application using the Fulcrum mobile database collection platform for data collection and reporting. This mobile application allowed our structural engineers to input field-collected data directly into the ASCE 41-17 structural and nonstructural seismic screening checklists, as well as site photography and related field documentation, while working remotely at each project site.

This data collection application technology was custom-designed by Reid Middleton in order to allow the field work and seismic screenings to be performed in an efficient, accurate, and uniform manner in the field, providing data that can be compiled, reviewed, and checked (if necessary) in real-time from multiple locations.

3.3.1 Seismic Screening Field Investigation Limitations

The field observations at each site were performed by an individual Structural Engineer. Consequently, visual examinations were limited to areas and building elements that were observable and safely accessible. Observations requiring access to confined spaces, potential hazardous material exposure, use of an unsecured ladder, work around energized electrical equipment or mechanical hazards, areas requiring OSHA fall-protection, steep or unstable slopes, deteriorated structural assemblies, or other field conditions deemed to be potentially unsafe by the engineer, were not performed. Removal of finishes (e.g., gypsum board, lathe and plaster, brick veneer, or roofing materials) for access to concealed conditions or to expose elements that cannot otherwise be visually observed and assessed, along with material sampling and testing, was beyond the scope of this project. The ASCE 41 Tier 1 seismic screening checklist items that are not documented due to access limitations are noted as unknown.

3.4 Seismic Screening and Evaluation Criteria

The following information was used by the project team in the field assessment and seismic evaluations as default criteria to help maintain consistency of the technical work.

3.4.1 Material Properties

All material properties were taken from information on available construction documents. In the absence of specified existing material properties, default ASCE 41-17 material properties were employed in the seismic screening evaluations. For site conditions and foundation information in the absence of an available geotechnical engineering report, the default foundation and soil bearing pressure values with accordance to Chapter 18 of IBC 2015 were utilized.

3.4.2 Dead Loads (Seismic Weight)

Dead loads are all permanent non-changing loads in a structure, such as floor and roof assemblies, wall assemblies, or mechanical and electrical equipment. These dead loads are also the primary contributor to the effective seismic weight of a building that is used to calculate the seismic force demands on a given building. These dead loads are often expressed in pounds per square foot (psf) and are applied over floor, roof, or wall areas to determine a total effective seismic weight. In the absence of specific record drawing information, the following tables were developed, based on our team's collective experience in evaluating the various building types and vintages of construction, and used to calculate the seismic force demands for specific Tier 1 screening evaluation statements.

Table 3.4.2-1. Roof/Floor Dead Loads (includes allowance for architectural finishes).

Load	Value	Example
Wood Roof		
Heavy	30 PSF	Tile
Medium-Heavy	20 PSF	Built-Up, Car Decking
Medium	15 PSF	Shingle
Light	10 PSF	
Wood Floor		
Heavy	40 PSF	Concrete Topping
Medium-Heavy	30 PSF	Gypcrete Topping
Medium	20 PSF	T&G Decking
Light-Medium	15 PSF	
Light	10 PSF	No Floor Finish
Untopped Metal Deck Roof		
Heavy	30 PSF	Tile
Medium-Heavy	20 PSF	Built-Up
Medium	15 PSF	Shingle, SSMR
Light	10 PSF	
Topped Metal Deck Roof/Floor		
Heavy	80 PSF	
Medium-Heavy	65 PSF	
Medium	45 PSF	
Light-Medium	30 PSF	
CIP Slab Roof/Floor		
Heavy	185 PSF	14-inch Slab
Medium-Heavy	160 PSF	12-inch Slab
Medium	110 PSF	8-inch Slab
Light-Medium	100 PSF	6-inch Slab
PC Slab Roof/Floor		
Heavy	125 PSF	
Medium-Heavy	110 PSF	
Medium	100 PSF	
Light-Medium	80 PSF	
Light	60 PSF	

Table 3.4.2-2. Wall Dead Loads – Structural and Exterior Wall (Distributed over Floor Area).

Load	Value	Example
Wood/Light-Gauge Walls		
Heavy	25 PSF	Brick Veneer
Medium-Heavy	15 PSF	Stucco
Medium	10 PSF	
Light	5 PSF	
Concrete Walls		
Heavy	45 PSF	12-inch Concrete
Medium-Heavy	35 PSF	10-inch Concrete
Medium	30 PSF	8-inch Concrete
Light-Medium	20 PSF	6-inch Concrete
URM Walls		
Heavy	45 PSF	Four-Wythe, 17 inches
Medium	35 PSF	Triple-Wythe, 13 inches
Light-Medium	25 PSF	Double-Wythe, 9 inches
Light	15 PSF	Single-Wythe, Plastered, 4 inches
CMU Walls		
Heavy	35 PSF	12-inch CMU Solid
Medium-Heavy	30 PSF	10-inch CMU Solid
Medium	25 PSF	8-inch CMU Solid
Light-Medium	15 PSF	6-inch CMU Solid

Table 3.4.2-3. Column Dead Loads – (Distributed over Floor Area).

Load	Value
Concrete Columns	10 PSF
Steel Columns	4 PSF

Table 3.4.2-4. Partition Dead Loads – (Distributed over Floor Area).

Load	Value	Example
Interior Partitions		
Heavy	70 PSF	6-inch CMU
Medium-Heavy	35 PSF	6-inch Hollow Clay Tile
Medium	15 PSF	
Light	10 PSF	Wood/Metal

Table 3.4.2-5. Mechanical Equipment Dead Loads – (Distributed over Floor Area).

Load	Value
Heavy	20 PSF
Medium	10 PSF
Light	5 PSF

Table 3.4.2-6. Miscellaneous Superimposed Dead Loads.

Load	Value
MISC	5 PSF
Added Weight	( ) PSF

3.4.3 Seismic Hazard Level

The following seismic hazard levels used in the study conform to ASCE 41-17.

Risk Category[a]	III
Structural Performance Objective[b] Performance	Limited Safety (LTD-S) Structural Level at BSE-2E Seismic Hazard Level.
Nonstructural Performance Objective[c] Level	Life Safety (LS) Nonstructural Performance at BSE-1E Seismic Hazard Level.
Site Class[d]	Based on ICOS database and values provided by site-specific surveys conducted by WGS as part of this study.

Notes:

a. All the school buildings are evaluated as Risk Category III structures as defined by ASCE 7-10 Section 1.5. Generally, schools with more than 250 occupants are classified as Risk Category III, and schools with less than 250 occupants are classified as Risk Category II. While it is possible that some school buildings may technically be classified as Risk Category II based on their current occupancy (quantity of occupants), we elected to evaluate all structures as Risk Category III structures for the following reasons:

   1. This study evaluates a small sample of the entire number of the school buildings in Washington State. The total quantity of school buildings in Washington State is approximately 4,476; 222 buildings are included for evaluation in this study. Using the same Risk Category to evaluate all structures means that the results can be extrapolated, where appropriate, to other structures not included in this study.
   2. Using a consistent Risk Category for all buildings means that the same criteria is used for all buildings and allows for consistent comparisons between buildings of the same construction type and across buildings of different construction types regardless of the number of occupants.

b. The Structural Performance Objective is Limited Safety (LTD-S) at the BSE-2E Seismic Hazard Level according to Table 2-2 of ASCE 41-17, with footnote c stating, "For Risk Category III, the Tier 1 screening checklists shall be based on the Collapse Prevention Performance Level (S-5), except that checklist statements using the Quick Check procedures of Section 4.4.3 shall be based on M_s factors taken as the average of the values for Life Safety and Collapse Prevention." The BSE-2E Seismic Hazard Level makes use of a probabilistic earthquake event with a probability of exceedance of 5% in 50 years or a return period of 975 years.

c. The Nonstructural Performance Objective was selected as Life Safety (LS) at the BSE-1E Seismic Hazard Level. This performance level was selected in lieu of Position Retention (PR) for the following reasons:

   1. This performance level is intended to allow building occupants to exit the building after an earthquake while minimizing the risk of fatalities. It is generally accepted as the minimum standard for buildings of any type.
   2. The amount of time and budget allotted for this project does not allow for a more-detailed evaluation of nonstructural systems required when evaluating to Position Retention.

d. Initially, the ICOS database site classifications were used to conduct the seismic evaluations until the DNR/WGS field work concluded. Once DNR/WGS's field work was concluded, the site classifications were updated based on the information provided by DNR/WGS, and these revised values were used for the seismic evaluation.

4.0 Seismic Screening Findings

4.1 Finding Summary and Database-Wide Trends

4.1.1 ASCE 41 Tier 1 Structural Findings Summary

The ASCE 41 Tier 1 structural evaluation results show that many buildings have items that are identified as seismic vulnerabilities. In general, older buildings are known to possess more seismic vulnerabilities than newer buildings. Older buildings were generally designed for lower levels of seismic force and with less interconnectedness than new buildings. Prior to the first Uniform Building Code in 1927, no seismic considerations were used in the design of buildings. URM buildings and nonductile concrete buildings are shown to categorically possess the highest percentages of noncompliant structural evaluation items. These results confirm that the evaluated school buildings included in this study possess seismic vulnerabilities that are in line with the expert's expectations that led to the formation of this study.

Figure 4.1.1-1 is a chart of the total number of permanent, public K-12 Washington school buildings (grey) categorized by decade built (or the date there was a last major seismic upgrade) and material type. This information is based on the OSPI's Information and Condition of Schools (ICOS) database. Figure 4.1.1-2 is a similar chart only of the schools assessed in this report and their construction type (wood, concrete, etc.) are color coded.

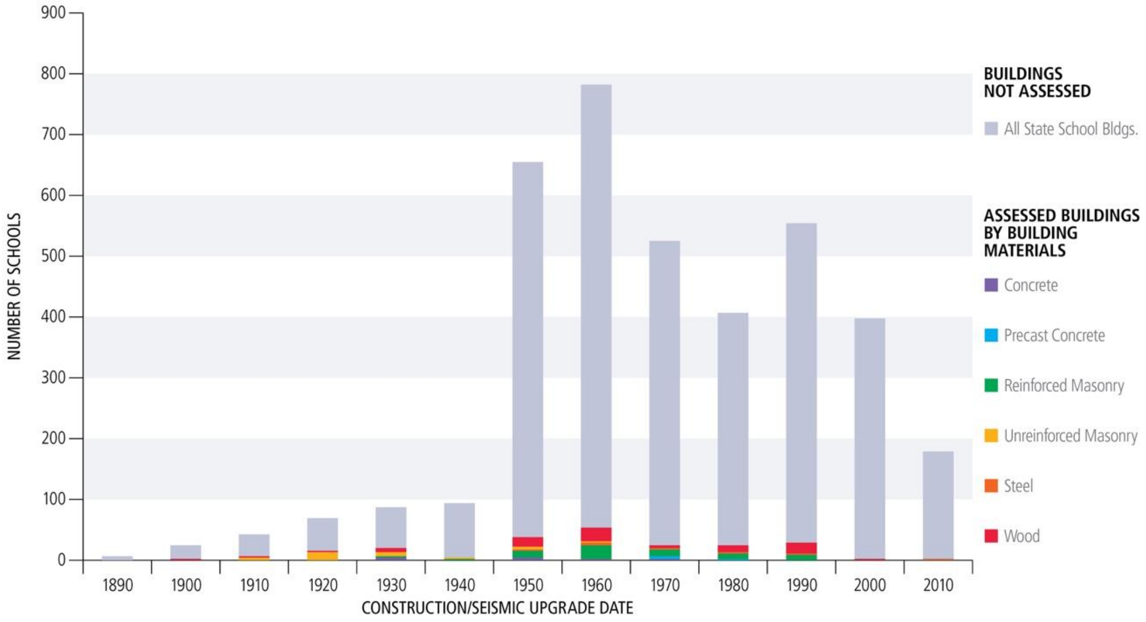


Figure 4.1.1-1. Distribution by Decade Built & Primary Construction Type of Buildings Assessed Compared to Overall Numbers of School Buildings Statewide.

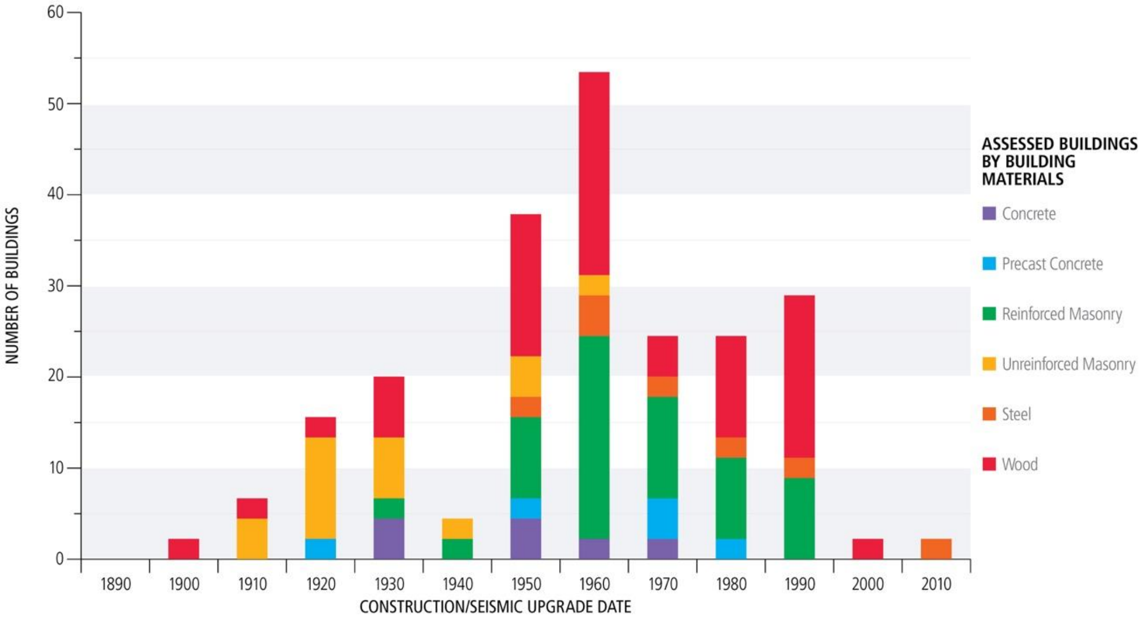


Figure 4.1.1-2. Distribution by Decade Built & Primary Construction Type of Buildings Assessed.

4.1.2 EPAT Summary

The Washington School Earthquake Performance Assessment Tool (EPAT) is a spreadsheet tool developed for the State of Washington that calculates expected earthquake performance of schools, based on basic school characteristics, using FEMA Hazus fragility curves. FEMA Hazus is a standardized natural hazards loss estimation tool initially developed by FEMA in the 1990s. Hazus uses basic building information and construction type fragility functions to estimate the probable losses of buildings from an earthquake. The loss estimates are probabilistic, meaning that the single-value estimates only represent the median expected outcome; the range of probabilities of the outcomes are not represented.

Table 4.1.2-1 shows the EPAT median, average, maximum, and minimum results for all 222 buildings included in the study. The information displayed in the table is based on each building’s existing configuration and estimations of loss, life safety risk level, and post-earthquake tagging as expected for the ASCE 7 design earthquake.

Table 4.1.2-1. Washington State Schools EPAT Summary Results (222 School Buildings).

Calculated Value	Median	Average	Maximum	Minimum
Building Damage Estimate Ratio (Amount of Building that is Damaged)	43%	45%	95%	5%
Probability Building is Not Repairable	22%	35%	82%	9%
Life Safety Risk Level	Moderate	-	Very High	Very Low
Most Likely Post-Earthquake Tagging	Red*	-	Red*	Green*

*Red = Unsafe to Occupy, Yellow = Restricted Building Access, Green = No Restrictions on Building Access

The EPAT summary results in Table 4.1.2-1 show that the median building is expected to have approximately half of its building elements damaged. It is expected that almost a quarter of the buildings included in the study will not be repairable, meaning these buildings will likely need to be demolished. The most likely post-earthquake tagging identified by EPAT is “Red”, meaning the majority of school buildings included in the study are expected to not be safe to occupy following the design earthquake event.

4.2 ASCE 41 Tier 1 Seismic Screening Findings and Data Analyses Trends

ASCE 41 Tier 1 seismic screening evaluations were conducted on the 222 school buildings included in the study. This section describes the findings and trends associated with these seismic screening evaluations. The ASCE 41 Tier 1 seismic screening process is conducted by reviewing generalized building seismic screening checklist statements from ASCE 41 and determining whether a building structural element complies with that particular seismic screening statement or is noncompliant with that particular seismic screening statement.

For about 35 percent of the buildings studied, original record construction drawings and other building construction and configuration information were not available for review, so the engineering data gathering was limited to visual observations by the project team of licensed structural engineers. Where building component seismic adequacy was unknown due to lack of available information, the unknown conditions were indicated on the ASCE 41-17 Tier 1 seismic screening checklists.

This section describes the results of the ASCE 41 Tier 1 seismic screening findings and trends by displaying the Tier 1 information that is “noncompliant” and “noncompliant or unknown”. This way, the information displayed reflects both the seismic structural vulnerabilities and the uncertainty associated with the data gathering.

In many cases, based on the vintage and the structural system of a building, it is suspected that a certain portion of “unknown” items would be seismically “noncompliant” based on the Tier 1 screening checklists if more detailed information were available for review. It is logical to evaluate building vulnerability and risk based on the multiple factors.

4.2.1 Data and Statistics for All School Building Types

The 222 buildings included in the study were selected by DNR and the project team with the intent of providing a sample of school buildings throughout Washington State. Rural and urban school buildings were selected. In addition, the selection of school buildings was geographically distributed across the state. Importantly, the numbers of school buildings were not proportionally selected based on the vicinity's population density. As a result, the density of selected school buildings is not proportional to Washington State population density.

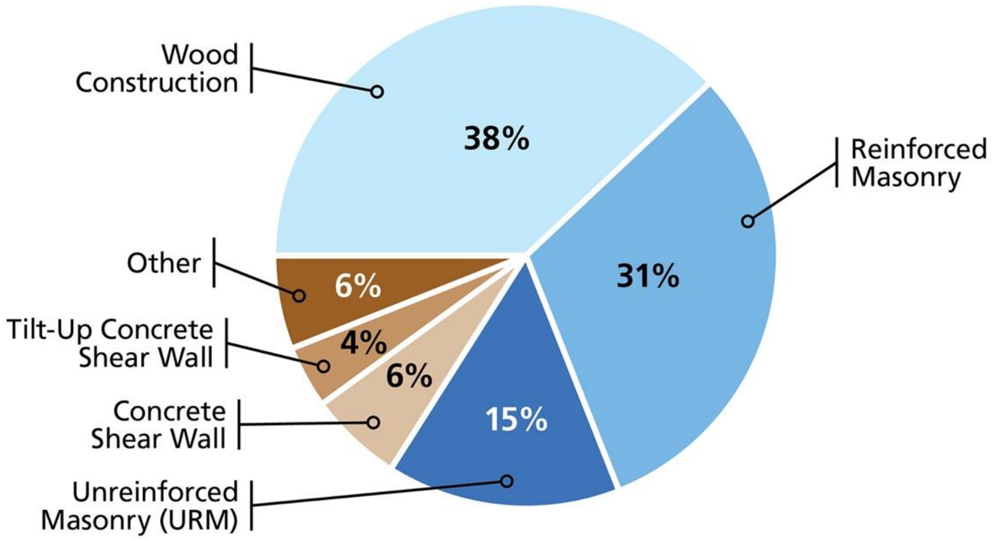


Figure 4.2.1-1. Distribution of School Building Construction Types Investigated within this Study.

Table 4.2.1-1 shows statistics about the 222 buildings investigated for this study.

Table 4.2.1-1. ASCE 41 Tier 1 School Building Statistics (222 School Buildings).

Parameter	Value	Notes
Average Year of Construction	1963	Washington State has many older school buildings built in the early 20th Century, with significant amounts of construction occurring all the way into the 21st Century. A significant percentage of Washington State school buildings were built in the 1950s and 1960s, resulting in this average year of construction.
Median Year of Construction	1963	The average and median year of construction are the same, indicating that the selected buildings are not heavily weighted in one direction around the median.
Geographic Centroid	47.2234° N, 121.7844° W	The geographic centroid is the "center of area" of all the buildings in the study. In effect, it is a weighted average of each school building location. This geographic centroid is located slightly southwest of Snoqualmie Pass.

Table 4.2.1-1. ASCE 41 Tier 1 School Building Statistics (222 School Buildings).

Parameter	Value	Notes
Average Square Footage	27,358	The average square footage exceeds the median square footage, meaning there are a smaller number of buildings included in the study with very large square footages that skew the average higher.
Median Square Footage	18,940	The median square footage is smaller than the average square footage, meaning that, while there are some buildings that are very large (largest is 121,400 square feet), the majority of buildings possess square footage values less than this number.
Median BSE-2N S_S	1.00 g	The BSE-2N earthquake is defined by ASCE 41 as the risk-adjusted Maximum Considered Earthquake (MCE$_R$). The median school building in the study possesses a horizontal short-period spectral acceleration value (S_S) that is equal to the acceleration of gravity (1.0 g).
Median BSE-2N S_1	0.42 g	The BSE-2N earthquake is defined by ASCE 41 as the risk-adjusted Maximum Considered Earthquake (MCE$_R$). S_1 denotes the horizontal spectral acceleration at a period of 1 second.
Median BSE-2E S_{XS}	0.85 g	The BSE-2E earthquake is defined by ASCE 41 as an earthquake with a probability of exceedance of 5% in 50 years. This is the primary earthquake level used for evaluation in accordance with ASCE 41-17.
Median BSE-2E S_{X1}	0.52 g	The BSE-2E earthquake is defined by ASCE 41 as an earthquake with a probability of exceedance of 5% in 50 years. This is the primary earthquake level used for evaluation in accordance with ASCE 41-17.
Median BSE-1N S_{XS}	0.70 g	The BSE-1N earthquake is defined by ASCE 41 as two-thirds of the MCE$_R$ earthquake. It is most similar to an earthquake with a probability of exceedance of 10% in 50 years for most locations. It is used by ASCE 41 to define the level of seismicity. The median building included in the study is located in an area of “High” seismicity.
Median BSE-1N S_{X1}	0.42 g	The BSE-1N earthquake is defined by ASCE 41 as two-thirds of the MCE$_R$ earthquake. It is most similar to an earthquake with a probability of exceedance of 10% in 50 years for most locations. It is used by ASCE 41 to define the level of seismicity. The median building included in the study is located in an area of “High” seismicity.

4.2.2 Data and Statistics for Wood (W2) School Buildings

Out of the 222 school buildings investigated through this study, 86 of these buildings are of wood construction. This accounts for 39 percent of the buildings and is the largest single proportion of school building type within the study.

The average and median year of construction of the 86 wood school buildings is 1968, and 1967, respectively. This year average for wood school buildings is approximately five years newer than the typical building type included in the study. This is likely because, prior to the 1940s, unreinforced masonry construction was the dominant material used for school construction.

However, some wood buildings were constructed prior to 1940, and wood was the most common type of construction for schools throughout the remainder of the 20th Century and into the 21st Century.

The wood school buildings have an average and median occupied space area of 24,590 square feet (SF), and 18,350 SF, respectively. The average wood building is about 10% smaller than the average school building in the study. The largest wood building is 97,150 square feet.

The most significant noncompliant findings from the Tier 1 checklist screening for wood (W2) school buildings were:

1. Load Path: About 35% of the wood school buildings had noncompliant or unknown seismic load paths that provide a well-defined seismic load path, including structural elements and connections, that serves to transfer the inertial forces associated with the mass of all elements of the building to the foundation.

2. Shear Stress: About 40% of the wood school buildings investigated had overstressed wood shear walls. This typically means that the capacity of the existing shear walls that provide lateral support for the school building may not be able to reliably resist earthquake loads.

3. Diaphragms: About 30% of the wood school buildings had weak diagonally sheathed or unblocked diaphragms (roof or floor). This typically means that a weakness may exist in a roof or floor to reliably transfer seismic loads to lateral elements such as shear walls and frames.

Tables 4.2.2-1 through 4.2.2-5 presents more detailed statistics and seismic screening data about the wood (W2) buildings included in this study.

Table 4.2.2-1. ASCE 41 Tier 1 Wood (W2) Building Statistics.

Parameter	Value	Notes
Average Year of Construction	1968	The average wood type of school building is approximately 5 years newer than the typical building type included in the study. This is because, prior to the 1940s, unreinforced masonry construction was the dominant material used for school construction. However, some wood buildings were constructed prior to 1940, and wood was the most common type of construction for schools throughout the 20th Century and into the 21st Century.
Median Year of Construction	1967	The average value is similar to the median year of construction, indicating that the selected buildings are not heavily weighted in one direction around the median.
Geographic Centroid	47.3887° N, 121.4394° W	The geographic centroid of the wood buildings is located near Snoqualmie Pass. The geographic centroid of the wood buildings included in the study is very similar to the typical building.

Table 4.2.2-1. ASCE 41 Tier 1 Wood (W2) Building Statistics.

Parameter	Value	Notes
Average Square Footage	24,590	The average wood building is about 10% smaller than the average school building in the study. The largest wood building is 97,150 square feet.
Median Square Footage	18,350	The median square footage of wood buildings is similar to the typical building in the study.
Median BSE-2N S_S	1.15 g	The typical wood building site possesses a slightly larger spectral acceleration value than the typical building in the study.
Median BSE-2N S_1	0.45 g	The typical wood building site possesses a slightly larger spectral acceleration value than the typical building in the study.
Median BSE-2E S_{XS}	0.91 g	The typical wood building site possesses a slightly larger spectral acceleration value than the typical building in the study.
Median BSE-2E S_{X1}	0.56 g	The typical wood building site possesses a slightly larger spectral acceleration value than the typical building in the study.
Median BSE-1N S_{XS}	0.74 g	The typical wood building site possesses a slightly larger spectral acceleration value than the typical building in the study.
Median BSE-1N S_{X1}	0.47 g	The typical wood building site possesses a slightly larger spectral acceleration value than the typical building in the study.

The ASCE 41 Tier 1 seismic screening checklists completed for each wood building were the 17-2 Collapse Prevention Basic Configuration Checklist and the 17-6 Collapse Prevention Structural Checklist for Building Type W2. Table 4.2.2-2 shows the top four most common noncompliant items for the wood buildings within this study for Checklist 17-2, and Table 4.2.2-3 shows the top four most common noncompliant or unknown items for wood buildings for Checklist 17-2.

Table 4.2.2-2. ASCE 41 Checklist 17-2 Top Four Most Common Noncompliant Items for Wood (W2) Buildings.

Evaluation Statement Item	Quantity of Buildings/Notes
Load Path The structure contains a complete, well-defined load path, including structural elements and connections, that serves to transfer the inertial forces associated with the mass of all elements of the building to the foundation. (Tier 2: Sec. 5.4.1.1; Commentary: Sec. A.2.1.10).	11 out of 86 (13%) Noncompliant

Table 4.2.2-2. ASCE 41 Checklist 17-2 Top Four Most Common Noncompliant Items for Wood (W2) Buildings.

Evaluation Statement Item	Quantity of Buildings/Notes
Ties Between Foundation Elements The foundation has ties adequate to resist seismic forces where footings, piles, and piers are not restrained by beams, slabs, or soils classified as Site Class A, B, or C. (Tier 2: Sec. 5.4.3.4; Commentary: Sec. A.6.2.2).	10 out of 86 (12%) Noncompliant
Adjacent Buildings The clear distance between the building being evaluated and any adjacent building is greater than 0.25% of the height of the shorter building in low seismicity, 0.5% in moderate seismicity, and 1.5% in high seismicity. (Tier 2: Sec. 5.4.1.2; Commentary: Sec. A.2.1.2).	9 out of 86 (10%) Noncompliant
Overturning The ratio of the least horizontal dimension of the seismic-force-resisting system at the foundation level to the building height (base/height) is greater than 0.6Sa. (Tier 2: Sec. 5.4.3.3; Commentary: Sec. A.6.2.1).	6 out of 86 (7%) Noncompliant

Table 4.2.2-3. ASCE 41 Checklist 17-2 Top Four Most Common Noncompliant or Unknown Items for Wood (W2) Buildings.

Evaluation Statement Item	Quantity of Buildings/Notes
Geologic Site Hazards Liquefaction, Slope Failure, and Surface Fault Rupture.	86 out of 86 (100%) Noncompliant or Unknown 0 out of 86 (0%) Noncompliant 86 out of 86 (100%) Unknown No geotechnical reports were available for any of the sites. Therefore, the geologic site hazards are categorically unknown.
Load Path The structure contains a complete, well-defined load path, including structural elements and connections, that serves to transfer the inertial forces associated with the mass of all elements of the building to the foundation. (Tier 2: Sec. 5.4.1.1; Commentary: Sec. A.2.1.10).	30 out of 86 (35%) Noncompliant or Unknown 11 out of 86 (13%) Noncompliant 19 out of 86 (22%) Unknown
Ties Between Foundation Elements The foundation has ties adequate to resist seismic forces where footings, piles, and piers are not restrained by beams, slabs, or soils classified as Site Class A, B, or C. (Tier 2: Sec. 5.4.3.4; Commentary: Sec. A.6.2.2).	17 out of 86 (20%) Noncompliant or Unknown 10 out of 86 (12%) Noncompliant 7 out of 86 (8%) Unknown

Table 4.2.2-3. ASCE 41 Checklist 17-2 Top Four Most Common Noncompliant or Unknown Items for Wood (W2) Buildings.

Evaluation Statement Item	Quantity of Buildings/Notes
Overturning The ratio of the least horizontal dimension of the seismic-force-resisting system at the foundation level to the building height (base/height) is greater than 0.6Sa. (Tier 2: Sec. 5.4.3.3; Commentary: Sec. A.6.2.1).	13 out of 86 (15%) Noncompliant or Unknown 6 out of 86 (7%) Noncompliant 7 out of 86 (8%) Unknown

Table 4.2.2-4 shows the top four most common noncompliant items for wood buildings for Checklist 17-6, and Table 4.2.2-5 shows the top four most common noncompliant or unknown items for wood buildings for Checklist 17-6.

Table 4.2.2-4. ASCE 41 Checklist 17-6 Top Four Most Common Noncompliant Items for Wood (W2) Buildings.

Evaluation Statement Item	Quantity of Buildings/Notes
Shear Stress Check The shear stress in the shear walls, calculated using the Quick Check procedure of Section 4.4.3.3, is less than the following values: Structural panel sheathing – 1,000 lb/ft; Diagonal sheathing – 700 lb/ft; Straight sheathing – 100 lb/ft; All other conditions – 100 lb/ft. (Tier 2: Sec. 5.5.3.1.1; Commentary: Sec. A.3.2.7.1).	35 out of 86 (41%) Noncompliant
Diagonally Sheathed and Unblocked Diaphragms All diagonally sheathed or unblocked wood structural panel diaphragms have horizontal spans less than 40 ft (12.2 m) and have aspect ratios less than or equal to 4-to-1. (Tier 2: Sec. 5.6.2; Commentary: Sec. A.4.2.3).	24 out of 86 (28%) Noncompliant
Spans All wood diaphragms with spans greater than 24 ft (7.3 m) consist of wood structural panels or diagonal sheathing. (Tier 2: Sec. 5.6.2; Commentary: Sec. A.4.2.2).	18 out of 86 (21%) Noncompliant
Roof Chord Continuity All chord elements are continuous, regardless of changes in roof elevation. (Tier 2: Sec. 5.6.1.1; Commentary: Sec. A.4.1.3).	13 out of 86 (15%) Noncompliant

Table 4.2.2-5. ASCE 41 Checklist 17-6 Top Four Most Common Noncompliant or Unknown Items for Wood (W2) Buildings.

Evaluation Statement Item	Quantity of Buildings/Notes
Shear Stress Check The shear stress in the shear walls, calculated using the Quick Check procedure of Section 4.4.3.3, is less than the following values: Structural panel sheathing – 1,000 lb/ft; Diagonal sheathing – 700 lb/ft; Straight sheathing – 100 lb/ft; All other conditions – 100 lb/ft. (Tier 2: Sec. 5.5.3.1.1; Commentary: Sec. A.3.2.7.1).	43 out of 86 (50%) Noncompliant or Unknown 35 out of 86 (41%) Noncompliant 8 out of 86 (9%) Unknown
Diagonally Sheathed and Unblocked Diaphragms All diagonally sheathed or unblocked wood structural panel diaphragms have horizontal spans less than 40 ft (12.2 m) and have aspect ratios less than or equal to 4-to-1. (Tier 2: Sec. 5.6.2; Commentary: Sec. A.4.2.3).	41 out of 86 (48%) Noncompliant or Unknown 24 out of 86 (28%) Noncompliant 17 out of 86 (20%) Unknown
Roof Chord Continuity All chord elements are continuous, regardless of changes in roof elevation. (Tier 2: Sec. 5.6.1.1; Commentary: Sec. A.4.1.3).	39 out of 86 (45%) Noncompliant or Unknown 13 out of 86 (15%) Noncompliant 26 out of 86 (30%) Unknown
Wood Sill Plates All wood sill plates are bolted to the foundation. (Tier 2: Sec. 5.7.3.3; Commentary: Sec. A.5.3.4).	38 out of 86 (44%) Noncompliant or Unknown 3 out of 86 (3%) Noncompliant 35 out of 86 (41%) Unknown

4.2.3 Data and Statistics for Reinforced Masonry (RM) School Buildings

Out of the 222 school buildings, 68 of the buildings included in the study are constructed out of reinforced masonry construction. This accounts for 31 percent of the buildings and is the second largest proportion (second to wood construction) of the building construction materials types.

The average and median year of construction of the 68 reinforced masonry school buildings is 1973, and 1970, respectively. The average reinforced masonry building is approximately 10 years newer than the typical building included in the study. This is because reinforced masonry buildings only started being built in the 1950s and were very common throughout the latter-half of the 20th century. While reinforced masonry buildings are still constructed today, they are a less common construction type for larger school buildings.

These reinforced masonry buildings have an average and median occupied space area of 30,857 SF, and 17,306 SF, respectively. The average reinforced masonry building is about 12% larger than the average school building in the study. The largest building is 121,246 square feet.

The most significant noncompliant findings from the Tier 1 checklist screening for reinforced masonry (RM) school buildings were:

1. Wall Anchorage: Forty-four percent of the reinforced masonry buildings were found to have noncompliant wall anchorage. An additional 43% of the reinforced masonry buildings (87% total) had wall anchorage configurations that were unknown. This means that exterior concrete or masonry walls that are dependent on the floor or roof diaphragm for out-of-plane lateral support may not be adequately anchored for out-of-plane earthquake forces.

2. Reinforcing Steel: Over 30% of the reinforced masonry buildings were found to have noncompliant reinforcing steel ratios in their walls. This means that the total vertical and horizontal reinforcing steel ratio in reinforced masonry walls do not meet minimum code requirements to ensure reliable strength and ductility (toughness).

3. Cross-Ties: Over 30% of the reinforced masonry school buildings investigated had inadequate or noncompliant continuous cross-ties between their diaphragm chords. An additional 34% of the reinforced masonry buildings (71% total) had unknown continuous cross-ties. Cross-ties are required for reliable transfer of lateral forces through floor and roof diaphragms to ensure that earthquake forces are resisted by masonry shear walls or lateral frames.

4. Diaphragms: Over 20% of the reinforced masonry school buildings had weak diagonally sheathed or unblocked diaphragms (roof or floor). This typically means that a weakness may exist in a roof or floor to reliably transfer seismic loads to lateral elements such as shear walls and frames.

Tables 4.2.3-1 through 4.2.3-5 presents more detailed statistics and seismic screening data about the reinforced masonry (RM) buildings included in this study.

Table 4.2.3-1. ASCE 41 Tier 1 Reinforced Masonry (RM) Building Statistics.

Parameter	Value	Notes
Average Year of Construction	1973	The average reinforced masonry building is approximately 10 years newer than the typical building included in the study. This is because reinforced masonry buildings only started being built in the 1950s and were very common throughout the latter-half of the 20th century. While reinforced masonry buildings are still constructed today, they are a less common construction type.
Median Year of Construction	1970	The median year of construction is less than the average year of construction, indicating that the bulk of buildings were constructed in the 1950s and 1960s, with fewer being constructed away from this period.
Geographic Centroid	47.1835° N, 121.6901° W	The geographic centroid of the wood buildings is located due east of Enumclaw and south-southwest of Snoqualmie Pass. The geographic centroid of the buildings is close to the typical geographic centroid for the buildings included in the study.

Table 4.2.3-1. ASCE 41 Tier 1 Reinforced Masonry (RM) Building Statistics.

Parameter	Value	Notes
Average Square Footage	30,857	The average reinforced masonry building is about 12% larger than the average school building in the study. The largest building is 121,246 square feet.
Median Square Footage	17,306	The median square footage of reinforced masonry buildings is smaller than the typical building in the study. This means that the majority of reinforced masonry buildings are smaller than the typical building, but a few very large buildings skew the average building size larger.
Median BSE-2N S_S	0.90 g	The typical reinforced masonry building site possesses a slightly smaller spectral acceleration value than the typical building in the study.
Median BSE-2N S_1	0.37 g	The typical reinforced masonry building site possesses a slightly smaller spectral acceleration value than the typical building in the study.
Median BSE-2E S_{XS}	0.82 g	The typical reinforced masonry building site possesses a slightly smaller spectral acceleration value than the typical building in the study.
Median BSE-2E S_{X1}	0.46 g	The typical reinforced masonry building site possesses a slightly smaller spectral acceleration value than the typical building in the study.
Median BSE-1N S_{XS}	0.65 g	The typical reinforced masonry building site possesses a slightly smaller spectral acceleration value than the typical building in the study.
Median BSE-1N S_{X1}	0.39 g	The typical reinforced masonry building site possesses a slightly smaller spectral acceleration value than the typical building in the study.

The ASCE 41 Tier 1 seismic screening checklists completed for each reinforced masonry building were 17-2 Collapse Prevention Basic Configuration Checklist and 17-34 Collapse Prevention Structural Checklist for Building Type RM1 and RM2. Table 4.2.3-2 shows the top four most common noncompliant items for reinforced masonry buildings for Checklist 17-2, and Table 4.2.3-3 shows the top four most common noncompliant or unknown items for the buildings for Checklist 17-2.

Table 4.2.3-2. ASCE 41 Checklist 17-2 Top Four Most Common Noncompliant Items for Reinforced Masonry (RM) Buildings.

Evaluation Statement Item	Quantity of Buildings/Notes
Load Path The structure contains a complete, well-defined load path, including structural elements and connections, that serves to transfer the inertial forces associated with the mass of all elements of the building to the foundation. (Tier 2: Sec. 5.4.1.1; Commentary: Sec. A.2.1.10).	12 out of 68 (18%) Noncompliant
Adjacent Buildings The clear distance between the building being evaluated and any adjacent building is greater than 0.25% of the height of the shorter building in low seismicity, 0.5% in moderate seismicity, and 1.5% in high seismicity. (Tier 2: Sec. 5.4.1.2; Commentary: Sec. A.2.1.2).	11 out of 68 (16%) Noncompliant
Torsion The estimated distance between the story center of mass and the story center of rigidity is less than 20% of the building width in either plan dimension. (Tier 2: Sec. 5.4.2.6; Commentary: Sec. A.2.2.7).	4 out of 68 (6%) Noncompliant
Overturning The ratio of the least horizontal dimension of the seismic-force-resisting system at the foundation level to the building height (base/height) is greater than 0.6Sa. (Tier 2: Sec. 5.4.3.3; Commentary: Sec. A.6.2.1).	3 out of 68 (4%) Noncompliant

Table 4.2.3-3. ASCE 41 Checklist 17-2 Top Four Most Common Noncompliant or Unknown Items for Reinforced Masonry (RM) Buildings.

Evaluation Statement Item	Quantity of Buildings/Notes
Geologic Site Hazards Liquefaction, Slope Failure, and Surface Fault Rupture.	68 out of 68 (100%) Noncompliant or Unknown 0 out of 68 (0%) Noncompliant 68 out of 68 (100%) Unknown No geotechnical reports were available for any of the sites. Therefore, the geologic site hazards are categorically unknown.
Load Path The structure contains a complete, well-defined load path, including structural elements and connections, that serves to transfer the inertial forces associated with the mass of all elements of the building to the foundation. (Tier 2: Sec. 5.4.1.1; Commentary: Sec. A.2.1.10).	27 out of 68 (40%) Noncompliant or Unknown 12 out of 68 (18%) Noncompliant 15 out of 68 (22%) Unknown

Table 4.2.3-3. ASCE 41 Checklist 17-2 Top Four Most Common Noncompliant or Unknown Items for Reinforced Masonry (RM) Buildings.

Evaluation Statement Item	Quantity of Buildings/Notes
Torsion The estimated distance between the story center of mass and the story center of rigidity is less than 20% of the building width in either plan dimension. (Tier 2: Sec. 5.4.2.6; Commentary: Sec. A.2.2.7).	15 out of 68 (22%) Noncompliant or Unknown 4 out of 68 (6%) Noncompliant 11 out of 68 (16%) Unknown
Adjacent Buildings The clear distance between the building being evaluated and any adjacent building is greater than 0.25% of the height of the shorter building in low seismicity, 0.5% in moderate seismicity, and 1.5% in high seismicity. (Tier 2: Sec. 5.4.1.2; Commentary: Sec. A.2.1.2).	12 out of 68 (18%) Noncompliant or Unknown 11 out of 68 (16%) Noncompliant 1 out of 68 (1%) Unknown

Table 4.2.3-4 shows the top four most common noncompliant items for reinforced masonry buildings for Checklist 17-34, and Table 4.2.3-5 shows the top four most common noncompliant or unknown items for reinforced masonry buildings for Checklist 17-34.

Table 4.2.3-4. ASCE 41 Checklist 17-34 Top Four Most Common Noncompliant Items for Reinforced Masonry (RM) Buildings.

Evaluation Statement Item	Quantity of Buildings/Notes
Wall Anchorage Exterior concrete or masonry walls that are dependent on the diaphragm for lateral support are anchored for out-of-plane forces at each diaphragm level with steel anchors, reinforcing dowels, or straps that are developed into the diaphragm. Connections have strength to resist the connection force calculated in the Quick Check procedure of Section 4.4.3.7. (Tier 2: Sec. 5.7.1.1; Commentary: Sec. A.5.1.1).	30 out of 68 (44%) Noncompliant
Cross Ties There are continuous cross ties between diaphragm chords. (Tier 2: Sec. 5.6.1.2; Commentary: Sec. A.4.1.2).	25 out of 68 (37%) Noncompliant
Reinforcing Steel The total vertical and horizontal reinforcing steel ratio in reinforced masonry walls is greater than 0.002 of the wall with the minimum of 0.0007 in either of the two directions; the spacing of reinforcing steel is less than 48 in. (1220 mm), and all vertical bars extend to the top of the walls. (Tier 2: Sec. 5.5.3.1.3; Commentary: Sec. A.3.2.4.2).	21 out of 68 (31%) Noncompliant

Table 4.2.3-4. ASCE 41 Checklist 17-34 Top Four Most Common Noncompliant Items for Reinforced Masonry (RM) Buildings.

Evaluation Statement Item	Quantity of Buildings/Notes
Diagonally Sheathed and Unblocked Diaphragms All diagonally sheathed or unblocked wood structural panel diaphragms have horizontal spans less than 40 ft (12.2 m) and aspect ratios less than or equal to 4-to-1. (Tier 2: Sec. 5.6.2; Commentary: Sec. A.4.2.3).	15 out of 68 (22%) Noncompliant

Table 4.2.3-5. ASCE 41 Checklist 17-34 Top Four Most Common Noncompliant or Unknown Items for Reinforced Masonry (RM) Buildings.

Evaluation Statement Item	Quantity of Buildings/Notes
Wall Anchorage Exterior concrete or masonry walls that are dependent on the diaphragm for lateral support are anchored for out-of-plane forces at each diaphragm level with steel anchors, reinforcing dowels, or straps that are developed into the diaphragm. Connections have strength to resist the connection force calculated in the Quick Check procedure of Section 4.4.3.7. (Tier 2: Sec. 5.7.1.1; Commentary: Sec. A.5.1.1).	59 out of 86 (87%) Noncompliant or Unknown 30 out of 86 (44%) Noncompliant 29 out of 86 (43%) Unknown
Reinforcing Steel The total vertical and horizontal reinforcing steel ratio in reinforced masonry walls is greater than 0.002 of the wall with the minimum of 0.0007 in either of the two directions; the spacing of reinforcing steel is less than 48 in. (1220 mm), and all vertical bars extend to the top of the walls. (Tier 2: Sec. 5.5.3.1.3; Commentary: Sec. A.3.2.4.2).	57 out of 68 (84%) Noncompliant or Unknown 21 out of 68 (31%) Noncompliant 36 out of 68 (53%) Unknown
Cross Ties There are continuous cross ties between diaphragm chords. (Tier 2: Sec. 5.6.1.2; Commentary: Sec. A.4.1.2).	48 out of 68 (71%) Noncompliant or Unknown 25 out of 68 (37%) Noncompliant 23 out of 68 (34%) Unknown
Stiffness of Wall Anchors Anchors of concrete or masonry walls to wood structural elements are installed taut and are stiff enough to limit the relative movement between the wall and the diaphragm to no greater than 1/8 in. (3 mm) before engagement of the anchors. (Tier 2: Sec. 5.7.1.2; Commentary: Sec. A.5.1.4).	46 out of 68 (68%) Noncompliant or Unknown 6 out of 68 (9%) Noncompliant 40 out of 68 (59%) Unknown

4.2.4 Data and Statistics for Unreinforced Masonry (URM) School Buildings

Thirty-three out of the 222 school buildings included in the study are built out of unreinforced masonry construction. This accounts for 15% of the buildings and is the third largest proportion of the building construction material types.

The average and median year of construction of the 33 unreinforced masonry school buildings is 1932, and 1928, respectively. The average unreinforced masonry building is much older than the typical building included in the study. The average year of construction is approximately 31 years older than the typical building. URM buildings were the most common type of school construction prior to the 1940s in Washington State. The median year of construction of the URMs is older than the average year of construction, indicating that the majority of these buildings were built earlier rather than later, however several of URM buildings were constructed in lower seismic zones after 1950.

These unreinforced masonry buildings have an average and median occupied space area of 29,968 SF, and 18,935 SF, respectively. The average unreinforced masonry building is about 10% larger than the average school building in the study. The largest building is 121,408 square feet. Since the URM buildings are much older than the typical building in the study, it might be expected that they would be smaller than the typical building, but that was not the case.

The most significant noncompliant findings from the Tier 1 checklist screening for unreinforced masonry (URM) school buildings were:

1. Shear Stress: About 55% of the unreinforced masonry school buildings investigated had overstressed URM shear walls. An additional 39% of URM buildings had shear wall stresses that were unknown. This typically means that the capacity of the existing unreinforced masonry shear walls that provide lateral support for the school building may not be able to reliably resist earthquake loads. This is not surprising for URM buildings as the vulnerability of URM buildings to earthquakes has been long-documented.

2. Transfer to Shear Walls: Over 30% of unreinforced masonry buildings were found to have noncompliant roof or floor diaphragm to wall anchorage. This typically means that exterior unreinforced masonry walls that are dependent on the floor or roof diaphragm for out-of-plane lateral support may not be adequately anchored for out-of-plane earthquake forces.

3. Proportions: About 40% of unreinforced masonry buildings were found to have noncompliant proportions. This typically means that the height-to-thickness ratio of the shear walls at each story is too large potentially leading to instability of unreinforced masonry bearing wall during earthquake shaking.

4. Cross-Ties: Almost 40% of the unreinforced masonry school buildings investigated had inadequate/noncompliant continuous cross-ties between their diaphragm chords. Cross-ties are required for reliable transfer of lateral forces through floor and roof diaphragms to ensure that earthquake forces are resisted by unreinforced masonry shear walls or lateral frames.

5. Load Path: Over 30% of the unreinforced masonry school buildings had noncompliant seismic load paths that provide a well-defined seismic load path, including structural

elements and connections, that serves to transfer the inertial forces associated with the mass of all elements of the building to the foundation.

6. Adjacent Buildings: Almost 30% of unreinforced masonry buildings investigated were found to have noncompliant building adjacencies. This means that the clear distance between the unreinforced masonry school building being evaluated is too short and the adjacent building may cause pounding between the two buildings during earthquake shaking.

Tables 4.2.4-1 through 4.2.4-5 presents more detailed statistics and seismic screening data about the unreinforced masonry (URM) buildings included in this study.

Table 4.2.4-1. ASCE 41 Tier 1 Unreinforced Masonry (URM) Building Statistics.

Parameter	Value	Notes
Average Year of Construction	1932	The average unreinforced masonry building is much older than the typical building included in the study. The average year of construction is approximately 31 years older than the typical building. URM buildings were the most common type of school construction prior to the 1940s in Washington State. A handful of URM buildings were constructed in lower seismic zones after 1950.
Median Year of Construction	1928	The median year of construction is older than the average year of construction, indicating that the majority of these buildings were built earlier rather than later, but a handful of buildings were constructed later in the 1950s and 1960s.
Geographic Centroid	47.0226° N, 120.6192° W	The geographic centroid of the unreinforced masonry buildings is located near Ellensburg. The geographic centroid of the URM buildings is further east compared to the other buildings in the study. This reflects the fact that almost half of the URM buildings in the study are located east of the Cascade Mountains. This biases the geographic centroid considerably more east compared with the other buildings in the study.
Average Square Footage	29,968	The average unreinforced masonry building is about 10% larger than the average school building in the study. The largest building is 121,408 square feet. Since the URM buildings are much older than the typical building in the study, it might be expected that they would be smaller than the typical building, but this is not the case.
Median Square Footage	18,935	The median square footage of unreinforced masonry buildings is about the same as the typical building in the study.
Median BSE-2N S_S	0.87 g	The typical unreinforced masonry building site possesses a slightly smaller spectral acceleration value than the typical building in the study. This is likely because the location of the typical URM building is biased east of the typical study building. Eastern Washington generally possesses lower site seismicity than Western Washington.

Table 4.2.4-1. ASCE 41 Tier 1 Unreinforced Masonry (URM) Building Statistics.

Parameter	Value	Notes
Median BSE-2N S_1	0.38 g	The typical unreinforced masonry building site possesses a slightly smaller spectral acceleration value than the typical building in the study. This is likely because the location of the typical URM building is biased east of the typical study building. Eastern Washington generally possesses lower site seismicity than Western Washington.
Median BSE-2E S_{XS}	0.82 g	The typical unreinforced masonry building site possesses a slightly smaller spectral acceleration value than the typical building in the study. This is likely because the location of the typical URM building is biased east of the typical study building. Eastern Washington generally possesses lower site seismicity than Western Washington.
Median BSE-2E S_{X1}	0.48 g	The typical unreinforced masonry building site possesses a slightly smaller spectral acceleration value than the typical building in the study. This is likely because the location of the typical URM building is biased east of the typical study building. Eastern Washington generally possesses lower site seismicity than Western Washington.
Median BSE-1N S_{XS}	0.61 g	The typical unreinforced masonry building site possesses a slightly smaller spectral acceleration value than the typical building in the study. This is likely because the location of the typical URM building is biased east of the typical study building. Eastern Washington generally possesses lower site seismicity than Western Washington.
Median BSE-1N S_{X1}	0.40 g	The typical unreinforced masonry building site possesses a slightly smaller spectral acceleration value than the typical building in the study. This is likely because the location of the typical URM building is biased east of the typical study building. Eastern Washington generally possesses lower site seismicity than Western Washington.

The ASCE 41 Tier 1 seismic screening checklists completed for each unreinforced masonry building were 17-2 Collapse Prevention Basic Configuration Checklist and 17-36 Collapse Prevention Structural Checklist for Building Types URM and URMa. Table 4.2.4-2 shows the top four most common noncompliant items for unreinforced masonry buildings for Checklist 17-2, and Table 4.2.4-3 shows the top four most common noncompliant or unknown items for the buildings for Checklist 17-2.

Table 4.2.4-2. ASCE 41 Checklist 17-2 Top Four Most Common Noncompliant Items for Unreinforced Masonry (RM) Buildings.

Evaluation Statement Item	Quantity of Buildings/Notes
Load Path The structure contains a complete, well-defined load path, including structural elements and connections, that serves to transfer the inertial forces associated with the mass of all elements of the building to the foundation. (Tier 2: Sec. 5.4.1.1; Commentary: Sec. A.2.1.10).	10 out of 33 (30%) Noncompliant

Table 4.2.4-2. ASCE 41 Checklist 17-2 Top Four Most Common Noncompliant Items for Unreinforced Masonry (RM) Buildings.

Evaluation Statement Item	Quantity of Buildings/Notes
Adjacent Buildings The clear distance between the building being evaluated and any adjacent building is greater than 0.25% of the height of the shorter building in low seismicity, 0.5% in moderate seismicity, and 1.5% in high seismicity. (Tier 2: Sec. 5.4.1.2; Commentary: Sec. A.2.1.2).	9 out of 33 (27%) Noncompliant
Overturning The ratio of the least horizontal dimension of the seismic-force-resisting system at the foundation level to the building height (base/height) is greater than 0.6Sa. (Tier 2: Sec. 5.4.3.3; Commentary: Sec. A.6.2.1).	6 out of 33 (18%) Noncompliant
Vertical Irregularities All vertical elements in the seismic-force-resisting system are continuous to the foundation. (Tier 2: Sec. 5.4.2.3; Commentary: Sec. A.2.2.4).	5 out of 33 (15%) Noncompliant

Table 4.2.4-4. ASCE 41 Checklist 17-2 Top Four Most Common Noncompliant or Unknown Items for Unreinforced Masonry (URM) Buildings.

Evaluation Statement Item	Quantity of Buildings/Notes
Geologic Site Hazards Liquefaction, Slope Failure and Surface Fault Rupture.	33 out of 33 (100%) Noncompliant or Unknown 0 out of 33 (0%) Noncompliant 33 out of 33 (100%) Unknown No geotechnical reports were available for any of the sites. Therefore, the geologic site hazards are categorically unknown.
Load Path The structure contains a complete, well-defined load path, including structural elements and connections, that serves to transfer the inertial forces associated with the mass of all elements of the building to the foundation. (Tier 2: Sec. 5.4.1.1; Commentary: Sec. A.2.1.10).	29 out of 33 (88%) Noncompliant or Unknown 10 out of 33 (30%) Noncompliant 19 out of 33 (58%) Unknown
Vertical Irregularities All vertical elements in the seismic-force-resisting system are continuous to the foundation. (Tier 2: Sec. 5.4.2.3; Commentary: Sec. A.2.2.4).	12 out of 33 (36%) Noncompliant or Unknown 5 out of 33 (15%) Noncompliant 7 out of 33 (21%) Unknown

Table 4.2.4-4. ASCE 41 Checklist 17-2 Top Four Most Common Noncompliant or Unknown Items for Unreinforced Masonry (URM) Buildings.

Evaluation Statement Item	Quantity of Buildings/Notes
Torsion The estimated distance between the story center of mass and the story center of rigidity is less than 20% of the building width in either plan dimension. (Tier 2: Sec. 5.4.2.6; Commentary: Sec. A.2.2.7).	10 out of 33 (30%) Noncompliant or Unknown 1 out of 33 (3%) Noncompliant 9 out of 33 (27%) Unknown

Table 4.2.4-4 shows the top four most common noncompliant items for unreinforced masonry buildings for Checklist 17-36, and Table 4.2.4-5 shows the top four most common noncompliant or unknown items for unreinforced masonry buildings for Checklist 17-36.

Table 4.2.4-5. ASCE 41 Checklist 17-36 Top Four Most Common Noncompliant Items for Unreinforced Masonry (URM) Buildings.

Evaluation Statement Item	Quantity of Buildings/Notes
Shear Stress Check The shear stress in the unreinforced masonry shear walls, calculated using the Quick Check procedure of Section 4.4.3.3, is less than 30 lb/in.^{2} (0.21 MPa) for clay units and 70 lb/in.^{2} (0.48 MPa) for concrete units. (Tier 2: Sec. 5.5.3.1.1; Commentary: Sec. A.3.2.5.1).	18 out of 33 (55%) Noncompliant
Proportions The height-to-thickness ratio of the shear walls at each story is less than the following: Top story of multi-story building – 9; First story of multi-story building – 15; All other conditions – 13. (Tier 2: Sec. 5.5.3.1.2; Commentary: Sec. A.3.2.5.2).	13 out of 33 (39%) Noncompliant
Cross Ties There are continuous cross ties between diaphragm chords. (Tier 2: Sec. 5.6.1.2; Commentary: Sec. A.4.1.2).	13 out of 33 (39%) Noncompliant
Transfer to Shear Walls Diaphragms are connected for transfer of seismic forces to the shear walls. (Tier 2: Sec. 5.7.2; Commentary: Sec. A.5.2.1).	11 out of 33 (33%) Noncompliant

Table 4.2.4-6. ASCE 41 Checklist 17-36 Top Four Most Common Noncompliant or Unknown Items for Unreinforced Masonry (URM) Buildings.

Evaluation Statement Item	Quantity of Buildings/Notes
Shear Stress Check The shear stress in the unreinforced masonry shear walls, calculated using the Quick Check procedure of Section 4.4.3.3, is less than 30 lb/in.^{2} (0.21 MPa) for clay units and 70 lb/in.^{2} (0.48 MPa) for concrete units. (Tier 2: Sec. 5.5.3.1.1; Commentary: Sec. A.3.2.5.1).	31 out of 33 (94%) Noncompliant or Unknown 18 out of 33 (55%) Noncompliant 13 out of 33 (39%) Unknown
Wall Anchorage Exterior concrete or masonry walls that are dependent on the diaphragm for lateral support are anchored for out-of-plane forces at each diaphragm level with steel anchors, reinforcing dowels, or straps that are developed into the diaphragm. Connections have strength to resist the connection force calculated in the Quick Check procedure of Section 4.4.3.7. (Tier 2: Sec. 5.7.1.1; Commentary: Sec. A.5.1.1).	31 out of 33 (94%) Noncompliant or Unknown 10 out of 33 (30%) Noncompliant 21 out of 33 (64%) Unknown
Transfer to Shear Walls Diaphragms are connected for transfer of seismic forces to the shear walls. (Tier 2: Sec. 5.7.2; Commentary: Sec. A.5.2.1).	28 out of 33 (85%) Noncompliant or Unknown 11 out of 33 (33%) Noncompliant 17 out of 33 (52%) Unknown
Wood Ledgers The connection between the wall panels and the diaphragm does not induce cross-grain bending or tension in the wood ledgers. (Tier 2: Sec. 5.7.1.3; Commentary: Sec. A.5.1.2).	27 out of 33 (82%) Noncompliant or Unknown 6 out of 33 (18%) Noncompliant 21 out of 33 (64%) Unknown

4.2.5 Data and Statistics for Concrete Shear Wall (C2) School Buildings

Fifteen out of the 222 school buildings included in the study are of concrete shear wall construction. This accounts for 7% of the buildings and is the fourth largest proportion of the building construction material types.

The average and median year of construction of the 15 concrete shear wall school buildings is 1950, and 1955, respectively. The average concrete shear wall building is 13 years older than the typical building included in the study. The oldest concrete shear wall building in the study was constructed in 1930, and the newest was constructed in 1972. This approximately 50-year period saw concrete construction gain and then wane in favor. The median year of construction is larger than the average year of construction, indicating that the majority of these buildings were built in the late 1950s and 1960s, but a fewer number were constructed in the early 1930s.

These concrete shear wall buildings have an average and median occupied space of 25,038 SF, and 26,200 SF, respectively. The average concrete shear wall building in the study is slightly smaller than the average building in the study. However, this may reflect the small quantity of concrete shear wall buildings included in the study, due to building age or some other factor.

The largest concrete shear wall building in the study is 47,190 square feet. It is unclear whether this smaller building size is by chance or if there is a reasoning why the concrete shear wall buildings tend to be smaller than other buildings in the study.

The most significant noncompliant findings from the Tier 1 checklist screening for concrete shear wall (C2) school buildings were:

1. Load Path: Almost 50% of the concrete shear wall school buildings had noncompliant seismic load paths that provide a well-defined seismic load path, including structural elements and connections, that serves to transfer the inertial forces associated with the mass of all elements of the building to the foundation.

2. Transfer to Shear Walls: Almost 50% of the concrete shear wall school buildings were found to have noncompliant flexible roof or floor diaphragm to wall anchorage. This typically means that concrete shear walls that are dependent on the floor or roof diaphragms to transfer seismic forces may have connections that are reliable or strong enough.

3. Wall Anchorage at Flexible Diaphragms: Almost 50% of the concrete shear wall school buildings were found to have noncompliant wall anchorage. This means that the exterior concrete walls that are dependent on flexible diaphragms for lateral support do not likely have adequate steel anchors, reinforcing dowels, or straps that are developed into the floor or roof diaphragm for out-of-plane forces.

4. Transfer to Shear Walls: Almost 50% of the concrete shear wall school buildings were found to have noncompliant flexible roof or floor diaphragm to wall anchorage. This typically means that concrete shear walls that are dependent on the floor or roof diaphragms to transfer seismic forces may have connections that are reliable or strong enough.

5. Cross-Ties: Almost 50% of the concrete shear wall school buildings investigated had inadequate or noncompliant continuous cross-ties between their diaphragm chords. Cross-ties are required for reliable transfer of lateral forces through floor and roof diaphragms to ensure that earthquake forces are resisted by concrete shear walls or lateral frames.

6. Shear Stress: Over 30% of the concrete shear wall school buildings investigated had overstressed concrete shear walls. This typically means that the capacity of the existing concrete shear walls that provide lateral support for the school building may not be able to reliably resist earthquake loads.

7. Adjacent Buildings: About 20% of the concrete shear wall buildings investigated were found to have noncompliant building adjacencies. This means that the clear distance between the concrete shear wall school building being evaluated is too short and the adjacent building may cause pounding between the two buildings during earthquake shaking.

8. Overturning: About 20% of the concrete shear wall buildings were found to have noncompliant overturning proportions. This means that the ratio of the least horizontal dimension of the seismic-force-resisting system at the foundation level to the building height (base/height) is greater than a specified limit resulting in the likelihood of foundation uplift and shear wall instability.

9. Vertical Irregularities: About 20% of the concrete shear wall buildings were found to have noncompliant vertical irregularities. This means that all vertical elements in the seismic-force-resisting system are not continuous to the foundation.

Tables 4.2.5-1 through 4.2.5-5 presents more detailed statistics and seismic screening data about the concrete shear wall (C2) buildings included in this study.

Table 4.2.5-1. ASCE 41 Tier 1 Concrete Shear Wall (C2) Building Statistics.

Parameter	Value	Notes
Average Year of Construction	1950	The average concrete shear wall building is 13 years older than the typical building included in the study. The oldest concrete shear wall building in the study was constructed in 1930, and the newest was constructed in 1972. This approximately 50-year period saw concrete construction gain and then wane in favor.
Median Year of Construction	1955	The median year of construction is larger than the average year of construction, indicating that the majority of these buildings were built in the late 1950s and 1960s, but a fewer number were constructed in the early 1930s.
Geographic Centroid	47.2982º N, 123.0359º W	The geographic centroid of the concrete shear wall buildings is located in Mason County. The geographic centroid of the concrete shear wall buildings is much further west compared to the other buildings in the study. The furthest eastern concrete shear wall buildings included in the study are located in White Salmon and Skykomish.
Average Square Footage	25,038	The average concrete shear wall building in the study is slightly smaller than the average building in the study. However, this may reflect the small quantity of concrete shear wall buildings included in the study, due to building age or some other factor. The largest concrete shear wall building in the study is 47,190 square feet. It is unclear whether this smaller building size is by chance or if there is a reasoning why the concrete shear wall buildings tend to be smaller than other buildings in the study.
Median Square Footage	26,200	The median concrete shear wall building has a much larger square footage than the typical building in the study. It is suspected this is by chance and reflects the relatively small quantity of concrete shear wall buildings in the study.

Table 4.2.5-1. ASCE 41 Tier 1 Concrete Shear Wall (C2) Building Statistics.

Parameter	Value	Notes
Median BSE-2N S_S	1.20 g	The typical concrete shear wall building has a larger spectral acceleration than the typical building in the study. This is because the concrete shear wall buildings are biased west of the typical building in the study. Western Washington generally has larger seismicity values compared to eastern Washington.
Median BSE-2N S_1	0.54 g	The typical concrete shear wall building has a larger spectral acceleration than the typical building in the study. This is because the concrete shear wall buildings are biased west of the typical building in the study. Western Washington generally has larger seismicity values compared to eastern Washington.
Median BSE-2E S_{XS}	0.94 g	The typical concrete shear wall building has a larger spectral acceleration than the typical building in the study. This is because the concrete shear wall buildings are biased west of the typical building in the study. Western Washington generally has larger seismicity values compared to eastern Washington.
Median BSE-2E S_{X1}	0.61 g	The typical concrete shear wall building has a larger spectral acceleration than the typical building in the study. This is because the concrete shear wall buildings are biased west of the typical building in the study. Western Washington generally has larger seismicity values compared to eastern Washington.
Median BSE-1N S_{XS}	0.82 g	The typical concrete shear wall building has a larger spectral acceleration than the typical building in the study. This is because the concrete shear wall buildings are biased west of the typical building in the study. Western Washington generally has larger seismicity values compared to eastern Washington.
Median BSE-1N S_{X1}	0.61 g	The typical concrete shear wall building has a larger spectral acceleration than the typical building in the study. This is because the concrete shear wall buildings are biased west of the typical building in the study. Western Washington generally has larger seismicity values compared to eastern Washington.

The ASCE 41 Tier 1 seismic screening checklists completed for each concrete shear wall building were 17-2 Collapse Prevention Basic Configuration Checklist and 17-24 Collapse Prevention Structural Checklist for Building Types C2 and C2a. Table 4.2.5-2 shows the top four most common noncompliant items for concrete shear wall buildings for Checklist 17-2, and Table 4.2.5-3 shows the top four most common noncompliant or unknown items for the buildings for Checklist 17-2.

Table 4.2.5-2. ASCE 41 Checklist 17-2 Top Four Most Common Noncompliant Items for Concrete Shear Wall (C2) Buildings.

Evaluation Statement Item	Quantity of Buildings/Notes
Load Path The structure contains a complete, well-defined load path, including structural elements and connections, that serves to transfer the inertial forces associated with the mass of all elements of the building to the foundation. (Tier 2: Sec. 5.4.1.1; Commentary: Sec. A.2.1.10).	7 out of 15 (47%) Noncompliant
Adjacent Buildings The clear distance between the building being evaluated and any adjacent building is greater than 0.25% of the height of the shorter building in low seismicity, 0.5% in moderate seismicity, and 1.5% in high seismicity. (Tier 2: Sec. 5.4.1.2; Commentary: Sec. A.2.1.2).	3 out of 15 (20%) Noncompliant
Overturning The ratio of the least horizontal dimension of the seismic-force-resisting system at the foundation level to the building height (base/height) is greater than 0.6Sa. (Tier 2: Sec. 5.4.3.3; Commentary: Sec. A.6.2.1).	3 out of 15 (20%) Noncompliant
Vertical Irregularities All vertical elements in the seismic-force-resisting system are continuous to the foundation. (Tier 2: Sec. 5.4.2.3; Commentary: Sec. A.2.2.4).	3 out of 15 (20%) Noncompliant

Table 4.2.5-3. ASCE 41 Checklist 17-2 Top Four Most Common Noncompliant or Unknown Items for Concrete Shear Wall (C2) Buildings.

Evaluation Statement Item	Quantity of Buildings/Notes
Geologic Site Hazards Liquefaction, Slope Failure, and Surface Fault Rupture.	15 out of 15 (100%) Noncompliant or Unknown 0 out of 15 (0%) Noncompliant 15 out of 15 (100%) Unknown No geotechnical reports were available for any of the sites. Therefore, the geologic site hazards are categorically unknown.
Load Path The structure contains a complete, well-defined load path, including structural elements and connections, that serves to transfer the inertial forces associated with the mass of all elements of the building to the foundation. (Tier 2: Sec. 5.4.1.1; Commentary: Sec. A.2.1.10).	10 out of 15 (67%) Noncompliant or Unknown 7 out of 15 (47%) Noncompliant 3 out of 15 (20%) Unknown

Table 4.2.5-3. ASCE 41 Checklist 17-2 Top Four Most Common Noncompliant or Unknown Items for Concrete Shear Wall (C2) Buildings.

Evaluation Statement Item	Quantity of Buildings/Notes
Vertical Irregularities All vertical elements in the seismic-force-resisting system are continuous to the foundation. (Tier 2: Sec. 5.4.2.3; Commentary: Sec. A.2.2.4).	4 out of 15 (27%) Noncompliant or Unknown 3 out of 15 (20%) Noncompliant 1 out of 15 (7%) Unknown
Torsion The estimated distance between the story center of mass and the story center of rigidity is less than 20% of the building width in either plan dimension. (Tier 2: Sec. 5.4.2.6; Commentary: Sec. A.2.2.7).	4 out of 15 (27%) Noncompliant or Unknown 3 out of 15 (20%) Noncompliant 1 out of 15 (7%) Unknown

Table 4.2.5-4 shows the top four most common noncompliant items for concrete shear wall buildings for Checklist 17-24, and Table 4.2.5-5 shows the top four most common noncompliant or unknown items for concrete shear wall buildings for Checklist 17-24.

Table 4.2.5-4. ASCE 41 Checklist 17-24 Top Four Most Common Noncompliant Items for Concrete Shear Wall (C2) Buildings.

Evaluation Statement Item	Quantity of Buildings/Notes
Wall Anchorage at Flexible Diaphragms Exterior concrete or masonry walls that are dependent on flexible diaphragms for lateral support are anchored for out-of-plane forces at each diaphragm level with steel anchors, reinforcing dowels, or straps that are developed into the diaphragm. Connections have strength to resist the connection force calculated in the Quick Check procedure of Section 4.4.3.7. (Tier 2: Sec.5.7.1.1; Commentary: Sec. A.5.1.1).	7 out of 15 (47%) Noncompliant
Transfer to Shear Walls Diaphragms are connected for transfer of seismic forces to the shear walls. (Tier 2: Sec.5.7.2; Commentary: Sec. A.5.2.1).	7 out of 15 (47%) Noncompliant
Cross Ties There are continuous cross ties between diaphragm chords. (Tier 2: Sec. 5.6.1.2; Commentary: Sec. A.4.1.2).	7 out of 15 (47%) Noncompliant
Shear Stress Check The shear stress in the concrete shear walls, calculated using the Quick Check procedure of Section 4.4.3.3, is less than the greater of 100 lb/in.^{2} (0.69 MPa) or $2\sqrt{f'c}$. (Tier 2: Sec.5.5.3.1.1; Commentary: Sec. A.3.2.2.1).	5 out of 15 (33%) Noncompliant

Table 4.2.5-5. ASCE 41 Checklist 17-24 Top Four Most Common Noncompliant or Unknown Items for Concrete Shear Wall (C2) Buildings.

Evaluation Statement Item	Quantity of Buildings/Notes
Transfer to Shear Walls Diaphragms are connected for transfer of seismic forces to the shear walls. (Tier 2: Sec.5.7.2; Commentary: Sec. A.5.2.1).	12 out of 15 (80%) Noncompliant or Unknown 7 out of 15 (47%) Noncompliant 5 out of 15 (33%) Unknown
Wall Anchorage at Flexible Diaphragms Exterior concrete or masonry walls that are dependent on flexible diaphragms for lateral support are anchored for out-of-plane forces at each diaphragm level with steel anchors, reinforcing dowels, or straps that are developed into the diaphragm. Connections have strength to resist the connection force calculated in the Quick Check procedure of Section 4.4.3.7. (Tier 2: Sec.5.7.1.1; Commentary: Sec. A.5.1.1).	10 out of 15 (67%) Noncompliant or Unknown 7 out of 15 (47%) Noncompliant 3 out of 15 (20%) Unknown
Cross Ties There are continuous cross ties between diaphragm chords. (Tier 2: Sec. 5.6.1.2; Commentary: Sec. A.4.1.2).	10 out of 15 (67%) Noncompliant or Unknown 7 out of 15 (47%) Noncompliant 3 out of 15 (20%) Unknown
Deflection Compatibility Secondary components have the shear capacity to develop the flexural strength of the components. (Tier 2: Sec.5.5.2.5.2; Commentary: Sec. A.3.1.6.2).	9 out of 15 (60%) Noncompliant or Unknown 2 out of 15 (13%) Noncompliant 7 out of 15 (47%) Unknown

4.2.6 Data and Statistics for Fire Stations

The project scope required ASCE 41 Tier 1 seismic screenings of five fire stations within one mile of a public school building. Table 4.2.6-1 provides a summary of the five buildings investigated.

Table 4.2.6-1. Fire Station Building Summary.

Fire Department/ Station No.	FEMA Bldg. Type	ASCE 41 Level of Seismicity / Site Class	Structural Performance Objective	Year of Constr.	Floor Area
Everett Fire Department/ Station No. 2	C2a	High / C	Immediate Occupancy	1969	4225 SF
Raymond Fire Department	C2a	High / E	Immediate Occupancy	1906	14,000 SF (Est)
Tumwater Fire Department/ Headquarters	W2	High / D	Immediate Occupancy	2000	19,000 SF
Vancouver Fire Department/ Station No. 9	W2	High / C	Immediate Occupancy	1991	7490 SF
Walla Walla Fire District 4/ Station 41	W2	Moderate / C	Immediate Occupancy	1996	15,190 SF
Averages				**1972**	**11,980 SF**

W: Wood-Framed; URM: Unreinforced Masonry; RM: Reinforced Masonry; C: Reinforced Concrete; PC: Precast concrete; S: Steel-framed

The average year of construction of the five fire stations is 1972. The oldest fire station is the one located in Raymond, Washington, that was reportedly constructed in 1906 with a series of building additions over its 100+ year lifetime. The newest building was constructed in 2000. These fire stations have an average gross building area of approximately 12,000 SF.

Since the sample size was only five buildings, Table 4.2.6-2 provides a list of the ASCE 41 Tier 1 seismic screening deficiencies for each of the buildings.

Table 4.2.6-2. ASCE 41 Tier 1 Seismic Screening Structural Deficiency Summary.

Fire Department/Station No.	Deficiency
Everett Fire Department/ Station No. 2	• Shear Stress Check • Overturning • Confinement Reinforcing
Raymond Fire Department	• Vertical Irregularities • Torsion • Redundancy • Diagonally Sheathed and Unblocked Diaphragms • Overturning
Tumwater Fire Department/ Headquarters	• None
Vancouver Fire Department/ Station No. 9	• Shear Stress Check • Deep Foundations • Overturning • Diagonally Sheathed and Unblocked Diaphragms
Walla Walla Fire District 4/ Station 41	• Narrow Wood Shear Walls

The complete ASCE 41 Tier 1 seismic screening checklists and reports for each building are located in the appendices.

4.2.7 ASCE 41 Tier 1 Seismic Screening Data Analyses Trends

The results of the ASCE 41 Tier 1 evaluations were analyzed for trends that may indicate characteristic hazards and similarities and differences between buildings of different vintages and with different features.

Figure 4.2.7-1 shows the percent noncompliant items that each building possesses, categorized by building type. The horizontal axis is plotted by construction or seismic upgrade date. The vertical axis displays the percent noncompliant items. The percent noncompliant items for each building was determined by dividing the quantity of noncompliant items for each building by the total possible quantity of evaluation statements.

The figure shows that older buildings generally have a slightly higher percentage of noncompliant items, but no single building has more than 50 percent identified noncompliant items. Several buildings have zero noncompliant items; however, in many instances this may be related to the lack of available information with which to complete the evaluation. These buildings may have evaluation items that are classified as "unknown".

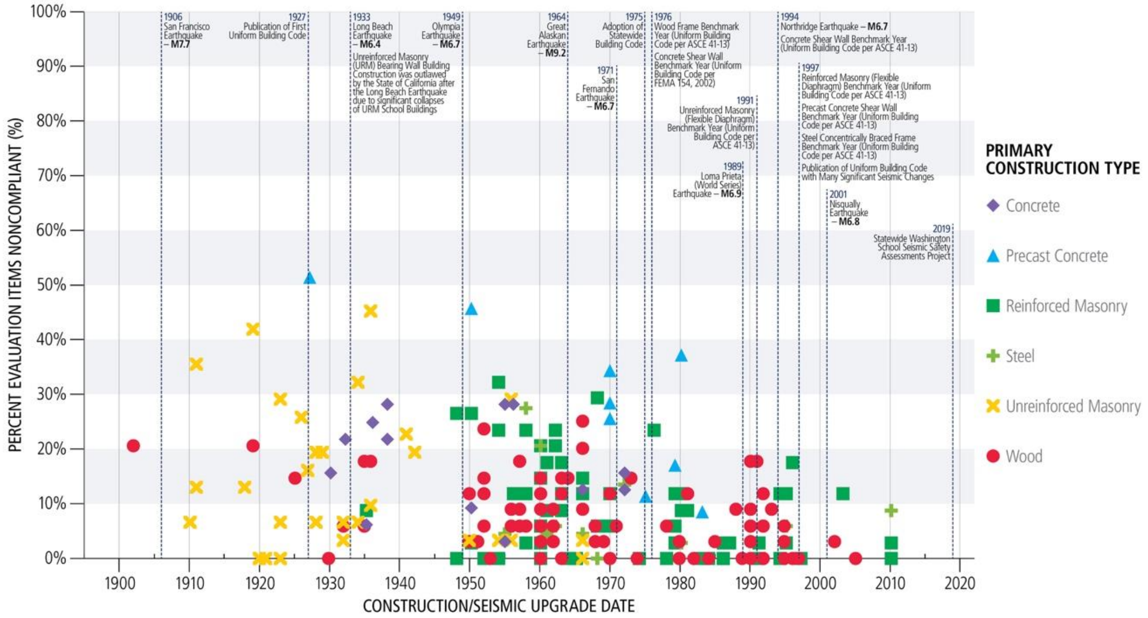


Figure 4.2.7-1. Percent ASCE 41 Tier 1 Items Noncompliant by Building Construction Type. (Appendix Figure A-1.1)

The previous figure only shows the percent of items identified as noncompliant. It does not show items that are classified as unknown. Figure 4.2.7-2 shows the percent of items classified as either noncompliant or unknown. The horizontal axis is plotted by construction or seismic upgrade date. The vertical axis displays the percent of noncompliant or unknown items. The percent of noncompliant or unknown items for each building was determined by dividing the total quantity of noncompliant or unknown items for each building by the total possible quantity of evaluation statements.

As expected, the figure shows that older buildings have a higher percentage of seismically noncompliant or unknown items. This relationship is more pronounced than in the previous figure. One URM building possesses a noncompliant or unknown percentage of about 90 percent. There is no building that has zero noncompliant or unknown evaluation items.

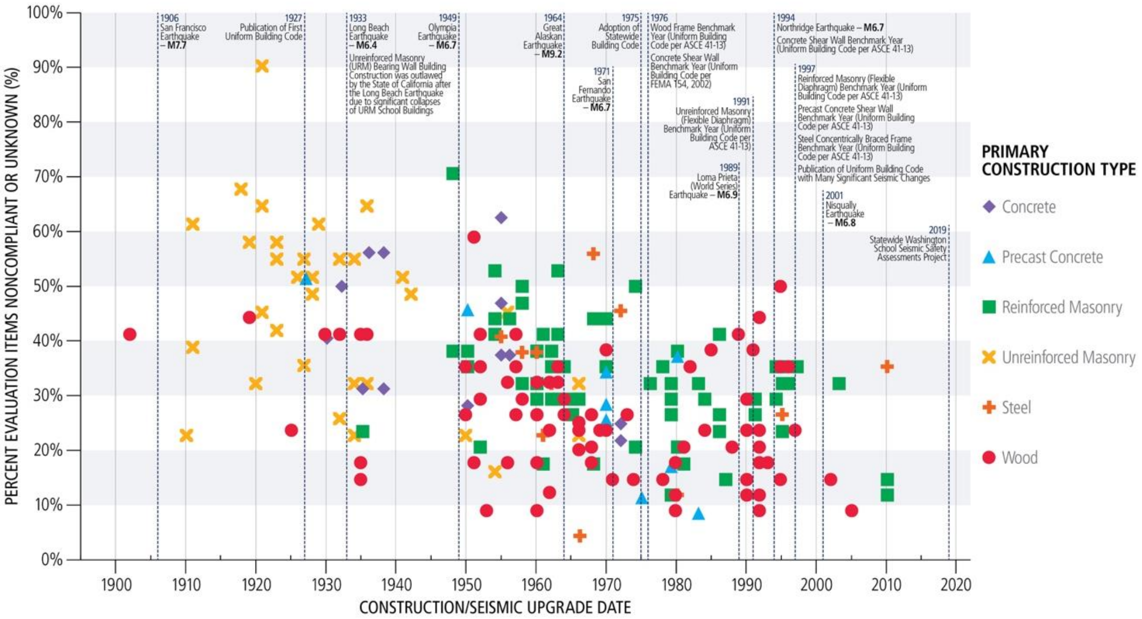


Figure 4.2.7-2. Percent ASCE 41 Tier 1 Items Identified as Noncompliant or Unknown Classified by Building Construction Type. (Appendix Figure A-1.2)

Figure 4.2.7-3 shows the percent of noncompliant items that each building possesses, categorized by design earthquake short-period spectral acceleration (S_{DS}). S_{DS} is used by ASCE 41 and ASCE 7 (in addition to S_{D1}) to define the level of seismicity for sites. The horizontal axis is plotted by construction or seismic upgrade date. The vertical axis displays the percent of noncompliant items.

The figure shows that buildings with S_{DS} less than 0.33g tend to have fewer noncompliant items than buildings with other levels of seismicity. This is likely because when buildings are located in low seismicity areas, many of the ASCE 41 checklist items become “not applicable”. There does not appear to be a strong correlation between percentage of noncompliant items and the other three higher levels of seismicity. While a building with an S_{DS} greater than or equal to 0.75g has the highest percentage of noncompliant items in the study, it is not clear whether this is by chance or due to the level of seismicity.

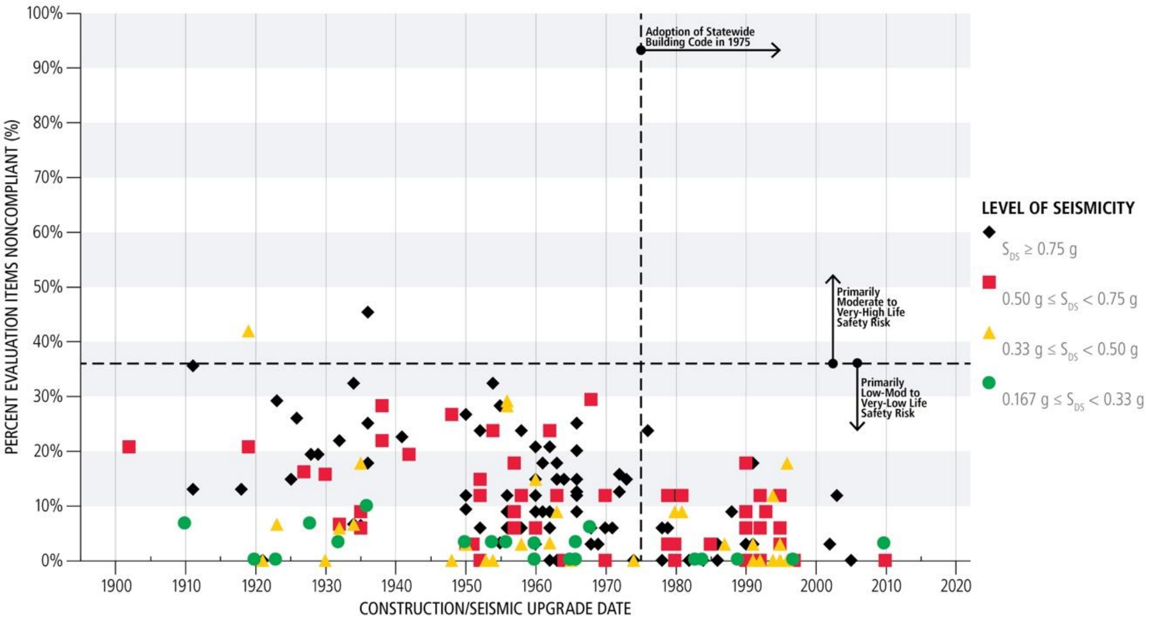


Figure 4.2.7-3. Percent ASCE 41 Tier 1 Items Identified as Noncompliant Classified by Design Earthquake Short-Period Spectral Acceleration (S_{DS}). (Appendix Figure A-1.3)

Figure 4.2.7-4 shows the percent of noncompliant or unknown items that each building possesses, categorized by design earthquake short-period spectral acceleration (S_{DS}). The horizontal axis is plotted by construction or seismic upgrade date. The vertical axis displays the percent of noncompliant or unknown items for each building.

Compared to Figure 4.2.7-3, Figure 4.2.7-4 still shows that buildings with S_{DS} less than 0.33g have the fewest combined noncompliant or unknown items compared to buildings with other seismicity levels. However, there appears to be little or no correlation of percent noncompliant or unknown items to level of seismicity for the other three levels. This is likely because the quantity of unknown items is a significant percentage of the combined noncompliant or unknown percentage. The quantity of unknown items for a building is related to the level of information available for review and would not be expected to be correlated to level of seismicity in any way.

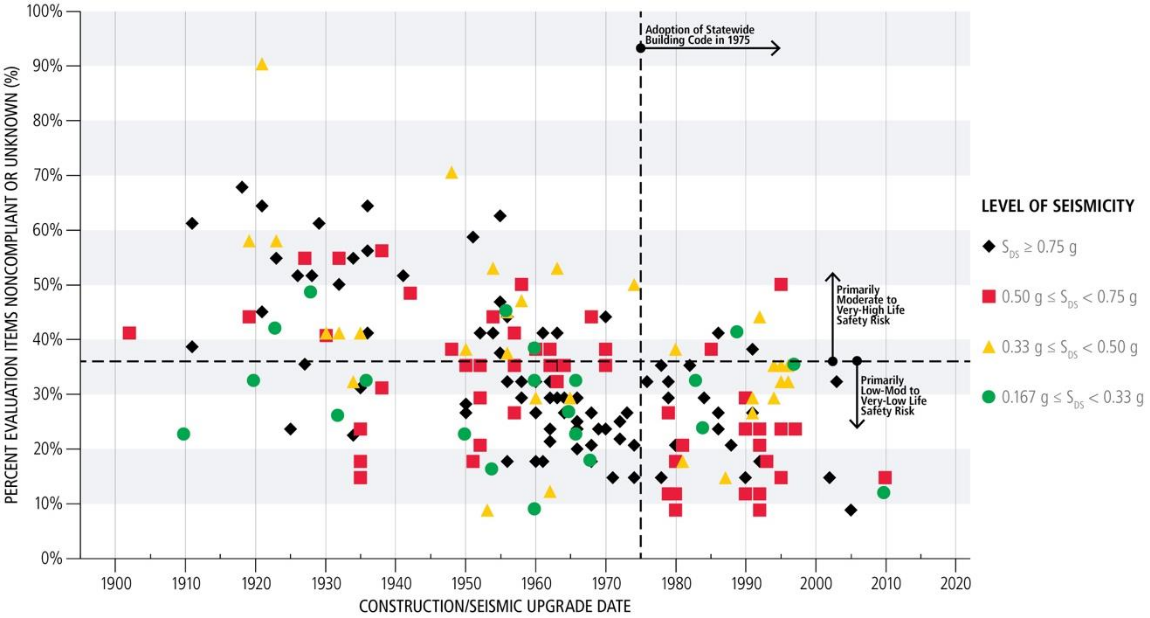


Figure 4.2.7-4. Percent ASCE 41 Tier 1 Items Identified as Noncompliant or Unknown Classified by Design Earthquake Short-Period Spectral Acceleration (S_{DS}). (Appendix Figure A-1.4)

4.3 EPAT Seismic Screening Findings and Data Analyses Trends

The primary value calculated for each building from EPAT is the amount of damage each existing building is expected to sustain in a design-level earthquake event. This value is displayed as a percentage of the building elements that are expected to be damaged. The design-level earthquake event is defined as being two-thirds of the magnitude of the maximum considered earthquake (MCE). The MCE is a risk-adjusted probabilistic event with a return period of 2,475 years. While not exact, the magnitude of the design-level earthquake event is similar to the magnitude of an earthquake event with a 475-year return period for many locations on the west coast of the United States. Earth scientists expect the average return period of a Cascadia Subduction Zone (CSZ) earthquake to be approximately 500 years. It is possible that a CSZ earthquake could be approximately the magnitude of the design level earthquake for many parts of Washington State, depending on the particular earthquake characteristics.

Figure 4.3-1 shows the building damage estimate ratio in the design earthquake plotted against building construction or seismic upgrade date. The figure also includes different symbols for the building lateral system's primary construction material type.

As illustrated in the figure, the dominant school construction type prior to the 1940s was unreinforced masonry. Prior to the 1940s, there were also some schools constructed of wood and concrete. Starting in the 1950s, many of the school buildings were constructed of reinforced masonry, wood, concrete, and steel. During the 1950s and after, the most prominent building construction types were wood and reinforced masonry.

Unreinforced masonry buildings and nonductile concrete buildings are especially vulnerable to earthquakes due to their weight and nonductile or brittle nature. As seen in the figure, many of these school buildings possess damage estimate ratios in the range of 70 to 80 percent. However, the figure also shows that many unreinforced masonry school buildings display damage estimate ratios of between 10 and 30 percent. For the most part, the unreinforced masonry buildings that display relatively low damage estimate ratios are not located in "high" seismic areas as defined by ASCE 41 (e.g., Eastern Washington). Approximately half of the unreinforced masonry school buildings included in the study are located east of the Cascade Mountain Range.

The figure shows that school buildings built after 1975 have precipitously decreasing damage estimate ratios, with school buildings constructed in the 1990s and the 2000s generally possessing the lowest damage estimate ratios of all the school buildings evaluated. One significant factor in earthquake performance is the building code standard to which a building was originally designed. The EPAT spreadsheet separates Washington State into zones where the design standards at the time of construction were different. According to the EPAT documentation, historically the Puget Sound Region has had the strictest building code requirements. Buildings in the Puget Sound Region were also designed for the highest level of earthquake shaking due to the high seismicity of the region. Buildings in the rest of Washington State were historically designed to lower seismic force and detailing standards.

Starting in 1975, the State of Washington adopted a statewide building code for the first time. The adoption of a statewide standard made construction requirements uniform across the state. This adoption of the statewide standard, in addition to significant improvements in the building codes through the 1970s, 1980s, and 1990s, led to school buildings that are significantly more resilient to earthquakes compared to older school buildings. This is illustrated in the figure, with the decreasing damage estimate ratios for buildings built in the 1980s, 1990s, and 2000s.

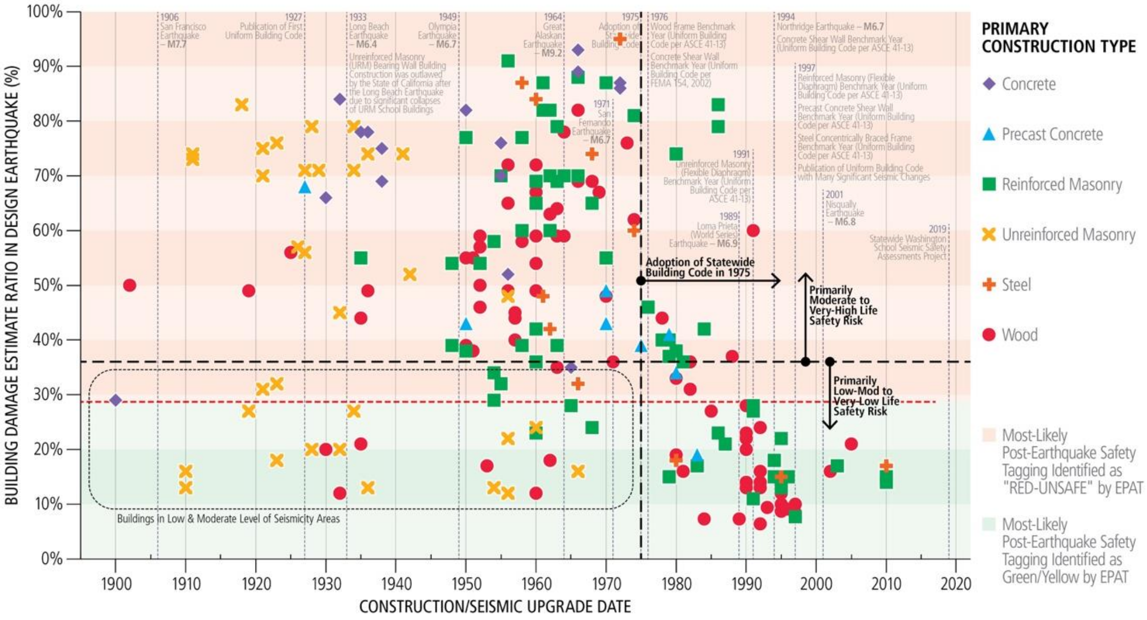


Figure 4.3-1. EPAT Damage Estimate Ratio Classified by Building Construction Type. (Appendix Figure A-4.1)

4.3.1 EPAT Sensitivity to Ground Motion

Figure 4.3.1-1 shows the EPAT building damage estimate ratios for the buildings, categorized by ground motion seismicity. The buildings are categorized by each site's short period spectral acceleration (S_{DS}) for the ASCE 7 design-level earthquake. It can be seen from the figure that the ground acceleration has a significant and strong effect on the expected performance of a building. Buildings located on sites of higher seismicity possess a consistently larger building damage estimate ratio compared to sites with lower seismicity.

Figure 4.3.1-2 shows the EPAT building damage estimate ratios for the buildings mapped across the state. The map background is shaded with the relative shaking hazard, which is based on the 2%/50-year USGS probabilistic peak ground acceleration values. The map shows that the most severe damage in a design-level earthquake is expected to occur in western Washington due to the higher probability of larger ground shaking combined with a vulnerable building stock. However, many buildings in central and eastern Washington are also expected to receive significant damage exceeding 25% and even 50% of the building's structural and nonstructural components in some cases.

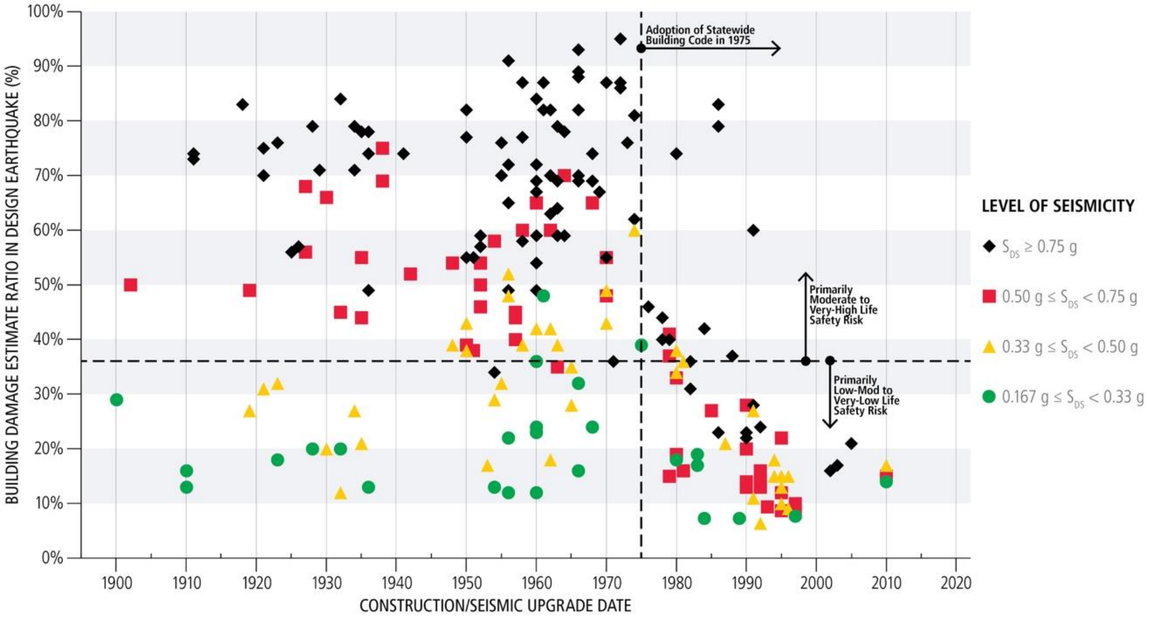


Figure 4.3.1-1. EPAT Damage Estimate Ratio Sensitivity to Ground Motion. (Appendix Figure A-4.2)

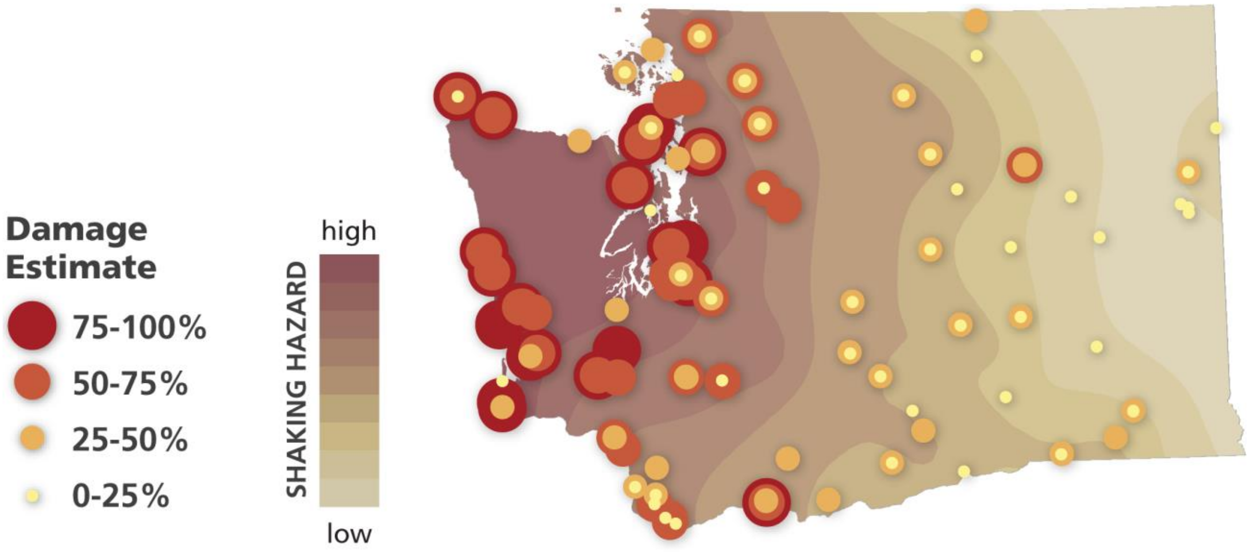


Figure 4.3.1-2. EPAT Damage Estimate Ratio Mapped Across the State (WA DNR, 2019).

4.3.2 EPAT Sensitivity to Liquefaction

Figure 4.3.2-1 shows the EPAT building damage estimate ratios for the buildings, categorized by the site's liquefaction potential as determined by statewide geologic mapping. The figure shows that the EPAT sensitivity to liquefaction potential is not as large as the sensitivity of the results to other factors, such as construction type, date of construction, and seismicity. It is possible the EPAT worksheets may underestimate the effect liquefaction has on building performance. Liquefaction tends to significantly increase ground deformation and ground settlement in an earthquake compared to sites without liquefiable soils.

The EPAT worksheets also do not consider foundation type as an input. Some of the buildings in the study that possess shallow foundations (i.e., strip and spread footings) are located on sites suspected from statewide mapping to have liquefaction potential. Deep foundations are usually required when buildings are constructed on liquefiable soils. The hazard created by a building with shallow foundations constructed on liquefiable soils is not captured within the EPAT worksheet framework. In addition, many of the older structures located on potentially liquefiable site soils are not likely explicitly designed to accommodate or resist additional demands from liquefaction (e.g., foundation cross ties).

The liquefaction potential based on statewide geologic mapping may not be accurate for some sites. Whether a site has liquefiable soils is incredibly important to understanding the seismic hazard. Due to the nature of the currently available information, the liquefaction hazard is not as detailed as it could be for the school sites.

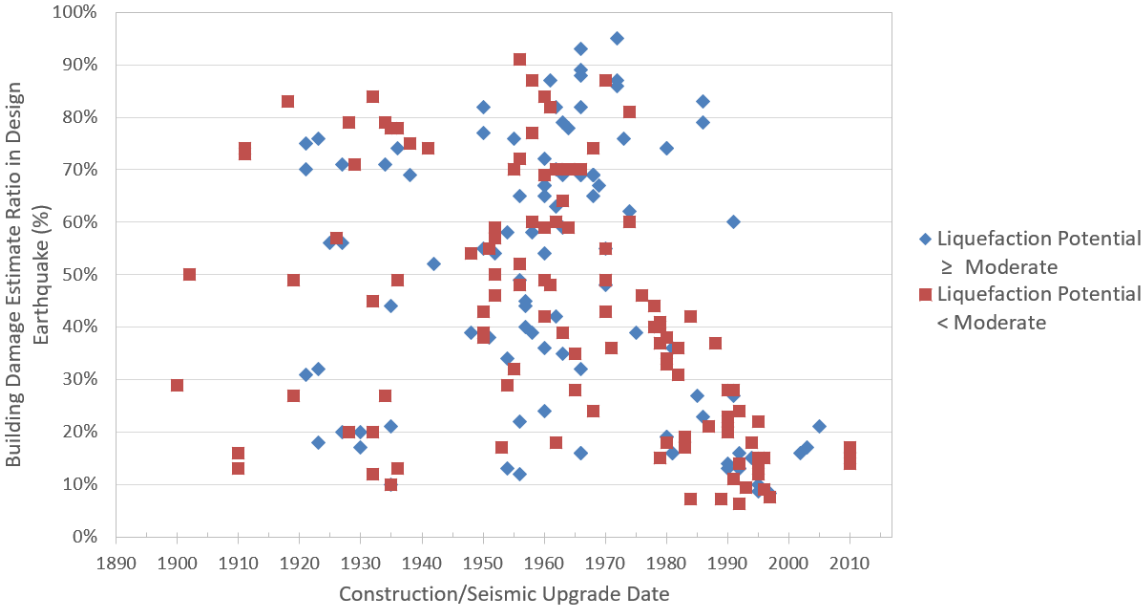


Figure 4.3.2-1. EPAT Damage Estimate Ratio Sensitivity to Liquefaction.

4.3.3 EPAT Sensitivity to Structural Irregularities

Figure 4.3.3-1 shows the EPAT building damage estimate ratios for the school buildings, categorized by whether a building possesses structural irregularities. Structural irregularities are typically related to whether the plan shape of a building is rectangular or not, or whether a building has significant variations in its horizontal or vertical stiffness and strength. Buildings without structural irregularities tend to perform better in earthquakes. The figure shows that the EPAT worksheets sensitivity to structural irregularities is not as large as the sensitivity of the results to other factors, such as construction type, date of construction, and seismicity.

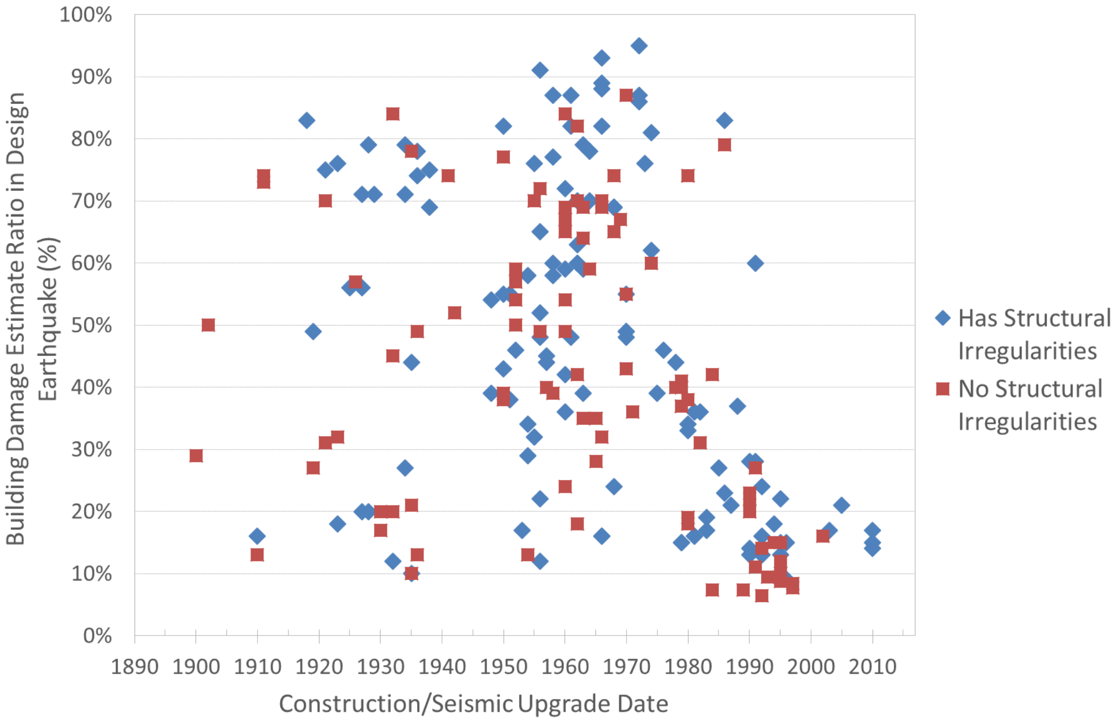


Figure 4.3.3-1. EPAT Damage Estimate Ratio Sensitivity to Building Irregularity.

4.3.4 EPAT Results for Most-Likely Post-Earthquake Tagging

Figure 4.3.4-1 shows the EPAT building damage estimate ratios for the school buildings, categorized by the EPAT-estimated post-earthquake tagging. Post-earthquake tagging is governed in the United States by building officials' adoption of the ATC-20 *Procedures for Post-Earthquake Safety Evaluation of Buildings* standard. This document separates post-earthquake tagging into three safety categories. Buildings can be tagged as Red Placard - UNSAFE, Yellow Placard - RESTRICRTED USE, or Green Placard - INSPECTED. The Red Placard indicates that a building is unsafe to occupy. A Yellow Placard indicates that access is restricted, and hazards exist, but limited access may be allowed under certain circumstances. A Green Placard indicates there are no restrictions on occupancy. The EPAT worksheets also include the possibility for buildings to be identified as Yellow/Red or Green/Yellow, presumably as damage states that lie midway between the RESTRICTED USE and UNSAFE placards and the INSPECTED and RESTRICTED USE placards. While these are not defined in the ATC-20 post-earthquake safety evaluation guidelines, these designations mean that there is a likelihood that a building may be tagged as either yellow or red, or green or yellow, respectively.

It should also be noted that the EPAT worksheets only identify the post-earthquake tagging outcome that is "most likely". It is possible that the building performance may be such that a different type of safety evaluation and tagging may be warranted after an earthquake. Earthquakes and building performance in earthquakes can be highly variable, and actual building performance can vary from estimated performance.

For the majority of buildings in the study (139 out of 222), the most-likely post-earthquake tagging is expected to be Red - UNSAFE (for the ASCE 7 design-level earthquake).

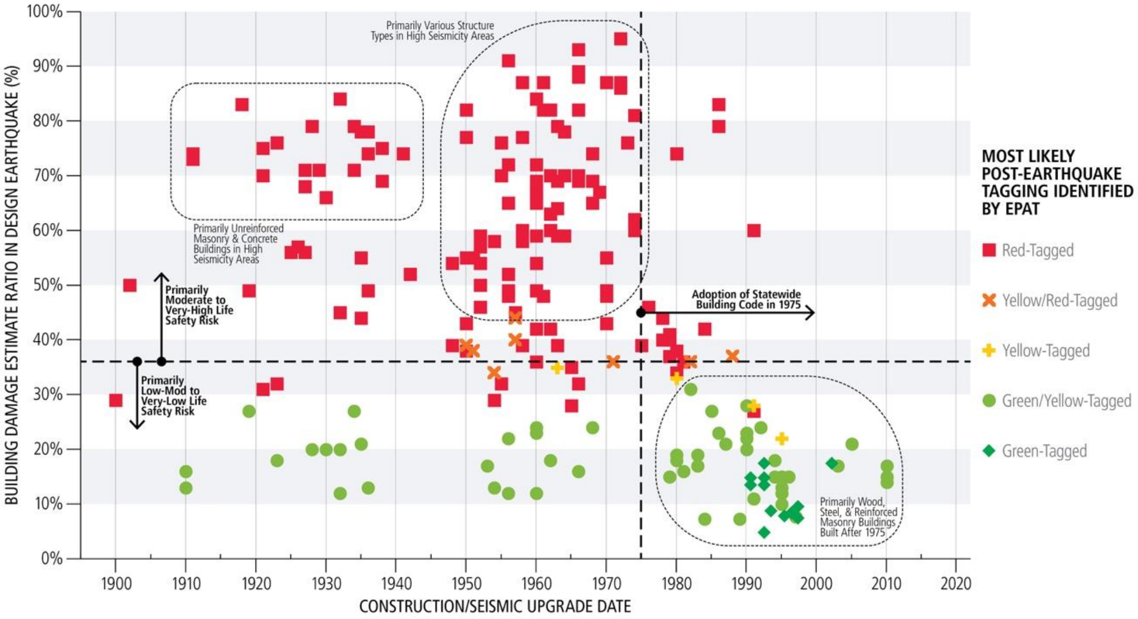


Figure 4.3.4-1. EPAT Most-Likely Post-Earthquake ATC 20 Building Safety Assessment Placard. (Appendix Figure A-4.3)

4.3.5 EPAT Worksheet Results for Life Safety Risk Level

Figure 4.3.5-1 shows the EPAT school building damage estimate ratios for the buildings, categorized by the EPAT-estimated life safety risk level. The life safety risk level reflects the relative risk for loss of life in the ASCE 7 design-level earthquake. As seen in the figure, almost half of the buildings in the study (95 of 222) pose a “high” or “very high” risk for life safety in the design-level earthquake.

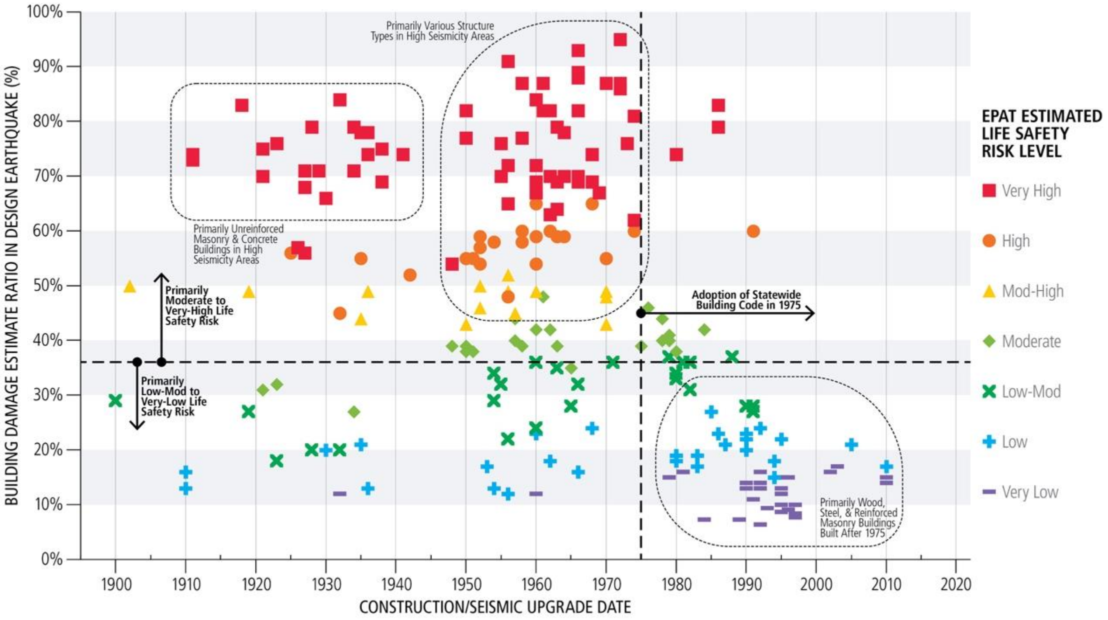


Figure 4.3.5-1. EPAT Results for Life Safety Risk Level.
(Appendix Figure A-4.4)

4.3.6 EPAT Economic Analysis

A detailed economic analysis was not included in the scope of this project. However, EPAT includes building damage estimate ratios that describe how much of a building is expected to be damaged during a design-level earthquake in relation to its replacement value. This information can be used to determine the direct financial cost to the building stock due to earthquake events.

In order to conduct an economic analysis of the buildings, it is important to know the replacement value of the buildings. Determining the replacement value of Washington State school buildings was not part of the scope of this project; however, OSPI provided Reid Middleton with a list of construction costs for new school buildings and renovations of school buildings from 2012 through 2017. The construction costs of new buildings varied depending on contract method, among other factors. In addition, buildings constructed in 2017 were, on average, more expensive than buildings constructed in 2012. In general, construction costs varied from a low of $256 to $324 per square foot in 2012 to $373 to $426 per square foot in 2017.

Given the recent 2017 construction cost information provided by OSPI, it was assumed that the replacement cost of the existing buildings was $250 per square foot. While this value is on the low end of the information provided by OSPI, it was selected assuming that existing buildings may not have as expensive or complicated finishes as some of the newest buildings, and we did not want to dramatically overestimate the value of the existing buildings due to scarcity in the construction environment in recent years. However, an extensive replacement value study was not conducted, and this value was arbitrarily selected based on the information provided by OSPI.

The 222 buildings included in the study have a combined square footage of 6,027,000 square feet. Using the assumed replacement cost of $250 per square foot, the 222 buildings have a replacement cost of $1.5 billion. In the 20%/50-year probabilistic earthquake event, the EPAT spreadsheets calculate that, based on these assumptions, the direct damage costs to the 222 buildings is expected to be $343 million. In the 10%/50-year probabilistic earthquake event, the EPAT spreadsheets calculate that the direct damage costs to the 222 buildings is expected to be $510 million. In the ASCE 7 and ASCE 41 design-level earthquake, the EPAT spreadsheets calculate that the direct damage costs to the 222 buildings is expected to be $642 million. In the 2%/50-year probabilistic earthquake event, the EPAT spreadsheets calculate that the direct damage costs to the 222 buildings is expected to be $904 million.

It is important to note that the direct damage costs above only account for the direct damage to the physical infrastructure. The costs do not account for costs associated with loss of life or costs associated with the school buildings being closed and inoperable for an extended period of time. These other costs can be substantial. If school buildings are closed for three to six months or longer, school districts must find alternative locations for student instruction. If schools are entirely closed for long periods of time, parents must find alternative activities or child care for their children when they would normally be in school. The long-term closure of school buildings could have profound effects on the economy and well-being of school-aged children beyond the direct damage costs listed above.

If the direct damage costs for the 222 buildings listed above are averaged over the return period associated with each earthquake event, this results in an annualized direct damage cost associated with each level. For the 20%/50-year earthquake with a return period of 225 years, the annualized direct damage costs are $1.5 million per year. For the 10%/50-year earthquake with a return period of 475 years, the annualized direct damage costs are $1.1 million per year. For the 2%/50-year earthquake with a return period of 2,475 years, the annualized direct damage costs are $0.4 million per year. The ASCE 7 and ASCE 41 design-level earthquake does not have a return period associated with it and, therefore, the annualized earthquake damage costs cannot be calculated for this earthquake level.

OSPI provided Reid Middleton with a list of all school buildings in the state. This list of 4,444 buildings only included permanent structures and removed temporary facilities and other facilities of a minor nature as determined by OSPI.

If the direct damage costs listed above for the 222 buildings are directly extrapolated to the 4,444 buildings in the state, the EPAT spreadsheets calculate that the 20%/50-year earthquake event is expected to produce $6.9 billion in direct damage costs to school buildings. If these costs are annualized over a 225-year return period, it results in an annualized cost of $30 million per year. As before, it is important to note that these direct damage estimates only account for the direct damage to the physical infrastructure.

The 20%/50-year earthquake event is one of the more likely earthquake events that could affect Washington State. A large magnitude Cascadia Subduction Zone earthquake is likely to be approximately equivalent to or larger than the 20%/50-year earthquake event. It is possible for a Cascadia Subduction Earthquake to affect the entirety of Washington State at the same time.

Less likely probabilistic earthquake events (i.e., 10%/50-year, 2%/50-year) are less likely to affect the entirety of Washington State at the same time, as these events are more likely to be focused on surface faults and have a smaller moment magnitude compared to a Cascadia Subduction Zone event. While these less likely probabilistic events are likely to have smaller moment magnitudes than a Cascadia Subduction Zone event, they are likely to have larger maximum ground accelerations at their epicenter compared to the ground accelerations produced by a Cascadia Subduction Zone event throughout most of the state. These less likely events may have a more damaging effect near their epicenter than a Cascadia Subduction Zone earthquake, but a Cascadia Subduction Zone earthquake is likely to affect a larger area.

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5.0 Concept-Level Seismic Upgrade Summaries

5.1 Concept-Level Design Seismic Upgrades Overview

Following the Tier 1 seismic evaluations, 15 school buildings were selected from those included in the study to receive more detailed concept-level upgrade designs. The 15 buildings were selected with the intent of providing variation in construction type, building use, building age, and whether drawings were available for the building. The primary intent of the concept-level seismic upgrades was to obtain cost estimates for each upgrade concept. Cost estimates were developed by a professional cost estimator.

While many buildings possess similarities, and there are similarities between the different seismic upgrades, each seismic upgrade is unique. Many of the seismic upgrades include similar items, such as wall strengthening, connection strengthening, out-of-plane wall strengthening, and diaphragm upgrades.

Table 5.1-1 includes a summarized list of the concept-level seismic upgrades. Data fields are provided for FEMA building type, ASCE 41 level of seismicity, site class, structural performance objective, year of construction, and summary of major seismic upgrade items.

Table 5.1-1. Concept-Level Seismic Upgrades Summary Table.

School District, School Building	FEMA Bldg. Type	ASCE 41 Level of Seismicity / Site Class	Structural Performance Objective	Year of Constr.	Summary of Major Seismic Upgrade Items
Battle Ground, Prairie HS Building 600	RM1	High / D	Life Safety	1979	Mezzanine Upgrades, Shear Wall Strengthening, Chord and Collector Strengthening, Out-of-Plane Wall Anchorage, Nonstructural Upgrades
Boistfort, Boistfort Elementary Gym	RM1	High / D	Immediate Occupancy	1963	Shear Wall Strengthening, Foundation Improvements, Added Roof Blocking and Nailing, Out-of-Plane Wall Upgrades and Anchorage
Carbonado, Carbonado Historical School 19, Gym	W2	High / C	Immediate Occupancy	1936	Shear Wall Upgrades, Diaphragm Upgrades, Load Path Improvements, Foundation Improvements, Nonstructural Upgrades
Centralia, Edison Elementary, Main Bldg.	URM	High / C	Life Safety	1918	Shear Wall Upgrades, Diaphragm Upgrades, Foundation Improvements, Nonstructural Upgrades
Cosmopolis, Cosmopolis Elementary, Main Bldg.	W2	High / D	Life Safety	1960	Exterior and Interior Wall Strengthening, Diaphragm Upgrades, Nonstructural Upgrades
Coupeville, Coupeville High School Gym	RM1	High / D	Life Safety	1981	New Concrete Shear Walls, Foundation Improvements, Nonstructural Upgrades
Dayton, Dayton High School Gym	S3	Low / B	Immediate Occupancy	1965	Added Rod Bracing, Moment Connection Strengthening, Nonstructural Upgrades
Grand Coulee Dam, Lake Roosevelt K-12 CTE Bldg.	S3	High / D	Life Safety	1955	Moment Connection Strengthening, Nonstructural Upgrades
Marysville, Totem Middle School Main Bldg.	RM1	High / D	Life Safety	1966	Out-of-Plane Wall Strengthening, New Shear Walls, Diaphragm Upgrades, Load Path Improvements, Nonstructural Upgrades
Mount Vernon, Lincoln Elementary Main Bldg.	C2	High / C	Life Safety	1938	Shear Wall Strengthening, Added Shear Walls, Foundation Improvements, Diaphragm Upgrades, Added Wall Anchorage, Nonstructural Upgrades
Naches Valley, Naches Valley HS Main Bldg.	RM1	High / D	Life Safety	1979	Wall Connection Strengthening, Added Wall Anchors, Nonstructural Upgrades
North Beach, Pacific Beach Elementary Gym	RM1	High / D	Immediate Occupancy	1956	Shear Wall Strengthening, Foundation Improvements, Diaphragm Upgrades, Nonstructural Upgrades

South Bend, South Bend Jr/Sr HS Koplitz Field House	RM1	High / E	Immediate Occupancy	1953	Shear Wall Strengthening, Foundation Improvements, Out-of-Plane Wall Strengthening and Added Anchorage, Nonstructural Upgrades
Spokane, Adams Elementary School Main Building	URM	Low / C	Life Safety	1910	Seismic Joint Strengthening, Diaphragm Upgrades, Added Out-of-Plane Wall Anchorage, Nonstructural Upgrades
White Salmon Valley, Columbia HS Gym	PC1a	High / C	Life Safety	1970	Diaphragm Upgrades, Added Out-of-Plane Wall Anchorage, Nonstructural Upgrades

W: Wood-Framed; URM: Unreinforced Masonry; RM: Reinforced Masonry; C: Reinforced Concrete; PC: Precast concrete; S: Steel-framed

5.2 Concept-Level Seismic Upgrades Design Methodology

The deficiencies identified in the ASCE 41 Tier 1 evaluations informed the concept-level seismic upgrades. Engineers used best judgement to develop the concept-level upgrades. These preliminary concept-level design sketches depict a design concept, or possibility for upgrade components for each of the 15 school buildings that could be implemented to improve the seismic safety of that specific school building. Figure 5.2-1 is an example of such a design for the first floor of Lincoln Elementary School, Mount Vernon, Washington. Refer to the appendices for the concept design reports for each school building.

Concept-level seismic upgrades were developed for either the IO or LS structural performance level at the direction of DNR. Five of the buildings were selected for development of concept-level upgrades for the IO level, and ten buildings were selected for development of concept-level upgrades for the LS level. All of the IO performance level buildings are gymnasium structures, with the intention of developing cost estimates for both an enhanced level of safety and approximate costs if gymnasiums were seismically upgraded to provide emergency shelter capabilities.

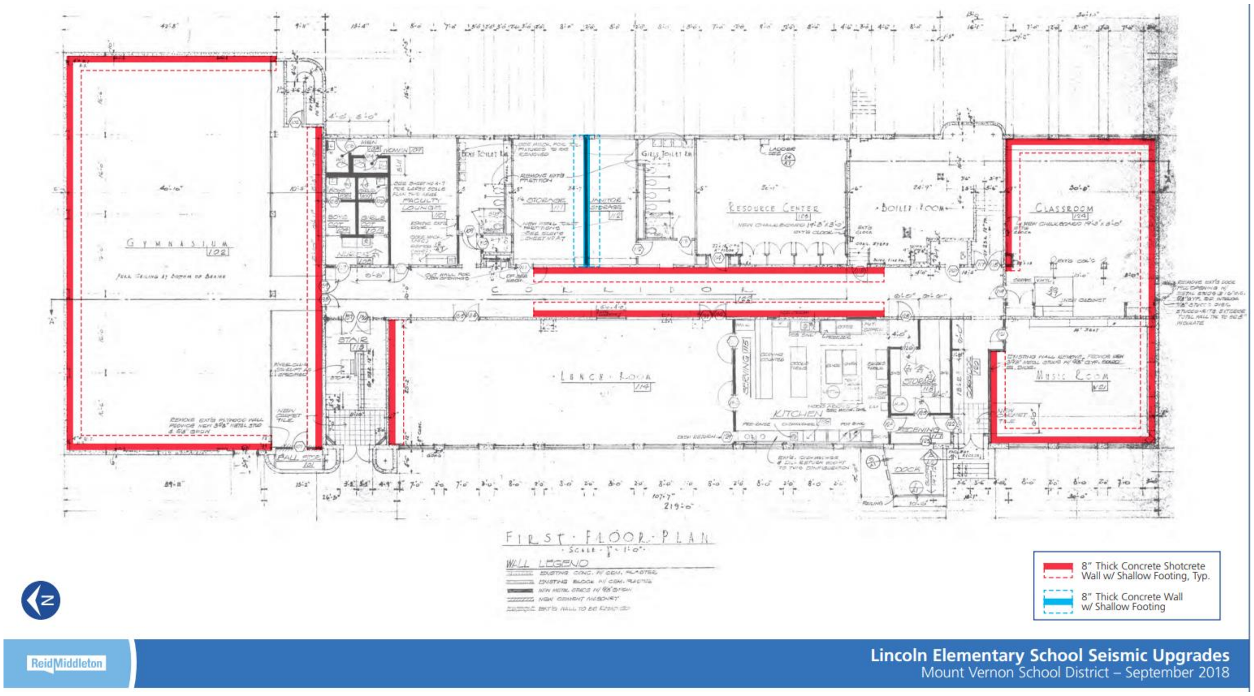

Figure 5.2-1. Example Concept-Level Seismic Upgrades Design Plan for the First Floor of Lincoln Elementary School, Mount Vernon, WA.

Class 5 cost estimates were developed by a professional cost estimator. Low and high cost range variances were developed in accordance with Table 1 of the AACE International Recommended Practice 56R-08, *Cost Estimate Classification System for Class 5 Estimates*. This table lists -20% to +50% range variance the averages costs for Class 5 cost estimates. Class 5 estimates are defined as 0% to 2% project definition level.

5.3 Typical Seismic Retrofit/Upgrade Costs

It is important to emphasize that the estimated seismic retrofit/upgrade costs developed for these buildings are preliminary in nature as they are based on the results of the Tier 1 seismic screening checklists and engineering design judgement and have not been substantiated by more typical detailed structural analyses. Consequently, the costs presented in this statewide seismic safety assessment study are preliminary in nature and are used to make generalized statewide costs ranges.

For these estimated costs, the current year (2019) construction cost of the probable scope of work was developed. Then a -20 percent (low) to +50 percent (high) range variance was used to develop the construction cost estimate ranges. The -20 percent to +50 percent range variance guidance is based on recommended estimated practices given the limited level of design. These preliminary estimates of construction costs include labor, materials, equipment, and general contractor conditions (mobilization), overhead, and profit. This is based on a public sector design-bid-build project delivery method. Project delivery methods such as negotiated, State of Washington General Contractor/Construction Manager (GC/CM), and design-build are not the basis of the construction costs. Owner's project costs not included in the construction cost estimate are building permits, design fees, change order contingencies, escalation at a recommended 4.1 percent[1] per year to the midpoint of construction (currently unknown), materials testing/inspection, project planning and design schedule delay contingencies, and owner's overall project contingency. Additional owner's project costs would likely include owner's general overhead costs, including project management, financing/bond costs, administration/contract/accounting costs, review of plans, value engineering studies, equipment, fixtures, furnishings and technology, and relocation of the school staff and students during construction. These additional costs are not included in these preliminary concept-level design construction cost estimates.

Costs of all types excluded from the construction costs are site work, construction of replacement facilities and mitigation of seismic risks for existing facilities and building code changes that occur over time after this report. Future planning budgets should not be set on the basis of the preliminary construction cost estimates presented in this report. For budget planning purposes, it is highly recommended that a seismic upgrade budget be determined after the owner defines the scope of work and obtains the services of a professional architect/engineer-led design team.

Because seismic upgrade costs are highly dependent on the building type, material, location, configuration, age, and quality among many other factors, the estimated seismic upgrade costs have been aggregated by material type. Table 5.3-1 below lists the total structural and nonstructural seismic upgrade estimated cost ranges for each of the 15 subject buildings and their corresponding averages. The cost ranges are presented as cost per square foot (SF) of building area so these estimated cost ranges can be extrapolated to other similar building types and sizes.

Seismic structural upgrade costs vary from a low of $0.55 per square foot to a high of $122 per square foot. The average seismic structural upgrade cost for the IO concept-level seismic upgrades is $69 per square foot. The average seismic structural upgrade cost for the LS concept upgrades is $42 per square foot. There is significant variation in seismic structural upgrade costs, dependent upon what structural deficiencies a building possesses and the extent of the required structural upgrades for each specific building case.

Nonstructural component seismic upgrade cost estimates were also prepared for the 15 school buildings in this study. These costs are only for the seismic upgrade of building nonstructural components such as suspended ceiling systems, fire protection equipment, and mechanical systems. Nonstructural component seismic upgrade costs vary from a low of $0.35 per square foot to a high of $71 per square foot. The average nonstructural component seismic upgrade cost is $27 per square foot. There is significant variation in nonstructural component seismic upgrade cost, dependent upon what seismic deficiencies a building possesses and the extent of the required seismic upgrades.

Table 5.3-1 lists combined structural and nonstructural component seismic upgrade costs, or total combined costs for these 15 buildings. Average total seismic upgrade costs vary from a low of

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[1] Note: -4.1%/year escalation rate for planning purposes should be compounded annually to the midpoint of construction and is sourced from *Engineering News Record (ENR),* November 2017, the most recent rate representative of the escalation of construction costs throughout the state of Washington.

$2.30 per square foot to a high of $182 per square foot. The average total seismic upgrade cost is $75 per square foot. There is also a significant variation in total seismic upgrade costs that are dependent upon what deficiencies a building possesses and the extent of the required seismic upgrades.

Similarly, fire station seismic upgrade costs to the immediate occupancy performance level are also highly variable due to building size, age, material type, location, configuration, and the extent of other renovations. Based on a database of 30 fire station buildings that received immediate occupancy seismic upgrades, average costs are $124 per square foot with ranges between a low of $25 per square foot to over $200 per square foot.

Table 5.3-1. Seismic Upgrade Cost Summaries Grouped by Building Type.

School District, School Building, Bldg. Type	Original Date of Construction	ASCE 41 Level of Seismicity / Site Class	Performance Objective	Bldg. Gross Area (SF)	Total Upgrade Cost Range $/SF (Total)			Median Total, $/SF (Total)
Battle Ground, Prairie HS Building 600, Reinforced Masonry	1979	High / D	Life Safety	10,725	$45 ($488K)	-	$85 ($915K)	$57 ($610K)
Boistfort, Boistfort Elementary Gym, Reinforced Masonry	1963	High / D	Life Safety	14,530	$60 ($910K)	-	$113 ($1.71M)	$75 ($1.14M)
Coupeville, Coupeville High School Gym, Reinforced Masonry	1981	High / D	Life Safety	10,000	$22 ($216K)	-	$40 ($404K)	$27 ($269K)
Marysville, Totem Middle School Main Bldg., Reinforced Masonry	1966	High / D	Life Safety	22,384	$66 ($1.45M)	-	$123 ($2.72M)	$82 ($1.81M)
Naches Valley, Naches Valley HS Main Bldg., Reinforced Masonry	1979	High / D	Life Safety	85,173	$22 ($1.07M)	-	$42 ($2.01M)	$29 ($1.34M)
North Beach, Pacific Beach Elementary Gym, Reinforced Masonry	1956	High / D	Life Safety	10,049	$145 ($1.46M)	-	$273 ($2.74M)	$182 ($1.83)
South Bend, South Bend Jr/Sr HS Koplitz Field House, Reinforced Masonry	1950	High / E	Life Safety	16,254	$63 ($1.03M)	-	$119 ($1.93M)	$79 ($1.29M)

School District, School Building, Bldg. Type	Original Date of Construction	ASCE 41 Level of Seismicity / Site Class	Performance Objective	Bldg. Gross Area (SF)	Total Upgrade Cost Range $/SF (Total)			Median Total, $/SF (Total)
Reinforced Masonry Averages	*1968*			*24,159* [2]	*$60*	-	*$114*	*$76*
Carbonado, Carbonado Historical School 19, Gym, Wood Framed	1936	High / C	Life Safety	5,700	$110 ($593K)	-	$206 ($1.11M)	$137 ($740K)
Cosmopolis, Cosmopolis Elementary, Main Bldg., Wood Framed	1960	High / D	Life Safety	30,460	$100 ($3.03M)	-	$187 ($5.69M)	$124 ($3.8M)
Wood Framed Averages	*1948*			*18,080* [2]	*$105*	-	*$197*	*$131*
Centralia, Edison Elementary, Main Bldg., Unreinforced Masonry	1918	High / C	Life Safety	31,520	$86 ($2.70M)	-	$160 ($5.05M)	$107 ($3.37M)
Spokane, Adams Elementary School Main Building, Unreinforced Masonry	1910	Low / C	Life Safety	27,300	$42 ($1.14M)	-	$78 ($2.14M)	$52 ($1.43M)
Unreinforced Masonry Averages	*1914*			*29,410* [2]	*$64*	-	*$119*	*$80*
Dayton, Dayton High School Gym, Steel Light Frame	1966	Low / B	Life Safety	27,152	$2 ($50K)	-	$3.50 ($95K)	$2.30 ($63K)
Grand Coulee Dam, Lake Roosevelt K-12 CTE Bldg., Steel Light Frame	1955	High / D	Life Safety	46,336	$3.10 ($142K)	-	$5.70 ($266K)	$3.80 ($177K)
Steel Light Frame Averages	*1960*			*36,744* [2]	*$3* [1]	-	*$5* [1]	*$3*[1]
Mount Vernon, Lincoln Elementary Main Bldg., Concrete Shear Wall	1938	High / C	Life Safety	40,002	$101 ($4.01M)	-	$188 ($7.52M)	$125 ($5.01M)
White Salmon Valley, Columbia HS Gym, Precast	1970	High / C	Life Safety	33,246	$37 ($464K)	-	$70 ($869K)	$47 ($580K)

School District, School Building, Bldg. Type	Original Date of Construction	ASCE 41 Level of Seismicity / Site Class	Performance Objective	Bldg. Gross Area (SF)	Total Upgrade Cost Range $/SF (Total)			Median Total, $/SF (Total)
Concrete Shear Wall								
Precast Concrete and Concrete Shear Wall Averages	*1954*			*36,624* [2]	*$69*	*-*	*$129*	*$86*
OVERALL AVERAGES	**1955**			**27,389** [2]	**$60**	**-**	**$113**	**$75**

[1] The S3 buildings estimated are Pre-Engineered Metal Buildings (PEMB) in regions with lower design seismic accelerations and may not be representative of PEMB in high-seismic hazard regions. Therefore, this cost/square foot should not be extrapolated to other steel buildings statewide.

[2] The average areas are being used by the study team to correlate the data gathered to the rest of the school buildings evaluated in this project.

These estimated seismic upgrade cost ranges and their corresponding variability are also illustrated in the following Figures 5.3-1 through 5.3-3.

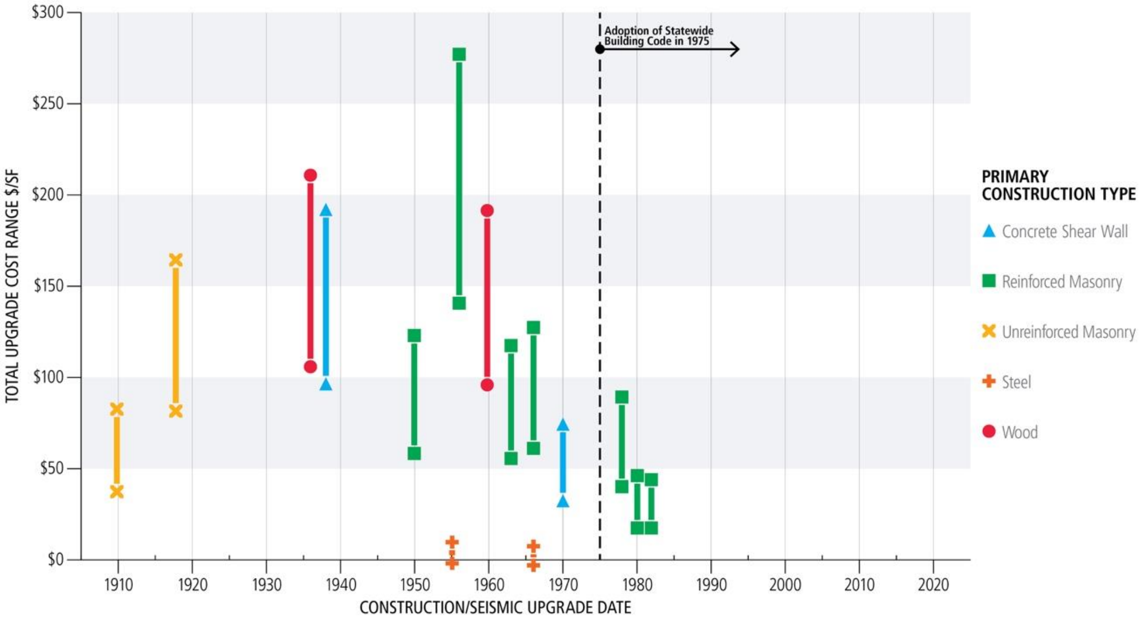


Figure 5.3-1. Total Seismic Upgrade (Structural and Nonstructural) Cost Ranges by Age and Building Construction Type.

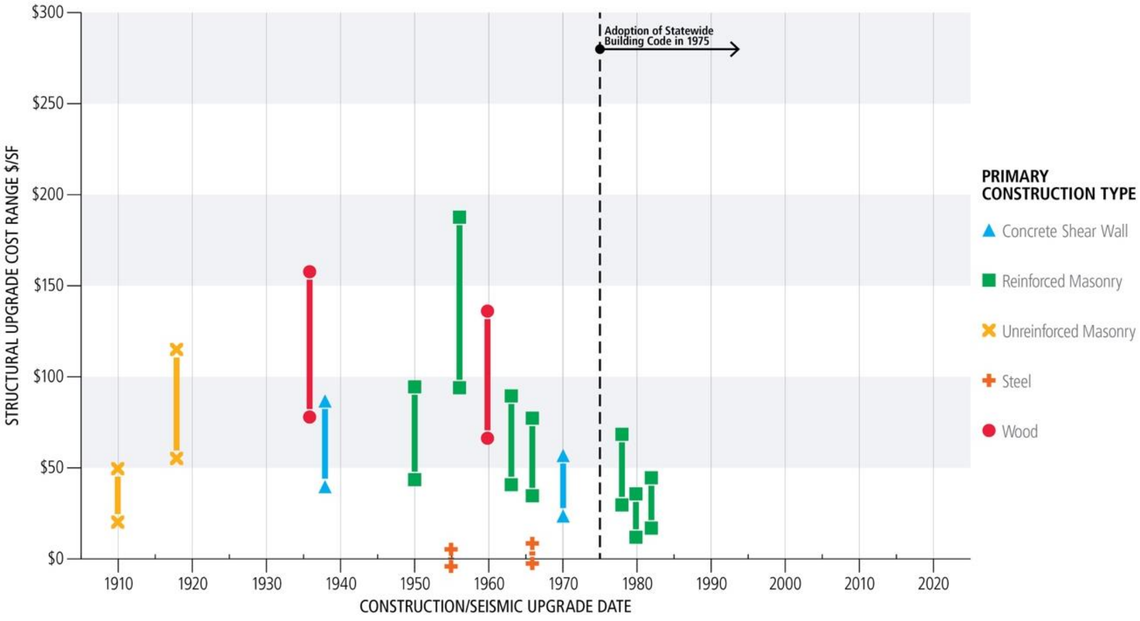


Figure 5.3-2. Structural Seismic Upgrade Cost Ranges by Age and Building Construction Type.

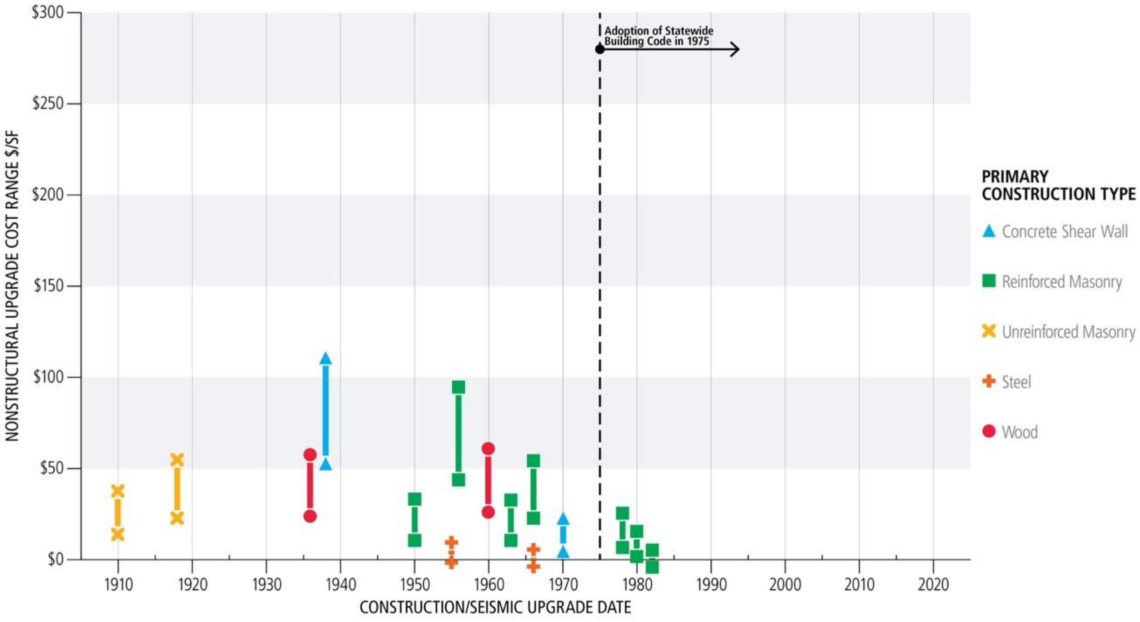


Figure 5.3-3. Nonstructural Seismic Upgrade Cost Ranges by Age and Building Construction Type.

For additional cost breakdown detail, the following tables provide breakdowns of the structural and nonstructural seismic upgrade costs.

Table 5.3-2 lists structural seismic upgrade costs. These costs are only for the upgrade of building structural components. Median structural upgrade costs vary from a low of $0.55 per square foot to a high of $122 per square foot. The average median structural upgrade cost for the IO concept upgrades is $69 per square foot. The average median structural upgrade cost for the LS concept upgrades is $42 per square foot. There is significant variation in structural upgrade cost, dependent upon what structural deficiencies a building possesses and the extent of the required structural upgrades.

Table 5.3-2. Structural Seismic Upgrade Cost Estimates.

School District, School Building	FEMA Bldg. Type	ASCE 41 Level of Seismicity / Site Class	Structural Performance Objective	Bldg. Gross Area (SF)	Structural Upgrade Cost Range ($/SF)	Median Structural Cost/SF
Battle Ground, Prairie HS Building 600	RM1	High / D	Life Safety	10,725	$34 - $64 ($366K) ($687K)	$43 ($458K)
Boistfort, Boistfort Elementary Gym	RM1	High / D	Immediate Occupancy	14,530	$45 - $85 ($687K) ($1.29M)	$57 ($859K)
Carbonado, Carbonado Historical School 19, Gym	W2	High / C	Immediate Occupancy	5,700	$82 - $153 ($465K) ($871K)	$102 ($581K)
Centralia, Edison Elementary, Main Bldg.	URM	High / C	Life Safety	31,520	$59 - $110 ($1.86M) ($3.48M)	$74 ($2.32M)
Cosmopolis, Cosmopolis Elementary, Main Bldg.	W2	High / D	Life Safety	30,460	$70 - $131 ($2.13M) ($3.99M)	$87 ($2.66M)
Coupeville, Coupeville High School Gym	RM1	High / D	Life Safety	10,000	$21 - $40 ($213K) ($399K)	$27 ($266K)
Dayton, Dayton High School Gym	S3	Low / B	Immediate Occupancy	27,152	$2 - $4 ($39K) ($73K)	$3 ($49K)
Grand Coulee Dam, Lake Roosevelt K-12 CTE Bldg.	S3	High / D	Life Safety	46,336	$0.50 - $0.85 ($21K) ($40K)	$0.55 ($26K)
Marysville, Totem Middle School Main Bldg.	RM1	High / D	Life Safety	22,384	$39 - $73 ($863K) ($1.62M)	$49 ($1.08M)
Mount Vernon, Lincoln Elementary Main Bldg.	C2	High / C	Life Safety	40,002	$44 - $82 ($1.74M) ($3.27M)	$54 ($2.18M)
Naches Valley, Naches Valley HS Main Bldg.	RM1	High / D	Life Safety	85,173	$16 - $31 ($781K) ($1.47M)	$21 ($977K)
North Beach, Pacific Beach Elementary Gym	RM1	High / D	Immediate Occupancy	10,049	$98 - $183 ($981K) ($1.84M)	$122 ($1.23M)
South Bend, South Bend Jr/Sr HS Koplitz Field House	RM1	High / E	Immediate Occupancy	16,254	$48 - $90 ($779K) ($1.46M)	$60 ($974K)
Spokane, Adams Elementary School Main Building	URM	Low / C	Life Safety	27,300	$24 - $45 ($655K) ($1.23M)	$30 ($820K)
White Salmon Valley, Columbia HS Gym	PC1a	High / C	Life Safety	33,246	$28 - $52 ($346K) ($649K)	$35 ($433K)

W: Wood-Framed; URM: Unreinforced Masonry; RM: Reinforced Masonry; C: Reinforced Concrete; PC: Precast concrete; S: Steel-framed

Table 5.3-3 lists nonstructural component seismic upgrade costs. These costs are only for the upgrade of building nonstructural components. Median nonstructural component upgrade costs vary from a low of $0.35 per square foot to a high of $71 per square foot. The average median nonstructural component upgrade cost is $27 per square foot. There is significant variation in nonstructural component upgrade cost, dependent upon what deficiencies a building possesses and the extent of the required upgrades.

Table 5.3-3. Nonstructural Component Seismic Upgrade Cost Estimates.

School District, School Building	FEMA Bldg. Type	ASCE 41 Level of Seismicity / Site Class	Nonstructural Performance Objective	Bldg. Gross Area (SF)	Nonstructural Upgrade Cost Range ($/SF)	Median Non-structural Cost/SF
Battle Ground, Prairie HS Building 600	RM1	High / D	Life Safety	10,725	$11 - $21 ($122K) ($228K)	$14 ($152K)
Boistfort, Boistfort Elementary Gym	RM1	High / D	Life Safety	14,530	$15 - $28 ($223K) ($418K)	$18 ($278K)
Carbonado, Carbonado Historical School 19, Gym	W2	High / C	Life Safety	5,700	$28 - $53 ($128K) ($239K)	$35 ($159K)
Centralia, Edison Elementary, Main Bldg.	URM	High / C	Life Safety	31,520	$27 - $50 ($837K) ($1.57M)	$33 ($1.05M)
Cosmopolis, Cosmopolis Elementary, Main Bldg.	W2	High / D	Life Safety	30,460	$30 - $56 ($909K) ($1.70M)	$37 ($1.14M)
Coupeville, Coupeville High School Gym	RM1	High / D	Life Safety	10,000	$0.28 - $0.52 ($3K) ($5K)	$0.35 ($4K)
Dayton, Dayton High School Gym	S3	Low / B	Life Safety	27,152	$0.55 - $1 ($12K) ($22K)	$0.70 ($15K)
Grand Coulee Dam, Lake Roosevelt K-12 CTE Bldg.	S3	High / D	Life Safety	46,336	$2.60 - $4.85 ($121K) ($226K)	$3.25 ($151K)
Marysville, Totem Middle School Main Bldg.	RM1	High / D	Life Safety	22,384	$27 - $50 ($586K) ($1.10M)	$33 ($733K)
Mount Vernon, Lincoln Elementary Main Bldg.	C2	High / C	Life Safety	40,002	$57 - $106 ($2.27M) ($4.25M)	$71 ($2.83M)
Naches Valley, Naches Valley HS Main Bldg.	RM1	High / D	Life Safety	85,173	$6 - $11 ($287K) ($538K)	$8 ($358K)
North Beach, Pacific Beach Elementary Gym	RM1	High / D	Life Safety	10,049	$48 - $90 ($481K) ($902K)	$60 ($601K)
South Bend, South Bend Jr/Sr HS Koplitz Field House	RM1	High / E	Life Safety	16,254	$15 - $29 ($251K) ($472K)	$19 ($315K)
Spokane, Adams Elementary School Main Building	URM	Low / C	Life Safety	27,300	$18 - $33 ($486K) ($911K)	$22 ($608K)
White Salmon Valley, Columbia HS Gym	PC1a	High / C	Life Safety	33,246	$9 - $18 ($118K) ($220K)	$12 ($147K)

W: Wood-Framed; URM: Unreinforced Masonry; RM: Reinforced Masonry; C: Reinforced Concrete; PC: Precast concrete; S: Steel-framed

5.4 Typical Seismic Retrofit/Upgrade Costs Analyses

5.4.1 Seismic Upgrade Costs Compared to Expected Damage Costs

One important metric when considering whether a seismic upgrade is worthwhile is whether a seismic upgrade is financially prudent. Other important metrics include life safety, injury prevention, repair costs, and repair time. The construction cost estimates developed in this study can be compared against expected damage costs at various earthquake levels, as predicted by EPAT. Detailed building replacement values were not available for use as part of this project, so a uniform building replacement value of $250 per square foot was assumed based on basic information provided by OSPI. Additional information is provided in Section 4.3.6. For future work, it may be prudent to conduct detailed building replacement value estimates in order to produce more-accurate results.

Table 5.4.1-1 displays the ratio of median estimated building earthquake damage costs divided by the building's median estimated total seismic upgrade costs, shown as the "cost ratio" in the table. The cost ratio is displayed for four different levels of earthquake. A 20%/50-year earthquake is a probabilistic event with a 225-year return period. A 10%/50-year earthquake is a probabilistic event with a 475-year return period. A 2%/50-year earthquake is a probabilistic event with a 2,475-year return period. The design earthquake is defined by ASCE 7 and ASCE 41 as an earthquake that is two-thirds of the magnitude of the 2%/50-year event. A cost ratio greater than 1.0 indicates that the expected damage in an earthquake event exceeds the total seismic upgrade costs.

For the 20%/50-year event, the results indicate the average cost ratio is 1.23. Six buildings have cost ratios less than 1.0, and nine buildings have cost ratios greater than 1.0. For the 10%/50-year event, the results indicate the average cost ratio is 2.59. Two of the buildings have cost ratios less than 1.0, and thirteen buildings have cost ratios greater than 1.0. For the design-level earthquake, the results indicate the average cost ratio is 4.90. Two of the buildings have cost ratios less than 1.0, and thirteen buildings have cost ratios greater than 1.0. For the 2%/50-year event, the results indicate the average cost ratio is 7.69. One of the buildings has a cost ratio less than 1.0, and fourteen buildings have cost ratios greater than 1.0.

These results indicate that for many buildings the cost to seismically upgrade the structure is less or much less than the damage costs the building would incur in an earthquake. Seismically upgrading a vulnerable structure will generally make the building stronger and stiffer, and decrease the damage costs the building will incur in an earthquake. For many buildings, the financial benefits to upgrading a structure exceed the construction costs of those upgrades.

For less vulnerable structures, especially structures in low seismicity areas, however, it may not be financially worth conducting seismic upgrades.

Table 5.4.1-1. Building Seismic Upgrade Costs Compared to Expected Damage Costs.

School District, School Building	FEMA Bldg. Type	Year of Constr.	20%/50-Year EQ Cost Ratio[1]	10%/50-Year EQ Cost Ratio[1]	Design EQ Cost Ratio[1]	2%/50-Year EQ Cost Ratio[1]
Battle Ground, Prairie HS Building 600	RM1	1979	1.31	2.26	2.59	3.46
Boistfort, Boistfort Elementary Gym	RM1	1963	1.81	2.41	2.62	3.03
Carbonado, Carbonado Historical School 19, Gym	W2	1936	0.48	0.75	0.89	1.27
Centralia, Edison Elementary, Main Bldg.	URM	1918	1.29	1.74	1.95	2.20
Cosmopolis, Cosmopolis Elementary, Main Bldg.	W2	1960	0.77	1.15	1.45	1.76
Coupeville, Coupeville High School Gym	RM1	1981	1.30	2.13	2.60	4.46
Dayton, Dayton High School Gym	S3	1965	1.92	8.46	10+	10+
Grand Coulee Dam, Lake Roosevelt K-12 CTE Bldg.	S3	1955	2.47	8.93	10+	10+
Marysville, Totem Middle School Main Bldg.	RM1	1966	1.59	2.03	2.12	2.61
Mount Vernon, Lincoln Elementary Main Bldg.	C2	1938	0.96	1.35	1.51	1.79
Naches Valley, Naches Valley HS Main Bldg.	RM1	1979	1.13	2.49	3.34	5.33
North Beach, Pacific Beach Elementary Gym	RM1	1956	0.74	1.06	1.25	1.33
South Bend, South Bend Jr/Sr HS Koplitz Field House	RM1	1953	1.99	2.28	2.44	2.86
Spokane, Adams Elementary School Main Building	URM	1910	0.02	0.12	0.63	1.40
White Salmon Valley, Columbia HS Gym	PC1a	1970	0.72	1.65	2.66	3.82

W: Wood-Framed; URM: Unreinforced Masonry; RM: Reinforced Masonry; C: Reinforced Concrete; PC: Precast concrete; S: Steel-framed

1. Cost ratio is the ratio of median estimated building earthquake damage costs divided by the building's median estimated total seismic upgrade costs.

6.0 Conclusions and Recommendations

6.1 Conclusions

The results of the seismic screening evaluations indicate that Washington State has many older public school buildings that are vulnerable to earthquakes. Older unreinforced masonry school buildings and non-ductile concrete school buildings located in high seismic hazard areas are especially vulnerable to earthquakes – this is a well-known fact. Many of these school buildings in high seismic hazard areas possess damage estimate ratios in the range of 70 to 80 percent. As expected, the unreinforced masonry school buildings in lower seismic hazard areas (Eastern Washington, for example) were calculated to have lower damage estimate ratios ranging between 10 to 30 percent. Approximately half of the unreinforced masonry school buildings included in the study are located east of the Cascade Mountain Range. As expected, many of the schools with the highest estimate of damage following a design-level earthquake are located in areas of highest earthquake hazard areas west of the Cascade Mountain Range.

The average date of construction of the buildings included in the study is 1963, which was well prior to the adoption of modern earthquake-resistant building codes. For buildings constructed prior to 1950, almost half of the seismic screening checklist items are identified as non-compliant. These older public school buildings should receive top priority for further study.

For buildings constructed between 1950 and 1990, approximately 30 percent of Tier 1 seismic screening checklist items are identified as non-compliant, again signifying additional seismic safety issues in these relatively newer buildings. Post-benchmark buildings (generally constructed after 1975) possess fewer non-compliant Tier 1 seismic screening items compared to older buildings. It is important to note that, due to the existence of building finishes, features, and other elements, many of the buildings evaluated were not able to have all of their seismic screening elements positively verified. This means that the estimated numbers of non-compliant seismic screening features are likely to increase as these buildings are examined with a more rigorous ASCE 41 Tier 2 and Tier 3 seismic evaluation procedure.

The EPAT spreadsheets estimate that the median building is expected to be 43 percent damaged in a design-level earthquake. EPAT also estimates that the majority (greater than 50 percent) of buildings in this study are expected to receive a “Red-Unsafe” post-earthquake building safety placard following a design-level earthquake, meaning that these buildings will likely be unsafe to occupy. In addition, the EPAT spreadsheets estimate that approximately one-fourth of buildings studied will not likely be repairable following a design-level earthquake and will likely require demolition.

The results of the 15 concept-level seismic retrofit/upgrades design case studies indicate that the cost to seismically upgrade a vulnerable structure is less or much less than the damage costs the building would incur from a design-level earthquake. For less vulnerable structures, especially structures in low seismic hazard areas, however, it may not be cost-effective to implement seismic improvements in these buildings due to lower levels of seismic risk. The cost results presented within this report are for statewide informational purposes. The goal is that this information can help the governor, state legislators, state agencies, school districts, school administrators, teachers, students, parents, and the public better understand the current level of seismic risk of older Washington State public school buildings. Public schools will need financial support to make the necessary changes suggested through this study.

6.2 Seismic Policy Recommendations

Over the last several decades, many disparate studies on improving the seismic safety of Washington State public school buildings have been performed. Experts in building safety, geologic hazards, emergency management, education, and even the news media have been asserting for decades that seismic risks in older public school buildings represent a significant risk to our communities. It is recognized that there are other natural hazards and operational needs that school districts' distinctively have; however, earthquake and tsunami hazards occur without warning, are potentially life-threatening, and can significantly impact Washington State on a regional level. Being prepared for such a sudden, unpredictable, and potentially catastrophic event is crucial for public schools and the communities that they serve to achieve better resiliency. The time to act is now, before we have a damaging earthquake and/or tsunami that could be catastrophic.

This statewide school seismic safety assessments project collects data on a statewide sample of public school buildings and provides a unique opportunity to draw attention to the need for statewide seismic safety policies and funding on behalf of all school districts that will help enable school districts to increase the seismic safety of their older buildings to make them safer for students, teachers, staff, parents, and the community.

One of the biggest roadblocks to seismically safe schools is that local funding through school district bond programs is how the majority of school facility construction is funded. Funding needs can far outstrip funding capabilities at the local school district level. To help close this gap, statewide public school seismic safety improvements policies and associated funding is needed. It is clear that seismically upgrading buildings can save lives, reduce economic loss, and help communities to recover following the next earthquake.

While the scope of the seismic risk problem may seem extensive, many seismic safety improvements can be made with relatively modest financial investments. For example, if building seismic upgrades are combined with roof replacements or school modernizations that are already planned to occur, the inclusion of seismic upgrades tends to lead to a relatively small overall cost increase. If a long-term seismic upgrade program is created to improve school seismic safety over many decades, the annual (or biannual) costs of the program are likely to be modest. When comparing the known financial costs of earthquakes to the costs of seismic upgrades, in many cases the financial benefits of seismic upgrades far exceed the costs. So, not only can seismically upgrading buildings save lives and allow schools to remain open after earthquakes, it can also save a lot of money.

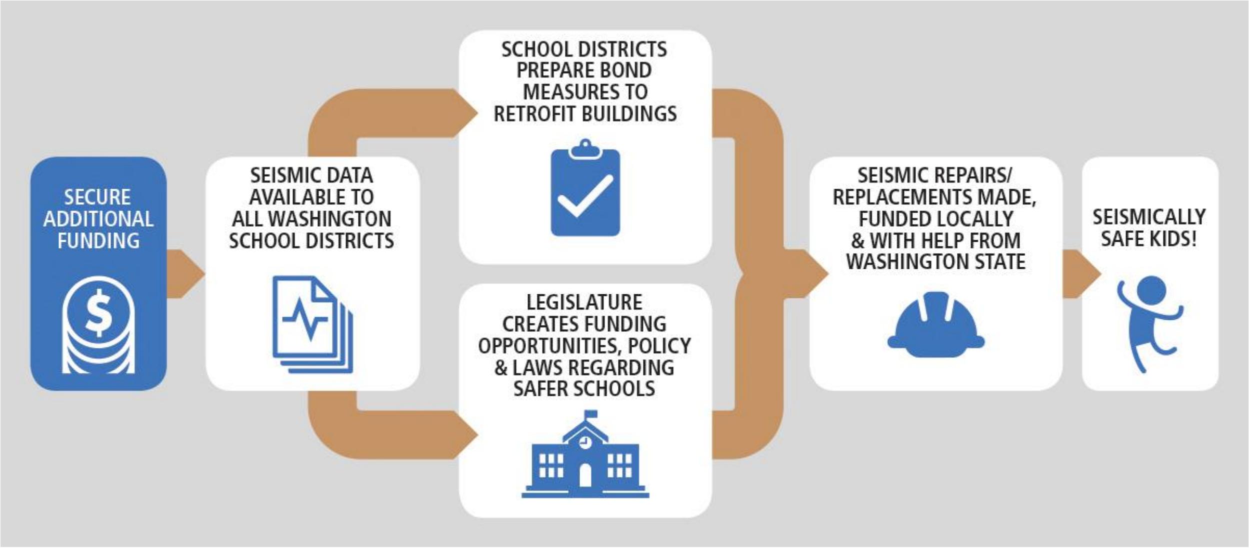


Figure 6.2-1. Possible School Seismic Safety Grant Funding Flow for School Districts.

The following are several generalized recommendations for improvements to statewide seismic safety policies for public school buildings.

1. We recommend that Washington State prioritize school seismic safety and resilience and create a pilot School Seismic Upgrade Assistance Grant Program that school districts can apply to for funding for seismic improvements based on the results of seismic screening evaluations. The proposed pilot program would provide funding assistance to school districts to implement seismic improvements to school buildings that have been identified as having a high seismic safety risk. Prioritized seismic screening results from the statewide school seismic safety assessments project conducted by the Department of Natural Resources could be used to help identify suitable school buildings. Grant funding could be used along with the school construction assistance grant program. We understand that OSPI proposes to include this in their 2021–2023 legislative budget request.

2. We recommend that DNR/WGS and OSPI continue to seismically assess Washington State public school buildings in high seismic and tsunami hazards areas to continue to collect the data for use in developing statewide school seismic safety improvement programs policy and to help define funding needs. This data should continue to be saved and maintained in OSPI’s ICOS database and could be augmented by additional seismic safety improvements data furnished directly to OSPI from the school districts.

3. We recommend refining Washington State’s school modernization policies in the Washington Administrative Code to specifically include school seismic safety improvements to be a required part of school modernization funding and construction programs.

4. We recommend that statewide public school specific seismic safety improvement criteria be developed and to make those criteria an incentive for school modernization and capital improvements funding.

5. We suggest that existing state-level public school modernization and capital improvements funding be evaluated to determine potential for allocating a small percentage (say 1 percent) of existing school modernization funding for a statewide school seismic upgrades assistance grant program for systematic and targeted seismic evaluation and upgrades construction for the most vulnerable buildings in the State's highest seismic and tsunami hazard areas.

It is not the intent of this study to create an unfunded mandate for school districts to seismically upgrade their schools without associated funding or statewide seismic safety policy support. The overall goal of this study is to screen and evaluate the current levels of seismic vulnerabilities of a statewide selection of our older public school buildings and to use the data and information to help quantify funding and policy needs to improve the seismic safety of our public schools. In this process, we are using this data and information to not only inform the Washington State governor and legislature of the policy and funding needs for seismically safe schools, but to also help inform and be an advocate for the public school districts that participated in this statewide study.

Additionally, while some districts may know that their older school buildings may not be seismically safe, many may not know the seismic vulnerability of their school buildings. These seismic screening reports help identify them and our expectation is that some of the seismically noncompliant items (structural and nonstructural) identified in the individual building reports could be tied into projects that are underway or planned. Providing this information should help facilitate incorporating seismic improvements during a school building modernization project.

6.3 Recommendations for Future Work

This study is the first statewide seismic assessment of Washington State schools. Given the social, communal, and financial importance of publicly owned schools within Washington State, it is essential that seismic assessment efforts be continued and incremental seismic improvements be made to buildings, where warranted, to increase earthquake safety for students, teachers, and staff, and to increase the seismic resiliency of Washington State communities.

Economically, incremental investments improving Washington's aged and seismically vulnerable public school buildings not only increases protection of students sooner, but also better protects the public's overall investment in school facilities and infrastructure; not only against the highly publicized Cascadia earthquake event, but also for other smaller and potentially more frequent seismic events. The overall costs of the investment to seismically upgrade the state's most vulnerable buildings is no doubt staggering. However, the cost and time to rebuild a multitude of school buildings at the same time, following a Cascadia type of earthquake event, effecting nearly 750,000 public school students, could be an overwhelming obstacle in Washington State's post-disaster recovery.

The following recommendations can be performed in subsequent phases of work to better define the extent of the statewide problem and the range of solutions for seismically safer schools throughout Washington State. As more data and information becomes available, we expect that statewide seismic safety policy recommendations and associated funding needs will evolve as we continue to learn more about the seismic risks of public school buildings in the State of Washington.

1. Further seismically screen, retrofit, or upgrade vulnerable public school buildings in higher risk areas to refine the understanding of policy and funding needs. This will help initiate long-term programs to make public schools safer. Consider prioritizing school building screening evaluations and improvements with the following features in descending order of priority:

    a. Seek immediate funding for seismic improvements or abatement for the buildings with the greatest known seismic risks such as Unreinforced Masonry (URM) Bearing Wall Buildings and Nonductile Concrete Buildings in high seismic hazard areas.

    b. Perform additional seismic screening evaluations and risk-based prioritization of reinforced masonry, wood framed, and concrete shear wall school buildings in the highest seismic and tsunami hazard areas.

    c. Prioritize school buildings with the highest student populations to ensure the greatest good for the most people.

    d. Generally, prioritize seismic screening and upgrades of the oldest pre-benchmark buildings first. This can be subdivided into building materials, ages (pre-benchmark), and student population size.

    e. Consider prioritizing schools in high seismic hazard areas where school bond levies have been recently successful. This could be an indicator of better public awareness and support of public school facility needs.

2. Perform an engineering and economic study to determine cost-benefit ratio thresholds for seismically upgrading older public school buildings of various construction types and vintages. This work could include an earthquake scenario-based use of FEMA P-58, Seismic Performance Assessment of Buildings, building evaluations on select case study school buildings to help characterize expected losses. FEMA P-58 is a tool similar to FEMA Hazus Loss Estimation Tool that allows for building loss estimation due to earthquakes but is more detailed and expected to be more accurate than Hazus. Unlike other building evaluation tools, FEMA P-58 allows users to properly account for uncertainty in building performance. The use of FEMA P-58 may allow the State of Washington to much better understand expected financial losses due to earthquakes.

3. Develop a statewide public school seismic safety outreach and advocacy program to help smaller school districts in rural or economically disadvantaged communities located within high seismic and tsunami hazard areas.

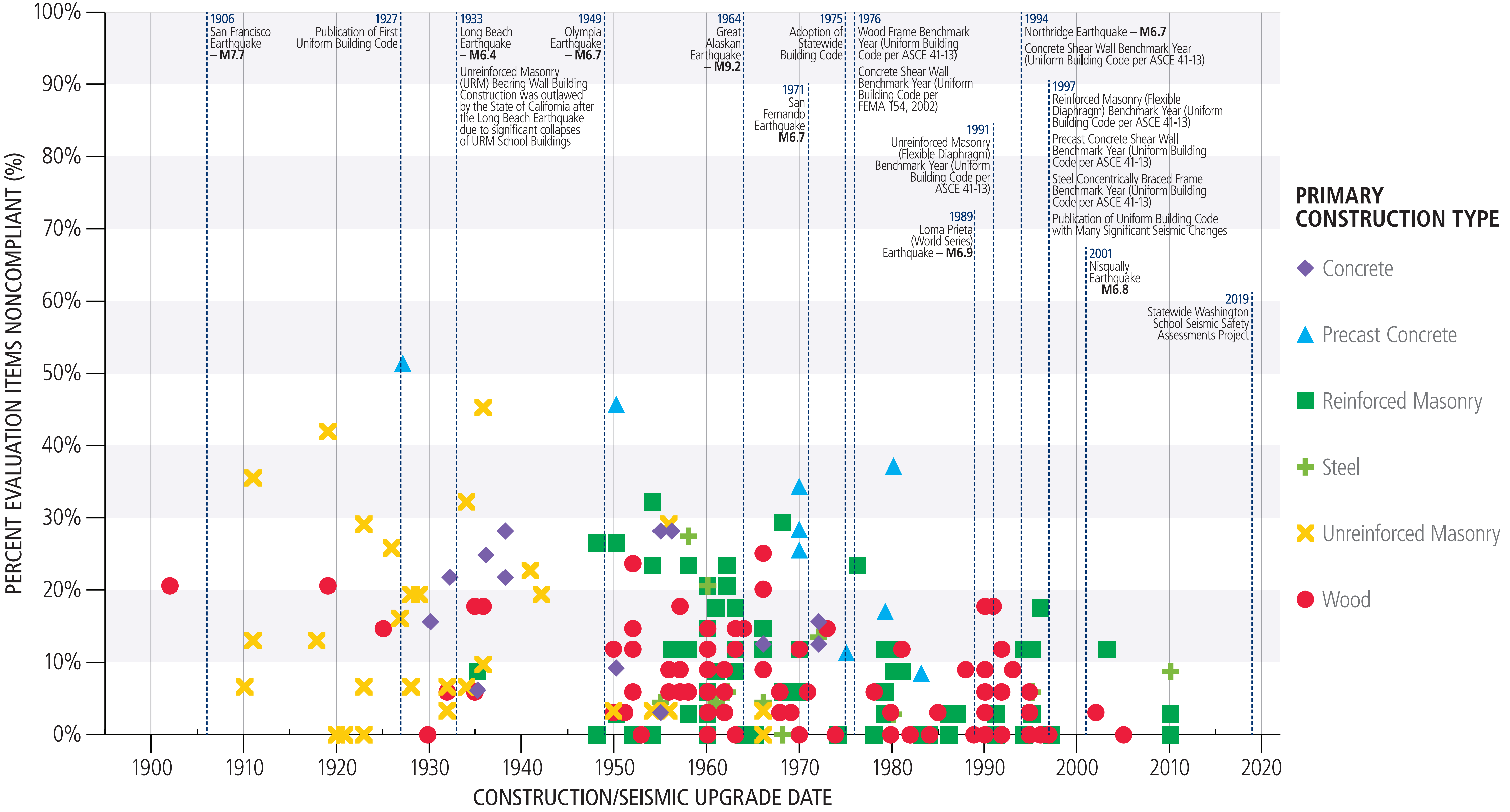
4. Study legislative policies and statewide funding levels in our region (CA, OR, UT, and BC Canada) to determine the effectiveness of public school seismic safety programs, policies, and laws and how much statewide public funding was beneficial to those communities for improving seismic safety of their public school buildings.

5. Complete a survey and seismic safety improvements inventory of all Washington State school districts to see where seismic upgrades to public school buildings have already been completed and enter this information into the OSPI ICOS database. Especially survey the larger urban (more well-funded) school districts such as Seattle Public Schools, Bellevue School District, Edmonds School District, and Bellingham Public Schools among many others.

6. Study the benefits and the costs of higher-than-life-safety seismic performance objectives such as Immediate Occupancy for assembly-occupancy public school buildings in high seismic and tsunami hazard areas. These facilities may be used as disaster shelters within the public school communities that they serve.

Solving large and complex statewide seismic safety concerns with thousands of aging public school buildings that need local school district funding support is going to take 21st century problem solving skills that rely on data to guide and inform the best approaches and most-efficient solutions. This statewide study is the first step towards obtaining the data and generating the information and knowledge required to better understand the extent and scope of the problem. This is a problem that may require a decade or more of action, policy creation, refinement, and funding to successfully complete. The solution will require significant leadership, long-term strategic thinking, public support, and funding necessary to start a statewide movement toward seismically safer older public school buildings.

APPENDIX A: SEISMIC SCREENING DATA FIGURES



1906
San Francisco Earthquake – **M7.7**

1927
Publication of First Uniform Building Code

1933
Long Beach Earthquake – **M6.4**

Unreinforced Masonry (URM) Bearing Wall Building Construction was outlawed by the State of California after the Long Beach Earthquake due to significant collapses of URM School Buildings

1949
Olympia Earthquake – **M6.7**

1964
Great Alaskan Earthquake – **M9.2**

1971
San Fernando Earthquake – **M6.7**

1975
Adoption of Statewide Building Code

1976
Wood Frame Benchmark Year (Uniform Building Code per ASCE 41-13)

Concrete Shear Wall Benchmark Year (Uniform Building Code per FEMA 154, 2002)

1989
Loma Prieta (World Series) Earthquake – **M6.9**

1991
Unreinforced Masonry (Flexible Diaphragm) Benchmark Year (Uniform Building Code per ASCE 41-13)

1994
Northridge Earthquake – **M6.7**

Concrete Shear Wall Benchmark Year (Uniform Building Code per ASCE 41-13)

1997
Reinforced Masonry (Flexible Diaphragm) Benchmark Year (Uniform Building Code per ASCE 41-13)

Precast Concrete Shear Wall Benchmark Year (Uniform Building Code per ASCE 41-13)

Steel Concentrically Braced Frame Benchmark Year (Uniform Building Code per ASCE 41-13)

Publication of Uniform Building Code with Many Significant Seismic Changes

2001
Nisqually Earthquake – **M6.8**

2019
Statewide Washington School Seismic Safety Assessments Project

Figure A-1.1 – ASCE 41 Tier 1 Percent Evaluation Items Noncompliant Categorized by Primary Construction Type

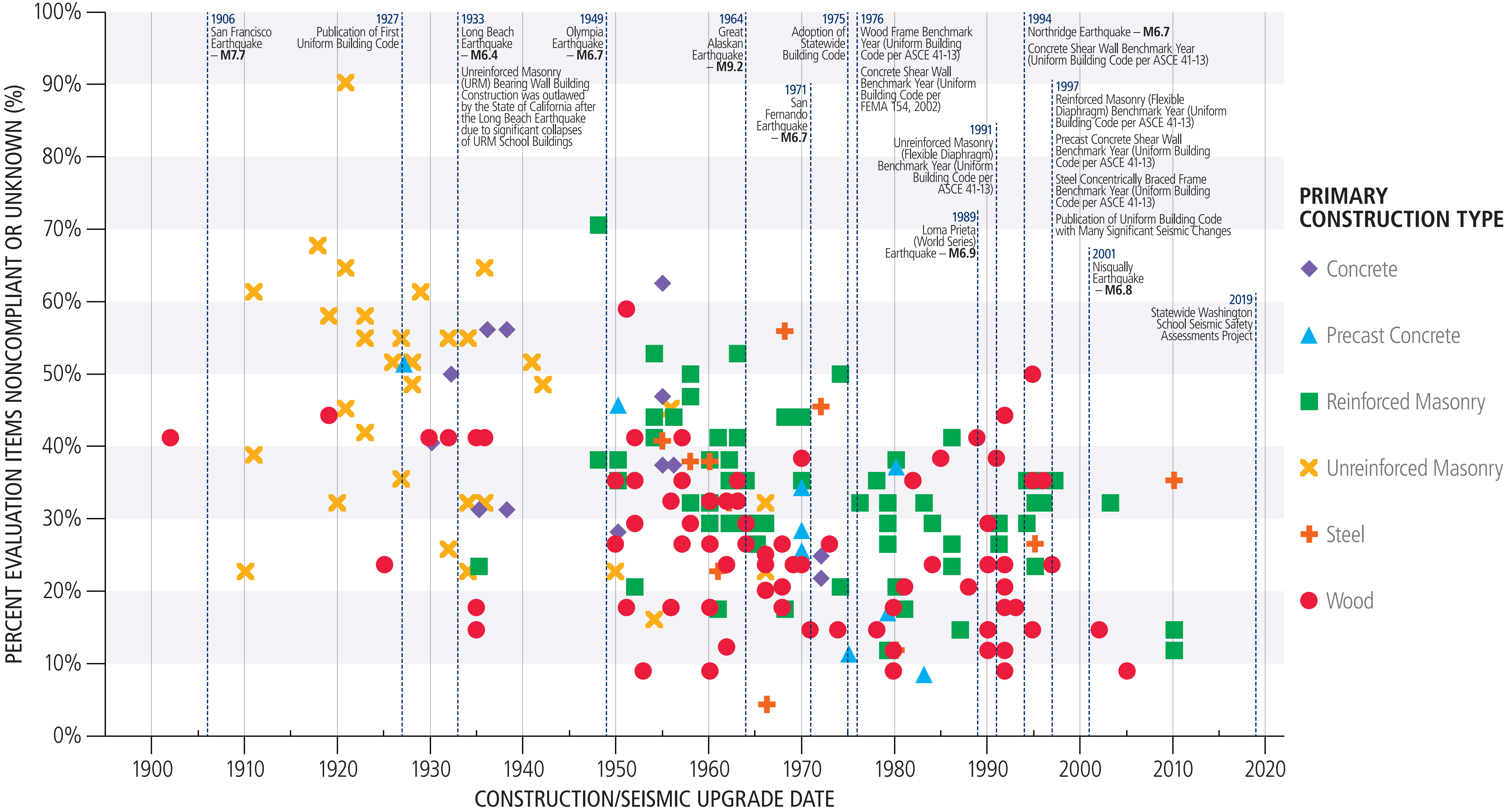


Figure A-1.2 - ASCE 41 Tier 1 Percent Evaluation Items Noncompliant Or Unknown Categorized By Primary Construction Type

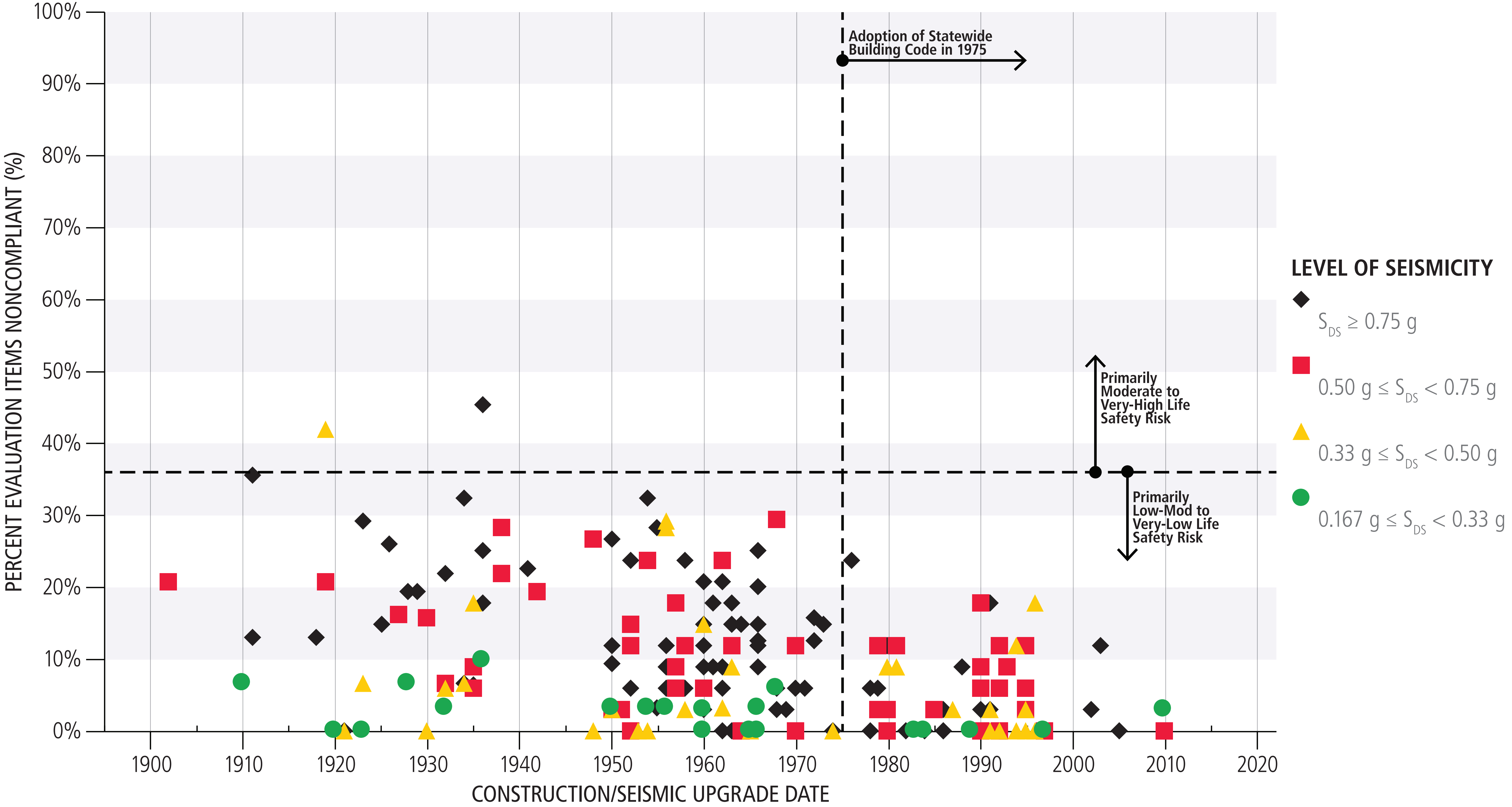


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Figure A-1.3 – ASCE 41 Tier 1 Percent Evaluation Items Noncompliant Categorized by Short-Period Spectral Acceleration (S_{DS})

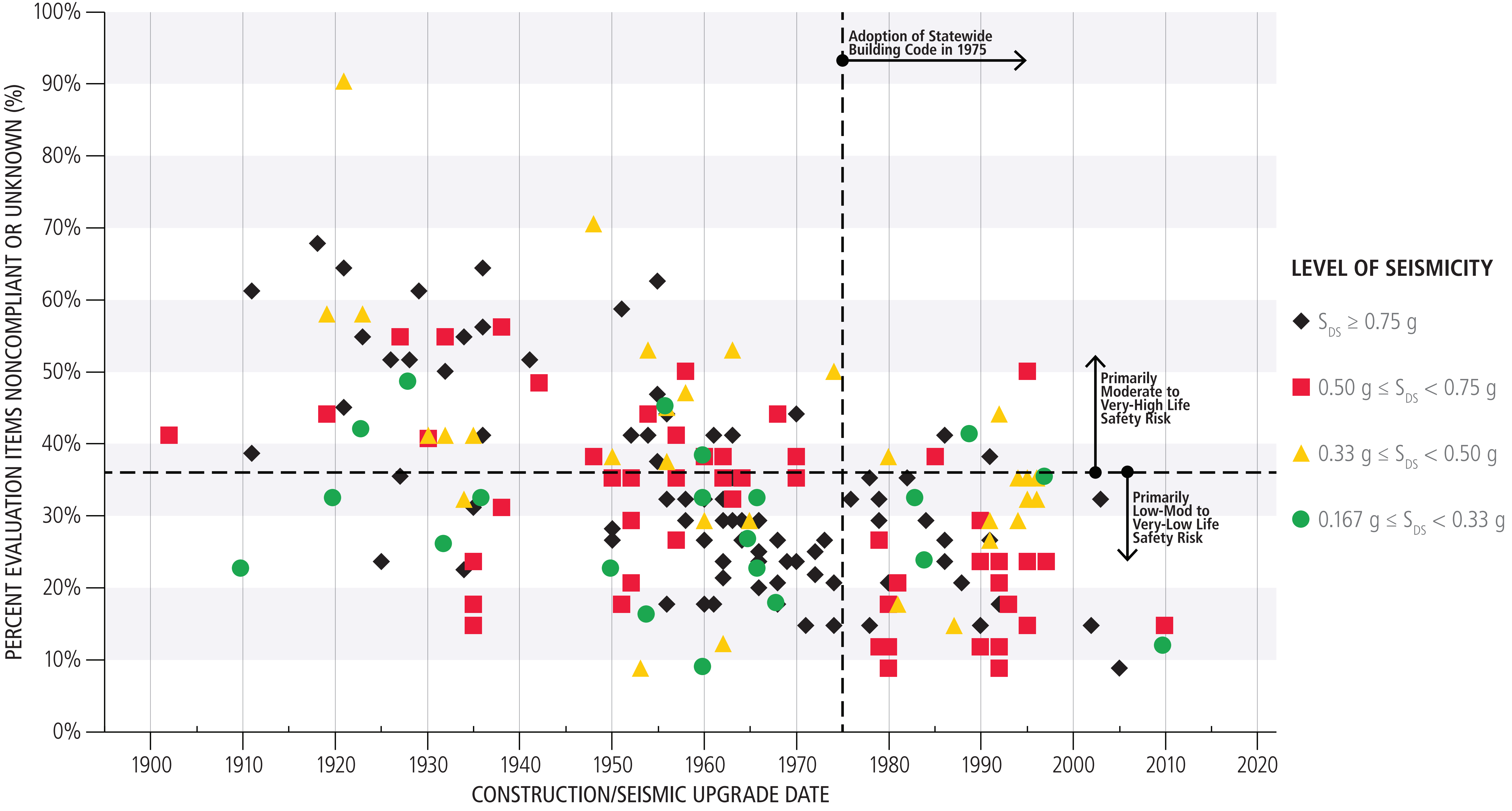

Figure A-1.4 – ASCE 41 Tier 1 Percent Evaluation Items Noncompliant or Unknown Categorized by Short-Period Spectral Acceleration (S_{DS})

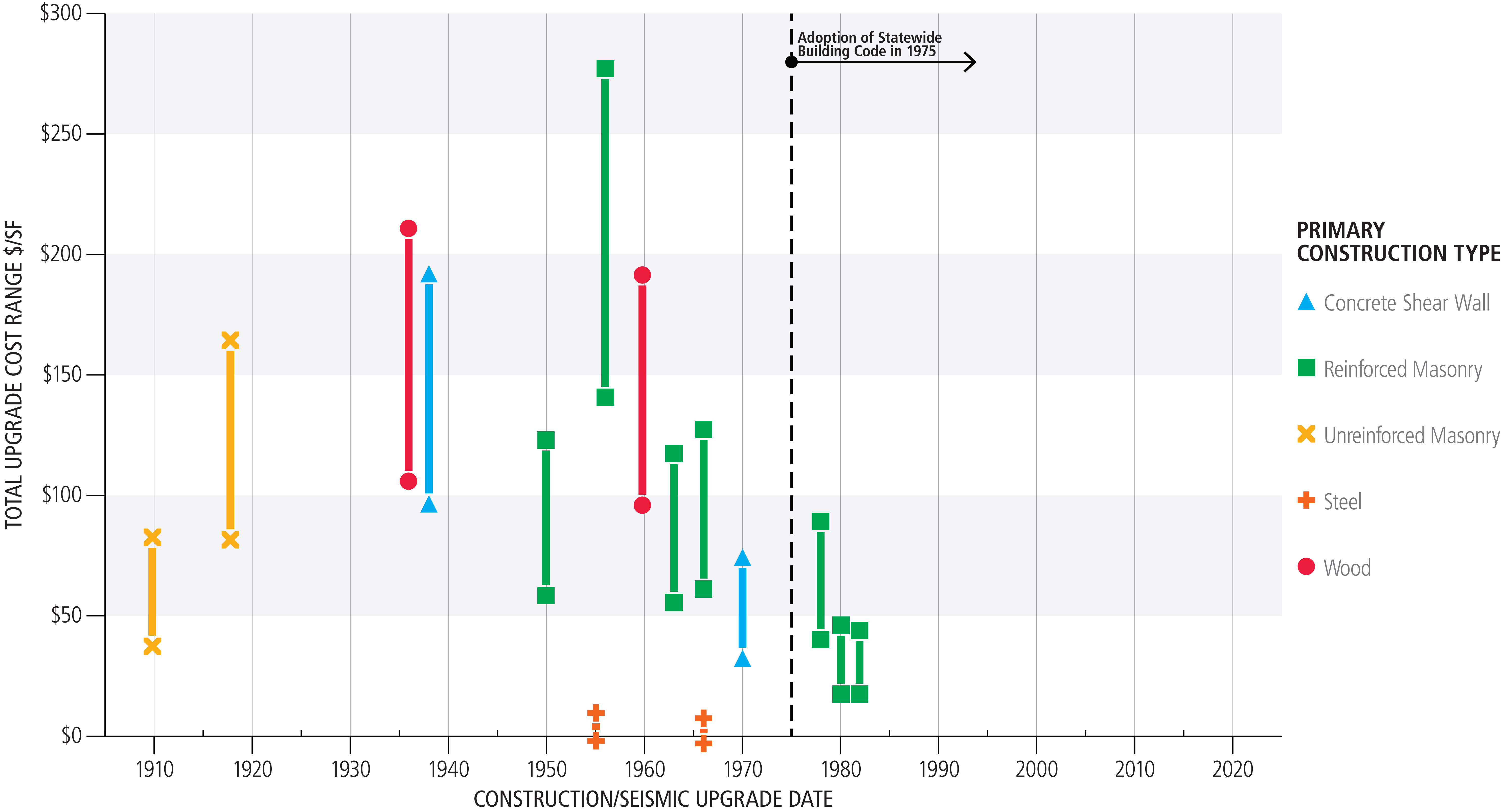

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Figure A-2.1 – Total Seismic Upgrade Cost Ranges

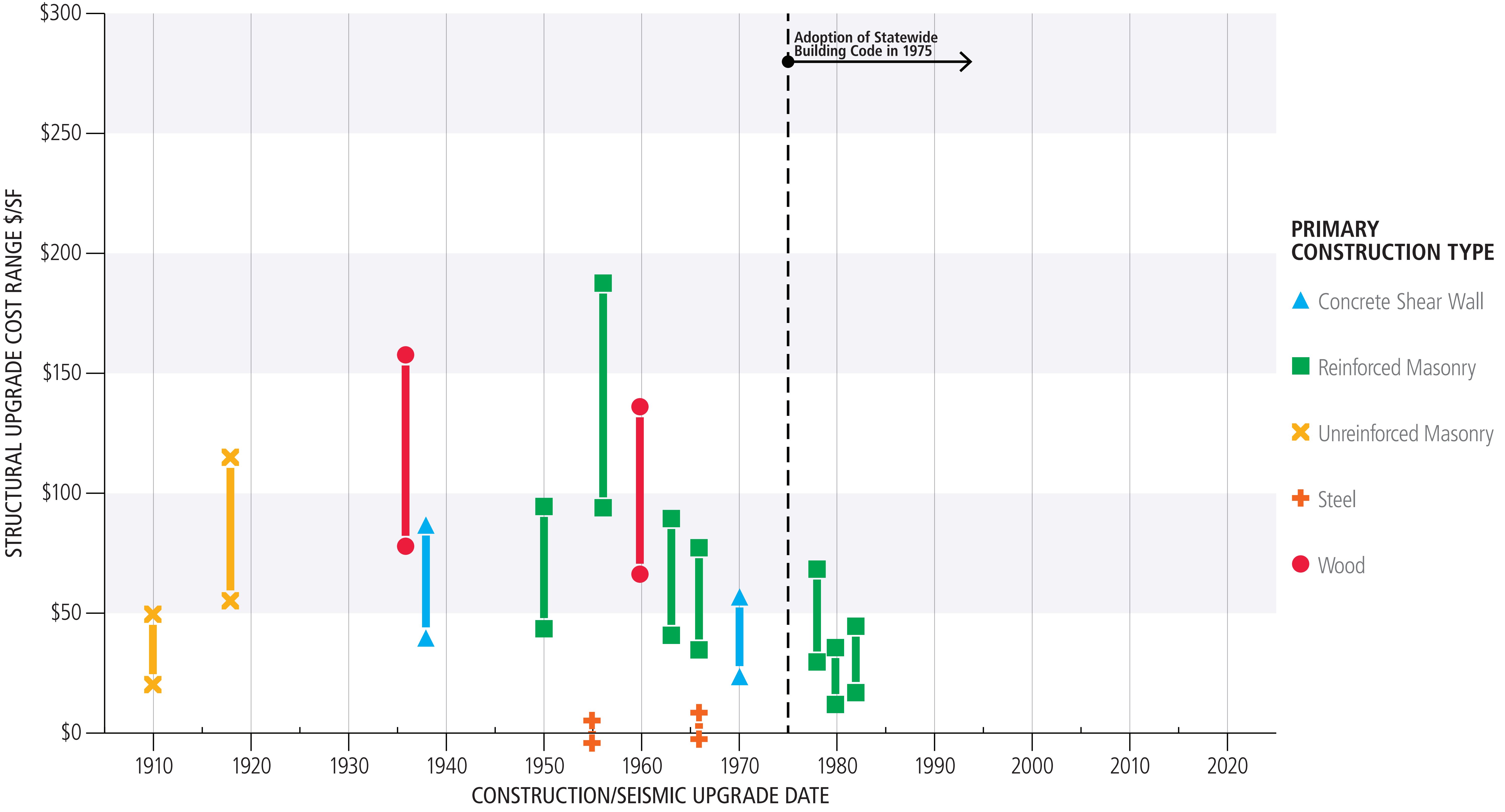

Figure A-2.2 – Structural Seismic Upgrade Cost Ranges

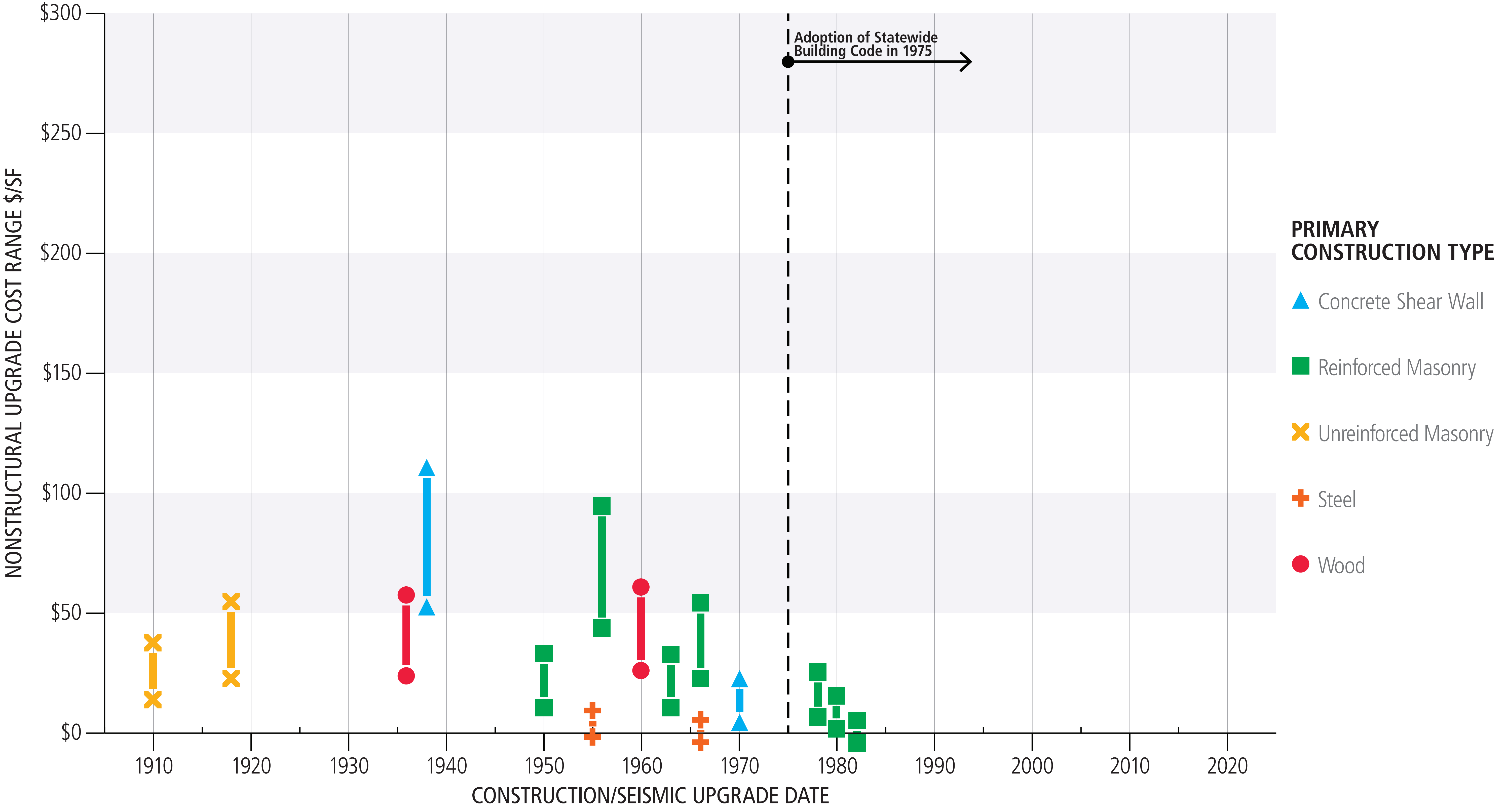

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Figure A-2.3 – Nonstructural Seismic Upgrade Cost Ranges

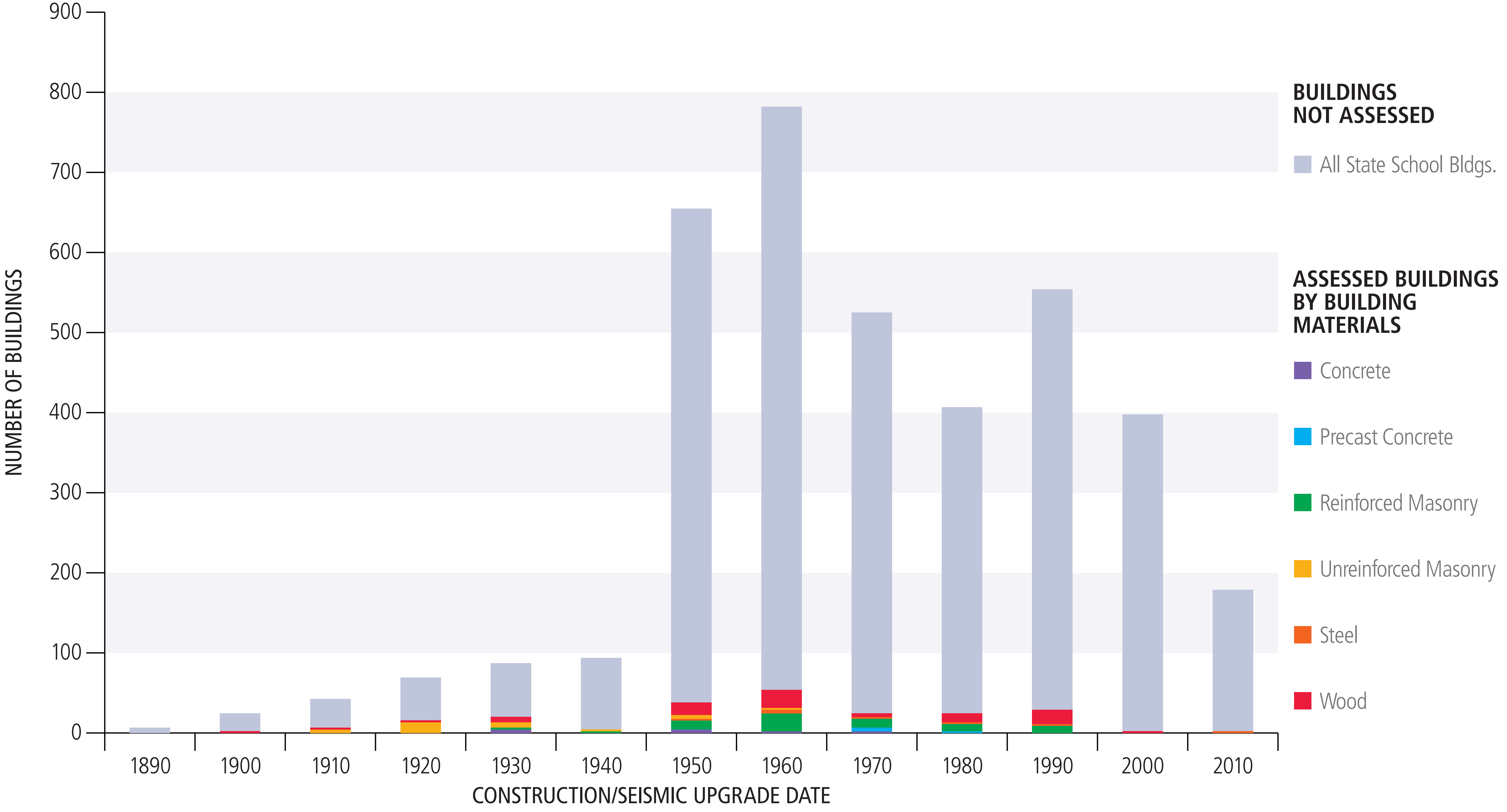

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Figure A-3.1 – Quantity of WA School Buildings Categorized by Construction Decade & Primary Construction Type of Buildings Assessed

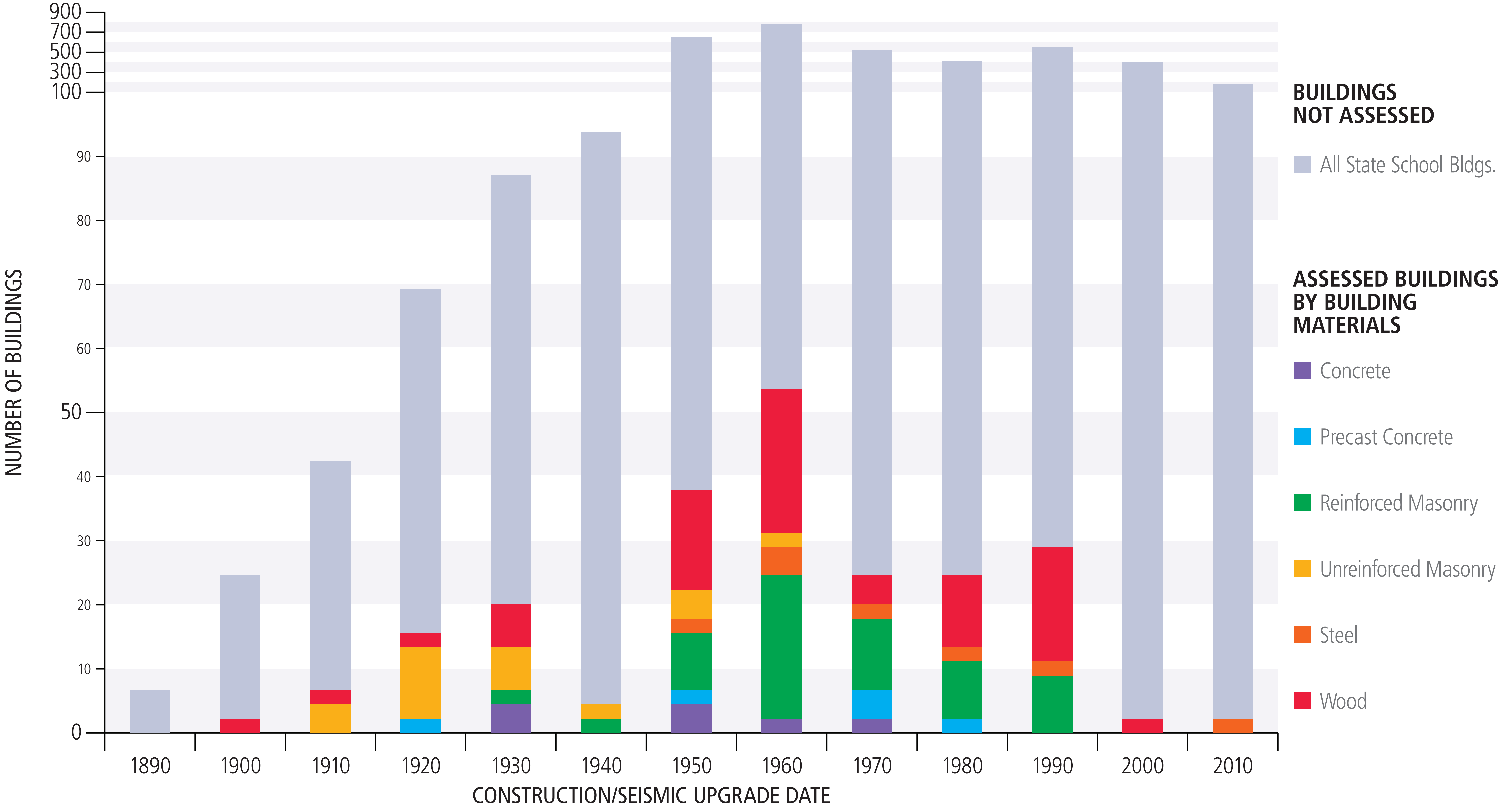

Figure A-3.2 – Quantity of WA School Buildings Categorized by Construction Decade & Primary Construction Type of Buildings Assessed

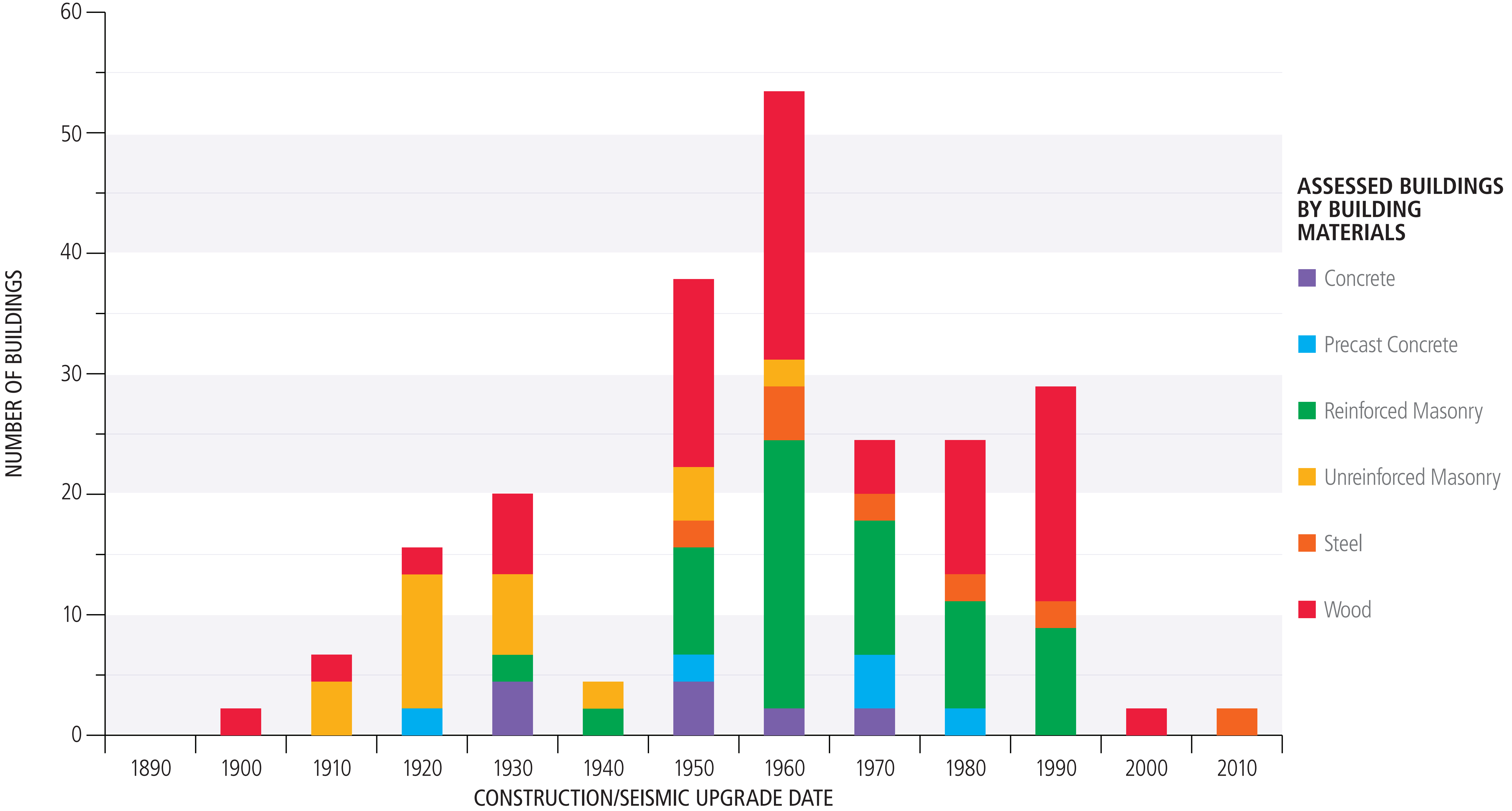

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Figure A-3.3 – Quantity of WA School Buildings Categorized by Construction Decade & Primary Construction Type of Buildings Assessed

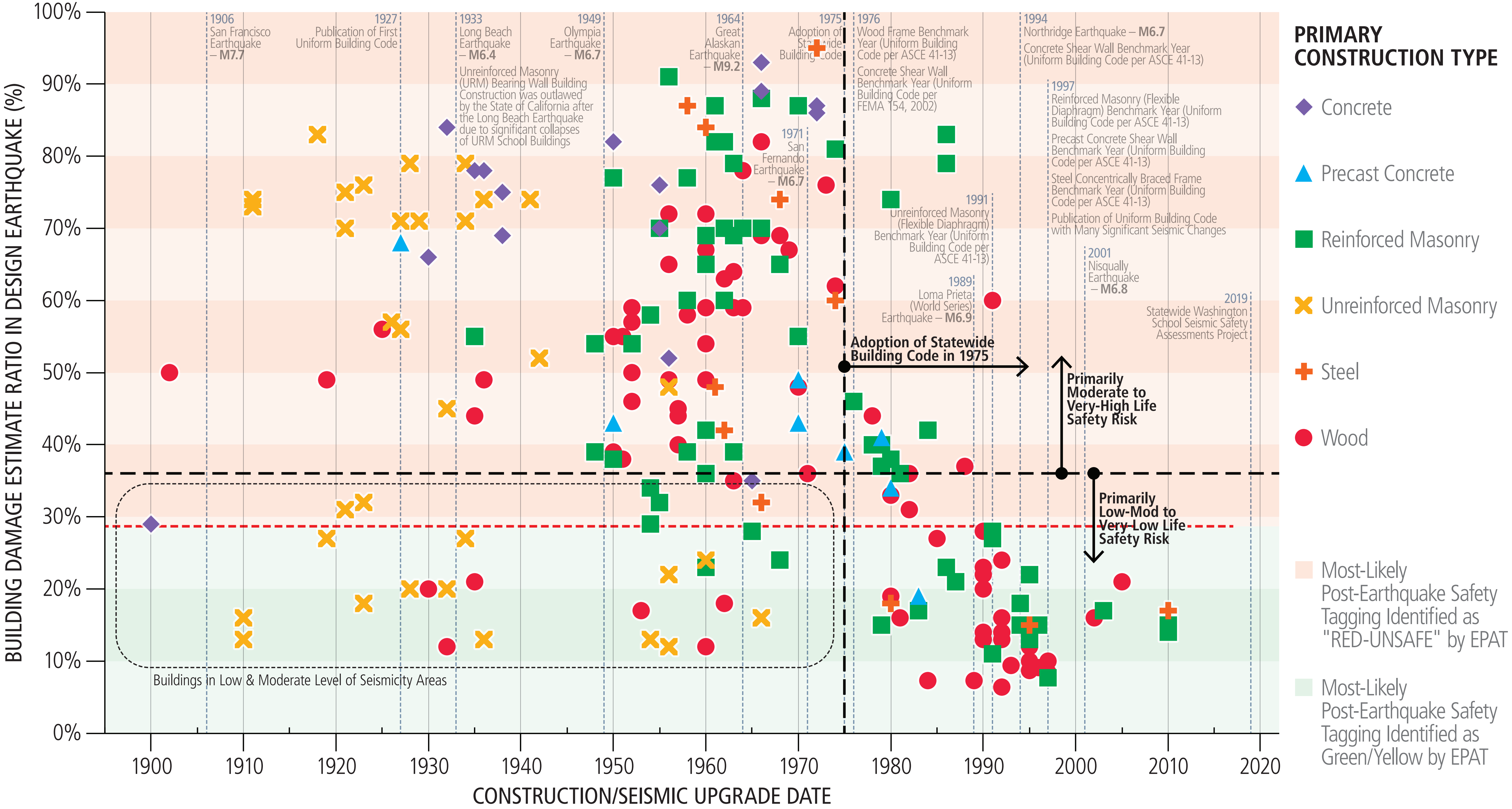

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Figure A-4.1 – EPAT Building Damage Estimate Ratio in ASCE 7/41 Design-Level Earthquake Categorized by Primary Construction Type

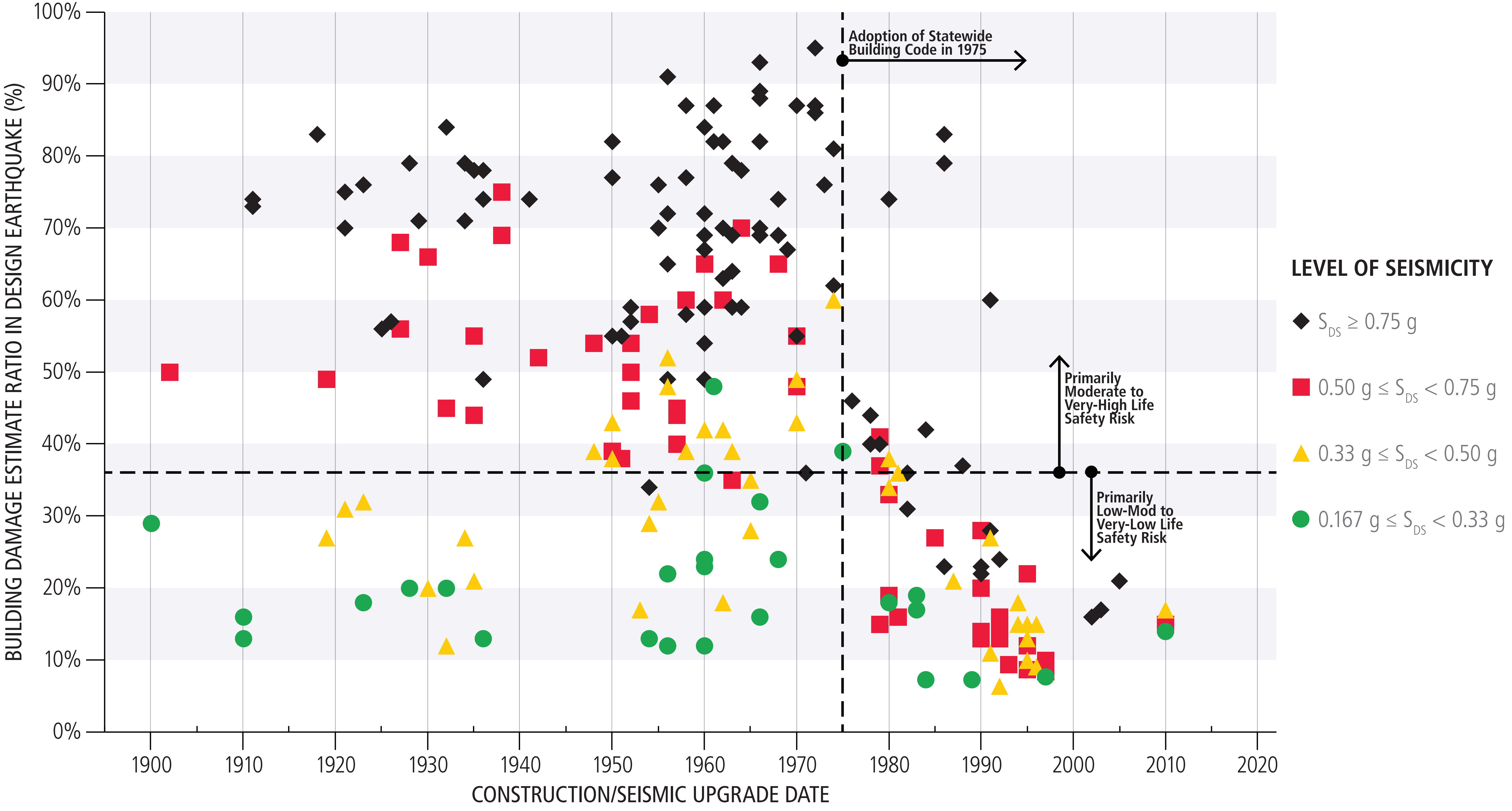


Figure A-4.2 – EPAT Building Damage Estimate Ratio in ASCE 7/41 Design-Level Earthquake Categorized by Short-Period Spectral Acceleration (S_{DS})

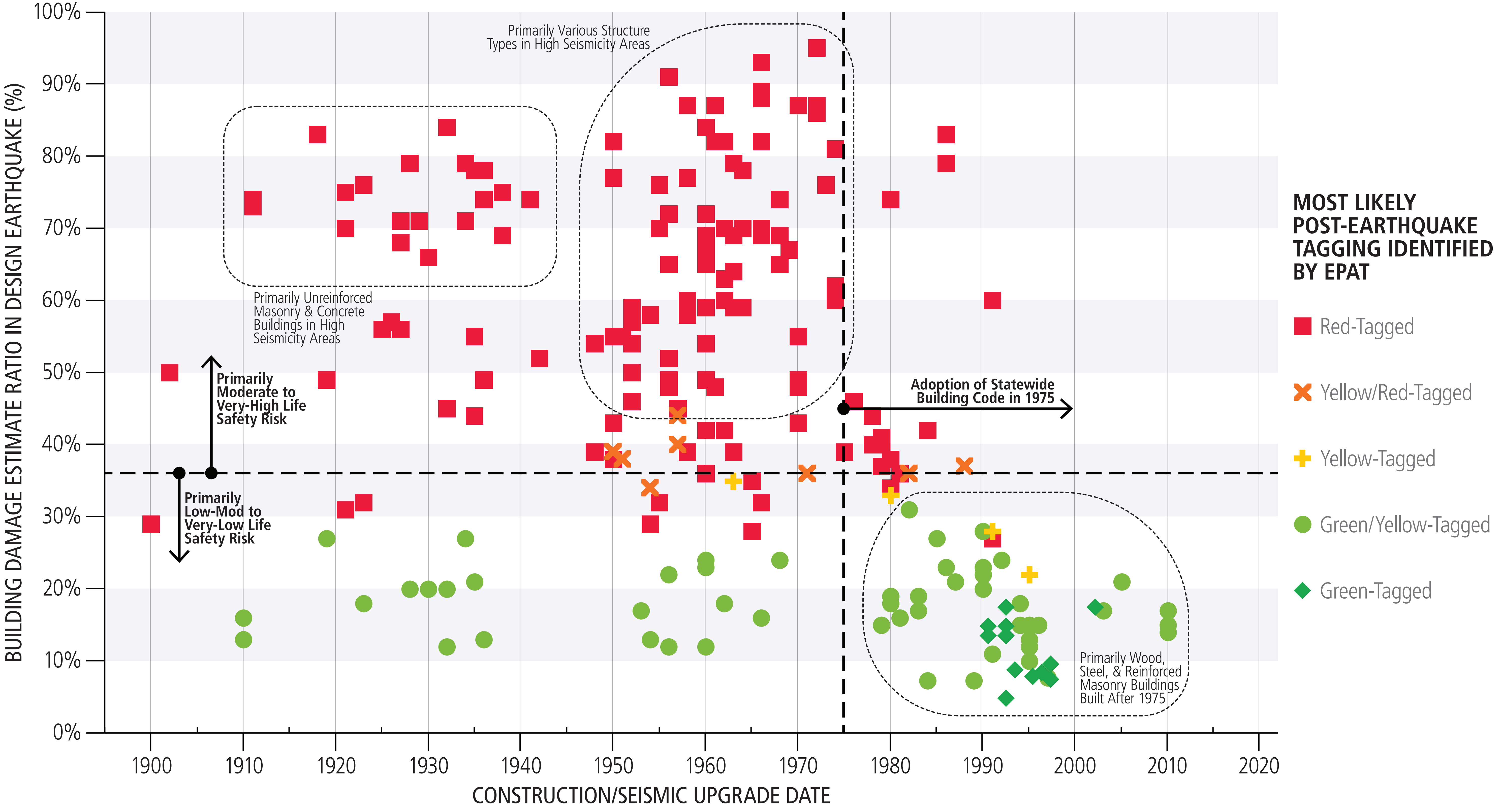


Figure A-4.3 – EPAT Estimated Most-Likely Post-Earthquake ATC-20 Tagging After ASCE 7/41 Design-Level Earthquake

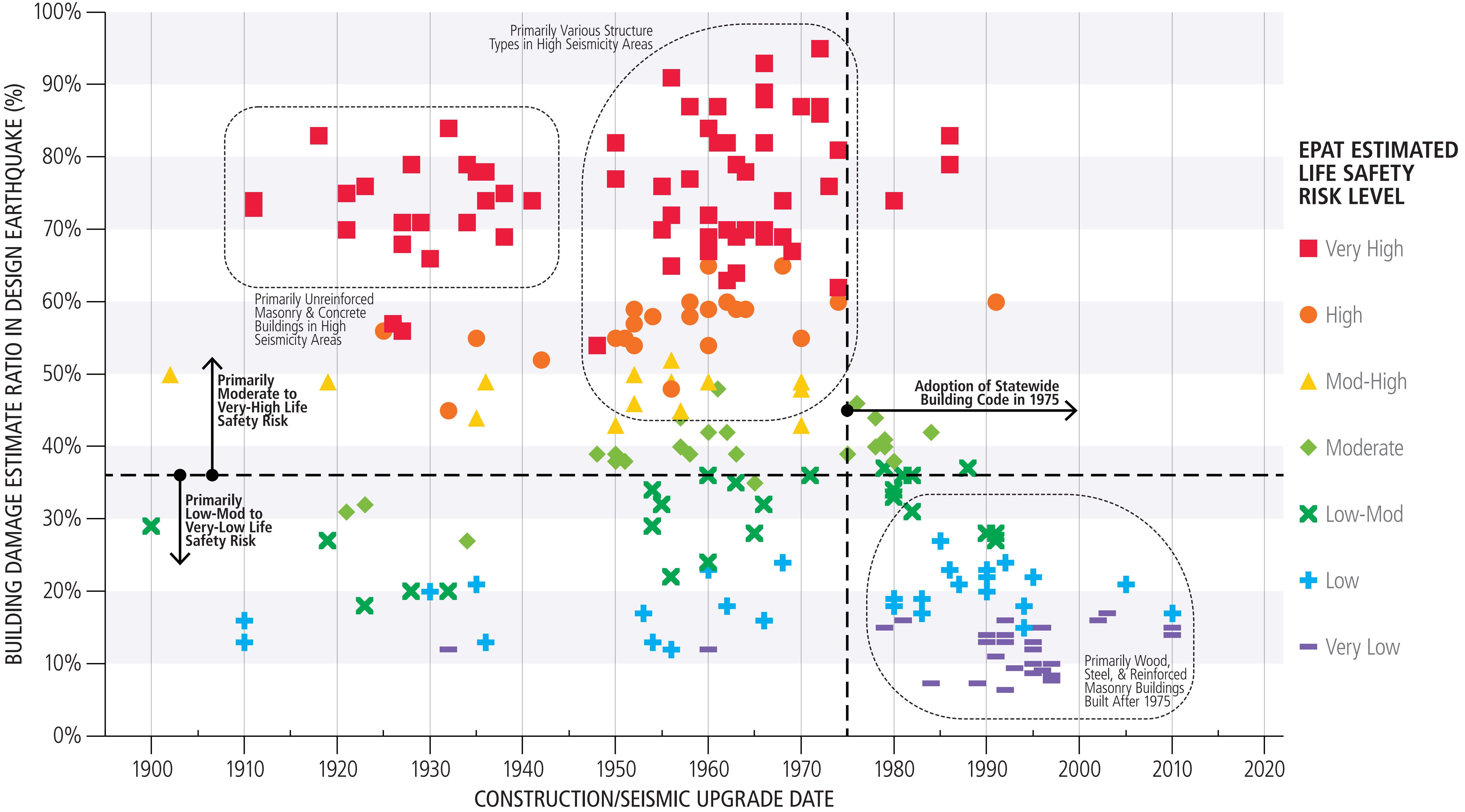


Figure A-4.4 – EPAT Estimated Life Safety Risk Level in ASCE 7/41 Design-Level Earthquake

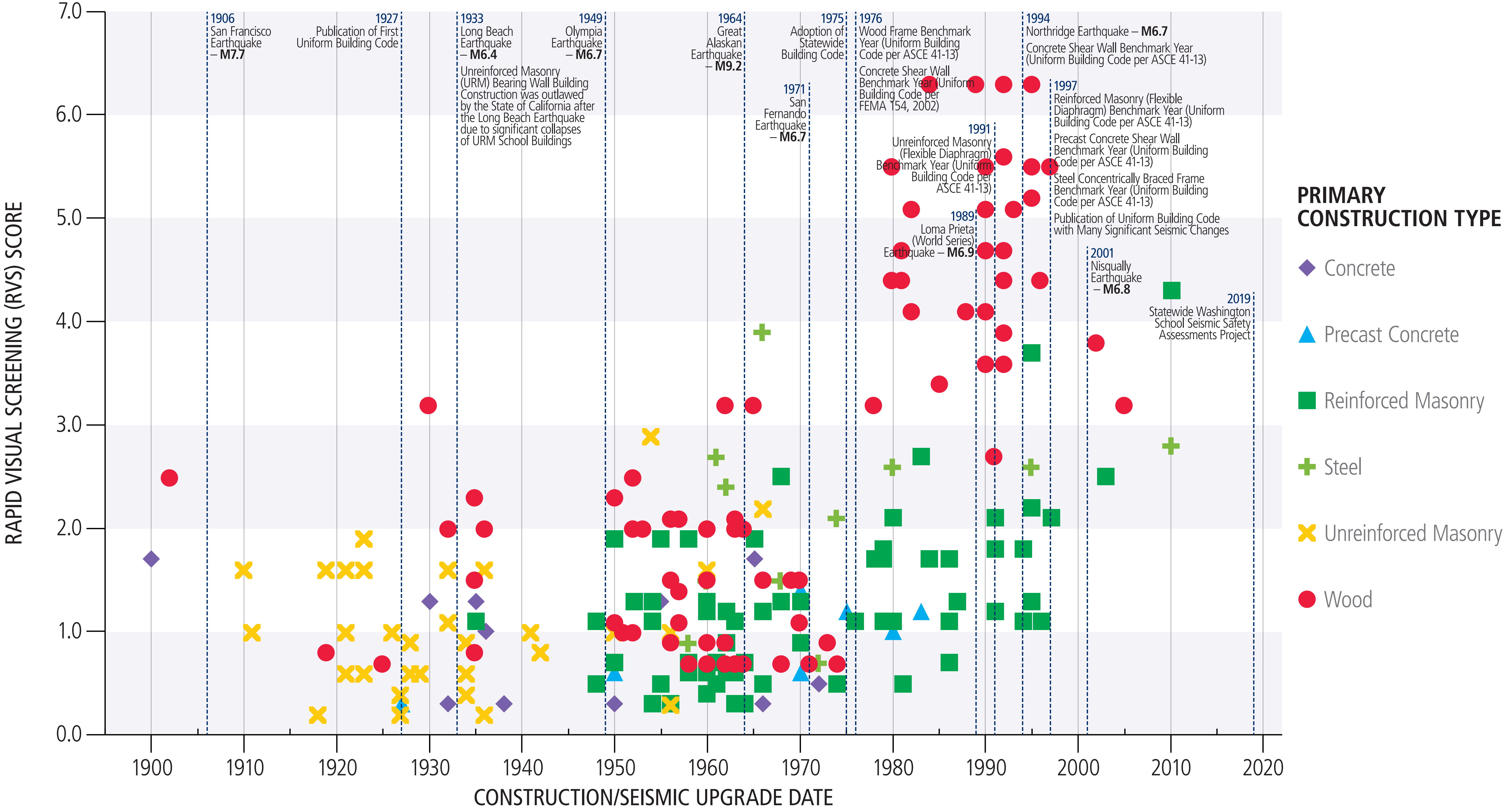


Figure A-5.1 – FEMA 154 Rapid Visual Screening (RVS) Score Categorized by Primary Construction Type

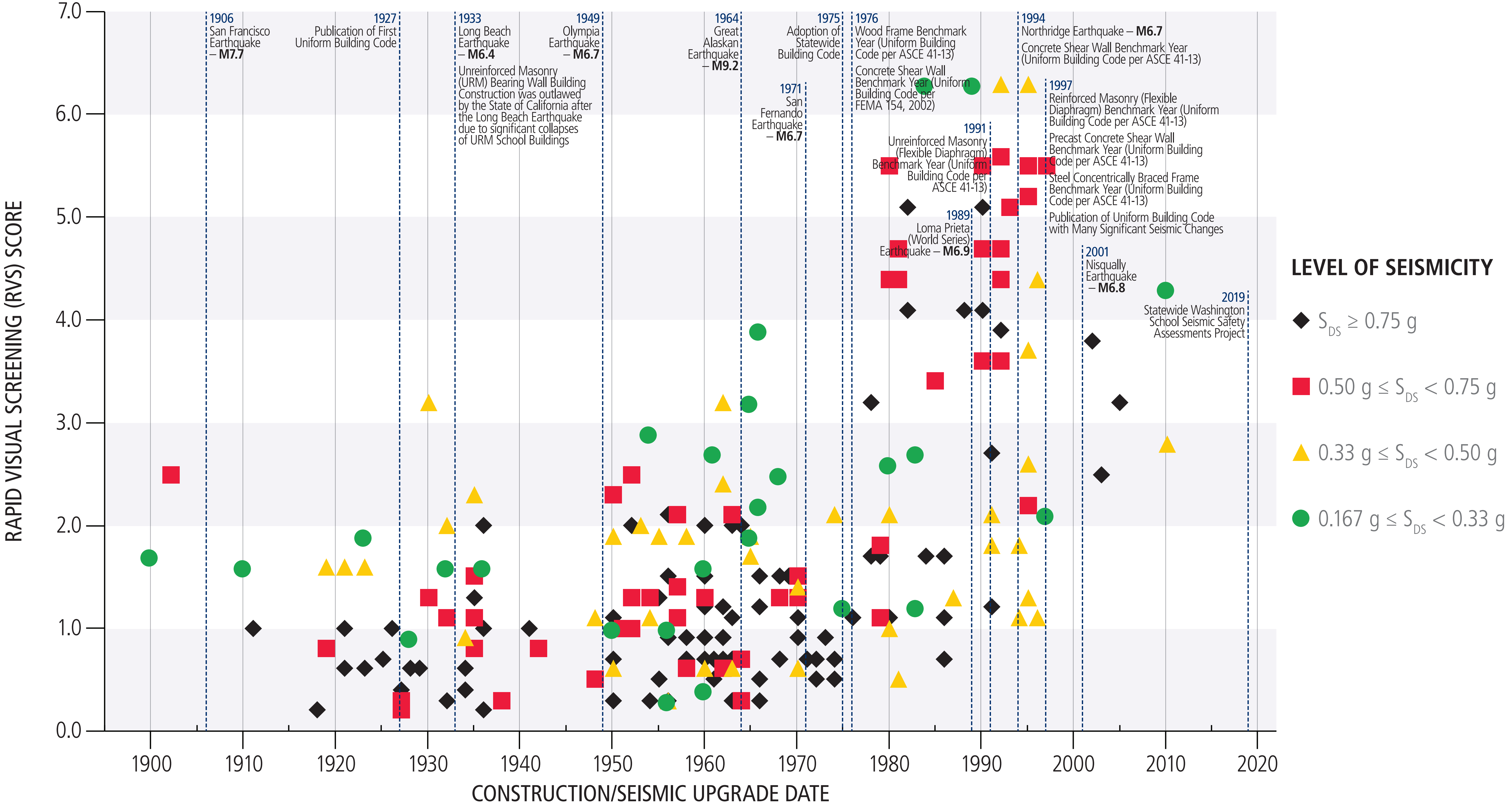
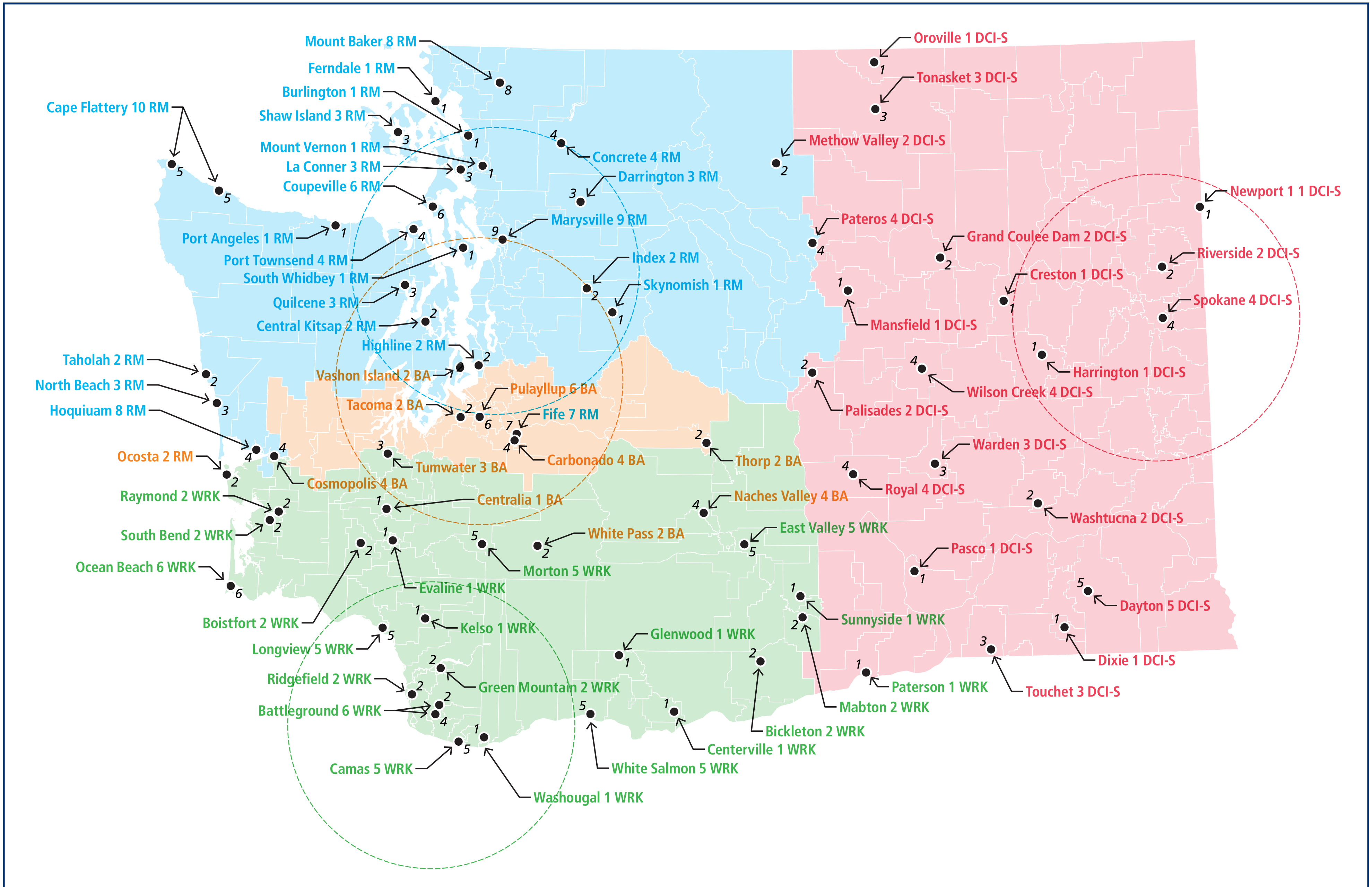


Figure A-5.2 – FEMA 154 Rapid Visual Screening (RVS) Score Categorized by Short-Period Spectral Acceleration (S_{DS})

APPENDIX B: WASHINGTON SCHOOL MAPS & SCHOOL SELECTION



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Map of Selected Schools

Washington State School Seismic Safety Assessments Project – June 2019

List of Schools Selected for ASCE 41-17 Tier 1 Seismic Evaluations

District Name	ICOS Facility ID	Facility Name	ICOS Building ID	Building Name	Enrollment	Latitude	Longitude	FEMA Construction Type	Number of Floors	Gross Sq Ft	Year Built	Last Major Renovation	Did Renovation Include Seismic Upgrades? (Y/N)	Structural Drawings Available	Original Bldg Code Year	Original Building Code	PGA 2% in 50 Year (%g)	Seismic PGA Class	Mapped Site Class	VS30 Site Class	VS30 (m/s)	Urban Or Rural	Earthquake Hazard Level	Liquefaction Potential	Tsunami Risk	Known Or Possible URM
Battle Ground	11856	Maple Grove K-8	17800	Gym	484	45.768	-122.544	W2	1	17,350	1990	-		Yes	1976	UBC	38%	30	C	D	320	Urban	Moderate to High	Very Low	None	
Battle Ground	11856	Maple Grove K-8	14257	Main Building	484	45.768	-122.544	W2	2	64,693	1990	-		Yes	1988	UBC	38%	30	C	D	320	Urban	Moderate to High	Very Low	None	
Battle Ground	10719	Prairie High School	15523	400 Building	1577	45.705	-122.555	W2	2	25,057	1995	-		Yes	1991	UBC	42%	30	D	D	297	Rural	High	Very Low	None	
Battle Ground	10719	Prairie High School	11537	500 Building	1577	45.705	-122.555	RM1	1	9,052	1979	-		Yes	1973	UBC	42%	30	D	D	297	Rural	High	Very Low	None	
Battle Ground	10719	Prairie High School	10577	600 Building	1577	45.705	-122.555	RM1	1	10,725	1979	-		Yes	1973	UBC	42%	30	D	D	297	Rural	High	Very Low	None	
Battle Ground	12402	River Homelink	11747	Main Building	966	45.767	-122.545	W2	1	34,863	1980	-		Yes	1976	UBC	38%	30	C	D	320	Urban	Moderate to High	Very Low	None	
Bickleton	10522	Bickleton Elementary & High School	23173	Bldg B - Vocational/Transportation	87	45.999	-120.293	S3	1	3,672	1961	-		No			20%	18	B	B	1031	Rural	Moderate	Bedrock	None	
Bickleton	10522	Bickleton Elementary & High School	23171	Main Building	87	45.999	-120.293	RM2	1	39,330	2010	-		Yes	2006	IBC	20%	18	B	B	1031	Rural	Moderate	Bedrock	None	
Boistfort	10441	Boistfort Elementary	16933	Gymnasium Building	99	46.550	-123.133	RM1	1	14,530	1963	-		No			49%	50	D-E	D	320	Rural	Very High	Moderate to High	None	
Boistfort	10441	Boistfort Elementary	18408	Main Building	99	46.550	-123.133	URM	1	18,935	1936	1990	No	Yes		UBC	49%	50	D-E	D	320	Rural	Very High	Moderate to High	None	Yes
Burlington-Edison	10031	Edison Elementary School	14601	Original Building	449	48.562	-122.439	W2	2	58,646	1995	-	No	No			42%	40	D-E	E	173	Rural	Very High	Moderate to High	High or Very High	
Camas	11833	Lacamas Heights Elementary School	14197	100 Pod	353	45.613	-122.403	RM1	1	8,182	1962	2012	No	Yes			38%	30	B-C	C	415	Urban	Moderate to High	Very Low	None	
Camas	11833	Lacamas Heights Elementary School	11253	Multipurpose	353	45.613	-122.403	RM1	1	18,804	1962	1997	No	Yes			38%	30	B-C	C	415	Urban	Moderate to High	Very Low	None	
Camas	11220	Liberty Middle School	14296	Main Building	763	45.592	-122.403	RM1	1	109,248	1958	2006	No	Yes			38%	30	B-C	C	667	Urban	Moderate to High	Very Low	None	
Camas	11220	Liberty Middle School	24118	Music Building	763	45.592	-122.403	RM1	1	4,928	1970	-		No			38%	30	B-C	C	667	Urban	Moderate to High	Very Low	None	
Camas	10049	Skyridge Middle School	10395	Main Building	936	45.616	-122.448	RM2	2	108,198	1995	-		Yes	1991	UBC	39%	30	B-C	D	312	Urban	Moderate to High	Very Low	None	
Cape Flattery	11636	Clallam Bay High & Elementary School	13292	Big Gym	115	48.252	-124.259	W2	1	11,909	1962	2007	No	No			58%	60	D-E	D	295	Rural	Very High	Moderate to High	Low	
Cape Flattery	11636	Clallam Bay High & Elementary School	18373	Elementary Building	115	48.252	-124.259	RM1	1	5,880	1962	2006	Yes	No			58%	60	D-E	D	295	Rural	Very High	Moderate to High	Low	
Cape Flattery	11636	Clallam Bay High & Elementary School	11357	Elementary Gym	115	48.252	-124.259	RM1	1	4,305	1980	-	No	Yes	1976	UBC	58%	60	D-E	D	295	Rural	Very High	Moderate to High	Low	
Cape Flattery	11636	Clallam Bay High & Elementary School	18300	High School Building	115	48.252	-124.259	C2a	1	27,217	1972	1995	No	Yes	1976	UBC	58%	60	D-E	D	295	Rural	Very High	Moderate to High	Low	
Cape Flattery	11636	Clallam Bay High & Elementary School	18358	Shop & Art Building	115	48.252	-124.259	RM1	1	6,058	1980	-	No	Yes	1976	UBC	58%	60	D-E	D	295	Rural	Very High	Moderate to High	Low	
Cape Flattery	11547	Neah Bay Elementary School	19336	Elementary School	166	48.364	-124.622	RM1	1	17,740	1961	2012	No	Yes	1976	UBC	59%	60	D-E	D	232	Rural	Very High	Moderate to High	High or Very High	
Cape Flattery	12040	Neah Bay Junior/ Senior High School	24280	Neah Bay High School Classroom Building	185	48.363	-124.623	W2	1	26,463	1976	-	No	Yes			59%	60	D-E	D	232	Rural	Very High	Moderate to High	High or Very High	
Cape Flattery	12040	Neah Bay Junior/ Senior High School	24281	Neah Bay High School Gym	185	48.363	-124.623	C2a	1	12,343	1972	-	No	No			59%	60	D-E	D	232	Rural	Very High	Moderate to High	High or Very High	
Cape Flattery	12040	Neah Bay Junior/ Senior High School	24282	Neah Bay High School Shop Building	185	48.363	-124.623	S3	1	8,081	1972	-	No	Yes	1985	UBC	59%	60	D-E	D	232	Rural	Very High	Moderate to High	High or Very High	
Cape Flattery	12040	Neah Bay Junior/ Senior High School	12393	Neah Bay Middle School & Gym	185	48.363	-124.623	W2	1	14,397	2002	-	No	Yes	1997	UBC	59%	60	D-E	D	232	Rural	Very High	Moderate to High	High or Very High	
Carbonado	11248	Carbonado Historical School 19	15411	1st & 2nd Grade & Special Education Building	179	47.081	-122.054	S1a	1	2,944	1968	1986	No	No	1964	UBC	49%	40	C-D	C	411	Urban	High	Very Low to Low	None	
Carbonado	11248	Carbonado Historical School 19	14620	A - Main Building	179	47.081	-122.054	URM	2	13,425	1929	-	No	No	1927	UBC	49%	40	C-D	C	411	Urban	High	Very Low to Low	None	Yes
Carbonado	11248	Carbonado Historical School 19	11276	B - Community Gym	179	47.081	-122.054	W2	2	5,700	1936	-	No	No	1927	UBC	49%	40	C-D	C	411	Urban	High	Very Low to Low	None	
Carbonado	11248	Carbonado Historical School 19	16857	Computer Lab & Library	179	47.081	-122.054	W2	1	2,289	1989	-	No	No	1985	UBC	49%	40	C-D	C	411	Urban	High	Very Low to Low	None	
Centerville	10167	Centerville Elementary School	13799	Main Building	82	45.752	-120.900	URM	2	16,188	1919	-		No			25%	18	C-D	C	412	Rural	Moderate	Very Low	None	Yes
Central Kitsap	11699	Ridgetop Junior High School	11861	Main Building	438	47.659	-122.668	RM2	1	121,246	1986	1992		No			57%	60	C	C	521	Rural	High	Very Low	Extremely Low	
Central Kitsap	11745	Silver Ridge Elementary School	11534	Main Building	412	47.659	-122.667	W2	1	49,531	1990	1990		Yes			57%	60	C	C	521	Rural	High	Very Low	Extremely Low	
Centralia	12216	Edison Elementary School	13954	Main Building	345	46.722	-122.959	URM	1	31,521	1918	-	Unknown	No			49%	50	D-E	C	424	Urban	Very High	Moderate to High	None	Yes
Concrete	10972	Concrete High School	15537	Main Building	271	48.533	-121.759	W2	2	58,216	1951	-	No	Yes	1991	UBC	38%	30	D-E	C	470	Urban	High	Moderate to High	None	
Concrete	10972	Concrete High School	18943	Tech Building	271	48.533	-121.759	RM1	1	7,875	1952	-	No	Yes	1991	UBC	38%	30	D-E	C	470	Urban	High	Moderate to High	None	
Concrete	12307	Concrete K-6 School	21078	Gym	254	48.535	-121.758	W2	1	12,264	1981	-	No	Yes	1976	UBC	38%	30	D-E	C	470	Urban	High	Moderate to High	None	
Concrete	12307	Concrete K-6 School	17024	Main Building	254	48.535	-121.758	W2	1	32,182	1981	-	No	Yes	1976	UBC	38%	30	D-E	C	470	Urban	High	Moderate to High	None	
Cosmopolis	10975	Cosmopolis Elementary School	17331	Auditorium Building	164	46.953	-123.772	W2	1	7,128	1960	-	No	Yes	1955	UBC	67%	60	D-E	D	230	Urban	Extremely High	Moderate to High	Moderate	
Cosmopolis	10975	Cosmopolis Elementary School	13714	Gymnasium Building	164	46.953	-123.772	W2	1	10,743	1969	-	No	Yes	1967	UBC	67%	60	D-E	D	230	Urban	Extremely High	Moderate to High	Moderate	
Cosmopolis	10975	Cosmopolis Elementary School	17703	Main Building	164	46.953	-123.772	W2	1	30,456	1960	-	No	Yes	1955	UBC	67%	60	D-E	D	230	Urban	Extremely High	Moderate to High	Moderate	
Cosmopolis	10975	Cosmopolis Elementary School	16322	Multipurpose Building	164	46.953	-123.772	W2	1	4,278	1960	-	No	Yes	1955	UBC	67%	60	D-E	D	230	Urban	Extremely High	Moderate to High	Moderate	
Coupeville	11903	Coupeville Elementary School	11115	Cedar Pod	413	48.212	-122.688	RM1	1	4,481	1979	-	Unknown	No			59%	50	C	C	412	Urban	High	Very Low	Extremely Low	
Coupeville	11903	Coupeville Elementary School	10916	Main	413	48.212	-122.688	RM1	1	31,835	1974	1992	Unknown	No			59%	50	C	C	412	Urban	High	Very Low	Extremely Low	
Coupeville	11903	Coupeville Elementary School	12528	Multipurpose	413	48.212	-122.688	RM1	1	7,808	1979	-	Unknown	No			59%	50	C	C	412	Urban	High	Very Low	Extremely Low	
Coupeville	11136	Coupeville High School	19984	Annex	321	48.207	-122.685	RM1	1	12,000	1978	-	No	Yes	2003	IBC	60%	50	D	D	279	Urban	Very High	Very Low	Very Low	
Coupeville	11136	Coupeville High School	11786	Gymnasium	321	48.207	-122.685	RM1	1	10,000	1981	-	No	Yes	2003	IBC	60%	50	D	D	279	Urban	Very High	Very Low	Very Low	
Coupeville	10967	Coupeville Middle School	10019	Middle & High School Building	222	48.207	-122.685	W2	2	33,550	1992	-	No	No			60%	50	D	D	279	Urban	Very High	Very Low	Very Low	
Creston	10372	Creston Junior Senior High School	11613	Creston K-12 School Building	57	47.755	-118.520	W2	1	50,425	1953	1984	Yes	Yes			21%	14	D	D	302	Urban	Moderate	Low	None	
Darrington	10754	Darrington Elementary School	13321	Main Elementary School	311	48.247	-121.602	W2	1	39,578	1990	-	No	Yes	1988	UBC	39%	30	D-E	D	343	Urban	High	Moderate to High	None	
Darrington	11118	Darrington Senior High School	14923	Darrington High School	134	48.248	-121.603	W2	1	39,857	1935	2001	Yes	No			39%	30	D-E	D	343	Urban	High	Moderate to High	None	
Darrington	11118	Darrington Senior High School	24149	Woodshop	134	48.248	-121.603	RM2	1	5,800	1960	-	Unknown	No			39%	30	D-E	D	343	Urban	High	Moderate to High	None	
Dayton	12210	Dayton High School	21435	Ag Shop	139	46.316	-117.973	URM	1	7,376	1954	-		No			27%	16	D-E	B	1013	Urban	Moderate to High	Moderate to High	None	Yes
Dayton	12210	Dayton High School	21434	Gymnasium	139	46.316	-117.973	S3	1	27,152	1966	-		Yes			27%	16	D-E	B	1013	Urban	Moderate to High	Moderate to High	None	
Dayton	12210	Dayton High School	21433	High School Building	139	46.316	-117.973	URM	3	37,524	1923	1985		No			27%	16	D-E	B	1013	Urban	Moderate to High	Moderate to High	None	Yes
Dayton	12210	Dayton High School	21436	Wood Shop	139	46.316	-117.973	URM	1	10,846	1966	-		No			27%	16	D-E	B	1013	Urban	Moderate to High	Moderate to High	None	Yes
Dayton	11321	Dayton K-8 School	16695	Elementary & Middle School Building	245	46.317	-117.975	URM	2	42,716	1966	-		No			27%	16	D-E	B	1013	Urban	Moderate to High	Moderate to High	None	Yes
Dixie	11381	Dixie Elementary School	18037	Main Building	30	46.141	-118.151	URM	3	15,291	1921	-		No			28%	16	D-E	D	359	Rural	Moderate to High	Moderate to High	None	Yes
East Valley (Yakima)	10494	East Valley Central Middle School	16974	6th Grade Building	686	46.573	-120.405	PC1	1	15,382	1980	2010	No	Yes			28%	20	D	C	487	Rural	Moderate	Low	None	
East Valley (Yakima)	10494	East Valley Central Middle School	13229	7th - 8th Grade Building	686	46.573	-120.405	S2	2	37,740	2010	-		Yes	2006	IBC	28%	20	D	C	487	Rural	Moderate	Low	None	
East Valley (Yakima)	10494	East Valley Central Middle School	18947	Computer Lab Building	686	46.573	-120.405	W2	1	2,703	1996	-		No			28%	20	D	C	487	Rural	Moderate	Low	None	
East Valley (Yakima)	10494	East Valley Central Middle School	14520	Gymnasium Building	686	46.573	-120.405	PC1	1	19,420	1950	2010	No	Yes			28%	20	D	C	487	Rural	Moderate	Low	None	
East Valley (Yakima)	12530	East Valley Elementary School	13907	Main Building	550	46.575	-120.403	RM1	1	71,064	1996	-		Yes		UBC	28%	20	D	C	582	Rural	Moderate	Low	None	
Evaline	12324	Evaline Elementary School	12903	Main Building	50	46.539	-122.938	URM	2	6,207	1926	2011	Yes	No			49%	40	C-D	D	326	Rural	High	Very Low	None	Yes
Ferndale	10288	Beach Elementary	13227	Main Building	30	48.725	-122.687	W2	3	8,919	1919	1979	No	No			46%	40	D	C	699	Rural	High	Low to Moderate	Very Low	
Fife	11714	Columbia Junior High School	19656	Main Building	552	47.230	-122.356	RM1	1	97,496	2003	-		Yes	1997	UBC	50%	50	D-E	E	168	Urban	Very High	high	Moderate	
Fife	11822	Fife High School	19844	Building IV 400 Library	837	47.238	-122.353	C2	1	34,556	1950	1975	Yes	Yes			50%	50	D-E	E	171	Urban	Very High	high	Moderate	
Fife	11822	Fife High School	16375	Building IX 900 Science	837	47.238	-122.353	W2	1	7,058	1970	1992	Yes	Yes			50%	50	D-E	E	171	Urban	Very High	high	Moderate	
Fife	11822	Fife High School	12911	Building V 500 Main	837	47.238	-122.353	W2	1	20,975	1950	1992	Yes	Yes			50%	50	D-E	E	171	Urban	Very High	high	Moderate	
Fife	11822	Fife High School	12402	Building VI 600 Gyms	837	47.238	-122.353	W2	1	43,632	1956	1992	Yes	Yes	1952	UBC	50%	50	D-E	E	171	Urban	Very High	high	Moderate	
Fife	11822	Fife High School	16347	Building VII 700 Cafeteria	837	47.238	-122.353	W2	1	15,655	1963	1992	Yes	Yes			50%	50	D-E	E	171	Urban	Very High	high	Moderate	
Fife	11822	Fife High School	14470	Building VIII 800 Shop	837	47.238	-122.353	RM1	1	9,989	1963	1992	Yes	Yes			50%	50	D-E	E	171	Urban	Very High	high	Moderate	
Glenwood	10419	Glenwood School	10464	Main Building	30	46.022	-121.290	RM1	1	38,961	1981	-		Yes	1979	UBC	33%	20	D-E	C	676	Rural	High	Moderate to High	None	
Grand Coulee Dam	12823	Lake Roosevelt K-12	23616	CTE Building	750	47.972	-118.971	S3	1	46,336	1955	-		Yes			24%	16	D	D	304	Urban	Moderate	Low	None	
Grand Coulee Dam	12823	Lake Roosevelt K-12	23615	Wood Shop	750	47.972	-118.971	RM1	1	4,043	1974	-		No			24%	16	D	D	304	Urban	Moderate	Low	None	
Green Mountain	12007	Green Mountain School	17949	Gymnasium	158	45.948	-122.539	W2	1	6,353	1950	1994	No	No			38%	30	B	D	341	Rural	Moderate to High	Bedrock	None	
Green Mountain	12007	Green Mountain School	12470	Main Building	158	45.948	-122.539	URM	2	3,554	1932	1994	No	No			38%	30	B	D	341	Rural	Moderate to High	Bedrock	None	Yes
Harrington	12885	Harrington Elementary & High School	24193	Main Building	87	47.479	-118.251	URM	1	53,605	1936	1955		No			13%	12	B	C	601	Urban	NULL	Bedrock	None	Yes
Highline	12812	Woodside Site	23449	Annex	27	47.438	-122.325	S5a	1	10,306	1960	-		Yes	1958	UBC	61%	60	C-D	D	355	Urban	Very High	Very Low	Extremely Low	
Highline	12812	Woodside Site	23448	Main Building	27	47.438	-122.325	S5a	1	22,768	1958	-		Yes	1955	UBC	61%	60	C-D	D	355	Urban	Very High	Very Low	Extremely Low	
Hoquiam	12309	Hoquiam High School	11908	A-Administration	491	46.983	-123.910	W2	2	28,385	1966	-	No	Yes	1964	UBC	68%	60	D-E	D	242	Urban	Extremely High	Moderate to High	High or Very High	
Hoquiam	12309	Hoquiam High School	13049	B-Science	491	46.983	-123.910	W2	2	22,992	1966	-	No	Yes	1964	UBC	68%	60	D-E	D	242	Urban	Extremely High	Moderate to High	High or Very High	
Hoquiam	12309	Hoquiam High School	16889	E-Library	491	46.983	-123.910	W2	2	11,193	1966	-	No	Yes	1964	UBC	68%	60	D-E	D	242	Urban	Extremely High	Moderate to High	High or Very High	
Hoquiam	12309	Hoquiam High School	15751	H-Gymnasium	491	46.983	-123.910	RM1	2	31,040	1966	-	No	Yes	1964	UBC	68%	60	D-E	D	242	Urban	Extremely High	Moderate to High	High or Very High	
Hoquiam	12193	Lincoln Elementary School	15720	Administrative & Library Building	317	46.991	-123.888	W2	1	4,055	1968	1994	No	Yes	1964	UBC	68%	60	D-E	E	111	Urban	Extremely High	Moderate to High	Moderate	
Hoquiam	12193	Lincoln Elementary School	12912	East Wing	317	46.991	-123.888	W2	1	10,933	1968	1994	No	Yes	1964	UBC	68%	60	D-E	E	111	Urban	Extremely High	Moderate to High	Moderate	
Hoquiam	12193	Lincoln Elementary School	15384	Multipurpose Building	317	46.991	-123.888	W2	1	10,569	1968	1994	No	Yes	1964	UBC	68%	60	D-E	E	111	Urban	Extremely High	Moderate to High	Moderate	

List of Schools Selected for ASCE 41-17 Tier 1 Seismic Evaluations

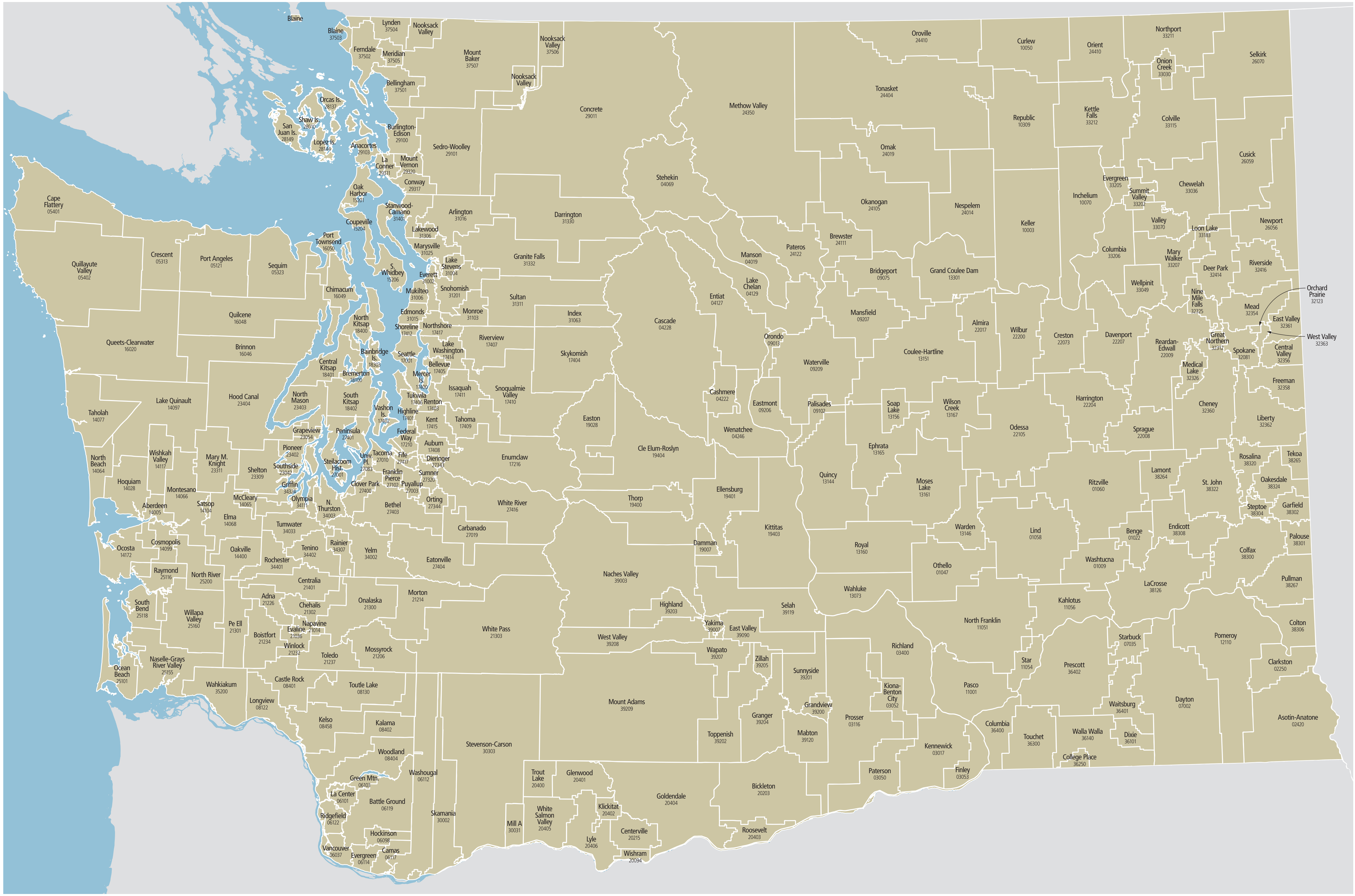
District Name	ICOS Facility ID	Facility Name	ICOS Building ID	Building Name	Enrollment	Latitude	Longitude	FEMA Construction Type	Number of Floors	Gross Sq Ft	Year Built	Last Major Renovation	Did Renovation Include Seismic Upgrades? (Y/N)	Structural Drawings Available	Original Bldg Code Year	Original Building Code	PGA 2% in 50 Year (%g)	Seismic PGA Class	Mapped Site Class	VS30 Site Class	VS30 (m/s)	Urban Or Rural	Earthquake Hazard Level	Liquefaction Potential	Tsunami Risk	Known Or Possible URM
Hoquiam	12193	Lincoln Elementary School	19717	West Wing	317	46.991	-123.888	W2	1	8,610	1968	1994	No	Yes	1964	UBC	68%	60	D-E	E	111	Urban	Extremely High	Moderate to High	Moderate	
Index	10385	Index Elementary School	10626	Enclosed Covered Play	44	47.821	-121.555	W2	1	1,408	1997	-		No			40%	30	D-E	C	419	Urban	Very High	Moderate to High	None	
Index	10385	Index Elementary School	14319	Main Building	44	47.821	-121.555	RM1	1	4,881	1954	1997		No			40%	30	D-E	C	419	Urban	Very High	Moderate to High	None	
Kelso	10689	Carrolls Elementary School	17276	Main Building	148	46.070	-122.866	RM1	1	17,276	1948	2003	No	Yes			41%	30	B	B	1038	Rural	High	Bedrock	None	
La Conner	10683	La Conner High School	21070	High School Auditorium	219	48.396	-122.490	URM	1	4,808	1921	2003	Yes	Yes	1973	UBC	47%	50	D-E	D	184	Urban	Very High	Moderate to High	Moderate	Yes
La Conner	10683	La Conner High School	14029	High School Main Building	219	48.396	-122.490	W2	1	46,822	1974	-	No	Yes	1973	UBC	47%	50	D-E	D	184	Urban	Very High	Moderate to High	Moderate	
La Conner	11153	La Conner Middle School (form. Elem.)	13210	Old Auditorium/Cafeteria Bldg	133	48.396	-122.490	URM	1	9,537	1921	-	Unknown	No			47%	50	D-E	D	184	Urban	Very High	Moderate to High	Moderate	Yes
Longview	11569	R. A. Long High School	18567	Gym	928	46.141	-122.955	PC1	1	44,541	1927	-		Yes			43%	40	D-E	E	166	Urban	Very High	Moderate to High	None	
Longview	11569	R. A. Long High School	14045	Main Building	928	46.141	-122.955	URMa	2	103,568	1927	-		Yes			43%	40	D-E	E	166	Urban	Very High	Moderate to High	None	Yes
Longview	11569	R. A. Long High School	18592	RA Long Annex	928	46.141	-122.955	W2	1	9,592	1963	-		No			43%	40	D-E	E	166	Urban	Very High	Moderate to High	None	
Longview	11569	R. A. Long High School	16645	Science Wing	928	46.141	-122.955	RM1	1	15,316	1935	-		Yes			43%	40	D-E	E	166	Urban	Very High	Moderate to High	None	
Longview	11569	R. A. Long High School	19084	Shop Bldg	928	46.141	-122.955	URM	1	10,422	1942	-		Yes			43%	40	D-E	E	166	Urban	Very High	Moderate to High	None	Yes
Mabton	12772	Mabton Jr/Sr High School	22857	Main Building	387	46.212	-119.995	RM1	1	57,540	1950	2001	No	No			28%	20	D	D	327	Urban	Moderate	Low	None	
Mabton	12772	Mabton Jr/Sr High School	24210	Shop/Ag Building	387	46.212	-119.995	RM1	1	10,400	1980	-		No			28%	20	D	D	327	Urban	Moderate	Low	None	
Mansfield	11647	Mansfield Elem & High School	13447	Main Building	106	47.816	-119.644	RM1	1	37,018	1983	-		No			24%	18	C-D	B	864	Rural	Moderate	Very Low to Low	None	
Marysville	10616	Liberty Elementary School	14493	Main Building	520	48.058	-122.169	W2	1	43,162	1951	-		Yes	1973	UBC	46%	40	D-E	D	245	Urban	High	Low to Moderate	Low	
Marysville	11698	Marysville Middle School	12492	Building B	800	48.059	-122.164	W2	1	2,997	1960	1983		Yes	1958	UBC	46%	40	D-E	D	245	Urban	High	Low to Moderate	Low	
Marysville	11698	Marysville Middle School	14481	Building C - Shop Classrooms	800	48.059	-122.164	RM1	1	2,592	1960	1983		Yes	1958	UBC	46%	40	D-E	D	245	Urban	High	Low to Moderate	Low	
Marysville	11698	Marysville Middle School	15640	Main Building	800	48.059	-122.164	W2	1	97,150	1960	-		Yes	1958	UBC	46%	40	D-E	D	245	Urban	High	Low to Moderate	Low	
Marysville	11618	Totem Middle School	14759	Cafeteria Gym Building	556	48.055	-122.174	RM2	1	48,594	1958	1988	No	Yes	1955	UBC	46%	40	D-E	D	246	Urban	High	Low to Moderate	Moderate	
Marysville	11618	Totem Middle School	13144	Home Economics Building	556	48.055	-122.174	C2a	1	4,420	1955	1988	No	Yes	1949	UBC	46%	40	D-E	D	246	Urban	High	Low to Moderate	Moderate	
Marysville	11618	Totem Middle School	19455	Main Building	556	48.055	-122.174	RM1	1	22,384	1966	-		Yes	1964	UBC	46%	40	D-E	D	246	Urban	High	Low to Moderate	Moderate	
Marysville	11618	Totem Middle School	18479	School House Cafe	556	48.055	-122.174	C2a	1	7,252	1955	1989	No	No			46%	40	D-E	D	246	Urban	High	Low to Moderate	Moderate	
Marysville	11618	Totem Middle School	13931	Science Building	556	48.055	-122.174	RM1	1	5,280	1962	-		Yes	1958	UBC	46%	40	D-E	D	246	Urban	High	Low to Moderate	Moderate	
Methow Valley	11419	Liberty Bell Junior Senior High School	11424	Main Building	259	48.443	-120.170	RM1	2	94,000	1994	-		Yes			29%	20	D	D	333	Rural	Moderate	Very Low to Low	None	
Methow Valley	10620	Methow Valley Elementary School	10546	Main Building	341	48.441	-120.167	RM1	1	62,640	1963	1996		Partial			29%	20	D	D	333	Rural	Moderate	Very Low to Low	None	
Morton	10190	Morton Elementary School	13705	Gymnasium	176	46.558	-122.279	W2	1	8,982	1985	-		No			44%	40	D-E	C	455	Urban	Very High	Moderate to High	None	
Morton	10190	Morton Elementary School	19845	Main Building	176	46.558	-122.279	C2a	2	25,182	1930	1987	No	No			44%	40	D-E	C	455	Urban	Very High	Moderate to High	None	
Morton	11868	Morton Junior Senior High School	12392	Gymnasium	152	46.552	-122.273	W2	1	18,787	1957	1998	No	No			44%	40	D-E	E	175	Urban	Very High	Moderate to High	None	
Morton	11868	Morton Junior Senior High School	10961	Main Building	152	46.552	-122.273	W2	1	34,955	1957	1998	No	Yes			44%	40	D-E	E	175	Urban	Very High	Moderate to High	None	
Morton	11868	Morton Junior Senior High School	17363	Shop	152	46.552	-122.273	W2	1	7,625	1957	1998	No	No			44%	40	D-E	E	175	Urban	Very High	Moderate to High	None	
Mount Baker	10867	Mount Baker Junior High School	12268	200 Building - JHS	256	48.825	-122.220	W2	1	36,425	1992	-	Unknown	Yes	1990	UBC	40%	40	D-E	D	248	Rural	Very High	Moderate to High	None	
Mount Baker	10867	Mount Baker Junior High School	24242	Pro-Rate Portion of Commons - Building 100	256	48.825	-122.220	W2	1	8,364	1990	-	Unknown	Yes	1990	UBC	40%	40	D-E	D	248	Rural	Very High	Moderate to High	None	
Mount Baker	11955	Mount Baker Senior High School	15592	300 North	579	48.825	-122.220	W2	1	8,079	1980	1992	Unknown	Yes	1990	UBC	40%	40	D-E	D	248	Rural	Very High	Moderate to High	None	
Mount Baker	11955	Mount Baker Senior High School	12454	300 South	579	48.825	-122.220	W2	1	23,348	1980	-	Unknown	Yes	1990	UBC	40%	40	D-E	D	248	Rural	Very High	Moderate to High	None	
Mount Baker	11955	Mount Baker Senior High School	14587	700 Building	579	48.825	-122.220	W2	1	15,710	1992	-	Unknown	Yes	1990	UBC	40%	40	D-E	D	248	Rural	Very High	Moderate to High	None	
Mount Baker	11955	Mount Baker Senior High School	11085	800 Building (Former Deming Elem.)	579	48.825	-122.220	W2	1	21,425	1970	-	Unknown	Yes	1990	UBC	40%	40	D-E	D	248	Rural	Very High	Moderate to High	None	
Mount Baker	11955	Mount Baker Senior High School	15469	Field House	579	48.825	-122.220	RM1	1	30,941	1968	-	Unknown	Yes	1990	UBC	40%	40	D-E	D	248	Rural	Very High	Moderate to High	None	
Mount Baker	11955	Mount Baker Senior High School	15937	Pro-rate Portion of Commons - Bldg 100	579	48.825	-122.220	W2	1	24,858	1992	-	Unknown	Yes	1990	UBC	40%	40	D-E	D	248	Rural	Very High	Moderate to High	None	
Mount Vernon	12495	Lincoln Elementary School	12009	Main Building	373	48.415	-122.328	C2	3	40,002	1938	1982	Unknown	Yes			48%	40	D	C	463	Urban	High	Low to Moderate	None	
Naches Valley	10868	Naches Valley High School		Gym Building	453	46.736	-120.703	PC1a	1	21,000	1979			Yes	1976	UBC				D	354			Very Low to Low		
Naches Valley	10868	Naches Valley High School	17680	Main Building	453	46.736	-120.703	RM1	2	85,173	1979	-		Yes	1976	UBC	31%	20	D	D	354	Urban	Moderate to High	Very Low to Low	None	
Naches Valley	10868	Naches Valley High School	15151	Vocational Building	453	46.736	-120.703	RM1	1	17,200	1979	-		Yes	1976	UBC	31%	20	D	D	354	Urban	Moderate to High	Very Low to Low	None	
Naches Valley	10533	Naches Valley Middle School	13843	Main Building	407	46.728	-120.695	RM1	1	65,803	1994	-		Some	1991	UBC	33%	20	D-E	C	587	Urban	High	Moderate to High	None	
Newport	10923	Newport High School	11366	Main Building	354	48.177	-117.062	PC1	1	78,838	1983	-		Yes	UBC		18%	14	C	C	427	Urban	NULL	Very Low	None	
North Beach	11715	Pacific Beach Elementary School	20660	Gym/Lunchroom	150	47.208	-124.200	RM1	1	10,049	1956	-	Unknown	No			74%	60	C-D	D	272	Rural	Very High	Very Low	High or Very High	
North Beach	11715	Pacific Beach Elementary School	12004	Main Building	150	47.208	-124.200	W2	1	7,857	1956	-	Unknown	No			74%	60	C-D	D	272	Rural	Very High	Very Low	High or Very High	
North Beach	11715	Pacific Beach Elementary School	12053	Quad Building	150	47.208	-124.200	RM1	1	4,884	1970	-	Unknown	No			74%	60	C-D	D	272	Rural	Very High	Very Low	High or Very High	
Ocean Beach	11737	Ilwaco (Hilltop) Middle School	12706	Auditorium	316	46.311	-124.039	C2a	2	7,369	1936	2007	Yes	No			71%	60	B	D	184	Urban	NULL	Bedrock	Very Low	
Ocean Beach	11737	Ilwaco (Hilltop) Middle School	14919	Main Building	316	46.311	-124.039	C2a	3	46,330	1932	2007	Yes	Yes			71%	60	B	D	184	Urban	NULL	Bedrock	Very Low	
Ocean Beach	11997	Ilwaco High School	20728	Ilwaco High School	286	46.313	-124.040	W2	1	89,249	1971	2014	No	Yes	1967	UBC	71%	60	B	D	184	Urban	High	Bedrock	Low	
Ocean Beach	11997	Ilwaco High School	12323	Stadium Complex	286	46.313	-124.040	RM2	1	11,568	1976	-	No	Yes	1976	UBC	71%	60	B	D	184	Urban	High	Bedrock	Low	
Ocean Beach	12330	Long Beach Elementary School	19098	Main Building	243	46.349	-124.052	W2	1	36,213	1964	2005	No	Yes			71%	60	D	D	212	Urban	Extremely High	Moderate to High	High or Very High	
Ocean Beach	10155	Ocean Park Elementary School	11935	Main Building	166	46.488	-124.051	W2	1	35,593	2005	-		Yes	2003	IBC	71%	60	D	D	250	Rural	Extremely High	Moderate to High	Moderate	
Ocosta	12476	Ocosta Elementary School	20357	Primary Addition	320	46.862	-124.100	RM1	1	15,530	1986	-	No	Yes	1982	UBC	73%	60	D	D	220	Rural	Extremely High	Moderate to High	High or Very High	
Ocosta	11919	Ocosta Junior Senior High School	13146	Junior Senior High	285	46.864	-124.101	RM1	1	67,265	1986	-	No	Yes	1982	UBC	73%	60	D	D	220	Rural	Extremely High	Moderate to High	High or Very High	
Oroville	10516	Oroville Elementary School	18565	Main Building	323	48.933	-119.437	RM1	1	65,534	1954	-		No			20%	14	C-D	D	258	Urban	Moderate	Very Low to Low	None	
Palisades	11629	Palisades Elementary School	15495	Grange Hall	32	47.416	-119.916	W2	1	3,049	1930	-		No			29%	18	D-E	D	263	Rural	Moderate to High	Moderate to High	None	
Palisades	11629	Palisades Elementary School	15206	Main Building	32	47.416	-119.916	URM	2	5,084	1923	-		No			29%	18	D-E	D	263	Rural	Moderate to High	Moderate to High	None	Yes
Pasco	11669	Edwin Markham Elementary School	12049	Main Building	371	46.430	-119.198	W2	1	36,500	1962	1984	Yes	Yes			24%	16	D	D	332	Rural	Moderate	Low	None	
Pateros	11925	Pateros K-12 School	10003	Main Building	138	48.052	-119.906	RM1	2	51,157	1948	1982		No			32%	20	D-E	D	327	Urban	High	Moderate to High	None	
Pateros	11925	Pateros K-12 School	17712	Metal Shop	138	48.052	-119.906	S2a	1	4,000	1962	-		No			32%	20	D-E	D	327	Urban	High	Moderate to High	None	
Pateros	11925	Pateros K-12 School	10259	Music Building	138	48.052	-119.906	RM1	1	1,680	1958	-		No			32%	20	D-E	D	327	Urban	High	Moderate to High	None	
Pateros	11925	Pateros K-12 School	12916	Wood Shop	138	48.052	-119.906	W2	1	3,420	1995	-		No			32%	20	D-E	D	327	Urban	High	Moderate to High	None	
Paterson	12001	Paterson Elementary School	11968	Main Building	145	45.939	-119.609	RM1	1	14,970	1968	2003	Yes	Yes			19%	18	B	B	980	Rural	Moderate	Low	None	
Port Angeles	11703	Roosevelt Elementary School	14120	Main Building	502	48.103	-123.390	W2	1	23,785	1978	-	No	Yes	1976	UBC	71%	60	C-D	C	431	Rural	Very High	Very Low	Extremely Low	
Port Townsend	12006	Port Townsend High School	13775	Gym	366	48.118	-122.768	URM	1	34,112	1941	1984	No	No	1984	UBC	56%	50	C	D	355	Urban	High	Very Low	Extremely Low	Yes
Port Townsend	12006	Port Townsend High School	18186	Main Building	366	48.118	-122.768	URM	3	45,578	1934	1984	No	Yes	1934		56%	50	C	D	355	Urban	High	Very Low	Extremely Low	Yes
Port Townsend	12006	Port Townsend High School	10330	Math Science Annex	366	48.118	-122.768	URM	2	13,169	1928	1996	No	Yes	1958		56%	50	C	D	355	Urban	High	Very Low	Extremely Low	Yes
Port Townsend	12006	Port Townsend High School	14775	Stuart Building	366	48.118	-122.768	W2	1	17,912	1952	1984	No	No			56%	50	C	D	355	Urban	High	Very Low	Extremely Low	
Puyallup	10055	Maplewood Elementary School	16592	Main Building	434	47.190	-122.309	URM	1	43,621	1934	1998	Yes	Yes	1927	UBC	50%	50	D-E	E	165	Urban	Very High	high	Low	Yes
Puyallup	10624	Puyallup High School	16154	Gymnasium & Swimming Pool Building	1752	47.191	-122.303	W2	2	66,488	1958	1984	Yes	Yes	1955	UBC	50%	50	D-E	E	167	Urban	Very High	high	Low	
Puyallup	10624	Puyallup High School	19196	Library Science Building	1752	47.191	-122.303	W2	2	25,262	1962	1986	Yes	Yes	1958	UBC	50%	50	D-E	E	167	Urban	Very High	high	Low	
Puyallup	10624	Puyallup High School	15709	Main Building	1752	47.191	-122.303	URM	3	121,408	1927	1995	Yes	Yes			50%	50	D-E	E	167	Urban	Very High	high	Low	Yes
Puyallup	12100	Spinning Elementary School		East & West Classroom Wings	318	47.189	-122.277	W2	1	27,300	1960	1971	No	No	1958	UBC				D	200			high		
Puyallup	12100	Spinning Elementary School	14564	Main Building	318	47.189	-122.277	URM	1	11,480	1890	1985	Yes	Yes						D	200	Urban		high		Yes
Quilcene	12092	Quilcene High And Elementary School	15294	Elementary	206	47.823	-122.875	W2	1	10,500	1952	1952	No	Yes	1952		55%	50	C-D	C	514	Rural	High	Low	Moderate	
Quilcene	12092	Quilcene High And Elementary School	15982	High School	206	47.823	-122.875	C2a	2	7,856	1935	1975	No	No			55%	50	C-D	C	514	Rural	High	Low	Moderate	
Quilcene	12092	Quilcene High And Elementary School	12798	Middle School	206	47.823	-122.875	W2	1	9,438	1964	1979	Unknown	No			55%	50	C-D	C	514	Rural	High	Low	Moderate	
Raymond	10382	Raymond Elementary School	14323	Raymond elementary	325	46.686	-123.726	C2a	1		1955	1997	No	Yes				60		D	305	Urban		Moderate to High		
Raymond	10926	Raymond Junior Senior High School	15212	Main Building	251	46.685	-123.726	W2	2	23,000	1925	2003	No	Yes				60		D	305	Urban		Moderate to High		
Ridgefield	11175	Union Ridge Elementary School		Covered Play Area	777	45.817	-122.742	W2		2,200				Yes						D	268			Very Low		
Ridgefield	11175	Union Ridge Elementary School	18602	Main Building	777	45.817	-122.742	W2	1	43,178	1952	1993	No	Yes			40%	30	C	D	268	Urban	High	Very Low	None	
Riverside	10900	Chattaroy Elementary School	20113	35 Wing Building	289	47.892	-117.358	URM	2	13,956	1934	1983		Yes			22%	14	D	D	291	Rural	Moderate	Low	None	Yes
Riverside	10900	Chattaroy Elementary School	14703	Main Building	289	47.892	-117.358	RM1	1	27,953	1987	1993		Yes	UBC	1988	22%	14	D	D	291	Rural	Moderate	Low	None	
Royal	12362	Red Rock Elementary School	12448	Main Building	596	46.911	-119.624	W2	2	57,631	1992	1994		No			22%	18	C	C	391	Urban	Moderate	Bedrock	None	
Royal	11889	Royal High School	15534	A Gymnasium	492	46.912	-119.628	C3	1	31,320	1965	1996		No			22%	18	C	C	391	Urban	Moderate	Bedrock	None	

List of Schools Selected for ASCE 41-17 Tier 1 Seismic Evaluations

District Name	ICOS Facility ID	Facility Name	ICOS Building ID	Building Name	Enrollment	Latitude	Longitude	FEMA Construction Type	Number of Floors	Gross Sq Ft	Year Built	Last Major Renovation	Did Renovation Include Seismic Upgrades? (Y/N)	Structural Drawings Available	Original Bldg Code Year	Original Building Code	PGA 2% in 50 Year (%g)	Seismic PGA Class	Mapped Site Class	VS30 Site Class	VS30 (m/s)	Urban Or Rural	Earthquake Hazard Level	Liquefaction Potential	Tsunami Risk	Known Or Possible URM
Royal	11889	Royal High School	16484	B Main Building	492	46.912	-119.628	RM1	1	28,636	1965	1996		No			22%	18	C	C	391	Urban	Moderate	Bedrock	None	
Royal	10671	Royal Middle School	12746	Main Building	248	46.911	-119.627	RM1	1		1991	1996		No				18		C	391	Urban		Bedrock		
Shaw Island	10186	Shaw Island School	17116	Admin/RR Building	16	48.572	-122.962	W2	1	1,096	1952	-		No			47%	50	B	B	1674	Rural	High	Bedrock	Extremely Low	
Shaw Island	10186	Shaw Island School	18914	Intermediate Classroom Building	16	48.572	-122.962	W2	1	1,009	1992	-		Yes			47%	50	B	B	1674	Rural	High	Bedrock	Extremely Low	
Shaw Island	10186	Shaw Island School	16507	Primary Classroom Building	16	48.572	-122.962	W2	1	892	1902	-		No			47%	50	B	B	1674	Rural	High	Bedrock	Extremely Low	
Skykomish	11195	Skykomish School	21304	Main Building	16	47.709	-121.362	C2	3	39,433	1938	-		No			39%	30	D-E	D	347	Urban	High	Moderate to High	None	
South Bend	10373	South Bend Jr/Sr High School	11955	Koplitz Field House	225	46.662	-123.792	RM1	1	16,254	1950	1995	Yes	Yes			65%	60	D-E	E	109	Urban	Extremely High	Moderate to High	High or Very High	
South Bend	10373	South Bend Jr/Sr High School	16963	Vocational Building	225	46.662	-123.792	RM1	1	6,542	1954	-		Yes			65%	60	D-E	E	109	Urban	Extremely High	Moderate to High	High or Very High	
South Whidbey	10199	South Whidbey Elementary School	13428	Main Building	510	48.014	-122.411	W2	1	49,577	1988			Yes	1985	UBC	65%	60	C	C	456	Rural	Very High	Very Low	Extremely Low	
Spokane	10486	Adams Elementary School		Gym & Cafeteria	334	47.621	-117.368	URM	1		1950			No				12		C	553	Urban		Bedrock		Yes
Spokane	10486	Adams Elementary School	19951	Main Building	334	47.621	-117.368	URM	3	34,628	1910			Partial			14%	12	B	C	553	Urban	NULL	Bedrock	None	Yes
Spokane	12427	Audubon Elementary School	19568	Main Building	427	47.680	-117.442	S2a	2	51,653	1980			Yes	UBC	1976	17%	12	C	C	422	Urban	NULL	Very Low	None	
Spokane	11231	Libby Center	20029	Main Building	278	47.656	-117.368	URMa	2	66,393	1928	1995		Partial			17%	12	C	C	385	Urban	NULL	Very Low	None	Yes
Sunnyside	11495	Outlook Elementary School	18506	Outlook Elementary Main Building	646	46.345	-120.097	W2	1	57,084	1932	2002	No	Yes			28%	18	D	D	279	Rural	Moderate	Low to Moderate	None	
Tacoma	10169	Fern Hill Elementary School	15423	Main Building	324	47.179	-122.443	URM	3	60,159	1911	2006	Yes	Yes			53%	50	C	C	535	Urban	High	Very Low	Extremely Low	Yes
Tacoma	11394	Oakland High School	18694	Main Building	203	47.230	-122.486	URM	3	41,575	1911	1957	No	No			54%	50	C-D	C	458	Urban	High	Very Low	Extremely Low	Yes
Taholah	10818	Taholah School	15170	Covered Court	187	47.344	-124.288	W2	1	3,600	1991	-	No	Yes			70%	60	D-E	D	278	Rural	Extremely High	Moderate to High	High or Very High	
Taholah	10818	Taholah School	13517	Main Building	187	47.344	-124.288	W2	1	68,105	1973	1991	No	Yes	1985	UBC	70%	60	D-E	D	278	Rural	Extremely High	Moderate to High	High or Very High	
Thorp	10044	Thorp Elementary & Junior Senior High School	21839	Brick Building	124	47.070	-120.676	W2	2	16,303	1930	-		Some	1927	UBC	33%	20	D-E	C	532	Rural	High	Moderate to High	None	
Thorp	10044	Thorp Elementary & Junior Senior High School	21838	Thorp Elem/Jr/Sr High School	124	47.070	-120.676	RM1	1	38,975	1991	-		Some	1988	UBC	33%	20	D-E	C	532	Rural	High	Moderate to High	None	
Tonasket	12342	Tonasket Elementary School	18140	Greenhouse	593	48.702	-119.432	S2a	1	400	1995	-		No			22%	16	C-D	D	313	Urban	Moderate	Very Low to Low	None	
Tonasket	12342	Tonasket Elementary School	21131	Tonasket Elementary	593	48.702	-119.432	RM1	1	60,825	1995	-		Yes	UBC	1991	22%	16	C-D	D	313	Urban	Moderate	Very Low to Low	None	
Tonasket	12540	Tonasket Middle-High School	21196	High School/Middle School	569	48.702	-119.434	RM2	2	106,398	1995	-		Yes	UBC		22%	16	C-D	D	313	Urban	Moderate	Very Low to Low	None	
Touchet	10625	Touchet Elementary & High School	20924	CTE Building	226	46.043	-118.672	RM1	1	3,440	1960	-		No			28%	18	D-E	C	427	Rural	Moderate to High	Moderate to High	None	
Touchet	10625	Touchet Elementary & High School	20922	Elementary - Main Building	226	46.043	-118.672	RM1	1	40,250	1960	1996		No			28%	18	D-E	C	427	Rural	Moderate to High	Moderate to High	None	
Touchet	10625	Touchet Elementary & High School	20926	Secondary Facility	226	46.043	-118.672	PC1	1	29,478	1975	-		Partial	UBC		28%	18	D-E	C	427	Rural	Moderate to High	Moderate to High	None	
Tumwater	10611	Black Lake Elementary School	14369	Building A	504	46.991	-122.967	W2	1	22,494	1982	-	No	Yes	1979	UBC	56%	60	D	C	394	Urban	High	Low to Moderate	Extremely Low	
Tumwater	10611	Black Lake Elementary School	11452	Building B	504	46.991	-122.967	W2	1	21,314	1982	-	No	Yes	1979	UBC	56%	60	D	C	394	Urban	High	Low to Moderate	Extremely Low	
Tumwater	10611	Black Lake Elementary School	20813	Building C	504	46.991	-122.967	RM1	1	4,018	1984	-	No	Yes	1979	UBC	56%	60	D	C	394	Urban	High	Low to Moderate	Extremely Low	
Vashon Island	10465	Vashon Island High School	20350	Building D - Gymnasium	596	47.423	-122.457	RM1	3	23,744	1961	-	No	some	1958	UBC	61%	60	C	C	377	Rural	Very High	Very Low	Extremely Low	
Vashon Island	10465	Vashon Island High School	20352	Building K - Annex	596	47.423	-122.457	W2	1	4,677	1957	-	Unknown	No	1961	UBC	61%	60	C	C	377	Rural	Very High	Very Low	Extremely Low	
Warden	10921	Warden K-12	24208	Cafeteria	326	46.961	-119.042	RM1	1	10,312	1900	-		Partial	IBC	2009	25%	16	D	C	503	Urban	Moderate	Low	None	
Warden	10921	Warden K-12	24207	Gymnasium	326	46.961	-119.042	C3a	1	22,453	1900	-		Partial	IBC	2006	25%	16	D	C	503	Urban	Moderate	Low	None	
Warden	10921	Warden K-12	21956	Middle School/High School	326	46.961	-119.042	W2	1	50,570	1998	-		Yes	UBC	1994	25%	16	D	C	503	Urban	Moderate	Low	None	
Washougal	10296	Hathaway Elementary School	23054	Main Building	422	45.582	-122.346	W2	1	48,901	1935	2002	Yes	Yes			37%	30	C	C	531	Urban	Moderate to High	Low to Moderate	None	
Washtucna	11966	Washtucna Elementary High School	22085	Ag Shop/ Music Room	46	46.752	-118.310	URM	2	8,375	1920	-		No			25%	14	D-E	C	511	Urban	Moderate to High	Moderate to High	None	Yes
Washtucna	11966	Washtucna Elementary High School	22084	Main Building	46	46.752	-118.310	URM	1	37,873	1956	-		Partial			25%	14	D-E	C	511	Urban	Moderate to High	Moderate to High	None	Yes
White Pass	11994	White Pass Elementary School	17591	Main Building	231	46.536	-121.928	RM1	1	30,659	1964	2011	Yes	Yes	1961	UBC	43%	40	C-D	D	304	Rural	High	Very Low to Low	None	
White Pass	10854	White Pass Junior Senior High School	11003	Main Building	227	46.537	-121.930	RM1	1	62,005	2010	-	Yes	Yes	2006	IBC	44%	40	C-D	D	304	Rural	High	Very Low to Low	None	
White Salmon Valley	10734	Columbia High School	22348	C Court - Gym	387	45.742	-121.494	PC1a	1	33,246	1970	-		Yes	1967	UBC	27%	20	C	C	380	Rural	Moderate	Very Low	None	
White Salmon Valley	10734	Columbia High School	22351	Libray	387	45.742	-121.494	PC1	1	5,225	1970	-		Yes	1967	UBC	27%	20	C	C	380	Rural	Moderate	Very Low	None	
White Salmon Valley	10734	Columbia High School	22349	Metal /Wood Shop	387	45.742	-121.494	PC1	1	7,560	1970	-		Yes	1967	UBC	27%	20	C	C	380	Rural	Moderate	Very Low	None	
White Salmon Valley	11511	Hulan L. Whitson Elementary School	14661	Main Building	427	45.731	-121.487	URM	2	47,190	1956	1990	No	Yes			23%	20	B	C	464	Urban	Moderate	Bedrock	None	Yes
White Salmon Valley	12450	Wayne M. Henkle Middle School	22355	Middle School	195	45.740	-121.494	RM1	1	36,587	1960	1990	No	Yes			27%	20	C	C	380	Rural	Moderate	Very Low	None	
Wilson Creek	10279	Wilson Creek K-12	10998	Business Building/Home Ec.	92	47.426	-119.121	W2	1	2,272	1984	-		No			19%	16	C	C	374	Urban	NULL	Very Low	None	
Wilson Creek	10279	Wilson Creek K-12	24318	Gym/Commons	92	47.426	-119.121	RM1	1	17,335	1997	-		No			19%	16	C	C	374	Urban	NULL	Very Low	None	
Wilson Creek	10279	Wilson Creek K-12	24204	Main - Gym & Classrooms	92	47.426	-119.121	URM	2	18,944	1932	1980		No			19%	16	C	C	374	Urban	NULL	Very Low	None	Yes
Wilson Creek	10279	Wilson Creek K-12	22654	Vo-Ag / Science Bldg	92	47.426	-119.121	W2	2	7,950	1989	-		No			19%	16	C	C	374	Urban	NULL	Very Low	None	

List of School Buildings Selected for Conceptual Seismic Upgrade Designs

District Name	ICOS Facility ID	Facility Name	Enrollment	ICOS Building ID	Building Name	FEMA Construction Type	Number of Floors	GrossSqFt	Concept Upgrade Performance Objective	Structural Drawings Available?	Year Built	Last Major Renovation	Did Renovation Include Seismic Upgrades? (Y/N)	PGA 2% in 50 Year (% g)	VS30 Site Class	VS30 (m/s)	Earthquake Hazard Level	Liquefaction Potential
Battle Ground	10719	Prairie High School	1577	10577	600 Building	RM1	1	10,725	Life Safety	Yes	1979	-		42.24%	D	298	High	None
Boistfort	10441	Boistfort Elementary	99	16933	Gymnasium Building	RM1	1	14,530	Immediate Occupancy	Yes	1963	-		48.68%	D	320	Very High	Moderate to High
Carbonado	11248	Carbonado Historical School 19	179	11276	B - Community Gym	W2	2	5,700	Immediate Occupancy	No	1936	-		49.47%	C	411	High	Very Low to Low
Centralia	12216	Edison Elementary School	345	13954	Main Building	URM	1	31,521	Life Safety	No	1918	-		49.45%	C	424	Very High	Moderate to High
Cosmopolis	10975	Cosmopolis Elementary School	164	17703	Main Building	W2	1	30,456	Life Safety	Yes	1960	-		66.56%	D	235	Extremely High	Moderate to High
Coupeville	11136	Coupeville High School	321	11786	Gymnasium	RM1	1	10,000	Life Safety	No	1981	-		59.81%	D	279	Very High	Very Low
Dayton	12210	Dayton High School	139	21434	Gymnasium	S3	1	27,152	Immediate Occupancy	Yes	1966	-		26.74%	B	1013	Moderate to High	Moderate to High
Grand Coulee Dam	12823	Lake Roosevelt K-12	750	23616	CTE Building	S3	1	46,336	Life Safety	Yes	1955	-		23.51%	D	304	Moderate	Low
Marysville	11618	Totem Middle School	556	19455	Main Building	RM1	1	22,384	Life Safety	Yes	1966	-		46.15%	D	246	High	Low to Moderate
Mount Vernon	12495	Lincoln Elementary School	373	12009	Main Building	C2	3	40,002	Life Safety	Yes	1938	1982	Unknown	47.51%	C	463	High	Low to Moderate
Naches Valley	10868	Naches Valley High School	453	17680	Main Building	RM1	2	85,173	Life Safety	Yes	1979	-		30.60%	D	354	Moderate to High	Very Low to Low
North Beach	11715	Pacific Beach Elementary School	150	20660	Gym/ Lunchroom	RM1	1	10,049	Immediate Occupancy	No	1956	-		73.99%	D	272	Very High	Very Low
South Bend	10373	South Bend Jr/ Sr High School	225	11955	Koplitz Field House	RM1	1	16,254	Immediate Occupancy	Renov. Only	1950	1995	Yes	64.61%	E	109	Extremely High	Moderate to High
Spokane	10486	Adams Elementary School	334	19951	Main Building	URM	3	34,628	Life Safety	No	1910			14.37%	C	553	NULL	None
White Salmon Valley	10734	Columbia High School	387	22348	Gym Building	PC1a	1	33,246	Life Safety	Yes	1970	-		26.51%	C	380	Moderate	Very Low



Map of Washington School Districts

Washington State School Seismic Safety Assessments Project – June 2019

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APPENDIX C: OSPI ICOS DATA

Building EQ & EPAT Data For Icos Upload Of The Schools Seismically Evaluated

Facility Name	Building Name	Year Built	Last Major Renovation	Did Renovation Include Seismic Upgrades?	Structural Drawings Available?	Known Or Possible URM	HAZUS Construction Type (for EPAT)	VS30 Site Class	VS30 (m/s)	Original Bldg Code Year	Original Building Code	Severe Vertical Irregularty? (Y/N)	Moderate Vertical Irregularty? (Y/N)	Plan Irregularties? (Y/N)
Maple Grove K-8	Gym	1990	-		Yes		W2	D	320	1976	UBC	N	N	N
Maple Grove K-8	Main Building	1990	-		Yes		W2	D	320	1988	UBC	N	Y	Y
Prairie High School	400 Building	1995	-		Yes		W2	D	297	1991	UBC	N	N	N
Prairie High School	500 Building	1979	-		Yes		RM1	D	297	1973	UBC	N	N	Y
Prairie High School	600 Building	1979	-		Yes		RM1	D	297	1973	UBC	N	N	Y
River Homelink	Main Building	1980	-		Yes		W2	D	320	1976	UBC	N	N	Y
Bickleton Elementary and High School	Bldg B - Vocational/Transportation	1961	-		No		S3	B	1031	Unknown	Unknown	N	N	Y
Bickleton Elementary and High School	Main Building	2010	-		Yes		RM2	B	1031	2006	IBC	N	Y	Y
Boistfort Elementary	Gymnasium Building	1963	-		No		RM1	D	320	Unknown	Unknown	Y	N	N
Boistfort Elementary	Main Building	1936	1990	No	Yes	Yes	URM	D	320	Unknown	UBC	Y	N	Y
Edison Elementary School	Original Building	1995	-	No	No		W2	E	173	Unknown	Unknown	N	N	N
Lacamas Heights Elementary School	100 Pod	1962	2012	No	Yes		RM1	C	415	Unknown	Unknown	N	N	Y
Lacamas Heights Elementary School	Multipurpose	1962	1997	No	Yes		RM1	C	415	Unknown	Unknown	N	N	Y
Liberty Middle School	Main Building	1958	2006	No	Yes		RM1	C	667	Unknown	Unknown	N	N	Y
Liberty Middle School	Music Building	1970	-		No		RM1	C	667	Unknown	Unknown	N	N	N
Skyridge Middle School	Main Building	1995	-		Yes		RM2	D	312	1991	UBC	Y	N	Y
Clallam Bay High and Elementary School	Big Gym	1962	2007	No	No		W2	D	295	Unknown	Unknown	N	N	Y
Clallam Bay High and Elementary School	Elementary Building	1962	2006	Yes	No		RM1	D	295	Unknown	Unknown	N	N	N
Clallam Bay High and Elementary School	Elementary Gym	1980	-		Yes		RM1	D	295	1976	UBC	N	N	N
Clallam Bay High and Elementary School	High School Building	1972	1995	No	Yes		C2	D	295	1976	UBC	N	N	Y
Clallam Bay High and Elementary School	Shop and Art Building	1980	-		Yes		RM1	D	295	1976	UBC	N	N	N
Neah Bay Elementary School	Elementary School	1961	2012	No	Yes		RM1	D	232	1976	UBC	N	N	Y
Neah Bay Junior/ Senior High School	Neah Bay High School Classroom Building	1976	-		Yes		W2	D	232	Unknown	Unknown	N	N	Y
Neah Bay Junior/ Senior High School	Neah Bay High School Gym	1972	-		No		C2	D	232	Unknown	Unknown	N	N	Y
Neah Bay Junior/ Senior High School	Neah Bay High School Shop Building	1972	-		Yes		S3	D	232	1985	UBC	N	N	Y
Neah Bay Junior/ Senior High School	Neah Bay Middle School & Gym	2002	-		Yes		W2	D	232	1997	UBC	N	N	N
Carbonado Historical School 19	1st and 2nd Grade and Special Education Building	1968	1986	No	No		S1	C	411	1964	UBC	N	N	N
Carbonado Historical School 19	A - Main Building	1929	-		No	Yes	URM	C	411	1927	UBC	N	Y	N
Carbonado Historical School 19	B - Community Gym	1936	-		No		W2	C	411	1927	UBC	N	N	N
Carbonado Historical School 19	Computer Lab and Library	1989	-		No		W2	C	411	1985	UBC	N	N	N
Centerville Elementary School	Main Building	1919	-		No	Yes	URM	C	412	Unknown	Unknown	N	N	N
Ridgetop Junior High School	Main Building	1986	1992	No	No		RM2	C	521	Unknown	Unknown	N	N	N
Silver Ridge Elementary School	Main Building	1990	1990	No	Yes		W2	C	521	Unknown	Unknown	N	N	Y
Edison Elementary School	Main Building	1918	-		No	Yes	URM	C	424	Unknown	Unknown	Y	N	Y
Concrete High School	Main Building	1951	-		Yes		W2	C	470	1991	UBC	Y	N	N
Concrete High School	Tech Building	1952	-		Yes		RM1	C	470	1991	UBC	N	N	N
Concrete K-6 School	Gym	1981	-		Yes		W2	C	470	1976	UBC	N	Y	N
Concrete K-6 School	Main Building	1981	-		Yes		W2	C	470	1976	UBC	N	N	Y
Cosmopolis Elementary School	Auditorium Building	1960	-		Yes		W2	D	230	1955	UBC	N	N	N
Cosmopolis Elementary School	Gymnasium Building	1969	-		Yes		W2	D	230	1967	UBC	N	N	N
Cosmopolis Elementary School	Main Building	1960	-		Yes		W2	D	230	1955	UBC	N	N	Y
Cosmopolis Elementary School	Multipurpose Building	1960	-		Yes		W2	D	230	1955	UBC	N	N	N
Coupeville Elementary School	Cedar Pod	1979	-		No		RM1	C	412	Unknown	Unknown	N	N	N
Coupeville Elementary School	Main	1974	1992	Unknown	No		RM1	C	412	Unknown	Unknown	N	N	Y
Coupeville Elementary School	Multipurpose	1979	-		No		RM1	C	412	Unknown	Unknown	N	N	N
Coupeville High School	Annex	1978	-		Yes		RM1	D	279	2003	IBC	N	N	N
Coupeville High School	Gymnasium	1981	-		Yes		RM1	D	279	2003	IBC	N	Y	N
Coupeville Middle School	Middle and High School Building	1992	-		No		W2	D	279	Unknown	Unknown	Y	N	N
Creston Junior Senior High School	Creston K-12 School Building	1953	1984	Yes	Yes		W2	D	302	Unknown	Unknown	N	N	Y
Darrington Elementary School	Main Elementary School	1990	-		Yes		W2	D	343	1988	UBC	N	Y	Y
Darrington Senior High School	Darrington High School	1935	2001	Yes	No		W2	D	343	Unknown	Unknown	N	Y	Y
Darrington Senior High School	Woodshop	1960	-		No		RM2	D	343	Unknown	Unknown	N	N	N
Dayton High School	Ag Shop	1954	-		No	Yes	URM	B	1013	Unknown	Unknown	N	N	N
Dayton High School	Gymnasium	1966	-		Yes		S3	B	1013	Unknown	Unknown	N	N	N
Dayton High School	High School Building	1923	1985	No	No	Yes	URM	B	1013	Unknown	Unknown	Y	N	N
Dayton High School	Wood Shop	1966	-		No	Yes	URM	B	1013	Unknown	Unknown	N	N	Y
Dayton K-8 School	Elementary and Middle School Building	1966	-		No	Yes	URM	B	1013	Unknown	Unknown	N	N	Y
Dixie Elementary School	Main Building	1921	-		No	Yes	URM	D	359	Unknown	Unknown	N	N	N
East Valley Central Middle School	6th Grade Building	1980	2010	No	Yes		PC1	C	487	Unknown	Unknown	N	N	Y
East Valley Central Middle School	7th - 8th Grade Building	2010	-		Yes		S2	C	487	2006	IBC	N	N	Y
East Valley Central Middle School	Computer Lab Building	1996	-		No		W2	C	487	Unknown	Unknown	N	N	Y
East Valley Central Middle School	Gymnasium Building	1950	2010	No	Yes		PC1	C	487	Unknown	Unknown	N	N	Y
East Valley Elementary School	Main Building	1996	-		Yes		RM1	C	582	Unknown	UBC	N	N	Y
Evaline Elementary School	Main Building	1926	2011	Yes	No	Yes	URM	D	326	Unknown	Unknown	N	N	N
Beach Elementary	Main Building	1919	1979	No	No		W2	C	699	Unknown	Unknown	Y	N	N
Columbia Junior High School	Main Building	2003	-		Yes		RM1	E	168	1997	UBC	N	Y	Y
Fife High School	Building IV 400 Library	1950	1975	Yes	Yes		C2	E	171	Unknown	Unknown	Y	N	Y
Fife High School	Building IX 900 Science	1970	1992	Yes	Yes		W2	E	171	Unknown	Unknown	N	N	Y
Fife High School	Building V 500 Main	1950	1992	Yes	Yes		W2	E	171	Unknown	Unknown	N	N	Y
Fife High School	Building VI 600 Gyms	1956	1992	Yes	Yes		W2	E	171	1952	UBC	N	N	N
Fife High School	Building VII 700 Cafeteria	1963	1992	Yes	Yes		W2	E	171	Unknown	Unknown	N	Y	Y
Fife High School	Building VIII 800 Shop	1963	1992	Yes	Yes		RM1	E	171	Unknown	Unknown	N	N	N
Glenwood School	Main Building	1981	-		Yes		RM1	C	676	1979	UBC	N	Y	Y
Lake Roosevelt K-12	CTE Building	1955	-		Yes		S3	D	304	Unknown	Unknown	N	N	Y
Lake Roosevelt K-12	Wood Shop	1974	-		No		RM1	D	304	Unknown	Unknown	N	N	N
Green Mountain School	Gymnasium	1950	1994	No	No		W2	D	341	Unknown	Unknown	N	N	N
Green Mountain School	Main Building	1932	1994	No	No	Yes	URM	D	341	Unknown	Unknown	N	N	N
Harrington Elementary & High School	Main Building	1936	1955	No	No	Yes	URM	C	601	Unknown	Unknown	N	N	N
Woodside Site	Annex	1960	-		Yes		S5	D	355	1958	UBC	N	N	N
Woodside Site	Main Building	1958	-		Yes		S5	D	355	1955	UBC	N	N	Y
Hoquiam High School	A-Administration	1966	-	No	Yes		W2	D	242	1964	UBC	N	N	N
Hoquiam High School	B-Science	1966	-	No	Yes		W2	D	242	1964	UBC	Y	N	Y
Hoquiam High School	E-Library	1966	-	No	Yes		W2	D	242	1964	UBC	N	N	N
Hoquiam High School	H-Gymnasium	1966	-	No	Yes		RM1	D	242	1964	UBC	N	Y	N
Lincoln Elementary School	Administrative and Library Building	1968	1994	No	Yes		W2	E	111	1964	UBC	N	N	Y
Lincoln Elementary School	East Wing	1968	1994	No	Yes		W2	E	111	1964	UBC	N	N	Y
Lincoln Elementary School	Multipurpose Building	1968	1994	No	Yes		W2	E	111	1964	UBC	N	N	Y
Lincoln Elementary School	West Wing	1968	1994	No	Yes		W2	E	111	1964	UBC	N	N	Y
Index Elementary School	Enclosed Covered Play	1997	-		No		W2	C	419	Unknown	Unknown	N	N	N
Index Elementary School	Main Building	1954	1997		No		RM1	C	419	Unknown	Unknown	N	N	N
Carrolls Elementary School	Main Building	1948	2003	No	Yes		RM1	B	1038	Unknown	Unknown	N	Y	Y
La Conner High School	High School Auditorium	1921	-	Yes	Yes	Yes	URM	D	184	1973	UBC	N	N	Y
La Conner High School	High School Main Building	1974	-		Yes		W2	D	184	1973	UBC	N	Y	Y
La Conner Middle School (form. Elem.)	Old Auditorium/Cafeteria Bldg	1921	-	Unknown	No	Yes	URM	D	184	Unknown	Unknown	N	N	N
R. A. Long High School	Gym	1927	-		Yes		PC1	E	166	Unknown	Unknown	N	N	Y
R. A. Long High School	Main Building	1927	-		Yes	Yes	URM	E	166	Unknown	Unknown	Y	N	Y
R. A. Long High School	RA Long Annex	1963	-		No		W2	E	166	Unknown	Unknown	N	N	N
R. A. Long High School	Science Wing	1935	-		Yes		RM1	E	166	Unknown	Unknown	N	N	N
R. A. Long High School	Shop Bldg	1942	-		Yes	Yes	URM	E	166	Unknown	Unknown	N	N	N
Mabton Jr/Sr High School	Main Building	1950	2001	No	No		RM1	D	327	Unknown	Unknown	N	N	N
Mabton Jr/Sr High School	Shop/Ag Building	1900	-		No		RM1	D	327	Unknown	Unknown	N	N	N
Mansfield Elem and High School	Main Building	1983	-		No		RM1	B	864	Unknown	Unknown	N	N	Y
Liberty Elementary School	Main Building	1951	-		Yes		W2	D	245	1973	UBC	N	N	Y
Marysville Middle School	Building B	1960	1983	No	Yes		W2	D	245	1958	UBC	N	N	N
Marysville Middle School	Building C - Shop Classrooms	1960	1983	No	Yes		RM1	D	245	1958	UBC	N	N	N
Marysville Middle School	Main Building	1960	-		Yes		W2	D	245	1958	UBC	N	Y	Y
Totem Middle School	Cafeteria Gym Building	1958	1988	No	Yes		RM2	D	246	1955	UBC	N	Y	N
Totem Middle School	Home Economics Building	1955	1988	No	Yes		C2	D	246	1949	UBC	N	N	N
Totem Middle School	Main Building	1966	-		Yes		RM1	D	246	1964	UBC	N	N	N
Totem Middle School	School House Cafe	1955	1989	No	No		C2	D	246	Unknown	Unknown	N	N	N
Totem Middle School	Science Building	1962	-		Yes		RM1	D	246	1958	UBC	N	N	N
Liberty Bell Junior Senior High School	Main Building	1994	-		Yes		RM1	D	333	Unknown	Unknown	N	N	Y
Methow Valley Elementary School	Main Building	1963	1996	No	Partial		RM1	D	333	Unknown	Unknown	N	N	Y
Morton Elementary School	Gymnasium	1985	-		No		W2	C	455	Unknown	Unknown	N	Y	Y
Morton Elementary School	Main Building	1930	1987	No	No		C2	C	455	Unknown	Unknown	N	N	N
Morton Junior Senior High School	Gymnasium	1957	1998	No	No		W2	E	175	Unknown	Unknown	N	N	N
Morton Junior Senior High School	Main Building	1957	1998	No	Yes		W2	E	175	Unknown	Unknown	N	N	Y
Morton Junior Senior High School	Shop	1957	1998	No	No		W2	E	175	Unknown	Unknown	N	Y	N
Mount Baker Junior High School	200 Building - JHS	1992	-		Yes		W2	D	248	1990	UBC	N	N	Y
Mount Baker Junior High School	Pro-Rate Portion of Commons - Building 100	1990	-		Yes		W2	D	248	1990	UBC	N	Y	N
Mount Baker Senior High School	300 North	1980	1992	Unknown	Yes		W2	D	248	1990	UBC	N	N	N
Mount Baker Senior High School	300 South	1980	-		Yes		W2	D	248	1990	UBC	N	N	N
Mount Baker Senior High School	700 Building	1992	-		Yes		W2	D	248	1990	UBC	N	Y	Y
Mount Baker Senior High School	800 Building (Former Deming Elem.)	1970	-		Yes		W2	D	248	1990	UBC	N	Y	N
Mount Baker Senior High School	Field House	1968	-		Yes		RM1	D	248	1990	UBC	N	N	N
Mount Baker Senior High School	Pro-rate Portion of Commons - Bldg 100	1992	-		Yes		W2	D	248	1990	UBC	N	Y	N
Lincoln Elementary School	Main Building	1938	1982	Unknown	Yes		C2	C	463	Unknown	Unknown	Y	N	N
Naches Valley High School	Gym Building	1979			Yes		PC1	D	354	1976	UBC	N	N	N
Naches Valley High School	Main Building	1979	-		Yes		RM1	D	354	1976	UBC	N	N	N
Naches Valley High School	Vocational Building	1979	-		Yes		RM1	D	354	1976	UBC	N	N	N
Naches Valley Middle School	Main Building	1994	-		Some		RM1	C	587	1991	UBC	N	N	N
Newport High School	Main Building	1983	-		Yes		PC1	C	427	Unknown	UBC	N	N	Y
Pacific Beach Elementary School	Gym/Lunchroom	1956	-		No		RM1	D	272	Unknown	Unknown	Y	N	N
Pacific Beach Elementary School	Main Building	1956	-		No		W2	D	272	Unknown	Unknown	N	N	N
Pacific Beach Elementary School	Quad Building	1970	-		No		RM1	D	272	Unknown	Unknown	N	N	N
Ilwaco (Hilltop) Middle School	Auditorium	1936	2007	Yes	No		C2	D	184	Unknown	Unknown	N	N	N
Ilwaco (Hilltop) Middle School	Main Building	1932	2007	Yes	Yes		C2	D	184	Unknown	Unknown	N	Y	Y
Ilwaco High School	Ilwaco High School	1971	2014	No	Yes		W2	D	184	1967	UBC	Y	N	Y
Ilwaco High School	Stadium Complex	1976	-		Yes		RM2	D	184	1976	UBC	N	N	N
Long Beach Elementary School	Main Building	1964	2005	No	Yes		W2	D	212	Unknown	Unknown	N	Y	Y
Ocean Park Elementary School	Main Building	2005	-		Yes		W2	D	250	2003	IBC	N	N	Y
Ocosta Elementary School	Primary Addition	1986	-		Yes		RM1	D	220	1982	UBC	N	N	N
Ocosta Junior Senior High School	Junior Senior High	1986	-		Yes		RM1	D	220	1982	UBC	N	N	Y

ReidMiddleton

Building EQ & EPAT Data For Icos Upload Of The Schools Seismically Evaluated

Washington State School Seismic Safety Assessments Project – June 2019

Building EQ & EPAT Data For Icos Upload Of The Schools Seismically Evaluated

Facility Name	Building Name	Year Built	Last Major Renovation	Did Renovation Include Seismic Upgrades?	Structural Drawings Available?	Known Or Possible URM	HAZUS Construction Type (for EPAT)	VS30 Site Class	VS30 (m/s)	Original Bldg Code Year	Original Building Code	Severe Vertical Irregularty? (Y/N)	Moderate Vertical Irregularty? (Y/N)	Plan Irregularties? (Y/N)
Oroville Elementary School	Main Building	1954	-		No		RM1	D	258	Unknown	Unknown	N	N	Y
Palisades Elementary School	Grange Hall	1930	-		No		W2	D	263	Unknown	Unknown	N	N	N
Palisades Elementary School	Main Building	1923	-		No	Yes	URM	D	263	Unknown	Unknown	N	N	N
Edwin Markham Elementary School	Main Building	1962	1984	Yes	Yes		W2	D	332	Unknown	Unknown	N	N	N
Pateros K-12 School	Main Building	1948	1982	No	No		RM1	D	327	Unknown	Unknown	N	N	Y
Pateros K-12 School	Metal Shop	1962	-		No		S2	D	327	Unknown	Unknown	N	N	N
Pateros K-12 School	Music Building	1958	-		No		RM1	D	327	Unknown	Unknown	N	N	N
Pateros K-12 School	Wood Shop	1995	-		No		W2	D	327	Unknown	Unknown	N	N	N
Paterson Elementary School	Main Building	1968	2003	Yes	Yes		RM1	B	980	Unknown	Unknown	N	N	Y
Roosevelt Elementary School	Main Building	1978	-		Yes		W2	C	431	1976	UBC	N	N	Y
Port Townsend High School	Gym	1941	1984	No	No	Yes	URM	D	355	1984	UBC	N	N	N
Port Townsend High School	Main Building	1934	1984	No	Yes	Yes	URM	D	355	1934	Unknown	N	N	Y
Port Townsend High School	Math Science Annex	1928	1996	No	Yes	Yes	URM	D	355	1958	Unknown	N	N	Y
Port Townsend High School	Stuart Building	1952	1984	No	No		W2	D	355	Unknown	Unknown	N	N	N
Maplewood Elementary School	Main Building	1934	1998	Yes	Yes	Yes	URM	E	165	1927	UBC	N	N	Y
Puyallup High School	Gymnasium and Swimming Pool Building	1958	1984	Yes	Yes		W2	E	167	1955	UBC	Y	N	Y
Puyallup High School	Library Science Building	1962	1986	Yes	Yes		W2	E	167	1958	UBC	Y	N	Y
Puyallup High School	Main Building	1927	1995	Yes	Yes	Yes	URM	E	167	Unknown	Unknown	N	N	Y
Spinning Elementary School	East and West Classroom Wings	1960	1971	No	No		W2	D	200	1958	UBC	N	N	N
Spinning Elementary School	Main Building	1890	1985	Yes	Yes	Yes	URM	D	200	Unknown	Unknown	N	N	Y
Quilcene High And Elementary School	Elementary	1952	1952	No	Yes		W2	C	514	1952	Unknown	N	N	N
Quilcene High And Elementary School	High School	1935	1975	No	No		C2	C	514	Unknown	Unknown	N	N	N
Quilcene High And Elementary School	Middle School	1964	1979	Unknown	No		W2	C	514	Unknown	Unknown	N	N	N
Raymond Elementary School	Raymond elementary	1955	1997	No	Yes		C2	D	305	Unknown	Unknown	N	N	Y
Raymond Junior Senior High School	Main Building	1925	2003	No	Yes		W2	D	305	Unknown	Unknown	Y	N	Y
Union Ridge Elementary School	Covered Play Area				Yes		W2	D	268	Unknown	Unknown	N	N	N
Union Ridge Elementary School	Main Building	1952	1993	No	Yes		W2	D	268	Unknown	Unknown	N	N	Y
Chattaroy Elementary School	35 Wing Building	1934	1983	No	Yes	Yes	URM	D	291	Unknown	Unknown	N	N	Y
Chattaroy Elementary School	Main Building	1987	1993	No	Yes		RM1	D	291	1988	UBC	N	N	Y
Red Rock Elementary School	Main Building	1992	1994	No	No		W2	C	391	Unknown	Unknown	N	N	N
Royal High School	A Gymnasium	1965	1996	No	No		C3	C	391	Unknown	Unknown	N	N	N
Royal High School	B Main Building	1965	1996	No	No		RM1	C	391	Unknown	Unknown	N	N	N
Royal Middle School	Main Building	1991	1996	No	No		RM1	C	391	Unknown	Unknown	N	N	N
Shaw Island School	Admin/RR Building	1952	-		No		W2	B	1674	Unknown	Unknown	N	N	N
Shaw Island School	Intermediate Classroom Building	1992	-		Yes		W2	B	1674	Unknown	Unknown	N	N	N
Shaw Island School	Primary Classroom Building	1902	-		No		W2	B	1674	Unknown	Unknown	N	N	N
Skykomish School	Main Building	1938	-		No		C2	D	347	Unknown	Unknown	Y	N	N
South Bend Jr/Sr High School	Koplitz Field House	1950	1995	Yes	Yes		RM1	E	109	Unknown	Unknown	N	N	N
South Bend Jr/Sr High School	Vocational Building	1954	-		Yes		RM1	E	109	Unknown	Unknown	N	Y	Y
South Whidbey Elementary School	Main Building	1988			Yes		W2	C	456	1985	UBC	N	N	Y
Adams Elementary School	Gym and Cafeteria	1950			No	Yes	URM	C	553	Unknown	Unknown	N	Y	N
Adams Elementary School	Main Building	1910			Partial	Yes	URM	C	553	Unknown	Unknown	N	N	N
Audubon Elementary School	Main Building	1980			Yes		S2a	C	422	1976	UBC	N	N	N
Libby Center	Main Building	1928	1995	No	Partial	Yes	URM	C	385	Unknown	Unknown	N	Y	Y
Outlook Elementary School	Outlook Elementary Main Building	1932	2002	No	Yes		W2	D	279	Unknown	Unknown	N	N	Y
Fern Hill Elementary School	Main Building	1911	-		No	Yes	URM	C	535	Unknown	Unknown	N	N	N
Oakland High School	Main Building	1911	1957	No	No	Yes	URM	C	458	Unknown	Unknown	N	N	N
Taholah School	Covered Court	1991	-		Yes		W2	D	278	Unknown	Unknown	N	Y	Y
Taholah School	Main Building	1973	1991	No	Yes		W2	D	278	1985	UBC	N	N	Y
Thorp Elementary and Junior Senior High School	Brick Building	1930	-		Some		W2	C	532	1927	UBC	N	N	N
Thorp Elementary and Junior Senior High School	Thorp Elem/Jr/Sr High School	1991	-		Some		RM1	C	532	1988	UBC	N	N	N
Tonasket Elementary School	Greenhouse	1995	-		No		S2	D	313	Unknown	Unknown	N	N	N
Tonasket Elementary School	Tonasket Elementary	1995	-		Yes		RM1	D	313	1991	UBC	N	N	Y
Tonasket Middle-High School	High School/Middle School	1995	-		Yes		RM2	D	313	Unknown	UBC	N	Y	N
Touchet Elementary and High School	CTE Building	1960	-		No		RM1	C	427	Unknown	Unknown	N	N	N
Touchet Elementary and High School	Elementary - Main Building	1960	1996	No	No		RM1	C	427	Unknown	Unknown	N	Y	Y
Touchet Elementary and High School	Secondary Facility	1975	-		Partial		PC1	C	427	Unknown	UBC	N	N	Y
Black Lake Elementary School	Building A	1982	-		Yes		W2	C	394	1979	UBC	N	N	N
Black Lake Elementary School	Building B	1982	-		Yes		W2	C	394	1979	UBC	N	N	Y
Black Lake Elementary School	Building C	1984	-		Yes		RM1	C	394	1979	UBC	N	N	N
Vashon Island High School	Building D - Gymnasium	1961	-		some		RM1	C	377	1958	UBC	N	Y	N
Vashon Island High School	Building K - Annex	1957	-		No		W2	C	377	1961	UBC	N	N	N
Warden K-12	Cafeteria	1900	-		Partial		RM1	C	503	2009	IBC	N	N	N
Warden K-12	Gymnasium	1900	-		Partial		C3	C	503	2006	IBC	N	N	N
Warden K-12	Middle School/High School	1998	-		Yes		W2	C	503	1994	UBC	N	N	N
Hathaway Elementary School	Main Building	1935	2002	Yes	Yes		W2	C	531	Unknown	Unknown	N	Y	Y
Washtucna Elementary High School	Ag Shop/ Music Room	1920	-		No	Yes	URM	C	511	Unknown	Unknown	N	Y	N
Washtucna Elementary High School	Main Building	1956	-		Partial	Yes	URM	C	511	Unknown	Unknown	N	Y	Y
White Pass Elementary School	Main Building	1964	2011	Yes	Yes		RM1	D	304	1961	UBC	N	Y	N
White Pass Junior Senior High School	Main Building	2010	-		Yes		RM1	D	304	2006	IBC	N	Y	Y
Columbia High School	C Court - Gym	1970	-		Yes		PC1	C	380	1967	UBC	N	N	Y
Columbia High School	Libray	1970	-		Yes		PC1	C	380	1967	UBC	N	N	Y
Columbia High School	Metal /Wood Shop	1970	-		Yes		PC1	C	380	1967	UBC	N	N	N
Hulan L. Whitson Elementary School	Main Building	1956	1990	No	Yes	Yes	URM	C	464	Unknown	Unknown	Y	N	Y
Wayne M. Henkle Middle School	Middle School	1960	1990	No	Yes		RM1	C	380	Unknown	Unknown	Y	N	Y
Wilson Creek K-12	Business Building/Home Ec.	1984	-		No		W2	C	374	Unknown	Unknown	N	N	N
Wilson Creek K-12	Gym/Commons	1997	-		No		RM1	C	374	Unknown	Unknown	N	N	N
Wilson Creek K-12	Main - Gym & Classrooms	1932	1980	No	No	Yes	URM	C	374	Unknown	Unknown	N	N	N
Wilson Creek K-12	Vo-Ag / Science Bldg	1989	-		No		W2	C	374	Unknown	Unknown	N	N	N

APPENDIX D: FEMA REFERENCE DOCUMENTS (BUILDING TYPES, IRREGULARITIES, FEMA E-74 NONSTRUCTURAL SEISMIC BRACING EXCERPTS)

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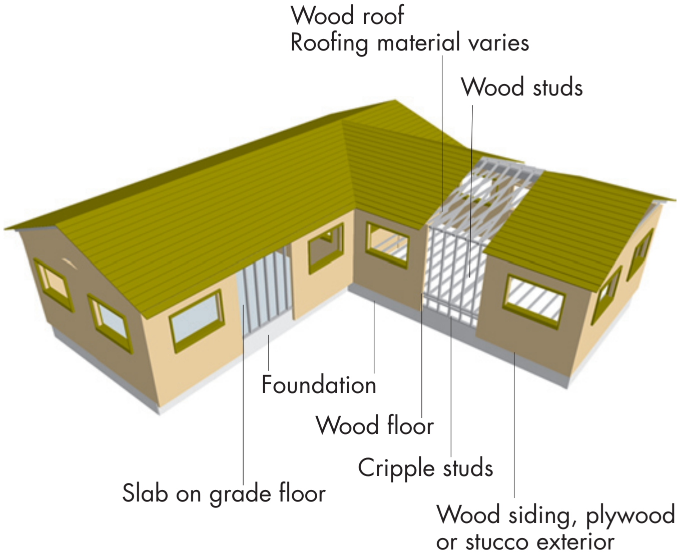
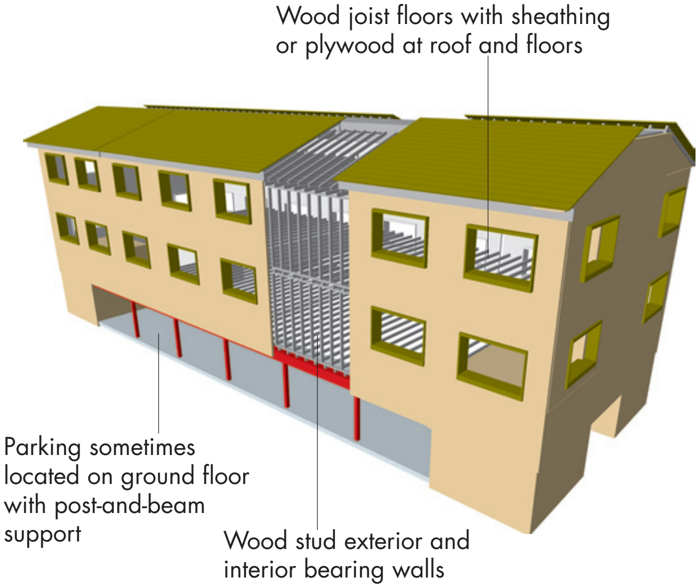
Building Types (FEMA 454 Excerpts)

FEMA Building Type W1 WOOD LIGHT FRAME (small residence)



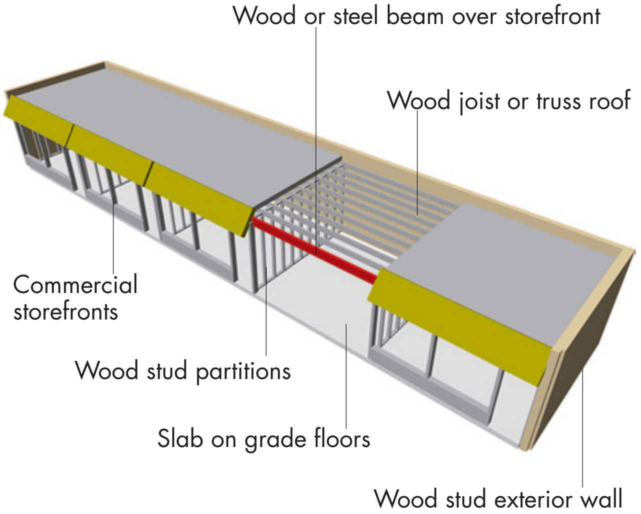
These buildings are generally single-family dwellings of one and two stories. Floor and roof framing consists of wood joists or rafters supported on wood studs spaced no more than 24 inches apart. The first floor may be slab on grade or wood raised above grade with cripple stud walls and post-and-beam supports. Lateral support is provided with shear walls of plywood, stucco, gypsum board, and a variety of other materials. Most often there is no engineering design for lateral forces.

FEMA Building Type W1A WOOD LIGHT FRAME (multi-unit residence)



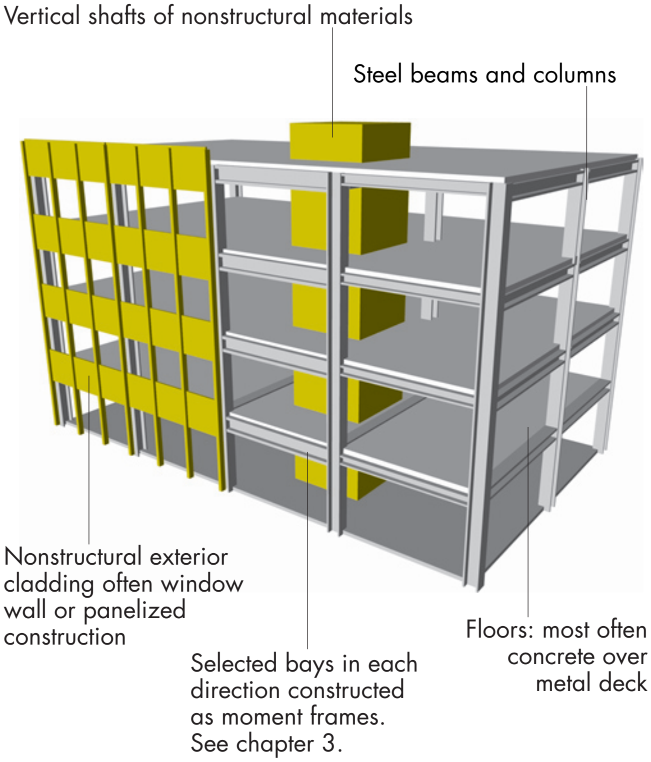
These buildings are framed with the same systems as W1 buildings but are most often multiple-story large residential-type structures, and, unless very old, are engineered. A common seismic deficiency is the tuck-under parking at the ground story that creates a soft or weak story. This building type is also often built on top of a one story concrete parking structure.

FEMA Building Type W2 WOOD FRAME (commercial and industrial)



These buildings are commonly commercial or smaller industrial buildings and are constructed primarily of wood framing. The floor and roof framing consists of wood joists and wood or steel trusses, glulam or steel beams, and wood posts or steel columns. Lateral forces are resisted by wood diaphragms and exterior stud walls sheathed with plywood, stucco, or wood sheathing, or sometimes rod bracing or a spot steel-braced frame. Large wall openings are common for storefronts or garage openings. This building type is also often used for schools, churchs and clubhouses.

FEMA Building Type S1 STEEL MOMENT FRAMES

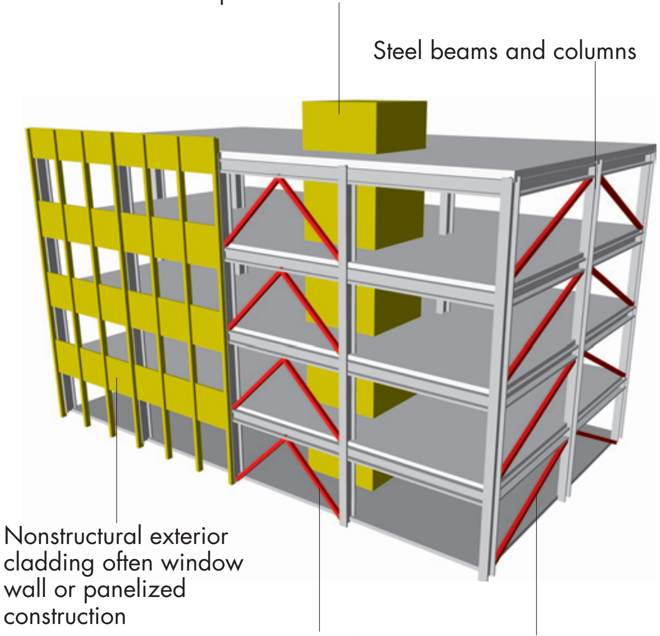


These buildings consist of an essentially complete frame assembly of steel beams and columns. Lateral forces are resisted by moment frames that develop stiffness through rigid connections of the beam and column created by angles, plates and bolts, or by welding. Moment frames may be developed on all framing lines or only in selected bays. It is significant that no structural walls are required. Floors are cast-in-place concrete slabs or metal deck and concrete. This building is used for a wide variety of occupancies such as offices, hospitals, laboratories, and academic and government buildings.

The S1A building type is similar but has floors and roof that act as flexible diaphragms, such as wood or uptopped metal deck. One family of these buildings are older warehouse or industrial buildings, while another more recent use is for small office or commercial buildings in which the fire rating of concrete floors is not needed.

from FEMA 454 Designing for Earthquakes - A Manual for Architects

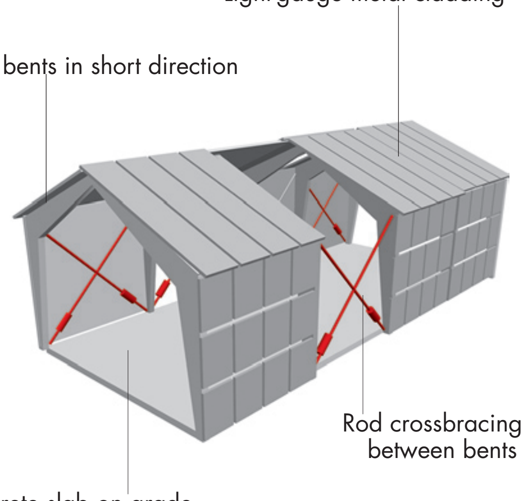
FEMA Building Type S2 STEEL-BRACED FRAMES



These buildings consist of a frame assembly of steel columns and beams. Lateral forces are resisted by diagonal steel members placed in selected bays. Floors are cast-in-place concrete slabs or metal deck and concrete. These buildings are typically used for buildings similar tos teel-moment frames, although are more often low rise.

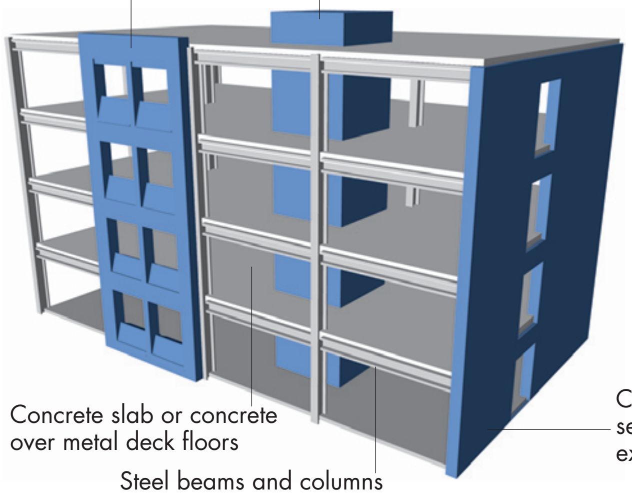
The S2A building type is similar but has floors and roof that act as flexible diaphragms such as wood, or uptopped metal deck. This is a relatively uncommon building type and is used mostly for smaller office or commercial buildings in which the fire rating of concrete floor is not needed.

FEMA Building Type S3 STEEL LIGHT FRAMES



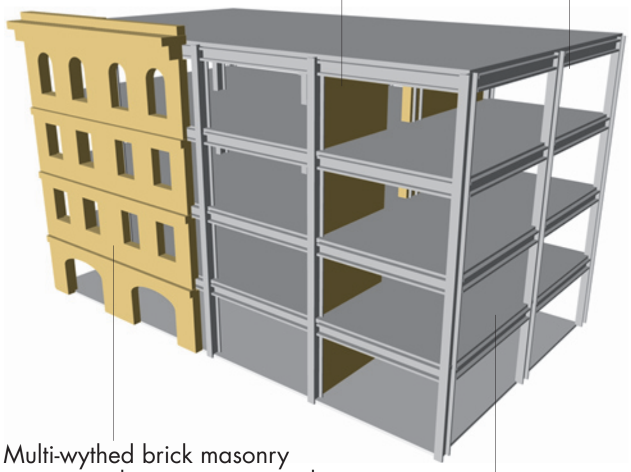
These buildings are one story, pre-engineered and partially prefabricated, and normally consist of transverse steel bents and light purlins. The roof and walls consist of lightweight metal, fiberglass, or cementitious panels. Lateral forces are resisted by the transverse steel bents acting as moment frames, and light rod diagonal bracing in the longitudinal direction. The roof diaphragm is either metal deck or diagonal rod bracing. These buildings are mostly used for industrial or agricultural occupancies.

FEMA Building Type S4 STEEL FRAMES with concrete shearwalls



These buildings consist of an essentially complete frame assembly of steel beams and steel columns. The floors are concrete slabs or concrete fill over metal deck. The buildings feature a significant number of concrete walls effectively acting as shear walls, either as vertical transportation cores, isolated in selected bays, or as a perimeter wall system. The steel column-and-beam system may act only to carry gravity loads or may have rigid connections to act as a moment frame. This building type is generally used as an alternate for steel moment or braced frames in similar circumstances. These buildings will usually be mid- or low-rise.

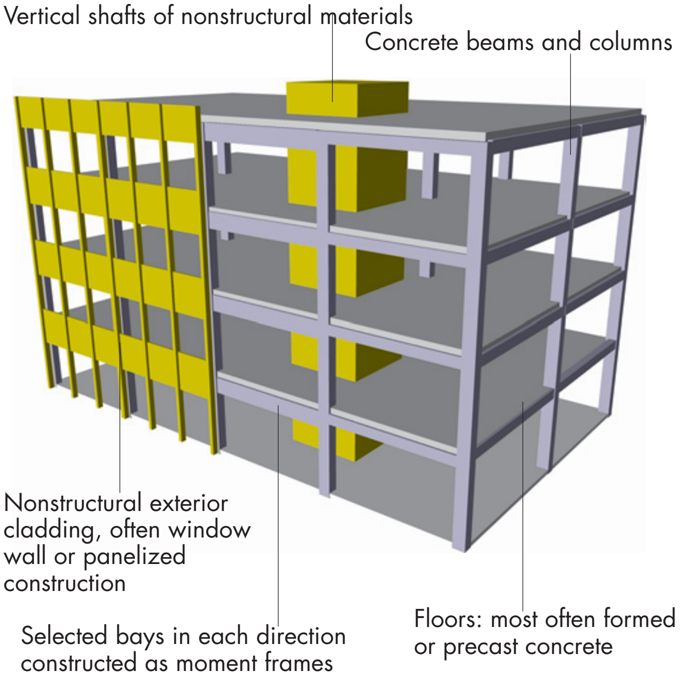
FEMA Building Type S5 STEEL FRAMES with infill masonry walls



This is normally an older building that consists of an essentially complete frame assembly of steel floor beams or trusses and steel columns. The floor consists of masonry flat arches, concrete slabs or metal deck, and concrete fill. Exterior walls and possibly some interior walls, are constructed of unreinforced solid clay brick, concrete block, or hollow-clay tile masonry infilling the space between columns and beams. Windows and doors may be present in the infill walls, but to act effectively as shear-resisting elements, the infill masonry must be constructed tightly against the columns and beams. Although relatively modern buildings in moderate or low seismic regions are built with unreinforced masonry exterior infill walls, the walls are generally not built tight against the beams and columns and therefore do not provide shear resistance. The buildings intended to fall into this category feature exposed clay brick masonry on the exterior and are common in commercial areas of cities with occupancies of retail stores, small offices, and hotels.

The S5A building type is similar but has floors and roof that act as flexible diaphragms, such as wood or uptopped metal deck. These buildings will almost all date to the 1930s and earlier, and were originally warehouses or industrial buildings.

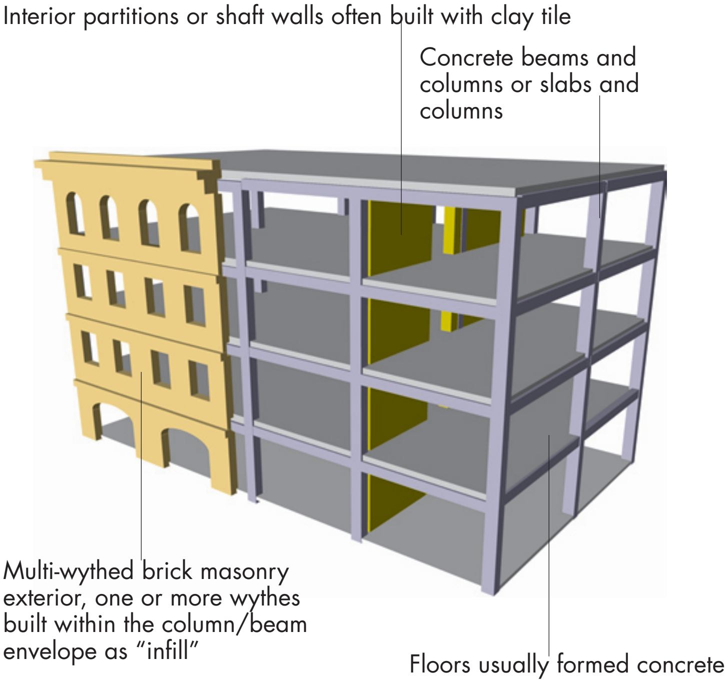
FEMA Building Type C1 CONCRETE MOMENT FRAMES



These buildings consist of concrete framing, either a complete system of beams and columns or columns supporting slabs without gravity beams. Lateral forces are resisted by moment frames that develop stiffness through rigid connections of the column and beams placed in a given bay. Moment frames may be developed on all framing lines or only in selected bays. It is significant that no structural walls are required. Floors are cast-in-place or precast concrete. Buildings with concrete moment frames could be used for most occupancies listed for steel moment frames, but are also used for multistory residential buildings.

The C1A building type is similar but has floors and roof that act as flexible diaphragms, such as wood or uptopped metal deck. This is a relatively unusual building type, but might be found as older warehouse-type buildings or small office occupancies.

FEMA Building Type C3 CONCRETE FRAMES with infill masonry shear walls



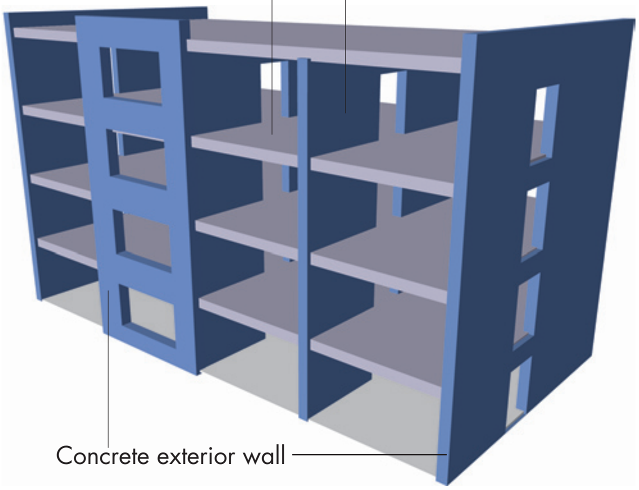
These buildings consist of concrete framing, either a complete system of beams and columns or columns supporting slabs without gravity beams. Exterior walls and possibly some interior walls are constructed of unreinforced solid clay brick, concrete block, or hollow clay tile masonry infilling the space between columns and beams. Windows and doors may be present in the infill walls, but to act effectively as shear-resisting elements, the infill masonry must be constructed tightly against the columns and beams. The building type is similar to S5, but is more often used for industrial and warehouse occupancies.

The C3A building type is similar but has floors and roof that act as flexible diaphragms, such as wood, or uptopped metal deck. Thisbuilding type not often found except as one-story industrial buildings.

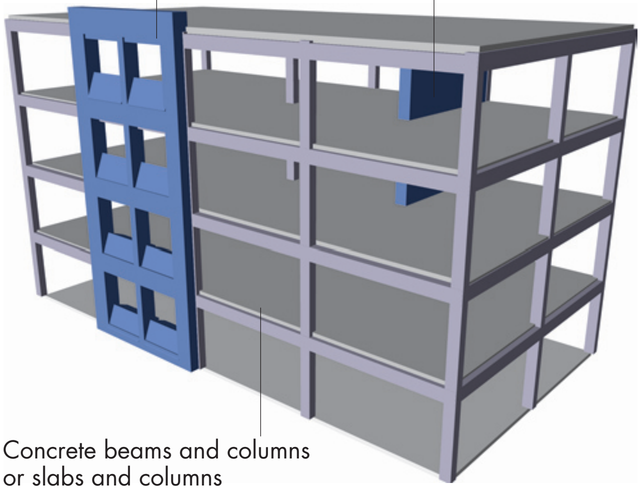
from FEMA 454 Designing for Earthquakes - A Manual for Architects

FEMA Building Type C2 CONCRETE SHEAR WALLS

with bearing walls



with gravity frames



Concrete shear walls are concrete walls in a building design to provide lateral stiffness and strength for lateral loads. There are two main types of shear-wall buildings, those in which the shear walls also carry the gravity loads (with bearing walls), and those in which a column-supported framing system carries the gravity loads (with gravity frame).

In the **bearing wall** type, all walls usually act as both bearing and shear walls. The building type is similar and often used in the same occupancies as type RM2, namely in mid- and low-rise hotels and motels. This building type is also used in residential apartment/ condo-type buildings.

In **gravity frame** buildings, shear walls are either strategically placed around the plan, or at the perimeter. Shear-wall systems placed around the entire perimeter must contain the windows, and other perimeter openings are called punched shear walls. These buildings were commonly built in the 1950s and 1960s for a wide variety of most institutional occupancy types.

The C2A building type is similar, but has floors and roof that act as flexible diaphragms such as wood, or uptopped metal deck. C2A buildings are normally bearing-wall buildings. These buildings are similar to building-type RM1 and are used for similar occupancies- such as small office or commercial and sometimes residential.

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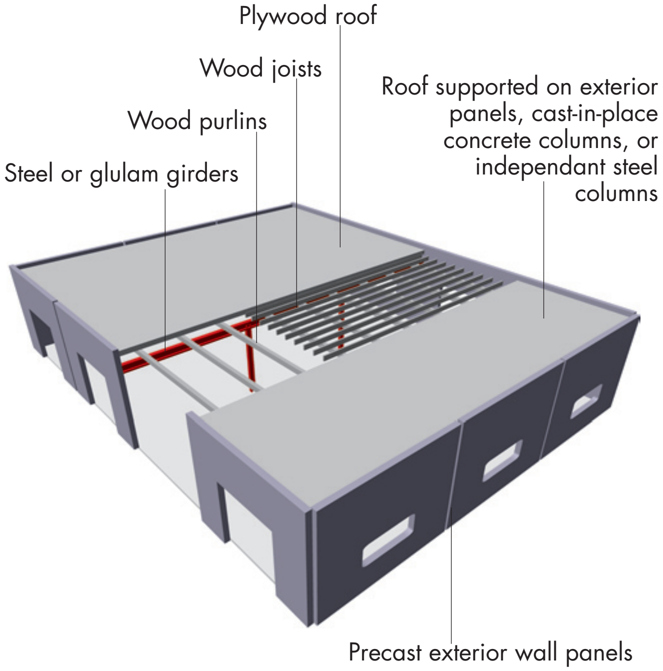
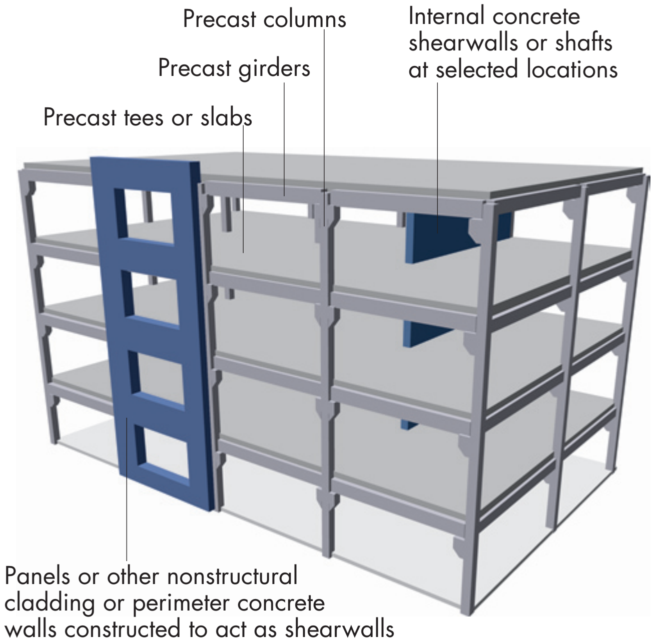
FEMA Building Type PC1 TILT-UP CONCRETE shear walls



These buildings are constructed with perimeter concrete walls precast on the site and tilted up to form the exterior of the buildings, to support all or a portion of the perimeter roof load, and to provide seismic shear resistance. These buildings are commonly one-story with a wood joist and plywood roof or sometimes with a roof of steel joists and metal deck. Two-story tilt-ups usually have a steel-framed second floor with metal deck and concrete and a wood roof. Tilt-up walls that support roof load are very common on the West Coast; due to economical construction cost, they are used for many occupancies, including warehouses, retail stores, and offices. In other parts of the country, these buildings more often have an independent load-carrying system on the inside face of the walls.

The PC1A building is similar but features all floors and/or roof constructed of materials that form a rigid diaphragm, normally concrete. This building type is similar to PC2.

FEMA Building Type PC2 PRECAST CONCRETE FRAMES with shear walls

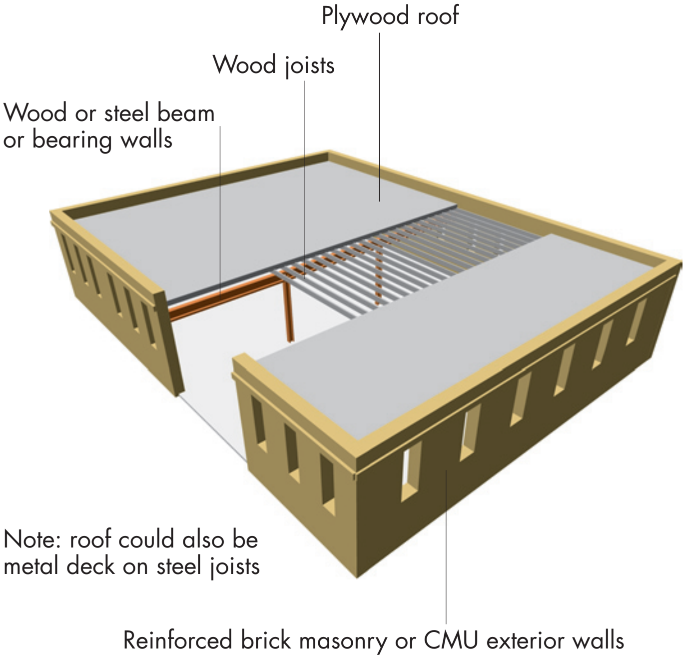


These buildings consist of concrete columns, girders, beams and/or slabs that are precast off the site and erected to form a complete gravity-load system. Type PC2 has a lateral force-resisting system of concrete shear walls, usually cast-in-place. Many garages have been built with this system The building type is most common in moderate and low seismic zones and could be used for many different occupancies in those areas.

The PC2A building is similar but obtains lateral support from specially connected precast girders and columns that form moment frames. Until recently, precast moment frames have not been allowed in regions of high seismicity, and these buildings will essentially only be found in moderate or low seismic zones.

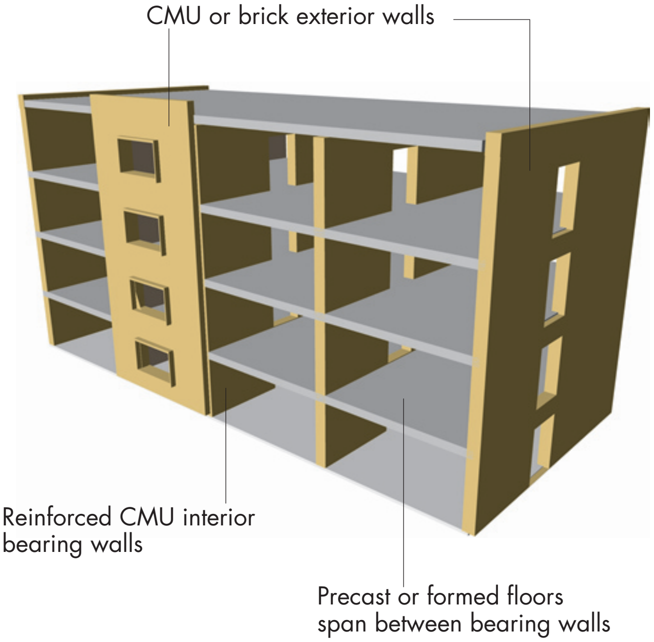
from FEMA 454 Designing for Earthquakes - A Manual for Architects

FEMA Building Type RM1 REINFORCED MASONRY WALLS with flexible diaphrams



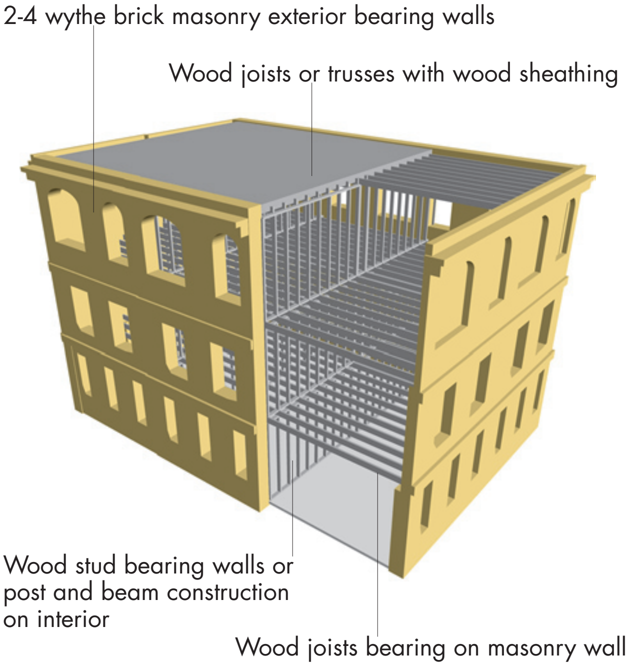
These buildings take a variety of configurations, but they are characterized by reinforced masonry walls (brick cavity wall or CMU) with flexible diaphragms, such as wood or metal deck. The walls are commonly bearing, but the gravity system often also contains post-and-beam construction of wood or steel. Older buildings of this type are generally small and were used for a wide variety of occupancies and are configured to suit. Recently, the building type is commonly used for one-story warehouse-type occupancies similar to tilt-up buildings.

FEMA Building Type RM2 REINFORCED MASONRY WALLS with stiff diaphrams



This building consists of reinforced masonry walls and concrete slab floors that may be either cast-in-place or precast. This building type is often used for hotel and motels and is similar to the concrete bearing-wall type C2.

FEMA Building Type URM UNREINFORCED MASONRY BEARING WALLS



This building consists of unreinforced masonry bearing walls, usually at the perimeter and usually brick masonry. The floors are wood joists and wood sheathing supported on the walls and on interior post-and-beam construction or wood-stud bearing walls. This building type is ubiquitous in the U.S. and was built for a wide variety of uses, from one-story commercial or industrial occupancies, to multistory warehouses, to mid-rise hotels. Unfortunately, it has consistently performed poorly in earthquakes. The most common failure is an outward collapse of the exterior walls, caused by loss of lateral support due to separation of the walls from the floor/roof diaphragm.

The URMA building is similar. but features all floors and/or roof constructed of materials that form a rigid diaphragm, usually concrete slabs or steel joists with flat-arched unreinforced masonry.

moment-frame buildings have received damage to their beam-column connections when subjected to strong shaking. Even in these cases, the damage is not 100% consistent and certainly not 100% predictable. In building types with less vulnerability, the damage has an even higher coefficient of variation. Engineers and policymakers, therefore, have struggled with methods to reliably evaluate existing buildings for their seismic vulnerability.

As discussed in Section 8.2, the initial engineering response was to judge older buildings by their capacity to meet the code for new buildings, but it became quickly apparent that this method was overly conservative, because almost every building older than one or two code-change cycles would not comply—and thus be considered deficient. Even when lower lateral force levels were used, and the presence of archaic material was not, in itself, considered a deficiency, many more buildings were found

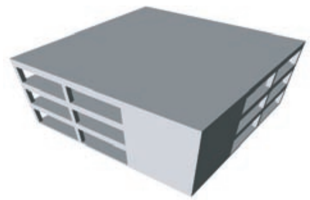
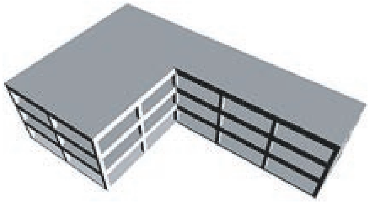
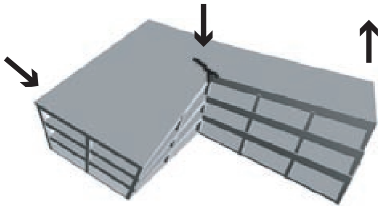
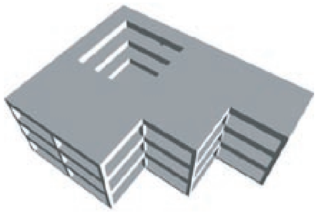
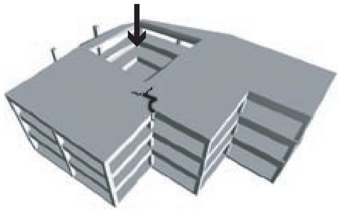
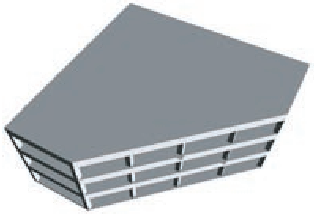
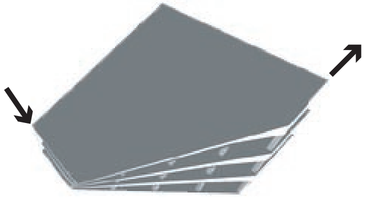
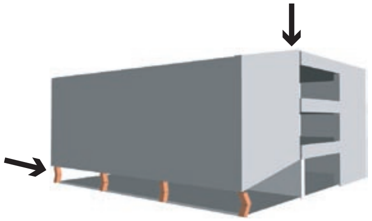
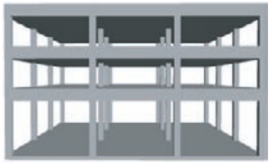
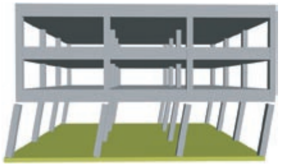
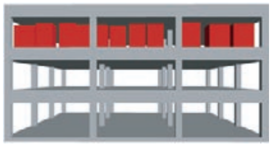
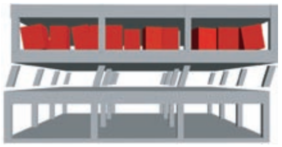
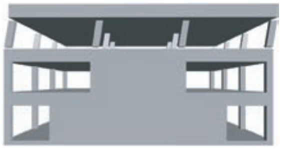
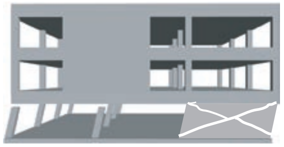
plan conditions	resulting failure patterns	performance	code remedies
		**P1 Torsional Irregularity: Unbalenced Resistance** Localized damage. Collapse mechanism in extreme instances.	Modal Analysis, +65 foot high in SDC D,E, F. 25% increase to diaphragm connection design forces. Amplified forces to max of X3.
		**P2 Re-entrant Corners** Local damage to diaphragm and attached elements. Collapse mechanism in extreme instances in large buildings.	25% increase in diaphragm connection design forces.
		**P3 Diaphragm Eccentricity and Cutouts** Localized structural damage.	25% increase in diaphragm connection design forces.
		**P4 Nonparallel Lateral Force-Resisting System** Leads to torsion and instability, localised damage.	Combine 100% and 30% of forces in 2 directions, use maximum.
		**P5 Out-of-Plane Offsets: Discontinuous Shearwalls** Collapse mechanism in extreme circumstances.	Modal Analysis, +65 foot high in SDC D,E, F. 25% increase to diaphragm connection design forces.

Figure 5-5: Horizontal (Plan) Irregularities (based on IBC, Section 1616.5.1).

from FEMA 454 Designing for Earthquakes - A Manual for Architects

Figure 5-6: Vertical Irregularities (based on IBC, Section 1616.5.2).

vertical conditions	resulting failure patterns	performance	code remedies
		**V1 Stiffness Irregularity: Soft Story**	
		Common collapse mechanism. Death and much damage in Northridge earthquake.	Modal Analysis, +65 feet high in SCD D,E,F. Extreme case not permitted in seismic use groups E and F.
		**V2 Weight/Mass Irregularity**	
		Collapse mechanism in extreme circumstances.	Modal Analysis,+65 foot high in SDC D,E,F.
		**V3 Vertical Geometric Irregularity**	
		Localized structural damage.	Modal Analysis,+65 foot high in SDC D,E,F.
		**V4 In-Plane Irregularity in Vertical Lateral Force System**	
		Localized structural damage.	Model Analysis, +65 foot high is SDC D, E, F. 25% increase to diaphragm connection design force. Supporting members designed for increased forces.
		**V5 Capacity Discontinuity: Weak Story**	
		Collapse mechanism in extreme circumstances	Modal Analysis, +65 foot high in SDC D,E,F.

from FEMA 454 Designing for Earthquakes - A Manual for Architects

Irregularities Guidelines

B.5 Vertical Irregularity Reference Guide

Table B-4 Vertical Irregularity Reference Guide

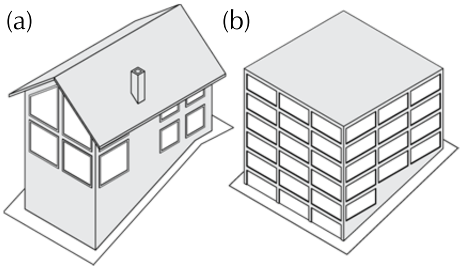
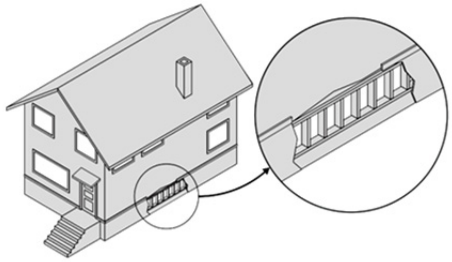
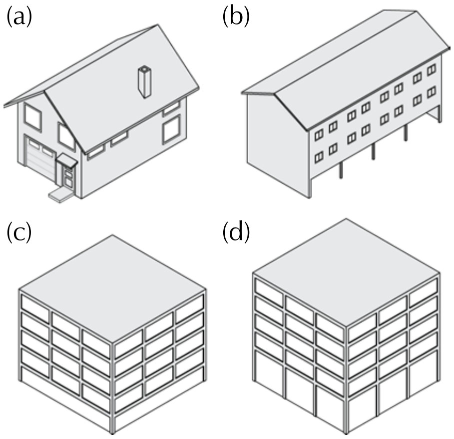
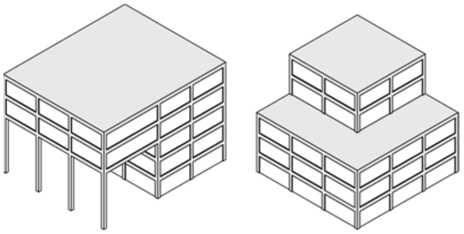
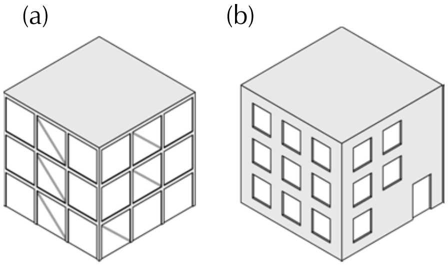
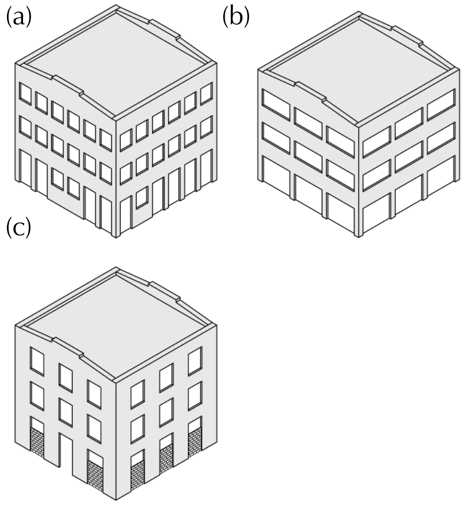
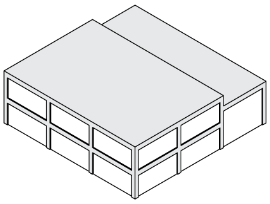
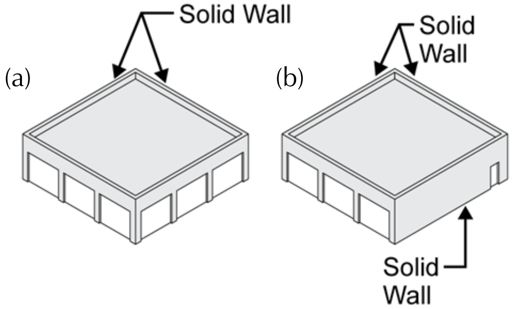
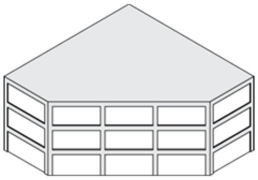
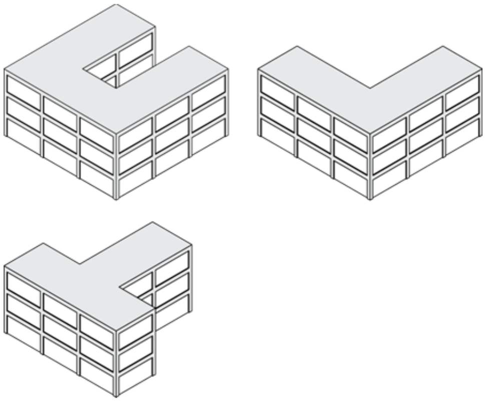
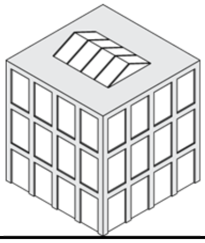
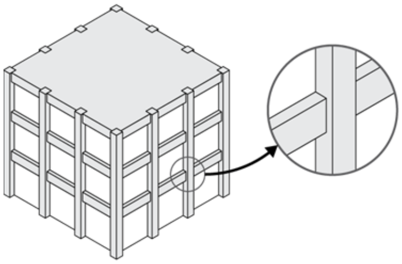
Vertical Irregularity		Severity	Level 1 Instructions
Sloping Site		Varies	Apply if there is more than a one-story slope from one side of the building to the other. Evaluate as Severe for W1 buildings as shown in Figure (a); evaluate as Moderate for all other building types as shown in Figure (b).
Unbraced Cripple Wall		Moderate	Apply if unbraced cripple walls are observed in the crawlspace of the building. This applies to W1 buildings. If the basement is occupied, consider this condition as a soft story.
Weak and/or Soft Story		Severe	Apply: Figure (a): For a W1 house with occupied space over a garage with limited or short wall lengths on both sides of the garage opening. Figure (b): For a W1A building with an open front at the ground story (such as for parking). Figure (c): When one of the stories has less wall or fewer columns than the others (usually the bottom story). Figure (d): When one of the stories is taller than the others (usually the bottom story).
Out-of-Plane Setback		Severe	Apply if the walls of the building do not stack vertically in plan. This irregularity is most severe when the vertical elements of the lateral system at the upper levels are outboard of those at the lower levels as shown in Figure (a). The condition in Figure (b) also triggers this irregularity. If nonstacking walls are known to be nonstructural, this irregularity does not apply. Apply the setback if greater than or equal to 2 feet.

Table B-4 Vertical Irregularity Reference Guide (continued)

Vertical Irregularity		Severity	Level 1 Instructions
In-plane Setback		Moderate	Apply if there is an in-plane offset of the lateral system. Usually, this is observable in braced frame (Figure (a)) and shear wall buildings (Figure (b)).
Short Column/Pier		Severe	Apply if: Figure (a): Some columns/piers are much shorter than the typical columns/piers in the same line. Figure (b): The columns/piers are narrow compared to the depth of the beams. Figure (c): There are infill walls that shorten the clear height of the column. Note this deficiency is typically seen in older concrete and steel building types.
Split Levels		Moderate	Apply if the floors of the building do not align or if there is a step in the roof level.

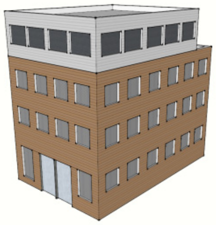
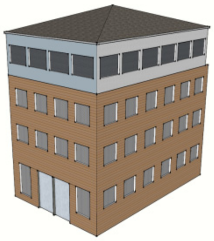
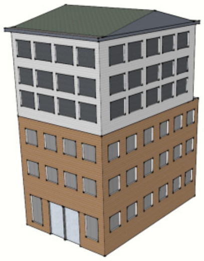
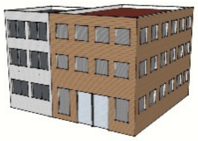
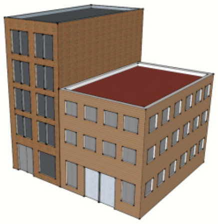
B.6 Plan Irregularity Reference Guide

Table B-5 Plan Irregularity Reference Guide

Plan Irregularity		Level 1 Instructions
Torsion		Apply if there is good lateral resistance in one direction, but not the other, or if there is eccentric stiffness in plan (as shown in Figures (a) and (b); solid walls on two or three sides with walls with lots of openings on the remaining sides).
Non-Parallel Systems		Apply if the sides of the building do not form 90-degree angles.
Reentrant Corner		Apply if there is a reentrant corner, i.e., the building is L, U, T, or + shaped, with projections of more than 20 feet. Where possible, check to see if there are seismic separations where the wings meet. If so, evaluate for pounding.
Diaphragm Openings		Apply if there is a opening that has a width of over 50% of the width of the diaphragm at any level.
Beams do not align with columns		Apply if the exterior beams do not align with the columns in plan. Typically, this applies to concrete buildings, where the perimeter columns are outboard of the perimeter beams.

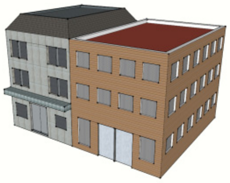
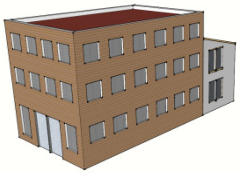
B.7 Level 2 Building Addition Reference Guide

Table B-6 Level 2 Building Addition Reference Guide

Addition Orientation	Type of Addition	Example	RVS Screening Recommendation	Notes and Additional Instructions
Vertical	Single story addition has a smaller footprint than the original building		Evaluate as a single building using the total number of stories of the original building and addition and indicate a setback vertical irregularity.	Vertical setback irregularity applies if the area of the addition is less than 90 percent of the area of the story below or if two or more walls of the addition are not aligned with the walls below.
Vertical	Single or multiple story addition with similar footprint and seismic force-resisting system as the original building		Evaluate as a single building using the total number of stories of the building plus the addition.	If the vertical elements of the seismic force-resisting system of the addition do not align with the vertical elements of the seismic force-resisting system below, apply the setback vertical irregularity.
Vertical	Single or multiple story addition in which the addition has a different seismic force-resisting system		Evaluate as a single building with another observable moderate vertical irregularity.	If the footprint of the addition is less than 90 percent of the story below or if two or more walls of the addition are not aligned with the walls below, a setback vertical irregularity should be indicated.
Horizontal	Addition with same construction type and number of stories as original and horizontal dimension of the narrower building at the interface is less than or equal to 50% of the length of the wider building		Evaluate as a single building with a torsional irregularity plan irregularity.	If the difference in horizontal dimension is between 50% and 75%, indicate a reentrant corner irregularity. If the floor heights are not aligned within 2 feet, presence of pounding is indicated.
Horizontal	Addition with a different height than the original building		Evaluate as a single building using the height of the taller building and indicate a Pounding Score Modifier if the heights of the buildings differ by more than 2 stories or if the floors do not align with 2 feet.	If the horizontal dimension of the narrower of the two buildings along the interface is less than 75% of the dimension of the wider, the reentrant corner plan irregularity should be indicated.

The above horizontal addition scenarios assume that there is not an obvious separation gap between the addition and the original building.

Table B-6 Level 2 Building Addition Reference Guide (continued)

Addition Orientation	Type of Addition	Example	RVS Screening Recommendation	Notes and Additional Instructions
Horizontal	Addition with different building type than original		Evaluate a single building with torsional irregularity using the building type with the lower basic score.	If the floors do not align within 2 feet or the number of stories differs by more than 2 stories, also indicate the appropriate Pounding Score Modifier.
Horizontal	Small addition where the addition relies on the original building for gravity support		Evaluate as a single building. Evaluate for the presence of a setback irregularity if there is a difference in the number of stories and plan irregularity if there is a difference in horizontal dimension of the original building and addition along the interface.	If the construction type of the addition is different than the original building, evaluate as two buildings with the addition as having an observable severe vertical irregularity.

The above horizontal addition scenarios assume that there is not an obvious separation gap between the addition and the original building.

Life Safety Systems

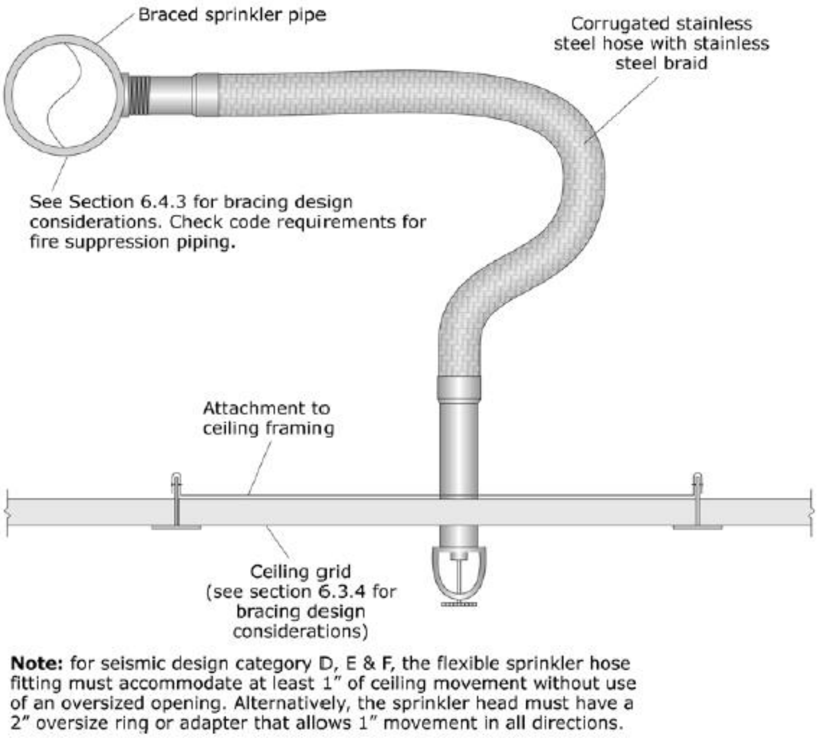


Figure G-1. Flexible Sprinkler Drop.

(FEMA E-74, 2012, Reducing the Risks of Nonstructural Earthquake Damage)

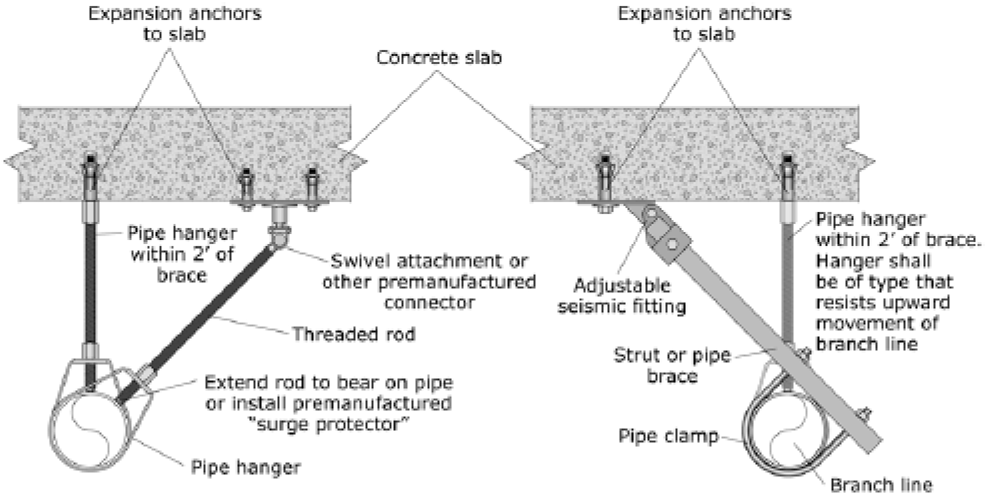


Figure G-2. End of Line Restraint.

(FEMA E-74, 2012, Reducing the Risks of Nonstructural Earthquake Damage)

Partitions

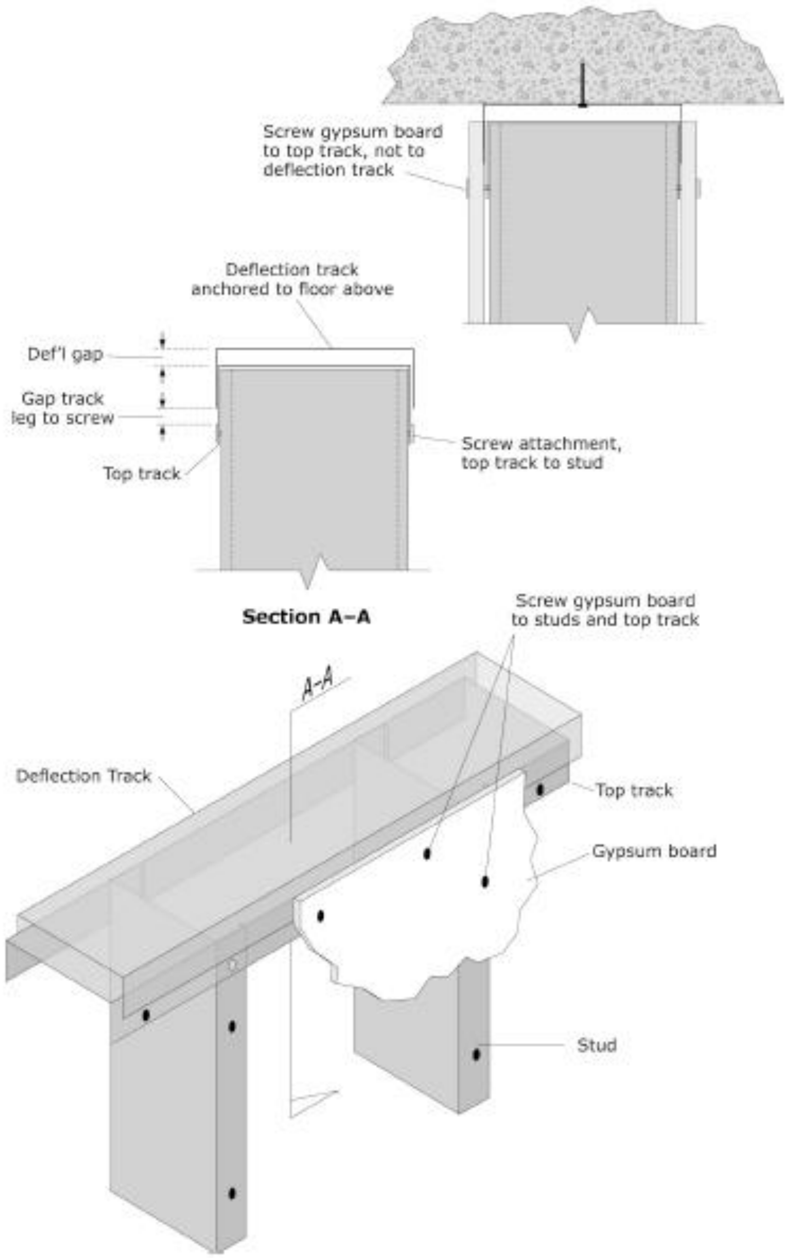


Figure G-3. Mitigation Schemes for Bracing the Tops of Metal Stud Partitions Walls.

(FEMA E-74, 2012, Reducing the Risks of Nonstructural Earthquake Damage)

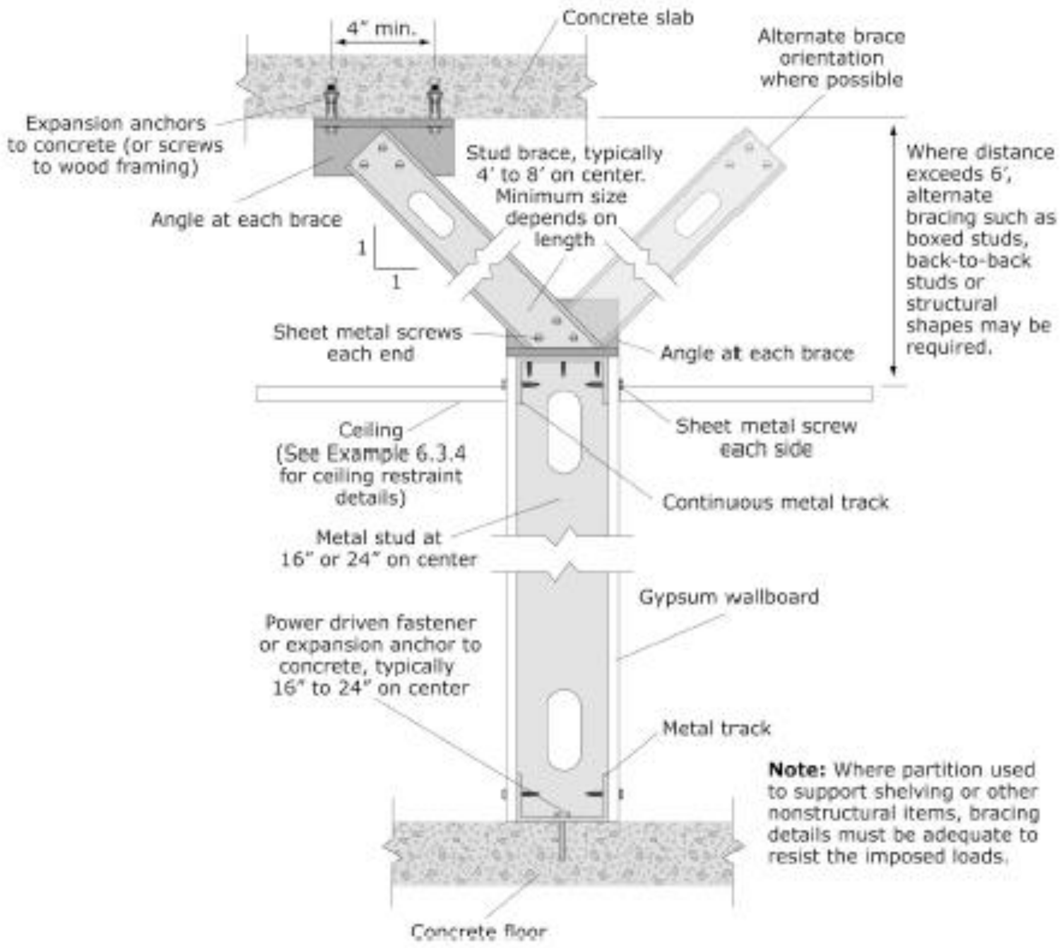
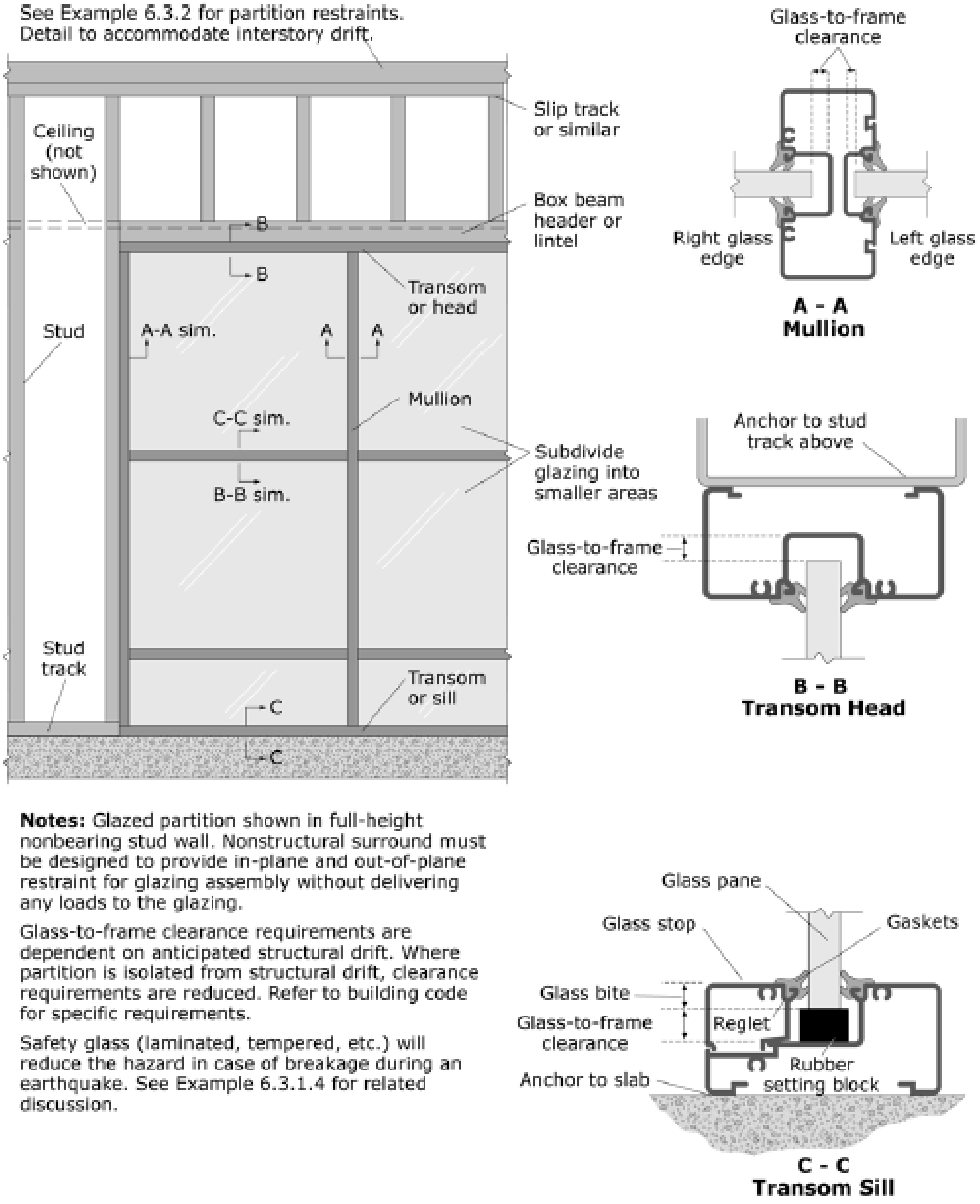


Figure G-4. Mitigation Schemes for Bracing the Tops of Metal Stud Partitions Walls.

(FEMA E-74, 2012, Reducing the Risks of Nonstructural Earthquake Damage)



Notes: Glazed partition shown in full-height nonbearing stud wall. Nonstructural surround must be designed to provide in-plane and out-of-plane restraint for glazing assembly without delivering any loads to the glazing.

Glass-to-frame clearance requirements are dependent on anticipated structural drift. Where partition is isolated from structural drift, clearance requirements are reduced. Refer to building code for specific requirements.

Safety glass (laminated, tempered, etc.) will reduce the hazard in case of breakage during an earthquake. See Example 6.3.1.4 for related discussion.

Figure G-5. Full-height Glazed Partition.

(FEMA E-74, 2012, Reducing the Risks of Nonstructural Earthquake Damage)

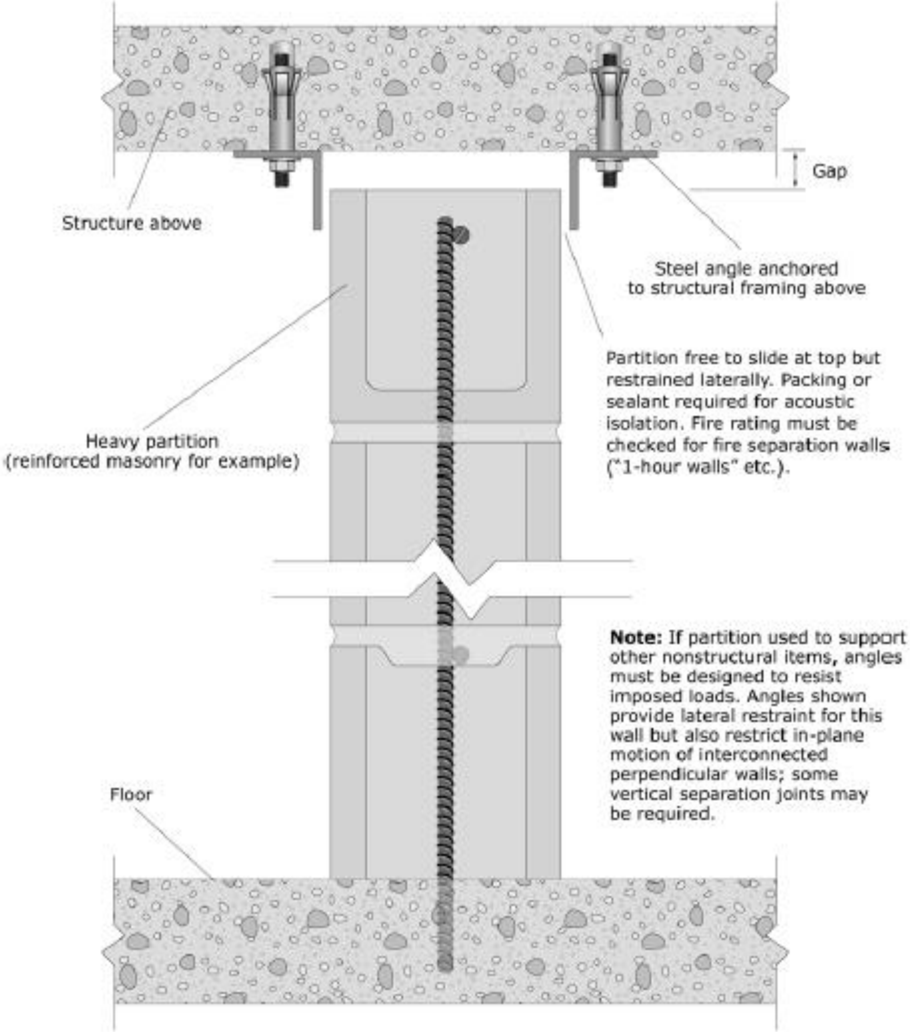


Figure G-6. Full-height Heavy Partition.

(FEMA E-74, 2012, Reducing the Risks of Nonstructural Earthquake Damage)

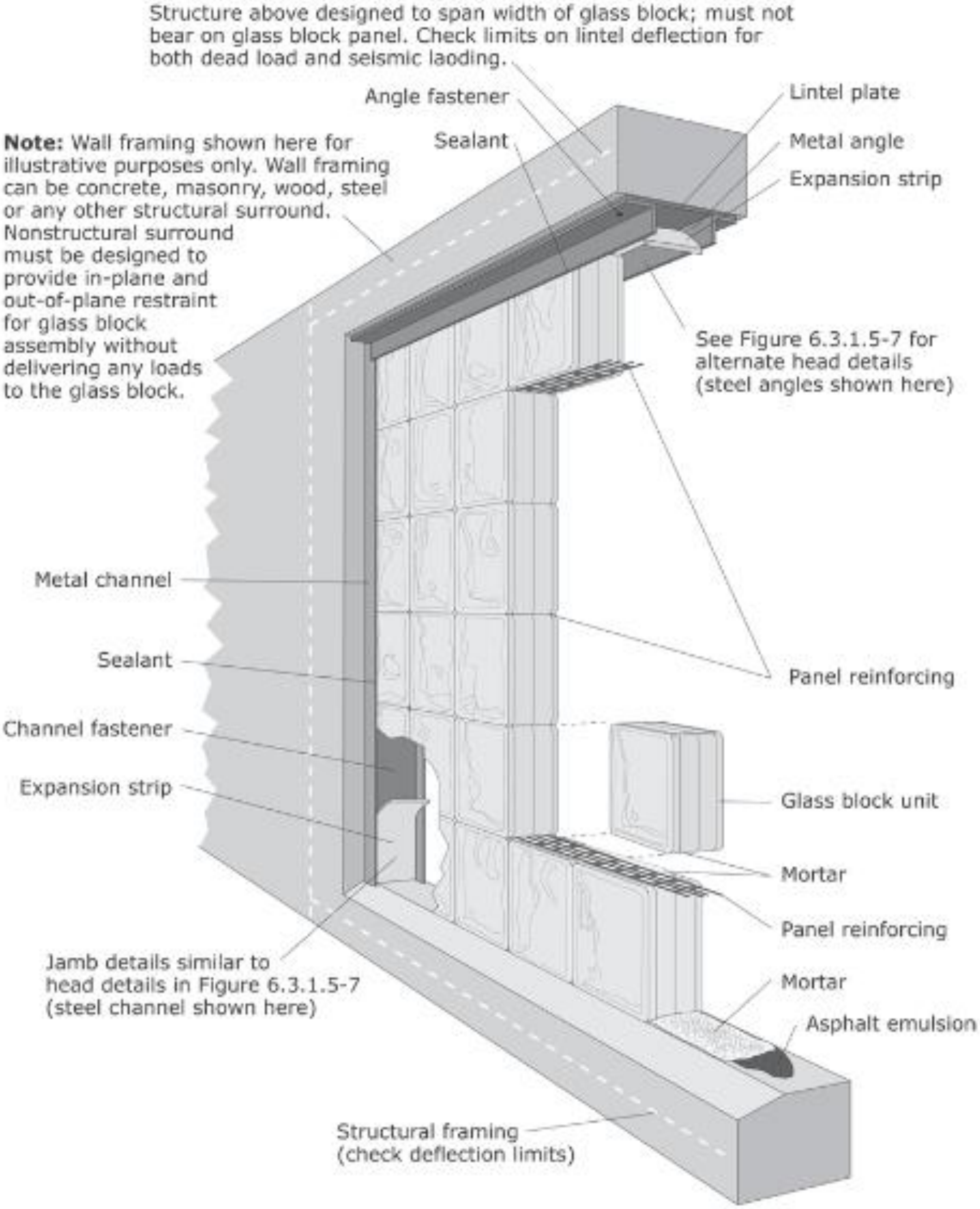


Figure G-7. Typical Glass Block Panel Details.

(FEMA E-74, 2012, Reducing the Risks of Nonstructural Earthquake Damage)

Ceilings

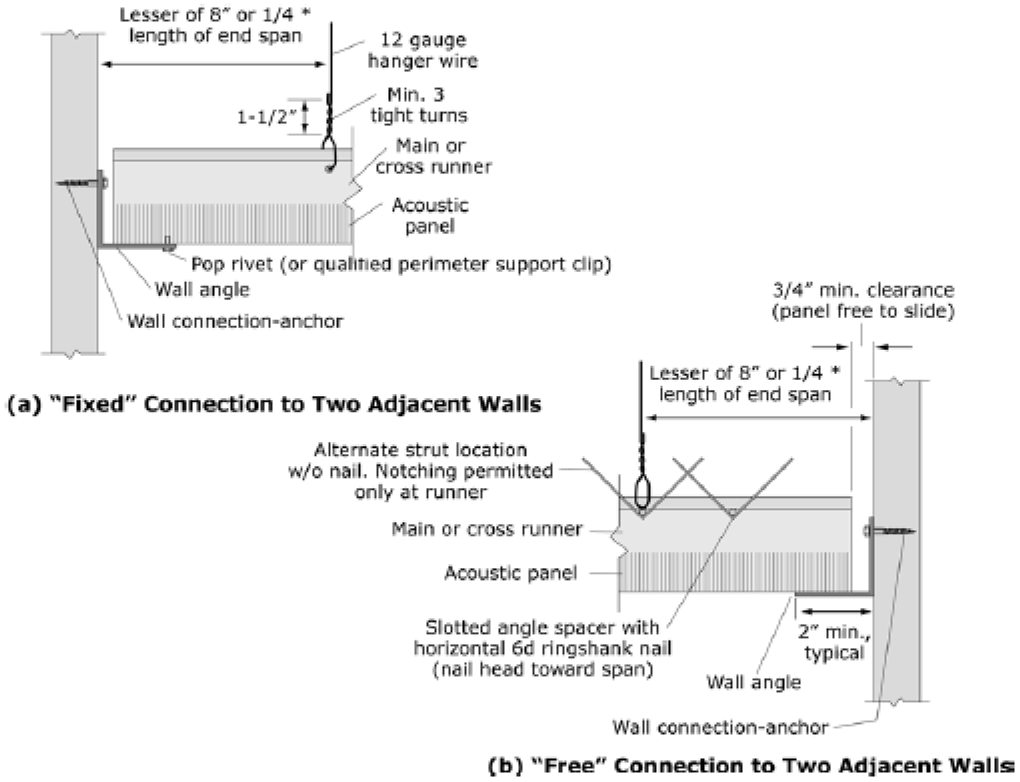
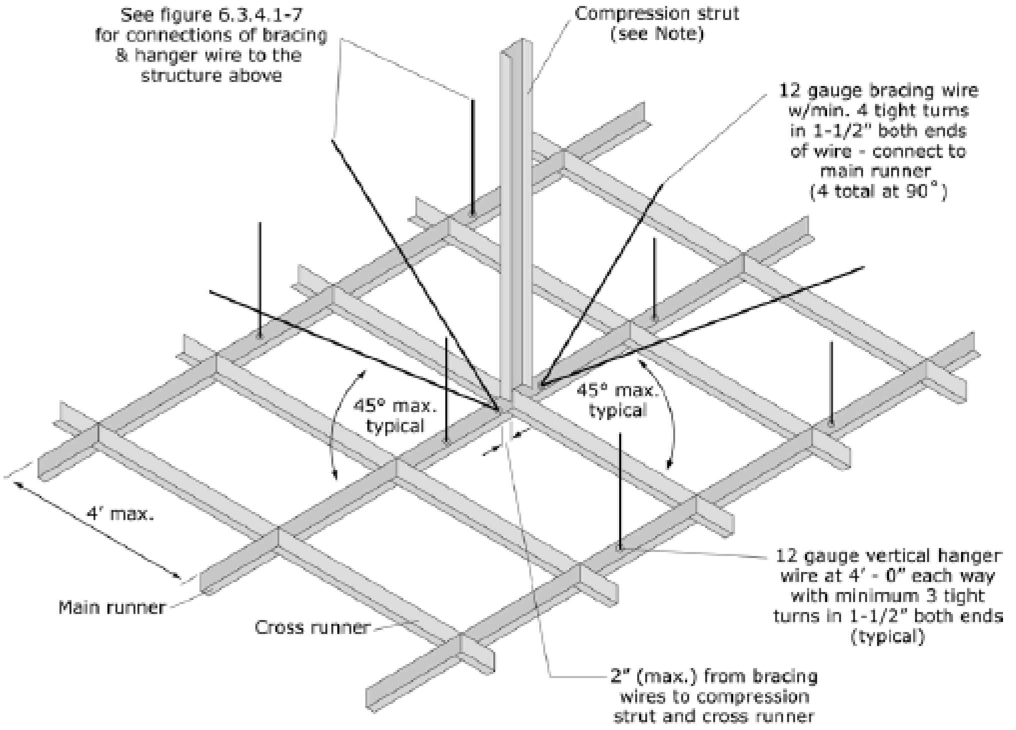


Figure G-8. Suspension System for Acoustic Lay-in Panel Ceilings – Edge Conditions.

(FEMA E-74, 2012, Reducing the Risks of Nonstructural Earthquake Damage)



Note: Compression strut shall not replace hanger wire. Compression strut consists of a steel section attached to main runner with 2 - #12 sheet metal screws and to structure with 2 - #12 screws to wood or 1/4" min. expansion anchor to structure. Size of strut is dependent on distance between ceiling and structure (l/r ≤ 200). A 1" diameter conduit can be used for up to 6', a 1-5/8" X 1-1/4" metal stud can be used for up to 10'

Per DSA IR 25-5, ceiling areas less than 144 sq. ft, or fire rated ceilings less than 96 sq. ft., surrounded by walls braced to the structure above do not require lateral bracing assemblies when they are attached to two adjacent walls. (ASTM E580 does not require lateral bracing assemblies for ceilings less than 1000 sq. ft.; see text.)

Figure G-9. Suspension System for Acoustic Lay-in Panel Ceilings – General Bracing Assembly.

(FEMA E-74, 2012, Reducing the Risks of Nonstructural Earthquake Damage)

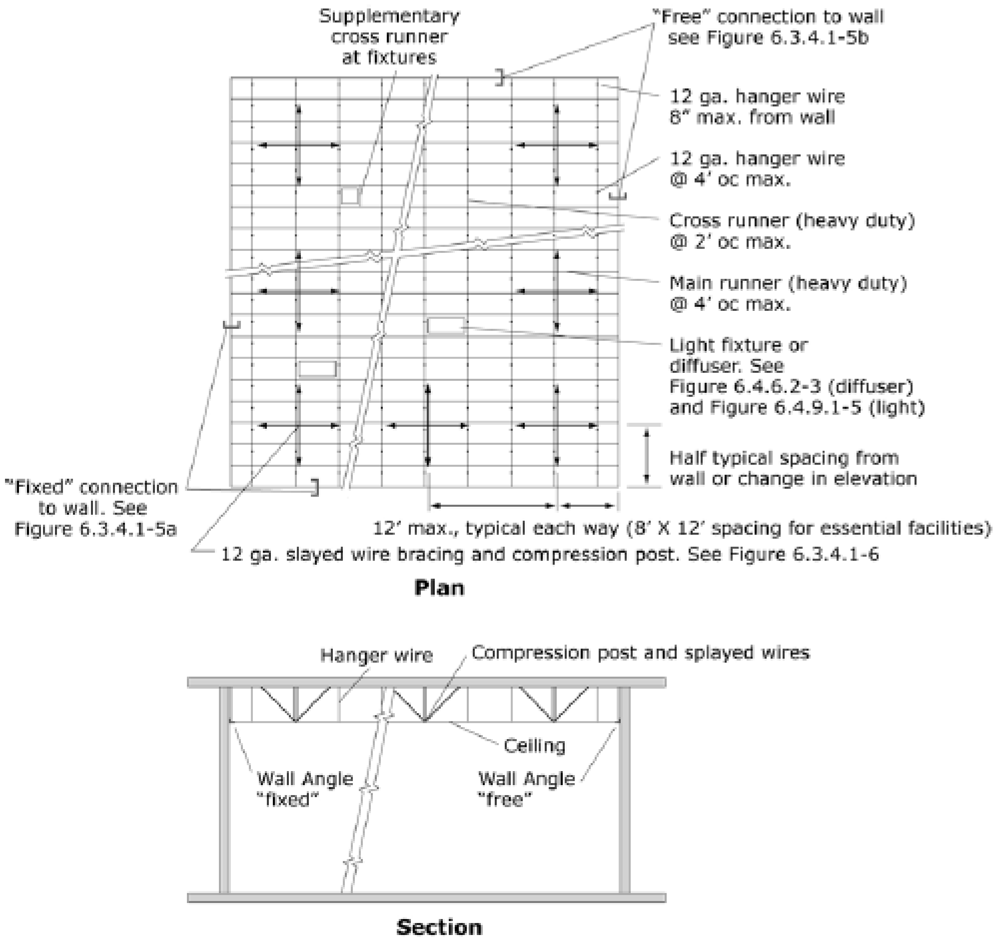
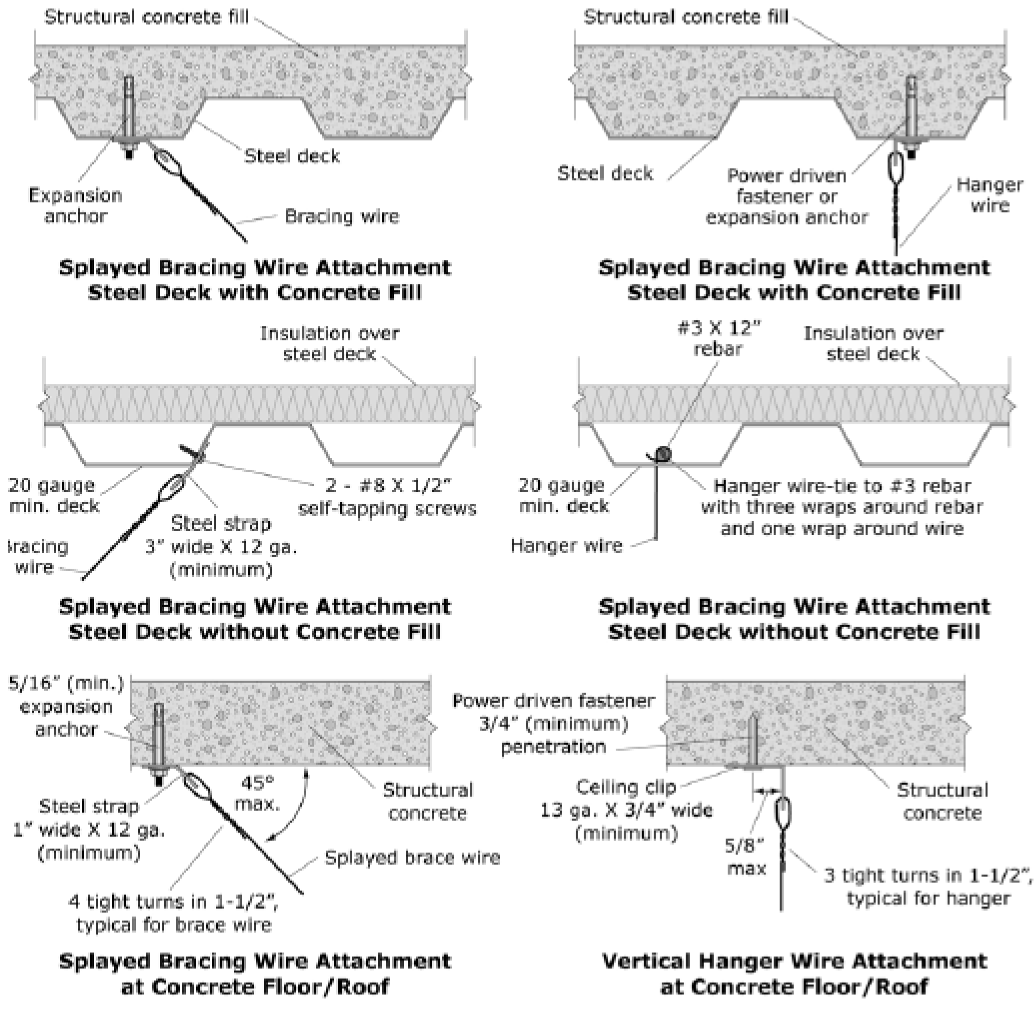


Figure G-10. Suspension System for Acoustic Lay-in Panel Ceilings – General Bracing Layout.

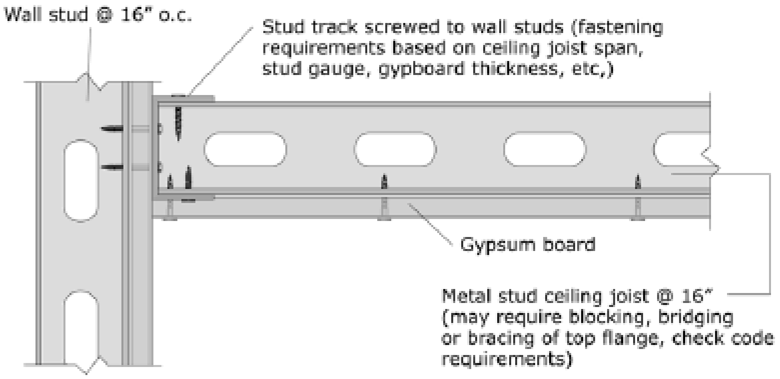
(FEMA E-74, 2012, Reducing the Risks of Nonstructural Earthquake Damage)



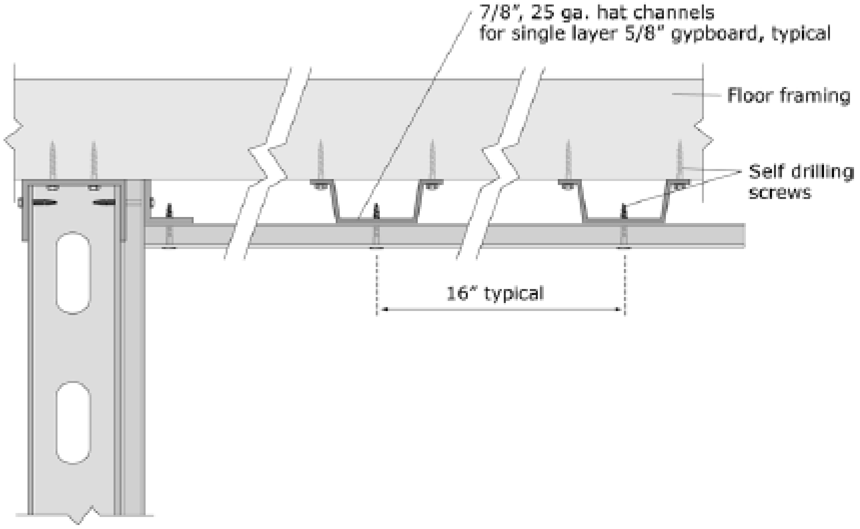
Note: See California DSA IR 25-5 (06-22-09) for additional information.

Figure G-11. Suspension System for Acoustic Lay-in Panel Ceilings – Overhead Attachment Details.

(FEMA E-74, 2012, Reducing the Risks of Nonstructural Earthquake Damage)



a) Gypsum board attached directly to ceiling joists



b) Gypsum board attached directly to furring strips (hat channel or similar)

Note: Commonly used details shown; no special seismic details are required as long as furring and gypboard secured. Check for certified assemblies (UL listed, FM approved, etc.) if fire or sound rating required.

Figure G-12. Gypsum Board Ceiling Applied Directly to Structure.

(FEMA E-74, 2012, Reducing the Risks of Nonstructural Earthquake Damage)

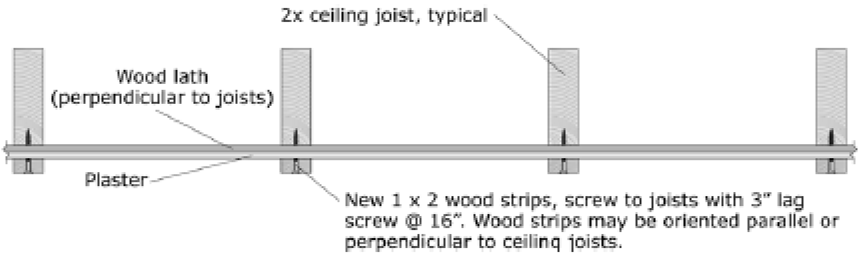


Figure G-13. Retrofit Detail for Existing Lath and Plaster.

(FEMA E-74, 2012, Reducing the Risks of Nonstructural Earthquake Damage)

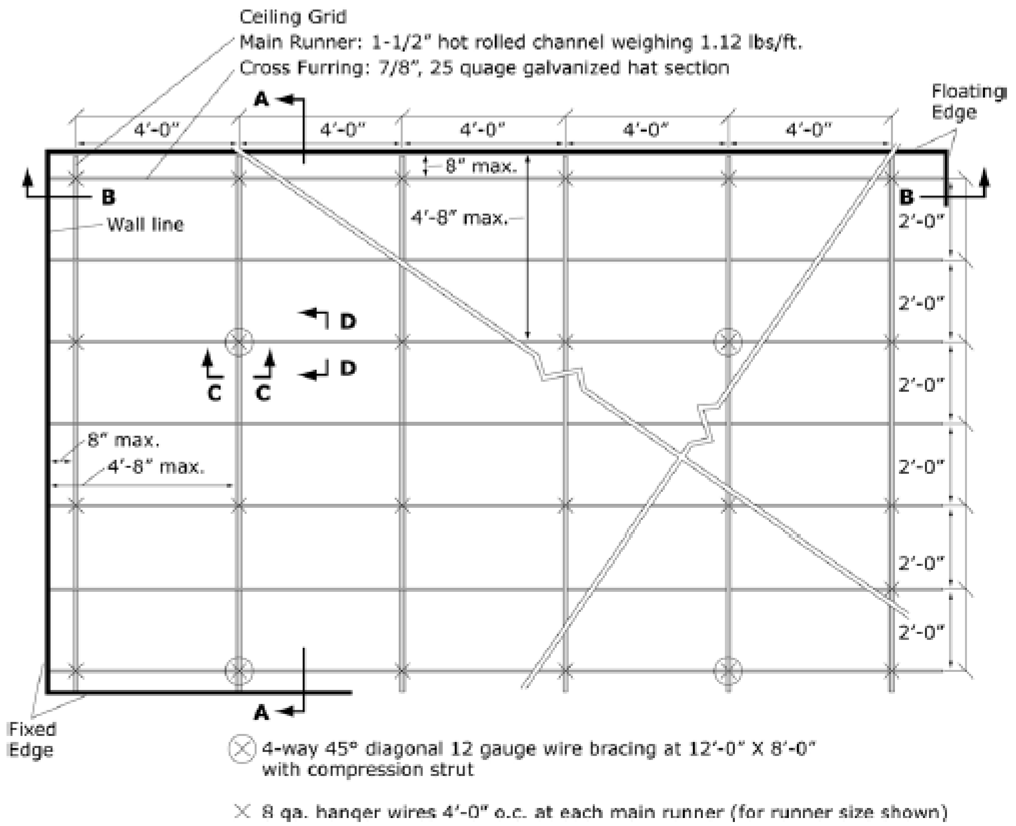
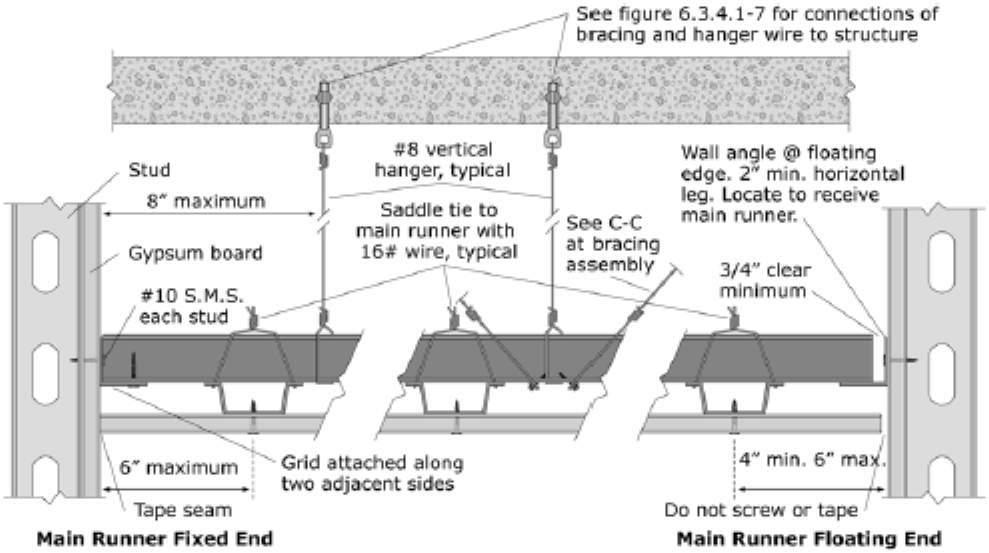
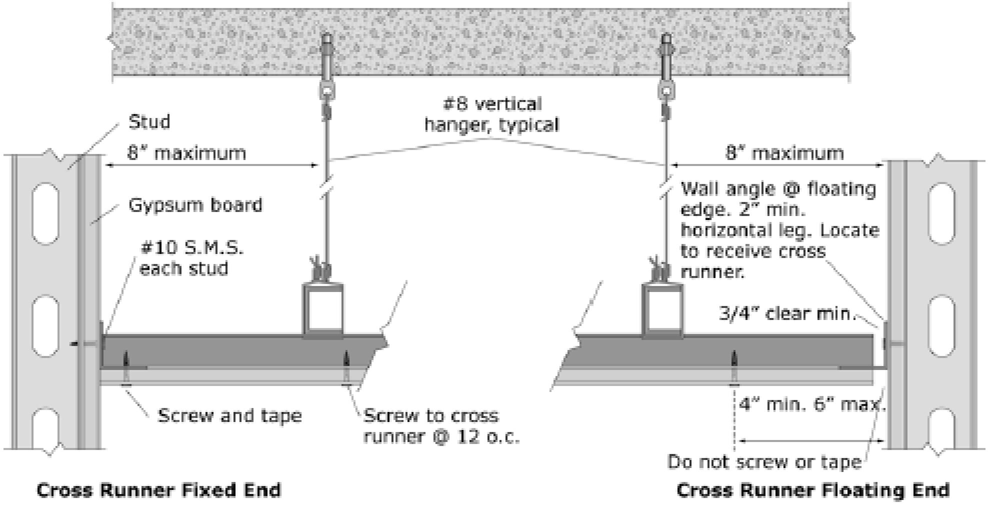


Figure G-14. Diagrammatic View of Suspended Heavy Ceiling Grid and Lateral Bracing.

(FEMA E-74, 2012, Reducing the Risks of Nonstructural Earthquake Damage)



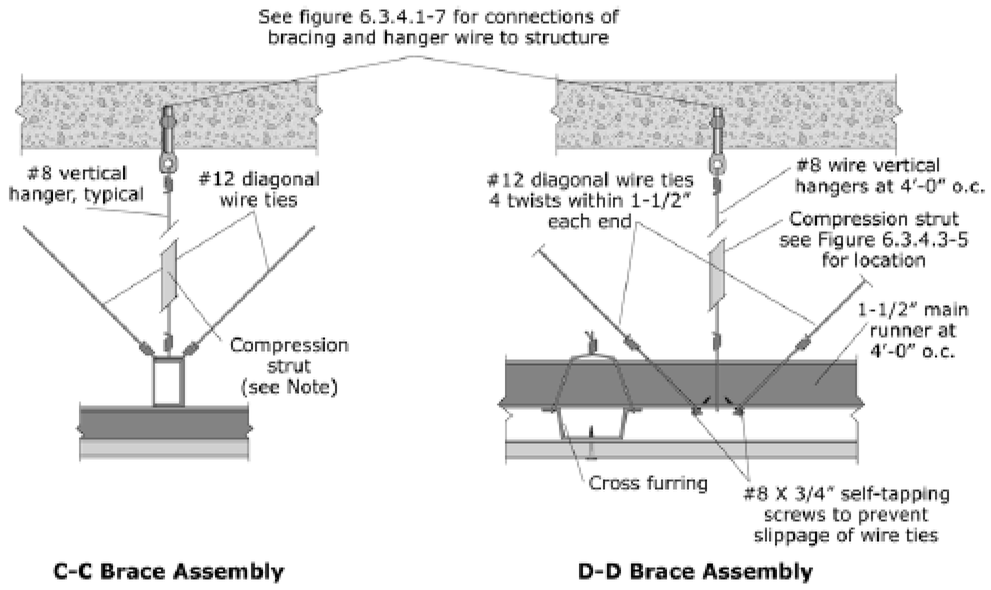
A-A Main Runner at Perimeter



B-B Cross Runner at Perimeter

Figure G-15. Perimeter Details for Suspended Gypsum Board Ceiling.

(FEMA E-74, 2012, Reducing the Risks of Nonstructural Earthquake Damage)



Note: Compression strut shall not replace hanger wire. Compresion strut consists of a steel section attached to main runner with 2 - #12 sheet metal screws and to structure with 2 - #12 screws to wood or 1/4" min. expansion anchor to concrete. Size of strut is dependent on distance between ceiling and structure (l/r ≤ 200). A 1" diameter conduit can be used for up to 6', a 1-5/8" X 1-1/4" metal stud can be used for up to 10'. See figure 6.3.4.1-6 for example of bracing assembly.

Figure G-16. Details for Lateral Bracing Assembly for Suspended Gypsum Board Ceiling.

(FEMA E-74, 2012, Reducing the Risks of Nonstructural Earthquake Damage)

Light Fixtures

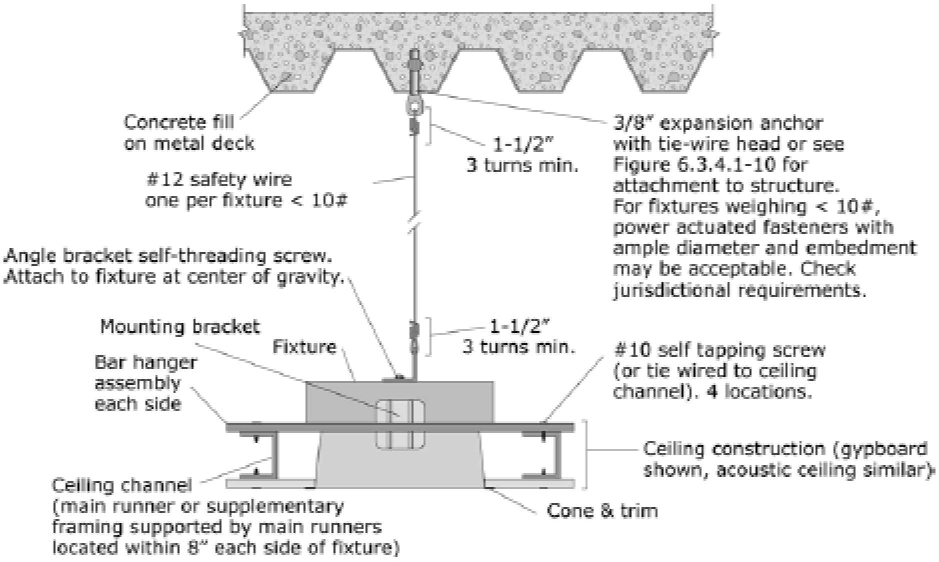


Figure G-17. Recessed Light Fixture in suspended Ceiling (Fixture Weight < 10 pounds).

(FEMA E-74, 2012, Reducing the Risks of Nonstructural Earthquake Damage)

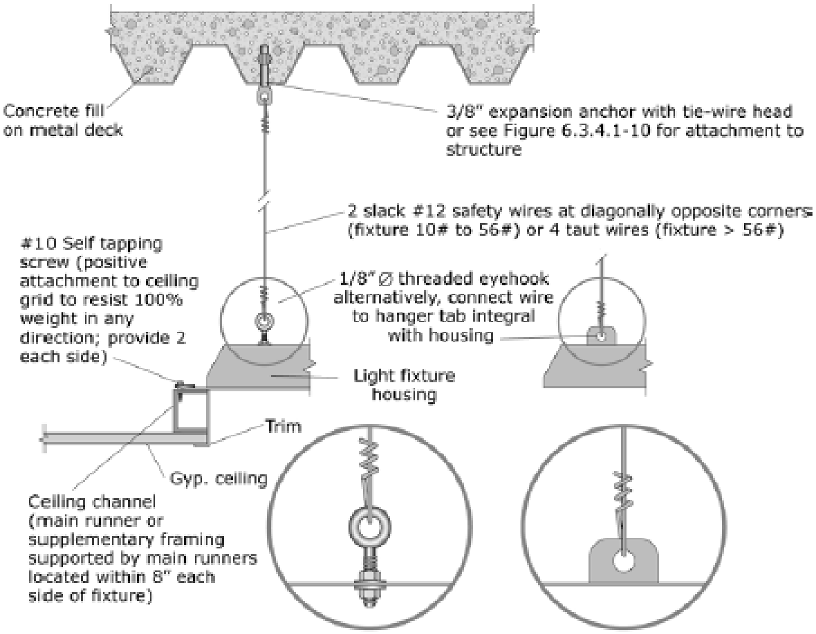
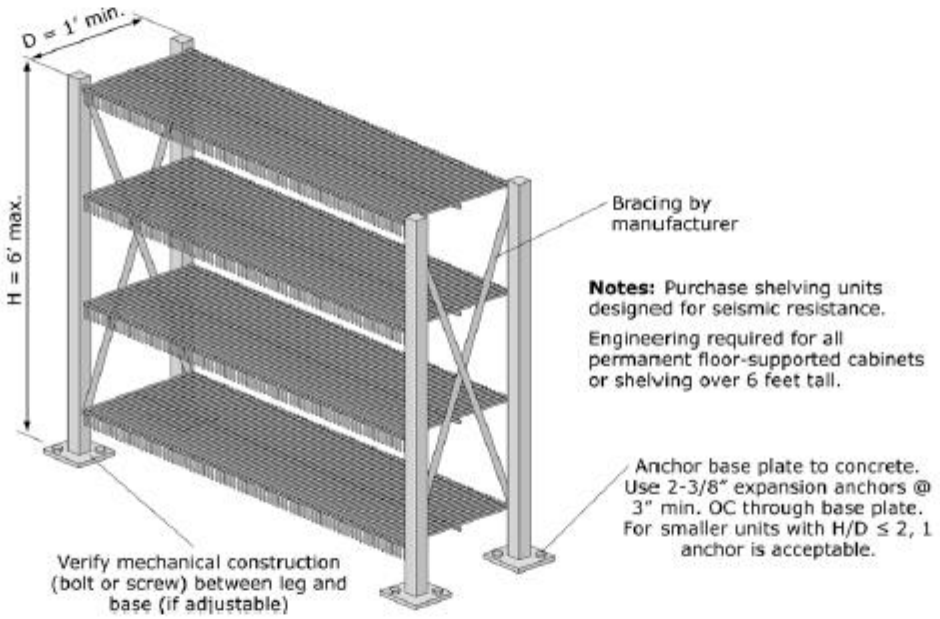


Figure G-18. Recessed Light Fixture in suspended Ceiling (Fixture Weight 10 to 56 pounds).

(FEMA E-74, 2012, Reducing the Risks of Nonstructural Earthquake Damage)

Contents and Furnishings



Notes: Purchase shelving units designed for seismic resistance.

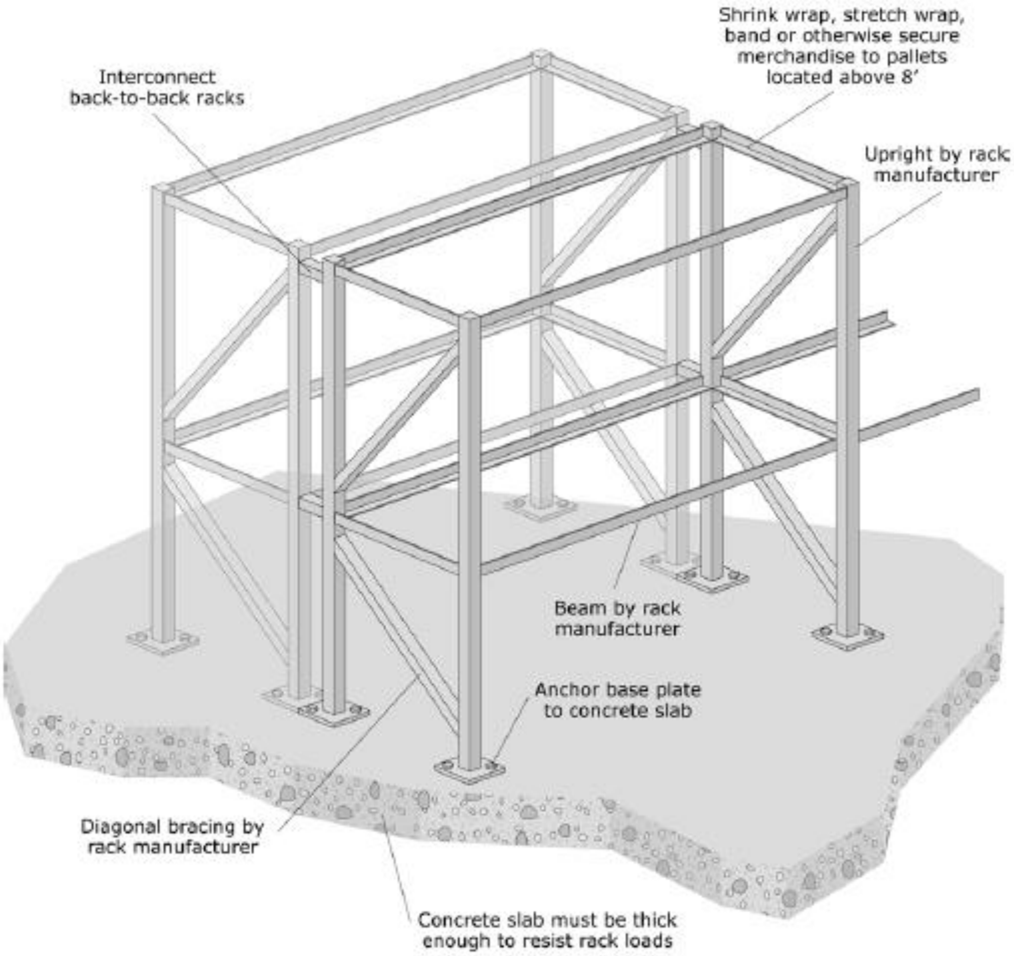
Engineering required for all permanent floor-supported cabinets or shelving over 6 feet tall.

Anchor base plate to concrete. Use 2-3/8" expansion anchors @ 3" min. OC through base plate. For smaller units with H/D ≤ 2, 1 anchor is acceptable.

Verify mechanical construction (bolt or screw) between leg and base (if adjustable)

Figure G-19. Light Storage Racks.

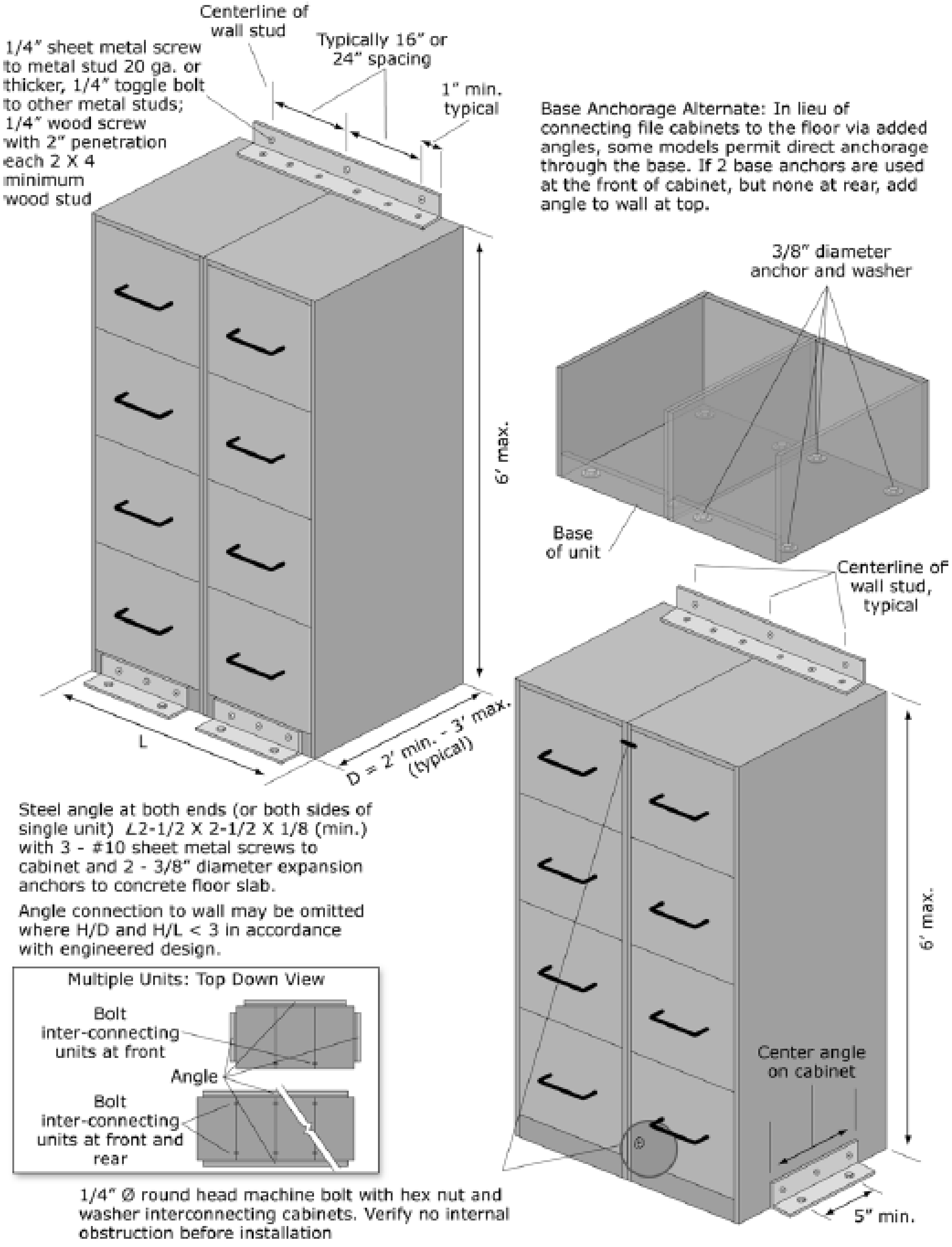
(FEMA E-74, 2012, Reducing the Risks of Nonstructural Earthquake Damage)



Note: Purchase storage racks designed for seismic resistance. Storage racks may be classified as either nonstructural elements or nonbuilding structures depending upon their size and support conditions. Check the applicable code to see which provisions apply.

Figure G-20. Industrial Storage Racks.

(FEMA E-74, 2012, Reducing the Risks of Nonstructural Earthquake Damage)



Base Anchorage Alternate: In lieu of connecting file cabinets to the floor via added angles, some models permit direct anchorage through the base. If 2 base anchors are used at the front of cabinet, but none at rear, add angle to wall at top.

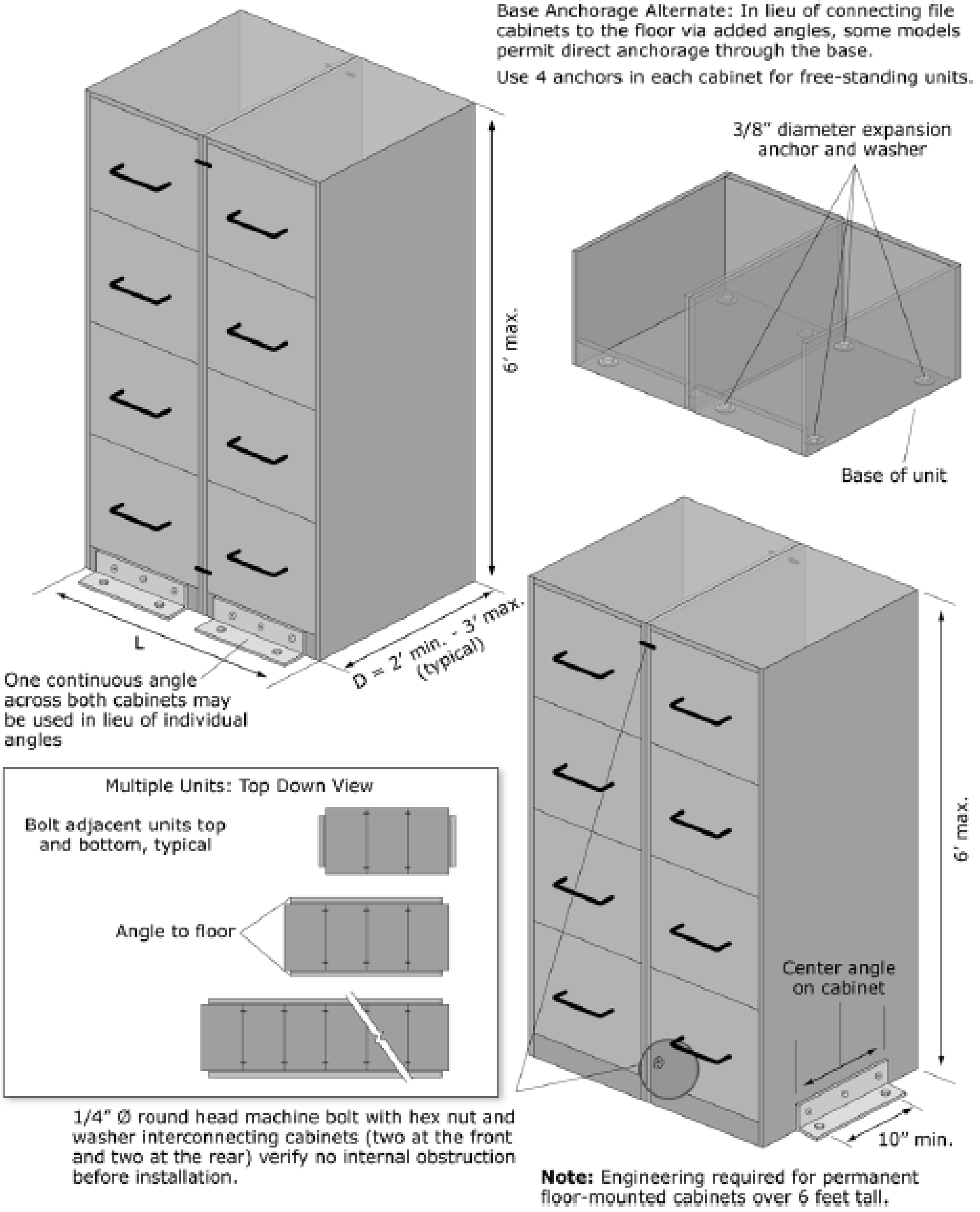
Steel angle at both ends (or both sides of single unit) ∠2-1/2 X 2-1/2 X 1/8 (min.) with 3 - #10 sheet metal screws to cabinet and 2 - 3/8″ diameter expansion anchors to concrete floor slab.

Angle connection to wall may be omitted where H/D and H/L < 3 in accordance with engineered design.

1/4″ Ø round head machine bolt with hex nut and washer interconnecting cabinets. Verify no internal obstruction before installation

Figure G-21. Wall-mounted File Cabinets.

(FEMA E-74, 2012, Reducing the Risks of Nonstructural Earthquake Damage)



Base Anchorage Alternate: In lieu of connecting file cabinets to the floor via added angles, some models permit direct anchorage through the base.

Use 4 anchors in each cabinet for free-standing units.

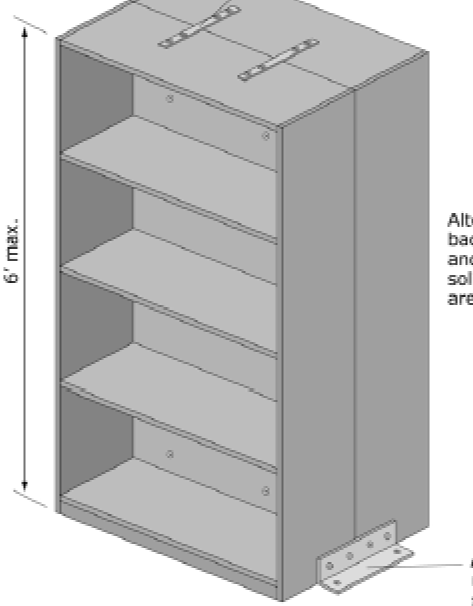
One continuous angle across both cabinets may be used in lieu of individual angles

1/4" Ø round head machine bolt with hex nut and washer interconnecting cabinets (two at the front and two at the rear) verify no internal obstruction before installation.

Note: Engineering required for permanent floor-mounted cabinets over 6 feet tall.

Figure G-22. Base Anchored File Cabinets.

(FEMA E-74, 2012, Reducing the Risks of Nonstructural Earthquake Damage)



Gang multiple units with steel plates, 1" X4" X 12 ga. min. with 2-#12 sheet metal screws or 1/4" Ø bolts each end, min.

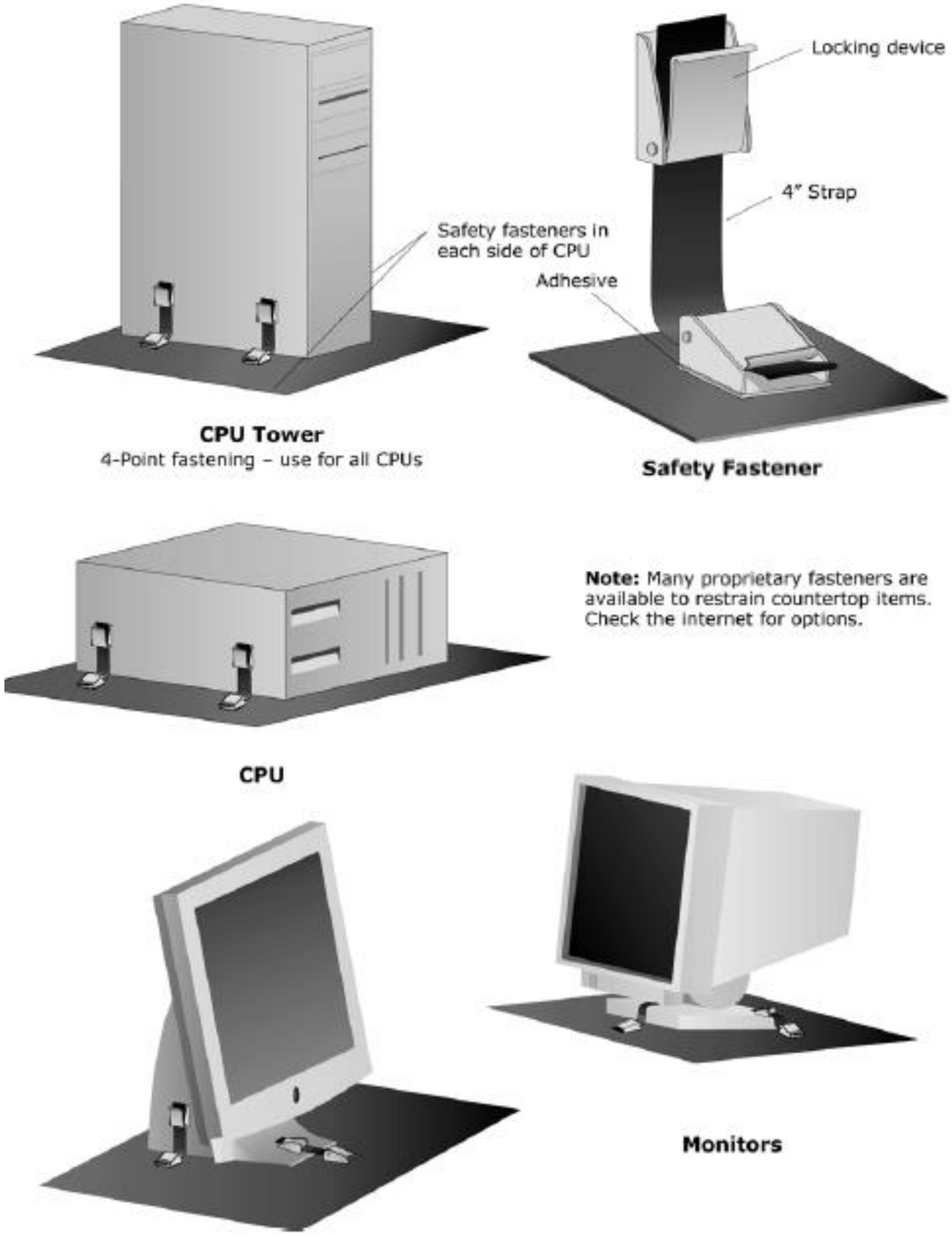
Alternate: Bolt together through back with 2 - 1/4" Ø bolts top and bottom between, min. Add solid blocking if backs of units are not in contact

∠2-1/2 X 2-1/2 X 1/8 X 1'-0" min. with 4 #10 sheet metal screws to bookcase. and 2 - 3/8" Ø expansion anchors to slab (each side)

Note: Engineering required for all permanent floor-supported cabinets or shelving over 6 feet tall. Details shown are adequate for typical shelving 6 feet or less in height.

Figure G-23. Anchorage of Freestanding Book Cases Arranged Back to Back.

(FEMA E-74, 2012, Reducing the Risks of Nonstructural Earthquake Damage)



CPU Tower
4-Point fastening – use for all CPUs

Safety Fastener

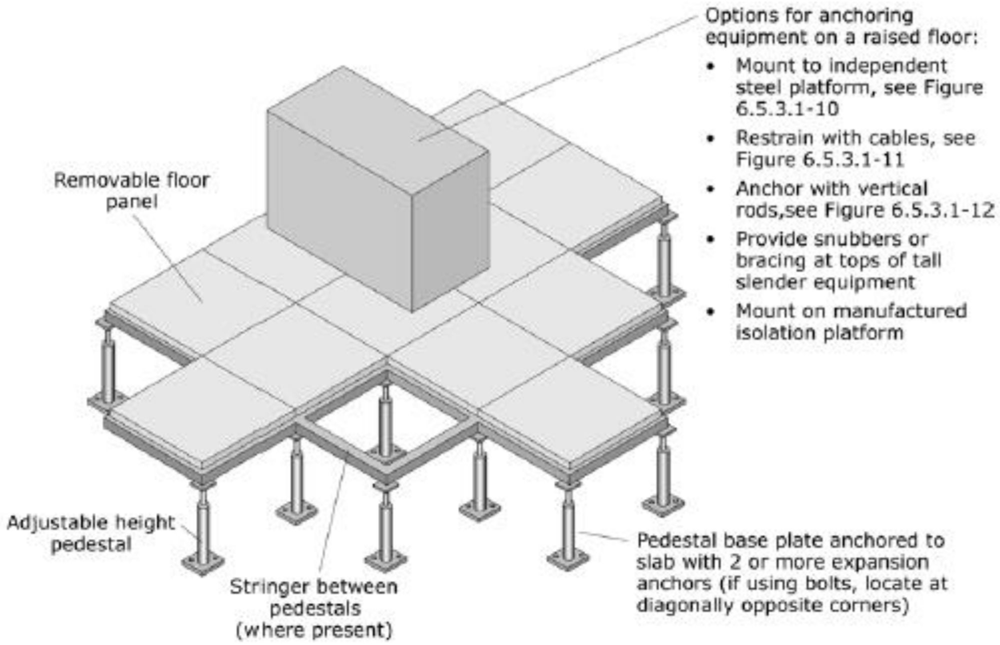
Note: Many proprietary fasteners are available to restrain countertop items. Check the internet for options.

CPU

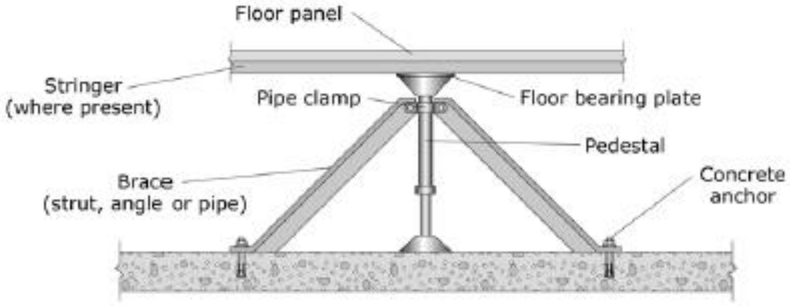
Monitors

Figure G-24. Desktop Computers and Accessories.

(FEMA E-74, 2012, Reducing the Risks of Nonstructural Earthquake Damage)



Cantilevered Access Floor Pedestal

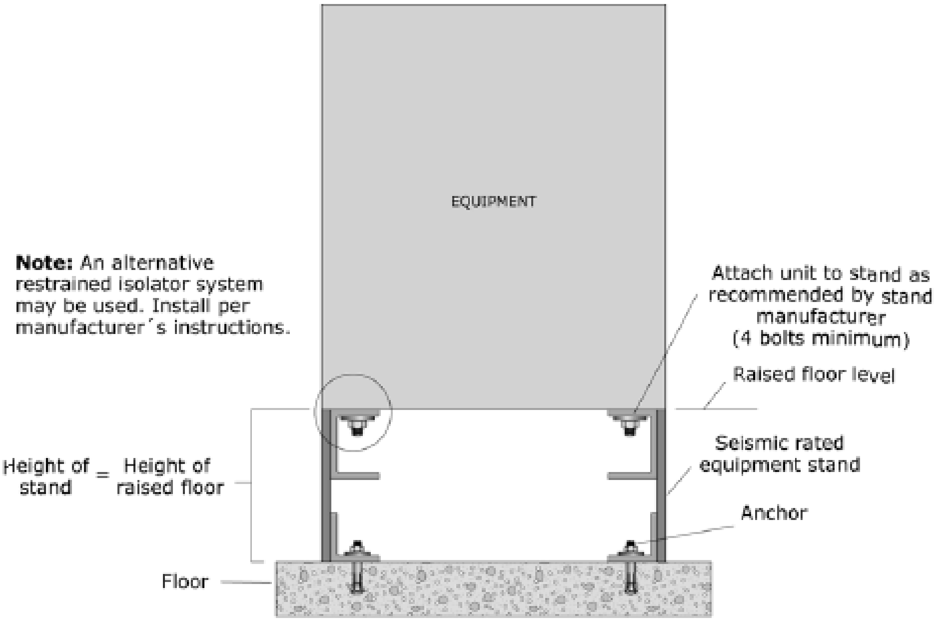


Braced Access Floor Pedestal
(use for tall floors or where pedestals are not strong enough to resist seismic forces)

Note: For new floors in areas of high seismicity, purchase and install systems that meet the applicable code provisions for "special access floors."

Figure G-25. Equipment Mounted on Access Floor.

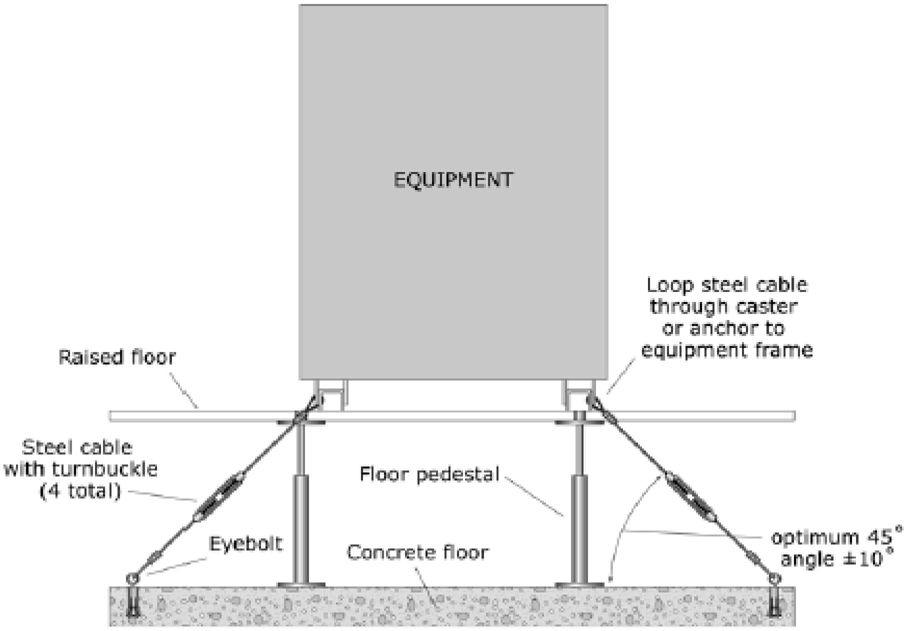
(FEMA E-74, 2012, Reducing the Risks of Nonstructural Earthquake Damage)



Equipment installed on an independent steel platform within a raised floor

Figure G-26. Equipment Mounted on Access Floor – Independent Base.

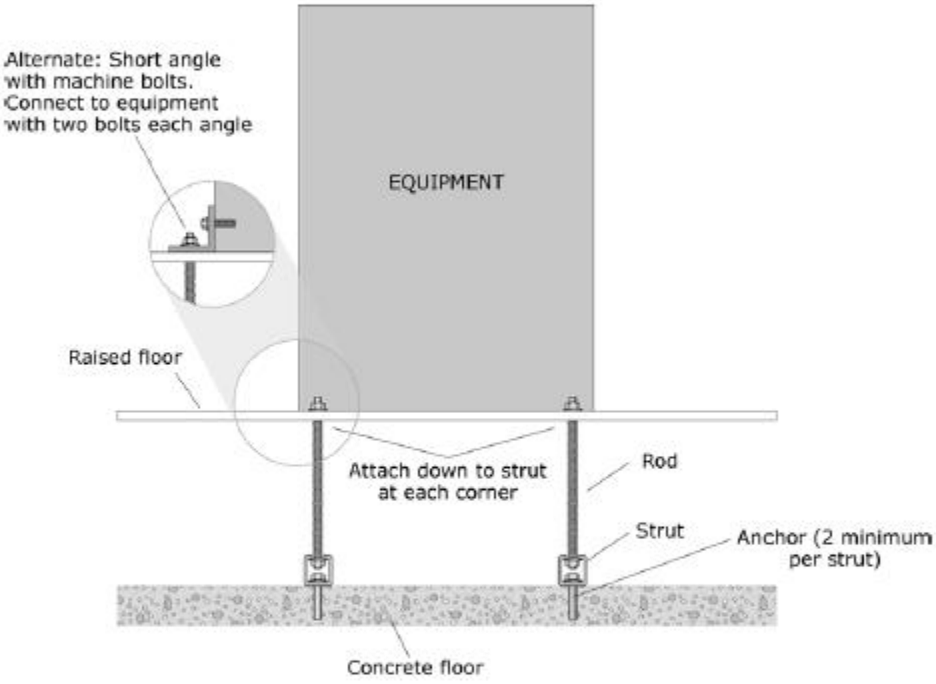
(FEMA E-74, 2012, Reducing the Risks of Nonstructural Earthquake Damage)



Equipment restrained with cables beneath a raised floor

Figure G-27. Equipment Mounted on Access Floor – Cable Braced.

(FEMA E-74, 2012, Reducing the Risks of Nonstructural Earthquake Damage)

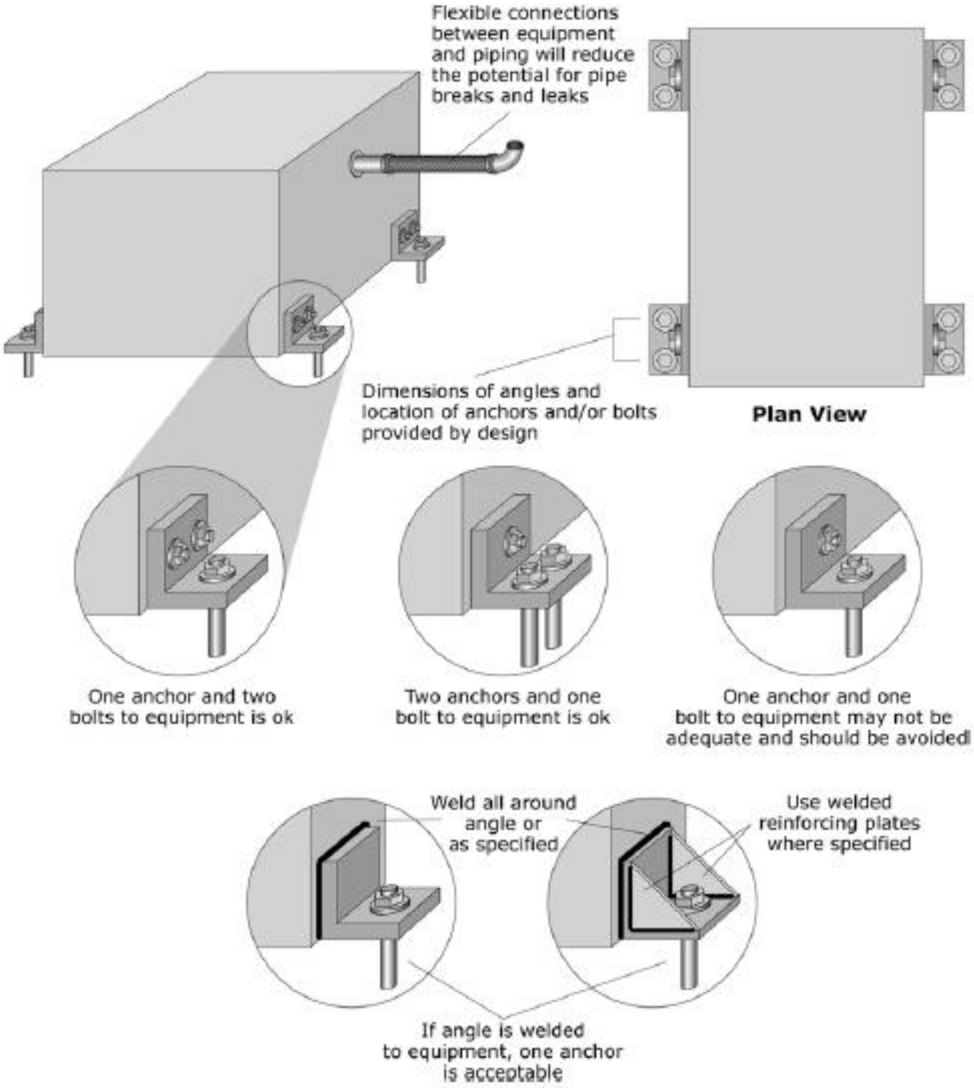


Equipment anchored with vertical rods beneath a raised floor

Figure G-28. Equipment Mounted on Access Floor – Tie-down Rods.

(FEMA E-74, 2012, Reducing the Risks of Nonstructural Earthquake Damage)

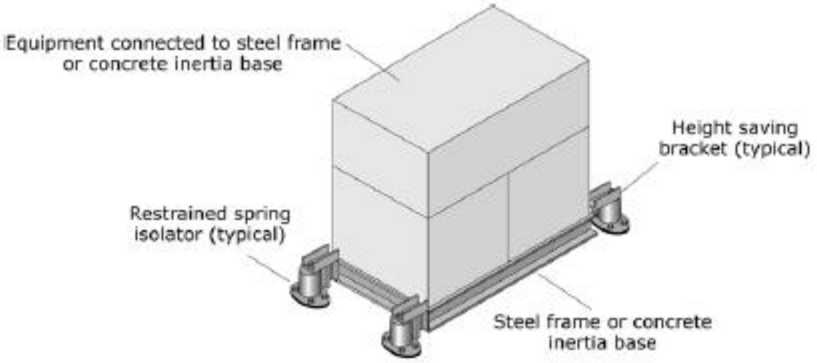
Mechanical and Electrical Equipment



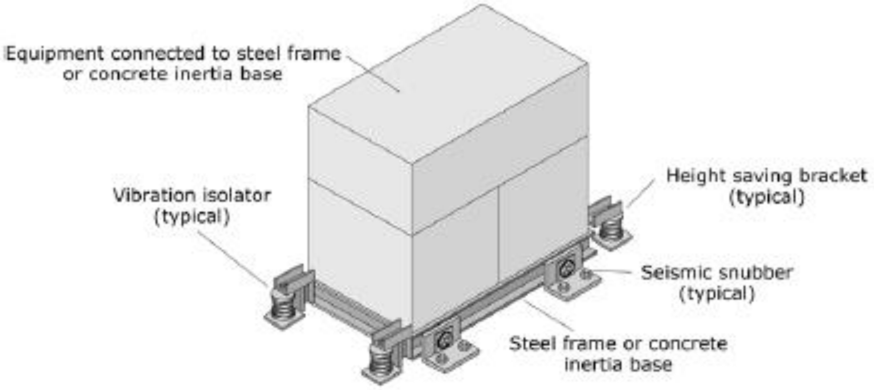
Note: Rigidly mounted equipment shall have flexible connections for the fuel lines and piping.

Figure G-29. Rigidly Floor-mounted Equipment with Added Angles.

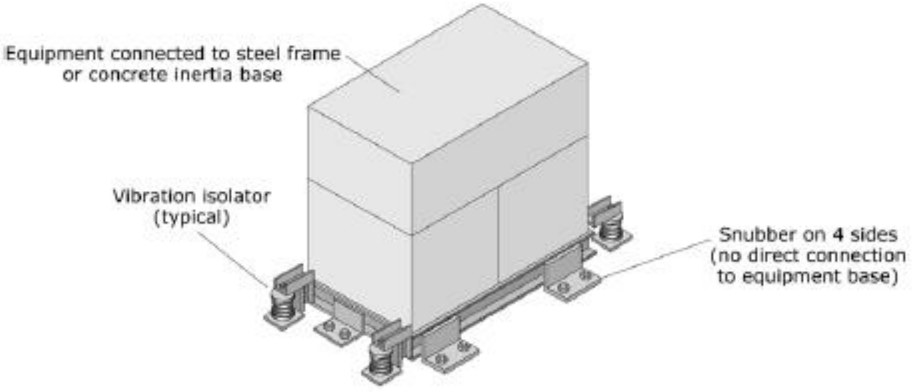
(FEMA E-74, 2012, Reducing the Risks of Nonstructural Earthquake Damage)



Supplemental base with restrained spring isolators



Supplemental base with open springs and all-directional snubbers



Supplemental base with open springs and one-directional snubbers

Figure G-30. HVAC Equipment with Vibration Isolation.

(FEMA E-74, 2012, Reducing the Risks of Nonstructural Earthquake Damage)

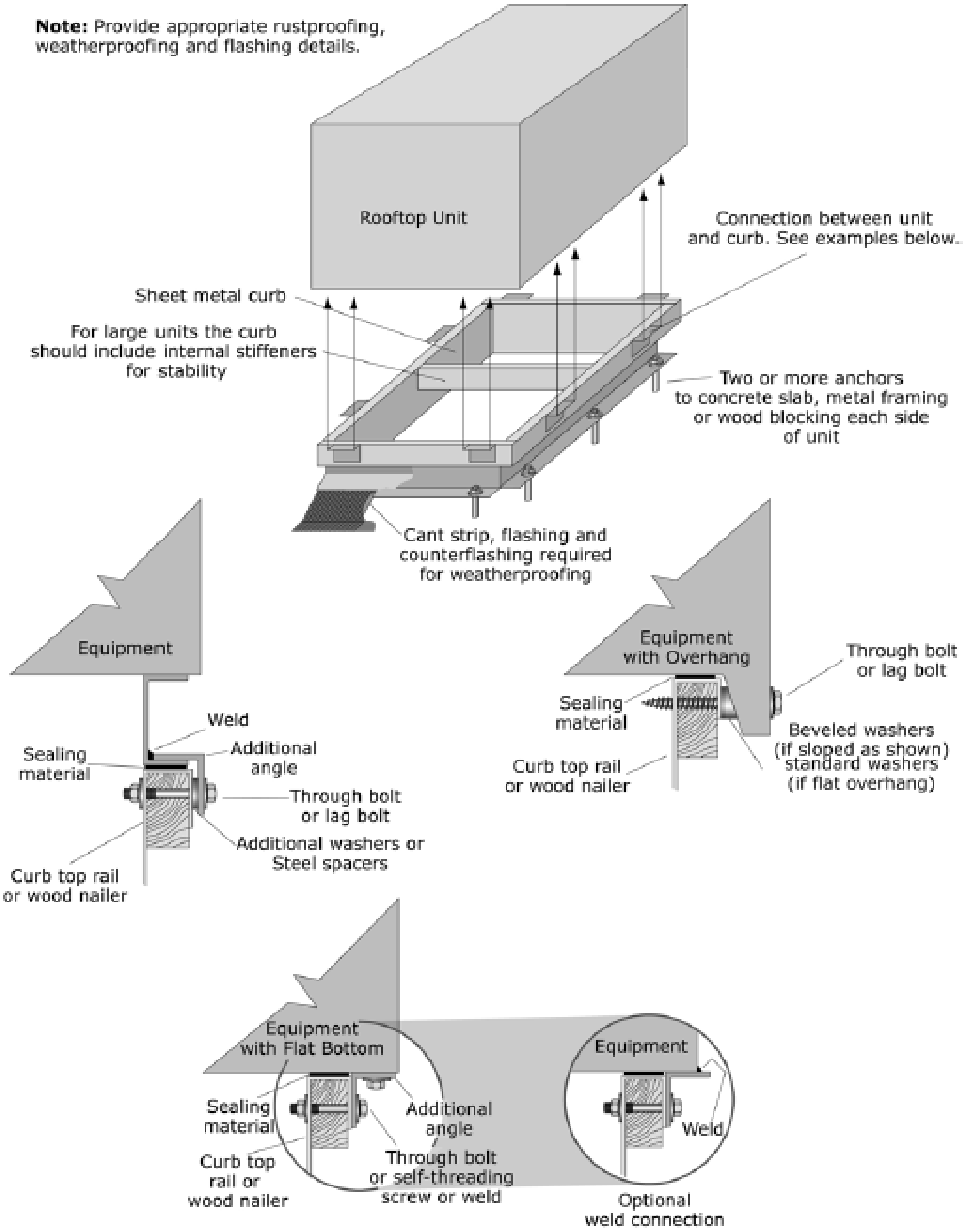


Figure G-31. Rooftop HVAC Equipment.

(FEMA E-74, 2012, Reducing the Risks of Nonstructural Earthquake Damage)

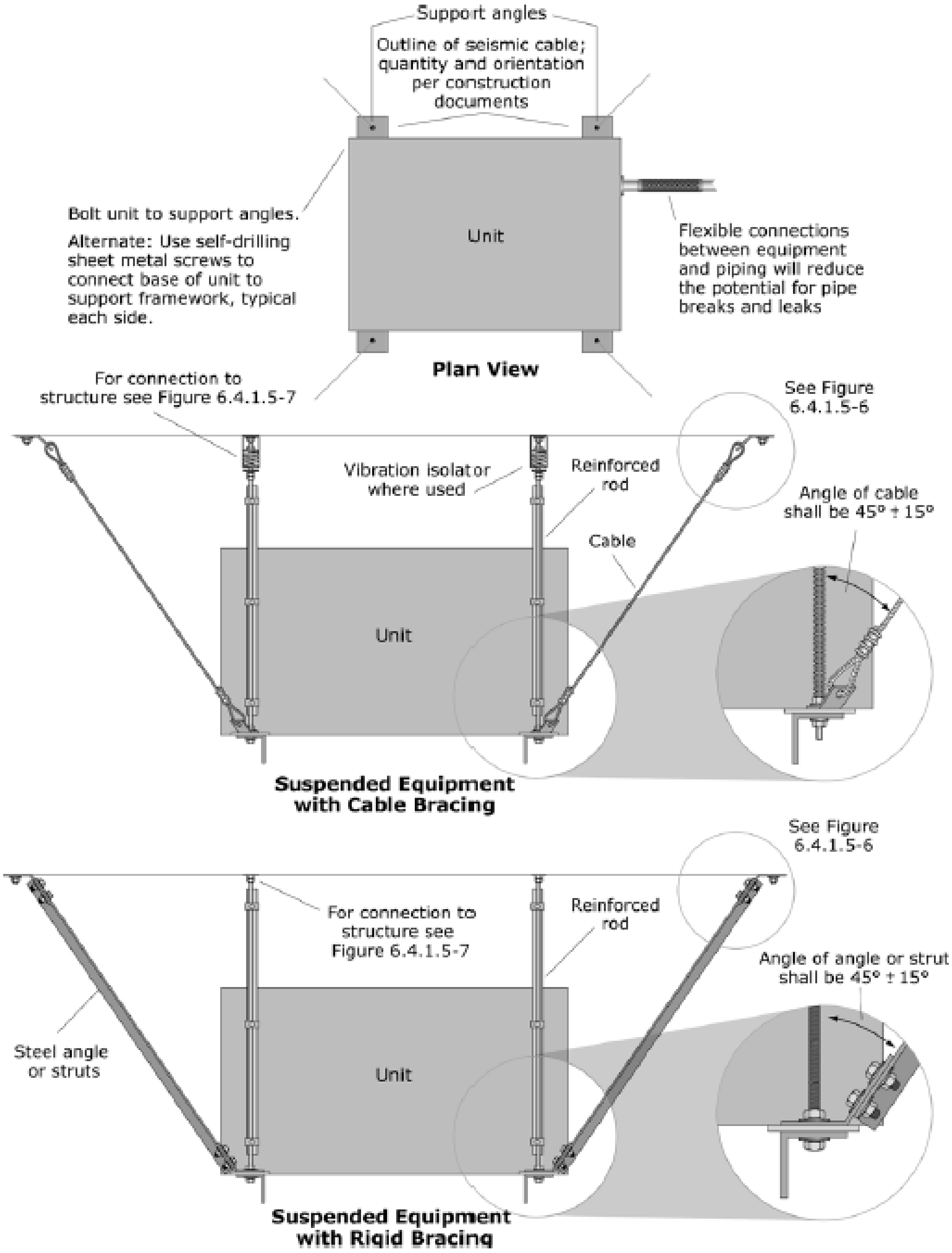


Figure G-32. Suspended Equipment.

(FEMA E-74, 2012, Reducing the Risks of Nonstructural Earthquake Damage)

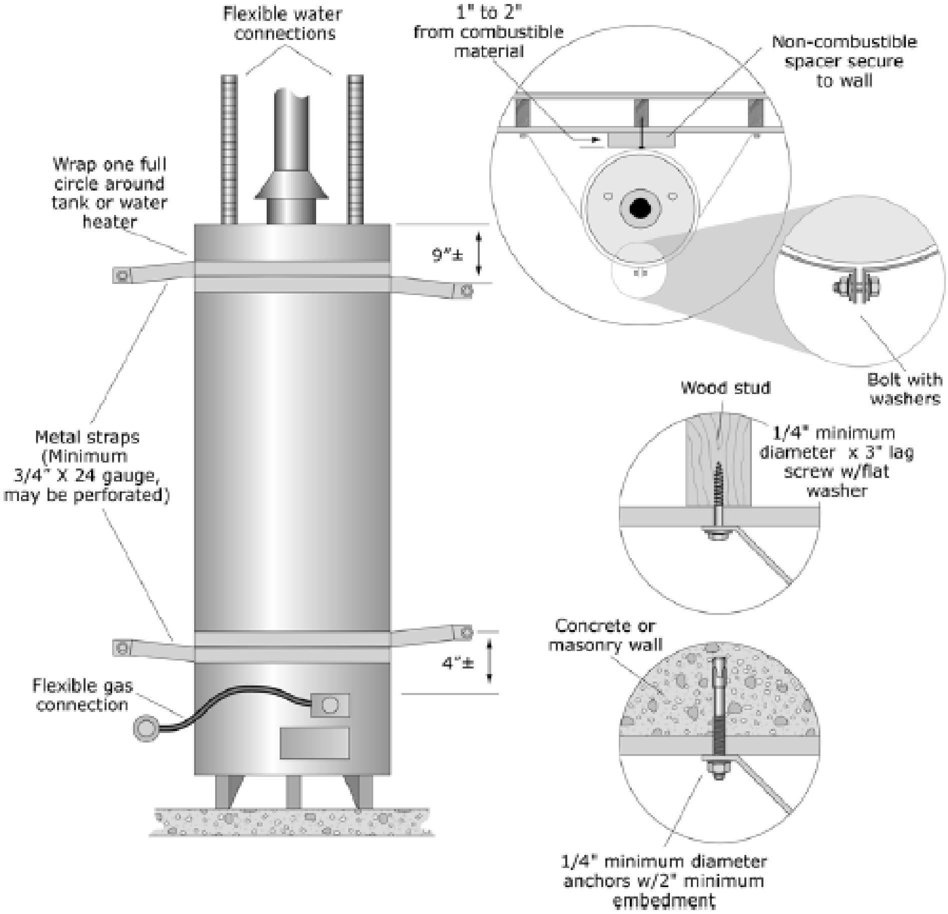


Figure G-33. Water Heater Strapping to Backing Wall.

(FEMA E-74, 2012, Reducing the Risks of Nonstructural Earthquake Damage)

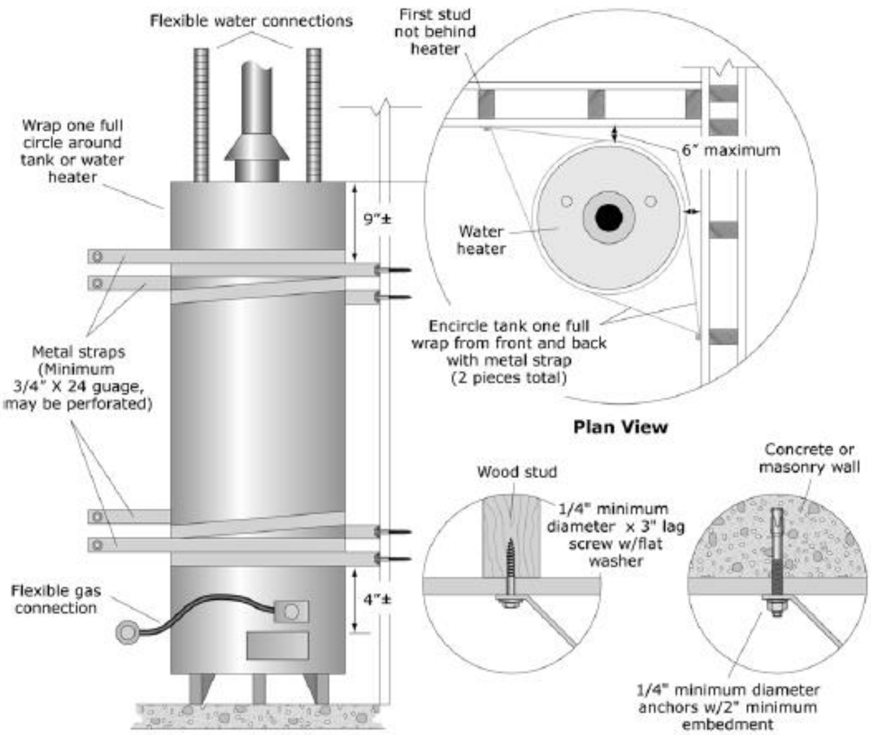


Figure G-34. Water Heater – Strapping at Corner Installation.

(FEMA E-74, 2012, Reducing the Risks of Nonstructural Earthquake Damage)

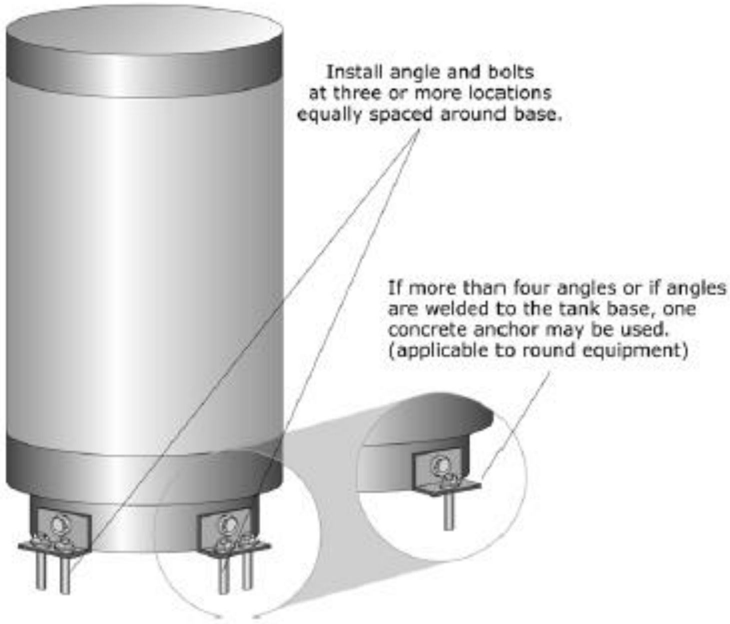


Figure G-35. Water Heater – Base Mounted.

(FEMA E-74, 2012, Reducing the Risks of Nonstructural Earthquake Damage)

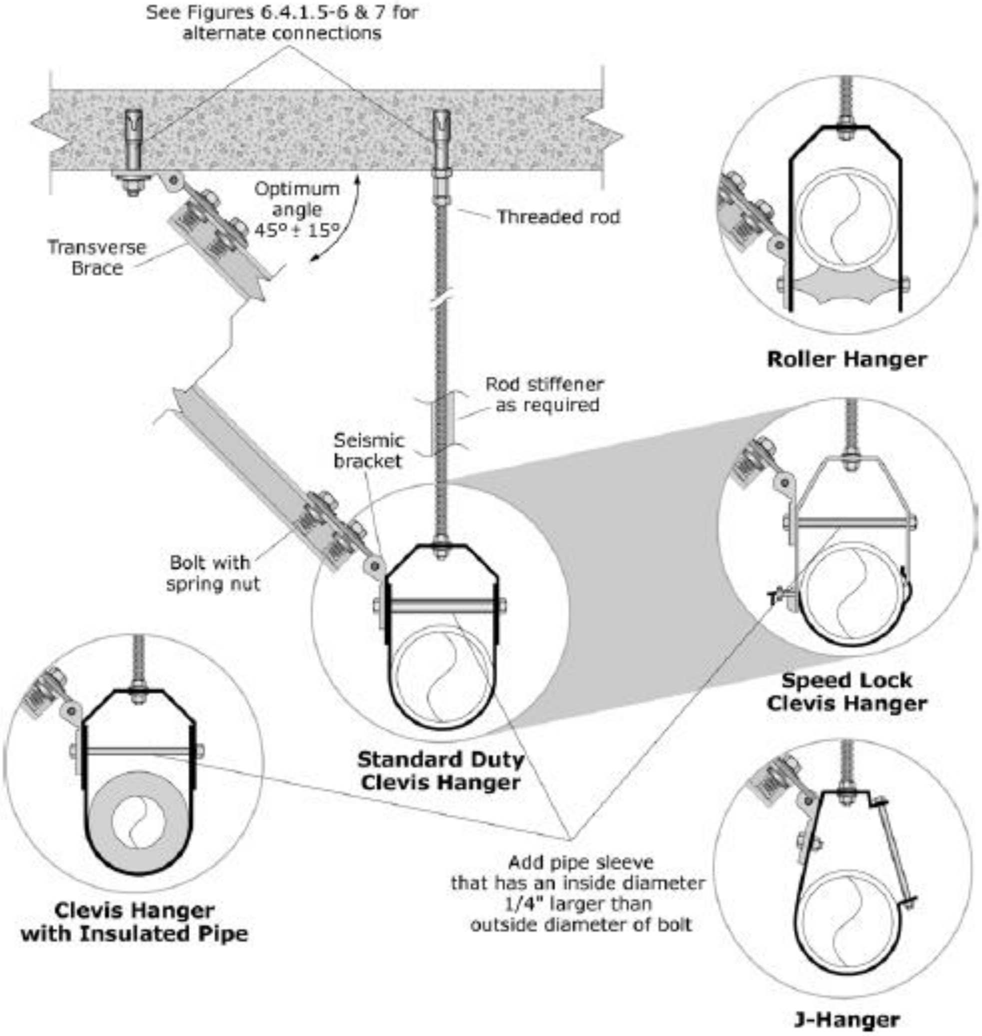


Figure G-36. Rigid Bracing – Single Pipe Transverse.

(FEMA E-74, 2012, Reducing the Risks of Nonstructural Earthquake Damage)

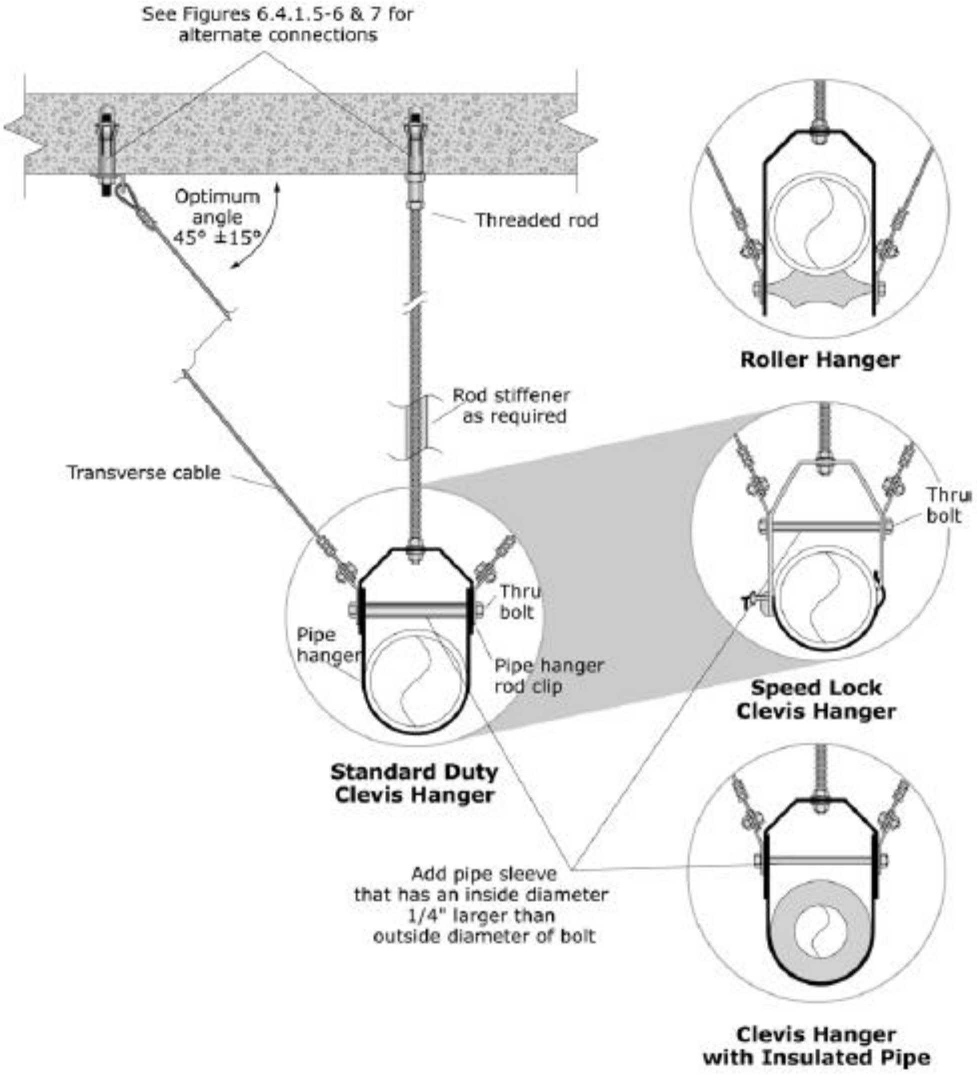
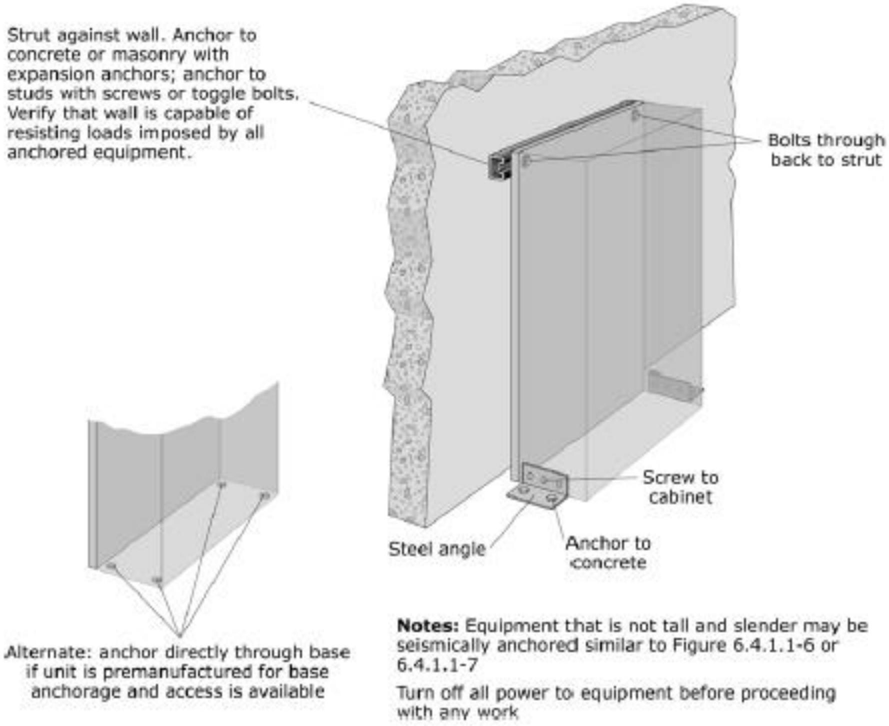


Figure G-37. Cable Bracing – Single Pipe Transverse.

(FEMA E-74, 2012, Reducing the Risks of Nonstructural Earthquake Damage)

Electrical and Communications



Notes: Equipment that is not tall and slender may be seismically anchored similar to Figure 6.4.1.1-6 or 6.4.1.1-7

Turn off all power to equipment before proceeding with any work

Figure G-38. Electrical Control Panels, Motor Controls Centers, or Switchgear.

(FEMA E-74, 2012, Reducing the Risks of Nonstructural Earthquake Damage)

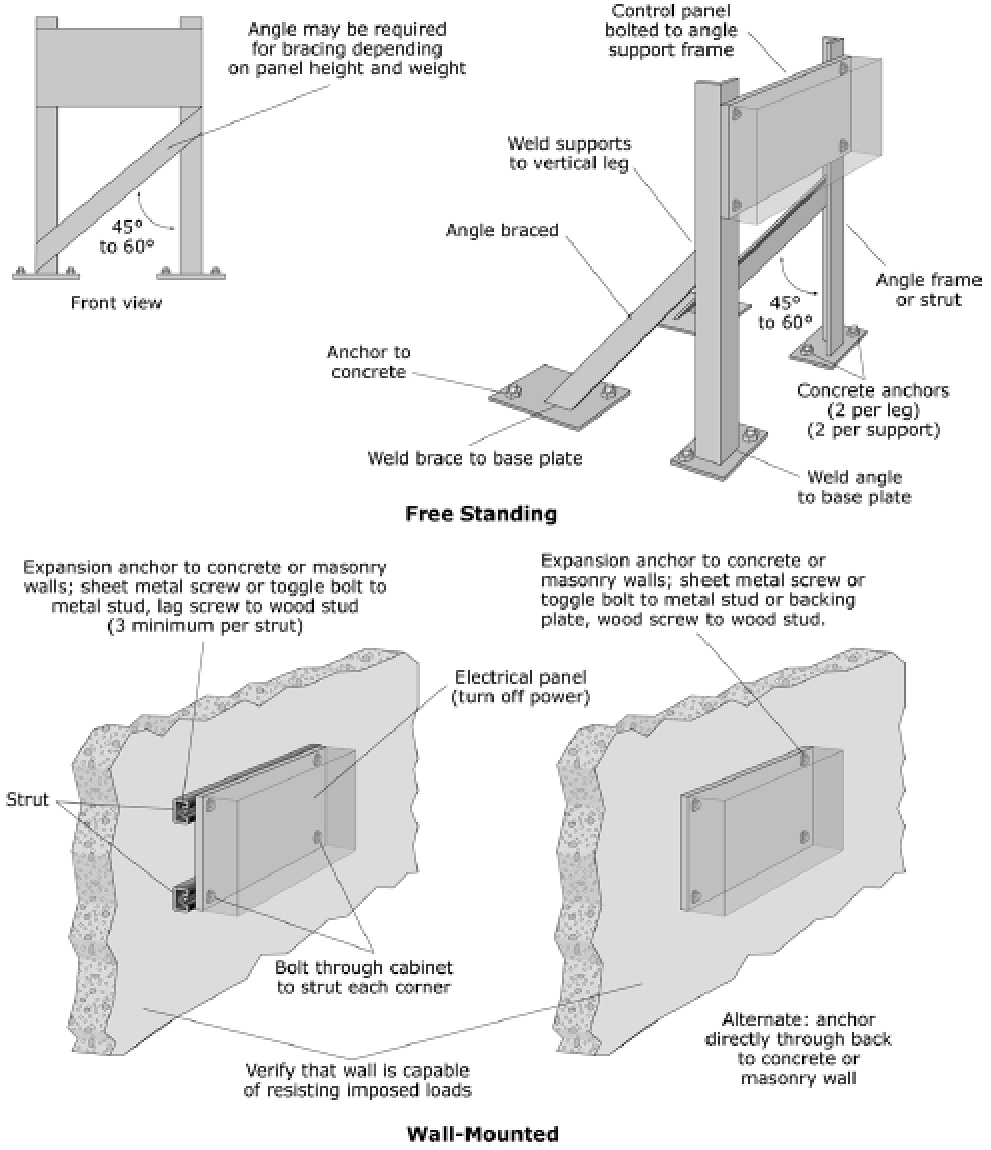


Figure G-39. Freestanding and Wall-mounted Electrical Control Panels, Motor Controls Centers, or Switchgear.

(FEMA E-74, 2012, Reducing the Risks of Nonstructural Earthquake Damage)

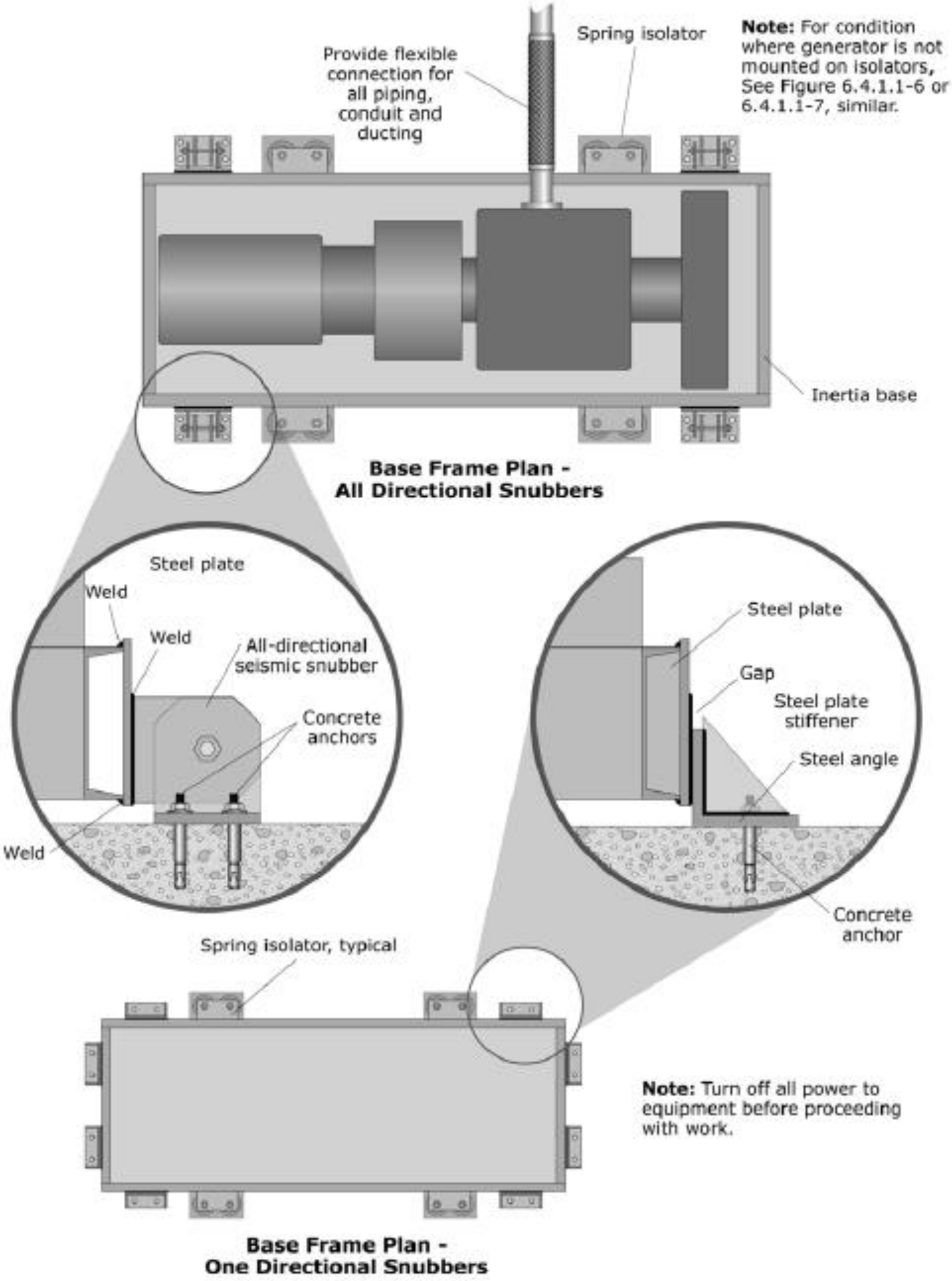


Figure G-40. Emergency Generator.

(FEMA E-74, 2012, Reducing the Risks of Nonstructural Earthquake Damage)

APPENDIX E: PROJECT COMMUNICATION MATERIALS

Washington State School Seismic Safety Assessment Project

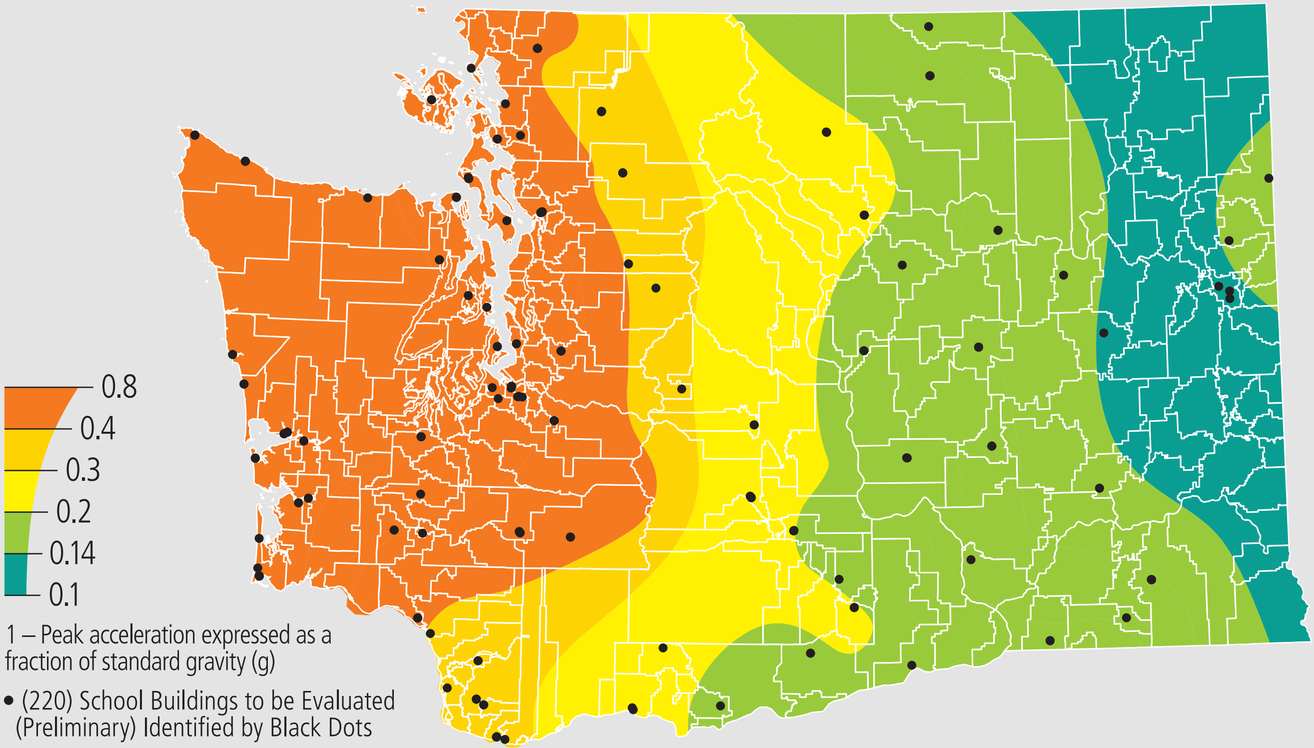
WHY SHOULD MY SCHOOL DISTRICT PARTICIPATE?

1 **DETERMINE SEISMIC SAFETY** of School District Buildings

2 **HELP INFORM** Public Officials of School Seismic Vulnerabilities

3 **SECURE** Seismic Retrofit Public Funding for Safer Schools

SEISMIC RISK MAP & PARTICIPATING SCHOOLS



1 – Peak acceleration expressed as a fraction of standard gravity (g)

• (220) School Buildings to be Evaluated (Preliminary) Identified by Black Dots

SEISMIC SAFETY ASSESSMENT STEPS

1 **DEFINE FACILITIES**

2 **FIELD ASSESSMENTS**

3 **CONCEPT DESIGN OF REPRESENTATIVE BUILDINGS**

4 **SUMMARY REPORT**
- *Vulnerable School Inventory*
- *Prioritize Types to be Retrofitted*
- *Located Funding Sources*

5 **INFORM STATE LEGISLATORS**

ReidMiddleton

FREQUENTLY ASKED QUESTIONS

Q Who will be doing these field assessments?

A Ten teams of structural engineers will perform 1-2 day field assessments of the pre-selected school buildings for districts distributed throughout Washington State.

Q What will they be doing?

A Structural engineers will perform visual observations of the building (no testing or material sampling) in order to complete seismic screening checklists. A team of geologists will also visit separately to survey the school grounds.

Q What do we (the school districts) need to do?

A Coordinate with the structural engineers to provide access to the buildings and provide structural/architectural record drawings for the buildings to be assessed.

Q When will the field assessments occur?

A Throughout Summer 2018 - we will schedule site visits in advance.

Q What is the project duration?

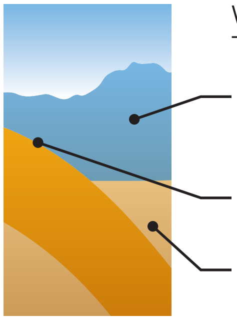
A Field assessments will occur throughout Summer 2018, followed by desktop analysis and concept design for 20 school buildings that will occur through the remainder of 2018. The final report is expected to be complete June 2019.

Q Why is this project run through the Department of Natural Resources (DNR) / Washington Geological survey (WGS)?

A The State Legislature funded $1.2M to the Department of Natural Resources (DNR) to do a combination of school assessments and to improve the seismic/soil characerization at each school site.

SEISMIC SAFETY FACTS

#2 WASHINGTON STATE RANKS #2 IN SEISMIC RISK IN THE US (NEXT TO CALIFORNIA)



WASHINGTON HAS ALL THREE TYPES OF EARTHQUAKES

Shallow Crustal Earthquakes
(e.g. M7.0 Seattle Fault, M7.4 South Whidbey Island Fault)

Subduction Zone Earthquakes
(e.g. M9.0 Cascadia Subduction Zone)

Deep Earthquakes
(e.g. 2001 M6.8 Nisqually Earthquake)

IN THE NEXT 50 YEARS

10-20%	*probability of an M9.0+ event*
80%	*probability of an M6.0+ event*

Source: Washington EMD

K-12 SCHOOL FACTS

~2000	campuses with ~1700 constructed before 2005
~4000	total buildings (~5% or ~220 buildings selected for seismic screening)

Source: OSPI & DNR

~200 schools are in high liquefaction zones

Source: OSPI & DNR

~70% are in high seismic risk areas

Source: OSPI & DNR

CONTACT

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BergerABAM DYKEMAN DCI ENGINEERS PD PRODIMS rolludaarchitects wrk engineers ReidMiddleton

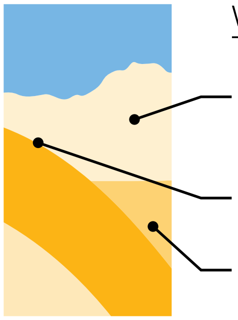
SEISMIC SAFETY FOR STUDENTS

Washington State School Seismic Safety Assessments Project

FY 17-19 Capital Budget

Washington State ranks second in the U.S. in seismic risk (next to California). Washington State agencies have the important task of mitigating seismic risk of schools for students. This document provides key facts about seismic safety in Washington State, what has been done to-date by Washington DNR regarding school seismic safety, and the importance of continuing to improve school seismic safety. Observations from the 2018 Anchorage Earthquake and the 2017 Central Mexico Earthquake are also included. Damage from the 2018 Anchorage Earthquake and the 2017 Central Mexico Earthquake illustrates the important reasons for performing seismic evaluations and conducting seismic upgrades on Washington schools.

WASHINGTON STATE SCHOOL SEISMIC SAFETY FACTS



WASHINGTON HAS ALL THREE TYPES OF EARTHQUAKES

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(e.g. M7.0 Seattle Fault, M7.4 South Whidbey Island Fault)

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(e.g. M9.0 Cascadia Subduction Zone)

Deep Earthquakes
(e.g. 2001 M6.8 Nisqually Earthquake)

IN THE NEXT 50 YEARS

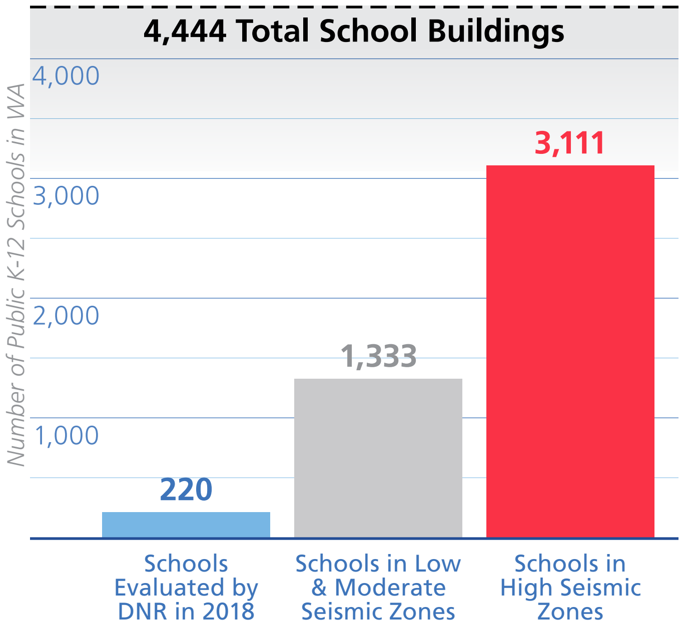
10-20%	*probability of an M9.0+ event*
80%	*probability of an M6.0+ event*

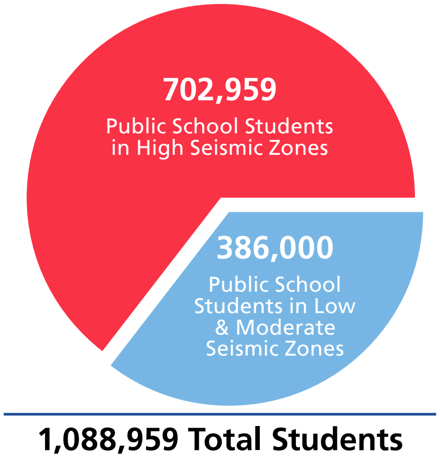
Source: Washington EMD

~70% of schools are in high seismic risk areas

Source: OSPI & DNR

WASHINGTON STATE SCHOOL SEISMIC EVALUATION BY THE NUMBERS

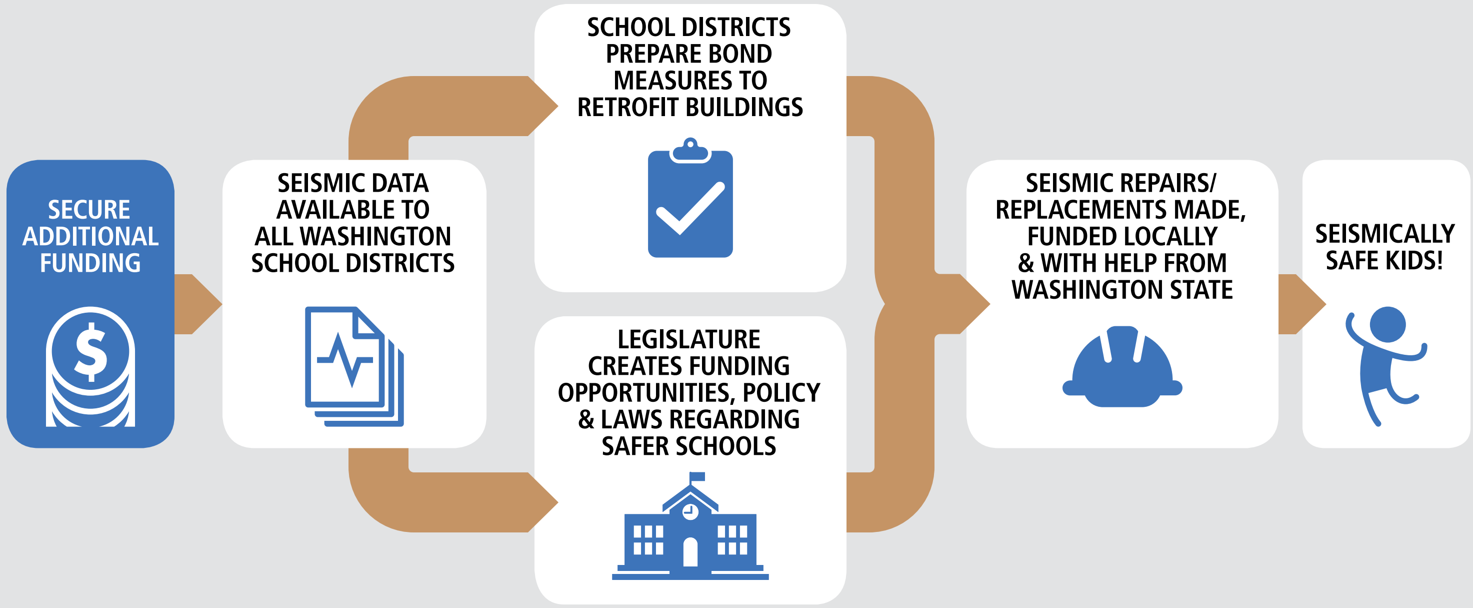




Reid Middleton

January 2019

SCHOOL SEISMIC SAFETY FUNDING STEPS

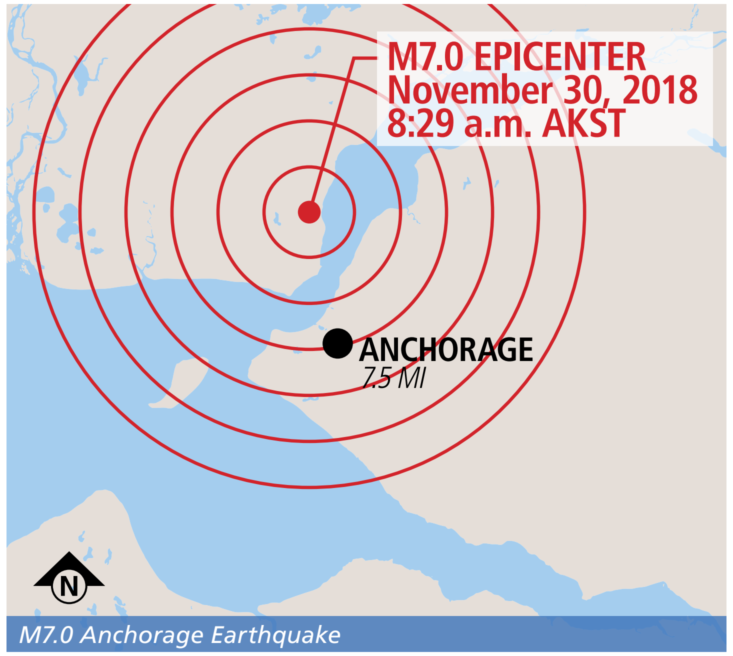


Earthquakes Educate

Earthquakes around the globe provide a real-world opportunity for structural engineers and earth scientists to learn more about the devastating effects of earthquakes and how to improve public safety and community resilience through improved building design and seismic retrofit. This document presents two recent North American earthquakes that Washington State agencies can learn from to improve seismic resilience for Washington schools; the 2018 M7.0 Earthquake near Anchorage, AK, and the 2017 M7.1 Central Mexico Earthquake near Mexico City and Puebla, Mexico.

2018 M7.0 Anchorage Earthquake Event

At 8:29 AM, Friday, November 30, 2018, a M7.0 earthquake struck the greater Anchorage, Alaska area. The deep earthquake (27.5 miles below the earth's surface) originated in close proximity to downtown Anchorage (7.5 miles NNW of the city). This earthquake magnitude and depth is slightly larger than the 2001 Nisqually Earthquake near Olympia, Washington. The USGS lists the intensity of the earthquake as "severe." While ground shaking varied across the Anchorage area, it was generally about 25%-75% of levels for which low-rise buildings are designed.



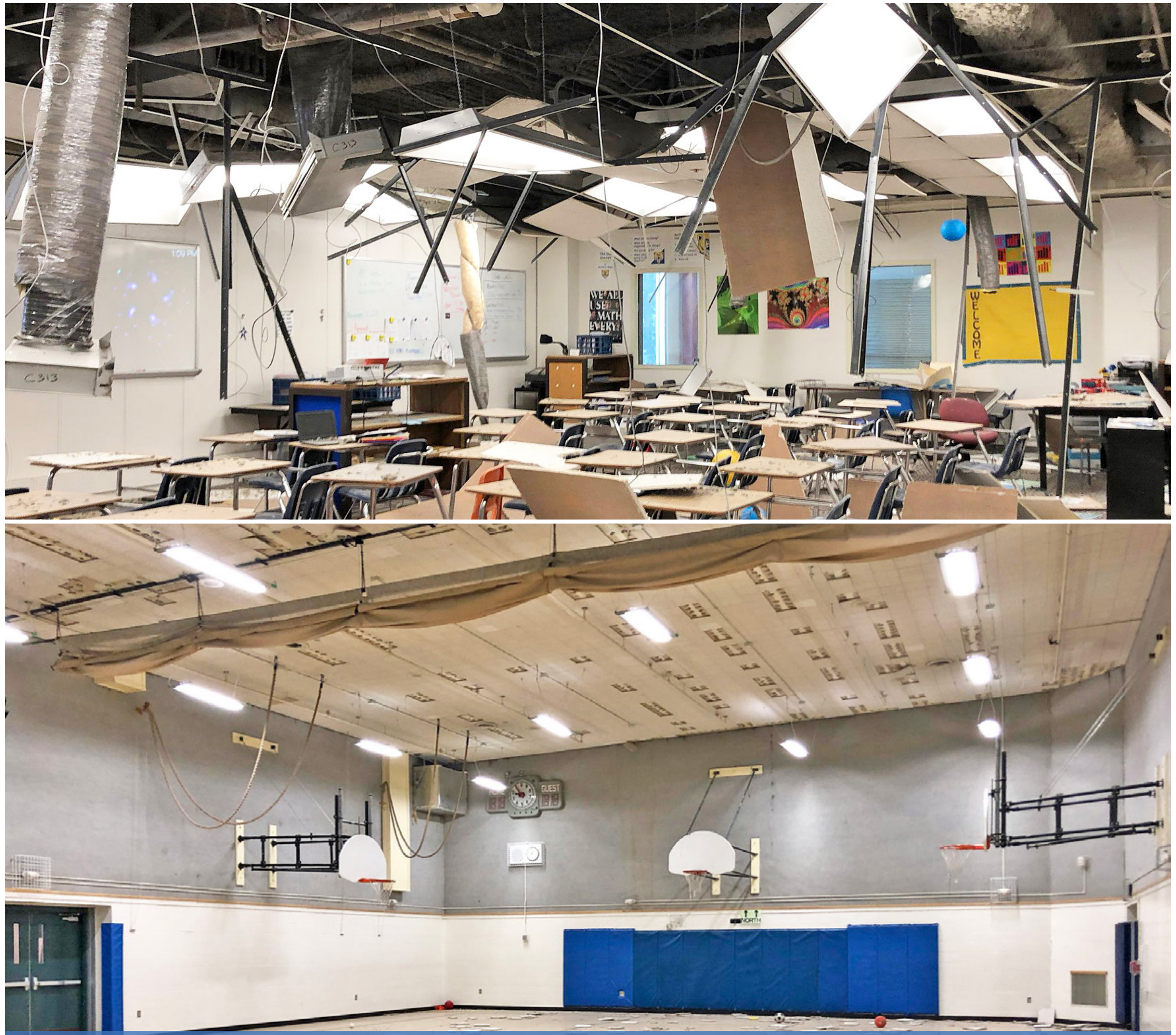
M7.0 Anchorage Earthquake

Anchorage School District Response

Some schools had already started their scheduled school day when the earthquake struck. During the earthquake, students and staff sheltered in-place and then evacuated the buildings. Thanks to extensive staff training, emergency protocols, and the nature of the earthquake damage, there were only two minor injuries within the school district. After the earthquake, students were sent home for the remainder of the day. All district schools remained closed for more than a week due to structural and nonstructural damage, reopening on Monday December 10. Some heavily damaged buildings will remain closed for the remainder of the 2018-2019 school year.

Anchorage School District has shared information with the public via its website, including photos and status updates. To learn more, visit: https://www.asdk12.org/2018earthquake.

TYPICAL SCHOOL DAMAGE OBSERVED



Extensive ceiling system damage in many schools caused falling hazards during and after the earthquake.
Credit: David Stierwalt, Reid Middleton, Inc.

ANCHORAGE EARTHQUAKE GENERAL SCHOOL BUILDING DAMAGE OBSERVATIONS

1. Out of the 92 school buildings evaluated after the earthquake, 2 were red-tagged (deemed unsafe to occupy), 61 were yellow-tagged (restricted use due to safety hazards), and 29 were green-tagged (no restrictions).

2. The school district has zero unreinforced masonry buildings (as the primary lateral system). This resulted in reduced building damage and likely saved lives.

3. In general, structural and nonstructural components met life safety criteria (or slightly better) resulting in minimal injuries and zero fatalities.

4. The school district experienced significant variation in ground shaking across the district (even at schools relatively close together) due to seismic basin effects, seismic wave focusing, directionality factors and local soil characteristics. Local geology greatly affects the ground motion and shaking. Washington State will experience similar effects given Washington's deep seismic basins, mountainous terrain and potential for subduction, crustal and deep earthquakes.

5. The school district and its facilities were well-prepared for earthquakes. This includes extensive staff training (ATC-20, great shake out, earthquake drills, shelter school plans, extensive evacuation and emergency planning), investment in ASCE 41 seismic evaluation and retrofit, and strictly enforced facility construction and inspection requirements.

6. The Municipality of Anchorage strictly enforces seismic building code requirements and has had strict enforcement since the late 1980's. Buildings that survived the 1964 M9.2 Great Alaska Earthquake performed relatively well in this earthquake. Buildings built immediately prior to strict building code enforcement (70's and early 80's) performed the worst. Buildings constructed after the adoption of modern building codes (circa 1997) generally performed well. Adequate building code and inspection enforcement significantly reduces structural and nonstructural damage.

Floor and floor finish cracking. – High School Flooring Crack. Credit: David Stierwalt, Reid Middleton, Inc.

Elementary School Fallen Contents. Credit: David Stierwalt, Reid Middleton, Inc.

Considerable cracking and damage in CMU bearing and partition walls. – High School CMU Partition Wall Damage. Credit: David Stierwalt, Reid Middleton, Inc.

Some suspended and ground supported HVAC and mechanical equipment sustained damage and sheared their support structural bolts causing unsafe conditions and chemical leaks. – Elementary School Leaking Glycol in Fan Room. Credit: David Stierwalt, Reid Middleton, Inc.

Significant wallboard cracking, brick and masonry veneer damage, window damage, and cladding damage caused falling hazards. – Elementary School Fallen Brick Veneer. Credit: David Stierwalt, Reid Middleton, Inc.

2017 M7.1 Central Mexico Earthquake

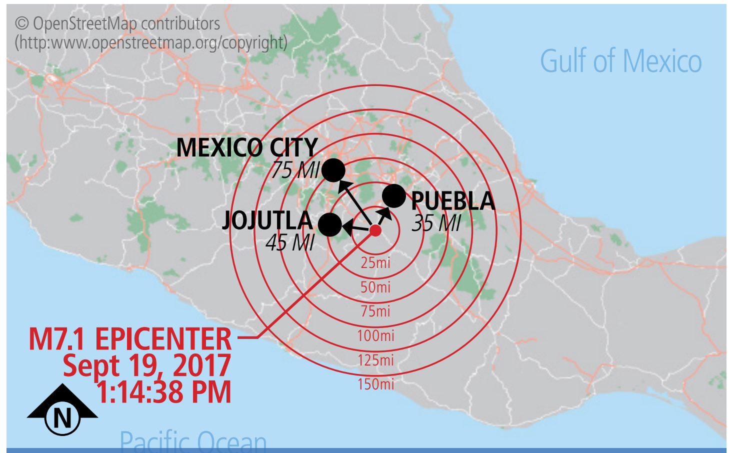
On September 19, 2017, at 1:14 P.M., exactly 32 years to the day after the tragic M8.0 1985 earthquake, central Mexico was struck by a M7.1 intraplate earthquake. The earthquake struck two hours after a citywide earthquake drill and put a dramatic end to commemoration activities taking place throughout the city. The deep earthquake (32 miles below the earth's surface) caused strong shaking lasting more than 20 seconds and resulted in an official government count of 369 fatalities. Approximately 5,800 buildings were damaged resulting in immediate direct losses of approximately US $2 Billion. The earthquake magnitude and type was similar to the 2001 Nisqually Earthquake near Olympia, Washington.

The earthquake caused damage to more than 1,000 schools in the greater Mexico City Area affecting over 250,000 students. A few school buildings collapsed in the earthquake killing many students. Approximately 7 school buildings had to be demolished due to earthquake damage. Many schools were closed for weeks to months following the earthquake. The government pledged several billion dollars to repair schools. However, repairing the structures has taken some time. One year after the earthquake, more than half of the damaged schools had not yet received repairs.

For additional information about the 2017 Central Mexico Earthquake and Reid Middleton's involvement in post-earthquake recovery and earthquake reconnaissance see:

1. http://www.reidmiddleton.com/reidourblog/central-mexico-earthquake-reconnaissance-day-1/

2. http://www.reidmiddleton.com/resources/2017-central-mexico-m7-1-earthquake-reconnaissance-report/



M7.1 Central Mexico Earthquake

Damaged Primary School in Jojutla. The unreinforced masonry infill walls were damaged. Many Washington state schools are constructed similarly. Credit: Erik Bishop, Reid Middleton, Inc.

CENTRAL MEXICO GENERAL SCHOOL BUILDING DAMAGE OBSERVATIONS

1. Unreinforced masonry and confined masonry buildings performed poorly compared to other types of structures. Washington State has many unreinforced masonry school buildings, and other structures, constructed in the same way as in Mexico City.

2. After the devastating 1985 Mexico City Earthquake, Mexico dramatically increased its building code standards, interagency coordination and earthquake preparedness. The 1985 Earthquake, while a slightly different type and magnitude of shaking, resulted in over 9,500 deaths. The 369 deaths caused by the 2017 earthquake, while still devastating, is much less than the 1985 earthquake. This is a direct result of improved construction standards.

3. Poor building code enforcement, where it occurred, made buildings more vulnerable. Numerous instances of unpermitted structures caused vulnerabilities. In several instances, unpermitted additions to buildings caused poor performance. This highlights the importance of having strong building code provisions and having adequate state, county and local enforcement.

4. The Mexico Earthquake Early Warning System, integrated with a civic alert system and cell phone apps, was able to alert a certain portion of people that an earthquake was about to arrive. While some system improvements are warranted, the early warning system was documented to help people.

5. A significant portion of damaged buildings had structural irregularities (e.g. odd-shaped buildings, building's with sharp changes in stiffness). A significant portion of Washington State school buildings have structural irregularities.

6. Soil amplification effects in Mexico City locally increased the ground motions for certain types of structures. Washington State will have similar types of soil amplification especially in areas near rivers and waterfronts.

Damaged Primary School in Jojutla. Total failure due to diagonal tension in unreinforced masonry wall. Many Washington state schools are constructed similarly. Credit: Erik Bishop, Reid Middleton, Inc.

REFERENCES

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https://mexiconewsdaily.com/news/many-schools-are-still-waiting-for-repairs/

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https://www.king5.com/article/news/local/disaster/72-percent-of-washington-schools-at-high-risk-from-earthquakes/281-532980773

http://www.reidmiddleton.com/resources/2017-central-mexico-m7-1-earthquake-reconnaissance-report/

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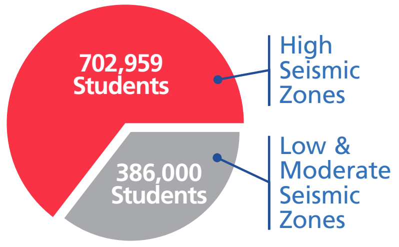
ABOUT REID MIDDLETON, INC.

Reid Middleton is a civil and structural engineering consulting firm with a 66-year history of serving public and private-sector clients throughout the United States, Pacific Rim, and Middle East. The firm focuses on education, aviation, civic, municipal commercial, healthcare, industrial, military, transportation, and waterfront. Reid Middleton serves as prime consultant to owners as well as consultants to architects and design professionals. Reid Middleton has offices in Anchorage, Alaska; San Diego, California; Honolulu, Hawaii; and Everett, Washington.

Washington State
SCHOOL SEISMIC SAFETY ASSESSMENT PROJECT

SEISMIC RISK & PROJECT SUMMARY

~65% of 1,088,959 Public School Students are in **High Seismic Zones**

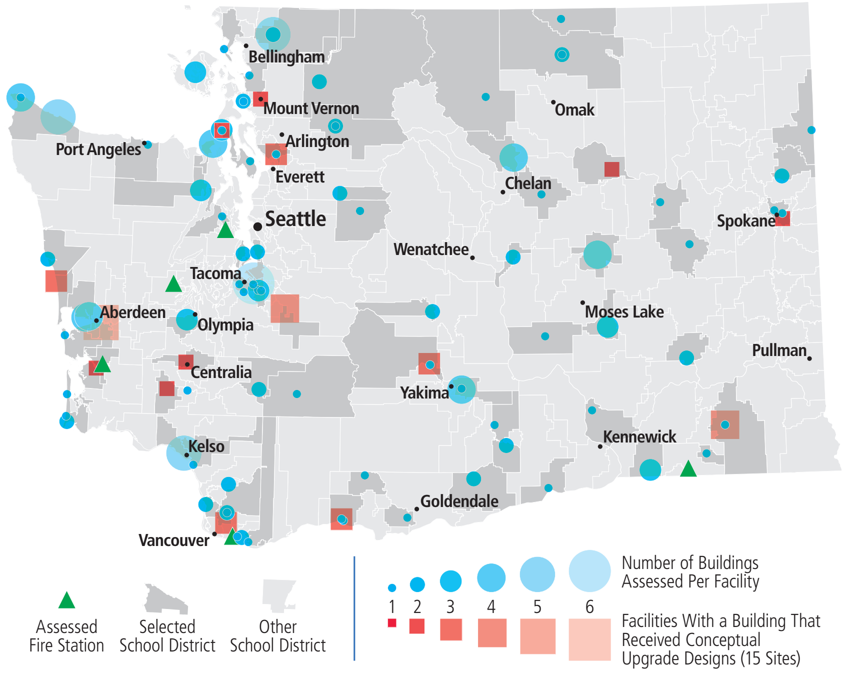


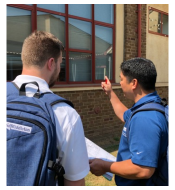
In the Next 50 Years

~10-20%
Probability of an **M9.0+** Earthquake

~80%
Probability of an **M6.0+** Earthquake

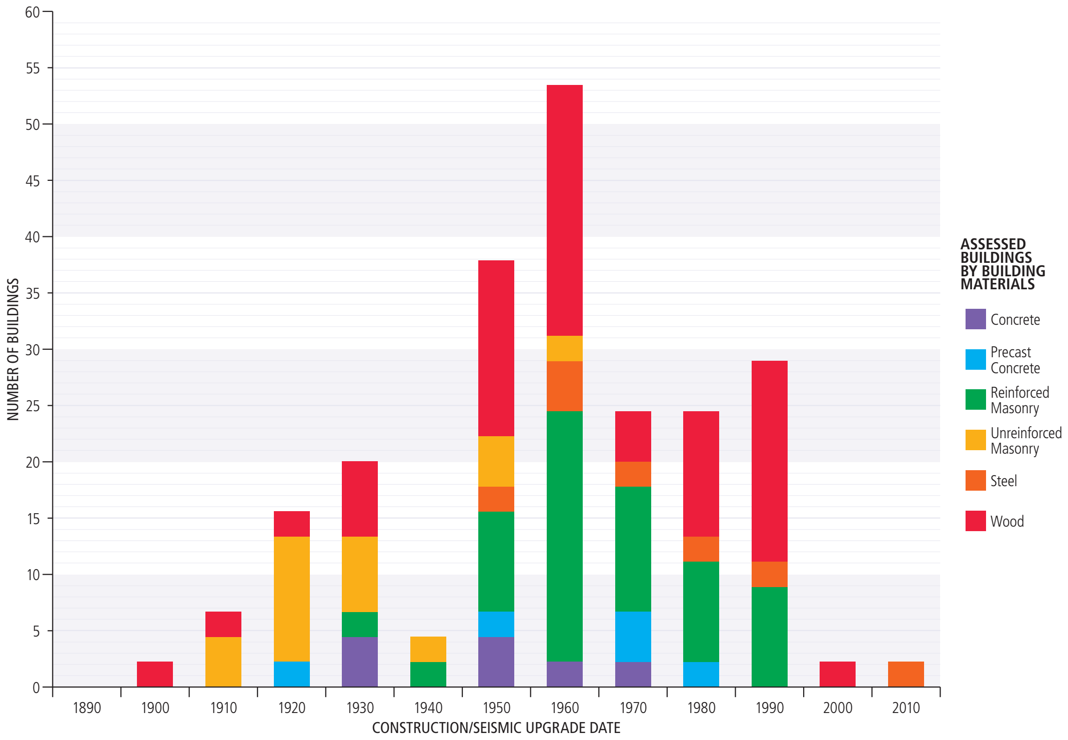
222
School Buildings Studied from **75 School Districts**



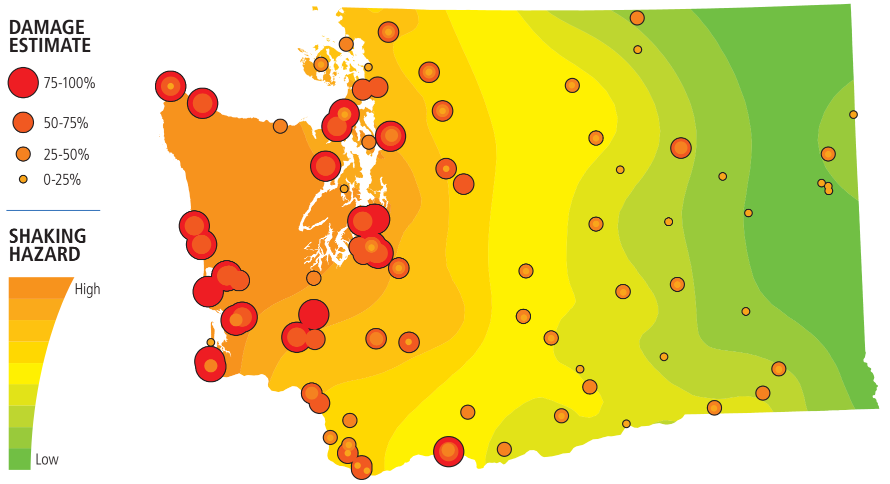



PROJECT RESULTS

AGE & TYPE DISTRIBUTION OF BUILDINGS STUDIED



BUILDING DAMAGE ESTIMATES



1963
Average Year of Construction

~50%
Non-Compliant Seismic Features for Pre-1950s Buildings

~25%
Buildings **too Costly to Repair** After Design Earthquake

~60%
Unsafe Buildings After Design Earthquake

Cost to Upgrade an Existing Building is Only
~5%-50%
of the **Cost to Replace** a Damaged Building

Washington State has many older school buildings built prior to the adoption of modern seismic safety codes. Older buildings and more vulnerable construction types (especially URM and concrete buildings built prior to 1970) are more at risk of collapse in an earthquake. Schools in high seismic hazard areas and on weak soil are also more vulnerable to collapse.

June 2019

PROJECT WEBSITE: **www.dnr.wa.gov/programs-and-services/geology/geologic-hazards/earthquakes-and-faults/school-seismic-safety** REID MIDDLETON: **www.reidmiddleton.com**

Legislature Poster
Washington State School Seismic Safety Assessment Project – June 2019

Washington State
SCHOOL SEISMIC SAFETY ASSESSMENTS PROJECT

Reid Middleton

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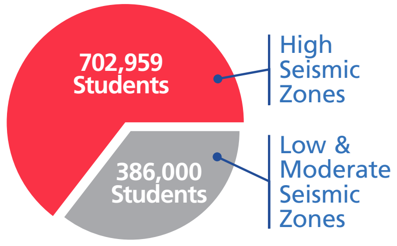

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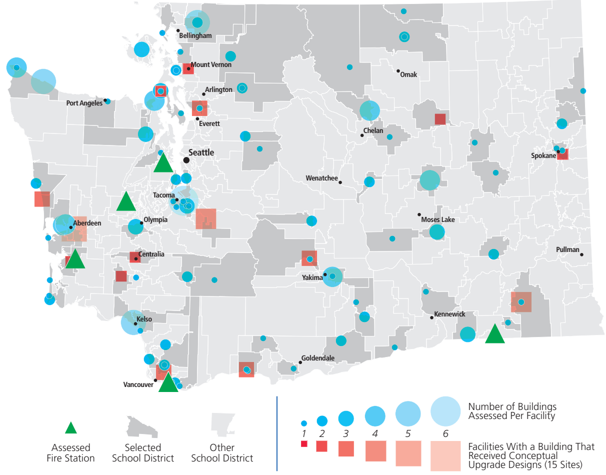

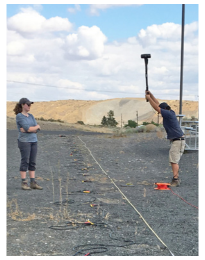

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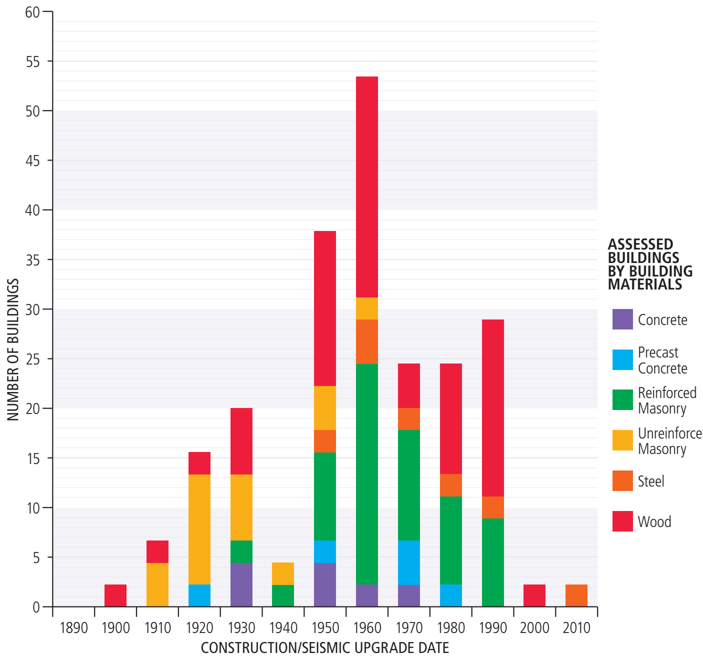

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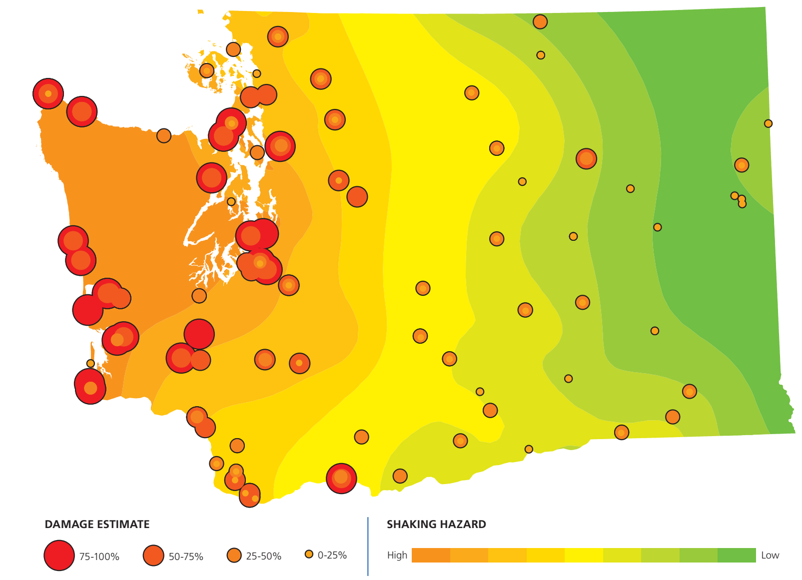

EARTHQUAKES TEACH — RECENT NORTH AMERICAN EARTHQUAKE DAMAGE TO PUBLIC SCHOOLS

photos provided by Reid Middleton

2018 M7.0 ANCHORAGE ALASKA EARTHQUAKE

Fallen contents in classroom

Elementary school unreinforced concrete masonry partition wall collapse

High school classroom extensive suspended ceiling system collapse

2017 M7.1 CENTRAL MEXICO EARTHQUAKE

Primary school unreinforced masonry infill walls damage

Primary school wall failure due to diagonal tension in unreinforced masonry bearing wall

June 2019

PROJECT WEBSITE: **www.dnr.wa.gov/programs-and-services/geology/geologic-hazards/earthquakes-and-faults/school-seismic-safety**

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Washington State School Seismic Safety Assessments Project – June 2019

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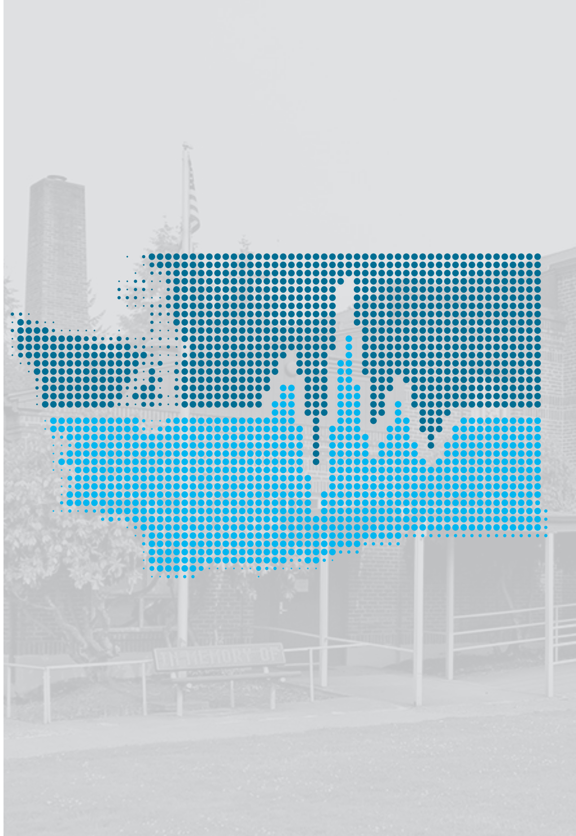

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