Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook

Third Edition

FEMA P-154 / January 2015

FEMA

nehrp

FEMA P-154

THIRD EDITION

Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook

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January 2015

Notice

Preface

In 2011, the Applied Technology Council (ATC), with funding from the Federal Emergency Management Agency (FEMA) under Task Order Contract HSFEHQ-08-D-0726, commenced a series of projects (ATC-71-4, ATC-71-5, and ATC-71-6) to update the FEMA 154 Report, *Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook* (FEMA, 2002a). The purpose of FEMA 154, which was developed by ATC under contract to FEMA (ATC-21 Project) and published in 1988, was to provide a methodology to evaluate the seismic safety of a large inventory of buildings quickly and inexpensively, with minimum access to the buildings, and determine those buildings that require a more detailed examination. In 2002, FEMA 154 was updated to create a *Second Edition*, based on (1) experience from the widespread use of FEMA 154 by federal, state, and municipal agencies and others; (2) new knowledge about the performance of buildings during damaging earthquakes; (3) new knowledge about seismic hazards; and (4) other then-new seismic evaluation and performance prediction tools, such as the FEMA 310 report, *Handbook for the Seismic Evaluation of Buildings - A Prestandard* (FEMA, 1998). Both the original FEMA 154 *Handbook* and the *Second Edition* were accompanied by a *Supporting Documentation* report (FEMA 155), which described the technical basis for the scoring system and other guidance provided in FEMA 154.

Since the publication of the second edition of FEMA 154, there have been several initiatives that have advanced the state-of-the-art in rapid visual screening of buildings for seismic risk. One of these was the development of the FEMA P-154 *Rapid Observation of Vulnerability and Estimation of Risk* (ROVER) software for use on smart phones (FEMA, 2014), which enables users to document and transmit data gathered in the field. The rapid visual screening application of FEMA P-154 ROVER is based on the second edition of FEMA 154 and incorporates several improvements made possible by the electronic calculation capability of the device (e.g., site-specific determinations of the seismic shaking hazard). In addition, users in Oregon and Utah have suggested modifications to the FEMA 154 screening process in the course of performing extensive seismic screenings of schools and other buildings.

The objective of the *Third Edition* remains the same as its predecessors: to identify, inventory, and screen buildings that are potentially hazardous. Although some sections of the text remained unchanged from the *Second Edition*, the *Third Edition* incorporates several major enhancements, including:

- Update of the Data Collection Form, and the addition of an optional more detailed page to the form,
- Update of the Basic Scores and Score Modifiers,
- Update of the ground motion definitions,
- Preparation of additional reference guides,
- Inclusion of additional building types that are prevalent,
- Inclusion of additional considerations, such as nonstructural hazards, existing retrofits, building additions, and adjacency,
- Addition of an optional electronic scoring methodology, and
- Additional information on how to run an effective screening program.

The technical basis for the rapid visual screening procedure is documented in the FEMA P-155 report, *Rapid Visual Screening of Buildings for Potential Seismic Hazards: Supporting Documentation*, (FEMA, 2015), which was also updated to the *Third Edition.* Note that per FEMA's current report numbering system, the third editions of FEMA 154 and FEMA 155 are now referred to as FEMA P-154 and FEMA P-155, respectively.

ATC is indebted to the leadership of Bret Lizundia, Project Technical Director, and to the members of the ATC-71-4, ATC-71-5, and ATC-71-6 Project Teams for their efforts in developing this updated *Handbook.* The Project Technical Committee, consisting of Michael Griffin, William Holmes, Brian Kehoe, Keith Porter, and Barry Welliver, managed and performed the technical development efforts. Updated scores were developed by Charles Kircher. Sarah Durphy, as a Project Working Group member, provided special assistance in the development of the updated *Handbook.* Andrew Bishop, Brian Kehoe, and Scott Hiner prepared the illustrations for the report. Nicolas Luco and Kenneth Rukstales prepared the seismicity maps in the document. The Project Review Panel, consisting of Charles Scawthorn (chair), Timothy Brown, Melvyn Green, Laura Kelly, Stephanie King, John Osteraas, Steven Sweeney, and Christine Theodoropoulos, provided technical review, advice, and consultation at key stages of the work. A workshop of invited experts was convened to obtain feedback on the updated *Handbook*, and input from this group was instrumental in shaping the final methodology and report. The names and affiliations of all who contributed to this report are provided in the list of Project Participants.

ATC also gratefully acknowledges Michael Mahoney (FEMA Project Officer), Mai Tong (FEMA Task Monitor), Erin Walsh (FEMA Task Monitor), and John Gillengerten (FEMA Technical Monitor) for their input and guidance in the preparation of this document. Ayse Hortacsu and Thomas McLane managed the project and Amber Houchen and Peter N. Mork provided report production services.

Jon A. Heintz	Christopher Rojahn
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Table of Contents

List of Figures

List of Tables

Chapter 1

Introduction

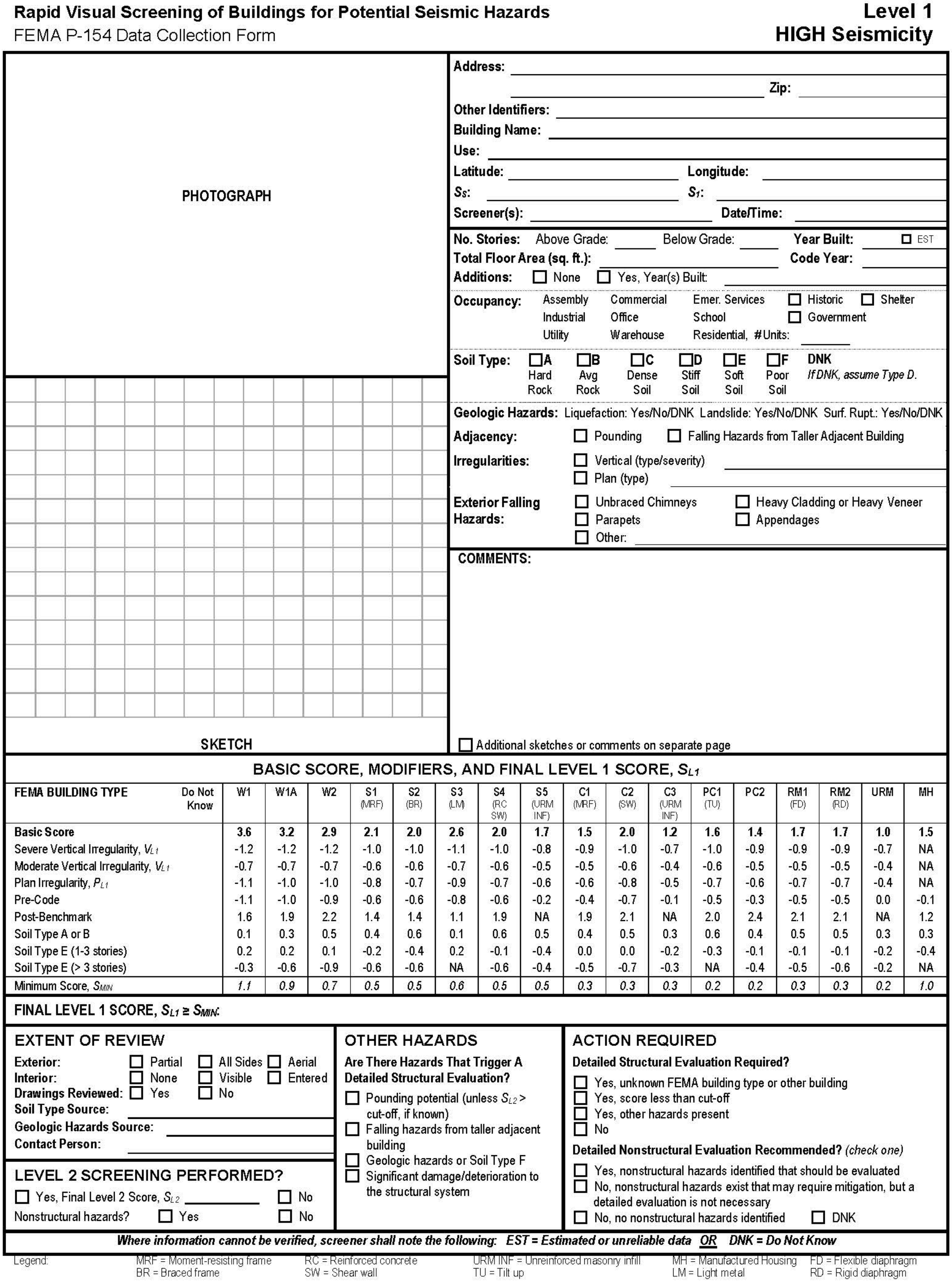
1.1 Summary of Rapid Visual Screening

The FEMA P-154 Report, *Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook*, is the first of a two-volume publication on recommended methodology for rapid visual screening of buildings for potential seismic hazards. The technical basis for the methodology, including the scoring system and its development, is contained in the companion volume, FEMA P-155 report, *Rapid Visual Screening of Buildings for Potential Seismic Hazards: Supporting Documentation* (FEMA, 2015). Both this document and the companion document are third editions of similar documents first published by FEMA in 1988 and updated in 2002.

The rapid visual screening (RVS) procedure has been developed to identify, inventory, and screen buildings that are potentially seismically hazardous. Once identified as potentially hazardous, such buildings should be further evaluated by a design professional experienced in seismic design to determine if, in fact, they are seismically hazardous. The RVS procedure uses a methodology based on a sidewalk survey of a building and a Data Collection Form, which the person conducting the survey completes, based on visual observation of the building from the exterior, and if possible, the interior. The two-page Data Collection Form (shown in Figures 1-1 and 1-2) includes space for documenting building identification information, including its use and size, a photograph of the building, sketches, and documentation of pertinent data related to seismic performance. Based on the data collected during the survey, a score is calculated that provides an indication of the expected seismic performance of the building.

Once the decision to conduct rapid visual screening for a community or group of buildings has been made, the screening effort can be expedited by pre-field planning, including the training of screeners, and careful overall management of the process.

Completion of the Data Collection Form in the field begins with identifying the primary structural seismic force-resisting system and structural materials of the building. Basic Scores for various building types are provided on the form, and the screener circles the appropriate one. The screener modifies the



Rapid Visual Screening of Buildings for Potential Seismic Hazards
FEMA P-154 Data Collection Form

Level 1
HIGH Seismicity

PHOTOGRAPH

SKETCH

Address: ______________________
______________________ **Zip:** ________
Other Identifiers: ______________________
Building Name: ______________________
Use: ______________________
Latitude: ____________ **Longitude:** ____________
S_S: ____________ **S_1:** ____________
Screener(s): ____________ **Date/Time:** ____________

No. Stories: Above Grade: ______ Below Grade: ______ **Year Built:** ______ ☐ EST
Total Floor Area (sq. ft.): ____________ **Code Year:** ______
Additions: ☐ None ☐ Yes, Year(s) Built: ____________

Occupancy:

Assembly	Commercial	Emer. Services	☐ Historic ☐ Shelter
Industrial	Office	School	☐ Government
Utility	Warehouse	Residential, #Units: ______	

Soil Type:

☐A	☐B	☐C	☐D	☐E	☐F	DNK
Hard Rock	Avg Rock	Dense Soil	Stiff Soil	Soft Soil	Poor Soil	*If DNK, assume Type D.*

Geologic Hazards: Liquefaction: Yes/No/DNK Landslide: Yes/No/DNK Surf. Rupt.: Yes/No/DNK
Adjacency: ☐ Pounding ☐ Falling Hazards from Taller Adjacent Building
Irregularities: ☐ Vertical (type/severity) ____________
☐ Plan (type) ____________
Exterior Falling Hazards: ☐ Unbraced Chimneys ☐ Heavy Cladding or Heavy Veneer
☐ Parapets ☐ Appendages
☐ Other: ____________

COMMENTS:

☐ Additional sketches or comments on separate page

BASIC SCORE, MODIFIERS, AND FINAL LEVEL 1 SCORE, S_{L1}

FEMA BUILDING TYPE Do Not Know	W1	W1A	W2	S1 (MRF)	S2 (BR)	S3 (LM)	S4 (RC SW)	S5 (URM INF)	C1 (MRF)	C2 (SW)	C3 (URM INF)	PC1 (TU)	PC2	RM1 (FD)	RM2 (RD)	URM	MH
Basic Score	**3.6**	**3.2**	**2.9**	**2.1**	**2.0**	**2.6**	**2.0**	**1.7**	**1.5**	**2.0**	**1.2**	**1.6**	**1.4**	**1.7**	**1.7**	**1.0**	**1.5**
Severe Vertical Irregularity, V_{L1}	-1.2	-1.2	-1.2	-1.0	-1.0	-1.1	-1.0	-0.8	-0.9	-1.0	-0.7	-1.0	-0.9	-0.9	-0.9	-0.7	NA
Moderate Vertical Irregularity, V_{L1}	-0.7	-0.7	-0.7	-0.6	-0.6	-0.7	-0.6	-0.5	-0.5	-0.6	-0.4	-0.6	-0.5	-0.5	-0.5	-0.4	NA
Plan Irregularity, P_{L1}	-1.1	-1.0	-1.0	-0.8	-0.7	-0.9	-0.7	-0.6	-0.6	-0.8	-0.5	-0.7	-0.6	-0.7	-0.7	-0.4	NA
Pre-Code	-1.1	-1.0	-0.9	-0.6	-0.6	-0.8	-0.6	-0.2	-0.4	-0.7	-0.1	-0.5	-0.3	-0.5	-0.5	0.0	-0.1
Post-Benchmark	1.6	1.9	2.2	1.4	1.4	1.1	1.9	NA	1.9	2.1	NA	2.0	2.4	2.1	2.1	NA	1.2
Soil Type A or B	0.1	0.3	0.5	0.4	0.6	0.1	0.6	0.5	0.4	0.5	0.3	0.6	0.4	0.5	0.5	0.3	0.3
Soil Type E (1-3 stories)	0.2	0.2	0.1	-0.2	-0.4	0.2	-0.1	-0.4	0.0	0.0	-0.2	-0.3	-0.1	-0.1	-0.1	-0.2	-0.4
Soil Type E (> 3 stories)	-0.3	-0.6	-0.9	-0.6	-0.6	NA	-0.6	-0.4	-0.5	-0.7	-0.3	NA	-0.4	-0.5	-0.6	-0.2	NA
Minimum Score, S_{MIN}	*1.1*	*0.9*	*0.7*	*0.5*	*0.5*	*0.6*	*0.5*	*0.5*	*0.3*	*0.3*	*0.3*	*0.2*	*0.2*	*0.3*	*0.3*	*0.2*	*1.0*

FINAL LEVEL 1 SCORE, $S_{L1} \geq S_{MIN}$:

EXTENT OF REVIEW
Exterior: ☐ Partial ☐ All Sides ☐ Aerial
Interior: ☐ None ☐ Visible ☐ Entered
Drawings Reviewed: ☐ Yes ☐ No
Soil Type Source: ____________
Geologic Hazards Source: ____________
Contact Person: ____________

LEVEL 2 SCREENING PERFORMED?
☐ Yes, Final Level 2 Score, S_{L2} ________ ☐ No
Nonstructural hazards? ☐ Yes ☐ No

OTHER HAZARDS
Are There Hazards That Trigger A Detailed Structural Evaluation?
☐ Pounding potential (unless S_{L2} > cut-off, if known)
☐ Falling hazards from taller adjacent building
☐ Geologic hazards or Soil Type F
☐ Significant damage/deterioration to the structural system

ACTION REQUIRED
Detailed Structural Evaluation Required?
☐ Yes, unknown FEMA building type or other building
☐ Yes, score less than cut-off
☐ Yes, other hazards present
☐ No
Detailed Nonstructural Evaluation Recommended? *(check one)*
☐ Yes, nonstructural hazards identified that should be evaluated
☐ No, nonstructural hazards exist that may require mitigation, but a detailed evaluation is not necessary
☐ No, no nonstructural hazards identified ☐ DNK

Where information cannot be verified, screener shall note the following: EST = Estimated or unreliable data OR DNK = Do Not Know

Legend:	MRF = Moment-resisting frame	RC = Reinforced concrete	URM INF = Unreinforced masonry infill	MH = Manufactured Housing	FD = Flexible diaphragm
	BR = Braced frame	SW = Shear wall	TU = Tilt up	LM = Light metal	RD = Rigid diaphragm

Figure 1-1 RVS Level 1 Data Collection Form for High seismicity region.

Rapid Visual Screening of Buildings for Potential Seismic Hazards
FEMA P-154 Data Collection Form

Level 2 (Optional)
HIGH Seismicity

Optional Level 2 data collection to be performed by a civil or structural engineering professional, architect, or graduate student with background in seismic evaluation or design of buildings.

Bldg Name:	**Final Level 1 Score:**	S_{L1} =	*(do not consider S_{MIN})*
Screener:	**Level 1 Irregularity Modifiers:**	*Vertical Irregularity, V_{L1} =*	*Plan Irregularity, P_{L1} =*
Date/Time:	**ADJUSTED BASELINE SCORE:**	$S' = (S_{L1} - V_{L1} - P_{L1})$ =	

STRUCTURAL MODIFIERS TO ADD TO ADJUSTED BASELINE SCORE

Topic	**Statement** *(If statement is true, circle the "Yes" modifier; otherwise cross out the modifier.)*		**Yes**	**Subtotals**
Vertical Irregularity, V_{L2}	Sloping Site	W1 building: There is at least a full story grade change from one side of the building to the other.	-1.2	
		Non-W1 building: There is at least a full story grade change from one side of the building to the other.	-0.3	
	Weak and/or Soft Story *(circle one maximum)*	W1 building cripple wall: An unbraced cripple wall is visible in the crawl space.	-0.6	
		W1 house over garage: Underneath an occupied story, there is a garage opening without a steel moment frame, and there is less than 8' of wall on the same line (for multiple occupied floors above, use 16' of wall minimum).	-1.2	
		W1A building open front: There are openings at the ground story (such as for parking) over at least 50% of the length of the building.	-1.2	
		Non-W1 building: Length of lateral system at any story is less than 50% of that at story above or height of any story is more than 2.0 times the height of the story above.	-0.9	
		Non-W1 building: Length of lateral system at any story is between 50% and 75% of that at story above or height of any story is between 1.3 and 2.0 times the height of the story above.	-0.5	
	Setback	Vertical elements of the lateral system at an upper story are outboard of those at the story below causing the diaphragm to cantilever at the offset.	-1.0	
		Vertical elements of the lateral system at upper stories are inboard of those at lower stories.	-0.5	
		There is an in-plane offset of the lateral elements that is greater than the length of the elements.	-0.3	
	Short Column/ Pier	C1,C2,C3,PC1,PC2,RM1,RM2: At least 20% of columns (or piers) along a column line in the lateral system have height/depth ratios less than 50% of the nominal height/depth ratio at that level.	-0.5	
		C1,C2,C3,PC1,PC2,RM1,RM2: The column depth (or pier width) is less than one half of the depth of the spandrel, or there are infill walls or adjacent floors that shorten the column.	-0.5	
	Split Level	There is a split level at one of the floor levels or at the roof.	-0.5	
	Other Irregularity	There is another observable severe vertical irregularity that obviously affects the building's seismic performance.	-1.0	V_{L2} = ______
		There is another observable moderate vertical irregularity that may affect the building's seismic performance.	-0.5	*(Cap at -1.2)*
Plan Irregularity, P_{L2}	Torsional irregularity: Lateral system does not appear relatively well distributed in plan in either or both directions. *(Do not include the W1A open front irregularity listed above.)*		-0.7	
	Non-parallel system: There are one or more major vertical elements of the lateral system that are not orthogonal to each other.		-0.4	
	Reentrant corner: Both projections from an interior corner exceed 25% of the overall plan dimension in that direction.		-0.4	
	Diaphragm opening: There is an opening in the diaphragm with a width over 50% of the total diaphragm width at that level.		-0.2	
	C1, C2 building out-of-plane offset: The exterior beams do not align with the columns in plan.		-0.4	P_{L2} = ______
	Other irregularity: There is another observable plan irregularity that obviously affects the building's seismic performance.		-0.7	*(Cap at -1.1)*
Redundancy	The building has at least two bays of lateral elements on each side of the building in each direction.		+0.3	
Pounding	Building is separated from an adjacent structure by less than 1% of the height of the shorter of the building and adjacent structure and:	The floors do not align vertically within 2 feet. *(Cap total pounding modifiers at -1.2)*	-1.0	
		One building is 2 or more stories taller than the other.	-1.0	
		The building is at the end of the block.	-0.5	
S2 Building	"K" bracing geometry is visible.		-1.0	
C1 Building	Flat plate serves as the beam in the moment frame.		-0.4	
PC1/RM1 Bldg	There are roof-to-wall ties that are visible or known from drawings that do not rely on cross-grain bending. *(Do not combine with post-benchmark or retrofit modifier.)*		+0.3	
PC1/RM1 Bldg	The building has closely spaced, full height interior walls (rather than an interior space with few walls such as in a warehouse).		+0.3	
URM	Gable walls are present.		-0.4	
MH	There is a supplemental seismic bracing system provided between the carriage and the ground.		+1.2	
Retrofit	Comprehensive seismic retrofit is visible or known from drawings.		+1.4	*M* = ______

FINAL LEVEL 2 SCORE, $S_{L2} = (S' + V_{L2} + P_{L2} + M) \geq S_{MIN}$: *(Transfer to Level 1 form)*

There is observable damage or deterioration or another condition that negatively affects the building's seismic performance: ☐ Yes ☐ No
If yes, describe the condition in the comment box below and indicate on the Level 1 form that detailed evaluation is required independent of the building's score.

OBSERVABLE NONSTRUCTURAL HAZARDS

Location	**Statement** *(Check "Yes" or "No")*	**Yes**	**No**	**Comment**
Exterior	There is an unbraced unreinforced masonry parapet or unbraced unreinforced masonry chimney.			
	There is heavy cladding or heavy veneer.			
	There is a heavy canopy over exit doors or pedestrian walkways that appears inadequately supported.			
	There is an unreinforced masonry appendage over exit doors or pedestrian walkways.			
	There is a sign posted on the building that indicates hazardous materials are present.			
	There is a taller adjacent building with an unanchored URM wall or unbraced URM parapet or chimney.			
	Other observed exterior nonstructural falling hazard:			
Interior	There are hollow clay tile or brick partitions at any stair or exit corridor.			
	Other observed interior nonstructural falling hazard:			

Estimated Nonstructural Seismic Performance (*Check appropriate box and transfer to Level 1 form conclusions*)
☐ Potential nonstructural hazards with significant threat to occupant life safety → Detailed Nonstructural Evaluation recommended
☐ Nonstructural hazards identified with significant threat to occupant life safety → But no Detailed Nonstructural Evaluation required
☐ Low or no nonstructural hazard threat to occupant life safety → No Detailed Nonstructural Evaluation required

Comments:

Figure 1-2 RVS Level 2 Optional Data Collection Form for High seismicity region.

Basic Score by identifying and circling Score Modifiers. The Score Modifiers are related to observed performance attributes and are then added (or subtracted) to the Basic Score to arrive at a Final Score. A more detailed screening of the building can be documented by using the optional form presented on the second page of the Data Collection Form. This optional form allows the user to adjust the Final Score with additional Score Modifiers. Basic Scores, Score Modifiers, and Final Scores relate to the probability of building collapse, should a rare earthquake occur (that is, a ground shaking level equivalent to the Maximum Considered Earthquake (MCE) currently used in national design and evaluation standards for the evaluation of existing buildings). Final Scores typically range from 0 to 7, with higher scores corresponding to better expected seismic performance and a lower potential for collapse.

The entity that decides to conduct an RVS program may be a state legislature, city council, private company, school district, or other organization and is known as the "RVS Authority." Use of RVS on a community-wide basis enables the RVS Authority to divide screened buildings into two categories: those that are expected to have acceptable seismic performance, and those that may be seismically hazardous and should be studied further. A Final Score of 2 is suggested as a "cut-off," based on present seismic design criteria. Using this cut-off level, buildings with Final Score of 2 or less should be investigated by a design professional experienced in seismic design.

The procedure presented in this *Handbook* is meant to be the preliminary screening phase of a multi-phase procedure for identifying potentially hazardous buildings. Buildings identified by this procedure as potentially hazardous should be analyzed in more detail by an experienced seismic design professional. The RVS method identifies building attributes that may contribute to poor seismic performance, and conservative assumptions have been made in developing the methodology. However, because rapid visual screening is designed to be performed from the sidewalk, with interior inspection not always possible, hazardous details will not always be visible, and seismically hazardous buildings may not be identified as such. Conversely, buildings initially identified as potentially hazardous by RVS may prove to be adequate.

The methodology presented here can serve as an efficient step in assessing risk as part of a broader seismic risk-management program. Its cost is 15 to 75 minutes of inspection time for each building of interest, plus travel time between buildings, potentially several person-days of preparation time, and potentially several person-days to compile results into decision-making information. Its benefits can be much greater, potentially eliminating the need for detailed seismic analysis of a large fraction of the buildings in question. Each such detailed evaluation that is avoided can save hours, days, or more of effort by an engineering professional.

1.2 Screening Procedure Purpose, Overview, and Target Audience

The updated RVS procedure presented in this *Handbook* has been formulated to identify, inventory, and screen buildings that are potentially seismically hazardous. The target audience for the *Handbook* includes (1) those agencies or organizations that are considering conducting a rapid visual screening program; and (2) the screeners who will conduct the evaluations. The screeners can be civil engineers, structural engineers, architects, design professionals, building officials, construction contractors, firefighters, architectural or engineering students, or other individuals with general familiarity or background in building design or construction. The instructions in this *Handbook* are intended to minimize ambiguity and limit the need for judgment, making the methodology accessible to a wide array of potential screeners.

The RVS procedure can be implemented relatively quickly and inexpensively to develop a list of potentially seismically hazardous buildings without the high cost of performing a detailed seismic analysis of every individual building. If a building receives a high score (i.e., above a specified cut-off score), the building is considered to have adequate seismic resistance to prevent collapse during a rare earthquake. The building score reflects probability of collapse or partial collapse only (as defined in the sidebar), and is not meant to be an indicator of the probability that the building will be usable following an earthquake. If a building receives a low score on the basis of this RVS procedure, it should be evaluated by a design professional experienced in seismic design. On the basis of a detailed inspection, engineering analyses, and other detailed procedures, a final determination of the seismic adequacy and the need for retrofit can be made. Typically, an evaluation based on ASCE/SEI 41-13, *Seismic Evaluation and Retrofit of Existing Buildings* (ASCE, 2014), will be most appropriate for those buildings that require a Detailed Structural Evaluation. Identification of selected nonstructural hazards is included in the methodology. Where a Detailed Nonstructural Evaluation is recommended based on the results of the rapid visual screening, FEMA E-74, *Reducing the Risks of Nonstructural Earthquake Damage – A Practical Guide, Fourth Edition* (FEMA, 2012e), can be used.

Definition of Collapse

FEMA P-154 defines collapse probability as the probability that the building will suffer partial or complete collapse. In that part of the building, the gravity load-carrying system (such as beams, columns, floors, and shear walls) loses the ability to carry its own weight and the weight of whatever else it supports. That failure leads to severe structural deformation of a potentially life-threatening nature, especially falling of all or portions of a structure. A potentially seismically hazardous building is one where, within the accuracy of the RVS procedure, the collapse probability is estimated to be more than 1% in rare earthquake shaking (using the default cut-off score of 2.0). See FEMA P-155 Section 4.4.1 for further details.

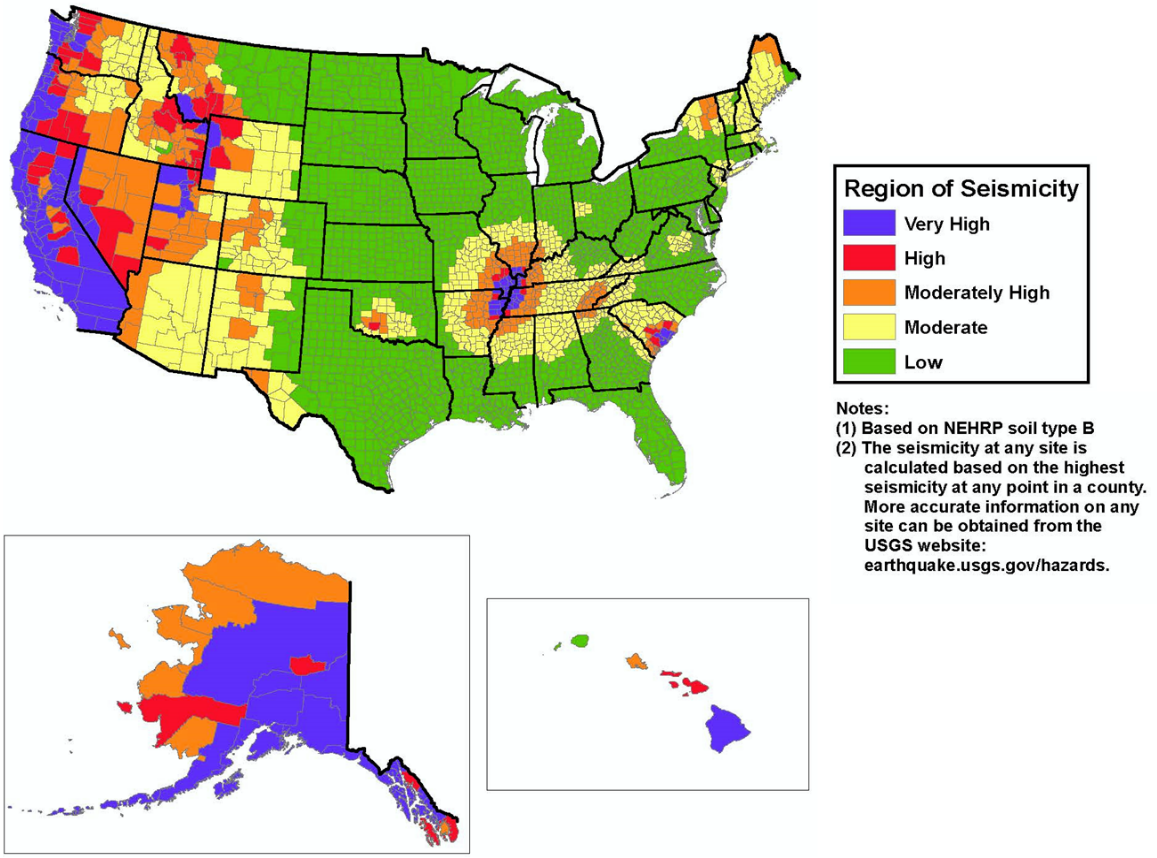
During the planning stage, which is discussed in Chapter 2, the RVS Authority will need to select both a Program Manager and a Supervising Engineer. The Program Manager oversees management and administration of the RVS program. The Supervising Engineer should be a structural engineer with a background in seismic evaluation. RVS programs have a wide range of goals, and constraints on budget, completion date, and accuracy, which must be considered when planning the program. For some RVS programs, it will be preferable to use more experienced design professionals as screeners.

The RVS procedure in this *Handbook* is designed to be implemented without performing structural analyses. The RVS procedure employs a scoring system that requires the screener to: (1) determine the building type by identifying the primary gravity load-carrying material of construction and the primary seismic force-resisting system; and (2) identify building attributes that modify the seismic performance expected of the respective average building type. Data collection and scoring typically will occur at the building site, taking an average of 15 to 30 minutes per building (additional time is needed if the interior is accessed or if a Level 2 screening is performed). Observations are recorded on one of five Data Collection Forms, depending on the seismicity of the region being surveyed. The Data Collection Forms, described in greater detail in Chapters 3 and 4, provide space for documenting building identification information, including its use and size, a photograph of the building, sketches, and documentation of pertinent data related to seismic performance.

Buildings may be reviewed from the sidewalk without the benefit of building entry, structural drawings, or structural calculations. Reliability and confidence in building attribute determination are increased, however, if the structural framing system can be verified during interior screening, or using construction documents.

The scores are based on average expected ground shaking levels for the seismicity region and are intended to reflect the seismic design and construction practices for that region. In general, there are little or no seismic design requirements in Low seismicity regions, limited seismic design requirements in Moderate seismicity regions, and extensive seismic design requirements in Moderately High, High, and Very High seismicity regions. Consequently, a building in a High seismicity region will have generally been constructed with more seismic resistance than a similar building in a Low seismicity region. Seismic design and construction practices, however, vary regionally and are not necessarily uniform across regions of similar seismic risk. Western states and particularly California have historically imposed stricter seismic design requirements sooner than other places, in large part because of greater awareness among design professionals. Moderately High, High, and Very High seismicity regions in other areas may have no seismic design provisions or may have only just recently adopted and begun to enforce seismic design provisions. The methodology provides Score Modifiers to adjust scores to reflect buildings built before seismic provisions were implemented (known as "pre-code") and after modern seismic provisions were required (known as the "benchmark" year). By identifying pre-code and benchmark years that accurately reflect the local design and construction practices, the RVS procedure can be implemented in any area (see Chapter 2 for further discussion of how the Supervising Engineer selects the pre-code and benchmark years).

In this edition, seismicity regions have been updated to consider risk-targeted Maximum Considered Earthquake (MCE_R) ground motions. These ground motions are described in more detail in FEMA P-155. Chapter 2 discusses determination of seismicity regions and Figure 1-3 provides a map of seismicity regions in the United States. Appendix A provides enlarged maps.



Notes:
(1) Based on NEHRP soil type B
(2) The seismicity at any site is calculated based on the highest seismicity at any point in a county. More accurate information on any site can be obtained from the USGS website: earthquake.usgs.gov/hazards.

Figure 1-3 Map showing Very High, High, Moderately High, Moderate, and Low seismicity regions in the United States. A different RVS Data Collection Form has been developed for each of these regions.

The RVS procedure is intended to be applicable nationwide, for all conventional building types. Bridges, large towers, and other non-building structure types, however, are not covered by the procedure. Because of budget or other constraints, some RVS Authorities may wish to restrict their RVS to identifying only selected building types that they consider potentially hazardous, such as unreinforced masonry or nonductile concrete buildings, or critical, such as schools. If an RVS program is limited to only select building types, it is possible that some potentially hazardous buildings may not be identified.

1.3 Role of FEMA 154 in the Spectrum of Seismic Evaluation Tools

The *Handbook* was originally developed as an integral and fundamental part of the FEMA report series on seismic safety of existing buildings. In the 26 years since the initial publication, the documents that were part of the original FEMA report series have been updated. In addition, the Applied Technology Council (ATC), the American Society of Civil Engineers (ASCE), and the National Institute of Building Sciences (NIBS) have also developed documents that address seismic safety of existing buildings. The following is a list of publications intended for use by design professionals and others as part of a program to mitigate the damaging effects of earthquakes on existing buildings:

- ASCE/SEI 41-13 provides both procedures to evaluate the seismic force-resisting capacity of buildings and recommended procedures for the seismic retrofitting of buildings with inadequate seismic capacity. The ASCE/SEI 41-13 procedure includes three tiers of evaluation and is ideal for those buildings that require a Detailed Structural Evaluation. Previously, evaluation was covered by ASCE/SEI 31-03, *Seismic Evaluation of Existing Buildings* (ASCE, 2003), and recommended retrofitting procedures, along with more in-depth evaluation procedures were contained in the separate ASCE/SEI 41-06 standard, *Seismic Evaluation and Retrofit of Existing Buildings* (ASCE, 2007). ASCE/SEI 31 was an updated version of FEMA 310, *Handbook for Seismic Evaluation of Buildings - A Prestandard* (FEMA, 1998), which in turn was an update of the original FEMA 178 report, *NEHRP Handbook for the Seismic Evaluation of Existing Buildings* (FEMA, 1992). ASCE/SEI 41 began as an updated version of FEMA 356, *Prestandard and Commentary for the Seismic Retrofit of Buildings* (FEMA, 2000b), which was in turn an update of FEMA 273, *NEHRP Guidelines for the Seismic Rehabilitation of Buildings* (FEMA, 1997a).

- FEMA P-58-1, *Seismic Performance Assessment of Buildings, Volume 1 – The Methodology* (FEMA, 2012d), is the initial volume in a series of publications that document a sophisticated "methodology for seismic performance assessment of individual buildings that properly accounts for uncertainty in accurately predicting response, and communicates performance in ways that better relate to the decision-making needs of stakeholders. The procedures are probabilistic, uncertainties are explicitly considered, and performance is expressed as the probable consequences, in terms of human losses (deaths and serious injuries), direct economic losses (building repair or replacement costs), and indirect losses (repair time and unsafe placarding) resulting from building damage due to earthquake shaking."

- HAZUS-MH is FEMA's nationally applicable software program that estimates potential building and infrastructure losses from earthquakes, riverine and coastal floods, and hurricane winds using methodology documented in the *Multi-Hazard Loss Estimation Methodology, Earthquake Model, HAZUS-MH MR4 Technical Manual* (FEMA, 2009a). HAZUS can be used to inform decision-making at all levels of government by providing a reasonable basis for developing mitigation, emergency preparedness, and response and recovery plans and policies.

- FEMA 547 report, *Techniques for the Seismic Rehabilitation of Existing Buildings* (FEMA, 2006), provides a comprehensive discussion of common techniques for seismic retrofitting, with extensive figures and advice on detailing.

- FEMA P-50 report, *Simplified Seismic Assessment of Detached, Single-Family, Wood-Frame Dwellings* (FEMA, 2012a), uses a simplified seismic assessment form to evaluate detached, single-family, wood-frame dwellings, and to assign each a grade that represents expected performance in future damaging earthquakes.

- FEMA P-50-1 report, *Seismic Retrofit Guidelines for Detached, Single-Family, Wood-Frame Dwellings* (FEMA, 2012b), provides practical information on retrofit measures to improve the earthquake resistance of a particular home.

- FEMA P-807 report, *Seismic Evaluation and Retrofit of Multi-Unit Wood-Frame Buildings with Weak First Stories* (FEMA, 2012c), provides guidance for evaluation and cost-effective retrofit procedures for wood buildings with weak ground stories.

- FEMA E-74 explains the sources of nonstructural earthquake damage in simple terms and provides methods for reducing potential risks. FEMA E-74 is ideal where a Detailed Nonstructural Evaluation is recommended based on the results of the rapid visual screening.

Additional publications exist to evaluate and repair buildings damaged in earthquakes. They include the following:

- ATC-20-1, *Field Manual: Postearthquake Safety Evaluation of Buildings* (ATC, 2005), provides a procedure to evaluate earthquake-damaged buildings and post them as INSPECTED (no occupancy restriction, green placard), RESTRICTED USE (yellow placard), or UNSAFE (red placard). This procedure has two tiers for conducting rapid and detailed evaluations.
- FEMA 352, *Recommended Postearthquake Evaluation and Repair Criteria for Welded Steel Moment-Frame Buildings* (FEMA, 2000a), provides guidance for evaluation and repair of damaged steel moment frame structures.
- FEMA 306, *Evaluation of Earthquake Damaged Concrete and Masonry Wall Buildings: Basic Procedures Manual* (FEMA 1999a), provides guidance for evaluating earthquake damage to concrete and masonry wall buildings. FEMA 307, *Evaluation of Earthquake Damaged Concrete and Masonry Wall Buildings: Technical Resources* (FEMA, 1999b), provides technical background to FEMA 306. FEMA 308, *The Repair of Earthquake Damaged Concrete and Masonry Wall Buildings* (FEMA, 1999c), provides guidance for the repair and retrofit of concrete and masonry wall buildings damaged in earthquakes.
- ATC-52-4, *Here Today—Here Tomorrow: The Road to Earthquake Resilience in San Francisco: Post-Earthquake Repair and Retrofit Requirements* (ATC, 2010), provides guidance for evaluating damage and determining repair and retrofit requirements for single family residences, multi-story multi-unit wood frame residential structures, and older concrete buildings. Though developed for San Francisco, the report has information and recommendations that can be applied to other seismically active areas.

Table 1-1 provides a simplified comparison of these seismic evaluation methods with respect to the time required to perform the evaluation, the relative cost, and the qualifications needed to perform the evaluation.

Table 1-1 Comparison of Prominent Seismic Evaluation Methods in the United States

Undamaged Buildings	FEMA P-154	ASCE/SEI 41 Tier 1	ASCE/SEI 41 Tier 2	ASCE/SEI 41 Tier 3 FEMA P-807 FEMA P-58 HAZUS
Earthquake-Damaged Buildings	ATC-20 Rapid	ATC-20 Detailed	FEMA 352 ATC-52-4	FEMA 306 ATC-52-4
Time Required	Minutes	Hours	Days	Weeks
Relative Cost	$	$$	$$$	$$$$
Qualifications	Properly trained building professionals (see Section 2.2)	Structural engineers experienced in seismic evaluation and design		

1.4 History of FEMA 154

Rapid visual screening of buildings for potential seismic hazards was discussed in a series of papers contained in *Techniques for Rapid Assessment of Seismic Vulnerability* (Scawthorn, 1986). The FEMA 154 methodology originated soon after in 1988 with the publication of the FEMA 154 report, *Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook* (FEMA, 1988a).

During the decade following publication of the first edition of the FEMA 154 *Handbook*, the RVS procedure was used by private-sector organizations and government agencies to evaluate more than 70,000 buildings nationwide (FEMA, 2002b). Through this widespread application, knowledge was gained about who the likely users of the RVS procedure are and why they use it, the ease-of-use of the *Handbook*, and the accuracy of the procedure's scoring system.

Concurrent with the widespread use of the document, damaging earthquakes occurred in California and elsewhere, and extensive research and development efforts were carried out under the National Earthquake Hazards Reduction Program (NEHRP). These efforts yielded important new data on the performance of buildings in earthquakes, and on the expected distribution, severity, and occurrence of earthquake-induced ground shaking.

The data and information gathered during the first decade after publication (experience in applying the original *Handbook*, new building earthquake performance data, and new ground shaking information) were used to update and improve the rapid visual screening procedure provided in the second edition of the FEMA 154 report, *Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook* (FEMA, 2002a). The procedure in the *Second Edition* retained the same framework and approach of the original procedure, but incorporated a revised scoring system compatible with the ground motion criteria in the FEMA 310 report and the damage and loss estimation methodology provided in the then recently developed FEMA-funded *HAZUS Technical Manual* (FEMA, 1999d).

The Basic Scores (referred to in the *Second Edition* as "Basic Structural Hazard Scores") and Score Modifiers were updated using analytical calculations and HAZUS fragility curves for the building types considered by the RVS methodology. As in the original *Handbook*, a Data Collection Form was provided for each of three seismicity regions: Low, Moderate, and High. However, the boundaries of the Low, Moderate, and High seismicity regions identified in the previous version of the *Handbook* were modified based on new knowledge on the expected distribution, severity, and occurrence of earthquake ground shaking. In addition, the recurrence interval was changed from a 475-year average return period (corresponding to ground motions having a 10% probability of exceedance in 50 years) to two-thirds of the values from a 2,475-year average return period (corresponding to ground motions having a 2% probability of exceedance in 50 years).

The second edition of the *Handbook* was also shortened from the original and focused to facilitate implementation. It included guidance on planning and managing an RVS survey and provided additional guidance for identifying the structural (seismic force-resisting) system. The Data Collection Form was revised to document soil type, falling hazards, and an expanded list of occupancy types.

FEMA has conducted training on the second edition of FEMA 154 through the National Earthquake Training Assistance Program (NETAP).

1.5 Third Edition Updates to FEMA 154

This third edition of FEMA P-154 comes about after the second decade of extensive use of the procedure, which has identified several areas of necessary enhancement. The *Third Edition* also takes into consideration the evolution of computer-aided tools for more efficient implementation of the procedure.

Major enhancements in the *Third Edition* include the following:

- The Data Collection Form (Level 1) has been reorganized to enhance usability.
- An optional Level 2 Data Collection Form has been added. The goal of the Level 2 screening is to obtain valuable additional information and a more accurate assessment without a substantial increase in effort or time.

It is still a rapid visual screening, but relies on further information gathered by an experienced engineer or architect.

- The number of seismicity regions has been expanded from three to five to increase accuracy of screening in higher seismicity regions. The *Third Edition* seismicity regions are based on MCE_R ground motions (rather than the two-thirds of MCE ground motions that were used in the *Second Edition*).
- All Basic Scores and Score Modifiers have been updated.
- Reference guides for identifying vertical and plan irregularities are now provided to guide the screeners in determining whether irregularities exist, reducing ambiguity and limiting the need for judgment. Additional figures have been added to the document to help illustrate various irregularities. Score Modifier values now vary depending on the severity of the irregularity.
- Large multi-unit, multi-story wood frame residential and manufactured housing building types have been added.
- The screening procedure for nonstructural hazards has been enhanced.
- The occupancy classes have been updated to align better with those in the *HAZUS-MH MR4 Technical Manual* (FEMA, 2009a) and the 2012 *International Building Code* (ICC, 2012).
- Pounding and adjacency are now considered.
- Better guidance for screening buildings with additions is provided.
- Consideration of existing retrofits has been included on the Level 2 Data Collection Form.
- A minimum score has been included on the Data Collection Form to address negative scores.
- An optional electronic scoring methodology has been provided, and FEMA P-154 *Rapid Observation of Vulnerability and Estimation of Risk* (ROVER) software (FEMA, 2014b) is discussed.
- Additional information has been provided on how to run an effective RVS program, including required and optional tasks and associated resources needs.
- Additional discussion on how to use the results of RVS for advocacy has been added.

1.6 Rapid Visual Screening Procedures

The Data Collection Form used for rapid visual screening has now been extended with an optional second page, where the first page represents a Level 1 screening and the second page represents an optional Level 2 screening. The Level 1 screening is similar to the procedure used in the second edition of the *Handbook*, with the same objectives and the same general level of expertise required from the screeners. The Level 2 screening is more detailed than the Level 1 screening, and requires greater expertise to complete, but it is still rapid and visual. In both levels, the screener fills out the form and determines a score for the building. This score provides an indication of the expected seismic performance of the building. The Level 2 score can be higher than the Level 1 score (indicating less seismic risk), because Score Modifiers within the Level 1 screening score have more conservative values. In some instances, the Level 2 score can be lower than the Level 1 score, because the Level 2 screening evaluates some items in more detail and includes some items not covered by the Level 1 screening. For both levels, the screeners require training, and, for quality assurance purposes, the screening program must be overseen by a design professional knowledgeable in seismic design, evaluation, and risk assessment.

There are five versions of each form, one each for regions of Low, Moderate, Moderately High, High, and Very High seismicity. The forms for Moderate, Moderately High, High, and Very High seismicity regions vary only in the values assigned to the Basic Scores and Score Modifiers and in the criteria used to assess pounding.

1.7 Optional Electronic Scoring

Data Collection Forms have been set up to be used as paper forms with simple arithmetic to determine a score for the building. This *Third Edition* also introduces an optional use of electronic scoring. There are a number of alternative methods that can be developed to implement electronic scoring for RVS, as described in Chapter 6. The use of electronic scoring is intended to improve the process by reducing errors when transferring data and to allow for more refinement in the scoring based on site-specific seismic hazard and soil information.

1.8 Using ROVER to Perform RVS

FEMA P-154 *Rapid Observation of Vulnerability and Estimation of Risk* (ROVER) software developed by the Applied Technology Council (ATC) for FEMA (2014) is free mobile software for pre- and post-earthquake building safety screening. Its pre-earthquake module implements FEMA 154 *Second*

Edition procedures and automates several RVS tasks. ROVER is platform-independent, currently operating through a web browser on Android, iPad, Blackberry, Windows Phone, or any web-connected smart device (smartphone, tablet, or other device with a browser).

Data are entered through the browser and transmitted to a secure, web-accessible server that is controlled by the user or optionally by a web service provider. The web server places the FEMA 154 RVS data into a database that allows for access to the data by the screener or other authorized person. Field data can be entered into the database either directly through the smart device's browser, or collected on paper forms and manually transcribed later into the database through a web browser. At the time of the preparation of the FEMA P-154 *Third Edition*, data entry into the web browser closely resembled the FEMA 154 *Second Edition* paper form with the addition that FEMAP-154 ROVER provides the following capabilities: geolocation, digital photos, automated site-specific hazard and soil lookup, automatic score calculation, integration with HAZUS-MH, ShakeCast, ATC-20, and user data files.

FEMA P-154 ROVER can be acquired on CD from the FEMA warehouse or downloaded from www.roverready.org. It is recommended that the reader check the website for the latest updates on FEMA P-154 ROVER, which may have since evolved. FEMA offers FEMA P-154 ROVER training in addition to FEMA 154 training through NETAP.

1.9 Uses of RVS Survey Results

While the principal purpose of the RVS procedure is to identify potentially seismically hazardous buildings needing further evaluation, results from RVS surveys can also be used for other purposes. These include: (1) evaluating a community's or agency's seismic retrofitting needs; (2) designing seismic hazard mitigation programs for a community or agency; (3) developing inventories of buildings for use in monitoring buildings for earthquake impacts or for facilitating earthquake damage and loss assessments; (4) planning post-earthquake building safety evaluation efforts; and (5) developing building-specific seismic vulnerability information for purposes such as insurance rating, decision making during building ownership transfers, and possible triggering of remodeling requirements during the permitting process. Chapter 2 discusses development of an RVS program, including establishment of goals and objectives. Additional discussion on the use of RVS survey results, including a discussion on using the survey results for seismic advocacy, is provided in Chapter 5.

1.10 Advantages and Limitations of the RVS Method

The RVS method described in this *Handbook* has a number of advantages as well as limitations that need to be understood when developing and implementing a screening program, and when using the results.

1.10.1 Advantages

The primary advantages of the RVS method are speed and ability to use screeners who are not necessarily structural engineers. The procedure in this *Handbook* has been designed to minimize ambiguity and limit the need for judgment by the screeners. As noted above, it fills a unique niche in the spectrum of available seismic evaluation tools, as other tools require greater effort, expertise, and cost. Because screening can be done quickly, large portfolios of buildings can be evaluated in a cost effective manner. The method has also been used by many different people and jurisdictions throughout the United States for over 25 years. As a result, it has had a long track record of actual use and opportunities for scrutiny and improvement, including both the second and third edition updates.

1.10.2 Limitations

The RVS method's primary advantage relates to its intrinsic limitations. Limited review—often only from the exterior, typically without the benefit of drawing review, and without calculation—means the accuracy of the RVS method is anticipated to be less than that of more detailed, time consuming, and expensive reviews. Determining the seismic force-resisting system is integral to the method (and to any seismic evaluation). It is likely that for a relatively small percentage of buildings in any screening program, the seismic force-resisting system cannot be identified by a rapid visual screening because the structure will be covered by architectural finishes. A Detailed Structural Evaluation will be required to determine the building type.

An interior review is desirable, but not always possible given either the available time or access limitations. As such, interior hazards can be missed, and an understanding of the structural system and some of its deficiencies is necessarily limited.

In more detailed evaluation methods, drawings are reviewed and calculations are done, providing a more refined understanding of the individual building's structural characteristics. With drawing review, it may be possible to spot deficiencies known to be of concern that cannot be seen in a rapid visual screening. Seismic evaluation calculations determine the relationship between demands on members and their associated capacities and whether they are expected to have more desirable ductile behaviors or less desirable nonductile behaviors. The RVS method does not include calculations, so assessments of seismic capacity are based on more general considerations related to building type, geometric irregularities, and site soil conditions.

Because large numbers of buildings are often screened and the level of expertise can vary widely, errors are inevitable. It is essential to have a thorough quality assurance program to minimize the extent of the errors. Given the large data collection effort and the potential flexibility in program goals, it is important to manage the program thoughtfully and with organizational skill to derive the most efficient use of personnel and to organize the collected information in the most useful way.

This *Handbook* provides advice in the following chapters to help minimize the limitations of the method so that the program can be as successful as possible.

1.11 Companion FEMA P-155 Report

The companion volume to this report, *Rapid Visual Screening of Buildings for Potential Seismic Hazards: Supporting Documentation (Third Edition)* (FEMA P-155) documents the technical basis for the RVS procedure described in this *Handbook*. The third edition of FEMA P-155 provides the basis for the updated Basic Scores and Score Modifiers and the basis for the updated criteria for considering pounding and building additions in the RVS procedure. It also provides an explanation of the risk associated with RVS scores.

1.12 Organization of This *Handbook*

The *Handbook* has been designed to facilitate the planning and execution of a rapid visual screening program. It is assumed that the RVS Authority has already decided to conduct the survey, and that detailed guidance is needed for all aspects of the surveying process. Therefore, the main body of the *Handbook* focuses on the three principal activities in the RVS procedure: planning, execution, and data interpretation. Chapter 2 contains detailed information on planning and managing an RVS program. Chapter 3 describes in detail how to complete the Level 1 Data Collection Form, and Chapter 4 describes in detail how to complete the optional Level 2 Data Collection Form. Chapter 5 provides guidance on interpreting and using the RVS results. Chapter 6 describes how to use optional electronic scoring. Finally, Chapter 7 provides example applications of the RVS procedure on sample buildings.

Relevant seismic hazard maps are provided in Appendix A. Full-sized Data Collection Forms and the Reference Guides (including the Quick Reference Guide and reference guides for irregularities, additions, and pounding), are provided in Appendix B. Guidance for reviewing design and construction drawings are provided in Appendix C and additional guidance for identifying a building's seismic force-resisting system from the street are provided in Appendix D. Appendix E provides additional information on the building types considered in the RVS procedure, and Appendix F provides guidance for assessing damage and deterioration of common building materials. Appendix G provides an overview of earthquake fundamentals, the seismicity of the United States, and earthquake effects.

Chapter 2

Planning and Managing a Successful Rapid Visual Screening Program

2.1 Planning and Implementing an RVS Program

Once the decision to conduct rapid visual screening (RVS) for a community or group of buildings has been made by the RVS Authority, the screening effort can be expedited by planning and careful overall management of the process. This chapter provides detailed information on important planning and management aspects of conducting an RVS program, including a description of the overall screening implementation sequence. Instructions on how to complete the Data Collection Forms are provided in Chapters 3 and 4.

"RVS Authority" refers to the entity that has made the decision to perform an RVS program. Examples of RVS Authorities include state legislatures, city councils, school districts, and private building owners.

There are several steps involved in planning a successful RVS program. As a first step, the RVS Authority should define the goals and objectives of the RVS program and describe how the RVS results will be used. The RVS Authority should then select a Program Manager to manage the program and a Supervising Engineer to provide the technical expertise necessary to conduct an RVS program. Next, the Program Manager, in consultation with the Supervising Engineer, should define the scope of the project. Defining the scope is done in conjunction with and concurrent to developing the project budget. Scope issues, such as deciding how many buildings will be screened, screener resources and experience, and whether Level 2 screenings will be performed, have a direct impact on the budget. Coordination is required to bring the project scope and the budget in line with one another.

Once the project scope and the project budget have been defined by the Program Manager and approved by the RVS Authority, implementation of the RVS program continues with additional pre-field activities, such as the following:

- Pre-field planning, including selection and development of a record-keeping system, development of electronic scoring tools (if desired), and compilation and development of maps that document local seismic hazard information,

- Selection of the Data Collection Form based on the seismic hazard and review and modification of the Data Collection Form for the individual needs of the RVS program,
- Selection and training of screening personnel,
- Acquisition and review of pre-field data, including review of available building files and databases to collect existing information on the buildings to be screened (e.g., address, lot number, number of stories, design date) and identifying soil types for the survey area, and
- Review of existing building plans, if available.

Following the completion of these pre-field activities, field screening of individual buildings is performed (see Chapters 3 and 4 for details). The RVS program concludes after the screening data are checked for quality and the screening results are filed in the record-keeping system or database. The RVS Authority can then use the RVS results for decision making.

The general sequence of implementing the RVS procedure is depicted in Figure 2-1.

2.2 Selecting the RVS Program Manager and the Supervising Engineer

The RVS Authority determines who will manage the RVS program. The Program Manager is responsible for defining the program scope, developing the program budget, and overseeing implementation of the screening program. The Program Manager must be knowledgeable about RVS and capable of managing the project. Whether the RVS Authority decides to manage the program itself or whether it decides to hire an outside consultant will depend on the capabilities of the RVS Authority, as well as the size and complexity of the program. If the RVS Authority is a building department, for example, it may be possible for individuals within the department to manage the program. If the RVS Authority is a state legislature, on the other hand, it will be desirable to hire a consultant to manage the program or assign the task to a qualified technical branch of government.

A Supervising Engineer is also required to run a successful RVS program. The Supervising Engineer should be a local practicing structural engineer with a background in seismic evaluation and risk assessments. The Supervising Engineer should ideally also have experience with the FEMA RVS methodology. If the Supervising Engineer is not knowledgeable about the technical basis of FEMA P-154, he or she should become so by reviewing both FEMA P-154 and FEMA P-155.

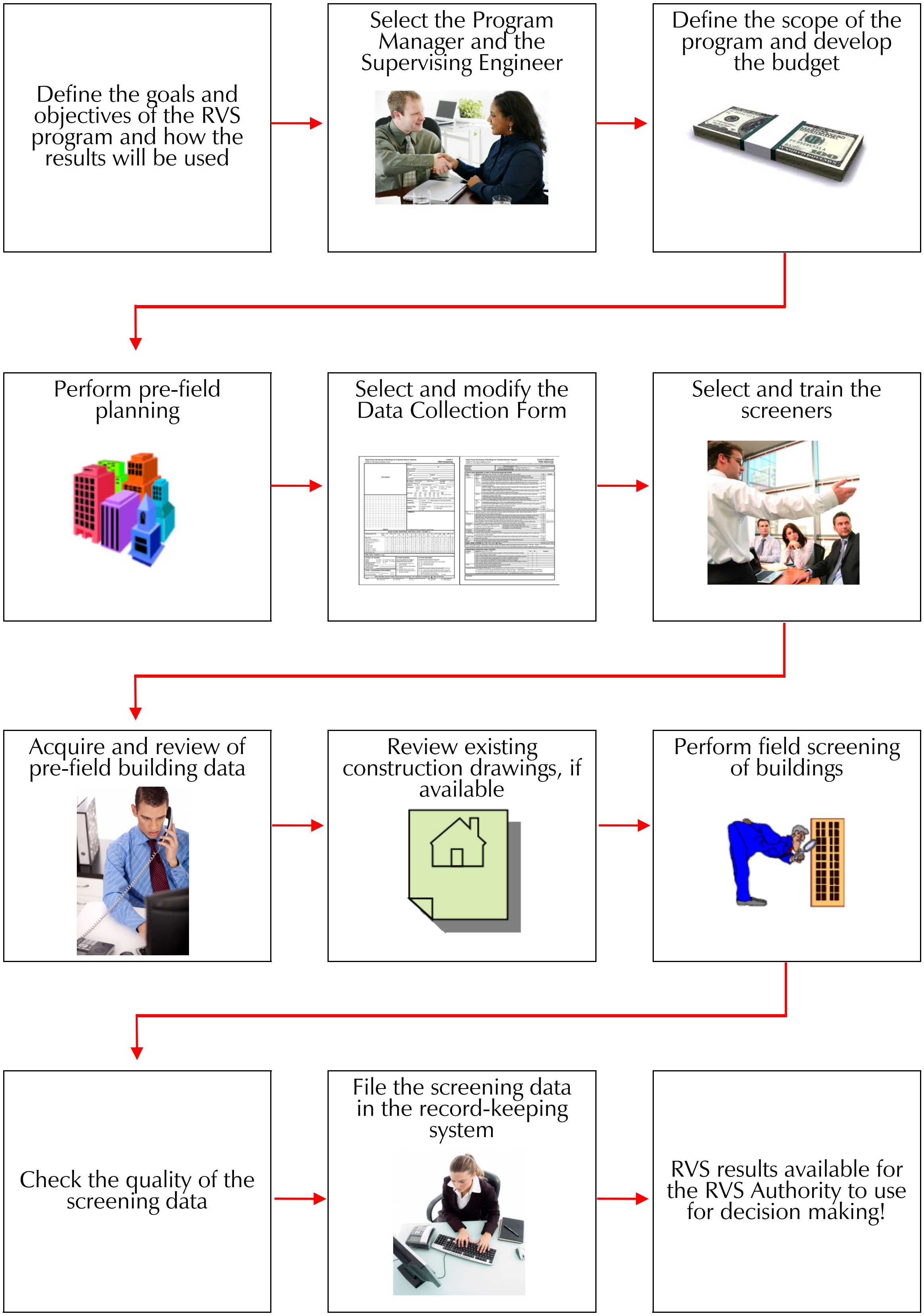


Figure 2-1 Rapid visual screening implementation sequence.

In addition to overall quality assurance, the Supervising Engineer has the following responsibilities:

- Selecting and modifying the Data Collection Form,
- Determining key seismic code adoption dates for the area being screened,
- Determining benchmark years for the area being screened,
- Determining the cut-off score to be used in concert with the RVS Authority and Program Manager,
- Training the screeners (alternatively, training courses may be available through FEMA),
- Being available for the screeners to consult with during the field screenings,
- Reviewing the completed forms, and
- Providing assistance in interpreting the results of the RVS screening.

If the Program Manager is an experienced structural engineer, he or she can perform the role of Supervising Engineer.

Table 2-1 provides a description of the key players in an RVS program, including the roles and responsibilities of each, as well as the recommended qualification for each position.

2.3 Defining the Scope of the RVS Program

Defining the scope of an RVS program involves many choices. This section presents some of the most important choices and describes the consequences of various decisions. Decisions generally vary based on the goals and objectives of individual programs and the resources available.

If the RVS program is to be a public or community project, the local governing body and local building officials should formally approve of the program plan and general procedure. Then, the public or the members of the community should be informed about the purpose of the screening process and how it will be carried out.

2.3.1 Determining Resources Needed for the RVS Program

Understanding the intended end uses of an RVS program before developing a project scope and budget is imperative.

Table 2-1 Key Players in an RVS Program

Entity	Description	Examples	Qualifications	Responsibilities
RVS Authority	Entity that has decided to conduct an RVS program and will use the results.	State legislature, city council, school district, private building owner.	Has authority to conduct an RVS program.	Sets the goals and objectives of the program and describes how the results will be used. Chooses the Program Manager and the Supervising Engineer. Approves the plan developed by the Program Manager.
Program Manager	Entity that will manage the RVS program on behalf of the RVS Authority.	Building department, qualified technical branch of government, outside consultant.	Knowledgeable about RVS. Capable of managing the project.	Defines the scope of the program and develops the budget. Oversees implementation of the screening program. Allocates screener resources to ensure efficient use of their time and minimize travel time. Program Manager likely has administrative staff to develop the record keeping system, conduct the pre-field data collection, and perform data entry.
Supervising Engineer	Individual who will provide the technical expertise necessary to run the RVS program.	Structural engineer (may be the Program Manager).	Structural engineer with a background in seismic evaluation and risk assessments. Understands RVS methodology and its technical basis as described in FEMA P-155.	Selects and modifies the Data Collection Form. Determines the key seismic code adoption dates and benchmark years. Determines cut-off score (with RVS Authority and Program Manager). May train the screeners. Available for screeners to consult with during field screening. Reviews completed forms. Assists in interpreting the results of the program.
Level 1 Screener	Individual who will conduct Level 1 screenings of buildings.	Civil or structural engineer, architect, design professional, building official, construction contractor, facility manager, firefighter, architectural or engineering student, or another individual with a general familiarity or background in building design or construction.	Receives appropriate FEMA P-154 training.	Performs Level 1 field screening.
Level 2 Screener	Individual who will conduct both Level 1 and Level 2 screenings of buildings.	Civil or structural engineering professional, architect, or graduate student with background in seismic evaluation or design of buildings.	Receives appropriate FEMA P-154 training.	Performs Level 1 and Level 2 field screenings.

If the RVS program will be used to help establish a hazardous building mitigation program for a community, then the information obtained in the RVS should be as complete as possible. This would benefit the RVS Authority in establishing the scope and need of such a mitigation program and will lend a high degree of confidence that decisions are based on the best available information regarding the seismic vulnerability of the buildings. In this case, a thorough search for building information during the pre-field planning stage will be warranted and should be budgeted for accordingly.

Other uses for RVS may include getting order-of-magnitude results to help focus concerns on vulnerable buildings. This could be accomplished without spending resources to research building information and instead rely on field determination of building type and age. In this type of program, the Supervising Engineer's quality assurance effort may be larger so that the information recorded by the screeners can be checked.

If the RVS Authority plans to notify owners of low-scoring buildings and either inform them of the building risk or possibly even require the owner to comply with an ordinance, the administrative costs of running the program will be more than if the screening program is used solely for potential seismic damage estimation. This is because the notification process, as well as increased quality assurance efforts, will require additional resources.

In general, an RVS program will offer an opportunity to collect valuable information about nonstructural features of buildings. Although deemed very important in high seismic regions, in areas of low seismicity, nonstructural hazards are typically less significant, but they can be important for life-safety considerations in a large rare earthquake. Heavy exterior cladding and parapets have dislodged during past earthquakes and killed passers-by. Nonstructural ceilings, light fixtures, heavy cabinets, and shelves can also injure occupants and block exitways. Glass shards from untempered windows and doors can also be hazardous, particularly if located near emergency exits. Failure of nonstructural components has also been shown to cause delays in helping communities return to normal functionality.

2.3.2 Deciding Which Buildings to Screen

The RVS Program Manager may decide that because of budget, time, or other constraints, priorities should be set and certain areas within the region should be surveyed immediately, whereas other areas can be surveyed at a later time because they are assumed to be less hazardous. An area may be selected because it contains an older building stock and may have a higher density of potentially seismically hazardous buildings relative to other areas. For example, an area with older buildings within the RVS Authority region that consists mainly of unreinforced masonry buildings may be of higher priority than a newer area with mostly warehouse facilities, or a residential section of a city consisting of wood frame single-family dwellings.

The Program Manager may also decide that only buildings with certain attributes, such as a particular building type or occupancy, will be screened. For example, it may be decided to screen only school buildings.

2.3.3 Combining Level 1 and Level 2 Screening

A Level 1 screening is performed for each building considered within the RVS program. The optional Level 2 screening collects information about additional structural features affecting risk and provides refined Score Modifiers. A background in seismic evaluation or seismic design of buildings is needed in order for the screener to be able to identify these additional features.

Performing the Level 2 screening adds cost because the Level 2 screening adds additional time, and the screener must be a structural engineer or other qualified professional (see Table 2-1). If the Level 2 screening occurs at the same time as the initial Level 1 screening, the added time per building is typically around 5-15 minutes. If the Level 2 screening is a follow-up to an earlier Level 1 screening, the added time per building is much greater because travel time must be repeated, and the Level 2 screener may need to redo the Level 1 screening. Hourly compensation for Level 2 screeners may be higher because of their necessary qualifications.

Various permutations of Level 1 and Level 2 screenings are described below.

- *Level 1 only.* In this approach, only Level 1 screenings are performed. This type of program will maximize the potential number of buildings screened at a minimum cost point. Screener qualifications are lower for Level 1 screeners, increasing the potential pool of participants. This may increase the need for additional Supervising Engineer review time to validate the results from Level 1 screeners.
- *Level 1 with Level 2 on higher priority buildings.* The added cost of the Level 2 screening is reserved for high priority buildings. High priority buildings are those with certain attributes, such as a particular building type or occupancy as identified during pre-field activities. This program will yield valuable Level 2 information on previously selected high priority buildings for a minimal additional cost.
- *Level 1 with Level 2 as part of a second round on a subset of buildings.* A follow-up screening with Level 2 is performed for buildings based on building type or the building's Final Score as determined by the Level 1 screening. For example, a subset of the total portfolio of buildings may be established from buildings with Final Scores within a given range

above and below the cut-off score. Level 2 screenings of these particular buildings may change the action required from “No Detailed Stuctural Evaluation Required” to “Detailed Structural Evaluation Required,” or vice versa. The added cost of the Level 2 screening per building is more than it would be if it were performed as part of the first round of screening because familiarization with the building, travel time, and the Level 1 review may need to be repeated. An advantage is that the number of detailed evaluations required may be reduced, benefiting the overall project results.

- *Level 1 and Level 2 for all buildings.* This option requires that all members of the screening team be structural engineers or other qualified professionals. If the RVS Authority has few buildings to screen or a large budget with which to screen them, and experienced engineers are available to perform the screenings, it may be appropriate to perform both Level 1 and Level 2 screenings of all the buildings. Although this approach will likely lead to the most accurate results, it will likely come with the highest cost as well. With a fixed budget, this may mean fewer buildings can be screened.

Some programs may wish to conduct screening programs that are as simple as possible, and may wish to base screening scores solely on the Basic Score associated with each building being screened, or similarly, the Minimum Score. This simplified approach is not recommended and is not expected to provide the RVS Authority with meaningful or accurate data on the seismic hazard of their building stock.

2.3.4 Determining Screeners

Potential RVS screeners for Level 1 range from individuals with a general familiarity or background in building design or construction to experienced engineers and architects. Engineers and architects are likely to be more costly on an hourly basis than nonprofessionals, but this cost may be offset by the efficiency of the screener in the field, and the increased accuracy of the screenings, which in turn reduces the Supervising Engineer’s effort. Of course, if the decision has been made to perform Level 1 and Level 2 screenings of all buildings at the same time, then all the screeners must be engineers or other qualified professionals.

Level 1 screeners should be generally familiar with the design and construction of buildings. This could include knowledge or hands-on experience with the structural elements of a building or historical interest in building materials or construction practices. All Level 1 and Level 2 screeners should receive the appropriate amount of FEMA P-154 training to help ensure competency.

2.3.5 Extent of Pre-Field Data Collection

Pre-field data can include building information stored in assessor, building department, or municipal files, as well as data from Sanborn maps, previous studies, soils information, and construction documents. Data collection can be time consuming; however, it can be extremely useful in reducing the total field time and can increase the reliability of data collected in the field. A good example of valuable pre-field data is the age, or design date of a building. This might be readily available from building department files but is much more difficult to estimate from the street. Another example is the FEMA Building Type, which is often concealed behind architectural finishes. It may be possible to determine the building type from a review of available construction drawings.

Depending on the type of supplemental data available, pre-field data collection may take up to 75 minutes per building (for example, if a thorough review will be performed including determining soil type, reviewing permit files, and reviewing construction documents or Sanborn maps) or as little as 15 minutes per building (for example, to determine soil type, confirm there are no permit files available, and perform a quick search on the internet for possible additional information).

The Program Manager should explore sources of information that are likely to contain useful information on the buildings to be screened. For example, the community may already have a Geographic Information System (GIS) database with building age and building type, and drawings may be available for some or all of the buildings. An estimate can then be made about how much time per building will be spent on pre-field data collection.

Time spent on acquisition and review of the pre-field data is often the most difficult portion to estimate in developing a preliminary budget. The unknowns are great, as are the implications. If not given sufficient attention during budget development, it can result in adjustments during the program and affect the desired results.

2.3.6 Electronic Scoring

The Program Manager can decide to incorporate the use of electronic scoring as part of the RVS program. Important considerations include whether the RVS program includes a large number of buildings and whether the seismicity in the area to be screened is relatively constant over the area or varies from the median seismicity of the appropriate Data Collection Form.

The paper-based RVS procedure uses a coarse gradation of the seismicity by dividing the country into regions of Low, Moderate, Moderately High, High, and Very High seismicity. In some areas, these coarse gradations may overestimate or underestimate the seismic hazard, which in turn affect the building score. Areas that have a large difference between the site-specific seismicity and the median seismicity considered by the Low, Moderate, Moderately High, High, and Very High seismicity paper forms will gain the most benefit in terms of accuracy of results with the use of electronic scoring. In addition, regions that include more than one level of seismicity will benefit because slight changes in seismicity within the region may not require changing the Data Collection Form when using electronic scoring.

One such system available is FEMA P-154 *Rapid Observation of Vulnerability and Estimation of Risk* (ROVER) (FEMA, 2014). FEMA P-154 ROVER is software developed by the Applied Technology Council (ATC) for FEMA and uses FEMA 154 *Second Edition* methodology. Other uses of electronic scoring will require effort to develop tools specific to the RVS program. When considering the use of electronic scoring, the Program Manager should take into account the availability of resources to develop and implement the electronic scoring system. If the types of buildings to be screened as part of the RVS program are similar, the development of the electronic scoring could be streamlined since the methodology would not need to be developed for all building types. However, once the electronic scoring system is developed for the first building type, adapting it for other building types will be less time consuming.

Another important consideration for government agencies is the availability of the appropriate technology platform to implement electronic scoring. Purchase of hardware for a government entity can be involved. In general, hardware and software used in a government effort has to be owned by the entity; personal equipment is not usually utilized. This is not an issue for private entities, but may be an important consideration when determining if a contractor or government personnel perform the evaluations.

2.3.7 Updating Existing *Second Edition* Screening Programs

RVS is a tool for initiating mitigation programs. If a program has been implemented based on *Second Edition* results, the mitigation program should generally continue, and there will usually not be a need to redo the RVS program.

If an RVS Authority has performed screening per the *Second Edition* and developed a set of scores for a portfolio of buildings, but has not yet begun to implement a mitigation program, the RVS Authority could continue to proceed using the *Second Edition* score. However, to obtain a more current assessment of relative risk and prioritization, the RVS Authority is encouraged to consider re-screening using the *Third Edition* methodology in some situations. These include how close the existing score was to the cut-off score, whether buildings had used the mid-rise or high-rise Score Modifiers, and if the buildings would be affected by the increased number of seismicity regions used in the *Third Edition*. Other factors that may lead the RVS Authority to consider re-screening might be new knowledge and data on seismicity. If the Final Score for a building screened using the *Second Edition* was within 0.5 points of the adopted cut-off score (i.e., it had a Final Score of 1.5 to 2.5), then re-screening these buildings should be considered. Buildings that used the mid-rise and high-rise Score Modifiers in the *Second Edition* may also be considered for re-screening since these Score Modifiers were eliminated in the *Third Edition* in favor of combining that effect with soil type Score Modifiers. Because the *Third Edition* now uses updated ground motion maps and has divided the older High seismicity region into three smaller regions, a re-screening of buildings that used the *Second Edition* High seismicity form may warrant consideration.

2.4 Budget Development and Cost Estimation

Many of the decisions that are made about the project scope will depend upon budget constraints. Funds should be allocated to cover the cost of the screenings, as well as for pre-field planning (8 to 40 hours), selection and optional modification of the Data Collection Form and determination of key seismic code adoption dates (8 to 12 hours), screener training (6 to 8 hours per screener), acquisition and review of pre-field building data (15 to 75 minutes per building), quality assurance (5 to 10 minutes per building), administrative costs (10% of total costs), development of the record keeping system (2% to 5% of costs), and post-processing of the data (15 to 30 minutes/building). See Chapter 7 for a suggested budget for an example RVS program.

It is expected that the field screening of each building should take about 15 to 30 minutes. If access to the interior is obtained, screenings may take an additional 15 to 30 minutes per building. If Level 2 screenings are performed, screenings may take an additional 5 to 15 minutes per building. The budget should also consider travel time. If the distance between buildings to be screened is large, then the corresponding costs will be greater. If the number of buildings to be screened is large, there is no urgency to completing the screening, and in-house staff who ordinarily visit the buildings for other reasons will do the screening, the RVS Authority may wish to integrate the data collection with the screeners' day-to-day activities, thus avoiding the cost of special trips to the buildings.

Opportunities exist to control the costs of an RVS program. Partnering with local colleges and universities to involve students as screeners can reduce costs. Upper division undergraduates and graduate students enrolled in programs that emphasize the design of building structures, such as civil, structural or architectural engineering, architecture, or construction can be well prepared to learn and implement screening procedures.

Additionally, if a public program is being performed, training materials and an instructor could be coordinated through the state's Earthquake Program Manager using FEMA's National Earthquake Technical Assistance Program (NETAP).

2.5 Pre-Field Planning

During pre-field planning, the Program Manager compiles maps that document local seismic hazard information, investigates sources of available building information, engages local design professionals to advise on the special features and vulnerabilities of the existing building stock, develops a record-keeping system for the RVS program, and develops electronic scoring tools (if desired).

Compiling and developing maps for the surveyed region is important in the initial planning phase as well as in scheduling of screeners. Maps of soil profiles will be useful for determining soil type prior to field screening. Maps of landslide, liquefaction, and fault rupture potential, if available, will also be useful for determining geologic hazards prior to field screening. Maps of lots will be useful in scheduling screeners and, as data are collected, in identifying areas with large numbers of potentially hazardous buildings.

An important element of pre-field planning is research and the collection of available building data. Many municipalities maintain a database of building data for their building stock. This data can vary from basic address and occupancy type to GIS mapping and more detailed data on building construction, which will assist in the RVS screening. Using these data as the starting point for the RVS database is a natural time saver. Construction drawings are ideal and should be collected when available. Acquiring information from architectural and structural drawings may require the expertise of an experienced design professional.

Another important phase of pre-field planning is interaction with the local design profession and building officials to gather information about local design practices, common seismic hazards, and the history of seismic code adoption and enforcement within the jurisdiction. Local design professionals may be able to identify falling hazards unique to the area, or may be able to focus the screening effort to particular buildings or areas of concern.

Another factor that should be considered during pre-field planning is the development and administration of a record-keeping system for the screening process. The type of record keeping system selected will be a function of existing procedures and available funds as well as the ultimate goal of the screening. The record-keeping system may be as simple as a list or it may be an extension of an existing GIS database. The record-keeping system may in fact consist of several systems.

Consideration should be given to developing an electronic database containing location and other building information. This information can be preprinted on the Data Collection Forms that the screeners use in the field. Following the field screening, data collected in the field is entered into the database. This process can be facilitated through the use of smart devices. Using an electronic application, such as FEMA P-154 ROVER, the screener can enter information directly into the database as it is collected in the field, including photographs and sketches.

If an electronic database is not used for record-keeping, the completed forms, including pictures and sketches, can be scanned and saved. Another method that has been used is to generate a separate hardcopy file for each building as it is screened. In fact, the screening form can be reproduced on a large envelope with all supporting material and photographs stored inside. This solves any problems associated with attaching multiple sketches and photographs. Even so, the files may grow rapidly and become unmanageable. Even when electronic databases are used, or when scanned electronic files are saved, hardcopies of the screening forms and supporting material can be kept as a valuable supplement or backup to the electronic files.

Part of this planning phase may include deciding how buildings are to be identified. Some suggestions are street address, assessor's parcel number, census tract, and lot number or owner.

If electronic scoring will be used, tools should be developed as described in Chapter 6.

2.6 Selection and Optional Modification of the Data Collection Form

To download Word or pdf files of the Data Collection Forms, visit www.atcouncil.org.

There are five Data Collection Forms, one for each of the following five regions of seismicity: Low, Moderate, Moderately High, High, and Very High. Each Data Collection Form has a Level 1 page and an optional Level 2 page. Full-sized versions of each form are provided in Appendix B. Electronic versions of the forms are available on ATC's website.

The structural scoring system consists of a matrix of Basic Scores (one for each FEMA Building Type and its associated seismic force-resisting system) and Score Modifiers to account for observed attributes that modify seismic performance. The five forms vary from each other only in the values of these Basic Scores and Score Modifiers and the Level 2 pounding criteria. The Basic Scores and Score Modifiers are based on (1) time-dependent seismic design and construction practices in the region; (2) attributes known to decrease or increase seismic resistance capacity; and (3) maximum considered ground motions for the seismicity region under consideration. The Basic Score, Score Modifiers, and Final Score all relate to the probability of building collapse, should the maximum ground motions considered by the RVS procedure occur at the site. Final Scores typically range from 0 to 7, with higher scores corresponding to better seismic performance.

The scoring system in the *Third Edition* considers risk-targeted (MCE_R) ground motions. These ground motions are consistent with the "BSE-2N" ground motions specified in ASCE/SEI 41-13, *Seismic Evaluation and Retrofit of Existing Buildings* (ASCE, 2014).

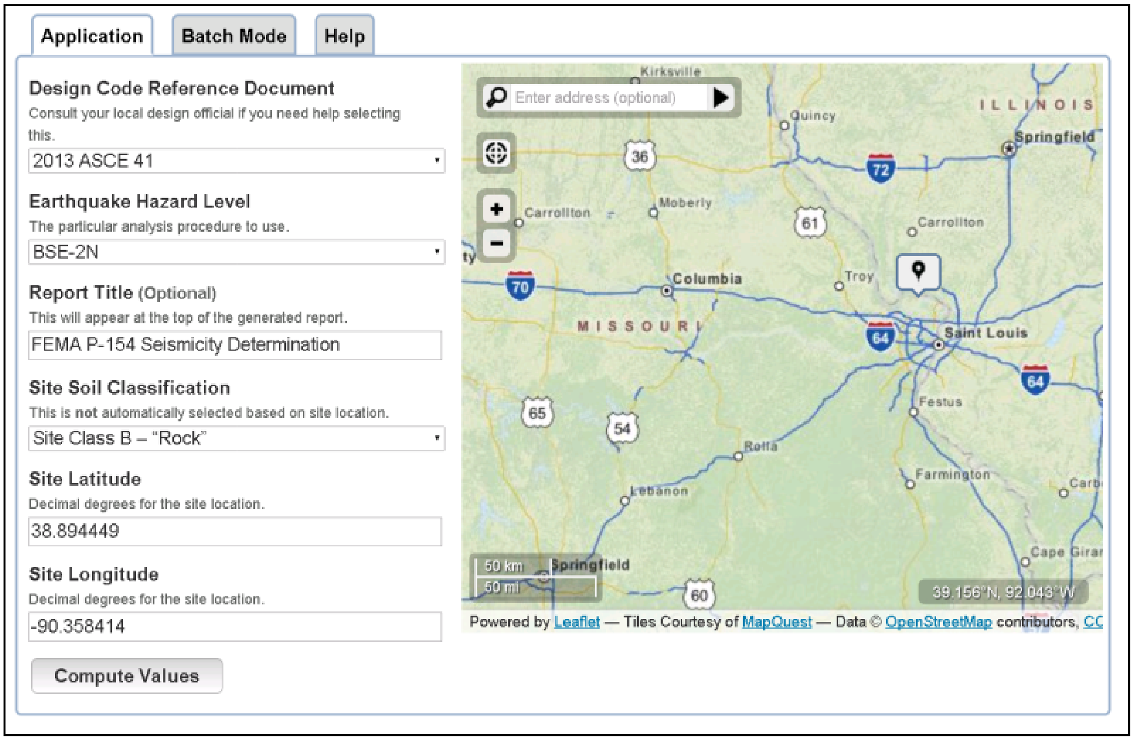
2.6.1 Determination of Seismicity Region

To select the appropriate Data Collection Form, it is first necessary to determine the seismicity of the region that is to be screened. If the RVS program covers a large geographic area, different seismicity regions may apply for different building sites. The seismicity region can be determined by one of two methods:

1. Find the county covering the surveyed region on the seismicity maps provided in Appendix A, and identify the corresponding seismicity region.

2. Determine the seismicity of the site using site-specific values of seismic hazard for MCE_R ground motions and Soil Type B as provided by the U.S. Geological Survey (USGS). An online tool for obtaining site-specific values of spectral acceleration response for short-period, S_S, and

one-second, S_1, is available at http://earthquake.usgs.gov/designmaps/usapp/. When using this tool, the design code reference document should be set to *2013 ASCE 41*, the earthquake hazard level to *BSE-2N*, and the site soil classification to *Site Class B – "Rock,"* as shown in Figure 2-2. The location of the site is defined using either latitude and longitude or street address. Using the provided values S_S and S_1 by the tool (see Figure 2-3), Table 2-2 can then be used to select the appropriate seismicity region, assuming that the highest seismicity level defined by the parameters in Table 2-2 shall govern.



Design Code Reference Document
Consult your local design official if you need help selecting this.
2013 ASCE 41

Earthquake Hazard Level
The particular analysis procedure to use.
BSE-2N

Report Title (Optional)
This will appear at the top of the generated report.
FEMA P-154 Seismicity Determination

Site Soil Classification
This is **not** automatically selected based on site location.
Site Class B – "Rock"

Site Latitude
Decimal degrees for the site location.
38.894449

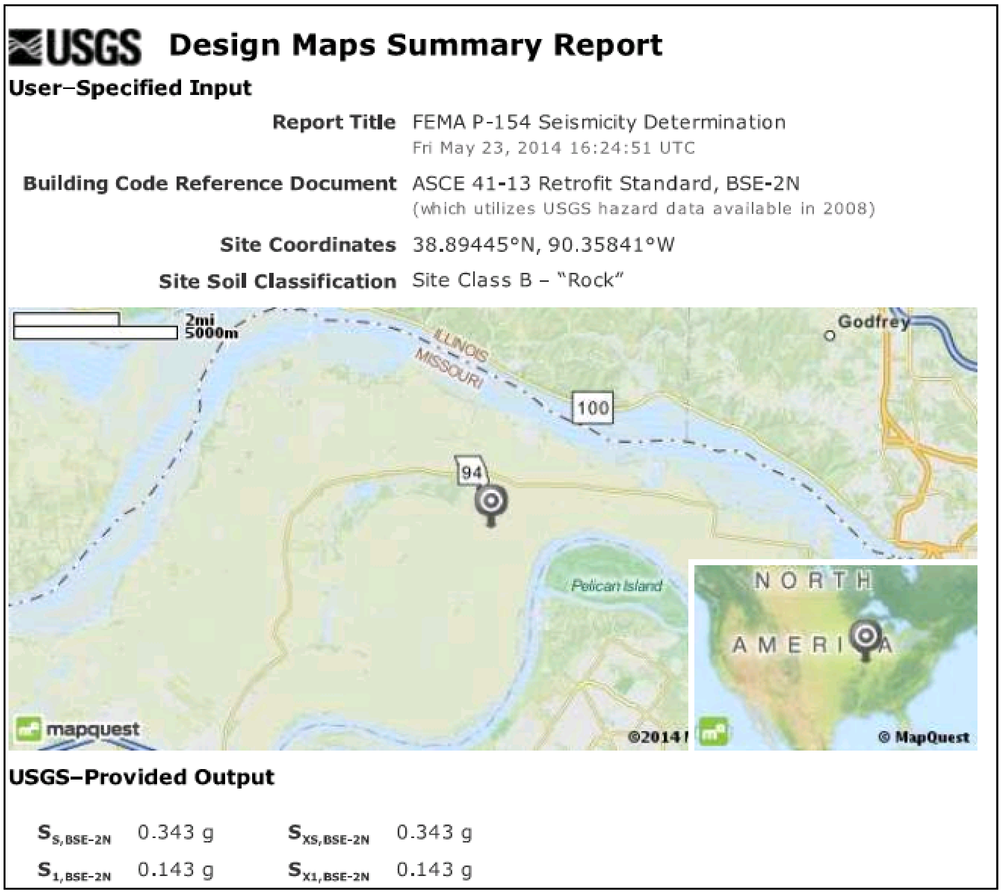
Site Longitude
Decimal degrees for the site location.
-90.358414

Figure 2-2 Input tool for determining site-specific seismicity using the USGS online tool (USGS, 2013a).

The site-specific approach of the second method, implemented by the Supervising Engineer, is preferred as it enables the user to determine seismicity based on a building's specific location. In contrast, each county shown in the Appendix A maps is assigned its seismicity designation on the basis of the highest seismicity in that county, even though it may only apply to a small portion of the county.

2.6.2 Optional Modification of the Data Collection Form

The Data Collection Form can be used as it is presented in this *Handbook* or modified by the Program Manager and Supervising Engineer according to the needs of the program. Therefore, another aspect of the screening planning process is to review the Data Collection Form to determine if all required data are represented or if modifications should be made to reflect the needs and special circumstances of the program.



USGS Design Maps Summary Report

User–Specified Input

Report Title FEMA P-154 Seismicity Determination
Fri May 23, 2014 16:24:51 UTC

Building Code Reference Document ASCE 41-13 Retrofit Standard, BSE-2N
(which utilizes USGS hazard data available in 2008)

Site Coordinates 38.89445°N, 90.35841°W

Site Soil Classification Site Class B – "Rock"

USGS–Provided Output

$S_{S,BSE-2N}$	0.343 g	$S_{XS,BSE-2N}$	0.343 g
$S_{1,BSE-2N}$	0.143 g	$S_{X1,BSE-2N}$	0.143 g

Figure 2-3 Output summary report from USGS online tool for determining site-specific seismicity (USGS, 2013a).

Table 2-2 Seismicity Region Determination from MCE_R Spectral Acceleration Response

Seismicity Region		Spectral Acceleration Response, S_S (short-period, or 0.2 seconds)	Spectral Acceleration Response, S_1 (long-period, or 1.0 second)
🟩	Low	less than 0.250g	less than 0.100g
🟨	Moderate	greater than or equal to 0.250g but less than 0.500g	greater than or equal to 0.100g but less than 0.200g
🟧	Moderately High	greater than or equal to 0.500g but less than 1.000g	greater than or equal to 0.200g but less than 0.400g
🟥	High	greater than or equal to 1.000g but less than 1.500g	greater than or equal to 0.400g but less than 0.600g
🟪	Very High	greater than or equal to 1.500g	greater than or equal to 0.600g

Notes: g = acceleration of gravity in horizontal direction

For example, an RVS Program Manager can choose to define additional occupancy classes such as "parking structure" or "multi-family residential." The RVS Program Manager can choose to add a field for the screener to note building number if, for example, the buildings being screened are on a college campus. There may also be an exterior falling hazard common to the area being screened. The Supervising Engineer can determine that liquefaction, landslide, and fault rupture are not significant hazards in the area being screened, and can recommend that these considerations be removed from the form.

During the Data Collection Form modification process, it is critically important that the Basic Scores and Score Modifiers and the Level 2 statements not be changed.

2.6.3 Determination of Key Seismic Code Adoption Dates

One of the key issues that must be addressed in the planning process is the determination of: (1) the year in which seismic codes were initially adopted and enforced by the local jurisdiction; and (2) the year in which significantly improved seismic codes were adopted and enforced (this latter year is known as the benchmark year).

On the Very High, High, Moderately High, and Moderate seismicity forms, Basic Scores are provided for buildings built after the initial adoption of seismic codes, but before substantially improved codes were adopted (benchmark year). This generally corresponds to buildings designed based on the *Uniform Building Code* (UBC) in the period between 1941 and 1975. Score Modifiers designated as "Pre-Code" and "Post-Benchmark" are provided, respectively, for buildings built before the adoption of codes and for buildings built after the adoption of substantially improved codes. In Low seismicity regions, the Basic Scores have been calculated assuming the buildings were built without consideration of seismic codes. For buildings in these regions, the Score Modifier designated as "Pre-Code" is not applicable (N/A), and the Score Modifier designated as "Post-Benchmark" is applicable for buildings built after the adoption of seismic codes.

In some jurisdictions, seismic anchorage requirements for heavy cladding have been adopted and enforced. Determining the dates that these requirements were adopted and enforced enables the screener to determine whether observed heavy cladding is a falling hazard or whether it is likely to be properly braced, and therefore should not be flagged during screening as a falling hazard.

Therefore, as part of this review process, the Supervising Engineer should identify the following: (1) the year in which seismic codes were first adopted and enforced in the area to be screened; (2) the "benchmark" year in which significantly improved seismic code requirements were adopted and enforced for each building type considered by the RVS procedure; and (3) the year in which the community adopted seismic anchorage requirements for heavy cladding.

Benchmark improvements are associated with building code years where significant provisions were introduced addressing particular seismic performance concerns. Examples include the wall-to-diaphragm connections introduced for tilt up (PC1) buildings in the 1997 *Uniform Building Code* (UBC; ICBO, 1997) and steel moment frames introduced in the Emergency Provisions of the 1994 UBC (ICBO, 1994) following observations made of beam-column connection damage in the Northridge earthquake.

The Supervising Engineer should confer with the Chief Building Official, plan checkers, and other local design professionals to identify the years in which the local jurisdiction initially adopted and enforced seismic codes (if ever) for the building types considered by the RVS procedure. Since municipal codes are generally adopted by the city council, another source for this information, in many municipalities, is the city clerk's office. If the Supervising Engineer in Very High, High, Moderately High, and Moderate seismicity regions is unsure of the year(s) in which codes were initially adopted, but does know that the region has traditionally both adopted and enforced the UBC, the default year for all but one building type is 1941 (the default year specified in the *Multi-hazard Loss Estimation Methodology, Earthquake Model, HAZUS-MH MR4 Technical Manual* (FEMA, 2009a)). The one exception is tilt-up (PC1) buildings, for which it is assumed that seismic codes were initially adopted in 1973, the year in which wall-diaphragm (ledger) connection requirements first appeared in the *Uniform Building Code* (ICBO, 1973).

Historically, the *Standard Building Code* (SBC) by the Southern Building Code Congress (SBCC) was used in many parts of the Southeast. In many areas of the East Coast and the Midwest, the *Basic Building Code* was used. The name of this reference evolved over the years as it was administered by the Building Officials Code Administrators International (BOCA) from *BOCA Basic Building Code* to *Basic National Building Code* to *BOCA National Building Code* (NBC). In some regions of the country, seismic design provisions under BOCA and SBCC were not enforced until the early 1990s. If codes other than the UBC apply to the region of interest, then it is suggested that a default code adoption year of 1992 be used for all building types.

In addition to determining the year in which seismic codes were initially adopted and enforced, the Supervising Engineer must also determine the benchmark years in which substantially improved seismic codes were adopted and enforced for the various building types. Table 2-3 provides the benchmark years for NBC/SBC and UBC for each FEMA Building Type. Benchmark years are also shown for the *International Building Code* (IBC) which more recently combined and replaced the NBC, SBC, and UBC. The IBC should only be used if the jurisdiction did not adopt the NBC, SBC or UBC. If one of these codes has been both adopted and enforced in the area being screened, the Supervising Engineer may select the benchmark years for each building type from the column for that code. If the area has both adopted and enforced a set of codes not listed in the table, the Supervising Engineer must determine the benchmark years based on an understanding of when the seismic codes were substantially improved for the various building types. If the area has not both adopted and enforced any seismic codes, no benchmark year is applicable. In this case, the screeners should be directed not to use the Post-Benchmark Score Modifiers.

The Supervising Engineer must also determine the year in which anchorage requirements for cladding were adopted and enforced. Heavy cladding installed prior to the year noted is considered an exterior falling hazard.

Once the Supervising Engineer has determined the dates corresponding to the initial adoption and enforcement of seismic codes and the benchmark years, and to the initial adoption of anchorage requirements for heavy cladding, these years should be inserted on the Quick Reference Guide in Appendix B, repeated here as Table 2-4.

Table 2-4 has been created to facilitate the use of the Data Collection Form. In order to consider the lapse in time that typically occurs between design date and year built, the Supervising Engineer may choose to add a few years to each date so that the screener can compare the year built directly to the years on the Quick Reference Guide.

Table 2-3 RVS Benchmark Years for FEMA Building Types (based on ASCE/SEI 41-13)

FEMA Building Type		Model Building Seismic Design Provisions		
		National Building Code/ Standard Building Code	Uniform Building Code	International Building Code
W1	Light wood frame single- or multiple-family dwellings of one or more stories in height	1993	1976	2000
W1A	Light wood frame multi-unit, multi-story residential buildings with plan areas on each floor of greater than 3.000 square feet	[1]	1997	2000
W2	Wood frame commercial and industrial buildings with a floor area larger than 5,000 square feet	1993	1976	2000
S1	Steel moment-resisting frame buildings	[1]	1994[2]	2000
S2	Braced steel frame buildings	[1]	1997	2000
S3	Light metal buildings	[1]	[1]	2000
S4	Steel frame buildings with concrete shear walls	1993	1994	2000
S5	Steel frame buildings with unreinforced masonry infill walls	[1]	[1]	2000
C1	Concrete moment-resisting frame buildings	1993	1994	2000
C2	Concrete shear wall buildings	1993	1994	2000
C3	Concrete frame buildings with unreinforced masonry infill walls	[1]	[1]	2000
PC1	Tilt-up buildings	[1]	1997	2000
PC2	Precast concrete frame buildings	[1]	[1]	2000
RM1	Reinforced masonry buildings with flexible floor and roof diaphragms	[1]	1997	2000
RM2	Reinforced masonry buildings with rigid floor and roof diaphragms	1993	1994	2000
URM	Unreinforced masonry bearing wall buildings	[1]	[1]	[1]
MH	Manufactured housing	[3]	[3]	[3]

[1] No benchmark year.

[2] Steel moment-resisting frame shall comply with the 1994 UBC Emergency Provisions, published September/October 1994.

[3] The model building codes in this table do not apply to manufactured housing. In California, relevant requirements appeared in the Mobile home Parks Act, the California Health and Safety Code, and the California Code of Regulations. They evolved between 1985 and 1994; the year 1995 is recommended here as the benchmark year for California. In other states, the U.S. Department of Housing and Urban Development's Installation Standards required tie-downs after October 2008. The year 2009 is recommended here as the benchmark year for states other than California.

Table 2-4 Quick Reference Guide from Appendix B

FEMA Building Type		Year Seismic Codes Initially Adopted and Enforced	Benchmark Year when Codes Improved
W1	Light wood frame single- or multiple-family dwellings of one or more stories in height		
W1A	Light wood frame multi-unit, multi-story residential buildings with plan areas on each floor of greater than 3,000 square feet		
W2	Wood frame commercial and industrial buildings with a floor area larger than 5,000 square feet		
S1	Steel moment-resisting frame		
S2	Braced steel frame		
S3	Light metal frame		
S4	Steel frame with cast-in-place concrete shear walls		
S5	Steel frame with unreinforced masonry infill walls		
C1	Concrete moment-resisting frame		
C2	Concrete shear wall		
C3	Concrete frame with unreinforced masonry infill walls		
PC1	Tilt-up construction		
PC2	Precast concrete frame		
RM1	Reinforced masonry with flexible floor and roof diaphragms		
RM2	Reinforced masonry with rigid floor and roof diaphragms		
URM	Unreinforced masonry bearing-wall buildings		
MH	Manufactured housing		
Anchorage of Heavy Cladding Year in which seismic anchorage requirements were adopted:			

2.6.4 Determination of Cut-Off Score

Use of the RVS methodology on a community-wide basis enables the RVS Authority to divide screened buildings into two categories: (1) those that are expected to have acceptable seismic performance; and (2) those that may be seismically hazardous and should be studied further. This requires that the RVS Authority determines, preferably as part of the pre-planning process, an appropriate cut-off score.

A score of 2.0 is suggested as a cut-off for standard occupancy buildings, based on present seismic design criteria. Using this cut-off level, buildings having a score of 2.0 or less should be investigated by a design professional experienced in seismic design. In some cases, a higher cut-off score may be warranted for critical or essential facilities. A higher score indicates a smaller probability of collapse. It does not, however, indicate a greater probability of other performance objectives being met, such as continued operation. See Section 5.3 for additional guidance on selecting an appropriate cut-off score.

2.7 Qualifications and Training for Screeners

Level 1 screenings can be performed by a wide array of individuals, including civil engineers, structural engineers, architects, design professionals, building officials, construction contractors, facility managers, firefighters, architecture and engineering students, or other individuals with a general familiarity or background in building design or construction.

Desirable attributes for potential screeners:

- Interest and knowledge about buildings and structures
- Some understanding and appreciation of the effects of earthquakes
- Willingness to be trained in RVS
- Attention to detail
- Previous ATC-20 training

These individuals will need to be trained to ensure consistent, high quality collection of data and uniformity of decisions among screeners. Training materials and an instructor can be coordinated through the state's Earthquake Program Manager using FEMA's NETAP.

Training should include discussions of seismic force-resisting systems and how they behave when subjected to seismic loads, how to identify building irregularities, how to complete the Level 1 Data Collection Form, what to look for in the field, and how to account for uncertainty.

It will be beneficial if the trainees, in conjunction with a professional engineer experienced in seismic design, can simultaneously score buildings of several different types and compare results. This will serve as a "calibration" for the screeners. This process can be accomplished in a classroom setting with photographs of actual buildings used as examples. Prospective screeners can review the photographs and perform the RVS procedure as though they were on the sidewalk. Upon completion, the class may discuss the results and students can compare how they did in relation to the rest of the class and the professional engineer. Alternately, the training can include a field exercise with real buildings. This can be easily accomplished using the training facility building as the example building. The screeners can be broken into small groups with each group independently reviewing the exterior and possibly the interior of the building, if access to mechanical and unfinished spaces can be secured. The groups can then return to the training room and inform the others how they scored the building, what structure type was selected and Score Modifiers applied.

The Level 2 screening is designed assuming that the screening will be performed by a civil or structural engineering professional, architect, or graduate student with a background in seismic evaluation or design of buildings. Training should be provided to these individuals to provide them with an understanding of how the FEMA P-154 methodology works and how to complete the Level 1 and Level 2 Data Collection Forms. For graduate students, the Supervising Engineer should determine on a case-by-case basis whether the student has the necessary knowledge and experience to perform Level 2 screenings.

Screener information, such as names, email addresses, and other contact information, should be archived with the survey results. This will allow for follow-ups during the final stages of reviewing the data and also for future references.

2.8 Acquisition and Review of Pre-Field Building Data

Information on the structural system, age or occupancy (that is, use) of the building may be available from supplemental sources. These data, from assessor and building department files, insurance (Sanborn) maps, and previous studies, should be reviewed and collated for a given area before commencing the field survey for that area. It is recommended that this supplemental information be either written directly on the Data Collection Forms as it is retrieved or entered into an electronic database. The advantage of a database is that selected information can be printed directly onto Data Collection Forms for the screeners to use in the field. Following the field screening, data collected in the field can be entered into the database and later used to generate reports and maps.

Some sources of supplemental information are described in Sections 2.8.1 through 2.8.7.

2.8.1 Assessor's Files

Assessor's files may contain information about the floor area and the number of stories of a building. These files often also include coordinates and zip codes that can be used to pre-populate an electronic database. The construction type may be indicated, but should be verified during screening. Property type and building style may also be available and can provide clues about the specific use of the property and its exterior wall finishes. Caution must be exercised with the age of a building retrieved from assessor's files, because usually assessor's files contain the year that the building was first eligible for taxation. Because the criteria for this may vary, the date may be several years after the building was designed or constructed. If no other source of information is available, this year will give a good estimate of the period during which the building was constructed. However, this date should not be used to establish conclusively the code under which a building was designed. Assessor's offices may also have parcel or lot maps, which may be useful for locating sites or may be used as a template for sketching building adjacencies on a particular city block.

2.8.2 Building Department Files

The extent and completeness of information in building department files will vary from jurisdiction to jurisdiction. For example, in some locations all old files have been removed or destroyed, so there is no information on older buildings. In general, files (or microfilm) may contain permits, plans, and structural calculations required by the city. Sometimes the building department files contain information about a building's occupancy and use. If building plans or calculations are included in the building department files, an engineer can review them to determine building type.

2.8.3 Sanborn Maps and Parcel Maps

These maps, published primarily for the insurance industry since the late 1800s, exist for about 22,000 communities in the United States. The Sanborn Map Company stopped routinely updating these maps in the early 1960s, and many communities have not kept these maps up-to-date. Thus, they may not be useful for newer construction. However, the maps may contain useful data for older construction. They can be found at the library or in some cases in building department offices. There exist services that provide digitized libraries of Sanborn maps with search engines and GIS capabilities.

Figure 2-4 shows a Sanborn map and photographs of the associated city block. Building descriptions obtained from the Sanborn maps are also included. Figures 2-5 and 2-6 show keys to identifiers on Sanborn maps.

Information found on a Sanborn map includes height of building, number of stories, year built, thickness of walls, building size (square feet), type of roof (tile, shingle, composite), building use (dwelling, store, apartment), presence of garage under structure, and structural type (wood frame, fireproof construction, adobe, stone, concrete). The structural type can be helpful in identifying the FEMA Building Type. Although the information on Sanborn maps may be useful, it is the responsibility of the screener to verify any information derived from these maps in the field.

Parcel maps are also available and contain lot dimensions. If building size information cannot be obtained from another source such as the assessor's file, the parcel maps are particularly helpful for determining building dimensions in urban areas where buildings cover the entire lot. However, even if the building does not cover the entire lot, it will be easier to estimate building dimensions if the lot dimensions are known.

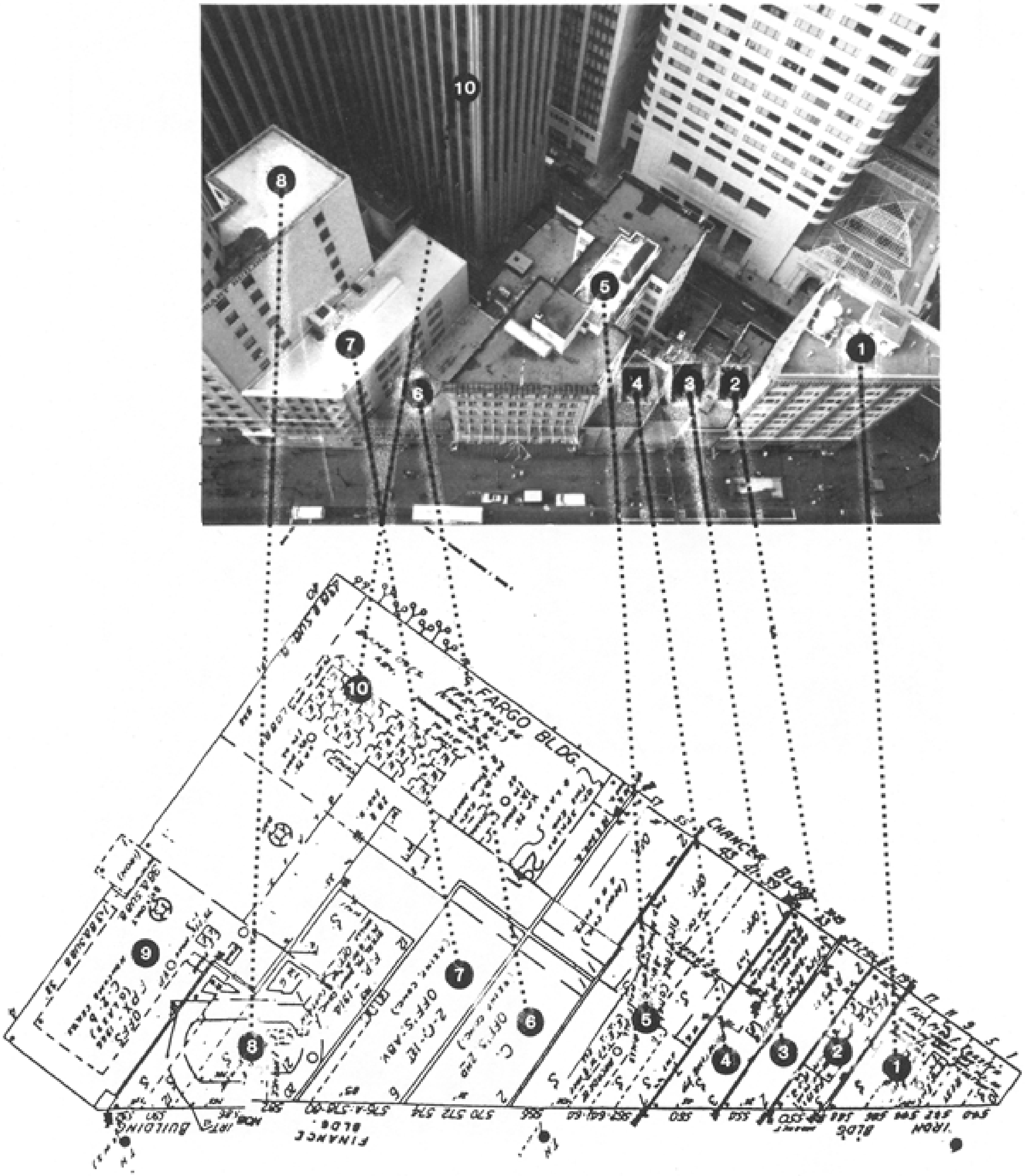


Figure 2-4 Sanborn map and corresponding aerial photograph of a city block.

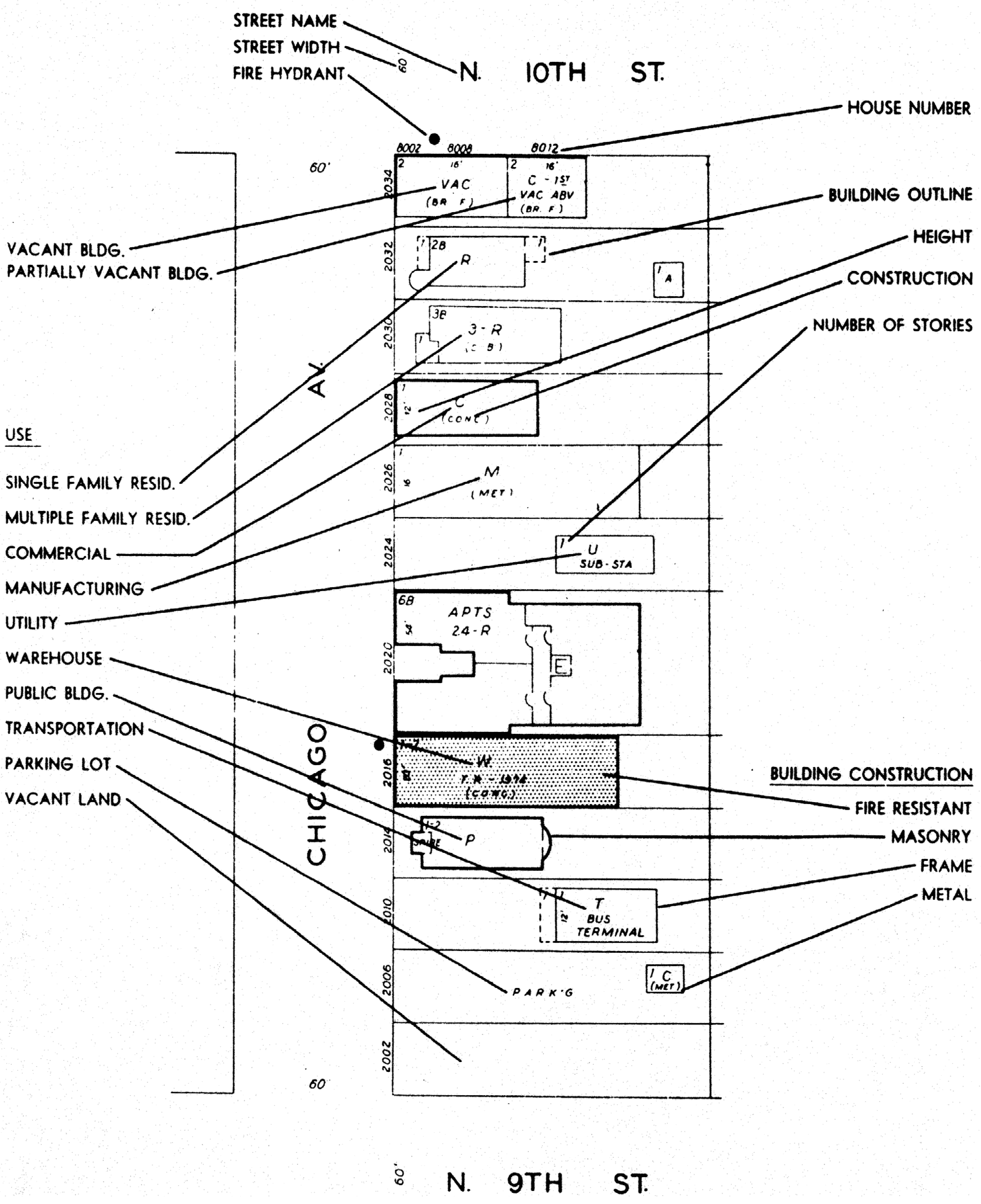
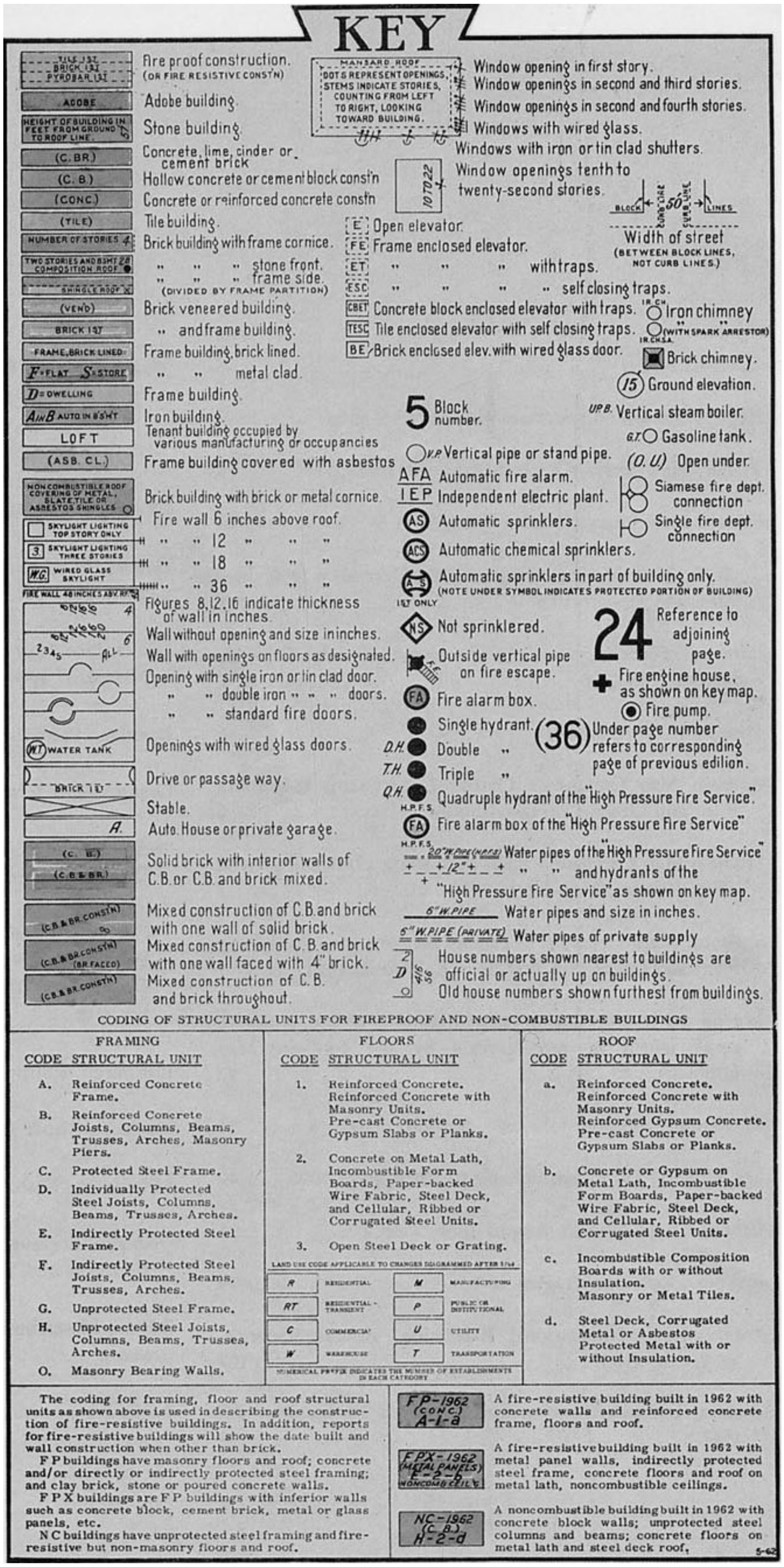


Figure 2-5 Key to Sanborn map symbols.



CODING OF STRUCTURAL UNITS FOR FIREPROOF AND NON-COMBUSTIBLE BUILDINGS

FRAMING

CODE	STRUCTURAL UNIT
A.	Reinforced Concrete Frame.
B.	Reinforced Concrete Joists, Columns, Beams, Trusses, Arches, Masonry Piers.
C.	Protected Steel Frame.
D.	Individually Protected Steel Joists, Columns, Beams, Trusses, Arches.
E.	Indirectly Protected Steel Frame.
F.	Indirectly Protected Steel Joists, Columns, Beams, Trusses, Arches.
G.	Unprotected Steel Frame.
H.	Unprotected Steel Joists, Columns, Beams, Trusses, Arches.
O.	Masonry Bearing Walls.

FLOORS

CODE	STRUCTURAL UNIT
1.	Reinforced Concrete. Reinforced Concrete with Masonry Units. Pre-cast Concrete or Gypsum Slabs or Planks.
2.	Concrete on Metal Lath, Incombustible Form Boards, Paper-backed Wire Fabric, Steel Deck, and Cellular, Ribbed or Corrugated Steel Units.
3.	Open Steel Deck or Grating.

ROOF

CODE	STRUCTURAL UNIT
a.	Reinforced Concrete. Reinforced Concrete with Masonry Units. Reinforced Gypsum Concrete. Pre-cast Concrete or Gypsum Slabs or Planks.
b.	Concrete or Gypsum on Metal Lath, Incombustible Form Boards, Paper-backed Wire Fabric, Steel Deck, and Cellular, Ribbed or Corrugated Steel Units.
c.	Incombustible Composition Boards with or without Insulation. Masonry or Metal Tiles.
d.	Steel Deck, Corrugated Metal or Asbestos Protected Metal with or without Insulation.

The coding for framing, floor and roof structural units as shown above is used in describing the construction of fire-resistive buildings. In addition, reports for fire-resistive buildings will show the date built and wall construction when other than brick.

F P buildings have masonry floors and roof; concrete and/or directly or indirectly protected steel framing; and clay brick, stone or poured concrete walls.

F P X buildings are F P buildings with inferior walls such as concrete block, cement brick, metal or glass panels, etc.

N C buildings have unprotected steel framing and fire-resistive but non-masonry floors and roof.

A fire-resistive building built in 1962 with concrete walls and reinforced concrete frame, floors and roof.

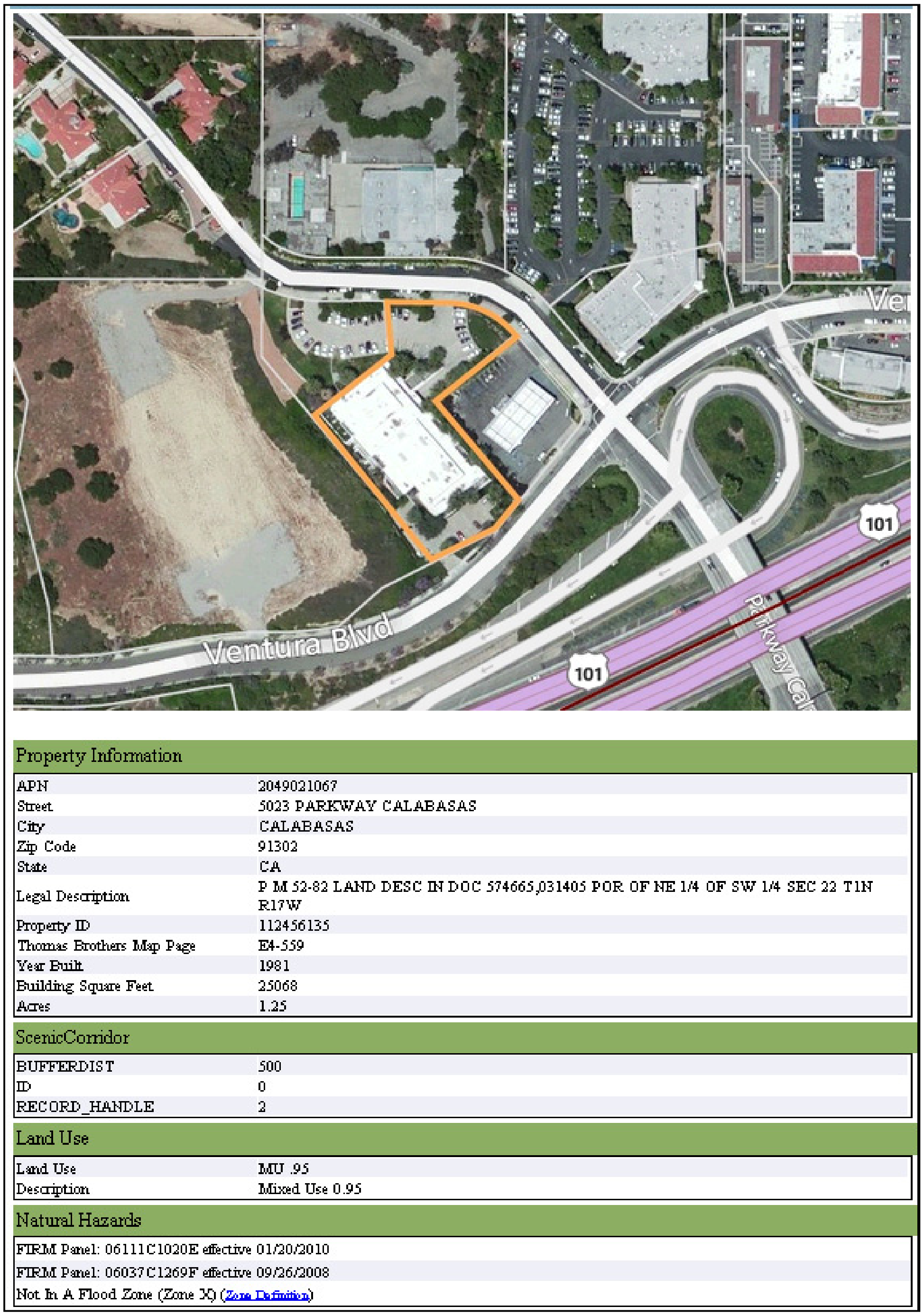
A fire-resistive building built in 1962 with metal panel walls, indirectly protected steel frame, concrete floors and roof on metal lath, noncombustible ceilings.

A noncombustible building built in 1962 with concrete block walls; unprotected steel columns and beams; concrete floors on metal lath and steel deck roof,

Figure 2-6 Detailed key to Sanborn map symbols. (From http://sanborn.umi.com/HelpFiles/key.html)

2.8.4 *Municipal Databases*

Many jurisdictions have made digital maps or databases available online for use by the general public. Figure 2-7 shows an example from a municipal database.



Property Information

APN	2049021067
Street	5023 PARKWAY CALABASAS
City	CALABASAS
Zip Code	91302
State	CA
Legal Description	P M 52-82 LAND DESC IN DOC 574665,031405 POR OF NE 1/4 OF SW 1/4 SEC 22 T1N R17W
Property ID	112456135
Thomas Brothers Map Page	E4-559
Year Built	1981
Building Square Feet	25068
Acres	1.25

ScenicCorridor

BUFFERDIST	500
ID	0
RECORD_HANDLE	2

Land Use

Land Use	MU .95
Description	Mixed Use 0.95

Natural Hazards

FIRM Panel: 06111C1020E effective 01/20/2010

FIRM Panel: 06037C1269F effective 09/26/2008

Not In A Flood Zone (Zone X) (Zone Definition)

Figure 2-7 Example of property details from City of Calabasas municipal database (from http://www.cityofcalabasas.com/departments/planning/).

These databases provide general information on the various building sites within the jurisdiction. The level of detail of these databases varies greatly. Some of them may provide information on building age, square footage, and occasionally, the construction type and presence of geologic hazards. These databases are expected to become more detailed over time, and hence, more useful to RVS.

2.8.5 Previous Studies

In a few cases, previous building inventories or studies of hazardous buildings or hazardous nonstructural elements (e.g., parapets) may have been performed. These studies may be limited to a particular structural or occupancy class, but they may contain useful maps or other relevant structural information and should be researched, collected, and reviewed. Other important studies might address related seismic hazard issues such as liquefaction or landslide potential. Local historical societies may have published books or reports about older buildings in the community. Fire departments are often aware of the overall condition and composition of building interiors.

Many communities have developed building inventories that might be of value. For example, the Utah Division of State History includes valuable information about historic buildings and is accessible online at http://historicbuildings.utah.gov. Additionally, the state has performed a series of Reconnaissance Level and Intensive Level Surveys, which provide additional information about historic buildings. Available at http://heritage.utah.gov/history/building-surveys.

2.8.6 Soil Information

Soil Type, also known as Site Class, has a major influence on amplitude and duration of shaking, and thus structural damage. Generally speaking, the greater the depth of soil to bedrock at a site, the more damaging the earthquake motion will be. Table 2-5 provides measurable parameters that define soil type using the site class definitions of ASCE/SEI 7-10 (ASCE, 2010).

Soil type cannot be readily identified by visual methods in the field. The soil type should be identified during the planning stage and put into a readily usable map format for use during RVS. During the screening, or the planning stage, the soil type should be documented on the Data Collection Form by checking the correct soil type, as designated by the letters A through F.

There are various sources of data for the soil conditions at a site, including geotechnical engineering reports. For the purpose of a rapid visual screening, the use of geotechnical engineering reports may be impractical. In some areas of the country, such as the San Francisco Bay Area, maps that provide the applicable soil types are publically available and can be used to determine site-specific soil type information.

If soil maps of the area are not available, soil type can be estimated based on average shear wave velocity in the top 30 meters of soil, V_S^{30}. These values have been derived using topographic slopes and using geological conditions of the surface soil. These values are available as maps or site-specific values from the U.S. Geological Survey web site http://earthquake.usgs.gov /hazards/apps/vs30/ (see Figure 2-8).

Table 2-5 Soil Type Definitions

Soil Type/Site Class	Shear Wave Velocity[1], V_S^{30}	Standard Blow Count[1], N	Undrained Shear Strength of the upper 100ft[1], s_u
A. Hard Rock	$V_S^{30} > 5000$ ft/s		
B. Rock	2500 ft/s $< V_S^{30} <$ 5000 ft/s		
C. Very Dense Soil and Soft Rock	1200 ft/s $< V_S^{30} <$ 2500 ft/s	$N > 50$	$s_u > 2000$ psf
D. Stiff Soil	600 ft/s $< V_S^{30} <$ 1200 ft/s	$15 < N < 50$	1000psf $< s_u <$ 2000 psf
E. Soft Clay Soil	$V_S^{30} \leq 600$ ft/s	$N < 15$	$s_u < 1000$ psf
	More than 10 feet of soft soil with plasticity index $PI > 20$, water content $w > 40\%$, and $s_u < 500$ psf		
F. Poor Soil	Soils requiring site-specific evaluations. • Soils vulnerable to potential failure or collapse under seismic loading, such as liquefiable soils, quick and highly-sensitive clays, collapsible weakly-cemented soils. • Thicker than 10 feet of peat or highly organic clay. • Very high plasticity clays (25 feet with $PI > 75$). • More than 120 ft of soft or medium stiff clays.		

[1] Average values.

The USGS also provides a tool called OpenSHA Site Data Viewer/Plotter (http://opensha.org/apps-SiteData) to download and plot data and maps for site-related data from various sources.

The most commonly encountered soil types are Soil Type C and Soil Type D. The average of these soil types is known as Soil Type CD. This average is used as the basis of the Basic Scores. If the soil type cannot be identified or estimated during the planning stage, Soil Type D should be assumed. Buildings on Soil Type F cannot be screened effectively by the RVS procedure, other than to recommend that buildings on this soil type be further evaluated by a geotechnical engineer and design professional experienced in seismic design.

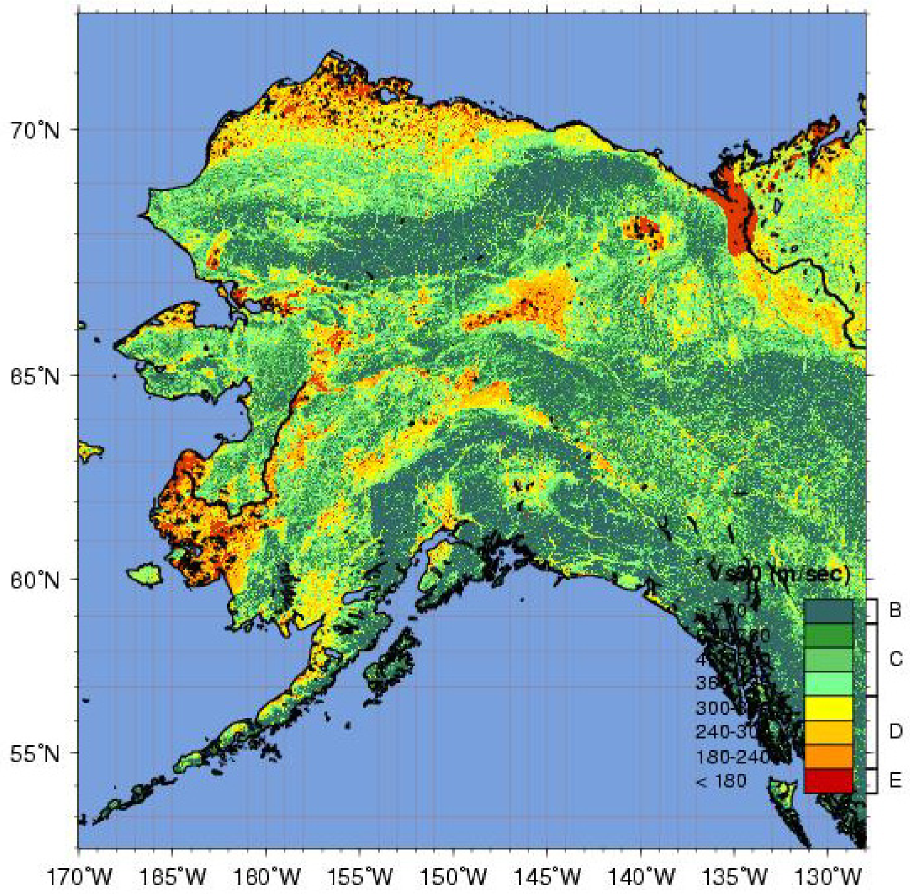


Figure 2-8 V_S^{30} map of Alaska from USGS website showing soil type (USGS, 2013b).

2.8.7 Using Resources from the Internet and Other Available Tools

The internet is home to vast amounts of information, including specific information about buildings. A web search of a specific building may reveal meaningful information about it, including its date of construction or information about a recent retrofit to it.

Additional tools that can aid in the RVS effort are available on the internet. For example, satellite images found on the internet can be used to view buildings from above. From these images, screeners can identify plan irregularities that may be hidden when viewing the building at street level. These images from above may also reveal the presence or absence of parapet bracing. Maps found on the internet can be used to quickly view the exterior of buildings without leaving the office. This tool can be particularly useful for the quality assurance process as it can be used by the Supervising

Engineer to verify number of stories, building type, and other building characteristics.

Additional tools are expected to become available in the future. Information from the internet should always be verified during the field screening.

2.9 Review of Construction Documents

Whenever possible, construction documents for the buildings to be screened should be reviewed prior to the conduct of field work. The review of construction documents substantially improves the confidence in the determination of building type. It also greatly assists in determining building age and in identifying building irregularities. Appendix C provides a list of common symbols shown on structural drawings. Determining the FEMA Building Type from existing drawings often requires some familiarity in reading architectural and structural drawings that an experienced design professional would have.

Some sources for obtaining construction documents include building departments, facilities managers, and building owner files. Building department records may include information about the original construction date and permitted work done over a number of years. Obtaining copies of files may involve getting permission from the original designers, but some information may be publically available over the counter.

Facilities mangers and building owners often keep records of the construction documents for reference purposes. These are generally the easiest to obtain and should be requested first. Persistence in discovering these documents is generally worth the effort since conversations with those responsible for maintaining the building will often uncover valuable information.

2.10 Field Screening of Buildings

Rapid visual screening of buildings in the field can be carried out by individuals or teams of two. Teams of two provide the screeners an opportunity to discuss issues requiring judgment and to facilitate the data collection process. Using teams of two, however, increases the number of screeners needed and related costs. The benefit of pairing up an experienced engineer or architect with an inexperienced screener will be minor, except as a way of training the less experienced person.

Relatively few tools or equipment are needed. Table 2-6 provides a list of items that may be needed in performing RVS as described in this *Handbook*.

The Level 1 screening procedure is described in Chapter 3. The optional Level 2 procedure is described in Chapter 4.

Table 2-6 Checklist of Field Equipment Needed for Rapid Visual Screening

✓	Field Equipment
	Binoculars, if high-rise buildings are to be evaluated
	Camera, preferably digital and spare batteries
	Clipboard for holding Data Collection Forms
	Copy of the FEMA P-154 *Handbook*
	Copies of the Quick Reference Guide and other reference guides (see Appendix B)
	Pen or pencil
	Straight edge (optional for drawing sketches)
	Graph paper (optional for drawing sketches)
	Flashlight for interior observations
	Manual or digital measuring device to assist in measuring distances and calculating building square footage
	Smartphone or tablet computer if using electronic tools for RVS review with spare batteries or car charger

2.11 Quality Assurance

The Supervising Engineer should provide quality assurance by reviewing the completed Data Collection Forms. The scope of the Supervising Engineer's review depends on the scope of the screening and can include review of each form, spot checking of forms, or review of the compiled data. The Supervising Engineer may choose to check specific fields on every form or check every form for a certain building type. It is recommended that the forms for all failing buildings be reviewed by the Supervising Engineer.

Some of this review should come early in the screening process to catch common errors and to allow for additional training of individual screeners that may be making too many mistakes or are repeatedly unable to narrow down the building type. Overlooking quality assurance early in the RVS program can result in significant amounts of added effort later on that will potentially impact the budget and time frame of the project.

The Supervising Engineer can perform this review using data and photos collected in the field, or the Supervising Engineer can go into the field to work with the screeners and check their work. Field involvement can be very beneficial. Pairing the Supervising Engineer with a less experienced screener at the start will be desirable as a training aid and will reduce the level of review required later.

The extent of the Supervising Engineer’s role will be dependent on the qualifications of the screeners. If the screeners are not familiar with building design and if they have limited experience performing screenings, the Supervising Engineer will need to be more available for consultation during the screenings and will need to review the completed screening forms more closely. If the screeners are experienced engineers or architects, the Supervising Engineer's efforts will be less. The cost of more experienced screeners may be offset by the cost of the added work for the Supervising Engineer.

In some programs, the Supervising Engineer may be assisted in performing quality assurance by additional experienced seismic design professionals. Reviewers should pay particular attention to “EST” (estimated) and “DNK” (do not know) marks on the forms, or screeners who circle too many building types.

Some common mistakes made include the following:

- Incorrect assumptions regarding the FEMA Building Type, particularly when architectural finishes cover the structural framing, such as precast cladding over steel framing.
- Incorrect use of the Pre-Code and Post-Benchmark Score Modifiers.
- Selection of the wrong seismicity level form based on limits established by the S_s and S_1 parameters.
- Use of the wrong or default soil type if this information is known or obtained for the project.
- Missing some of the possible situations that trigger one of the Vertical Irregularity Score Modifiers.
- Incorrectly applying the Minimum Score.

2.12 Filing the Field Data in the Record-Keeping System

The last step in the implementation of rapid visual screening is filing the RVS data in the record-keeping system established for this purpose. If FEMA P-154 ROVER is used to collect field data, then this step is unnecessary, as the data are already stored in a database when the field data are entered. Alternatively, if RVS data are recorded on paper they can be transcribed into FEMA P-154 ROVER’s database, which can serve as the record-keeping system. If the data are to be stored in file folders or envelopes containing data for each building that was screened, the process is straightforward, and requires careful organization. If the data are to be stored in digital form, it is important that the data input and verification process include either double entry of all data, or systematic in-depth review of print outs (item-by-item review) of all entered data.

Chapter 3

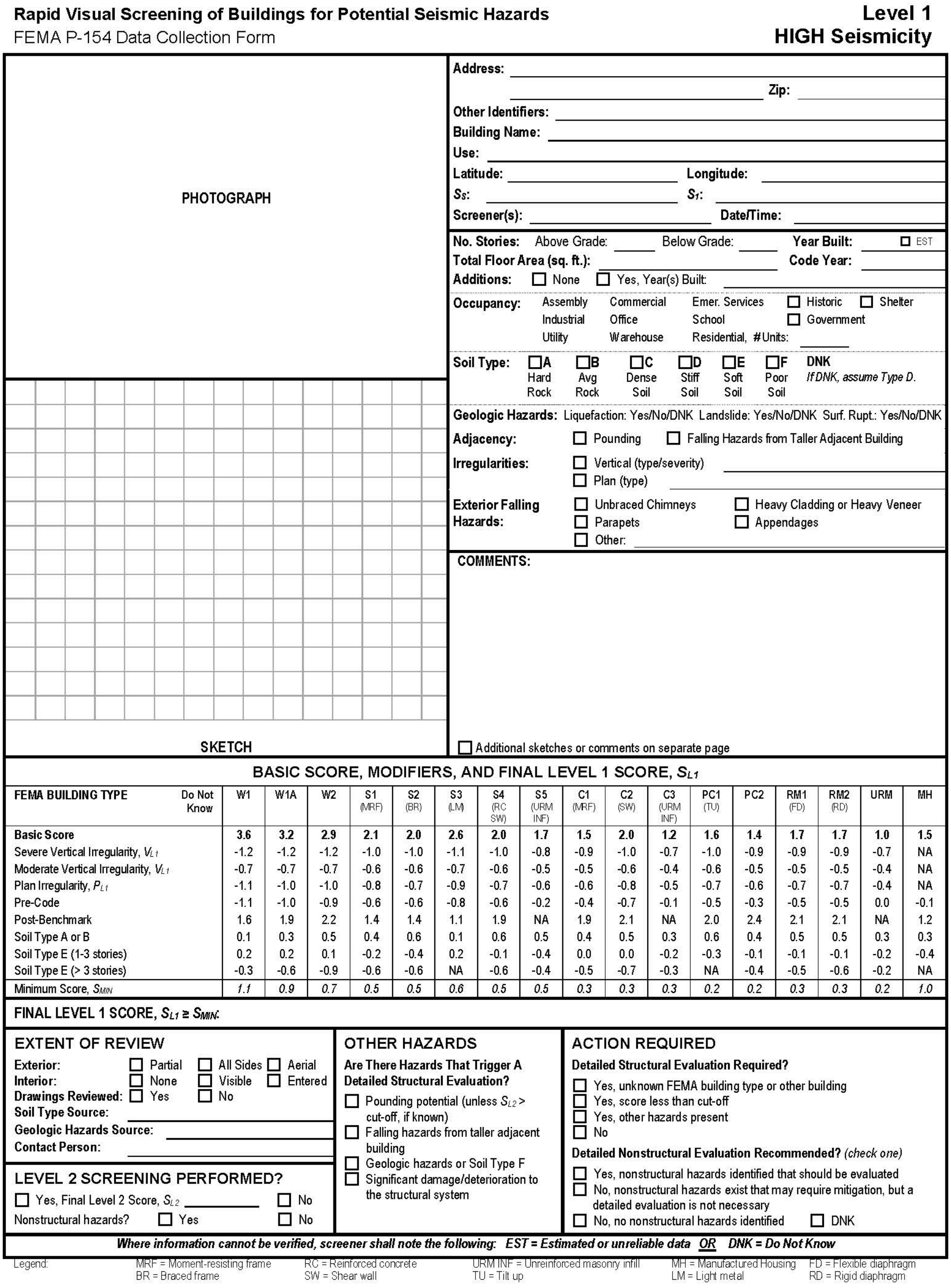
Completing the Level 1 Data Collection Form

3.1 Introduction

This chapter provides instructions on how to complete the Level 1 Data Collection Form (Figure 3-1). It is assumed that pre-field planning activities (as described in Chapter 2) have already been conducted, including the selection of the Data Collection Form, based on the seismicity level of the area to be screened, and the determination of the soil type. Instructions for completing the optional Level 2 Data Collection Form are provided in Chapter 4.

The Level 1 Data Collection Form is completed for each building screened through execution of the following steps:

1. Verifying and updating the building identification information;
2. Walking around the building to identify the number of stories and shape, and sketching a plan and elevation view on the Data Collection Form;
3. Photographing the building;
4. Determining and documenting occupancy;
5. Reviewing the soil type and geologic hazards, as identified during the pre-field planning process;
6. Identifying adjacency issues, building irregularities, and any potential exterior falling hazards;
7. Adding any comments about unusual conditions or circumstances that may affect the screening;
8. Identifying the building material, gravity load-carrying system, and seismic force-resisting system to identify the FEMA Building Type (entering the building, if possible, to facilitate this process) and circling the Basic Score on the Data Collection Form;
9. Circling the appropriate seismic performance attribute Score Modifiers (e.g., irregularities, design date, and soil type) on the Data Collection Form;



Rapid Visual Screening of Buildings for Potential Seismic Hazards
FEMA P-154 Data Collection Form

Level 1
HIGH Seismicity

PHOTOGRAPH

SKETCH

Address: ____________________
____________________ **Zip:** __________
Other Identifiers: ____________________
Building Name: ____________________
Use: ____________________
Latitude: __________ **Longitude:** __________
S_S: __________ **S_1:** __________
Screener(s): __________ **Date/Time:** __________

No. Stories: Above Grade: _____ Below Grade: _____ **Year Built:** _____ ☐ EST
Total Floor Area (sq. ft.): __________ **Code Year:** __________
Additions: ☐ None ☐ Yes, Year(s) Built: __________

Occupancy:

Assembly	Commercial	Emer. Services	☐ Historic	☐ Shelter
Industrial	Office	School	☐ Government	
Utility	Warehouse	Residential, #Units: _____		

Soil Type:

☐**A**	☐**B**	☐**C**	☐**D**	☐**E**	☐**F**	**DNK**
Hard Rock	Avg Rock	Dense Soil	Stiff Soil	Soft Soil	Poor Soil	*If DNK, assume Type D.*

Geologic Hazards: Liquefaction: Yes/No/DNK Landslide: Yes/No/DNK Surf. Rupt.: Yes/No/DNK
Adjacency: ☐ Pounding ☐ Falling Hazards from Taller Adjacent Building
Irregularities: ☐ Vertical (type/severity) __________
☐ Plan (type) __________
Exterior Falling Hazards: ☐ Unbraced Chimneys ☐ Heavy Cladding or Heavy Veneer
☐ Parapets ☐ Appendages
☐ Other: __________

COMMENTS:

☐ Additional sketches or comments on separate page

BASIC SCORE, MODIFIERS, AND FINAL LEVEL 1 SCORE, S_{L1}

FEMA BUILDING TYPE	Do Not Know	W1	W1A	W2	S1 (MRF)	S2 (BR)	S3 (LM)	S4 (RC SW)	S5 (URM INF)	C1 (MRF)	C2 (SW)	C3 (URM INF)	PC1 (TU)	PC2	RM1 (FD)	RM2 (RD)	URM	MH
Basic Score		**3.6**	**3.2**	**2.9**	**2.1**	**2.0**	**2.6**	**2.0**	**1.7**	**1.5**	**2.0**	**1.2**	**1.6**	**1.4**	**1.7**	**1.7**	**1.0**	**1.5**
Severe Vertical Irregularity, V_{L1}		-1.2	-1.2	-1.2	-1.0	-1.0	-1.1	-1.0	-0.8	-0.9	-1.0	-0.7	-1.0	-0.9	-0.9	-0.9	-0.7	NA
Moderate Vertical Irregularity, V_{L1}		-0.7	-0.7	-0.7	-0.6	-0.6	-0.7	-0.6	-0.5	-0.5	-0.6	-0.4	-0.6	-0.5	-0.5	-0.5	-0.4	NA
Plan Irregularity, P_{L1}		-1.1	-1.0	-1.0	-0.8	-0.7	-0.9	-0.7	-0.6	-0.6	-0.8	-0.5	-0.7	-0.6	-0.7	-0.7	-0.4	NA
Pre-Code		-1.1	-1.0	-0.9	-0.6	-0.6	-0.8	-0.6	-0.2	-0.4	-0.7	-0.1	-0.5	-0.3	-0.5	-0.5	0.0	-0.1
Post-Benchmark		1.6	1.9	2.2	1.4	1.4	1.1	1.9	NA	1.9	2.1	NA	2.0	2.4	2.1	2.1	NA	1.2
Soil Type A or B		0.1	0.3	0.5	0.4	0.6	0.1	0.6	0.5	0.4	0.5	0.3	0.6	0.4	0.5	0.5	0.3	0.3
Soil Type E (1-3 stories)		0.2	0.2	0.1	-0.2	-0.4	0.2	-0.1	-0.4	0.0	0.0	-0.2	-0.3	-0.1	-0.1	-0.1	-0.2	-0.4
Soil Type E (> 3 stories)		-0.3	-0.6	-0.9	-0.6	-0.6	NA	-0.6	-0.4	-0.5	-0.7	-0.3	NA	-0.4	-0.5	-0.6	-0.2	NA
Minimum Score, S_{MIN}		*1.1*	*0.9*	*0.7*	*0.5*	*0.5*	*0.6*	*0.5*	*0.5*	*0.3*	*0.3*	*0.3*	*0.2*	*0.2*	*0.3*	*0.3*	*0.2*	*1.0*

FINAL LEVEL 1 SCORE, $S_{L1} \geq S_{MIN}$:

EXTENT OF REVIEW

Exterior: ☐ Partial ☐ All Sides ☐ Aerial
Interior: ☐ None ☐ Visible ☐ Entered
Drawings Reviewed: ☐ Yes ☐ No
Soil Type Source: __________
Geologic Hazards Source: __________
Contact Person: __________

LEVEL 2 SCREENING PERFORMED?

☐ Yes, Final Level 2 Score, S_{L2} __________ ☐ No
Nonstructural hazards? ☐ Yes ☐ No

OTHER HAZARDS

Are There Hazards That Trigger A Detailed Structural Evaluation?

☐ Pounding potential (unless S_{L2} > cut-off, if known)
☐ Falling hazards from taller adjacent building
☐ Geologic hazards or Soil Type F
☐ Significant damage/deterioration to the structural system

ACTION REQUIRED

Detailed Structural Evaluation Required?

☐ Yes, unknown FEMA building type or other building
☐ Yes, score less than cut-off
☐ Yes, other hazards present
☐ No

Detailed Nonstructural Evaluation Recommended? *(check one)*

☐ Yes, nonstructural hazards identified that should be evaluated
☐ No, nonstructural hazards exist that may require mitigation, but a detailed evaluation is not necessary
☐ No, no nonstructural hazards identified ☐ DNK

Where information cannot be verified, screener shall note the following: EST = Estimated or unreliable data OR DNK = Do Not Know

Legend:	MRF = Moment-resisting frame	RC = Reinforced concrete	URM INF = Unreinforced masonry infill	MH = Manufactured Housing	FD = Flexible diaphragm
	BR = Braced frame	SW = Shear wall	TU = Tilt up	LM = Light metal	RD = Rigid diaphragm

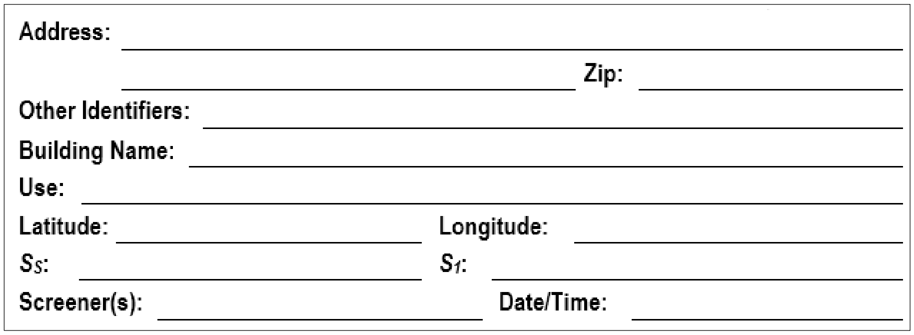
Figure 3-1 Level 1 Data Collection Form (High seismicity).

10. Determining the Final Level 1 Score, S_{L1} (by adjusting the Basic Score from Step 8 with the Score Modifiers identified in Step 9); and
11. Completing the summary section at the bottom of the form (i.e., Extent of Review, Other Hazards and Action Required).

Full-sized copies of the Level 1 Data Collection Forms (one for each seismicity region) are provided in Appendix B. The form has been designed to be filled out from top to bottom, with a minimum of writing (most items can simply be checked or circled). The following sections provide instructions and guidance on completing sections of the form from top to bottom.

3.2 Building Identification Information

Space is provided in the upper right-hand portion of the Level 1 Data Collection Form (see Figure 3-2) to document building identification information (address, building name, use, latitude and longitude, and site-specific ground motion values), name of the screener(s), and the date and time of the screening. As indicated in Chapter 2, it is desirable to develop and document this information during the pre-field planning stage, if possible. This information may be filled out manually, or it can be preprinted on a peel-off label or printed directly onto the Data Collection Form.



Address: ____________________
____________________ **Zip:** __________
Other Identifiers: ____________________
Building Name: ____________________
Use: ____________________
Latitude: __________ **Longitude:** __________
S_S: __________ **S_1:** __________
Screener(s): __________ **Date/Time:** __________

Figure 3-2 Building Identification Information portion of Level 1 Data Collection Form.

3.2.1 Building Identification

Proper identification and location of the building is critically important for subsequent use in hazard assessment and mitigation by the RVS Authority. As described in Chapter 2, the structure can be identified by street address, parcel number, building owner, or some other scheme. However, it is recommended that as a minimum the street address and zip code be recorded on the form. Zip code is important because it is universal to all municipalities, and as such, is an especially useful item for later collation and summary analyses. Assessor parcel number or lot number is also useful for jurisdictional record-keeping purposes and can be entered in the "Other Identifiers" field on the form.

Caution should be exercised for buildings that contain multiple tenants with individual addresses for the same building structure. In these instances, it is suggested to include the full range of address numbers for the building, for example "6200 – 6250," and complete the screening for the building using one form.

Assuming the identification information is provided directly on the form, such information should be verified in the field. If the building identification information is not developed during the pre-field planning stage, it must be completed in the field.

3.2.2 Latitude and Longitude and Site Seismicity

Fields are provided to document the latitude and longitude of the building and to document S_S and S_1 values, which describe the site-specific ground motion. These fields may be completed during pre-field planning. Latitude and longitude can be determined using tools found on the internet. Once latitude and longitude are known, S_1 and S_S can be determined as described in Section 2.6.

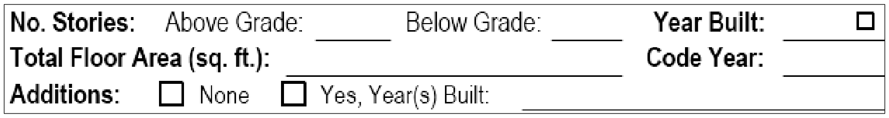
It is not expected that the screener will use these fields while performing the screening. However, they may be useful later for data keeping purposes or if electronic scoring will be performed (as described in Chapter 6). If a GPS device is available to the screener while at the building site, the screener should verify the latitude and longitude information on the form.

3.2.3 Screener Identification

The screener should be identified by name, initials, or some other type of code. At some later time, it may be important to know who the screener was for a particular building. The date and time of the screening should also be noted. In particular, noting the time of the screening will be helpful later in matching digital photos to the appropriate Data Collection Form.

3.3 Building Characteristics

Space is provided to document important building characteristics (see Figure 3-3). It is desirable to develop and document this information during the pre-field planning stage, if at all possible. This information may be filled out manually, or it can be preprinted on a peel-off label or printed directly onto the Data Collection Form. Assuming the information is compiled during pre-field planning, the information should be verified in the field. If the information is not compiled during the pre-field planning stage, it must be completed in the field.



No. Stories: Above Grade: ______ Below Grade: ______ **Year Built:** ______ ☐
Total Floor Area (sq. ft.): ______ **Code Year:** ______
Additions: ☐ None ☐ Yes, Year(s) Built: ______

Figure 3-3 Building Characteristics portion of the Level 1 Data Collection Form.

3.3.1 Number of Stories

The amount of damage a building may sustain is sometimes related to the height of a structure. The number of stories is a good indicator of the height of a building (approximately 9-to-10 feet per story for residential, 12 feet per story for commercial or office).

Counting the number of stories may not be a straightforward issue if the building is constructed on a hill or if it has several different roof levels. As a general rule, the largest number (that is, count floors from the downhill side to the highest roof) should be used. The comment section and the sketch can be used to indicate variations in the number of stories.

The number of stories below grade should also be indicated if the screener can verify the number. Collecting this information is particularly useful if the community decides later to investigate flooding issues.

3.3.2 Year Built and Code Year

Information pertaining to the design and code year of the building is one of the key elements of the RVS procedure. Building age is tied directly to design and construction practices. Therefore, age can be a factor in determining FEMA Building Type and thus can affect the Final Score. This information is not typically available at the site and thus should be obtained in advance of the fieldwork.

If information on “year built” is not available during pre-field planning (see Chapter 2), a rough estimate of the building’s age can be made on the basis of architectural style and building use. Appendix D provides guidance on determining building attributes from the street. An additional source of obtaining the building vintage is from a dedication placard or plate. These are more common for public buildings and usually are located near the main entrance of the building. If the year built is only an approximation, check the “EST” box to indicate the entry is estimated.

Code year is the year of the building code that was used to design the building. The building may have been designed several years before it was constructed and thus designed to an earlier code with different requirements for seismic detailing. Code year can generally only be determined from the drawings during pre-field planning (see Chapter 2). If code year is not known, it should be left blank.

3.3.3 Total Floor Area

The total floor area, in some cases available from building department or assessor files (see Chapter 2), will most likely be estimated by multiplying the estimated area of one story by the total number of stories in the building. The length and width of the building can be paced off in the field or estimated during the pre-field planning stage from Sanborn or other parcel maps or satellite images. Repeating modules on the façade of the building can also be measured and extrapolated to determine the building dimensions. Total floor area may be useful at a later time for estimating the value of the building or for estimating occupancy load. If the value is an estimate, "EST" should be noted.

3.3.4 Buildings with Additions or Multiple Parts

Many buildings are comprised of more than one independent structural framing system divided by joints. In some cases, the joints are provided to separate portions of buildings that were constructed at the same time. This may be to separate portions of the building that have different structural systems, and thus different responses to lateral forces or portions of buildings with different total height or story heights. Alternately, buildings can be divided to accommodate expansion and contraction caused by temperature changes.

Buildings can also be considered as having multiple portions when additions are constructed to expand the original building. Building additions may be constructed as independent structures with separation joints or may be integrally tied to the original building.

Information obtained in advance of the screening may be useful in identifying buildings that have additions. Section 3.14.5 provides guidance for assessing whether to evaluate a building as a single building or as multiple buildings.

When additions are present, the "Yes" box should be checked and the year the addition was built should be indicated. "EST" should be added if the year built for the addition is estimated.

3.4 Photographing the Building

A space is provided on the Level 1 form to place a photograph of the building (see Figure 3-4). At least one photograph of the building should be taken for identification purposes. The screener is not limited to one photograph. If possible, the screener should take a photograph of each side of the building and of any important features (such as observed irregularities and falling hazards). These additional photographs will be helpful to the Supervising Engineer during the quality assurance phase.

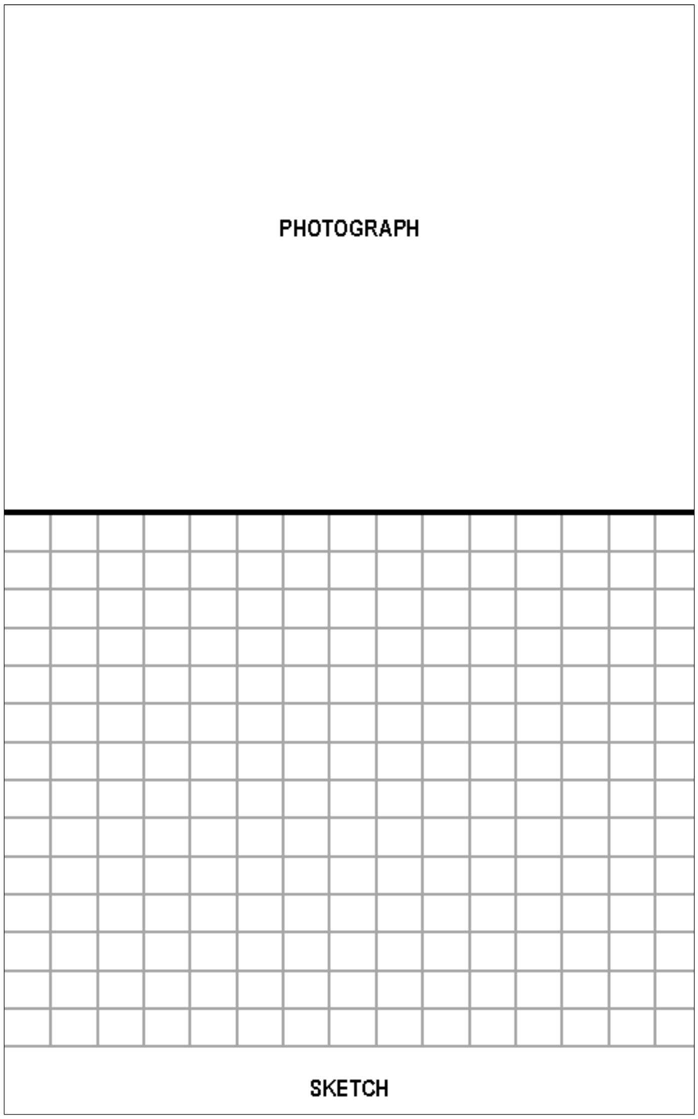


Figure 3-4 Photograph and Sketch portions of the Level 1 Data Collection Form.

Large buildings are difficult to photograph from the street and the camera lens introduces distortion for high-rise buildings. If possible, the photograph should be taken from a sufficient distance to include a full building elevation, such that adjacent faces are included. Two examples are shown in Figure 3-5. A wide angle lens may be helpful. Strong sunlit façades should be avoided, as harsh contrasts between shadows and sunlit portions of the façade will be introduced. Lastly, if possible, the photographed elevation of the building should not be obscured by trees, vehicles or other objects, as they obscure the lower stories.

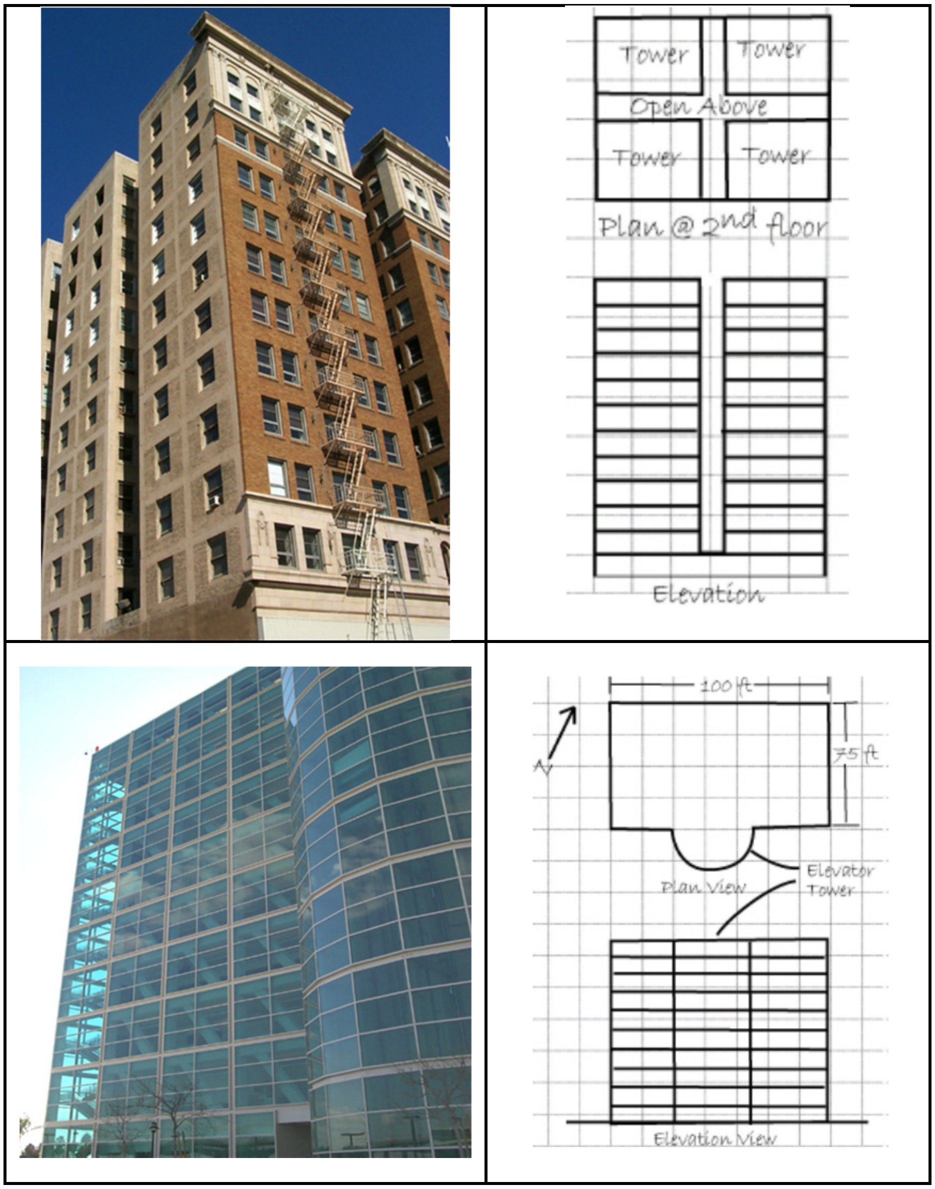


Figure 3-5 Sample sketches and photos.

It is expected that screeners will most often use a digital camera. In this case, one or two of the photographs can later be electronically added to the Data Collection Form. Additional photographs can be saved in an electronic file or printed and arranged on an additional page to be saved along with the paper copy of the Data Collection Form.

3.5 Sketching the Building

A place is provided on the Level 1 Data Collection Form to draw a sketch of the building (see Figure 3-4). As a minimum, the screener should draw a plan sketch. An elevation sketch may also be useful in indicating significant features. Drawing the sketch is an important part of the screening procedure because many of the building's attributes will be revealed to the screener as the screener systematically views all aspects of the building in order to prepare the sketch. A photograph contains more detailed information than a sketch, but the sketch can better emphasize important features.

The plan sketch should show the shape of the building from above and any plan irregularities. It can also show the location of the building on the site and the relative or approximate distance to adjacent buildings. The plan sketch can be made during pre-field planning using a Sanborn map or an image of the building from above, such as a satellite image. In this case, the sketch should be verified in the field. More often, the sketch will be drawn by the screener in the field. Screeners with access to a smart device will find it helpful to view the satellite image of the building while performing the screening. This is especially valuable when access between buildings is not available.

The elevation sketch should show the number of stories, any steps in elevation, and any vertical irregularities. If all sides of the building are different, an elevation can be sketched for each side. If all sides are similar, the screener can note that the sketch is typical of all sides. The sketch can also be used to emphasize special features such as significant cracks, falling hazards, and floor levels where pounding could occur.

The length and width of the building can be paced off or estimated (during the planning stage) from Sanborn maps, other parcel maps, or satellite images. Repeating modules on the façade of the building can also be measured and extrapolated to determine the building dimensions. These estimated dimensions should be included on the sketch. It will not usually be practical for the screener to draw the sketch to scale while in the field. Screeners may want to sketch in pencil on a separate sheet of gridded paper. In this case, the sketch can be scanned and added to the form in the same manner as photographs.

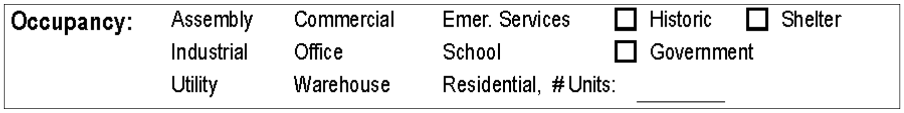
Sample photos and related sketches are shown in Figure 3-5.

3.6 Building Occupancy

The occupancy of a building refers to its use. Although it does not usually bear directly on the structural hazard or probability of sustaining major damage, the occupancy of a building is of interest and used when determining priorities for mitigation.

3.6.1 Occupancy Classes

Nine general occupancy classes have been identified as easy to recognize in a rapid visual screening and are defined below (Figure 3-6). These occupancy classes have characteristics that are easily identifiable from the street, they generally represent the broad spectrum of building uses in the United States, and they are similar to the occupancy classes used in the *Multi-hazard Loss Estimation Methodology, Earthquake Model, HAZUS-MH MR4 Technical Manual* (FEMA, 2009a) and the *International Building Code* (ICC, 2012).



Occupancy:	Assembly	Commercial	Emer. Services	☐ Historic	☐ Shelter
	Industrial	Office	School	☐ Government	
	Utility	Warehouse	Residential, # Units: ________		

Figure 3-6 Occupancy portion of the Level 1 Data Collection Form.

It is strongly encouraged that for RVS Programs where data collection is being performed with the intent of inputting the data into HAZUS, the HAZUS Building Occupancy Classes be used when evaluating the building stock. The ROVER, *Rapid Observation of Vulnerability and Estimation of Risk* (FEMA, 2011), software provides a module, RedROVER, containing an export file for HAZUS's *Advanced Engineering Building Module* (FEMA, 2003). This enables mapping of FEMA 154 RVS occupancy classes to HAZUS occupancy classes.

The nine occupancy classes in RVS are described below:

- *Assembly.* Places of public assembly are those where large groups of people might be gathered in one room at the same time. A threshold of 300 people is typically used in building codes, and it is used here, as well. Examples are theaters, auditoriums, community centers, performance halls, and churches.
- *Commercial.* The commercial occupancy class refers to retail and wholesale businesses, financial institutions, restaurants, and parking structures.
- *Emergency Services.* The emergency services class is defined as any facility that would likely be needed in a major catastrophe. These include police and fire stations, hospitals, and communications centers.

- *Industrial.* Included in the industrial occupancy class are factories, assembly plants, and heavy manufacturing facilities.
- *Office.* Typical office buildings house clerical, management, and professional services occupancies.
- *Residential.* This occupancy class refers to residential buildings such as houses, townhouses, dormitories, motels, hotels, apartments and condominiums, and residences for the aged or disabled. Indicate the number of dwelling units in the building on the line next to the word "Residential."
- *School.* This occupancy class includes all public and private educational facilities from nursery school to university level.
- *Utility.* This occupancy class includes all buildings that house public or private utilities, such as power plants, water treatment facilities, and electric substations.
- *Warehouse.* This occupancy class includes both large warehouses where items are stored and commercial warehouses where items are sold.

The occupancy class that best describes the building being evaluated should be circled on the form. If there are several types of uses in the building, such as commercial and residential, all applicable types should be circled. The actual use of the building can be written in the Building Identification portion of the form. For example, one might indicate that the building is a restaurant on the line titled "Use" in the upper right of the form. For occupancy, the screener would circle "Commercial."

If none of the defined classes seem to fit the building, an explanation should be included in the Comments section.

3.6.2 Additional Designations

Of additional interest are whether the building is historic, whether it houses government services, and whether it is designated as an emergency shelter. These are not occupancy classes, but may be used for setting priorities for hazard mitigation.

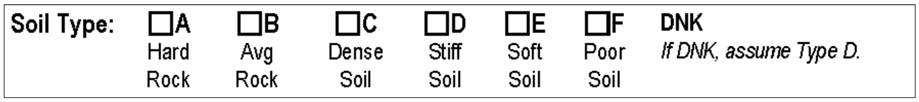
- *Historic.* This will vary from community to community. It is included because historic buildings may be subjected to specific ordinances and codes.
- *Government.* This includes local, state, and federal non-emergency related buildings.

- *Shelter*. Some buildings may be designated as shelters to be used in the event of an emergency. The community may set a higher priority on upgrading these buildings.

If the building is any of these, the screener should circle the occupancy and check the appropriate box. For example, when screening a school designated as an emergency shelter, the screener will circle “School” and check the “Shelter” box.

3.7 Soil Type

As indicated in Chapter 2, the soil type should be identified and documented on the Data Collection Form (see Figure 3-7) during pre-field planning. If the soil type has not been determined as part of that process, it needs to be identified by the screener during the building site visit. If there is no basis for classifying the soil type, “DNK” should be selected and Soil Type D should be assumed.



Soil Type:	☐**A**	☐**B**	☐**C**	☐**D**	☐**E**	☐**F**	**DNK**
	Hard	Avg	Dense	Stiff	Soft	Poor	*If DNK, assume Type D.*
	Rock	Rock	Soil	Soil	Soil	Soil	

Figure 3-7 Soil Type portion of the Level 1 Data Collection.

3.8 Geologic Hazards

Liquefaction, landslide potential, and surface fault rupture are three types of geologic hazards. Any one of these three conditions can increase a building’s risk of sustaining damage and collapse during an earthquake. If any of these hazards are identified at a building site, a Detailed Structural Evaluation of the building is triggered.

Geologic hazards may be identified and documented on the Data Collection Form (see Figure 3-8) during pre-field planning.

Geologic Hazards: Liquefaction: Yes/No/DNK Landslide: Yes/No/DNK Surf. Rupt.: Yes/No/DNK

Figure 3-8 Geologic Hazards portion of the Level 1 Data Collection Form.

The presence of possible landslide hazards should be evaluated or confirmed during the field visit by assessing the distance between the building to a steep slope either above or below the building grade level. As a rule of thumb, if the height of the slope is greater than the distance from the nearest side of the building to the slope, a potential landslide hazard should be marked on the form (see Figure 3-9).

For each of the three geologic hazards, “Yes” or “No” should be circled depending on whether the geologic hazard exists at the building site. If the

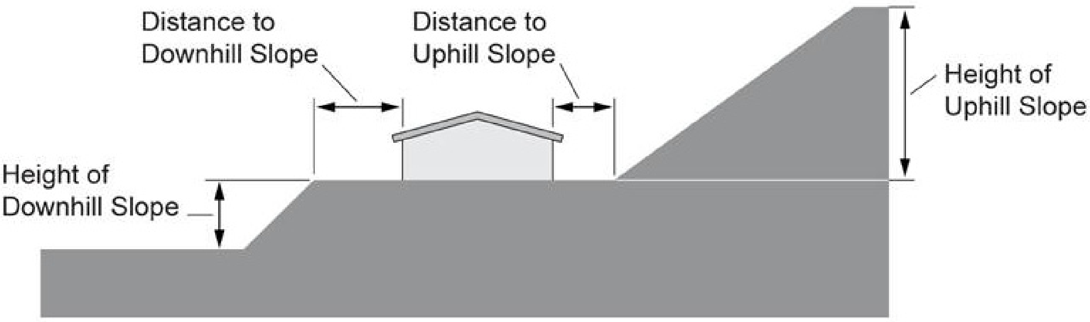


Figure 3-9 Building with potential landslide hazard.

presence of the geologic hazard has not been determined as part of the pre-field planning process and cannot be determined during the screening, the screener should circle "DNK" (do not know).

3.9 Adjacency

The interaction between adjacent buildings can lead to several types of damage during earthquakes. When there is insufficient separation between buildings, they can pound together as they respond to ground shaking. In some cases, an addition may pound against the original building. See Section 3.14.5 for a discussion of how to screen buildings with additions.

Another potential concern is falling hazards from an adjacent building. These can be chimneys, parapets, walls, appendages, tanks, signs, or any other building components that if dislodged, could fall onto the building being screened or block major means of egress from the building being screened.

In the Level 1 screening, the intent is to capture these situations by checking the appropriate box, which is either "Pounding" or "Falling Hazards from Taller Adjacent Building" (see Figure 3-10). If either of these conditions is identified, a Detailed Structural Evaluation of the building is triggered.

Adjacency: ☐ Pounding ☐ Falling Hazards from Taller Adjacent Building

Figure 3-10 Adjacency portion of the Level 1 Data Collection Form.

The Level 1 pounding criteria is described in the Level 1 Pounding Reference Guide which is provided in Appendix B. The guide provides minimum separation gaps between adjacent buildings (see Figure 3-11). In Very High seismicity regions, the minimum gap between the two buildings is 2 inches per story. In High seismicity regions, the minimum gap is 1 1/2 inches per story. In Moderately High seismicity regions, the minimum gap is 1 inch per story. In Moderate and Low seismicity regions, the minimum gap is 1/2 inch per story.

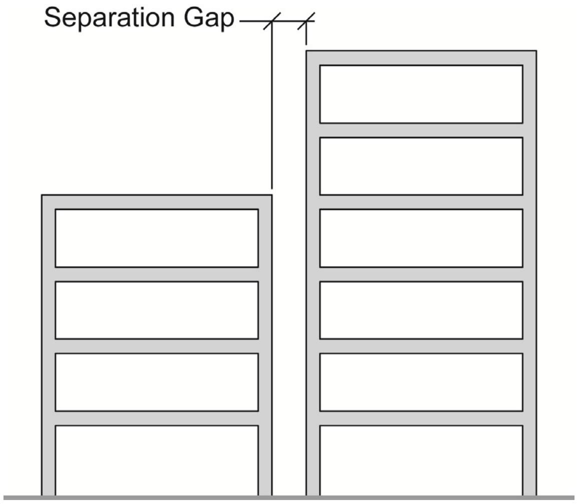


Figure 3-11 Definition of separation gap between adjacent buildings.

For example, for two adjacent six-story buildings, the minimum gap is 12” in Very High seismicity, 9” in High seismicity, 6” in Moderately High seismicity, and 3” in Moderate or Low seismicity.

Pounding is considered when the actual gap is less than the minimum separation gap and when at least one of three additional conditions also applies:

1. Floors are separated vertically by more than two feet, as shown in Figure 3-12. Damage and potential collapse are considered to be more likely when the floor mass of one building can directly impact the columns or walls of the adjacent building.

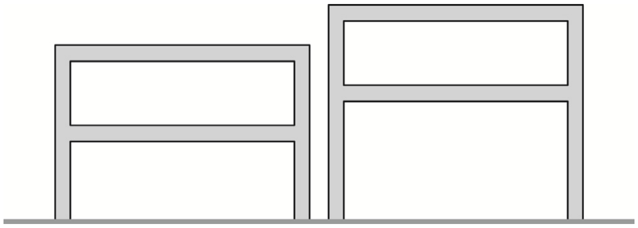


Figure 3-12 Schematic illustration of floors not aligning vertically.

2. One building is two or more stories taller than the adjacent building, as illustrated in Figure 3-13. Damage may concentrate in the taller building at the roof level of the shorter building.
3. The building is at the end of a row of three or more buildings, as illustrated in Figure 3-14. Higher demands are imposed on the end building when the adjacent building moves toward it and because it does not have a building on the other side to balance the loads. Higher levels of damage have been observed at end buildings in past earthquakes.

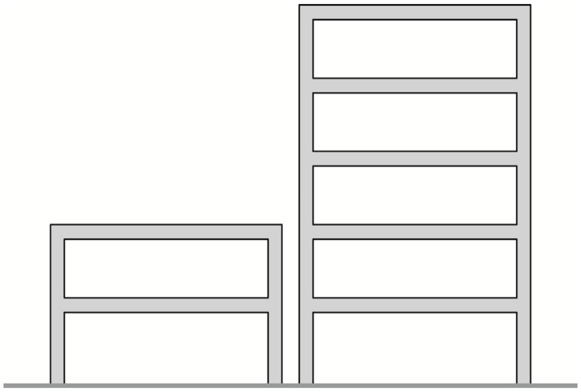


Figure 3-13 Schematic illustration of buildings of different height.

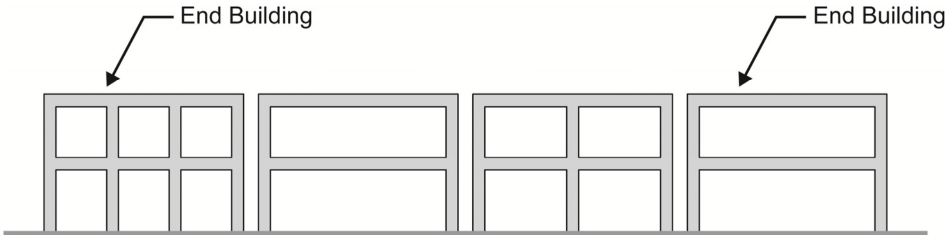


Figure 3-14 Schematic illustration of end buildings.

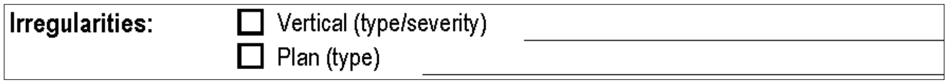
If the building meets any of the three criteria above, the screener checks the "Pounding" box and a Detailed Structural Evaluation is triggered in the "Other Hazards" and "Action Required" fields at the bottom of the Level 1 form. Similarly, if falling hazards from an adjacent building are identified, the screener checks the "Falling Hazards" box and a Detailed Structural Evaluation is triggered in the "Other Hazards" and "Action Required" fields at the bottom of the Level 1 form.

3.10 Irregularities

Buildings are often irregular for architectural, functional, or economic reasons. Often the first floor of a building is taller than the stories above, as in the case of a building with commercial space on the ground floor and apartments above. A building on a corner may have many windows on the two sides facing the street, but have solid walls on the other two sides. Irregularities such as these adversely affect the seismic performance of a building by concentrating demands at certain floor levels or elements. The concentrated demands can lead to damage, failure, and, in some cases, collapse.

Building irregularities are generally grouped into two categories: vertical irregularities and plan irregularities. For the Level 1 RVS procedure, vertical irregularities are further divided into severe vertical irregularities (those that have a significant adverse effect on building performance) and moderate vertical irregularities (those that have a less significant adverse effect on building performance). The RVS score takes into account irregularities by including negative Score Modifiers whose values depend on the type and severity of the building's irregularities.

The following sections describe how to identify vertical and plan irregularities during the Level 1 screening. If any irregularities are observed, the screener describes them using the Irregularities portion of the form (see Figure 3-15).



Irregularities: ☐ Vertical (type/severity) ____________________

☐ Plan (type) ____________________

Figure 3-15 Irregularity portion of the Level 1 Data Collection Form.

3.10.1 Vertical Irregularities

Vertical irregularities can affect all building types. There are seven common types of vertical irregularities, as shown in the Vertical Irregularity Reference Guide (see Appendix B, Table B-4) and as described below:

- *Sloping Site.* If the building is on a steep hill, as illustrated in Figure 3-16, a problem may exist because the horizontal stiffness along the lower side may be different from the uphill side. In addition, in the up-slope direction, the stiff short columns attract more of the seismic shear forces and may fail. For all FEMA Building Types other than light wood frame buildings (W1), the Moderate Vertical Irregularity Score Modifier should be applied when there is at least a one-story slope from one side of the building to the other. For W1 buildings, the effect of a sloping site is more severe and the Severe Vertical Irregularity Score Modifier should be applied when there is at least a one-story slope from one side of the building to the other.

  Weak and/or Soft Story. A weak story exists when one story has less strength (fewer walls or columns) than the story above or below it. A soft story exists if the stiffness of one story is dramatically less than that of most of the others. In a rapid visual screening, it is not possible to quantitatively determine and compare the strength and stiffness of each story. Certain observable conditions, however, provide clues that a soft or weak story may exist. If any of the conditions described below exist, the screener checks the vertical irregularity box on the form and indicates the type and severity of the irregularity. If there is doubt about whether any of the following conditions exist, it is best to be conservative and assume that it does exist. Use an asterisk and the comment section to explain the source of uncertainty.

Figure 3-16 Illustration of a building on a sloping site.

- Light wood frame residential buildings (W1) often have cripple walls. A cripple wall is a short wall that rests on the foundation and supports the floor and exterior walls. When cripple walls are unbraced, they are often the weakest part of the structure. A cripple wall is considered unbraced when there is no plywood sheathing. In this case, the walls are sheathed only with stucco or wood siding on the exterior side of the wall, as shown in Figure 3-17. It will not usually be possible for the screener to determine if a W1 building has unbraced cripple walls from a sidewalk survey. However, in the event that there is access to the crawl space and unbraced cripple walls are observed, the screener should note this condition. Unbraced cripple walls may sometimes be observed in garage spaces as well. Unbraced cripple walls are considered a moderate vertical irregularity. If the basement is occupied, consider this condition as a soft story and apply the Severe Vertical Irregularity Score Modifier.

- For a wood framed home (W1) with occupied space over a garage, there are limited or short wall lengths on both sides of the garage opening, as shown in Figure 3-18. This is considered a severe vertical irregularity.

- A wood framed multi-unit residential building (W1A) has an open front at the ground floor, such as for parking. Apartment buildings with this common condition are often referred to as “tuckunder” buildings (see Figure 3-19). Several past earthquakes in California have shown the vulnerability of this type of construction. This is considered a severe vertical irregularity.

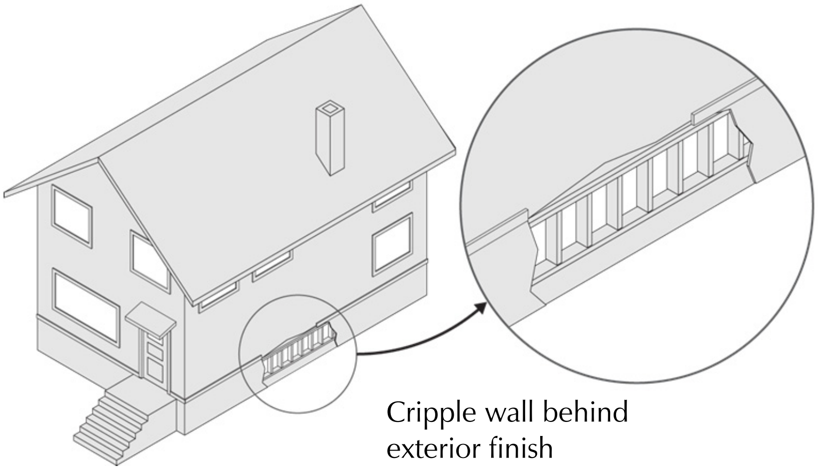


Figure 3-17 Schematic illustration of a W1 building with cripple wall.

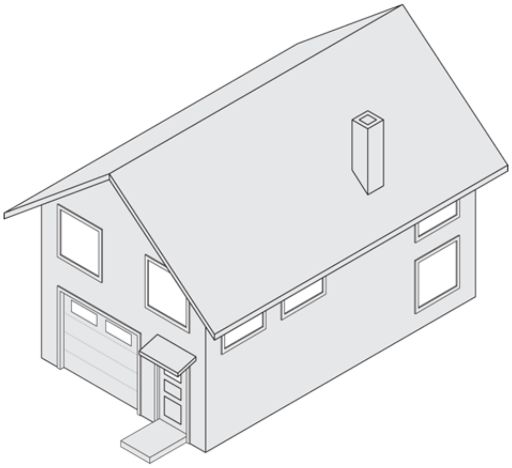


Figure 3-18 Schematic illustration of a W1 building with occupied space over a garage.

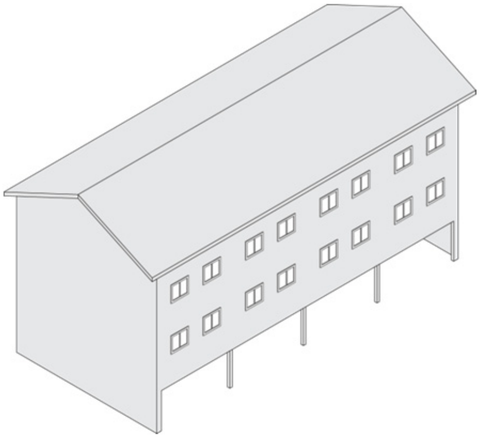


Figure 3-19 Schematic illustration of building with a soft-story condition where parking requirements result in large openings.

- One of the stories has fewer walls or columns (or more windows and openings) than the floor above it. In many commercial buildings, the first story is weak/soft due to large window openings for display purposes. Figure 3-20 shows an industrial building with large openings at the ground floor. These large openings cause the first floor piers to be narrower than the piers at upper stories resulting in a weak story. This is considered a severe vertical irregularity.

Figure 3-20 Illustration of a building with a soft ground story due to large openings and narrow piers.

- One of the stories is particularly tall compared to the other stories. Figure 3-21 shows a building with a ground story significantly taller than the stories above. This difference in story height causes the piers to be taller at the first floor than at the upper stories resulting in a soft story. This is considered a severe vertical irregularity.

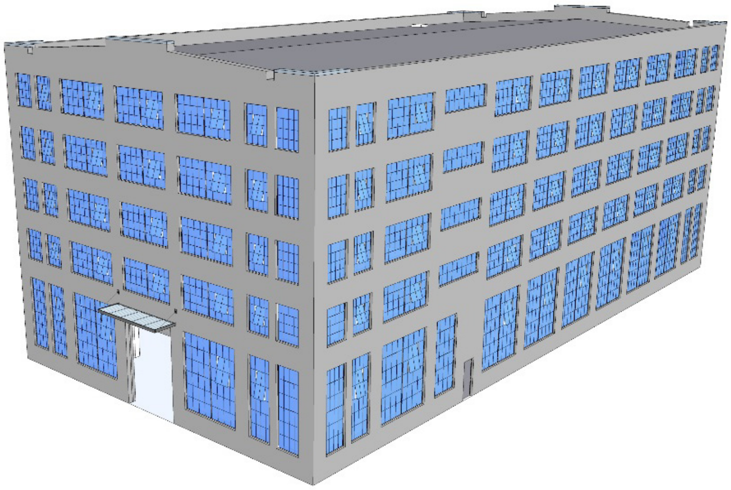


Figure 3-21 Illustration of a building with a soft ground story due to tall piers.

- *Out-of-Plane Setback.* The out-of-plane setback irregularity occurs when the seismic force-resisting system at one story is not aligned vertically with the seismic force-resisting system above or below. One such example is shown in Figure 3-22. In more severe cases, the walls at an upper story are outboard of the walls below causing the diaphragm to cantilever as shown in Figure 3-23. The out-of-plane setback irregularity is usually identified based on the exterior walls. The exterior walls of the building, however, may not correctly indicate the location of the seismic force-resisting elements, such as when there are interior shear walls that are not visible from the exterior. If there is doubt about whether an out-of-plane setback exists, it is best to be conservative and assume that it does exist. Out-of-plane setbacks are considered severe vertical irregularities and should be considered where the setback is greater than or equal to 2 feet.
- *In-Plane Setback.* This condition occurs when elements of the seismic force-resisting system at upper levels are offset from elements of the seismic force-resisting system at lower levels. It is usually observable in braced frame and shear wall buildings. Damage can become concentrated in the horizontal elements that connect the offset lateral elements and in the vertical elements that occur below the lateral elements at the upper levels. This is considered a moderate vertical irregularity. Figure 3-24 shows an example where the shear walls at the ground story are offset from the shear walls above due to the loading dock location.

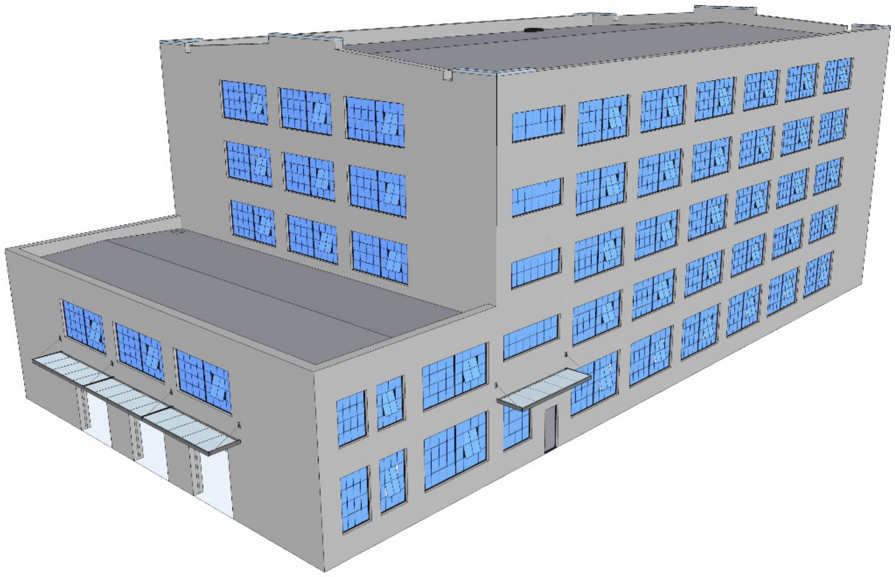


Figure 3-22 Illustration of a building with out-of-plane setback at the third story.

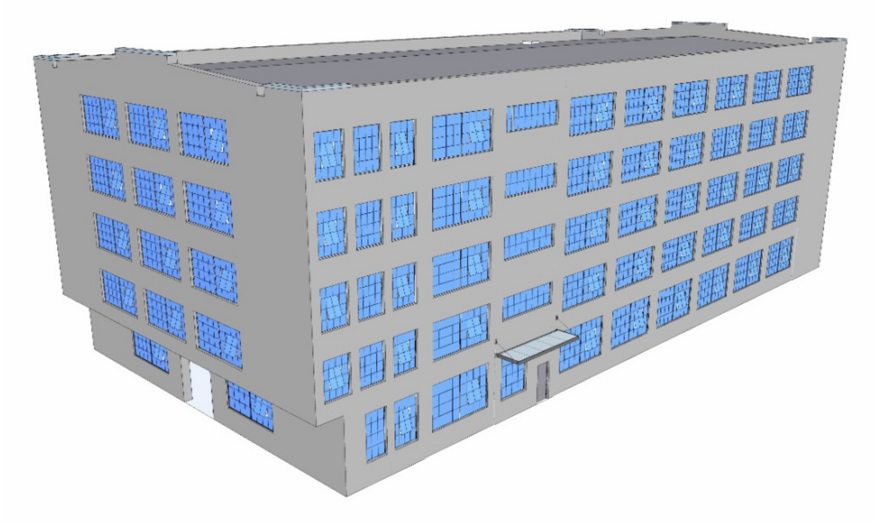


Figure 3-23 Illustration of a building with out-of-plane setback where the upper floors cantilever out over the smaller ground story footprint.

- *Short Column/Pier*. When some columns (or wall piers) are shorter than the typical columns, these shorter, stiffer columns attract more of the lateral load. Consequently, they can experience significant damage. Short columns can occur when there are partial height infill walls that shorten the clear height of the column or when a slab has been added between floor levels (e.g., for a mezzanine floor). Columns or piers that are narrow compared to the depth of the spandrels are also a concern. In these cases, damage concentrates in the columns rather than the beams, increasing the potential for loss of vertical support and subsequent collapse. Short columns or piers are considered severe vertical irregularities. This deficiency is typically seen in older concrete and steel buildings. Figure 3-25 shows three short column conditions.
- *Split Levels.* This condition occurs where floor or roof levels in one part of the building do not align with floor or roof levels in other parts of the buildings. Damage can become concentrated in the elements that connect the offset floor level to the vertical framing. This is considered a moderate vertical irregularity and is shown in Figure 3-26.

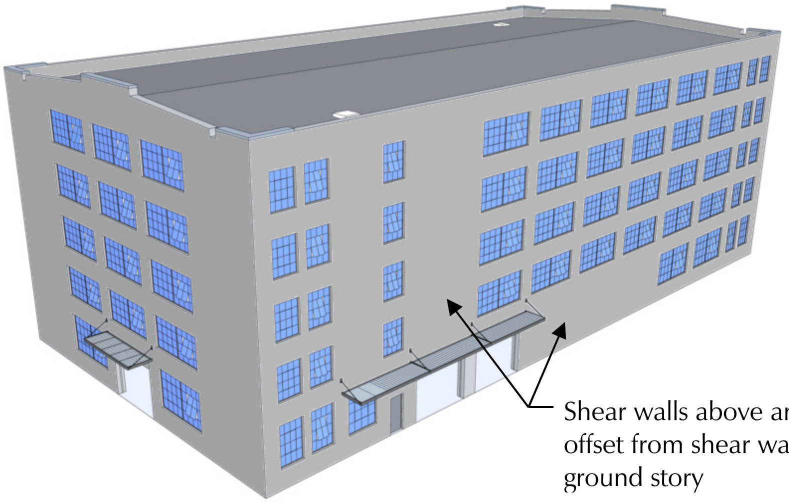

Shear walls above are offset from shear walls at ground story

Figure 3-24 Illustration of a building with an in-plane setback.

In some cases, a single building will have multiple vertical irregularities, such as the building shown in Figure 3-27. In this case, the screener should note all observed irregularities on the Data Collection Form and apply the Vertical Irregularity Score Modifier as described in Section 3.15.1.

3.10.2 Plan Irregularities

Although plan irregularity can occur in all building types, the primary concern lies with wood, tilt-up, pre-cast frame, reinforced masonry, and unreinforced masonry construction. Damage at roof connections may significantly reduce the capacity of a gravity load-carrying element, leading to partial or total collapse. There are five common types of plan irregularities, as shown in the Plan Irregularity Reference Guide (see Table B-5 in Appendix B) and as described below:

- *Torsion.* This condition applies when a building has a definable or good lateral-load resistance in one direction but not the other, or when there are major stiffness eccentricities in the seismic force-resisting system which may cause twisting (torsion) around a vertical axis. Plan irregularities causing torsion are especially prevalent among corner

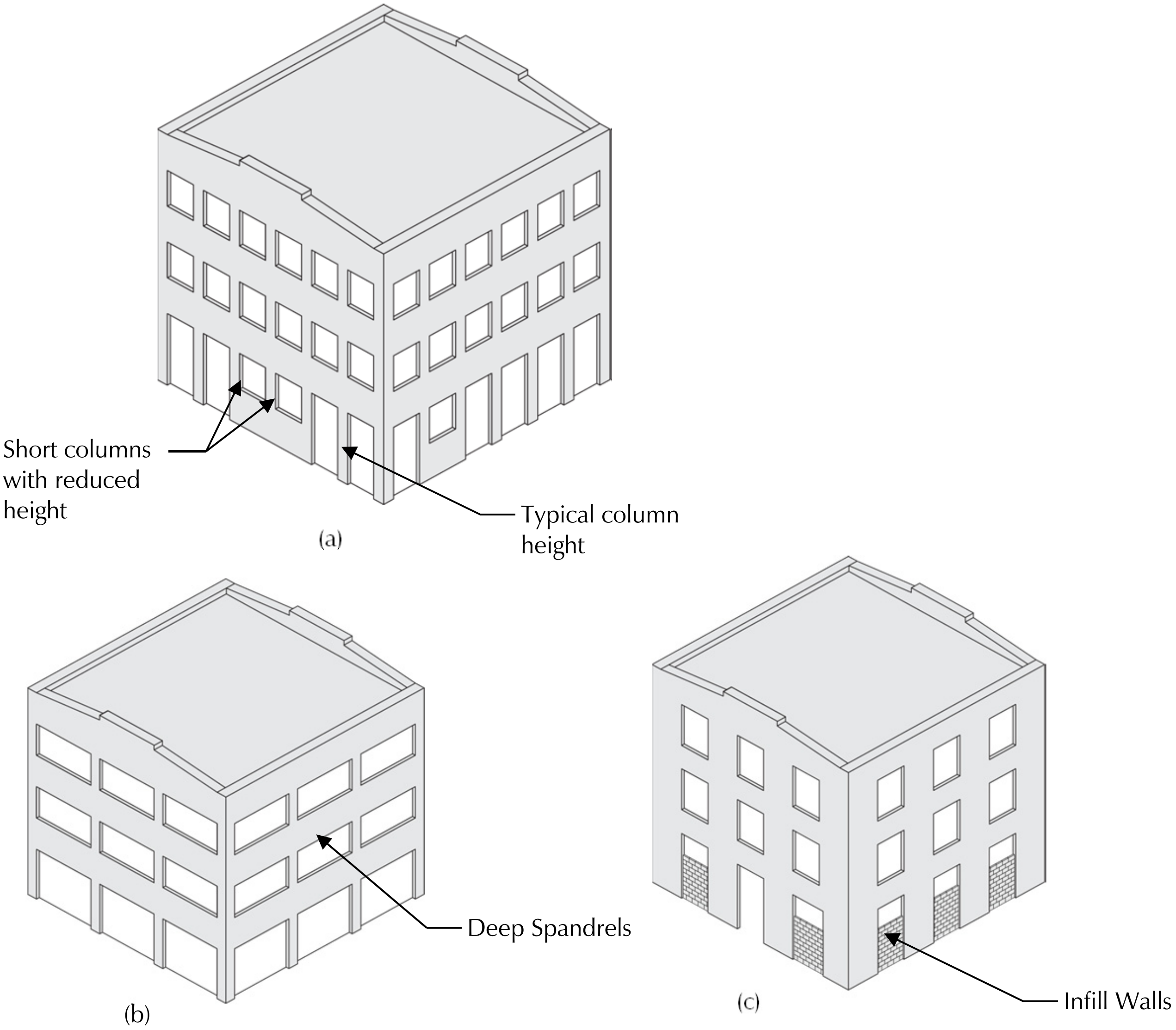


Figure 3-25 Schematic illustrations of buildings with short columns due to: (a) irregular wall openings; (b) deep spandrels; and (c) infill walls.

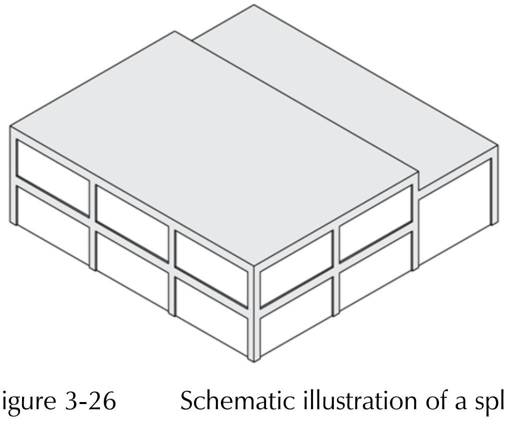


Figure 3-26 Schematic illustration of a split level irregularity.

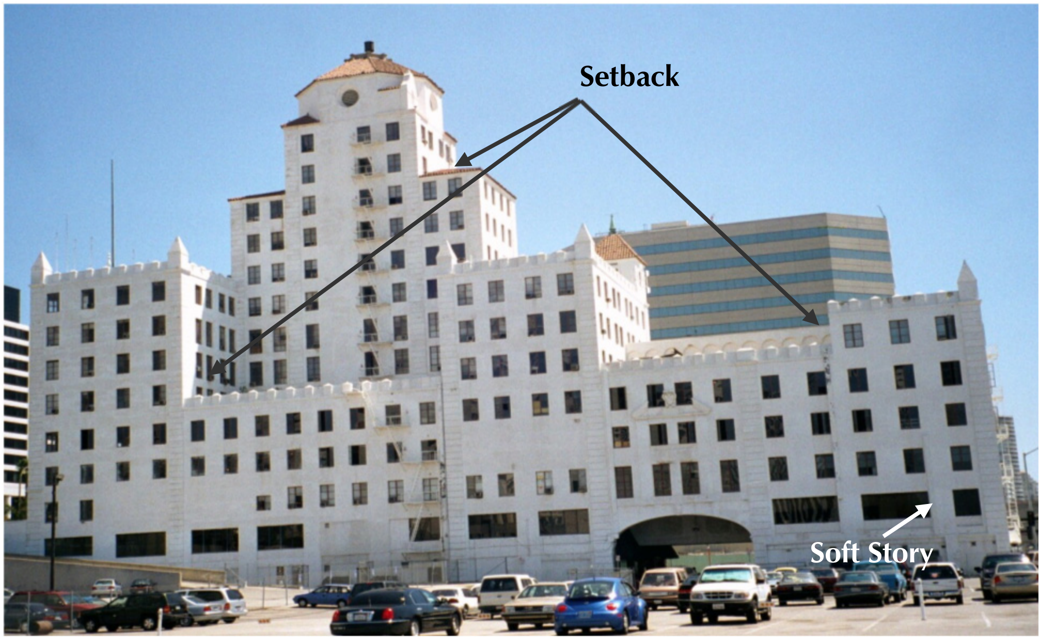


Figure 3-27 Building with multiple vertical irregularities: setbacks and a soft first story.

buildings, in which the two adjacent street sides of the building have significant window openings, whereas the other two sides are generally solid. Figure 3-28 shows an unreinforced masonry bearing wall building with similar pier and window patterns at all stories on all sides. This building does not have a plan irregularity. Figure 3-29 shows a common condition where the front or street façade on the ground story has windows such as for a store, with the walls in a C-shaped configuration. This would be considered a plan irregularity. Figure 3-30 shows a building with windows on two adjacent sides and more solid walls on the other two sides. This would also be considered a plan irregularity.

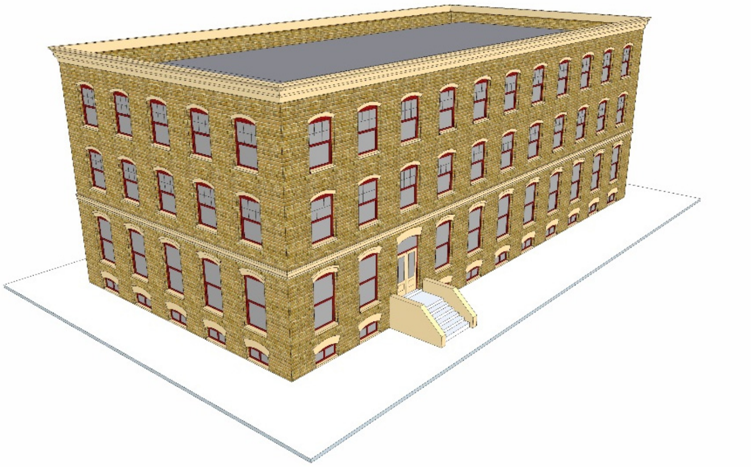


Figure 3-28 Illustration of a building without a plan irregularity.

Figure 3-29 Illustration of a building with the torsion plan irregularity due to the C-shaped configuration of walls at the ground floor.

Figure 3-30 Illustration of a corner building with the torsion plan irregularity due to L-shaped configuration of walls at the ground floor due to windows on two sides (visible in figure) and solid walls on two sides (hidden in the figure).

- *Non-Parallel Systems*. Wedge-shaped buildings, triangular in plan, on corners of streets not meeting at 90 degrees, are similarly susceptible to torsion and increased damage and collapse potential (see Figure 3-31).
- *Reentrant Corners.* Buildings with reentrant corners include those with long wings that are E, L, T, U, or + shaped, with projections of more than 20 feet (see Figure 3-32, Figure 3-33, and Figure 3-34). Stress concentrations can develop at reentrant corners and lead to damage or collapse. In addition, these buildings are likely to experience torsion. Where possible, the screener should check to see if there is a seismic separation where the wings meet. If so, the two portions of the building can be screened separately with consideration for pounding.

Figure 3-31 Building with a plan irregularity (non-parallel systems) due to its triangular footprint.

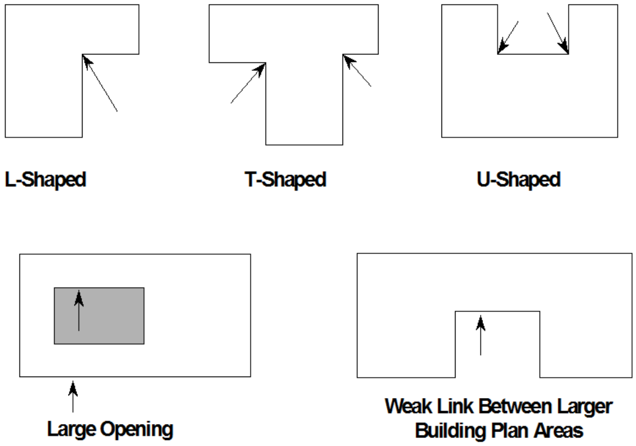


Figure 3-32 Plan views of various building configurations showing reentrant corners and large diaphragm openings; arrows indicate possible areas of damage.

Figure 3-33 Building with a plan irregularity with two wings meeting at right angles.

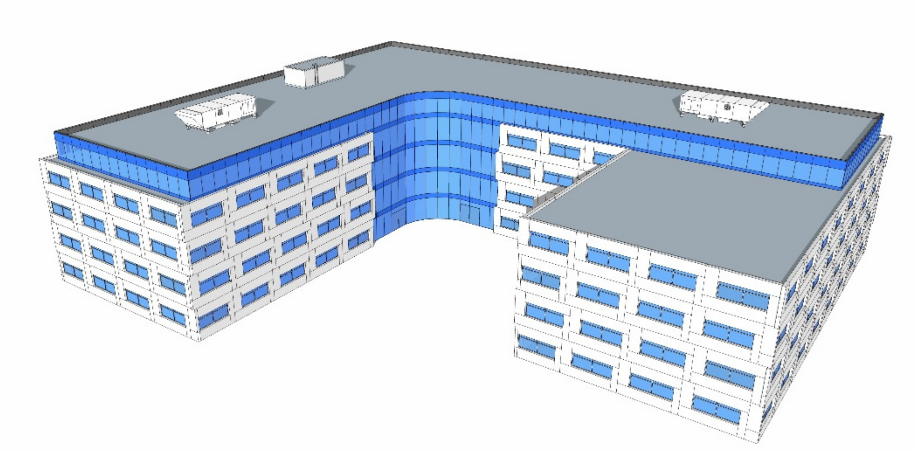


Figure 3-34 Illustration of a building with a reentrant corner plan irregularity.

- *Diaphragm Openings*. The floors and roof of a building have the important role of distributing seismic forces to the vertical elements of the seismic force-resisting system. Large openings in the floors or roof weaken the diaphragm and reduce its ability to transfer seismic forces. As a rule of thumb, a large opening is one that has a width of over 50% of the width of the diaphragm (see Figure 3-35). These openings occur for architectural features, such as roof skylights.
- *Beams do not align with columns*. This condition occurs when the exterior beams do not align with the columns in plan, as shown in Figure 3-36. Typically, this applies to concrete buildings, where the perimeter columns are outboard of the perimeter beams.

If the building being screened has a plan irregularity, the screener should check the plan irregularity box in the Irregularities section of the form and note the type of irregularity.

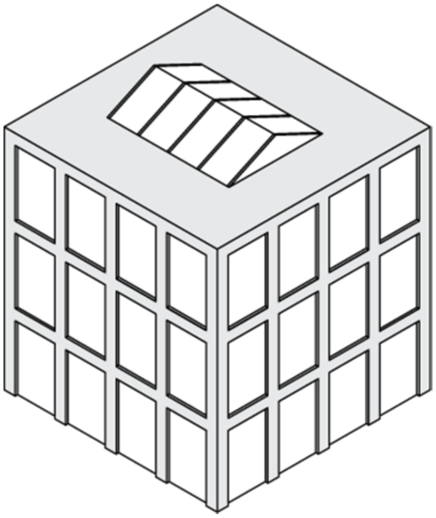


Figure 3-35 Schematic illustration of large diaphragm openings.

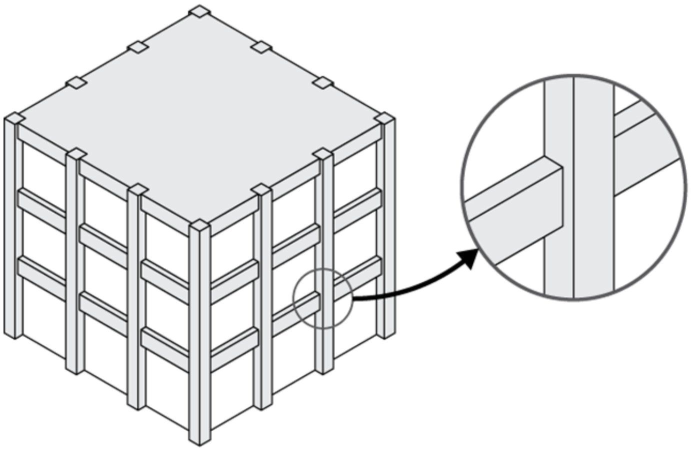


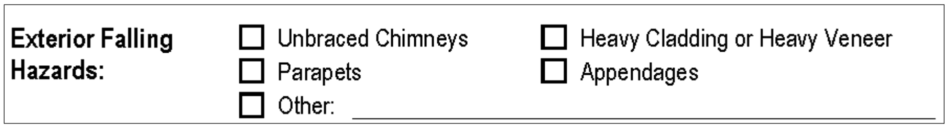
Figure 3-36 Schematic illustration of a building with beams that do not align with columns.

3.11 Exterior Falling Hazards

Nonstructural falling hazards such as chimneys, parapets, cornices, veneers, overhangs, and heavy cladding can pose hazards to life safety if not adequately anchored to the building. Some of these are illustrated in Figure 3-37.

Although the basic seismic force-resisting system for the building may be adequate and require no further review, if the presence of such hazards may still be a danger to building occupants and passersby. Several boxes are provided in the Exterior Falling Hazards portion of the Data Collection Form to help the screener identify potential hazards (see Figure 3-38).

Figure 3-37 Illustration of a building with parapets and other potential falling hazards, including canopy over loading dock and water tank on roof.



Exterior Falling Hazards:

☐ Unbraced Chimneys

☐ Parapets

☐ Other: ____________________

☐ Heavy Cladding or Heavy Veneer

☐ Appendages

Figure 3-38 Exterior Falling Hazards portion of the Level 1 Data Collection Form.

Falling hazards of major concern are:

- *Unbraced Chimneys.* Unbraced, unreinforced masonry chimneys are common in older masonry and wood frame dwellings. They are often inadequately tied to the structure and fall in moderate to strong shaking. If in doubt as to whether a chimney is braced or unbraced, assume that it is unbraced.
- *Parapets.* A parapet is the portion of the exterior wall or façade that extends above the roof. The primary concern is parapets constructed of unreinforced masonry, such as brick, stone, or concrete block. In an earthquake, these can break and fall onto the roof or out into the street. It is sometimes difficult to tell if a façade projects above the roofline, forming a parapet and, if there is a parapet, it is often difficult to tell if it is braced. Parapets often exist on three sides of the building, and their height may be visible from the back of the structure. In some cases, the presence of bracing may be verified using satellite imagery. If in doubt as to whether an unreinforced masonry parapet is braced or unbraced, assume that it is unbraced.
- *Heavy Cladding or Heavy Veneer.* Large heavy cladding elements, usually precast concrete or cut stone, may fall off the building during an earthquake if improperly anchored. The loss of panels may also create major changes to the building stiffness (the elements are considered nonstructural but may contribute substantial stiffness to a building), thus setting up plan irregularities or torsion when only some fall. (Glass curtain walls in which the area of glass exceeds the area of metal or stucco spandrel panels and column covers are not considered as heavy cladding in the RVS procedure.) Masonry veneer can also be a falling hazard concern if improperly anchored. The concern is greater with heavy veneer, such as full thickness bricks used as the façade material in front of wood frame construction, rather than adhered veneer that uses partial thickness masonry units. The existence of heavy cladding or heavy veneer is of concern if the connections were designed and installed before the jurisdiction adopted seismic anchorage requirements (normally based on forces that are twice that for gravity loads). The date of such code adoption will vary with jurisdiction and should be established by the Supervising Engineer in the planning stages of the

RVS process (see Chapter 2). If the jurisdiction has not adopted cladding ordinances or the building predates adopted ordinances, then it should be indicated that heavy cladding hazards exist. If the building postdates the adopted ordinances, then the cladding connections may be properly designed and not pose a hazard.

- *Appendages.* Building appendages may fall off the building during an earthquake if improperly anchored. Such appendages include canopies and architectural elements that add detail and decorative interest to the façade. The concern is greater with larger elements that pose a significant falling hazard risk. The box should be checked only if heavier appendages exist.
- *Other.* The screener may observe a falling hazard that does not fit into any of the above categories. If so, the "Other" box should be checked and additional details should be provided in the space next to it and in the comments section, if needed. For example, tall and heavy roof equipment and components near the perimeter of the building, such as the elevated tank shown in Figure 3-37, could be considered an "Other" falling hazard.

If any of the above nonstructural falling hazards exist, the appropriate box (or boxes) should be checked. Additional details can be provided in the comments section. Taking a photograph of the falling hazard is also recommended. The RVS authority may later use this information to develop a mitigation program.

3.12 Damage and Deterioration

The scoring system in RVS is established assuming that the building is constructed of sound materials. Deterioration of structural elements can have a significant impact on the expected performance of a building and therefore needs to be captured when performing a survey.

Buildings that are poorly maintained and show obvious signs of deterioration due to weathering to their major structural elements are candidates for further investigation.

Determination of the potential impact on performance is difficult at best since not all damage and deterioration is visible, nor is it easy to assess. Prior damage may be concealed by finishes or in areas not directly examined during a rapid visual screening.

For a Level 1 screening, it is anticipated that the surveyor may not have sufficient time to fully assess the potential effects of damage and deterioration; however, this issue should not be ignored. The focus should be on examining the major elements of the seismic force-resisting system for significant damage that could weaken the building.

The key question is whether the level of deterioration and damage rises to the level of "significant" and thus triggers a Detailed Structural Evaluation under the "Other Hazards" and "Action Required" boxes on the Level 1 form. This is best determined by an experienced engineer, but general guidance is provided below to assist the screener in conducting a RVS.

Ideally, the focus should be on inspecting the major components of the seismic force-resisting system for signs of distress. Corroded steel columns, deteriorated mortar joints in a masonry wall, concrete walls with large cracks from previous earthquakes, and wood cripple walls with termite damage are examples of damage and deterioration that increase the probability of collapse of the building in a future earthquake. Deteriorated or compromised foundation elements or significant erosion of confining soils may also reduce the building's ability to withstand earthquake loads.

For the purpose of the Level 1 screening, where access to the interior of the building is limited, it is recommended that the screener focus on observable conditions such as the following:

- Is the building abandoned? An abandoned structure may have not had adequate maintenance. As a result, there is a greater likelihood of significant deterioration inside the structure that will not be observable during a rapid visual screening based on an exterior review only.
- Are there beams, floors, or roofs that are visibly sagging?
- Are there beams or columns that are visibly broken?
- Are there sloping floors or large exterior cracks that indicate significant settlement has occurred?
- Is there visible distress from prior earthquakes that has not been repaired (i.e., the building is leaning slightly or there are large x-cracks in the concrete or masonry walls)?
- Is there visible fire damage that has not been repaired?
- For wood buildings, is there extensive wood rot and/or water staining that is visible?
- For unreinforced masonry buildings, is the mortar eroding away, leaving areas of uneven depth?

- For concrete buildings, has the concrete been damaged or eroded such that the rebar is exposed?
- For steel buildings, are there members that are corroded? (Note that it is common for steel to appear rusted; the focus should be on members that actually have reduced cross-section due to corrosion.)
- Are there visible foundation elements with large cracks?
- Are foundation elements exposed due to significant erosion of adjacent soil?

If the screener observes any of these conditions, or another example of visible damage or deterioration, the condition should be described in the comments section. The screener should also take additional photographs of the condition.

Refer to Appendix F for additional guidance on assessing damage and deterioration for common building materials.

3.13 Comments Section

This section of the form is for recording any comments the screener may wish to make regarding the building, occupancy, condition, quality of the data, or unusual circumstances of any type. For example, if not all significant details can be effectively photographed or drawn, the screener could describe additional important information in the comments area. Comments may be made on building features that can be seen at or through window openings. If the screener is unsure of certain conditions, such as whether a vertical irregularity is severe or moderate, the source of the uncertainty should be described here. Other examples where comments are helpful are described throughout Chapter 3. If the screener elects to provide additional comments on a separate page, the “Additional sketches or comments on separate page” box should be checked to notify the Supervising Engineer that additional comments exist.

3.14 Identifying the FEMA Building Type and Documenting the Related Basic Score

Two key characteristics of seismic performance are construction material (e.g., wood, concrete) and type of seismic force-resisting-system (moment frame, braced frame, or shear wall). A building classification system allows buildings with similar materials and seismic force-resisting systems to be grouped together, facilitating the fast identification of a building’s likely strengths and vulnerabilities, and thus the building’s expected performance during an earthquake. The FEMA P-154 RVS procedure groups the most common combinations of construction materials and seismic force-resisting systems in the United States into 17 types, referred to here as “FEMA Building Types.” Each FEMA Building Type has its own Basic Score for each seismicity region, providing a measure of the expected performance of each FEMA Building Type in each seismicity region.

These 17 FEMA Building Types are based on the set of building types that were first defined in ATC-14, *Evaluating the Seismic Resistance of Existing Buildings* (ATC, 1987), and have since been updated and expanded in numerous FEMA guideline documents, including the first and second editions of FEMA 154, and in ASCE/SEI 41-13, *Seismic Evaluation and Retrofit of Existing Buildings* (ASCE, 2014) and the FEMA-funded HAZUS damage and loss estimation methodology *HAZUS-MH MR4 Technical Manual* (FEMA, 2009a).

ASCE/SEI 41-13 defines a set of 25 building types, referred to as “Common Building Types.” This includes 16 of the 17 FEMA Building Types plus additional sub-classifications of certain framing types that specify that the roof and floor diaphragms are either rigid or flexible. Such distinctions in diaphragm flexibility are used less often within the FEMA P-154 system, accounting for the smaller number of FEMA Building Types.

HAZUS defines a set of 36 building types, referred to as “Model Building Types.” The HAZUS Model Building Types include distinctions between low-rise, mid-rise, and high-rise buildings. Such distinctions in height are excluded from the 17 FEMA Building Types used here. The seventeenth FEMA Building Type, Manufactured Housing (MH), is similar to HAZUS’s Mobile Home (MH) Model Building Type, but is expanded to include nonresidential buildings, such as school portables.

The RVS procedure is based on the premise that the building being screened is one of the 17 FEMA Building Types, and further, that the screener will be able to determine the FEMA Building Type from the street, or eliminate all those that it cannot possibly be.

The building stock in the United States is very diverse, and there are many buildings that do not strictly conform to a single FEMA Building Type. Some judgment will be necessary to assign the most relevant FEMA Building Type to each building, with the focus on the seismic force-resisting system and construction material. If the building is particularly unique such that none of the 17 FEMA Building Types is appropriate, the FEMA P-154 procedure cannot be used to determine if the building is potentially hazardous. Examples of this include steel plate shear wall buildings, rammed earth structures, and certain types of Native American construction. A building that cannot be assigned a FEMA Building Type will require a special investigation to determine whether it is seismically hazardous.

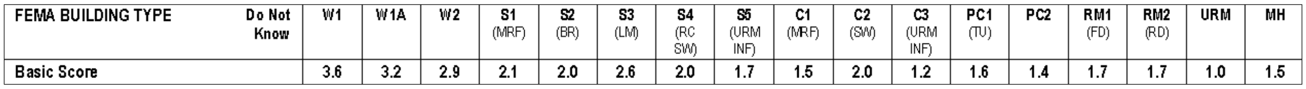
3.14.1 FEMA Building Types Considered and Basic Scores

Following are the 17 FEMA Building Types considered in the FEMA P-154 RVS procedure. Alpha-numeric reference codes used on the Data Collection Form are shown in parentheses.

- Light wood frame single- or multiple-family dwellings of one or more stories in height (W1)
- Light wood frame multi-unit, multi-story residential buildings with plan areas on each floor of greater than 3,000 square feet (W1A)
- Wood frame commercial and industrial buildings with a floor area larger than 5,000 square feet (W2)
- Steel moment-resisting frame buildings (S1)
- Braced steel frame buildings (S2)
- Light metal buildings (S3)
- Steel frame buildings with cast-in-place concrete shear walls (S4)
- Steel frame buildings with unreinforced masonry infill walls (S5)
- Concrete moment-resisting frame buildings (C1)
- Concrete shear-wall buildings (C2)
- Concrete frame buildings with unreinforced masonry infill walls (C3)
- Tilt-up buildings (PC1)
- Precast concrete frame buildings (PC2)
- Reinforced masonry buildings with flexible floor and roof diaphragms (RM1)
- Reinforced masonry buildings with rigid floor and roof diaphragms (RM2)
- Unreinforced masonry bearing-wall buildings (URM)
- Manufactured housing (MH)

Using available damage and loss estimation functions, a Basic Score has been computed for each FEMA Building Type that reflects the estimated likelihood that building collapse will occur if the building is subjected to risk-targeted maximum considered earthquake (MCE_R) ground motions. For more information about the development of the Basic Scores, see FEMA P-155 *Third Edition* (FEMA, 2015).

The Basic Scores are provided on the Level 1 Data Collection Form. The scores vary by seismicity region. As such, the Very High, High, Moderately High, Moderate, and Low seismicity forms each have a unique set of basic scores. Figure 3-39 shows Basic Scores as they appear on the High seismicity Data Collection Form.



FEMA BUILDING TYPE **Do Not Know**	**W1**	**W1A**	**W2**	**S1** (MRF)	**S2** (BR)	**S3** (LM)	**S4** (RC SW)	**S5** (URM INF)	**C1** (MRF)	**C2** (SW)	**C3** (URM INF)	**PC1** (TU)	**PC2**	**RM1** (FD)	**RM2** (RD)	**URM**	**MH**
Basic Score	**3.6**	**3.2**	**2.9**	**2.1**	**2.0**	**2.6**	**2.0**	**1.7**	**1.5**	**2.0**	**1.2**	**1.6**	**1.4**	**1.7**	**1.7**	**1.0**	**1.5**

Figure 3-39 FEMA Building Type and Basic Score portion of the Level 1 Data Collection Form for High seismicity.

In Very High, High, Moderately High, and Moderate seismicity regions, the Basic Scores apply to buildings built after the initial adoption and enforcement of seismic codes, but before the relatively recent significant improvement of codes (that is, before the applicable benchmark year, as determined during the pre-planning phase). In Low seismicity regions, they apply to all buildings except those designed and constructed after the applicable benchmark year, as determined during the pre-planning phase. The identification of those years in which seismic codes were initially adopted and later significantly improved is a key issue to be addressed in the planning stage (as described in Chapter 2). As described later in this chapter, the Level 1 Data Collection Form includes Score Modifiers that provide a means for modifying the Basic Score as a function of design and construction date.

Brief summaries of the physical characteristics and expected earthquake performance of each of the 17 FEMA Building Types, along with a photograph of a sample exterior view, and the Basic Scores for regions of Very High (VH), High (H), Moderately High (MH), Moderate (M), and Low (L) seismicity are provided in Table 3-1.

Table 3-1 FEMA Building Type Descriptions, Basic Scores, and Performance in Past earthquakes

FEMA Building Type	Photograph	Basic Score	Characteristics and Performance
W1 Light wood frame single- or multiple-family dwellings of one or more stories in height		(VH) = 2.1 (H) = 3.6 (MH) = 4.1 (M) = 5.1 (L) = 6.2	• Wood stud walls are typically constructed of 2-inch by 4-inch (2-inch by 6-inch for multiple stories) vertical wood members set about 16 inches apart. • Most common exterior finish materials are wood siding, metal siding, or stucco. • Buildings of this type performed very well in past earthquakes due to inherent qualities of the structural system and because they are lightweight and low rise. • Earthquake-induced cracks in the plaster and stucco (if any) may appear, but are classified as non-structural damage. • The most common type of structural damage in older buildings results from a lack of connection between the superstructure and the foundation, and inadequate chimney support.
W1A Light wood frame multi-unit, multi-story residential buildings with plan areas on each floor of greater than 3,000 square feet		(VH) = 1.9 (H) = 3.2 (MH) = 3.7 (M) = 4.5 (L) = 5.9	• These are typically residential buildings, but some may have commercial space at the ground floor. • Large openings are common at the ground floor for parking. These are often termed tuckunder buildings. • W1A buildings with large openings at the ground floor for parking or commercial purposes have performed poorly in past earthquakes because the large openings create a soft story.

Table 3-1 FEMA Building Type Descriptions, Basic Scores, and Performance in Past earthquakes (continued)

FEMA Building Type	Photograph	Basic Score	Characteristics and Performance
W2 Wood frame commercial and industrial buildings with a floor area larger than 5,000 square feet		(VH) = 1.8 (H) = 2.9 (MH) = 3.2 (M) = 3.8 (L) = 5.7	• These are typically commercial buildings or industrial structures usually of one to three stories, and, rarely, as tall as six stories. • For commercial and industrial buildings with less than 5,000 square feet, the W2 type can be assigned as well.
S1 Steel moment-resisting frame		(VH) = 1.5 (H) = 2.1 (MH) = 2.3 (M) = 2.7 (L) = 3.8	• Typical steel moment-resisting frame structures have similar bay widths in both the transverse and longitudinal directions, around 20-30 feet. • The floor diaphragms are usually concrete, sometimes over steel decking. This structural type is used for commercial, institutional, and public buildings. • The 1994 Northridge and 1995 Kobe earthquakes showed that the welds in steel moment frame buildings were vulnerable to severe damage. The damage took the form of broken connections between the beams and columns. • The relatively low stiffness of the frame can lead to substantial nonstructural damage. • This building could also have a concrete seismic force-resisting system. See Appendix D for advice on how to identify FEMA Building Type.

Table 3-1 FEMA Building Type Descriptions, Basic Scores, and Performance in Past earthquakes (continued)

FEMA Building Type	Photograph	Basic Score	Characteristics and Performance
S2 Braced steel frame	  Close-up photo of building above	(VH) = 1.4 (H) = 0 2 (MH) = 2.2 (M) = 2.6 (L) = 3.9	• These buildings are braced with diagonal members, which usually cannot be detected from the building exterior. • Braced frames are sometimes used for long and narrow buildings because of their stiffness. • From the building exterior, it is difficult to tell the difference between steel moment frames, steel braced frames, and steel frames with interior concrete shear walls. • In recent earthquakes, braced frames were found to have damage to brace connections and, in some cases to the braces, especially at the lower levels.
S3 Light metal building		(VH) = 1.6 (H) = 2.6 (MH) = 2.9 (M) = 3.5 (L) = 4.4	• The structural system usually consists of moment frames in the transverse direction and braced frames in the longitudinal direction, with corrugated sheet-metal siding. In some regions, light metal buildings may have partial height masonry walls. • The interiors of most of these buildings do not have interior finishes and their structural skeleton can be seen easily. • Insufficient capacity of tension braces can lead to their elongation and consequent building damage during earthquakes. • Inadequate connection to a slab foundation can allow the building columns to slide on the slab. • Loss of the cladding can occur.

Table 3-1 FEMA Building Type Descriptions, Basic Scores, and Performance in Past earthquakes (continued)

FEMA Building Type	Photograph	Basic Score	Characteristics and Performance
S4 Steel frames with cast-in-place concrete shear walls		(VH) = 1.4 (H) = 2.0 (MH) = 2.2 (M) = 2.5 (L) = 4.1	• Lateral loads are resisted by shear walls, which usually surround elevator cores and stairwells, and are covered by finish materials. • An interior investigation will permit a wall thickness check. A thickness in excess of six inches usually indicates a concrete shear wall. • Shear cracking and distress can occur around openings in concrete shear walls during earthquakes. • Wall construction joints can be weak planes, resulting in wall shear failure below expected capacity. • This building could also have a concrete frame. See Appendix D for advice on how to identify FEMA Building Type.
S5 Steel frames with unreinforced masonry infill walls		(VH) = 1.2 (H) = 1.7 (MH) = 2.0 (M) = 2.7 (L) = 4.5	• Steel columns are relatively thin and may be hidden in walls. • Usually masonry is exposed on exterior with narrow piers (less than 4 ft wide) between windows. • Portions of solid walls will align vertically. • Infill walls are usually two to three wythes thick. • Veneer masonry around columns or beams is usually poorly anchored and detaches easily. • This building could also have a concrete frame. See Appendix D for advice on how to identify FEMA Building Type.

Table 3-1 FEMA Building Type Descriptions, Basic Scores, and Performance in Past earthquakes (continued)

FEMA Building Type	Photograph	Basic Score	Characteristics and Performance
C1 Concrete moment-resisting frames		(VH) = 1.0 (H) = 1.5 (MH) = 1.7 (M) = 2.1 (L) = 3.3	• All exposed concrete frames are reinforced concrete (not steel frames encased in concrete). • A fundamental factor governing the performance of concrete moment-resisting frames is the level of ductile detailing. • Large spacing of ties in columns can lead to a lack of concrete confinement and shear failure. • Lack of continuous beam reinforcement can result in hinge formation during load reversal. • The relatively low stiffness of the frame can lead to substantial nonstructural damage. • Column damage due to pounding with adjacent buildings can occur.
C2 Concrete shear wall buildings		(VH) = 1.2 (H) = 2.0 (MH) = 2.1 (M) = 2.5 (L) = 4.2	• Concrete shear wall buildings are usually cast-in-place, and show typical signs of cast-in-place concrete. • Shear wall thickness often ranges from 6 to 18 inches. • These buildings generally perform better than concrete frame buildings. • They are heavier than steel-frame buildings but more rigid due to the shear walls. • Damage commonly observed in taller buildings is caused by vertical discontinuities, pounding, and irregular configuration.

Table 3-1 FEMA Building Type Descriptions, Basic Scores, and Performance in Past earthquakes (continued)

FEMA Building Type	Photograph	Basic Score	Characteristics and Performance
C3 Concrete frames with unreinforced masonry infill walls		(VH) = 0.9 (H) = 1.2 (MH) = 1.4 (M) = 2.0 (L) = 3.5	• Concrete columns and beams may be full wall thickness and may be exposed for viewing on the sides and rear of the building. • Usually masonry is exposed on the exterior with narrow piers (less than four feet wide) between windows. • Portions of solid walls will align vertically. • This type of construction was generally built before 1940 in high seismicity regions but continues to be built in other regions. • Infill walls tend to buckle and fall out-of-plane when subjected to strong lateral out-of-plane forces. • Veneer masonry around columns or beams is usually poorly anchored and detaches easily.
PC1 Tilt-up buildings	  Partial roof collapse due to failed diaphragm-to-wall connection	(VH) = 1.1 (H) = 1.6 (MH) = 1.8 (M) = 2.1 (L) = 3.8	• Tilt-ups are typically one or two stories high and are basically rectangular in plan. • Exterior walls were traditionally formed and cast on the ground adjacent to their final position, and then tilted up and attached to the floor slab. • The roof can be a plywood diaphragm carried on wood purlins and glulam beams or a light steel deck and joist system, supported in the interior of the building on steel pipe columns. • Weak diaphragm-to-wall anchorage results in the wall panels falling and the collapse of the supported diaphragm (or roof).

Table 3-1 FEMA Building Type Descriptions, Basic Scores, and Performance in Past earthquakes (continued)

FEMA Building Type	Photograph	Basic Score	Characteristics and Performance
PC2 Precast concrete frame buildings	 Building under construction  Detail of the precast components  Building nearing completion	(VH) = 1.0 (H) = 1.4 (MH) = 1.5 (M) = 1.9 (L) = 3.3	• Precast concrete frames are, in essence, post and beam construction in concrete. • Structures often employ concrete or reinforced masonry (brick or block) shear walls. • The performance varies widely and is sometimes poor. In addition to damage to shear walls similar to C2 buildings, PC2 buildings have additional issues as follows. • Poorly designed connections between prefabricated elements can fail. • Loss of vertical support can occur due to inadequate bearing area and insufficient connection between floor elements and columns. • Corrosion of metal connectors between prefabricated elements can occur.

Table 3-1 FEMA Building Type Descriptions, Basic Scores, and Performance in Past earthquakes (continued)

FEMA Building Type	Photograph	Basic Score	Characteristics and Performance
RM1 Reinforced masonry buildings with flexible diaphragms	  Truss-joists support plywood and light-weight concrete slab  Detail showing reinforced masonry	(VH) = 1.1 (H) = 1.7 (MH) = 1.8 (M) = 2.1 (L) = 3.7	• Walls are either brick or concrete block. • Wall thickness is usually 8 inches to 12 inches. • Interior inspection is required to determine if diaphragms are flexible or rigid. • The most common flexible floor and roof diaphragm systems are wood or light steel. • These buildings can perform well in moderate earthquakes if they are adequately reinforced and grouted, with sufficient diaphragm anchorage. • Poor construction practice can result in ungrouted and unreinforced walls, which will fail easily.

Table 3-1 FEMA Building Type Descriptions, Basic Scores, and Performance in Past earthquakes (continued)

FEMA Building Type	Photograph	Basic Score	Characteristics and Performance
RM2 Reinforced masonry buildings with rigid diaphragms		(VH) = 1.1 (H) = 1.7 (MH) = 1.8 (M) = 2.1 (L) = 3.7	• Walls are either brick or concrete block. • Wall thickness is usually 8 inches to 12 inches. • Interior inspection is required to determine if diaphragms are flexible or rigid. • The most common rigid floor and roof diaphragm systems are precast concrete or concrete over metal deck. • These buildings can perform well in moderate earthquakes if they are adequately reinforced and grouted, with sufficient diaphragm anchorage. • Poor construction practice can result in ungrouted and unreinforced walls, which will fail easily.
URM Unreinforced masonry buildings		(VH) = 0.9 (H) = 1.0 (MH) = 1.2 (M) = 1.7 (L) = 3.2	• These buildings often used weak lime mortar to bond the masonry units together. • Arches are often an architectural characteristic of older brick bearing wall buildings. • Other methods of spanning are also used, including steel and stone lintels. • Unreinforced masonry usually shows header bricks in the wall surface. • The performance of this type of construction is poor due to lack of anchorage of walls to floors and roof, soft mortar, and narrow piers between window openings.

Table 3-1 FEMA Building Type Descriptions, Basic Scores, and Performance in Past earthquakes (continued)

FEMA Building Type	Photograph	Basic Score	Characteristics and Performance
MH Manufactured housing		(VH) = 1.4 (H) = 1.8 (MH) = 2.2 (M) = 2.9 (L) = 4.6	• These buildings can be mobile homes or modular buildings, such as those used for portable classrooms. • The buildings are mobile, raised up off the ground, not anchored to the ground, and may or may not have an earthquake resistant bracing system (ERBS). • Manufactured homes are typically one story and come in different sizes. A single-wide unit can be up to 18 feet in width. A double-wide unit is 20 feet or more in width. • Floors and roofs are usually constructed with plywood or oriented strand board, and the outside surfaces are covered with sheet metal. • The primary source of damage is due to the lack of a permanent foundation connection or an earthquake-resistant bracing system (ERBS). In moderate shaking, the building can fall off its supports, and jack stands can penetrate the floor. Connecting utility lines can be severed, and escaping gas can cause fires.

3.14.2 Identifying the FEMA Building Type

At the heart of the RVS procedure is the task of identifying the FEMA Building Type from the street. Once the FEMA Building Type is identified, the screener finds the appropriate alpha-numeric code on the Level 1 Data Collection Form and circles the Basic Score immediately beneath it.

Each FEMA Building Type corresponds to a construction material and a type of seismic force-resisting system. Ideally, the FEMA Building Type for each building to be screened would be identified prior to field work through the review and interpretation of construction documents for each building (i.e., during the planning stage, as discussed in Chapter 2). More commonly, the screener must determine the FEMA Building Type in the field. When possible, the screener should enter the building to verify the FEMA Building Type selected. See Section 3.14.3 for additional information on interior inspections.

Appendix D provides additional guidance for identifying FEMA Building Types from a sidewalk survey. Additional background information on the physical characteristics and earthquake performance of these FEMA Building Types, not essential to the RVS procedure, is provided in Appendix E.

Determining the FEMA Building Type in the field is often difficult. A careful review of Table 3-1 and the information provided in Appendices D and E, along with training by knowledgeable building design professionals, should assist the screener in the determination of the FEMA Building Type.

The following process is recommended:

- *Step 1: Identify the gravity system.* Is the building primarily wood, steel, concrete, or masonry? Screen out materials that the building obviously is not to arrive at one or two materials.
- *Step 2: Identify the type of seismic force-resisting system.* Is the seismic force-resisting system a frame, braced frame, or bearing wall?
- *Step 3: Based on the material type from Step 1 and the type of seismic force-resisting system from Step 2, eliminate as many FEMA Building Types as possible*. The screener should be able to narrow down the possible FEMA Building Types to between one and three.

Of these steps, identifying the seismic force-resisting system (Step 2) is perhaps the most challenging. A frame structure (for example, S1, S3, S4, C1, or PC2) is made up of beams and columns throughout the entire structure, resisting both vertical and lateral loads. A braced frame structure (S2) has beams and columns that resist vertical loads and diagonal braces that resist lateral loads. A bearing wall structure (for example, PC1 and URM) uses vertical-load-bearing walls, which are more or less solid, to resist the vertical and lateral loads.

When a building has large openings on all sides, as illustrated in Figure 3-40, it is probably a frame structure as opposed to a bearing wall structure. A common characteristic of a frame structure is the rectangular grid patterns of the façade, indicating the location of the columns and girders behind the finish material. This is particularly revealing when windows occupy the entire opening in the frame, and no infill wall is used. A newer multistory commercial building should be assumed to be a frame structure, even though there may exist interior shear walls carrying the lateral loads (this would be a frame structure with shear walls, such as a S4 or C2 building).

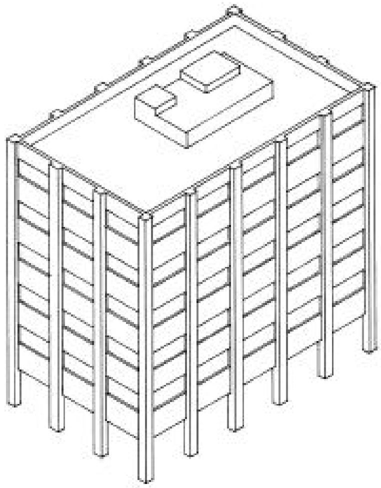


Figure 3-40 Typical frame structure. Features include large window spans, window openings on many sides, and clearly visible column-beam grid pattern.

Bearing-wall systems (also called box systems), as illustrated in Figure 3-41, carry vertical and lateral loads with walls rather than solely with columns. Structural floor members such as slabs, joists, and beams, are supported by load-bearing walls. A bearing wall system is thus characterized by more or less solid walls and, as a rule of thumb, a load-bearing wall will have more solid areas than openings. It also will have no wide openings, unless a structural lintel is used.

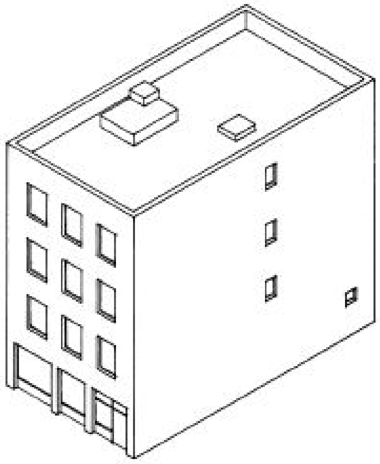


Figure 3-41 Typical bearing wall structure. Features include small window span, at least two mostly solid walls, and thick load-bearing walls.

Some bearing-wall structures incorporate structural columns, or are partly frame structures. This is especially popular in multistory commercial buildings in urban lots where girders and columns are used in the ground floor of a bearing wall structure to provide larger openings for retail spaces.

Another example is where the loads are carried by both interior columns and a perimeter wall. Both of these examples should be considered as bearing wall structures, because lateral loads are resisted by the bearing walls. Bearing wall structures sometimes utilize only two walls for load bearing. The other walls are non-load-bearing and thus may have large openings.

Therefore, the openness of the front elevation should not be used to determine the structure type. The screener should also look at the side and rear façades. If at least two of the four exterior walls appear to be solid then it is likely that it is a bearing wall structure.

Window openings in older frame structures can sometimes be misleading. Since wide windows were excessively costly and fragile until relatively recently, several narrow windows separated by thin mullions are often seen in older buildings. These thin mullions are usually not load bearing. When the narrow windows are close together, they constitute a large opening typical of a frame structure, or a window in a bearing wall structure with steel lintels.

Whereas open façades on all sides clearly indicate a frame structure, solid walls may be indicative of a bearing wall structure or a frame structure with solid infill walls. Bearing walls are usually much thicker than infill walls, and increase in thickness in the lower stories of multi-story buildings. This increase in wall thickness can be detected by comparing the wall thickness at windows on different floors. Thus, solid walls can be identified as bearing or non-bearing walls according to their thickness, if the structural material is known.

Unreinforced masonry and tilt-up buildings are usually bearing-wall type, steel buildings and pre-cast concrete buildings are usually frame type, concrete buildings may be of either type.

There will be some buildings for which the FEMA Building Type cannot be identified because of their façade treatment. In this case, the screener should eliminate those FEMA Building Types that are not possible and assume that any of the others are possible. If two or three possibilities remain, the Basic Scores for all the possible FEMA Building Types would be circled on the Data Collection Form. If more than three possibilities remain, the screener circles “Do Not Know” and does not calculate a score for the building.

3.14.3 Interior Inspections

Ideally, whenever possible, the screener should seek access to the interior of the building to identify, or verify, the FEMA Building Type. In the case of reinforced masonry buildings, entry is particularly important so that the screener can distinguish between RM1 buildings, which have flexible floor and roof diaphragms, and RM2 buildings, which have rigid floor diaphragms and either flexible or rigid roof diaphragms. Flexible diaphragms are typically wood framed. Whether the floor is concrete or wood can usually be determined from the sound of footfall or tapping with a hard object on the floor. The screener should look in storage or mechanical rooms where ceilings are not present to view the underside of the floor construction.

The RVS procedure does not require the removal of finish materials that are otherwise permanently affixed to the structure. There are a number of places within a building where it is possible to see the exposed structure. The following are some ways to determine the structure type.

- If the building has a basement that is not occupied, the first-floor framing may be exposed. The framing will usually be representative of the floor framing throughout the building.
- If the structural system is a steel or concrete frame, the columns and beams will often be exposed in the basement. The perimeter basement walls will likely be concrete, but this does not mean that they are concrete all the way to the roof.
- High rise and mid-rise structures usually have one or more levels of parking below the building. When fireproofed steel columns and girders are seen, the screener can be fairly certain that the structure is a steel building (S1, S2, or S4; see Figure 3-42).

Figure 3-42 Interior view showing fire-proofed columns and beams, which indicate a steel building (S1, S2, or S4).

- If the columns and beams are constructed of concrete, the structure is most likely a concrete moment-frame building (C1, see Figure 3-43). However, this is not guaranteed as some buildings will use steel framing above the ground floor. To ascertain the FEMA Building Type, the screener will need to look at the columns above the first floor.

Figure 3-43 Interior view showing concrete columns and girders with no identifiable shear walls, which indicates a concrete moment frame (C1).

- If there is no basement, the inspection of the mechanical and electrical equipment rooms may enable identification of the framing for the floor above.
- If suspended ceilings are used, one of the ceiling tiles can be lifted and simply pushed aside. In many cases, the floor framing will then be exposed. Caution should be used in identifying the framing materials, because prior to about 1960, steel beams were encased in concrete to provide fireproofing. If steel framing is seen with what appears to be concrete beams, the latter are most likely steel beams encased in concrete.
- If plastered ceilings are observed above suspended ceilings, the screener will not be able to identify the framing materials; however, plaster is not generally used for ceilings in post-1960 buildings.
- At exterior walls, if the structural system is a frame system, there will be regularly spaced locations where the wall is thicker and projects into the interior space of the building farther than the adjacent wall areas. These are the building columns. If the exterior walls between the columns are constructed of brick masonry and the thickness of the wall is 9 inches or

more for each story, the structure type is either steel frame with unreinforced masonry infill (S5) or concrete frame with unreinforced masonry infill (C3). However, if the exterior walls are constructed of thick brick masonry and there is no discernible frame system, the FEMA Building Type may be unreinforced masonry (URM).

- Pre-1930 brick masonry buildings that are six stories or less in height and that have wood-floor framing supported on masonry ledges in pockets formed in the wall are unreinforced masonry bearing-wall buildings (URM).

3.14.4 Screening Buildings with More Than One FEMA Building Type

In some cases, the screener may observe buildings having more than one FEMA Building Type. Examples might include a wood frame building atop a precast concrete parking garage, or a building with reinforced concrete shear walls in one direction and a reinforced moment-resisting frame in the other.

A building that has one FEMA Building Type in one direction and another FEMA Building Type in the other direction should be evaluated for both types, and the lowest Final Score should govern.

A building with one FEMA Building Type above another should be evaluated for both types. For example, in the case of a three-story wood frame residential structure over a one-story concrete moment frame podium, one score can be calculated for the three-story W1A and another score can be calculated for the one-story C1. Use the lowest score as the Final Score.

Other, more complicated scenarios also exist. If in doubt about how to screen the building, the screener should note the complication in the Comments section of the form and the Supervising Engineer should determine whether the building requires a Detailed Structural Evaluation.

3.14.5 Screening Buildings with Additions

Some buildings are modified with additions after the original construction. There are a number of aspects of building additions that need to be considered when evaluating the significance of the addition and its effect on the seismic resistance of the structure as a whole. The additions can be horizontal, adding to the plan area of the building (as shown in Figure 3-44), or vertical, adding stories to the building (as shown in Figure 3-45).

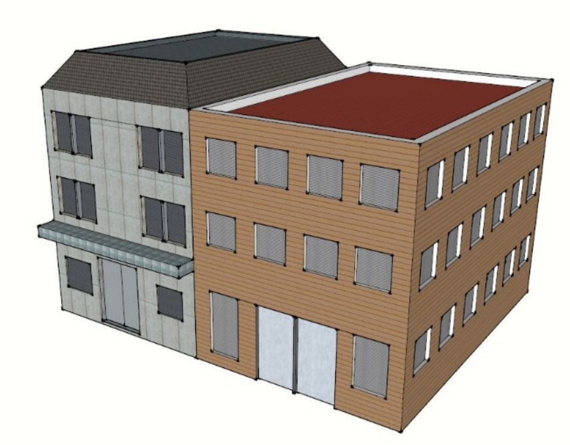


Figure 3-44 Illustration of a horizontal addition.

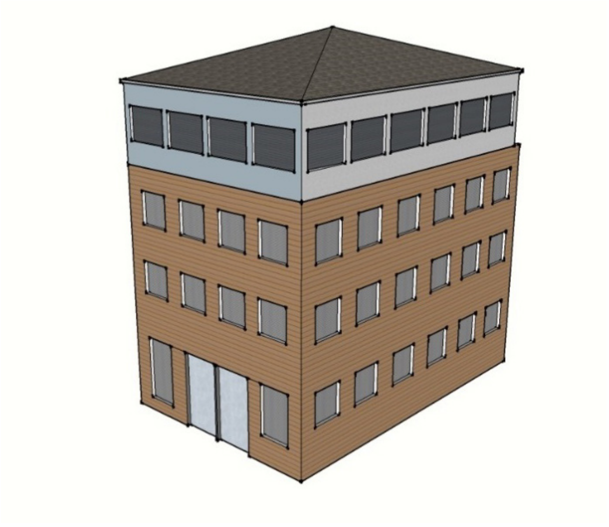


Figure 3-45 Illustration of a vertical addition.

An important characteristic of an addition is that it is structurally connected to the original building. Where structural separation gaps exist between buildings or portions of buildings, the structures on either side of the separation gap should be treated as separate buildings. Additions are common for many types of buildings, such as hospitals or schools that change over time.

Separation joints can be present to separate a horizontal addition from the original building or to separate portions of a building constructed at the same time. These separation joints occur over the entire height of the building and across the width of the building. On the exterior, these joints typically are either filled with material that is compressible and water tight or covered with a joint cover that allows the two parts of the building to move independently. Some building additions, such as vertical additions, are integrally connected to the original structure while others are constructed as essentially a separate structure. Single story penthouses need not be considered as a vertical addition if not used as normally habitable space.

Additions are often identified by observing obvious differences in the architectural style or exterior cladding materials (non-matching brick color and texture) of different parts of the building relative to each other. An addition may be constructed using framing and materials that are similar to those used for the original building, or the framing of the addition may be different than the original building. Differences in construction materials used typically indicate that the lateral stiffness of the addition and original building are different, and therefore the two parts will respond differently to earthquake forces. The differences between sections may also be indicated where there are differences in floor levels between adjacent portions of a building or where the structural framing material used for parts of the building are different.

Where complex conditions involving additions or buildings with multiple independent sections are encountered for the building being screened, the preferred approach would be to recommend that the building receive a Detailed Structural Evaluation. If the screener is unable to determine whether a building is an addition or a separate structure, the buildings should be noted as requiring a Detailed Structural Evaluation.

For horizontal additions, a checklist is presented in Table 3-2 for use in assessing whether to screen a building as a single building or multiple buildings based on the characteristics of the additions.

3.15 Score Modifiers

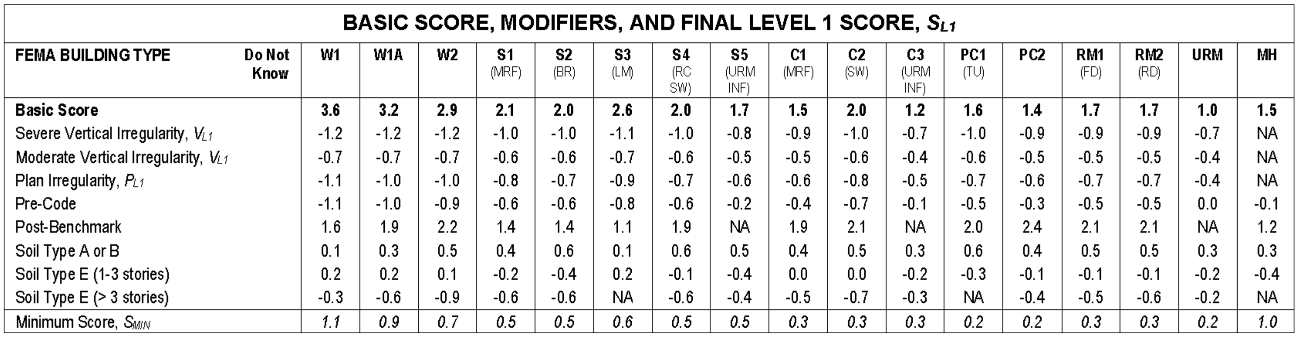
Once the screener has completed the top half of the Level 1 Data Collection Form and identified the FEMA Building Type, he or she is ready to calculate the building's RVS score using the scoring matrix. The scoring matrix, shown in Figure 3-46, provides the Basic Score and Score Modifiers related to building characteristics or performance attributes. Building characteristics that positively affect the performance of the building have positive Score Modifiers and increase the score. Building characteristics that negatively affect the performance of the building have negative Score Modifiers and decrease the score.

The severity of the impact of the performance attribute on structural performance varies with the FEMA Building Type; thus the assigned Score Modifiers depend on FEMA Building Type. If a performance attribute does

Table 3-2 Level 1 Reference Guide for Reviewing Buildings with Horizontal Additions

Building Addition Screening Criteria	Response	Screening Guidance
Criterion 1: Does the building have visible and aligned joints over the entire height of two exterior walls and across the roof?	Yes	Determine scores for each separate building defined by the joints and consider the potential for pounding using the adjacency guidelines in Section 3.9.
	No	See Criterion 2
Criterion 2: Does the building have any of the following characteristics: a) abrupt and noticeable differences in architectural style that occur on two sides of the building over the entire height of the exterior walls? b) visible differences in structural framing between distinct portions of the building? c) differences in floor elevation between portions of the building?	Yes	Screen as separate buildings defined by the differences noted in Criterion 2. Determine score for each portion and record the lower score.
	No	Screen as a single building.

not apply to a given FEMA Building Type, the Score Modifier is indicated with "N/A," which indicates that this Score Modifier is not applicable. Score Modifiers associated with each building characteristic are indicated in the scoring matrix on the Level 1 Data Collection Form.



BASIC SCORE, MODIFIERS, AND FINAL LEVEL 1 SCORE, S_{L1}

FEMA BUILDING TYPE Do Not Know	W1	W1A	W2	S1 (MRF)	S2 (BR)	S3 (LM)	S4 (RC SW)	S5 (URM INF)	C1 (MRF)	C2 (SW)	C3 (URM INF)	PC1 (TU)	PC2	RM1 (FD)	RM2 (RD)	URM	MH
Basic Score	**3.6**	**3.2**	**2.9**	**2.1**	**2.0**	**2.6**	**2.0**	**1.7**	**1.5**	**2.0**	**1.2**	**1.6**	**1.4**	**1.7**	**1.7**	**1.0**	**1.5**
Severe Vertical Irregularity, V_{L1}	-1.2	-1.2	-1.2	-1.0	-1.0	-1.1	-1.0	-0.8	-0.9	-1.0	-0.7	-1.0	-0.9	-0.9	-0.9	-0.7	NA
Moderate Vertical Irregularity, V_{L1}	-0.7	-0.7	-0.7	-0.6	-0.6	-0.7	-0.6	-0.5	-0.5	-0.6	-0.4	-0.6	-0.5	-0.5	-0.5	-0.4	NA
Plan Irregularity, P_{L1}	-1.1	-1.0	-1.0	-0.8	-0.7	-0.9	-0.7	-0.6	-0.6	-0.8	-0.5	-0.7	-0.6	-0.7	-0.7	-0.4	NA
Pre-Code	-1.1	-1.0	-0.9	-0.6	-0.6	-0.8	-0.6	-0.2	-0.4	-0.7	-0.1	-0.5	-0.3	-0.5	-0.5	0.0	-0.1
Post-Benchmark	1.6	1.9	2.2	1.4	1.4	1.1	1.9	NA	1.9	2.1	NA	2.0	2.4	2.1	2.1	NA	1.2
Soil Type A or B	0.1	0.3	0.5	0.4	0.6	0.1	0.6	0.5	0.4	0.5	0.3	0.6	0.4	0.5	0.5	0.3	0.3
Soil Type E (1-3 stories)	0.2	0.2	0.1	-0.2	-0.4	0.2	-0.1	-0.4	0.0	0.0	-0.2	-0.3	-0.1	-0.1	-0.1	-0.2	-0.4
Soil Type E (> 3 stories)	-0.3	-0.6	-0.9	-0.6	-0.6	NA	-0.6	-0.4	-0.5	-0.7	-0.3	NA	-0.4	-0.5	-0.6	-0.2	NA
Minimum Score, S_{MIN}	*1.1*	*0.9*	*0.7*	*0.5*	*0.5*	*0.6*	*0.5*	*0.5*	*0.3*	*0.3*	*0.3*	*0.2*	*0.2*	*0.3*	*0.3*	*0.2*	*1.0*

Figure 3-46 Scoring Matrix portion of the Level 1 Data Collection Form for High seismicity.

The screener circles Score Modifiers for the building in the appropriate column (i.e., under the reference code for the identified FEMA Building Type). Following are instructions for when to apply each Score Modifier.

3.15.1 Vertical Irregularity

If one or more severe vertical irregularities have been identified in the Irregularities section of the form (as per Section 3.10.1), the Severe Vertical Irregularity Score Modifier should be circled. If one or more moderate vertical irregularities have been identified, and no severe vertical irregularities exist, the Moderate Vertical Irregularity Score Modifier should be circled.

3.15.2 Plan Irregularity

If one or more plan irregularities have been identified in the Irregularities section of the form (as per Section 3.10.2), the Plan Irregularity Score Modifier should be circled.

3.15.3 Pre-Code

This Score Modifier is applicable if the building being screened was designed and constructed prior to the initial adoption and enforcement of seismic codes applicable for that FEMA Building Type. The year(s) in which seismic codes were initially adopted and enforced for the various FEMA Building Types should have been identified during the pre-planning stage (as recommended in Chapter 2) and added to the Quick Reference Guide in Appendix B. Using the Quick Reference Guide, the screener compares the year built (or code year, if known) to the year seismic codes were initially adopted and enforced for that FEMA Building Type. If the year built is earlier than the year seismic codes were adopted, the screener should apply the Pre-Code Score Modifier. Because of the method used to calculate the Basic Scores, this Score Modifier does not apply to buildings in a Low seismicity region.

3.15.4 Post-Benchmark

This Score Modifier is applicable if the building being screened was designed and constructed after significantly improved seismic codes applicable for that FEMA Building Type were adopted and enforced by the local jurisdiction. The year in which such improvements were adopted is termed the “benchmark” year. Benchmark year(s) for the various FEMA Building Types should have been identified during the pre-planning stage (as recommended in Chapter 2) and added to the Quick Reference Guide. Using the Quick Reference Guide, the screener should compare the year built (or code year, if known) to the benchmark year. If the year built matches or is later than the benchmark year, the screener applies the Post-Benchmark Score Modifier.

3.15.5 Soil Type

Score Modifiers are provided for Soil Type A or B and for Soil Type E. If Soil Type A or B has been identified in the Soil Type portion of the form, the screener circles the Soil Type A or B Score Modifier. If Soil Type E has been identified and there are three or fewer stories, the screener circles the

"Soil Type E (1-3 stories)" Score Modifier. If Soil Type E has been identified, and there are more than three stories, the screener circles the "Soil Type E (>3 stories)" Score Modifier.

Basic Scores were calculated assuming Soil Type CD (the average of Soil Type C and Soil Type D). Therefore, no Score Modifier applies when one of these soil types occurs. There is no Score Modifier for Soil Type F because buildings on Soil Type F cannot be screened effectively with the RVS procedure. If the building is on Soil Type F, the screener should note that "Geologic hazards or Soil Type F" are present under the Other Hazards portion of the form, which will trigger a Detailed Structural Evaluation for the building.

3.15.6 Minimum Score, S_{MIN}

Individual Score Modifiers were developed by calculating the probability of collapse when varying a single condition. Summing multiple Score Modifiers can overestimate the combined effect of multiple conditions and may result in a final score less than zero. A negative score implies a probability of collapse greater than 100%, which is not possible.

To address this, a Minimum Score, S_{MIN}, is provided. The Minimum Score was developed by considering the worst possible combination of soil type, vertical and plan irregularities, and building age, all at once.

3.16 Determining the Final Level 1 Score

The Final Level 1 Score, S_{L1}, is determined for a given building by adding the circled Score Modifiers for that building to the Basic Score for the building. The screener should check the sum of Basic Score and Score Modifiers against the Minimum Score, S_{MIN}, and use the Minimum Score if it is larger than the sum.

The result is documented on the bottom line of the scoring matrix next to "Final Level 1 Score, S_{L1}."

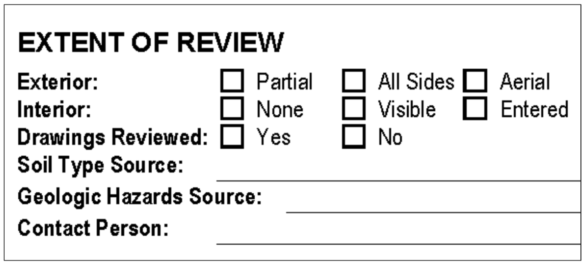
When the screener is uncertain of the FEMA Building Type, an attempt should be made to eliminate all unlikely FEMA Building Types. If the screener is still left with several choices, the screener calculates S_{L1} for all the remaining FEMA Building Types and chooses the lowest score. This is a conservative approach, and has the disadvantage that the assigned score may indicate that the building presents a greater risk than it actually does.

If the screener has little or no confidence about any choice for the structural system, as in the case of buildings with uncertain façade treatment (see

Section 3.14.2), the screener should circle DNK for "FEMA Building Type," which indicates the screener does not know. In this case, no S_{L1} score is calculated.

3.17 Documenting the Extent of Review

The "Extent of Review" portion of the form is provided to document the thoroughness of the building screening (see Figure 3-47). The screener notes whether he or she had access to all sides of the exterior of the building and whether the interior was accessed. There is also a field for the screener to note any contacts made in the field. It is valuable to know if the screener was able to talk to the building owner or facility manager, particularly if these individuals were the source of any information used by the screener in completing the form.



EXTENT OF REVIEW

Exterior: ☐ Partial ☐ All Sides ☐ Aerial

Interior: ☐ None ☐ Visible ☐ Entered

Drawings Reviewed: ☐ Yes ☐ No

Soil Type Source: ____________

Geologic Hazards Source: ____________

Contact Person: ____________

Figure 3-47 Extent of Review portion of the Level 1 Data Collection Form.

There are also fields to document the resources that were used during pre-field planning. The soil type source, geologic hazards source, and whether drawings were reviewed should be noted on the form prior to the field visit.

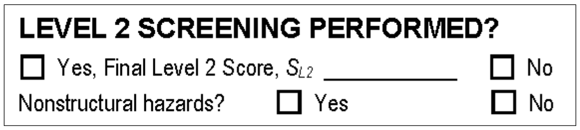
The information collected in this portion of the form reflects on the accuracy of the building's score. If fewer sources of information were available, it is less likely that the FEMA Building Type and the building attributes were accurately discerned. This information is expected to be valuable to the Program Manager in the analysis of the RVS results and the Supervising Engineer during the quality assurance review.

3.18 Documenting the Level 2 Screening Results

If the screener has also completed the optional Level 2 portion of the form, the results of the Level 2 screening are recorded in this section of the Level 1 form (see Figure 3-48).

3.19 Documenting Other Hazards

Pounding potential, falling hazards from a taller adjacent building, geologic hazards, and damage or deterioration to the structural system are all conditions that are not considered in the Level 1 score, but can have a



LEVEL 2 SCREENING PERFORMED?

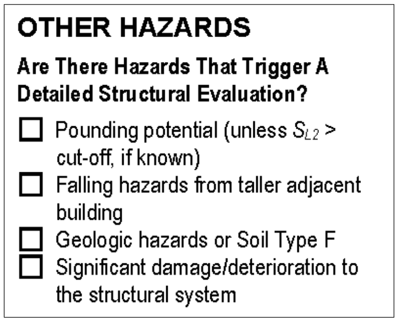
☐ Yes, Final Level 2 Score, S_{L2} ___________ ☐ No

Nonstructural hazards? ☐ Yes ☐ No

Figure 3-48 Level 2 screening results portion of the Level 1 Data Collection Form.

negative effect on the performance of the building. If these hazards exist, the building may be seismically hazardous even if the Level 1 score is greater than the designated cut-off score. Therefore, a Detailed Structural Evaluation is required if the screener identifies that any of the following hazardous conditions exist (see Figure 3-49).

- *Pounding potential (unless S_{L2} > cut-off, if known).* This box is checked if "Pounding" has been checked in the Adjacency section of the form. If a Level 2 screening has been performed, however, and the Final Level 2 score (which considers pounding) is greater than the cut-off score, then the box does not need to be checked.
- *Falling hazards from a taller adjacent building.* This box is checked if the "Falling Hazards from Taller Adjacent Building" has been checked in the Adjacency section of the form.
- *Geologic hazards or Soil Type F.* If "Yes" has been circled for any geologic hazards in the Geologic Hazards section of the Data Collection Form or if the building is on Soil Type F, the screener checks this box in the Other Hazards section. If all of the geologic hazards are noted as "No" or as "DNK," the screener does not check this box.
- *Significant damage/deterioration.* If the screener has identified any significant damage or deterioration during the screening, the "Significant damage/deterioration to the structural system" box should be checked. A Detailed Structural Evaluation is recommended of any building with significant damage or deterioration.



OTHER HAZARDS

Are There Hazards That Trigger A Detailed Structural Evaluation?

☐ Pounding potential (unless S_{L2} > cut-off, if known)

☐ Falling hazards from taller adjacent building

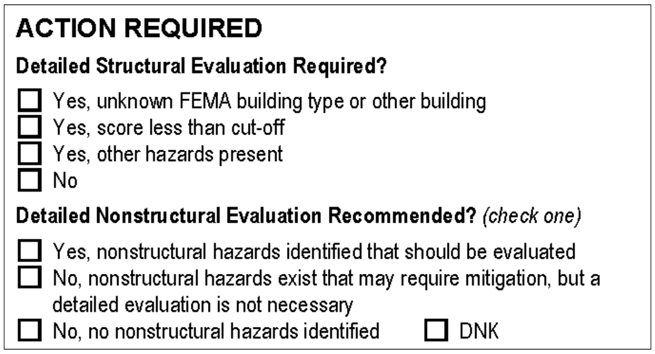
☐ Geologic hazards or Soil Type F

☐ Significant damage/deterioration to the structural system

Figure 3-49 Other Hazards portion of the Level 1 Data Collection Form.

3.20 Determining the Action Required

The final step to complete the Level 1 Data Collection Form is to indicate the action required. Based on information collected during the screening, the screener indicates whether detailed evaluation of the building is required (see Figure 3-50).



ACTION REQUIRED

Detailed Structural Evaluation Required?

☐ Yes, unknown FEMA building type or other building
☐ Yes, score less than cut-off
☐ Yes, other hazards present
☐ No

Detailed Nonstructural Evaluation Recommended? *(check one)*

☐ Yes, nonstructural hazards identified that should be evaluated
☐ No, nonstructural hazards exist that may require mitigation, but a detailed evaluation is not necessary
☐ No, no nonstructural hazards identified ☐ DNK

Figure 3-50 Action Required portion of the Level 1 Data Collection Form.

3.20.1 Detailed Structural Evaluation

The screener indicates whether a Detailed Structural Evaluation is required by checking one of four boxes.

- *Yes, unknown FEMA Building Type or other building.* If the screener has little or no confidence about any choice for the structural system, or if the building does not conform to any of the 17 FEMA Building Types considered on the form, the screening cannot be used to conclude that the building is not potentially hazardous. Therefore, a Detailed Structural Evaluation of the building should be conducted by an experienced design professional. In some cases, the Supervising Engineer or another more experienced screener may be able to determine the FEMA Building Type and complete the screening.
- *Yes, score less than cut-off.* If the building receives a score that is less than the cut-off, it may be seismically hazardous and should receive a Detailed Structural Evaluation by an experienced design professional.
- *Yes, other hazards present.* If other hazards are present, as indicated in the "Other Hazards" section of the form, the building may be seismically hazardous and should receive a Detailed Structural Evaluation by an experienced design professional.
- *No*. If the building receives a score greater than the cut-off, and no other hazards are present, then a Detailed Structural Evaluation is not required.

3.20.2 Detailed Nonstructural Evaluation

The final step of the screening is to indicate whether a Detailed Nonstructural Evaluation is recommended.

- *Yes, nonstructural hazards identified that should be evaluated.* This box is checked if a nonstructural hazard has been observed and further nonstructural evaluation is recommended to determine whether the identified potential falling hazard is actually a threat. For example, a detailed evaluation would be necessary to determine whether a building's heavy cladding is properly anchored. If the detailed evaluation reveals that it is properly anchored, the heavy cladding is no longer considered a falling hazard.
- *No, nonstructural hazards exist that may require mitigation, but a detailed evaluation is not necessary.* This box is checked if a nonstructural hazard that is a known threat has been observed. For example, an unreinforced brick chimney. In these cases, additional evaluation is not necessary, although mitigation will be necessary if the threat is to be reduced. The jurisdiction may decide to make mitigation of these falling hazards mandatory.
- *No, no nonstructural hazards identified.* If no exterior falling hazards have been observed during the screening, further nonstructural evaluation is not necessary.
- *DNK.* A "do not know" option is also provided if the screener is unable to determine whether to recommend a detailed nonstructural evaluation. The screener should note the cause of his or her uncertainty in the comments box.

The RVS Authority may later use this information as a basis for notifying the owner of potential problems.

Chapter 4

Completing the Optional Level 2 Data Collection Form

4.1 Introduction

This chapter provides instructions on how to complete the optional Level 2 Data Collection Form, shown in Figure 4-1. Level 2 screening should only be performed by a civil or structural engineering professional, architect, or graduate student with a background in seismic evaluation or design of buildings. The statements on the Level 2 form have been designed assuming this level of training.

It is assumed that the Level 1 form has already been completed, either by the current screener or previously during an earlier screening. If the Level 1 form was completed by a different screener, the Level 2 screener should repeat the Level 1 screening, or at least verify the information on the Level 1 form.

The same seismicity region used for the Level 1 screening applies to the Level 2 screening. If the Level 1 screening was performed using the High seismicity Level 1 form, the Level 2 screening should be performed using the High seismicity Level 2 form.

Like the Level 1 form, the screener fills out the Level 2 form beginning at the top. The screener notes the name of the building, its Level 1 score, and the irregularity Score Modifiers used on Level 1. The screener then responds to a series of statements about the building, applying Score Modifiers where applicable. The Very High, High, Moderately High, Moderate, and Low seismicity forms differ in the Score Modifier values and in the pounding criteria. The screener calculates a Level 2 score and transfers this score to the Level 1 form.

At the bottom of the Level 2 form is a limited nonstructural screening section. The screener replies to a series of statements regarding common nonstructural hazards and then makes a judgment about the estimated nonstructural seismic performance of the building.

Rapid Visual Screening of Buildings for Potential Seismic Hazards **Level 2 (Optional)**

FEMA P-154 Data Collection Form **HIGH Seismicity**

Optional Level 2 data collection to be performed by a civil or structural engineering professional, architect, or graduate student with background in seismic evaluation or design of buildings.

Bldg Name:	**Final Level 1 Score:**	S_{L1} =	*(do not consider S_{MIN})*
Screener:	**Level 1 Irregularity Modifiers:**	*Vertical Irregularity, V_{L1} =*	*Plan Irregularity, P_{L1} =*
Date/Time:	**ADJUSTED BASELINE SCORE:**	$S' = (S_{L1} - V_{L1} - P_{L1})$ =	

STRUCTURAL MODIFIERS TO ADD TO ADJUSTED BASELINE SCORE

Topic	**Statement** *(If statement is true, circle the "Yes" modifier; otherwise cross out the modifier.)*		**Yes**	**Subtotals**
Vertical Irregularity, V_{L2}	Sloping Site	W1 building: There is at least a full story grade change from one side of the building to the other.	-1.2	
		Non-W1 building: There is at least a full story grade change from one side of the building to the other.	-0.3	
	Weak and/or Soft Story *(circle one maximum)*	W1 building cripple wall: An unbraced cripple wall is visible in the crawl space.	-0.6	
		W1 house over garage: Underneath an occupied story, there is a garage opening without a steel moment frame, and there is less than 8' of wall on the same line (for multiple occupied floors above, use 16' of wall minimum).	-1.2	
		W1A building open front: There are openings at the ground story (such as for parking) over at least 50% of the length of the building.	-1.2	
		Non-W1 building: Length of lateral system at any story is less than 50% of that at story above or height of any story is more than 2.0 times the height of the story above.	-0.9	
		Non-W1 building: Length of lateral system at any story is between 50% and 75% of that at story above or height of any story is between 1.3 and 2.0 times the height of the story above.	-0.5	
	Setback	Vertical elements of the lateral system at an upper story are outboard of those at the story below causing the diaphragm to cantilever at the offset.	-1.0	
		Vertical elements of the lateral system at upper stories are inboard of those at lower stories.	-0.5	
		There is an in-plane offset of the lateral elements that is greater than the length of the elements.	-0.3	
	Short Column/ Pier	C1,C2,C3,PC1,PC2,RM1,RM2: At least 20% of columns (or piers) along a column line in the lateral system have height/depth ratios less than 50% of the nominal height/depth ratio at that level.	-0.5	
		C1,C2,C3,PC1,PC2,RM1,RM2: The column depth (or pier width) is less than one half of the depth of the spandrel, or there are infill walls or adjacent floors that shorten the column.	-0.5	
	Split Level	There is a split level at one of the floor levels or at the roof.	-0.5	
	Other Irregularity	There is another observable severe vertical irregularity that obviously affects the building's seismic performance.	-1.0	V_{L2} = ______
		There is another observable moderate vertical irregularity that may affect the building's seismic performance.	-0.5	*(Cap at -1.2)*
Plan Irregularity, P_{L2}	Torsional irregularity: Lateral system does not appear relatively well distributed in plan in either or both directions. *(Do not include the W1A open front irregularity listed above.)*		-0.7	
	Non-parallel system: There are one or more major vertical elements of the lateral system that are not orthogonal to each other.		-0.4	
	Reentrant corner: Both projections from an interior corner exceed 25% of the overall plan dimension in that direction.		-0.4	
	Diaphragm opening: There is an opening in the diaphragm with a width over 50% of the total diaphragm width at that level.		-0.2	
	C1, C2 building out-of-plane offset: The exterior beams do not align with the columns in plan.		-0.4	P_{L2} = ______
	Other irregularity: There is another observable plan irregularity that obviously affects the building's seismic performance.		-0.7	*(Cap at -1.1)*
Redundancy	The building has at least two bays of lateral elements on each side of the building in each direction.		+0.3	
Pounding	Building is separated from an adjacent structure by less than 1% of the height of the shorter of the building and adjacent structure and:	The floors do not align vertically within 2 feet. *(Cap total pounding modifiers at -1.2)*	-1.0	
		One building is 2 or more stories taller than the other.	-1.0	
		The building is at the end of the block.	-0.5	
S2 Building	"K" bracing geometry is visible.		-1.0	
C1 Building	Flat plate serves as the beam in the moment frame.		-0.4	
PC1/RM1 Bldg	There are roof-to-wall ties that are visible or known from drawings that do not rely on cross-grain bending. *(Do not combine with post-benchmark or retrofit modifier.)*		+0.3	
PC1/RM1 Bldg	The building has closely spaced, full height interior walls (rather than an interior space with few walls such as in a warehouse).		+0.3	
URM	Gable walls are present.		-0.4	
MH	There is a supplemental seismic bracing system provided between the carriage and the ground.		+1.2	
Retrofit	Comprehensive seismic retrofit is visible or known from drawings.		+1.4	*M* = ______

FINAL LEVEL 2 SCORE, $S_{L2} = (S' + V_{L2} + P_{L2} + M) \geq S_{MIN}$: *(Transfer to Level 1 form)*

There is observable damage or deterioration or another condition that negatively affects the building's seismic performance: ☐ Yes ☐ No

If yes, describe the condition in the comment box below and indicate on the Level 1 form that detailed evaluation is required independent of the building's score.

OBSERVABLE NONSTRUCTURAL HAZARDS

Location	**Statement** *(Check "Yes" or "No")*	**Yes**	**No**	**Comment**
Exterior	There is an unbraced unreinforced masonry parapet or unbraced unreinforced masonry chimney.			
	There is heavy cladding or heavy veneer.			
	There is a heavy canopy over exit doors or pedestrian walkways that appears inadequately supported.			
	There is an unreinforced masonry appendage over exit doors or pedestrian walkways.			
	There is a sign posted on the building that indicates hazardous materials are present.			
	There is a taller adjacent building with an unanchored URM wall or unbraced URM parapet or chimney.			
	Other observed exterior nonstructural falling hazard:			
Interior	There are hollow clay tile or brick partitions at any stair or exit corridor.			
	Other observed interior nonstructural falling hazard:			

Estimated Nonstructural Seismic Performance (*Check appropriate box and transfer to Level 1 form conclusions*)

☐ Potential nonstructural hazards with significant threat to occupant life safety → Detailed Nonstructural Evaluation recommended

☐ Nonstructural hazards identified with significant threat to occupant life safety → But no Detailed Nonstructural Evaluation required

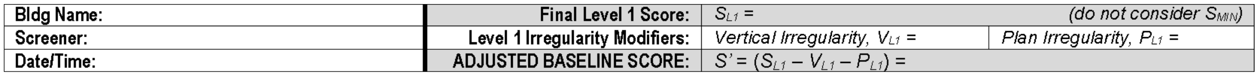
☐ Low or no nonstructural hazard threat to occupant life safety → No Detailed Nonstructural Evaluation required

Comments:

Figure 4-1 Optional Level 2 Data Collection Form.

4.2 Building Information and Adjusted Baseline Score for Level 2

The screener records the building name and the Level 1 score, S_{L1}, at the top of the page. The Level 1 score includes Level 1 Score Modifiers for vertical and plan irregularities (V_{L1} and P_{L1}). These Score Modifiers are removed from the score so that the refined Level 2 Irregularity Score Modifiers (V_{L2} and P_{L2}) can be used instead. To accomplish this, the screener calculates an Adjusted Baseline Score, *S*', by subtracting V_{L1} and P_{L1} from S_{L1}. This Adjusted Baseline Score is the basis for the Level 2 score (see Figure 4-2).



Bldg Name:	**Final Level 1 Score:**	S_{L1} =	*(do not consider S_{MIN})*
Screener:	**Level 1 Irregularity Modifiers:**	*Vertical Irregularity,* V_{L1} =	*Plan Irregularity,* P_{L1} =
Date/Time:	**ADJUSTED BASELINE SCORE:**	$S' = (S_{L1} - V_{L1} - P_{L1}) =$	

Figure 4-2 Portion of the Level 2 form for recording building name and calculating adjusted baseline score.

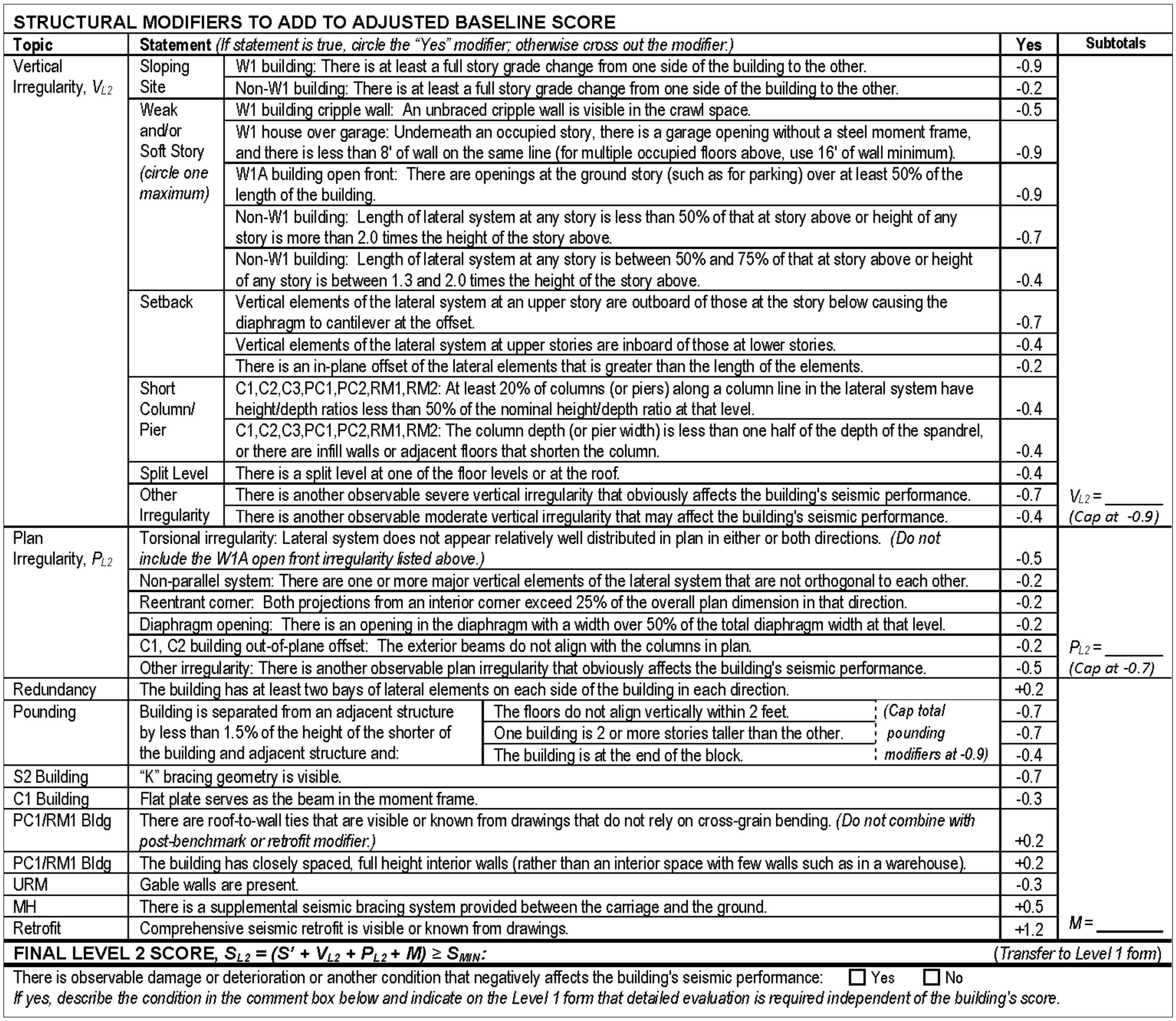
For the purpose of calculating the Adjusted Baseline Score, the Minimum Score on the Level 1 form should not be considered. The Final Level 1 Score, S_{L1}, shall be taken as the sum of the Basic Score and all applicable Level 1 Score Modifiers.

4.3 Reviewing the Level 2 Statements and Recording Score Modifiers

The middle section of the Level 2 form is shown in Figure 4-3. The statements address vertical and plan irregularities, pounding, and seismic retrofit. Some statements are specific to particular FEMA Building Types. For each true statement, the screener circles the Score Modifier. For false statements, the screener crosses out the Score Modifier. The screener notes subtotals for V_{L2} and P_{L2}. These are the effective Level 2 Score Modifiers for vertical and plan irregularities, respectively. The screener also notes the subtotal, *M*, which includes the remainder of the Level 2 Score Modifiers. The screener can also record comments in this subtotal area.

4.3.1 Vertical Irregularities

The Vertical Irregularity section of the Level 2 form includes statements and Score Modifiers for each of the vertical irregularities discussed and shown in Chapter 3 and the Vertical Irregularity Reference Guide in Appendix B. The sum of Score Modifiers in this section, subject to a cap, is the Level 2 Vertical Irregularity Score Modifier, V_{L2}, and should be noted in the space provided in the subtotals column. The cap for V_{L2} is defined on the Level 2 form and varies by seismicity region. A building with a vertical irregularity will be more vulnerable if there is a second irregularity present; however, the addition of Vertical Irregularity Score Modifiers (each of which represents a



STRUCTURAL MODIFIERS TO ADD TO ADJUSTED BASELINE SCORE

Topic	Statement *(If statement is true, circle the "Yes" modifier; otherwise cross out the modifier.)*			Yes	Subtotals
Vertical Irregularity, V_{L2}	Sloping Site	W1 building: There is at least a full story grade change from one side of the building to the other.		-0.9	
		Non-W1 building: There is at least a full story grade change from one side of the building to the other.		-0.2	
	Weak and/or Soft Story *(circle one maximum)*	W1 building cripple wall: An unbraced cripple wall is visible in the crawl space.		-0.5	
		W1 house over garage: Underneath an occupied story, there is a garage opening without a steel moment frame, and there is less than 8' of wall on the same line (for multiple occupied floors above, use 16' of wall minimum).		-0.9	
		W1A building open front: There are openings at the ground story (such as for parking) over at least 50% of the length of the building.		-0.9	
		Non-W1 building: Length of lateral system at any story is less than 50% of that at story above or height of any story is more than 2.0 times the height of the story above.		-0.7	
		Non-W1 building: Length of lateral system at any story is between 50% and 75% of that at story above or height of any story is between 1.3 and 2.0 times the height of the story above.		-0.4	
	Setback	Vertical elements of the lateral system at an upper story are outboard of those at the story below causing the diaphragm to cantilever at the offset.		-0.7	
		Vertical elements of the lateral system at upper stories are inboard of those at lower stories.		-0.4	
		There is an in-plane offset of the lateral elements that is greater than the length of the elements.		-0.2	
	Short Column/ Pier	C1,C2,C3,PC1,PC2,RM1,RM2: At least 20% of columns (or piers) along a column line in the lateral system have height/depth ratios less than 50% of the nominal height/depth ratio at that level.		-0.4	
		C1,C2,C3,PC1,PC2,RM1,RM2: The column depth (or pier width) is less than one half of the depth of the spandrel, or there are infill walls or adjacent floors that shorten the column.		-0.4	
	Split Level	There is a split level at one of the floor levels or at the roof.		-0.4	
	Other Irregularity	There is another observable severe vertical irregularity that obviously affects the building's seismic performance.		-0.7	V_{L2} = ______
		There is another observable moderate vertical irregularity that may affect the building's seismic performance.		-0.4	*(Cap at -0.9)*
Plan Irregularity, P_{L2}	Torsional irregularity: Lateral system does not appear relatively well distributed in plan in either or both directions. *(Do not include the W1A open front irregularity listed above.)*			-0.5	
	Non-parallel system: There are one or more major vertical elements of the lateral system that are not orthogonal to each other.			-0.2	
	Reentrant corner: Both projections from an interior corner exceed 25% of the overall plan dimension in that direction.			-0.2	
	Diaphragm opening: There is an opening in the diaphragm with a width over 50% of the total diaphragm width at that level.			-0.2	
	C1, C2 building out-of-plane offset: The exterior beams do not align with the columns in plan.			-0.2	P_{L2} = ______
	Other irregularity: There is another observable plan irregularity that obviously affects the building's seismic performance.			-0.5	*(Cap at -0.7)*
Redundancy	The building has at least two bays of lateral elements on each side of the building in each direction.			+0.2	
Pounding	Building is separated from an adjacent structure by less than 1.5% of the height of the shorter of the building and adjacent structure and:	The floors do not align vertically within 2 feet.	*(Cap total pounding modifiers at -0.9)*	-0.7	
		One building is 2 or more stories taller than the other.		-0.7	
		The building is at the end of the block.		-0.4	
S2 Building	"K" bracing geometry is visible.			-0.7	
C1 Building	Flat plate serves as the beam in the moment frame.			-0.3	
PC1/RM1 Bldg	There are roof-to-wall ties that are visible or known from drawings that do not rely on cross-grain bending. *(Do not combine with post-benchmark or retrofit modifier.)*			+0.2	
PC1/RM1 Bldg	The building has closely spaced, full height interior walls (rather than an interior space with few walls such as in a warehouse).			+0.2	
URM	Gable walls are present.			-0.3	
MH	There is a supplemental seismic bracing system provided between the carriage and the ground.			+0.5	
Retrofit	Comprehensive seismic retrofit is visible or known from drawings.			+1.2	M = ______

FINAL LEVEL 2 SCORE, $S_{L2} = (S' + V_{L2} + P_{L2} + M) \geq S_{MIN}$: *(Transfer to Level 1 form)*

There is observable damage or deterioration or another condition that negatively affects the building's seismic performance: ☐ Yes ☐ No

If yes, describe the condition in the comment box below and indicate on the Level 1 form that detailed evaluation is required independent of the building's score.

Figure 4-3 Portion of the Level 2 High seismicity Data Collection Form for adjusting the baseline score.

logarithmic increase in probability of collapse) overestimates the effect of the added irregularity. As an approximation of the expected performance of the structure, the cap is used. See FEMA P-155 for more information about why V_{L2} is capped. See Chapter 3 for additional discussion, including photographs and illustrations of the various types of irregularities.

The Level 2 vertical irregularities are as follows.

- Sloping Site
    - *"W1 building: There is at least a full story grade change from one side of the building to the other."* Homes with flexible basement walls on all sides, such as those with wood frame construction, on steep hills have performed poorly in past earthquakes, such as the

1994 Northridge earthquake. The downslope side of the structure is often too weak and flexible to resist earthquake forces. As a result, the Score Modifier is large for this irregularity. The Score Modifier does not apply when the foundation walls of the partly below-grade basement are all constructed of reinforced concrete.

  - *"Non-W1 building: There is at least a full story grade change from one side of the building to the other."* The Score Modifier for this statement is smaller than the Score Modifier for the first statement, since a sloping site condition has a greater impact on W1 buildings than other types of buildings.

- Weak and/or Soft Story: Several statements on the form capture conditions related to weak or soft story. Each condition is unique; however, for certain buildings, more than one of the statements may be true. To avoid double counting the irregularity, the screener is directed to circle one at most. If more than one applies to the building, the screener should select the worst case of the applicable Score Modifiers.
  - *"W1 building cripple wall: An unbraced cripple wall is visible in the crawl space."* A cripple wall is a perimeter stud wall between the foundation and the floor joists of the lowest occupied floor. A cripple wall is unbraced if it lacks plywood or oriented strand board (OSB) structural sheathing. Note that cripple wall damage can be costly but tends not to greatly threaten life-safety. However, since the scoring in FEMA P-154 is intended to reflect collapse risk directly, and life safety only indirectly, this modifier is significant.
  - *"W1 house over garage: Underneath an occupied story, there is a garage opening without a steel moment frame, and there is less than 8' of wall on the same line (for multiple occupied floors above, use 16' of wall minimum)."* This question is more specific than the general description provided in the Vertical Irregularity Reference Guide in Appendix B. For Level 2, even if there is an occupied story above the garage opening, the modifier need not be triggered if a steel moment frame is present at the opening or if there is a shear wall (i.e., a stud wall sheathed with plywood or OSB) adjacent to the opening. The minimum wall length increases if there are multiple occupied floors above the opening.
  - *"W1A building open front: There are openings at the ground story (such as for parking) over at least 50% of the length of the building."* This question is more specific than the general description on the Vertical Irregularity Reference Guide in Appendix

B. This Score Modifier applies if there are door or window openings along more than 50% of the length of the building. This would include most buildings with tuckunder parking.

- *"Non-W1 building: Length of lateral system at any story is less than 50% of that at story above or height of any story is more than 2.0 times the height of the story above."* In the case of shear walls, length of the lateral system is the length of shear walls. In the case of moment frames, the length of the lateral system is measured in terms of number of bays. The exclusion of W1 is intended to avoid double-counting of the open-front Score Modifier. An illustration of a building that meets this definition is shown in Figure 4-4.

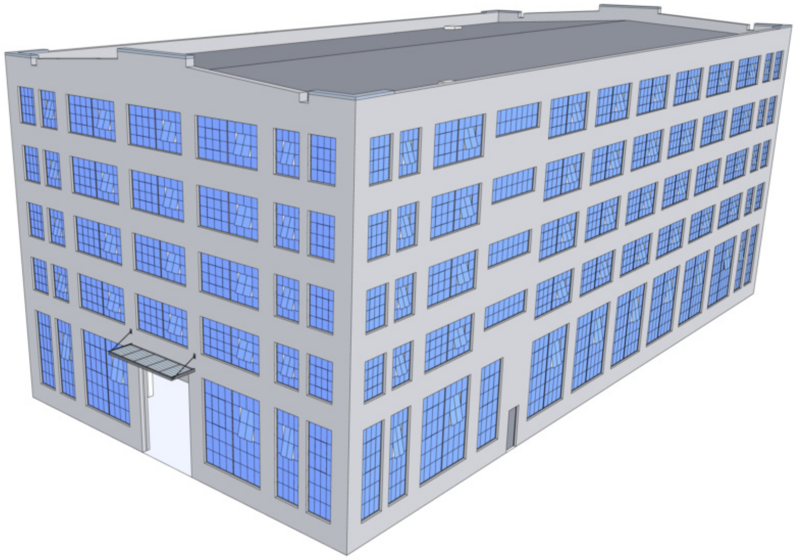


Figure 4-4 Illustration of a building with a ground floor story height that is twice the height of the stories above.

- *"Non-W1 building: Length of lateral system at any story is between 50% and 75% of that at story above or height of any story is between 1.3 and 2.0 times the height of the story above."* This statement represents a less severe irregularity and has a smaller Score Modifier. An illustration of a building that meets this definition is shown in Figure 4-5.

- Setback
  - *"Vertical elements of the lateral system at an upper story are outboard of those at the story below causing the diaphragm to cantilever at the offset."* This condition occurs when the footprint of the building at a lower level is smaller than at an upper level. This condition is severe because the diaphragm must cantilever back to

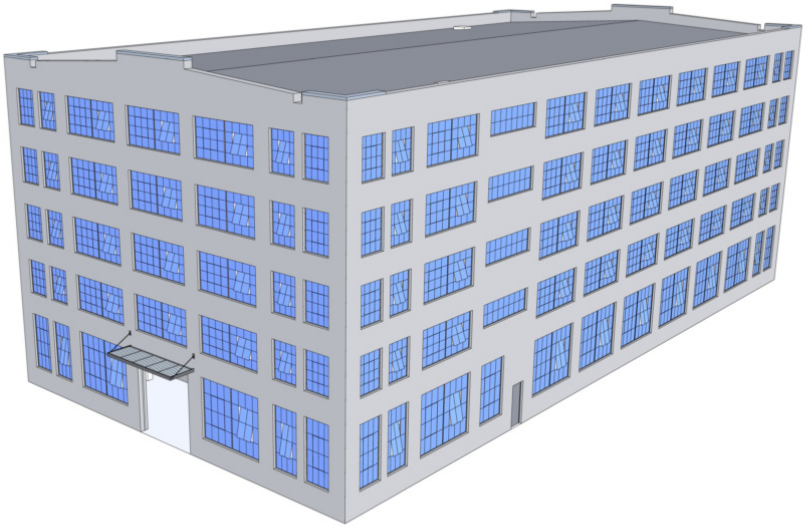


Figure 4-5 Illustration of a building with a ground floor story height that is 1.5 times the height of the stories above.

the interior of the building, rather than simply span between lateral elements. If there are columns under the discontinuous upper story walls, they can undergo large overturning forces from the walls above and may sustain large drifts from cantilever action of the floor diaphragm just above them.

- *"Vertical elements of the lateral system at upper stories are inboard of those at lower stories."* In this case, the upper story is set back from the lower story such that the footprint of the building at the lower story is larger than at an upper story.
- *"There is an in-plane offset of the lateral elements that is greater than the length of the elements."* For example, a braced frame has braces at Story X+1 in one bay, but the brace in Story X is in a different bay. In the case of a shear wall, the shear wall in Story X+1 does not overlap with the shear wall in Story X.

- Short Column/Pier
  - *"C1, C2, C3, PC1, PC2, RM1, RM2: At least 20% of columns (or piers) along a column line in the lateral system have height/depth ratios less than 50% of the nominal height/depth ratio at that level."* These columns or piers tend to be stiffer and will undergo higher forces and may suffer severe damage before loads are redistributed to the other columns or piers. An illustration of a building that meets this definition is shown in Figure 4-6.

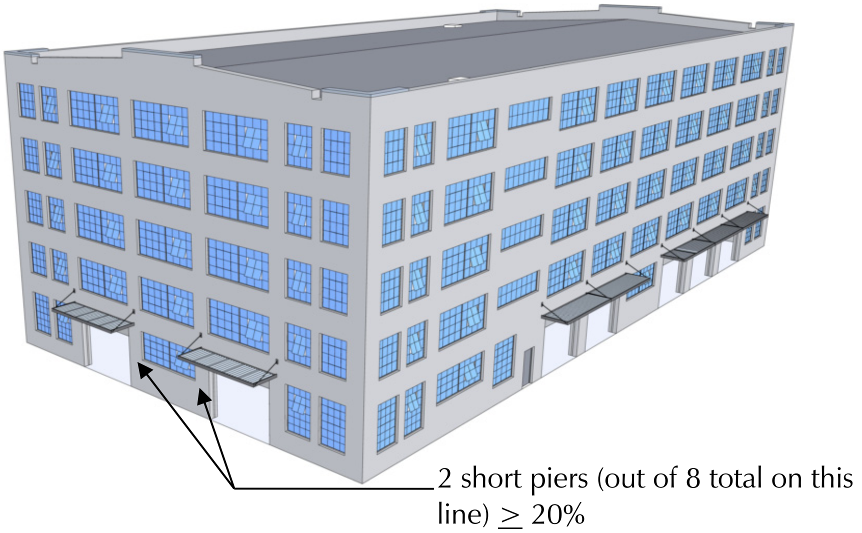


Figure 4-6 Illustration of a building with short piers.

- *"C1, C2, C3, PC1, PC2, RM1, RM2: The column depth (or pier width) is less than one half of the depth of the spandrel, or there are infill walls or adjacent floors that shorten the column."* The two conditions described in this statement are less severe than the condition in the first short column/pier statement. An illustration of a building that meets this definition is shown in Figure 4-7.

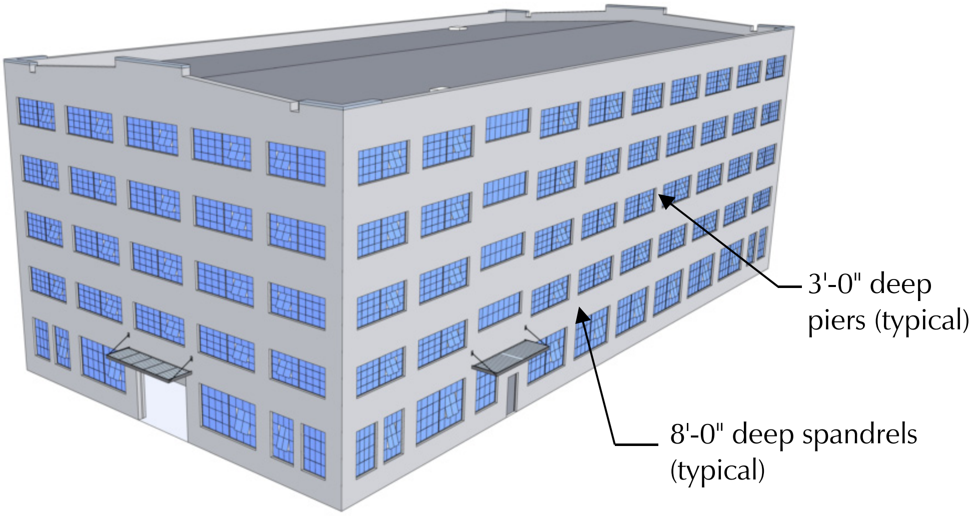


Figure 4-7 Illustration of a building with piers that are less than one half as deep as the spandrels.

- Split Level
  - *"There is a split level at one of the floor levels or at the roof."* This condition creates discontinuity in the floor or roof diaphragm.

- Other Irregularity: The following statements allow the screener to apply a Score Modifier if a vertical irregularity is observed that is not considered by the other irregularity statements. This statement may be triggered by an observed mass irregularity, or an unusual condition such as a rooftop pool. The screener uses judgment to decide when to use this and whether the observed irregularity has a severe or moderate effect on the seismic performance of the building. The screener should describe the observed irregularity in the comments area.
    - *"There is another observable severe vertical irregularity that obviously affects the building's seismic performance.*"
    - *"There is another observable moderate vertical irregularity that may affect the building's seismic performance."*

4.3.2 Plan Irregularities

The Plan Irregularity section of the Level 2 form includes statements and Score Modifiers for each plan irregularity in the Plan Irregularity Reference Guide, Table B-5 in Appendix B. The sum of Score Modifiers in this section, subject to a cap, is the Level 2 Plan Irregularity Score Modifier, P_{L2}, and should be noted in the space provided in the subtotals column. The cap for P_{L2} is defined on the Level 2 form and is the same value as the Plan Irregularity Score Modifier on the Level 1 form, P_{L1}. The cap is used as an approximation of the expected performance of the structure. See FEMA P-155 for more information about why P_{L2} is capped. The Level 2 plan irregularities are as follows. See Chapter 3 for additional discussion, including photographs and illustrations of the various types of irregularities.

- *"Torsional irregularity: Lateral system does not appear relatively well distributed in plan in either or both directions. (Do not include the W1A open front irregularity listed above.)"* W1A with an open front is excluded because the penalty has already been applied in the vertical irregularity section and need not be double counted.

- *"Non-parallel systems: There are one or more major vertical elements of the lateral system that are not orthogonal to each other."* This means that column lines or shear walls do not meet at right angles. This is considered to be only a moderate irregularity.

- *"Reentrant corner: Both projections from an interior corner exceed 25% of the overall plan dimension in that direction."* This is considered to be only a moderate irregularity. Damage tends to concentrate at the reentrant corner, but overall collapse is expected to be less likely than a building that is torsionally irregular. An illustration of a building that meets this definition is shown in Figure 4-8. Additional considerations should be made for rigid wall, flexible diaphragm buildings where smaller reentrant offsets may initiate local building damage or partial collapse. An example would be a large rectangular building, as shown in Figure 4-9, with a small midspan offset where the tributary loads to the wall would generate large overturning and drag/collector forces that may not have been adequately provided for in the building's design.

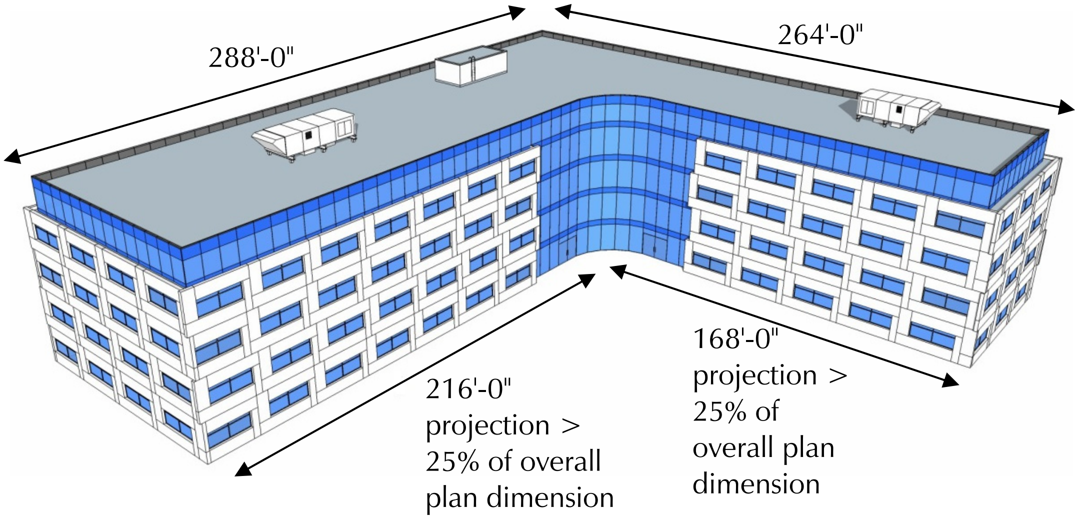


Figure 4-8 Illustration of a building with a reentrant corner.

- *"Diaphragm opening: There is an opening in the diaphragm with a width over 50% of the total diaphragm width at that level."* This is considered to be only a moderate irregularity, with less impact than a reentrant corner.

- *"C1, C2 building out-of-plane offset: The exterior beams do not align with the columns in plan."* This irregularity has a relatively high Score Modifier because it can lead to joint damage and potential collapse when the beam-to-column connection is inadequately reinforced. In older buildings this is likely to be the case. The impact of the condition varies with how great the offset of the centerline of the beam is from the centerline of the column. In the most severe case, the beam is entirely outside of the depth of the column. Only one Score Modifier is provided to capture all cases. This is for simplicity and because it will often only be possible to see the front face of the beam and column during the screening.

- *"Other irregularity: There is another observable plan irregularity that obviously affects the building's seismic performance."* This statement allows the screener to apply a Score Modifier if a plan irregularity is

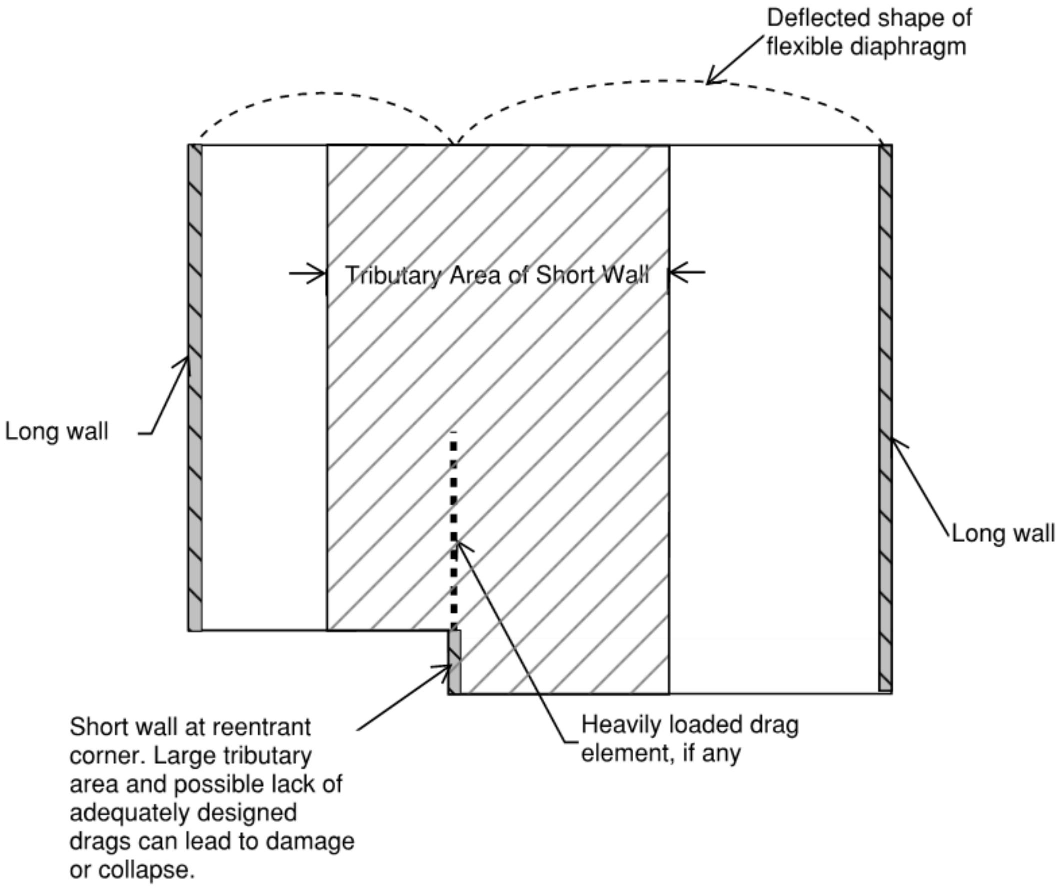


Figure 4-9 Rigid wall, flexible diaphragm building with short wall at small reentrant corner.

observed that is not considered by the other irregularity statements. The screener uses judgment to decide when to use this. If such an irregularity is observed, the screener should describe it in the comments area.

4.3.3 Redundancy

Buildings that have more seismic force-resisting elements have greater redundancy and are expected to perform better in an earthquake than buildings with fewer seismic force-resisting elements. If the building has at least two bays of seismic force-resisting elements on each side of the building in each direction, there is a sufficient level of redundancy, the statement on the form is true, and the screener applies a positive Score Modifier. For buildings with shear walls, if the number of bays is not clear, then a bay can be defined as at least the height of the story.

4.3.4 Pounding

In the Level 2 screening, pounding is considered in the structural score. This is different than the Level 1 screening where, if there is pounding potential, the score is not adjusted, but a Detailed Structural Evaluation is automatically triggered.

In Very High seismicity regions, if the building being screened is separated from an adjacent structure by less than 1.50% of the height of the shorter of the building and adjacent structure, pounding may be an issue. This is reduced to 1.00% in High seismicity, 0.50% in Moderately High seismicity, 0.25% in Moderate seismicity, and 0.10% in Low seismicity regions. The separation values are based on considerations of worst-case modal displacement at the upper end of the range for that seismicity region. See FEMA P-155 for more information on the basis of the separation thresholds.

The Pounding Score Modifier varies according to the severity of type of pounding condition that exists. Where the separation gap is less than the threshold, three conditions are considered. Each of the conditions is stated and illustrated below. For each true statement, the screener circles the associated Score Modifier. For each false statement, the screener crosses out the associated Score Modifier. More than one of the pounding conditions may apply for a given building. In this case, the applicable Score Modifiers are summed, but need not exceed the cap indicated on the Level 2 form.

- "*The floors do not align vertically within 2 feet*." Illustrated in Figure 4-10.

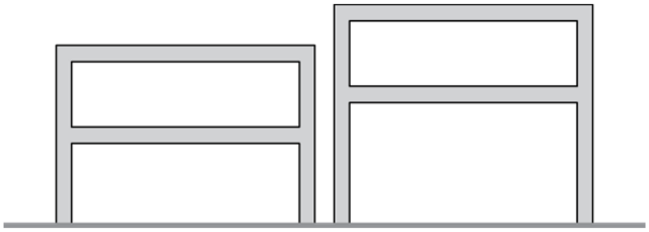


Figure 4-10 Illustration of floors not aligning vertically.

- "*One of the buildings is two or more stories taller than the other.*" Illustrated in Figure 4-11.
- "*The building is at the end of the block.*" This statement is applicable for a building at the end of a row of three or more buildings. Illustrated in Figure 4-12.

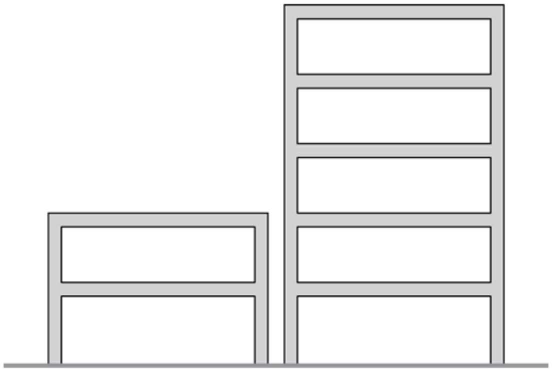


Figure 4-11 Illustration of a building that is two or more stories taller than the adjacent building.

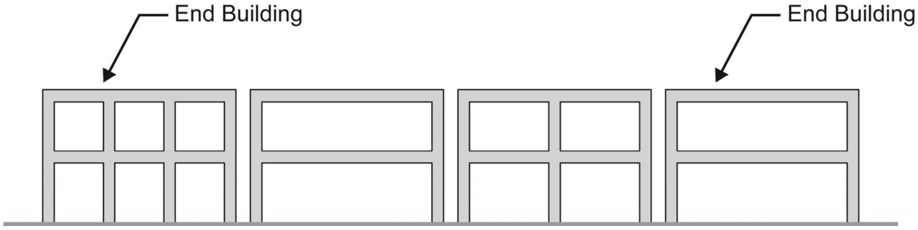


Figure 4-12 Illustration of end buildings.

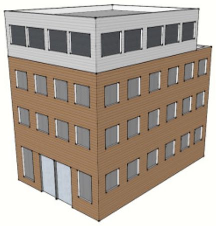
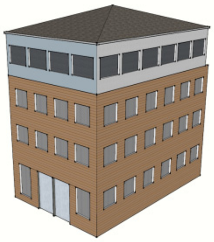
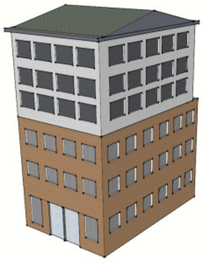
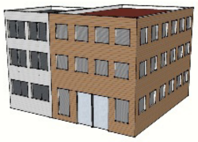
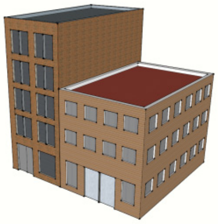
4.3.5 Consideration of Building Additions

The Level 2 screening form does not have statements specific to building additions. Instead, the effect of different addition configurations on the seismic performance of the building is addressed by considering vertical or plan irregularities, or some combination of these depending on the configuration of the addition. See Section 3.14.5 for a general discussion regarding additions and the screening approach used in Level 1.

For Level 2 screening, the Building Additions Reference Guide in Table 4-1 (also repeated in Appendix B) provides guidance for considering additions. Based on the characteristics of the addition, the guide directs the screener to consider the original building and addition either as a single building or as two separate buildings and perform two separate screenings. However, if the addition is separated from the original building with an obvious gap, the building and the addition should be screened as two separate buildings and both scores should be recorded. Pounding criteria in Section 4.3.4 should be considered in this case.

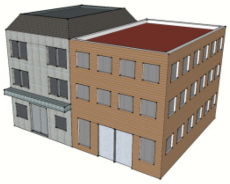
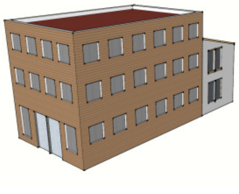
In a Level 2 screening, a vertical addition is evaluated for its effect on the presence of a vertical irregularity. A vertical addition is defined as the addition of one or more stories to a building after the initial construction.

Table 4-1 Building Additions 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 also 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 4-1 Building Additions Reference Guide (continued)

Addition Orientation	Type of Addition	Example	RVS Screening Recommendation	Notes and Additional Instructions
Horizontal	Addition with different FEMA Building Type than original		Evaluate a single building with torsional irregularity using the FEMA 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.

Buildings originally constructed with different building types over their height, as is typical with wood framed residential buildings constructed over a concrete podium structure, should not be considered as having an addition.

If a vertical addition is observed and there is a significant difference (more than 10%) in the plan area of a vertical addition compared to the plan area of the original building, a setback irregularity should be indicated on the Level 2 form. A setback irregularity may also occur where more than one exterior wall of the addition does not align with an exterior wall below, implying that there may be an offset in the seismic force-resisting system. A rooftop penthouse need not be considered a vertical addition if there are no windows (implying no continuous occupancy) and the plan area is small relative to the area of the roof.

If there is a difference in the seismic force-resisting system between the vertical addition and the original building, the weak/soft story evaluation criteria for the Level 2 form should be used to assess whether the addition creates a moderate or severe vertical irregularity.

The presence of horizontal building additions can generally be identified by either vertical changes in the architectural or vertical system over the height of the building between portions of the building, difference in floor levels between portions of the building, differences in the seismic force-resisting system or construction materials between various parts of the building, or abrupt differences in the architectural style on two or more sides of the building.

Horizontal additions that have a smaller or larger horizontal dimension along the interface than the original building should be evaluated for the presence of a reentrant corner irregularity using the reentrant corner subcategory of the Level 2 form. If the seismic force-resisting system of the addition is different than that of the original building, the torsional irregularity statement for plan irregularity should be indicated as applicable on the Level 2 form. Where the height of the horizontal addition is greater than or less than the height of the original building, a moderate vertical setback irregularity is also present.

Small horizontal additions may rely on the original building for gravity support. Small additions constructed with the same FEMA Building Type as the original building can be considered a single building, but should be evaluated for the presence of setback and plan irregularities. Where the addition is of a different FEMA Building Type than the original building, the structures may respond differently and may become disconnected at the interface. In this case the addition should be considered as a separate structure to evaluate whether it has sufficient independent lateral force resistance.

4.3.6 Building Type Specific Statements

The Level 2 form includes several building type specific statements. These statements allow the Level 2 screener to modify the building score for several conditions that are known to affect building performance.

- *"S2 building: 'K' bracing geometry is visible."* K bracing is when the braces intersect the column at mid-height without a horizontal member or connection to a diaphragm. When one of the braces buckles in compression, it can place high horizontal demands on the column, and the column can be at increased risk of failure and collapse.
- *"C1 building: Flat plate serves as the beam in the moment frame."* In many older concrete moment frame buildings, the flat plate floor serves as an effective beam in the moment frame system. However, the flat plate is not detailed like a beam with stirrups and does not have a drop capital like a flat slab. The flat plate can thus be at increased risk of a punching shear failure, leading to local collapse.
- *"PC1/RM1 building: There are roof-to-wall ties that are visible or known from drawings that do not rely on cross-grain bending."* Do not

apply this Score Modifier in combination with the post-benchmark or retrofit Score Modifiers, to avoid double-counting this benefit. Note that roof-to-wall ties may also be observed in C2 buildings with wood roof diaphragms. Basic Scores for C2 are based on the more typical condition where diaphragms are concrete and tied to the concrete walls with continuous rebar. Thus, an added benefit for anchored wood diaphragms is not provided.

- *"URM: Gable walls are present."* URM gable walls are normally not braced and are often vulnerable to out-of-plane failure. Because these walls often provide vertical support for the roof, failure of the gable wall can result in partial collapse. An illustration of a building with a gable wall is provided in Figure 4-13.

Figure 4-13 Illustration of a URM building with a gable end wall.

- *"MH: There is a supplemental seismic bracing system provided between the carriage and the ground."* The Basic Score for MH type buildings has been defined assuming that supplemental seismic bracing is absent. In some cases, the bracing is observed in the field, although this is rare because MH type buildings commonly have skirts on all sides. More often, bracing is known to exist only if there are local codes requiring bracing or the mobile home park in which it is located has specific bracing requirements.

4.3.7 Retrofits

In the Level 2 screening, the screener may apply a positive Score Modifier when there is evidence that the building has been retrofitted. The Score Modifier should only be applied when the retrofit is comprehensive. A comprehensive retrofit is one that addresses all of the elements in the lateral load path. Added elements that mitigate localized hazards, such as added wall ties or parapet bracing, do not qualify for the Score Modifier.

Partial retrofits and in-progress or incremental retrofits should be noted in the comments section, without applying the Score Modifier. If the retrofit appears to effectively counteract an observed deficiency, the screener can simply apply neither the deficiency nor the retrofit Score Modifier, but mention both in the comments. The screener can recognize a retrofit that introduces a deficiency (e.g., by introducing a torsional irregularity) by applying the appropriate Score Modifier for the deficiency and by commenting that it is the retrofit that produced it.

In a visual screening, it is unlikely that all elements in a lateral load path can be observed. However, it is often possible to see the vertical elements of a seismic retrofit, such as moment frames, braced frames, and sometimes shear walls. Because of the cost and disruption involved, when these elements are added, it is likely that these elements are part of a comprehensive retrofit. For example, when braced frames are added in a URM building, it would be expected that ties between the diaphragm and walls have been installed, as well as parapet and gable bracing. Thus, if vertical elements in a retrofit are observed, the Score Modifier can be applied.

Common observable retrofit measures that are indicative of a sufficiently comprehensive retrofit include:

- Added cripple wall bracing and holdowns in a W1.
- Added steel moment frames in a W1 house over garage or W1A open front building.
- Added steel moment frames or braced frames in a S5, C3, or URM.

Ideally, the retrofit will be documented in available construction drawings. In this case, the pre-field planning should identify whether the Score Modifier is applicable. If drawings are not available but the screener observes evidence of a retrofit in the field, the screener may use judgment about the efficacy of the retrofit. For example, a URM building that has been retrofitted with small braced frames adjacent to URM walls may not warrant the retrofit Score Modifier because the braced frame likely has insufficient stiffness to attract much load away from the URM wall.

The screener should describe the observed retrofit in the comments section. In general, the value of the Retrofit Score Modifier has been set to be equivalent to having mitigated the effects of a plan irregularity. A retrofit does not guarantee that a building will receive a score above the cut-off.

4.4 Determining the Final Level 2 Score

The Final Level 2 Score, S_{L2}, is calculated by summing the baseline score, S', and the Level 2 Score Modifiers, V_{L2}, P_{L2}, and M subject to the same minimum score that applies to the Level 1 Score. In many cases, the Level 2 screening results in a higher score than the Level 1 screening. Because building attributes are examined in more detail in the Level 2 screening, the Score Modifiers can be less conservative. The Final Score more accurately represents the expected performance of the building with less built-in conservatism.

The Final Level 2 Score is subject to the same minimum, S_{MIN}, as the Level 1 Score.

4.5 Other Observable Conditions

The screener is asked whether there is observable damage or deterioration or another condition that negatively affects the building's seismic performance. If there is such a condition, the screener is given the option to note on the Level 1 form that a Detailed Structural Evaluation is required, regardless of the building's score. This allows for flexibility in the event that the Level 2 screener observes an uncommon condition he or she knows may represent a significant hazard. The screener should describe the condition in the comments box. The screener should also take additional photographs of the condition. This information will be further reviewed by the Supervising Engineer.

4.5.1 Damage and Deterioration

Suggestions for evaluating damage and deterioration during a Level 1 screening are provided in Section 3.12. The Level 2 screener should review these same items. The Level 2 screener, however, should use judgment to distinguish between damage to components of the seismic force-resisting system and damage that is cosmetic only. The Level 2 screener may be able to determine whether observed cracks in concrete are due to settlement or are due to past earthquake damage. Corrosion in steel elements that are primary members of the gravity load-carrying or seismic force-resisting system is a greater cause for concern than corrosion in elements that are purely architectural.

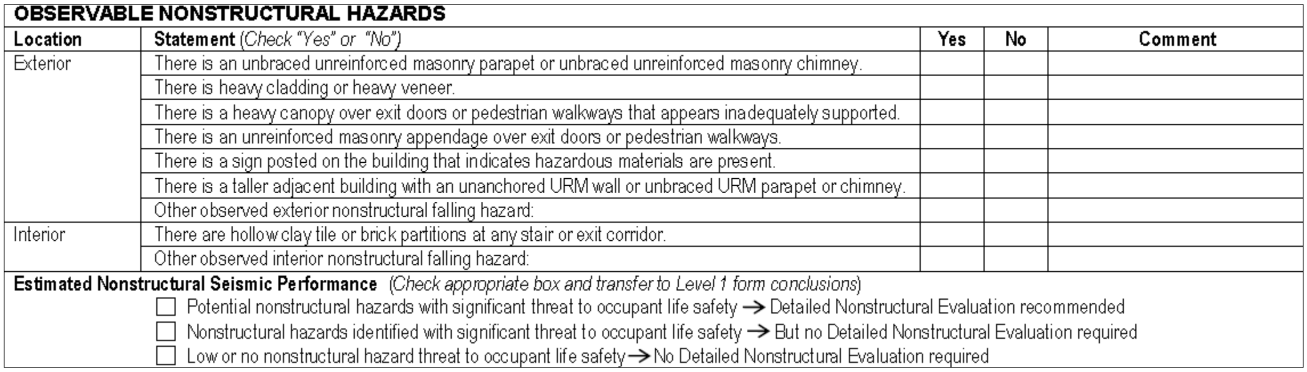
4.5.2 *Other Conditions*

If the Level 2 screener observes a condition that indicates the building is potentially seismically hazardous, even if that condition is not discussed here, the screener should describe this condition in the comments box and indicate on the Level 1 form that a Detailed Structural Evaluation is required.

For example, tilt-ups and some S1 and S3 buildings commonly have added mezzanines with no seismic force-resisting system. As a result, the mezzanine can be at risk of collapse, or it may be located where it can pound into the primary seismic force-resisting system of the building, potentially causing damage or collapse of the building.

4.6 Observable Nonstructural Hazards

The bottom portion of the Level 2 form focuses on nonstructural hazards (see Figure 4-14). Nonstructural modifiers do not strongly affect collapse probability, thus these modifiers do not affect the building Final Score.



OBSERVABLE NONSTRUCTURAL HAZARDS

Location	**Statement** *(Check "Yes" or "No")*	**Yes**	**No**	**Comment**
Exterior	There is an unbraced unreinforced masonry parapet or unbraced unreinforced masonry chimney.			
	There is heavy cladding or heavy veneer.			
	There is a heavy canopy over exit doors or pedestrian walkways that appears inadequately supported.			
	There is an unreinforced masonry appendage over exit doors or pedestrian walkways.			
	There is a sign posted on the building that indicates hazardous materials are present.			
	There is a taller adjacent building with an unanchored URM wall or unbraced URM parapet or chimney.			
	Other observed exterior nonstructural falling hazard:			
Interior	There are hollow clay tile or brick partitions at any stair or exit corridor.			
	Other observed interior nonstructural falling hazard:			

Estimated Nonstructural Seismic Performance *(Check appropriate box and transfer to Level 1 form conclusions)*

☐ Potential nonstructural hazards with significant threat to occupant life safety → Detailed Nonstructural Evaluation recommended

☐ Nonstructural hazards identified with significant threat to occupant life safety → But no Detailed Nonstructural Evaluation required

☐ Low or no nonstructural hazard threat to occupant life safety → No Detailed Nonstructural Evaluation required

Figure 4-14 Portion of the Level 2 form for nonstructural hazards.

In areas of low seismicity, nonstructural hazards can be important for life-safety considerations in a large rare earthquake. Heavy exterior cladding and parapets have dislodged during past earthquakes and killed passers-by. Nonstructural ceilings, light fixtures, heavy cabinets, and shelves can also injure occupants and block exitways. Glass shards from untempered windows and doors can also be hazardous, particularly if located near emergency exits.

The statements on this portion of the form primarily relate to falling hazards, but unlike the Level 1 form, they also include some other nonstructural hazards as well. The screener notes whether each statement is true and makes any relevant comments as the statements are reviewed. There are seven statements addressing exterior falling hazards and two statements addressing interior falling hazards. These later statements should be addressed if access to the interior of the building is available. The statements on the Level 2 form reflect similar falling hazards as those listed on the Level 1 form, but the Level 2 statements are more specific.

- Exterior:
    - *"There is an unbraced unreinforced masonry parapet, or unbraced unreinforced masonry chimney."*
    - *"There is heavy cladding or heavy veneer."*
    - *"There is a heavy canopy over exit doors or pedestrian walkways that appears inadequately supported."*
    - *"There is an unreinforced masonry appendage over exit doors or pedestrian walkways."*
    - *"There is a sign posted on the building that indicates hazardous materials are present."*
    - *"There is a taller adjacent building with an unanchored URM wall or unbraced URM parapet or chimney."*
    - *"Other observed exterior nonstructural falling hazard:"*
- Interior:
    - *"There are hollow clay tile or brick partitions at any stair or exit corridor."*
    - *"Other observed interior nonstructural falling hazard:"*

After reviewing each of the statements, the screener uses judgment to estimate the nonstructural seismic performance of the building. One of three boxes is checked:

- *"Potential nonstructural hazards with significant threat to occupant life safety → Detailed Nonstructural Evaluation recommended."* This box should be checked if a potential nonstructural hazard has been identified and additional evaluation may reveal that the suspected hazard is not actually a threat to occupant life safety. For example, a detailed evaluation of a building's heavy cladding may reveal that it is properly anchored and is not a threat.
- *"Nonstructural hazard identified with significant threat to occupant life safety → But no Detailed Nonstructural Evaluation required."* This box should be checked if a nonstructural hazard has been identified and no additional evaluation is necessary. For example, additional evaluation of an unbraced unreinforced masonry chimney will not be able to show that the chimney is not a hazard.

- *"Low or no nonstructural hazard threat to occupant life safety → No Detailed Nonstructural Evaluation required."* This box should be checked if all of the statements are false. If one of the statements is true but the screener does not believe that the identified hazard is a threat to life safety, the screener should check this box and describe in the comments section why the falling hazard is not a threat.

If the screener is in doubt about whether any of the statements is true, these doubts should be noted in the comments section. Similarly, the screener should note any doubts about the estimated nonstructural seismic performance.

4.7 Comments

A space is provided on the Level 2 form for comments. The screener should use this area to note any special conditions that have been observed or to indicate issues that could not be verified in the field. In particular, the screener should describe in detail any observed damage or deterioration or any observed other vertical or plan irregularities. If additional space is needed for notes or sketches, the screener can use the comments section and the sketch space on the Level 1 form or attach a separate sheet of paper.

4.8 Transferring the Level 2 Results to the Level 1 Form

The Final Level 2 Score, S_{L2}, is transferred to the Level 1 form and supersedes the Final Level 1 Score. The Level 2 screener should also indicate on the Level 1 form the results of the Level 2 nonstructural screening. The screener then completes or revises the "Other Hazards" and "Action Required" portions of the Level 1 form based on these results.

Chapter 5

Using the RVS Procedure Results

5.1 Using the RVS Procedure Results

The rapid visual screening (RVS) procedure presented in this *Handbook* is meant to be the preliminary screening phase of a multi-phase procedure for identifying earthquake-hazardous buildings. Buildings identified by this procedure as potentially seismically hazardous should be analyzed in more detail by an experienced seismic design professional. Typically, an evaluation according to ASCE/SEI 41-13, *Seismic Evaluation and Retrofit of Existing Buildings* (ASCE, 2014), will be most appropriate for those buildings that require a Detailed Structural Evaluation. Where further nonstructural evaluation is desired based on the results of the rapid visual screening, FEMA E-74, *Reducing the Risks of Nonstructural Earthquake Damage – A Practical Guide, Fourth Edition* (FEMA, 2012e), is recommended. Based on more detailed evaluation, some of the buildings identified as potentially hazardous by the RVS procedure will prove to be adequate. The procedure is designed to catch as many of the potentially hazardous buildings as possible, but, because rapid visual screening is designed to be performed from the street, with interior inspection not always possible, hazardous details may not always be visible, and some seismically hazardous buildings may not be identified as such.

Since the original publication of FEMA 154 in 1988, the RVS procedure has been widely used by local communities and government agencies. A critical issue in the implementation of FEMA 154 has been the interpretation of the Final Score, S_{L1} *or* S_{L2} (combined as S for this chapter), and the selection of a cut-off score, below which a Detailed Structural Evaluation of the building by a design professional experienced in seismic design is required.

This chapter discusses: (1) interpretation and selection of the cut-off score; (2) prior uses of the FEMA 154 RVS procedure, including decisions regarding the cut-off score; (3) using the RVS program for seismic advocacy; and (4) other possible uses of the RVS procedure, including resources needed for the various possible uses. These discussions are intended to illuminate both the limitations and potential applications of the RVS procedure.

5.2 Interpretation of RVS Score

Having employed the RVS procedure and determined the building's Final Score, *S*, which is based on the Basic Score and Score Modifiers associated with the various performance attributes, the RVS Authority is faced with the question of what these *S* scores mean. Fundamentally, the final *S* score is an estimate of the collapse probability (as described in Chapter 1) if an earthquake occurs with ground motions called the risk-targeted maximum considered earthquake, MCE_R, as described in Chapter 2. These estimates of the score are based on limited observed and analytical data, and the probability of collapse is therefore approximate.

A Final Score, *S*, of 3 implies there is a chance of 1 in 10^3, or 1 in 1,000, that the building will collapse if such ground motions occur. A Final Score, *S*, of 2 implies there is a chance of 1 in 10^2, or 1 in 100, that the building will collapse if such ground motions occur. (Additional information about the basis for the RVS scoring system is provided in the third edition companion FEMA P-155 Report, *Rapid Visual Screening of Buildings for Potential Seismic Hazards: Supporting Documentation*.) An understanding of the physical essence of the scoring system, as described above, will facilitate the interpretation of results from implementation of the RVS procedure

5.3 Selection of RVS Cut-Off Score

One of the most difficult issues pertaining to rapid visual screening is answering the question, "What is an acceptable Final Score, *S*?" This is a question for the community that involves the costs of safety versus the benefits. The costs of safety include:

- the costs of reviewing and investigating in detail hundreds or thousands of buildings in order to identify some fraction of those that would actually sustain major damage in an earthquake; and
- the costs associated with retrofitting those buildings finally determined to be unacceptably weak.

The most compelling benefit is the saving of lives and prevention of injuries due to reduced damage in those buildings that are retrofitted. This reduced damage includes not only less material damage, but fewer major disruptions to daily lives and businesses. The identification of hazardous buildings and the mitigation of their hazards are critical because there are thousands of existing buildings in all parts of the United States that may suffer severe damage or possible collapse in the event of strong ground shaking. Such damage or collapse can be accompanied by loss of life and serious injury. In a great earthquake, deaths could number in the thousands.

Each community or RVS Authority needs to engage in some consideration of these costs and benefits of seismic safety, and decide what value of S is an appropriate "cut-off" for their situation. The final decision involves many non-technical factors, such as determining the acceptable level of risk for the community, and is not straightforward. A study quantifying the risk inherent in modern building codes, conducted by the National Bureau of Standards (NBS, 1980), observed: "In selecting the target reliability it was decided, after carefully examining the resulting reliability indices for the many design situations, that a $\beta_0 = 3$ is a representative average value for many frequently used structural elements when they are subjected to gravity loading, while $\beta_0 = 2.5$ and $\beta_0 = 1.75$ are representative values for loads that include wind and earthquake, respectively." Note that β_0, as used in the National Bureau of Standards study, is approximately equivalent to $S - 1$ as used herein.

More recently, FEMA P-695, *Quantification of Building Seismic Performance Factors* (FEMA, 2009b), which established consistent and rational building system performance and response parameters for the linear design methods traditionally used in current building codes, concluded that it is acceptable that: "The probability of collapse due to MCE ground motions applied to a population of [buildings of the same type] is limited to 10%, on average." The 10% figure is an upper bound. After accounting for how conservative it is, that is, how the average real new building behaves rather than the upper limit, and accounting for the fraction of the building area that collapses, one can estimate that new buildings might realistically have an average $S = 2.5$. (See FEMA P-155 Chapter 8 for more details on this estimate.) Assuming that existing buildings can reasonably have a somewhat lower value of S than new buildings, the authors of the present work suggest that the acceptable probability of collapse in existing buildings is again roughly equivalent to a value of S of about 2.0.

Thus, an S value of about 2.0 is a reasonable preliminary value to use within the context of RVS to differentiate adequate buildings from those potentially inadequate and requiring detailed review. This is the value that has traditionally been used by RVS programs in the past. Use of a higher cut-off S value implies greater desired safety but increased community-wide costs for evaluations and rehabilitation; use of a lower value of S equates to increased seismic risk and lower short-term community-wide costs for evaluations and rehabilitation (prior to an earthquake).

It is important to keep in mind that the final *S* score relates specifically to the probability of collapse. Use of a higher cut-off score implies less probability of collapse, but it does not ensure that other performance objectives, such as continued operation after an earthquake, will be met. If higher performance objectives are desired, for example for special structures such as hospitals, the use of a more detailed structural evaluation, along with a nonstructural evaluation, is necessary.

Further guidance on cost and other societal implications of seismic rehabilitation of hazardous buildings is available in other publications of the FEMA report series on existing buildings. See FEMA 156 and FEMA 157, *Typical Costs for Seismic Rehabilitation of Buildings*, 2nd Edition, Volumes 1 and 2 (FEMA, 1994a and FEMA, 1995), and FEMA 255 and FEMA 256, *Seismic Rehabilitation of Federal Buildings – A Benefit/Cost Model*, Volumes 1 and 2 (FEMA, 1994b and FEMA, 1994c).

5.4 Prior Uses of the RVS Procedure

Following publication of the first edition of the FEMA 154 *Handbook*, the rapid visual screening procedure was used by private-sector organizations and government agencies to evaluate more than 70,000 buildings nationwide (FEMA, 2002b). As reported at the FEMA 154 Users Workshop in San Francisco in September 2000 (see second edition of FEMA 155 report for additional information), these applications included surveys of the following buildings: (1) commercial buildings in Beverly Hills, California; (2) National Park Service facilities; (3) public buildings and designated shelters in southern Illinois; (4) U. S. Army facilities; (5) facilities of the U. S. Department of the Interior; and (6) buildings in other local communities and for other government agencies. The results from some of these efforts are described below.

In its screening of 11,500 buildings using the FEMA 154 RVS procedure, the U. S. Army Corps of Engineers Civil Engineering Research Laboratory (CERL) used a cut-off score of 2.5, rather than 2.0 (S. Sweeney, oral communication, September 2000), with the specific intent of using a more conservative approach. As a result of the FEMA 154 screening, approximately 5,000 buildings had final *S* scores less than 2.5. These buildings, along with a subset of buildings that had FEMA 154 scores higher than 2.5, but were of concern for other reasons, were further evaluated in detail using the FEMA 178 report, *NEHRP Handbook for the Seismic Evaluation of Existing Buildings* (FEMA, 1992). Results from the subsequent FEMA 178 evaluations indicated that some buildings that failed the FEMA 154 RVS procedure (that is, had scores less than 2.5) passed the

FEMA 178 evaluations and that some that passed the FEMA 154 RVS procedure (with scores higher than 2.5) failed the FEMA 178 evaluation (that is, were found to have inadequate seismic resistance). This finding emphasizes the concern identified at the beginning of this chapter that the use of FEMA 154 may not always identify potentially earthquake hazardous buildings as such, and that buildings identified as potentially hazardous may prove to be adequate.

Other conclusions and recommendations pertaining to the use of the FEMA 154 RVS procedure that emanated from these early applications included the following:

- Involve design professionals in RVS implementation whenever possible to ensure that the seismic force-resisting systems are correctly identified (such identification is particularly difficult in buildings that have been remodeled and added to over the years);
- Conduct intensive training for screeners so that they fully understand how to implement the methodology, in all of its aspects;
- Inspect both the exterior and, if at all possible, the interior of the building;
- Review construction drawings when available as part of the screening process;
- Review soils information prior to implementation of the methodology in the field; and
- Interpret the results from FEMA 154 screenings in a manner consistent with the level of resources available for the screening (for example, cut-off scores may be dictated by budget constraints).

Most of these recommendations were incorporated into the second edition of the *Handbook.* In this *Third Edition*, the recommendation to involve a design professional in RVS implementation has been further stressed with the introduction of the Supervising Engineer. See Chapter 2 for more details.

More recent uses of the RVS procedure include several efforts in Oregon and Utah.

The state of Oregon has conducted many assessments of the vulnerability of facilities using the rapid visual screening method based upon the second edition of FEMA 154. One example is for Clackamas County where all the schools and emergency facilities were screened, which helped lead to a statewide assessment (Wang et al., 2004).

In Oregon, a series of bills were passed in 2005 to assess the state's vulnerability to earthquakes on critical buildings. Of these, the 2005 Senate Bill 2 directed Oregon's Department of Geology and Mineral Industries (DOGAMI) to create a seismic survey of K-12 public school buildings, community college buildings with an occupancy of 250 persons or more, hospitals with acute inpatient care facilities, fire stations, police stations, sheriff's offices, and other law enforcement agency buildings. DOGAMI used a modified version of FEMA 154 *Second Edition* report by developing an enhanced RVS methodology called the E-RVS methodology. The results for all screened sites in each county are available at http://www.oregongeology.org/sub/projects/rvs/county/county-sites.htm. This E-RVS method has also been integrated into the Oregon Seismic Rehabilitation Grant Program, which requires that benefit cost analysis methods incorporate E-RVS (http://www.oregon.gov/OMD/OEM/Pages/plans_train/SRGP.aspx; and Wang and Goettel (2007)).

The survey was performed on 3,352 pre-1994 unretrofitted buildings by experienced university engineering and architecture professors from Oregon, along with selected students. DOGAMI senior staff and project leaders reviewed and verified the findings to produce the final results. The project identified over 60% of the buildings screened as having moderate to very high collapse potential with a score of 2.0 or below. The survey included buildings of all ages and is considered to be a representative example of the classes of buildings considered by FEMA 154.

In Utah, given that a significant number of schools pre-dated the 1975 advent of lateral design in the state's adopted code, the Utah Seismic Safety Commission together with the Structural Engineers Association of Utah (SEAU) recognized that Utah schools represent an important class of buildings that deserve special consideration for seismic safety. Beginning in 2008, they supported legislation to perform RVS on schools. In 2010, a pilot project was undertaken to support HB 279 (Rep. Wiley, L., 2012 Legislative session) using FEMA P-154 *Rapid Observation of Vulnerability and Estimation of Risk* (ROVER) (FEMA, 2014), an electronic version of FEMA 154, by trained structural engineers on a sampling of 128 schools.

The findings, published in the report *Utah Students at Risk* (Utah Seismic Safety Commission and Structural Engineers Association of Utah, 2011) showed that 60% of the sample buildings surveyed were at danger of collapse during a major earthquake along the Wasatch fault. The project sampled buildings in all age groups and was distributed proportionally throughout the state. Additionally, buildings were selected in four major building categories: elementary, middle, high and charter schools. The report was used to support continuing legislative efforts to inventory all Utah schools.

During the 2013 legislative session, lawmakers approved two measures to help advance the seismic safety of Utah's school buildings. The School Building Earthquake Inspection program is a $150,000 one-time budget item championed by Utah's governor to perform FEMA P-154 Rapid Visual Screening on all Utah schools. Additionally, House Bill HB278S01 Public Schools Seismic Studies requires that school districts requesting bond monies perform FEMA P-154 Rapid Visual Screening or more detailed studies on all of their buildings constructed before 1975 and provide the results to the Utah Seismic Safety Commission (USSC). The costs for these studies would be paid for out of the general obligation bonds. If a district has already performed a seismic safety evaluation on the affected buildings within the last 25 years, the district need only submit the information to the USSC. Both programs anticipate using the FEMA P-154 ROVER tool for data collection and evaluation purposes.

In 2011, the SEAU received a grant from the FEMA to provide a survey of 2,500 buildings in Salt Lake County. The purpose of the work was to assist in the development of the state's catastrophic earthquake support plan. The project involved the use of 50 structural engineers over a period of several months. Buildings for the survey were selected from Salt Lake county assessor data and were refined to include buildings with brick exterior older than 1975 and occupancy categories that would reflect the greatest threat to human life and mutually benefit FEMA and state response and mitigation planning.

Results from the survey revealed that approximately 72% of the buildings were deemed to need additional detailed evaluation with scores equal or below 2.0. FEMA's HAZUS software [whose methodology is documented in the *Multi-hazard Loss Estimation Methodology, HAZUS-MH MR4 Technical Manual* (FEMA, 2009a)] was used to assess potential impacts using the results from the survey and a magnitude 7.0 scenario earthquake and published online in FEMA's GeoPlatform: http://bit.ly/13Y5w6L. The 1,228 buildings that scored below 1.5 were specifically flagged for Urban Search and Rescue (USAR) planning. Additionally, it was found that the actual number of unreinforced masonry buildings was somewhat less than had been estimated using the 1975 benchmark date and those described as brick exterior, thereby providing a better estimate of vulnerability.

5.5 RVS and Seismic Advocacy

5.5.1 Overview

As noted in the foreword to the first edition of FEMA 155, "The publication is one of a series that FEMA is sponsoring to encourage local decision makers, the design professions, and other interested groups to undertake a program of mitigating risks that would be posed by existing hazardous buildings in case of an earthquake."

Perhaps one of the primary reasons for performing rapid visual screening of buildings is to advocate for greater seismic safety in our communities. An uninformed public cannot be expected to make decisions about risk without fully realizing the impact inaction may have on the quality of life following an earthquake. Recognizing the potential impacts and planning to reduce them only comes when good information is available and that understanding starts with rapid visual screening.

Finding support for performing RVS can often be a challenging task. Identifying vulnerable buildings in communities is sometimes seen as a liability with the inherent responsibility to fix or eliminate the danger. But these concerns can often be assuaged by noting that the RVS survey points toward the need for additional investigation to better determine the vulnerability of the identified buildings. If public buildings are the focus of the survey, specific language can often be added to legislation that effectively limits the liability associated with identifying dangerous buildings and creates a form of governmental immunity from lawsuits.

If surveys are performed on public buildings, strong consideration should be given to making the information directly available to the general public. When doing so, the information should be clearly explained, including the limitations of the assessment and that it is a first step in identifying vulnerable buildings.

Rapid visual screening can provide better information when developing seismic rehabilitation programs that benefit communities in becoming more resilient to the effects of earthquakes. Surveys will help quantify the problem and help communities make informed decisions about their risk. Rehabilitation programs will inevitably require accepting some portion of risk and knowing the potential extent of damage to buildings through RVS will provide support for those decisions.

Pilot programs that sample a small percentage of buildings have been effectively used in Utah to promote the need for an inventory of all Utah school buildings. In Oregon, a comprehensive survey has helped guide that state's investment in seismic mitigation of high-risk buildings. In short, RVS is an effective tool when addressing large portfolio building owners.

5.5.2 Audience Types

Information such as that provided by a rapid visual screening program will have value to a variety of audience types. It is important to identify the target audiences when constructing an RVS program so that the results will meet the desired goals.

Local elected and appointed officials as well as design professionals will benefit not only from the engineering and technical results, but it may also bolster their efforts to help shape public policy through designing mitigation programs and identifying a community's seismic rehabilitation needs. Another benefit to this group will be in helping to understand the post-earthquake inspection needs in terms of inspectors and the time frame for recovery.

Emergency management personnel will benefit from the use of more accurate building inventories incorporated into their regional earthquake damage and loss estimate projections. Additionally, temporary housing and medical and emergency response facility needs can be better understood once the extent of vulnerable buildings and its impact on the region are estimated and understood.

Building owners, facility managers, financial managers, and risk managers can use the RVS results to better assess ways to reduce financial exposure from the effects of earthquakes on their buildings.

Planners and development professionals can benefit from the use of RVS surveys as they consider land use policies appropriate for existing and new construction.

Lastly, the public will benefit from inventories identifying the vulnerable building stocks in their communities. This is one of the most under-utilized benefits of RVS in that an informed public is perhaps the best advocate for advancing seismic safety in our communities.

5.5.3 RVS Program Types

As noted in the previous section, there are a number of potential audiences that will benefit from a rapid visual screening program. Keeping the goal of the RVS survey in mind will help shape the extent of resources needed.

The RVS program described in this *Handbook* assumes a comprehensive approach to researching and examining the building stock as the primary goal. There are, however, many pieces of information, which may either not be available, or provide contradictory data which will establish the level of credibility of the findings. For instance, the availability of construction drawings adds significant confidence to the identification of the FEMA Building Type in the Data Collection Forms. Also, field confirmation of construction quality can add a valuable component in estimating building vulnerability during an earthquake.

Given that not all the necessary attributes to a "full" RVS survey will be known when the process is started, it may be particularly hard to commit to the quality of the survey until well into the process. This aspect should be tracked by the Program Manager and documented in the final recommendations.

There are, however, steps during the determination of the purpose of the RVS survey and the desired audiences to address that can help shape the extent of investigation needed.

For instance, surveys intended to help shape the development of retrofit ordinances need to be fairly comprehensive since the number of buildings captured and the economic effects of policies will be a significant factor in setting the thresholds and priority criteria in legislation.

For loss estimation purposes, rapid visual screening surveys can sample significant portions of the building stock and extrapolate data to make likely projections of vulnerability within a community.

Lastly, when beginning to look for specific dangerous building types within a community, such as unreinforced masonry or nonductile concrete construction, surveys that capture numbers of instances are often more useful than specific ratings. Results of these surveys are often used as an indication that appropriate seismic mitigation action is necessary.

Some programs may wish to conduct screening programs that are as simple as possible, and may wish to base screening scores solely on the Basic Score associated with each building being screened, or similarly, the Minimum Score. This simplified approach is not recommended and is not expected to provide the RVS Authority with meaningful or accurate data on the seismic hazard of their building stock.

5.5.4 Use of RVS Inventories in Advocating Seismic Safety

Developing mitigation programs generally starts with determining the scope and number of targeted building types. This crucial first step is necessary to develop interest and support for any necessary action a community may desire to reduce their risk.

Inventories can often form the backbone of support for legislation such as improving the performance of public school buildings during earthquakes. Identifying poor and questionable performers often raises significant support for greater accountability for seismic safety in public buildings. RVS is a relatively simple method of identifying the extent of potentially inadequate seismic performance of a large inventory of buildings.

In particular, an electronic database of building information can help with advocating for seismic safety by providing visibility. Information collected during an RVS program can be downloaded into Geographic Information Systems (GIS) and displayed visually in reports or presentations. Use of a program, such as FEMA P-154 ROVER, makes this process easier. These visual depictions are helpful in persuading decision-makers since they put a face on the problems or issues related to poor buildings in our communities.

Inventories can also be made publically available on the web and searchable for specific information. These uses generally require full agreement by the building owners and often are most easily agreed to if they involve public buildings. An example of this is the Oregon *Statewide Seismic Needs Assessment Using Rapid Visual Screening (RVS)* reports, available at http://www.oregongeology.org/sub/projects/rvs/county/county-sites.htm.

5.5.5 Using RVS Results in Advocating for Seismic Safety

Rapid visual screening can be a valuable tool for supporting efforts to raise awareness about building vulnerabilities in communities. Information can be gathered both in advance of seeking support and as the result of wanting to better assess and plan for the needs for mitigation efforts. The following examples illustrate these two approaches.

The findings of the 2010 pilot study conducted by USSC and SEAU surveying school buildings were used in legislative committee hearings to help substantiate the need for a complete survey. As a result, FEMA provided a grant to survey 2,500 additional buildings in the county.

In Oregon, the results of the RVS program directed by DOGAMI in 2005 were later used to create a grant program for local communities to strengthen the most vulnerable schools and emergency facilities as directed through Senate Bill 3.

5.5.6 *Additional FEMA Tools for Supporting Mitigation Programs*

Once an RVS program has helped establish the need for consideration of seismic vulnerabilities in a community, there are a number of additional tools available to promote mitigation efforts.

The Seismic Rehabilitation Cost Estimator (SRCE) provides a simple way to estimate approximate rehabilitation costs by answering a series of questions about the building(s) being evaluated. This can be valuable in determining orders of magnitude costs when discussing the implications of a mitigation program.

When advocating for seismic mitigation programs, actual rehabilitation costs are often stumbling blocks if perceived as single stage expenses. FEMA has developed the *Incremental Seismic Rehabilitation* series of documents to address alternative ways to integrate seismic improvements over extended periods of time by integrating seismic work into regular and planned maintenance and improvement projects.

The SRCE and the *Incremental Seismic Rehabilitation* series of documents are both available from FEMA's website (www.fema.gov/earthquake).

When RVS data include information on numbers of occupants and square footage, FEMA's *HAZUS Advanced Engineering Building Module* (FEMA, 2003) could further help characterize impacts into estimated casualties, as well as structural and nonstructural economic losses. This information greatly helps in translating vulnerability into easily understood potential impacts and can be used to further prioritize additional evaluation and mitigation strategies.

A further step could involve use of FEMA P-58, *Seismic Performance Assessment of Buildings, Volume 1 – The Methodology* (FEMA, 2012d), to evaluate selected buildings that do not meet the cut-off score to provide refined estimates of deaths and injuries, repair and replacement costs, repair time and post-earthquake safety evaluation tagging or placarding status.

Additionally, advocates may consider other resources such as FEMA state earthquake programs that support funding of RVS surveys to determine seismic vulnerability.

5.6 Other Possible Uses of the RVS Procedure

In addition to identifying potentially seismically hazardous buildings needing further evaluation, results from RVS surveys can also be used for other purposes, including: (1) designing seismic hazard mitigation programs for a community (or agency); (2) ranking a community's (or agency's) seismic rehabilitation needs; (3) developing inventories of buildings for use in regional earthquake damage and loss impact assessments; (4) developing inventories of buildings for use in planning post earthquake building safety evaluation efforts; (5) monitoring buildings for the occurrence of earthquakes to improve post-earthquake response (e.g., USGS ShakeCast); and (6) developing building-specific seismic vulnerability information for purposes such as insurance rating, decision making during building ownership transfers, and possible triggering of remodeling requirements during the permitting process.

Following are descriptions of how RVS results could be used for several of these purposes.

5.6.1 Using RVS Scores as a Basis for Hazardous Building Mitigation Programs

Communities need to develop hazard mitigation plans to establish a solid foundation for the detailed seismic evaluation and rehabilitation of buildings. In developing any hazardous buildings mitigation program, the cost effectiveness of the seismic evaluation and rehabilitation work must be determined. The costs should be evaluated against the direct benefits of the seismic rehabilitation program (that is, reduced physical damage, reduced injuries and loss of life). Additionally, secondary benefits to the community should be considered with the direct benefits. These secondary benefits are difficult to quantify in dollars, but must be considered. Secondary benefits are those that apply to the community as a whole. Examples include:

- reduced interruption to business and services;
- reduced potential for secondary damage (for example, fires) that could impact otherwise undamaged structures;
- reduced potential for traffic flow problems around areas of significant damage;
- increased resiliency and reduced recovery times; and
- other reduced economic impacts.

The process of selecting buildings to be retrofitted begins with the determination of the cut-off Final Score, *S*, below which a Detailed Structural Evaluation is required (e.g., by use of the ASCE/SE1 41-13 procedures). Such a determination allows estimates to be made on the costs of additional seismic evaluation and rehabilitation work. From this, the benefits are determined. The most cost-effective solution will be the one where the least amount is spent in direct costs to gain the greatest direct and secondary benefits.

After the RVS Authority establishes the appropriate cut-off score and completes the screening process, it needs to determine the best way to notify building owners of the need for more review of buildings that score less than the cut-off (if the authority is not the owner of the buildings being screened). At the same time, the community needs to develop the appropriate standards (for example, adoption of ASCE/SEI 41-13) to accomplish the goal of the mitigation program. Ultimately, the mitigation program needs to address those buildings that represent the largest potential threat to life safety and the community. Timelines for compliance with the new standards and the mitigation program should be developed on a priority basis, such that the first priority actions relate to those buildings posing the most significant risk, after which those posing a lesser risk are addressed.

Finally, every hazardous building mitigation program will be a compromise of good intentions. The hard decisions regarding whether to mandate compliance, allow for voluntary compliance, or set community goals for future compliance may change as the scope of the risk and effects on the community become apparent.

5.6.2 Using RVS Data in Community Building Inventory Development

Rapid visual screening data can be used to establish building inventories that characterize a community's seismic risk. For example, RVS data could be used to improve the HAZUS characterization of the local inventory, which has a default level based on population, economic factors, and regional trends by importing RVS data for use in the *HAZUS Advanced Engineering Building Module*. Similarly, RVS data could be incorporated directly into a community's GIS, allowing the community to generate electronic and paper maps that reflect the building stock of the community. Electronic color coding of the various types of buildings under the RVS Authority, based on their ultimate vulnerability, allows the community to see at a glance where the vulnerable areas of the community are found. This information can then inform comprehensive pre-earthquake evaluation and mitigation efforts.

5.6.3 Using RVS Data to Plan Postearthquake Building-Safety-Evaluation

In a postearthquake environment, one of the initial response priorities is to determine rapidly the safety of buildings for continued occupancy. The procedure most often used is that represented in the ATC-20-1, *Field Manual: Postearthquake Safety Evaluation of Buildings* (ATC, 2005). This procedure is similar in nature to that of the RVS procedure in that initial rapid evaluations are performed to find those buildings that are obviously unsafe (red placard) and those that have no damage or damage that does not pose a threat to continued occupancy (green placard). All other buildings fall into a condition where occupancy will need to be restricted in some form (yellow placard).

The database developed following the completion of the RVS process in a given community will be valuable in setting the priorities of where safety evaluation will be performed first, after a damaging earthquake. For example, a community could use HAZUS software, in combination with RVS-based inventory information, to determine areas where significant damage may exist for various earthquake scenarios. Similarly, a building department, or large building owner could use RVS data with the USGS ShakeCast software to monitor buildings for the occurrence of earthquakes. When one occurs and affects the buildings in the inventory, ShakeCast (or the special ShakeCast ROVER Edition) can estimate likely ATC-20 tag placard colors, which can help prioritize ATC-20 inspections. Or the community could use an existing GIS containing RVS inventory data and computer-generated maps of strong ground shaking, such as the ShakeMaps developed by the USGS, to estimate the location and distribution of damaged buildings. With such information, community officials would be able to determine those areas where building safety evaluations should be conducted.

Later, the data collected during the postearthquake building safety evaluations could be added to the RVS authority's RVS-based building inventory database. Using GIS, maps can then be prepared showing the damage distribution within the community based on actual building damage.

5.6.4 Resources Needed for the Various Uses of the RVS Procedure

For most applications of the RVS procedure, the resources needed to implement the process are similar, consisting principally of an RVS Program Manager, a Supervising Engineer, a team of screeners, materials to be taken into the field (e.g., the *Handbook* and other items listed in Section 2.10), and accumulated building information. See Chapter 2 for descriptions of the recommended qualifications of the Program Manager, Supervising Engineer, and the screeners. Most applications are assisted by the development and maintenance of a computerized database for recordkeeping and the use of GIS.

A matrix showing recommended resources for various FEMA P-154 RVS applications is provided in Table 5-1.

Table 5-1 Matrix of Recommended Personnel and Material Resources for Various FEMA P-154 RVS Applications

Application	RVS Manager and Supervising Engineer	Trained Screeners	Screening Equipment and Supplies	Accumulated Building Information	Computerized Record Keeping System	GIS
Ranking seismic rehabilitation needs	X			X		
Designing seismic hazard mitigation programs	X			X	X	X
Developing inventories for regional earthquake damage and loss studies	X	X	X	X	X	X
Planning postearthquake building safety evaluation efforts	X	X	X	X	X	X
Developing building specific vulnerability information	X			X		

Chapter 6

Optional Electronic Scoring

6.1 Introduction

The RVS procedure described in Chapter 3 uses a coarse gradation of the seismicity by dividing the country into regions of Low, Moderate, Moderately High, High, and Very High seismicity. In some areas, these coarse gradations may overestimate or underestimate the seismic hazard, which in turn affects the building score. This chapter presents an optional methodology that provides an approach to more accurately assess the seismicity for a site. Electronic scoring methodologies that use smartphones or other electronic devices in the field can also reduce the effort and the error in transferring data from paper forms to a database, as this information can be directly transferred from the device. The Supervising Engineer should consider whether the benefits of implementing an electronic scoring methodology outweigh the cost of resources needed to develop the methodology.

One existing tool for electronic scoring is the FEMA P-154 *Rapid Observation of Vulnerability and Estimation of Risk* (ROVER) software, as discussed in Section 1.8.

6.2 Changes from and Comparisons with the Paper Forms

The major difference in the scores between the paper form and an electronic scoring approach will depend primarily on the difference in seismic hazard at a specific site and the median response values that were used to generate the Basic Scores and Score Modifiers on the paper forms. In some geographic areas, the use of electronic scoring may result in an increase in the building score compared to the values provided on the paper RVS forms for the applicable region of seismicity; in many areas, however, the building score will go down. The use of electronic scoring can make the difference between a building having a Final Score below or above the cut-off score. Example comparisons are provided in Section 6.5.

6.3 Concepts in Electronic Scoring

Chapter 2 defines five seismicity regions: Low, Moderate, Moderately High, High, and Very High. The Basic Scores provided on the forms are based on the median response value of seismicity for each of these five regions. Many sites will have a seismic hazard that is different than one of the median values. For these sites, the difference between the median seismic hazard and the site-specific seismic hazard will probably affect the score for a given building. A building that passes the rapid visual screening under the assumption of the median shaking for the region might not pass when accounting for local seismicity (an overlooked life-safety problem). Or the reverse might be true: the building does not pass the RVS methodology, but it would, if the site-specific hazard was used (an efficiency problem, because now a Detailed Structural Evaluation is required).

The purpose of the electronic scoring methodology is to use site-specific seismic hazard data to produce a refined Basic Score. There are many sources of data available that can be used to develop site-specific information for providing a better estimate of the seismic hazards for a given building, as described in the following sections. The geographically referenced data are generally publically available. A site's geolocation can be estimated as precisely as ten feet with commonly available Global Positioning System (GPS) technology. Site-specific seismic hazards can be accurate within perhaps a few hundred feet, using publically available data from the U.S. Geological Survey (USGS), whereas the location upon which the median hazard is based may be dozens or more miles away. The available site-specific hazard precision is generally not necessary as part of a rapid visual screening, but given the ease with which site-specific soil and hazard can be estimated with an electronic system, it seems unnecessary to add location error to other uncertainties in the scoring system.

Optional electronic scoring is not intended as a substitute for more detailed building evaluations. Electronic scoring is still considered part of a rapid visual screening methodology. As such, the precision of the results should be considered to be only moderately more accurate than scores obtained using the paper-based forms described in Chapter 3. Where large differences occur, it is typically when a site is near the transition from one seismicity region to another and thus the assumption of the median seismicity for the region is less accurate.

Electronic scoring can be implemented using various available technologies and can be utilized as part of pre-field activities, during the field screening, or as part of the post-field activities. Some approaches to implementation are described below in Section 6.4.

6.3.1 Site-Specific Seismicity

As described in Chapter 2, the seismic hazard for the RVS procedure corresponds to the risk-targeted Maximum Considered Earthquake (MCE_R) adjusted to account for site amplification at the boundary of V_S^{30} between NEHRP site classes C and D. Site-specific values of seismic hazard can be obtained based on the location of the site using either the longitude and latitude or the address using tools available from the USGS, e.g., http://earthquake.usgs.gov/designmaps/usapp/.

6.3.2 Soil Type Effects

Soil conditions at a site will affect the seismic shaking at a site. There are various sources of data for determining the soil type at a site, including geotechnical engineering reports. As discussed in Chapter 2, V_S^{30} values can also be used to determine soil type. These values can be obtained from the U.S. Geological Survey web site or by using a site data viewer application distributed by OpenSHA at http://www.opensha.org/apps.

6.4 How to Implement the Optional Electronic Scoring Approach

Electronic scoring can be implemented in a variety of approaches as part of a rapid visual screening program. The method chosen will depend on the availability of labor and technology resources. Any electronic scoring approach should be implemented with the goal of increasing the efficiency of the data collection and improving the accuracy of the results. The approaches can vary from development of tables that can be used before, during, or after the field screening to specialized hardware and software. This document is not intended to provide a detailed description of any specific method for implementing electronic scoring. Instead, general approaches are described and a basic methodology is presented.

A pre-field approach to implementing electronic scoring could involve the development of tables relating the building Basic Scores to seismicity for a given region. The tables would be based on the seismicity of the region included in the RVS program and the range of soil conditions that would be expected. The tables would provide the Basic Scores and Score Modifiers for the site-specific seismicity. Maps or other aids would need to be developed to guide the screeners to use the appropriate Basic Score values from the tables for each building. The Basic Scores and Score Modifiers from the tables would then be used in lieu of the Basic Scores and Score Modifiers on the RVS forms, and the calculation of the Final Score would be made using the same mathematics as in the RVS forms. The calculation could be done manually or with the aid of some form of technology, such as a smartphone, tablet, or laptop computer.

A post-field approach to implementing electronic scoring could involve the use of a database or spreadsheet when compiling the RVS screening results. With this approach, the RVS forms would be filled out in the field using the standard paper forms and then the results would be compiled electronically after the field screening. The database, spreadsheet, or other electronic data file in which the data are compiled could be programmed to determine the site-specific seismicity and soil class for the building based on the longitude and latitude. The Basic Score and Score Modifiers determined using the paper form during the field screening could then be updated using the electronically-calculated score or other means and then the Final Score would be re-calculated.

The implementation of electronic scoring could also be accomplished using a methodology that determines the seismic hazard and soil class while at the site and then calculates a Basic Score, Score Modifiers, and Final Score while at the building. This approach requires the use of an electronic device that has been programmed to perform the necessary calculations and determine the site location using a GPS device or a service that geolocates the building based on its street address. An example of such an approach is FEMA P-154 ROVER (FEMA, 2014). Alternative hardware and software can also be developed to provide similar functionality as needed. As a minimum, the hardware and software needs to be able to locate the site, determine the seismic hazard and soil type based on the site's location, adjust the Basic Score and Score Modifiers for the building based on the site-specific hazards and building height, and sum the applicable Score Modifiers to the Basic Score to produce a Final Score.

6.4.1 General Electronic Scoring Approach

Any approach chosen for electronic scoring should follow the general steps described below.

1. Determine the site-specific risk-targeted Maximum Considered Earthquake (MCE_R) ground motion response acceleration values for S_s (5%-damped, spectral response acceleration parameter at short period) and S_1 (5%-damped spectral response acceleration parameter at a period of 1 second).

2. Use Table 6-1 and Table 6-2 to calculate the site coefficients, F_a and F_v, for the short-period acceleration and the 1-second period acceleration on Soil Type CD.

Table 6-1 Site Coefficient F_a

Mapped Spectral Response Acceleration at Short Period					
Soil Type	$S_S \leq 0.25$	$S_S = 0.5$	$S_S = 0.75$	$S_S = 1.0$	$S_S \geq 1.25$
C	1.2	1.2	1.1	1.0	1.0
CD	1.4	1.3	1.15	1.05	1.0
D	1.6	1.4	1.2	1.1	1.0

Table 6-2 Site Coefficient F_v

Mapped Spectral Response Acceleration at One-Second Period					
Soil Type	$S_1 \leq 0.1$	$S_1 = 0.2$	$S_1 = 0.3$	$S_1 = 0.4$	$S_1 \geq 0.5$
C	1.7	1.6	1.5	1.4	1.3
CD	2.05	1.8	1.65	1.5	1.4
D	2.4	2.0	1.8	1.6	1.5

3. Calculate the MCE_R, 5%-damped spectral response acceleration parameter at short periods adjusted for Soil Type CD, S_{MS}, and the MCE_R, 5%-damped spectral response acceleration parameter at a period of 1 second adjusted for Soil Type CD, S_{M1}, using the following equations.

$$S_{MS} = F_a \times S_s \tag{6-1}$$

$$S_{M1} = F_v \times S_1 \tag{6-2}$$

4. During the field screening, determine if the building is a low-rise (1 to 3 stories), mid-rise (4 to 7 stories), or high-rise (more than 7 stories).

5. Determine Basic Score and Score Modifiers by interpolating (or extrapolating) values of S_{MS} and S_{M1}. Spreadsheet programs and other software can perform the interpolation or extrapolation automatically; see Chapter 9 of FEMA P-155 (FEMA, 2015) for a more detailed discussion.

6. Add the Basic Score determined from Step 5 and the applicable Score Modifiers, including the Soil Type Score Modifiers, obtained during the field screening to calculate the Final Score for the building.

It should be noted that the procedure described above provides a score for the building that includes the Basic Score and the effects of the site-specific soil type.

6.4.2 Refined Electronic Scoring Approach for Soil Types C and D

The foregoing approach is reasonable for all site conditions, but if the user desires additional accuracy for sites whose Soil Type is in the higher half of the range of V_S^{30} for Soil Type C (1850 ft/sec $\leq V_S^{30} <$ 2500 ft/sec) or in the lower half of the range of V_S^{30} for Soil Type D (600 ft/sec $\leq V_S^{30} <$ 900 ft/sec), an alternative approach is offered here.

1. Determine the site-specific risk-targeted Maximum Considered Earthquake (MCE_R) ground motion response acceleration values for S_s (5%-damped, spectral response acceleration parameter at short period) and S_1 (5%-damped spectral response acceleration parameter at a period of 1 second).

2. Use Tables 6-1 and 6-2 to calculate the site coefficients, F_a and F_v, for the short-period acceleration and the one-second period acceleration on Soil Type CD, and for the site's Soil Type, denoted here by F_a^* and F_v^*.

3. Calculate the MCE_R, 5%-damped spectral response acceleration parameter at short periods adjusted for Soil Type CD, S_{MS}, and the MCE_R, 5%-damped spectral response acceleration parameter at a period of 1 second adjusted for Soil Type CD, S_{M1}, using Equations 6-1 and 6-2.

4. Calculate the MCE_R, 5%-damped spectral response acceleration parameter at short periods adjusted for site's Soil Type, S_{MS}^*, and the MCE_R, 5%-damped spectral response acceleration parameter at a period of 1 second adjusted for the site's Soil Type, S_{M1}^*, using the following equations.

$$S_{MS}^* = F_a^* \times S_S \tag{6-3}$$

$$S_{M1}^* = F_v^* \times S_1 \tag{6-4}$$

5. During the field screening, determine if the building is a low-rise (1 to 3 stories), mid-rise (4 to 7 stories), or high-rise (more than 7 stories).

6. For low-rise buildings, determine the Basic Score and Score Modifiers using the value of S_{MS}^* from Equation 6-3 and an interpolation function of Basic Score and Score Modifiers versus S_{MS}. For mid-rise and high-rise buildings, determine the Basic Score and Score Modifiers for the building using the value of S_{M1}^* from Equation 6-4 and a look-up table or interpolation function of Basic Score and Score Modifiers versus S_{M1}.

7. Add the Basic Score determined from Step 6 and the applicable Score Modifiers obtained during the field screening to calculate the Final Score for the building. Because this refined approach is only for sites with V_S^{30}

in the ranges 1850 ft/sec $\leq V_S^{30} <$ 2500 ft/sec (higher-V_S^{30} Soil Type C) or 600 ft/sec $\leq V_S^{30} <$ 900 ft/sec (lower-V_S^{30} Soil Type D), do not apply a Score Modifier for Soil Type.

6.5 Comparisons between Electronic Scoring and Paper-Based Scoring

The use of electronic scoring is expected often to result in higher Final Scores for buildings because of the use of site-specific seismic hazard data. In some cases the use of electronic scoring will result in lower Final Scores, and in some cases the electronic scoring will result in approximately the same Final Score. To demonstrate the possible benefit of using electronic scoring, RVS Final Scores have been calculated for example buildings using both paper forms and the electronic scoring methodology as described above (Table 6-3). The buildings are located at the location of the city hall in selected cities, representing a variety of seismic hazard locations. The examples have assumed that there are no Score Modifiers, such as irregularities, that apply. Each of the example buildings is considered to be low-rise.

Table 6-3 Comparison of Final Scores using Electronic and Paper-Based Scoring for Soil Type CD

Building Type	Seismicity	Location	Paper-Based Final Score	Electronic Final Score
S1	Moderately High	Sacramento, CA	2.3	2.4
S1	High	Memphis, TN	2.3	2.2
S2	Low	Boston, MA	3.9	3.8
S2	Very High	Emeryville, CA	1.4	1.6
C3	High	Memphis, TN	1.4	1.3
C3	Low	Boston, MA	3.5	3.4
RM1	Very High	Emeryville, CA	1.1	1.3
RM1	Moderate	New York, NY	2.1	2.3
URM	Moderate	New York, NY	1.7	2.0
URM	Moderately High	Sacramento, CA	1.2	1.3

Table 6-3 compares the Final Scores computed using both the forms and the electronic scoring methodology for five different building types located in six different cities with Soil Type CD, representing ten different city/building type combinations. The results show that for six of the ten city/building type combinations, the Final Scores increased; for four of the city/building type combinations the scores decreased, and none stayed the same. The differences are due to the difference between the actual seismicity at the cities and the median seismicity for which the Basic Scores were derived and the effects of site conditions.

The results of these examples should not be generalized to all locations. Differences in scores using electronic scoring as compared to the paper-based scoring are dependent on the site-specific seismic hazard values. Prior to implementing electronic scoring, the development of the methodology used should be overseen by the Supervising Engineer. The Supervising Engineer should verify that differences between the paper-based scoring and the electronic scoring are appropriate and rational.

Chapter 7

Example Rapid Visual Screening Programs

7.1 Introduction

Presented in this chapter are two illustrative examples of rapid visual screening programs. In the first scenario, Level 1 screenings are performed in the hypothetical community of Anyplace, USA. In the second scenario, Level 1 and Level 2 screenings are performed on K-12 school buildings in the hypothetical state of Any State, USA. The RVS implementation process (as depicted in Figure 2-1) is described, from development of program scope to selection of the appropriate Data Collection Form, to the screening of individual buildings in the field.

7.2 RVS Program Scenario A: Level 1 Screening in Anyplace, USA

The city council of Anyplace, USA tasked the local building department with conducting an RVS program to identify all buildings in the city, excluding detached single-family and two-family dwellings, that are potentially seismically hazardous and that should be further evaluated by a design professional experienced in seismic design (the principal purpose of the RVS procedure). It was understood that, depending on the results of the RVS program, the city council might adopt future ordinances that establish policy on when, how, and by whom low-scoring buildings should be evaluated and on future seismic rehabilitation requirements. It was desired that the results from the RVS program be incorporated in the city's geographic information system (GIS).

In this scenario, the city council was the RVS Authority. The head of the local building department acted as the Program Manager. An experienced structural engineer from a local firm was selected to serve as the Supervising Engineer. The city council was able to provide a budget of $120,000 for the program.

7.2.1 Step 1: Defining the Scope of the Program

The Program Manager determined there are approximately 1,000 buildings in the city that are not detached single-family or two-family dwellings and that some of the buildings are at least 100 years old. In order to perform screenings of all 1,000 buildings as quickly as possible, and within the given budget, Level 2 screenings were not performed as part of this program. The Program Manager also decided to focus on the downtown sector of Anyplace during the initial phase of the RVS field work, and to expand to the outlying areas later.

The Program Manager tasked the Supervising Engineer with selecting and reviewing the Data Collection Form, determining the code and benchmark years for the city, and performing quality assurance of the completed forms. The Supervising Engineer was tasked with attending the training and being available during the field screening to advise the screeners.

Three building department staff members, as well as 15 architectural and engineering undergraduates from the local university, received FEMA P-154 training and then served as screeners.

The Program Manager explored possible sources of information about the city's buildings and decided to commit resources to extracting data from the city's existing GIS database, permitting files, Sanborn maps, and any available construction drawings. The information gathered from these sources during pre-field data acquisition reduced the amount of field time required and increased the accuracy of the screenings.

An electronic database was created for the RVS program. Pre-field data were entered into the RVS database and then extracted and placed on Data Collection Forms to be used by the screeners in the field. After the field screening, the data collected in the field were entered back into the RVS database. A building department staff member was tasked with creating the database and automating the transfer of the pre-field data onto the Data Collection Forms to be printed and used in the field.

Electronic scoring was not used.

7.2.2 Step 2: Budget and Cost Estimation

Costs to conduct the RVS program were estimated per Table 7-1. The entire process was scheduled to take 6 months.

7.2.3 Step 3: Pre-Field Planning

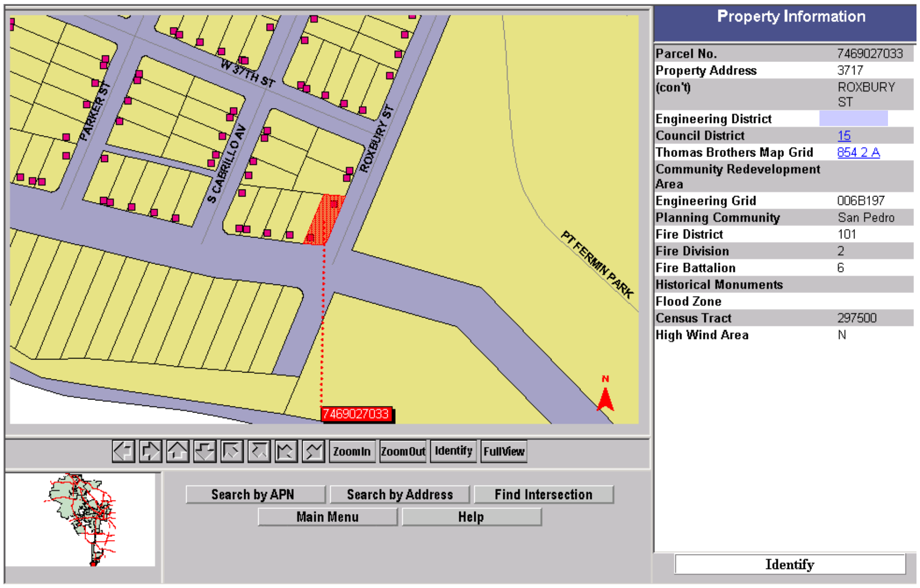
During the pre-field planning process, the Program Manager confirmed that the city's existing GIS was capable of being expanded to include RVS-related information and results. A member of the building department's staff extracted street addresses and parcel numbers for most of the properties in

Table 7-1 RVS Budget for Anyplace, USA

Task	Hours				Cost
Task Description	Program Manager $120/hr	Structural Engineer $150/hr	Staff $60/hr	Screeners (no cost[1])	Task Cost
Select and review Data Collection Form; establish code and benchmark years		40			$6,000
Create RVS database from GIS database; overlay soils and extract soil type for each building			40		$2,400
Review and extract building Information from permitting files (500 buildings x 30 minutes/building)			250		$15,000
Review and extract building information from Sanborn maps (200 buildings x 45 minutes/building)			150		$9,000
Review and extract Building Information from construction documents (100 buildings x 30 minutes/building)			50		$3,000
Create individual Data Collection Forms from the database			40		$2,400
Training (Program Manager, Supervising Engineer, 3 Building Dept. Staff, and 15 student volunteers attend 8 hour training)	8	8	24	120	$3,600
Field Screening (Total of Days 1-8 below)	16	40	160	880	$17,520
Day 1: 5 groups x 6 buildings/group (Project Manager + Struc. Eng. + 3 staff each with 3 student volunteers)	*8*	*8*	*24*	*120*	
Day 2: 5 groups x 6 buildings/group (Project Manager + Struc. Eng. + 3 staff each with 3 student volunteers)	*8*	*8*	*24*	*120*	
Day 3: 18 screeners x 10 buildings/screener = 180 buildings (3 staff + 15 student volunteers)		*4*	*24*	*120*	
Day 4: 18 screeners x 10 buildings/screener = 180 buildings (3 staff + 15 student volunteers)		*4*	*24*	*120*	
Day 5: 18 screeners x 10 buildings/screener = 180 buildings (3 staff + 15 student volunteers)		*4*	*24*	*120*	
Day 6: 18 screeners x 10 buildings/screener = 180 buildings (3 staff + 15 student volunteers)		*4*	*24*	*120*	
Day 7: 11 screeners x 10 buildings/screener = 110 buildings (1 staff + 10 student volunteers)		*4*	*8*	*80*	
Day 8: 11 screeners x 10 buildings/screener = 110 buildings (1 staff + 10 student volunteers)		*4*	*8*	*80*	
Quality assurance on completed forms (250 buildings x 15 minutes/building); quality assurance on compiled data	20	100			$17,400
Enter field data into database + verification (1,000 buildings x 12 minutes/building [2 people, 6 minutes each]); photograph and sketch management (1,000 buildings x 12 minutes/building [once only])			400		$24,000
Subtotal Cost					$100,320
Program Management (10% of subtotal)					$10,032
Total Cost					$110,352

[1] Volunteer student screeners are assumed. Alternatively, if screeners are paid at a rate of $60/hr, the total program cost increases to $176,352.

the city (developed earlier from the tax assessor's files) from the existing GIS and imported them into a standard off-the-shelf electronic database as a table. See Figure 7-1 for a screen capture of GIS display showing parcel number and other available information for an example site.



Property Information

Parcel No.	7469027033
Property Address	3717
(con't)	ROXBURY ST
Engineering District	
Council District	15
Thomas Brothers Map Grid	854 2 A
Community Redevelopment Area	
Engineering Grid	006B197
Planning Community	San Pedro
Fire District	101
Fire Division	2
Fire Battalion	6
Historical Monuments	
Flood Zone	
Census Tract	297500
High Wind Area	N

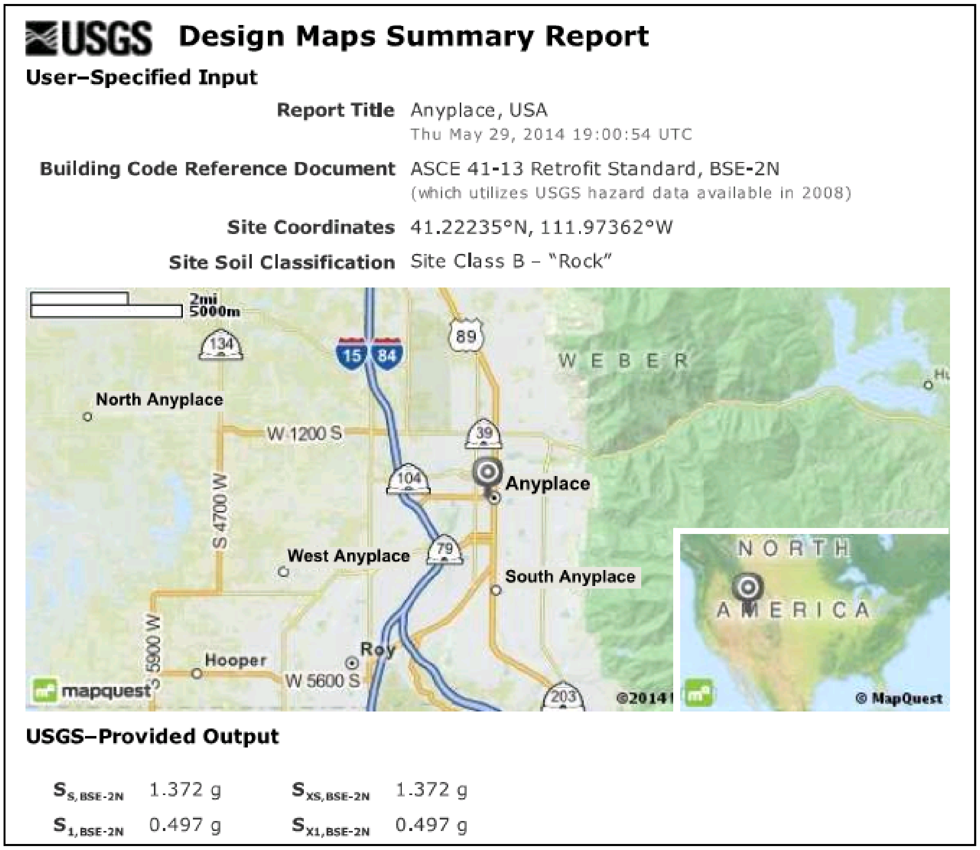
Figure 7-1 Property information at example site in city's geographic information system (FEMA, 2002a).

To facilitate later use in the GIS, the street addresses were subdivided into the following fields: the numeric part of the address; the street prefix (for example, "North"); the street name; and the street suffix (for example, "Drive"). A zip code field was added, zip codes for each street address were obtained using zip code lists available from the U.S. Postal Service, and these data were also added to the database. This process yielded 950 street addresses, with parcel number and zip code, and established the initial information in Anyplace's electronic "Building RVS Database." Additional fields were added to this new database for RVS-related information such as date of construction, number of stories, soil type, FEMA Building Type, and RVS score.

Next, the Supervising Engineer confirmed that sufficient soil information was available from the State Geologist to develop an overlay for the GIS containing soils information for the entire city. The Supervising Engineer concluded that GIS overlays for geologic hazards were not warranted since the city included only isolated pockets of low liquefaction potential, and no areas with landslide or fault rupture potential.

7.2.4 Step 4: Selection and Review of the Data Collection Form

Based on the seismicity maps in Appendix A, Anyplace, USA is located in a High seismicity region. The Supervising Engineer elected to also check the seismicity of the city using Method 2, as described in Section 2.6.1. The longitude and latitude corresponding to the approximate center of the city were entered into the USGS website (http://earthquake.usgs.gov /designmaps/us/application.php). The design code was set to "2013 ASCE 41," the earthquake hazard level was set to "BSE-2N," and the site soil classification was set to "Site Class B - Rock." Spectral acceleration values for 0.2 second, S_S, and 1.0 second, S_1, for BSE-2N (or MCE_R) ground motions were reported as 1.372g and 0.497g, respectively. Figure 7-2 shows the USGS generated summary report for the site.



USGS Design Maps Summary Report

User–Specified Input

Report Title	Anyplace, USA Thu May 29, 2014 19:00:54 UTC
Building Code Reference Document	ASCE 41-13 Retrofit Standard, BSE-2N (which utilizes USGS hazard data available in 2008)
Site Coordinates	41.22235°N, 111.97362°W
Site Soil Classification	Site Class B – "Rock"

USGS–Provided Output

$S_{S,BSE-2N}$	1.372 g	$S_{XS,BSE-2N}$	1.372 g
$S_{1,BSE-2N}$	0.497 g	$S_{X1,BSE-2N}$	0.497 g

Figure 7-2 USGS web page showing S_S and S_1 values for MCE_R ground motions (USGS, 2013a).

These values were compared to the criteria in Table 2-2. It was determined that the ground motions at the city center meet the "High seismicity" criteria for both short-period and long-period motions (that is, 1.372g is greater than 1.000g and less than 1.500g for the 0.2 second [short-period] motions, and 0.497g is greater than 0.400g and less than 0.600g for the 1.0 second [long-period] motions). Further, by reviewing ground motions at other locations across the city, the Supervising Engineer determined that that the entire city is a High seismicity region and that all buildings being surveyed in Anyplace's RVS program should use the Level 1 Data Collection Form for High seismicity.

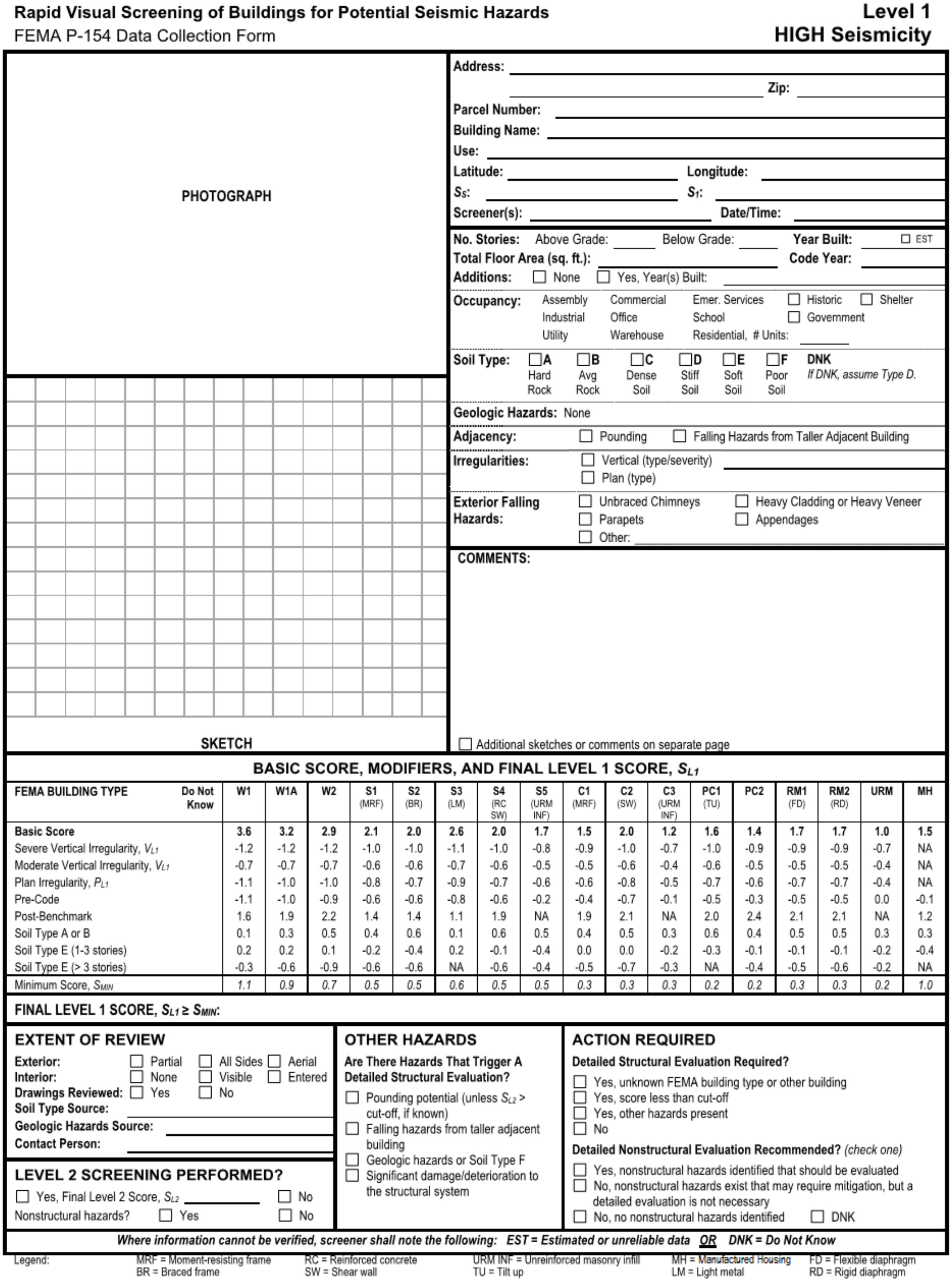
The Program Manager and the Supervising Engineer downloaded the editable versions of the forms from www.atcouncil.org and then reviewed them to determine if any changes to the form should be made for the unique needs of the program. Since each building in the city was to be identified by Parcel Number, they revised the "Other Identifiers" field to "Parcel Number." Since no geologic hazards are present in the city, they decided to replace the list of geologic hazards and "Yes/No/DNK" fields with "None." They determined that the occupancy categories on the form were useful for their purposes and decided not to change them. The values of the Basic Scores and Score Modifiers were not changed. The customized Level 1 Data Collection Form for Anyplace, USA is shown in Figure 7-3.

The Supervising Engineer conferred with the Chief Building Official, the department's plan checkers, and local design professionals to establish key seismic code adoption dates for the various FEMA Building Types and for anchorage of heavy cladding. It was determined that Anyplace has a history of both adopting and enforcing the latest versions of the UBC. The code year was therefore set as 1941 for all FEMA Building Types except PC1, for which the code year was set as 1973, and URM, for which seismic codes were never adopted (after 1933, URMs were no longer permitted to be built). Because Anyplace has been consistently adopting the *Uniform Building Code*, benchmark years for all FEMA Building Types, except URM, were taken from the "UBC" column in Table 2-3. The year in which seismic anchorage requirements for heavy cladding were adopted was determined to be 1967. These findings are presented in Table 7-2.

The Program Manager and the Supervising Engineer decided that 2.0 would be an appropriate cut-off score.

7.2.5 Step 5: Acquisition and Review of Pre-Field Data

Permitting files, which contained data on buildings constructed or remodeled within the last 30 years (including parcel number), were reviewed to obtain information on building name (if available), use, building height (height in feet and number of stories), total floor area, age (year built), and structural system. This process yielded information (from paper file folders) on approximately 500 buildings. Fields were added to Anyplace's Building



Rapid Visual Screening of Buildings for Potential Seismic Hazards
FEMA P-154 Data Collection Form

Level 1
HIGH Seismicity

PHOTOGRAPH

Address: ____________________
____________________ **Zip:** __________
Parcel Number: ____________________
Building Name: ____________________
Use: ____________________
Latitude: __________ **Longitude:** __________
S_S: __________ **S_1:** __________
Screener(s): __________ **Date/Time:** __________

No. Stories: Above Grade: _____ Below Grade: _____ **Year Built:** _____ ☐ EST
Total Floor Area (sq. ft.): __________ **Code Year:** __________
Additions: ☐ None ☐ Yes, Year(s) Built: __________

Occupancy: Assembly Industrial Utility Commercial Office Warehouse Emer. Services School Residential, # Units: _____ ☐ Historic ☐ Government ☐ Shelter

Soil Type: ☐**A** Hard Rock ☐**B** Avg Rock ☐**C** Dense Soil ☐**D** Stiff Soil ☐**E** Soft Soil ☐**F** Poor Soil **DNK** *If DNK, assume Type D.*

Geologic Hazards: None

Adjacency: ☐ Pounding ☐ Falling Hazards from Taller Adjacent Building

Irregularities: ☐ Vertical (type/severity) __________
☐ Plan (type)

Exterior Falling Hazards: ☐ Unbraced Chimneys ☐ Parapets ☐ Other: __________ ☐ Heavy Cladding or Heavy Veneer ☐ Appendages

COMMENTS:

SKETCH

☐ Additional sketches or comments on separate page

BASIC SCORE, MODIFIERS, AND FINAL LEVEL 1 SCORE, S_{L1}

FEMA BUILDING TYPE	**Do Not Know**	**W1**	**W1A**	**W2**	**S1** (MRF)	**S2** (BR)	**S3** (LM)	**S4** (RC SW)	**S5** (URM INF)	**C1** (MRF)	**C2** (SW)	**C3** (URM INF)	**PC1** (TU)	**PC2**	**RM1** (FD)	**RM2** (RD)	**URM**	**MH**
Basic Score		**3.6**	**3.2**	**2.9**	**2.1**	**2.0**	**2.6**	**2.0**	**1.7**	**1.5**	**2.0**	**1.2**	**1.6**	**1.4**	**1.7**	**1.7**	**1.0**	**1.5**
Severe Vertical Irregularity, V_{L1}		-1.2	-1.2	-1.2	-1.0	-1.0	-1.1	-1.0	-0.8	-0.9	-1.0	-0.7	-1.0	-0.9	-0.9	-0.9	-0.7	NA
Moderate Vertical Irregularity, V_{L1}		-0.7	-0.7	-0.7	-0.6	-0.6	-0.7	-0.6	-0.5	-0.5	-0.6	-0.4	-0.6	-0.5	-0.5	-0.5	-0.4	NA
Plan Irregularity, P_{L1}		-1.1	-1.0	-1.0	-0.8	-0.7	-0.9	-0.7	-0.6	-0.6	-0.8	-0.5	-0.7	-0.6	-0.7	-0.7	-0.4	NA
Pre-Code		-1.1	-1.0	-0.9	-0.6	-0.6	-0.8	-0.6	-0.2	-0.4	-0.7	-0.1	-0.5	-0.3	-0.5	-0.5	0.0	-0.1
Post-Benchmark		1.6	1.9	2.2	1.4	1.4	1.1	1.9	NA	1.9	2.1	NA	2.0	2.4	2.1	2.1	NA	1.2
Soil Type A or B		0.1	0.3	0.5	0.4	0.6	0.1	0.6	0.5	0.4	0.5	0.3	0.6	0.4	0.5	0.5	0.3	0.3
Soil Type E (1-3 stories)		0.2	0.2	0.1	-0.2	-0.4	0.2	-0.1	-0.4	0.0	0.0	-0.2	-0.3	-0.1	-0.1	-0.1	-0.2	-0.4
Soil Type E (> 3 stories)		-0.3	-0.6	-0.9	-0.6	-0.6	NA	-0.6	-0.4	-0.5	-0.7	-0.3	NA	-0.4	-0.5	-0.6	-0.2	NA
Minimum Score, S_{MIN}		*1.1*	*0.9*	*0.7*	*0.5*	*0.5*	*0.6*	*0.5*	*0.5*	*0.3*	*0.3*	*0.3*	*0.2*	*0.2*	*0.3*	*0.3*	*0.2*	*1.0*

FINAL LEVEL 1 SCORE, $S_{L1} \geq S_{MIN}$:

EXTENT OF REVIEW

Exterior: ☐ Partial ☐ All Sides ☐ Aerial
Interior: ☐ None ☐ Visible ☐ Entered
Drawings Reviewed: ☐ Yes ☐ No
Soil Type Source: __________
Geologic Hazards Source: __________
Contact Person: __________

LEVEL 2 SCREENING PERFORMED?

☐ Yes, Final Level 2 Score, S_{L2} __________ ☐ No
Nonstructural hazards? ☐ Yes ☐ No

OTHER HAZARDS

Are There Hazards That Trigger A Detailed Structural Evaluation?

☐ Pounding potential (unless S_{L2} > cut-off, if known)
☐ Falling hazards from taller adjacent building
☐ Geologic hazards or Soil Type F
☐ Significant damage/deterioration to the structural system

ACTION REQUIRED

Detailed Structural Evaluation Required?

☐ Yes, unknown FEMA building type or other building
☐ Yes, score less than cut-off
☐ Yes, other hazards present
☐ No

Detailed Nonstructural Evaluation Recommended? *(check one)*

☐ Yes, nonstructural hazards identified that should be evaluated
☐ No, nonstructural hazards exist that may require mitigation, but a detailed evaluation is not necessary
☐ No, no nonstructural hazards identified ☐ DNK

Where information cannot be verified, screener shall note the following: EST = Estimated or unreliable data <u>OR</u> DNK = Do Not Know

Legend:
MRF = Moment-resisting frame
BR = Braced frame
RC = Reinforced concrete
SW = Shear wall
URM INF = Unreinforced masonry infill
TU = Tilt up
MH = Manufactured Housing
LM = Light metal
FD = Flexible diaphragm
RD = Rigid diaphragm

Figure 7-3 Customized Level 1 Data Collection Form for Anyplace, USA.

Table 7-2 Customized Quick Reference Guide for Anyplace, USA

FEMA Building Type		Year Seismic Codes Initially Adopted and Enforced	Benchmark Year when Codes Improved
W1	Light wood frame single- or multiple-family dwellings	*1941*	*1976*
W1A	Light wood frame multi-unit, multi-story residential buildings with plan areas on each floor of greater than 3,000 sqft	*1941*	*1997*
W2	Wood frame commercial and industrial buildings > 5,000 sqft	*1941*	*1976*
S1	Steel moment-resisting frame	*1941*	*1994*
S2	Braced steel frame	*1941*	*1997*
S3	Light metal frame	*1941*	*None*
S4	Steel frame with cast-in-place concrete shear walls	*1941*	*1994*
S5	Steel frame with unreinforced masonry infill walls	*1941*	*None*
C1	Concrete moment-resisting frame	*1941*	*1994*
C2	Concrete shear wall	*1941*	*1994*
C3	Concrete frame with unreinforced masonry infill walls	*1941*	*None*
PC1	Tilt-up construction	*1973*	*1997*
PC2	Precast concrete frame	*1941*	*None*
RM1	Reinforced masonry with flexible floor and roof diaphragms	*1941*	*1997*
RM2	Reinforced masonry with rigid floor and roof diaphragms	*1941*	*1994*
URM	Unreinforced masonry bearing-wall buildings	*None*	*None*
MH	Manufactured housing	*1941*	*None*
Anchorage of Heavy Cladding Year in which seismic anchorage requirements were adopted:		*1967*	

RVS Database for each of these attributes, and data were added to the appropriate records (based on parcel number) in the database; in the case of structure type, the entry included an asterisk to denote uncertainty. If an address was missing in the database, a new record containing that address and related data was added. On average, 30 minutes per building were required to extract the correct information from the permitting files and insert it into the electronic database.

The city's librarian provided copies of available Sanborn maps, which were reviewed to identify information on number of stories, year built, building size (square footage), building use, and limited information on structural type for approximately 200 buildings built prior to 1960. These data were added to the appropriate record (based on address) in the Building RVS Database; in the case of structure type, the entry included an asterisk to denote uncertainty. If an address was missing in the database, a new record containing that address and related data was added. For this effort, 45 minutes per building, on average, were required to extract the correct information from the Sanborn maps and insert it into the electronic database.

During the pre-field data collection and review process, the Program Manager also obtained an electronic file of soils data (characterized in terms of the soil types described in Section 2.8.6) from the State Geologist and created an overlay of this information in the city's GIS system. Points defined by the addresses in the GIS reference tables (including newly identified addresses added to the references tables as a result of the above-cited efforts) were combined with the soils type overlay, and soil type was then assigned to each point (address) by a standard GIS operating procedure. The soil type information for each address was then transferred back to the database table as a new field for each building's soil type.

Based on the above efforts, Anyplace's Building RVS Database was expanded to include approximately 1,000 records with address, parcel number, zip code, and soils information, and approximately 700 of these records also contained information on building name (if any), use, number of stories, total floor area, year built, and structure type.

7.2.6 Step 6: Review of Construction Documents

Fortuitously, the city had retained many of the microfilm or pdf copies of building construction documents submitted with each permit filing during the last 30 years. Copies of these construction documents were available for 100 buildings. Building department plans examiners reviewed these documents to verify, or identify, the FEMA Building Type for each building. Any new or revised information on structure type derived as part of this process was then inserted in the Building RVS Database, in which case previously existing information in this field, along with the associated asterisk denoting uncertainty, was removed. On average, this effort required approximately 30 minutes per plan set, including database corrections.

7.2.7 Step 7: Training for Screeners

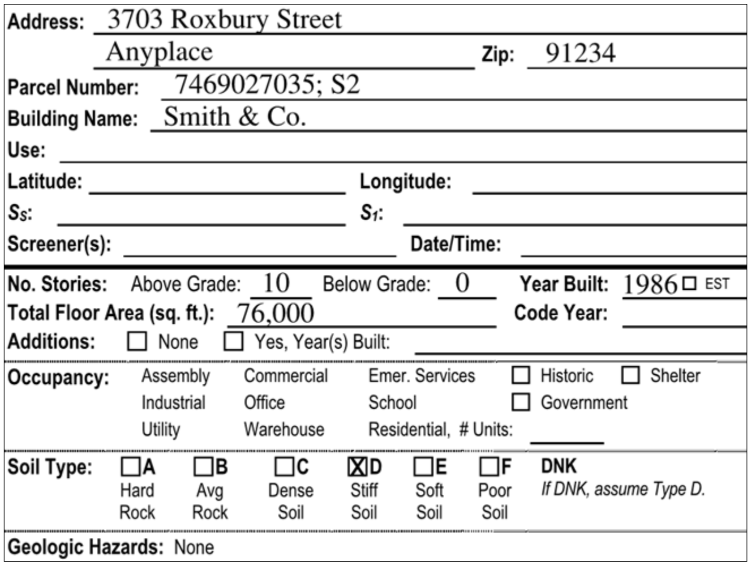
The screeners for the RVS program included staff from the building department and architectural and engineering students from the local university. All of these screeners underwent training obtained through FEMA's National Earthquake Technical Assistance Program (NETAP). The Program Manager and the Supervising Engineer attended the training as well.

The training was conducted in a classroom setting and consisted of the following: (1) discussions of FEMA Building Types and how they behave when subjected to seismic loads; (2) how to use the Level 1 Data Collection

Form and the Reference Guides; (3) a review of the Basic Scores and Score Modifiers; (4) how to identify building irregularities; (5) what to look for in the field; (6) how to account for uncertainty; and (7) an exercise in which screeners were shown interior and exterior photographs of buildings and asked to identify the FEMA Building Type and vertical and plan irregularities. The training class also included focused group interaction sessions, principally in relation to the identification of structural systems and irregularities using exterior and interior photographs. Screeners were also instructed on items to take into the field.

7.2.8 Step 8: Field Screening of Buildings

Prior to field screening, a staff member at the building department created an individual Data Collection Form for each record in the Building RVS Database. All 1,000 Data Collection Forms had street address, parcel number, zip code, and soil type information. Approximately 700 of the 1,000 forms had additional, but not necessarily verified, information, such as date of construction and number of stories (see Figure 7-4).



Address: 3703 Roxbury Street
Anyplace **Zip:** 91234
Parcel Number: 7469027035; S2
Building Name: Smith & Co.
Use:
Latitude: **Longitude:**
S_S: **S_1:**
Screener(s): **Date/Time:**

No. Stories: Above Grade: 10 Below Grade: 0 **Year Built:** 1986 ☐ EST
Total Floor Area (sq. ft.): 76,000 **Code Year:**
Additions: ☐ None ☐ Yes, Year(s) Built:

Occupancy: Assembly Commercial Emer. Services ☐ Historic ☐ Shelter
Industrial Office School ☐ Government
Utility Warehouse Residential, # Units:

Soil Type: ☐**A** Hard Rock ☐**B** Avg Rock ☐**C** Dense Soil ☒**D** Stiff Soil ☐**E** Soft Soil ☐**F** Poor Soil **DNK** *If DNK, assume Type D.*

Geologic Hazards: None

Figure 7-4 Partially completed Building Identification portion of the Data Collection Form for a sample site for use by the screener.

In those instances where the FEMA Building Type was included in the database, this information was noted next to the parcel number, with an asterisk if still uncertain.

Where drawings were reviewed, the drawings reviewed "Yes" box was checked. Soil Type and Geologic Hazards sources were noted as State Geologist.

Field screening of all 1,000 buildings was scheduled to occur over the course of eight (nonconsecutive) days. For the first two days, fifteen student volunteer screeners worked in five teams, each led by the Program Manager, the Supervising Engineer, or one of the three building department staff members. Each of these five team leaders was experienced in identifying the FEMA Building Type and was able to provide oversight and additional training of the student volunteers during these first days. For the following six days, the screeners worked individually. The Supervising Engineer remained available throughout the field screening to advise and consult.

The Data Collection Forms, including blank forms for use with buildings not yet in the Building RVS Database, were distributed to the RVS screeners along with their RVS assignments (on a block-by-block basis). Screeners were advised that the information printed on the form from the database should be verified in the field, particularly items denoted with an asterisk.

Prior to field work, each screener was reminded to complete the Data Collection Form at each site before moving on to the next site, including adding his or her name as the screener and the screening date (in the building identification section of the form).

Following are several examples illustrating rapid visual screening in the field and completion of the Data Collection Form. Some examples use forms containing relatively complete building identification information, including FEMA Building Type, obtained during the pre-field data acquisition and review process; others use forms containing less complete building identification information; and still others use blank forms completely filled in at the site.

7.2.8.1 Example 1: 3703 Roxbury Street

Upon arriving at the site, the screener observed the building as a whole (Figure 7-5) and began the process of verifying the information in the building identification portion of the form (upper right corner), starting with the street address. The screener added her name and the date and time of the field screening to the building identification portion of the form.

The FEMA Building Type (S2, steel braced frame) was verified by looking at the building with binoculars (see Figure 7-6). The number of stories (10) was confirmed by inspection, and the year built noted on the form (1986) appeared appropriate. The base dimensions of the building were estimated by pacing off the distance along each face, assuming 3 feet per stride, resulting in the determination that it was 75 feet by 100 feet in plan. On this basis, the listed square footage of 76,000 square feet was verified as correct. No additions to the building were observed.

Figure 7-5 Exterior view of 3703 Roxbury Street.

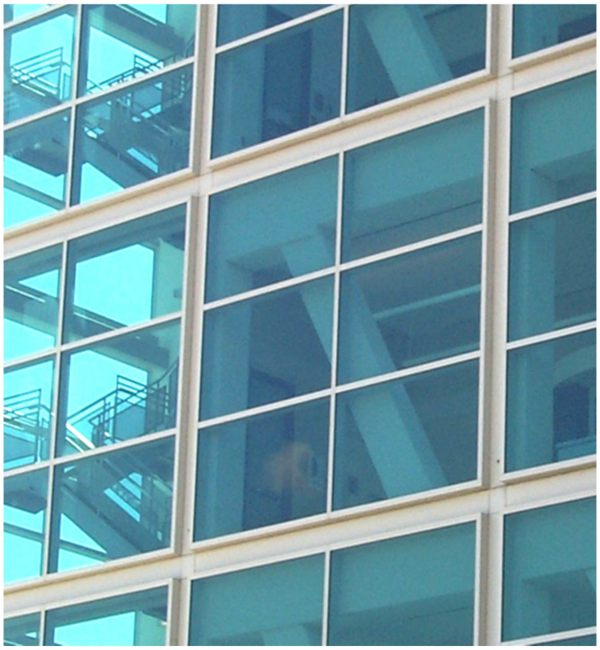


Figure 7-6 Close-up view of 3703 Roxbury Street exterior showing perimeter braced steel framing.

Sketches of the plan and elevation views of the building were drawn in the "Sketch" portion of the form. Several digital photographs were taken of the building, to be added to the form later.

The building use (office) was circled in the "Occupancy" portion of the form.

No adjacent buildings were observed.

The next step for the screener was to identify any vertical or plan irregularities. The screener consulted the Vertical and Plan Irregularity Reference Guides and found that none of the listed irregularities applied to the building being screened.

No falling hazards were observed, as glass cladding is not considered as heavy cladding.

The next step in the process was to circle the appropriate Basic Score and the appropriate Score Modifiers. Having verified the FEMA Building Type as S2, the screener circled "S2" on the form along with the Basic Score beneath it. No irregularities were observed, so none of the irregularity modifiers was circled. The screener checked the Quick Reference Guide and found that the building did not qualify for the Post-Benchmark modifier. Since the building is on Soil Type D, no soil modifiers were applied. The Final Level 1 Score, S_{L1}, was determined to be 2.0.

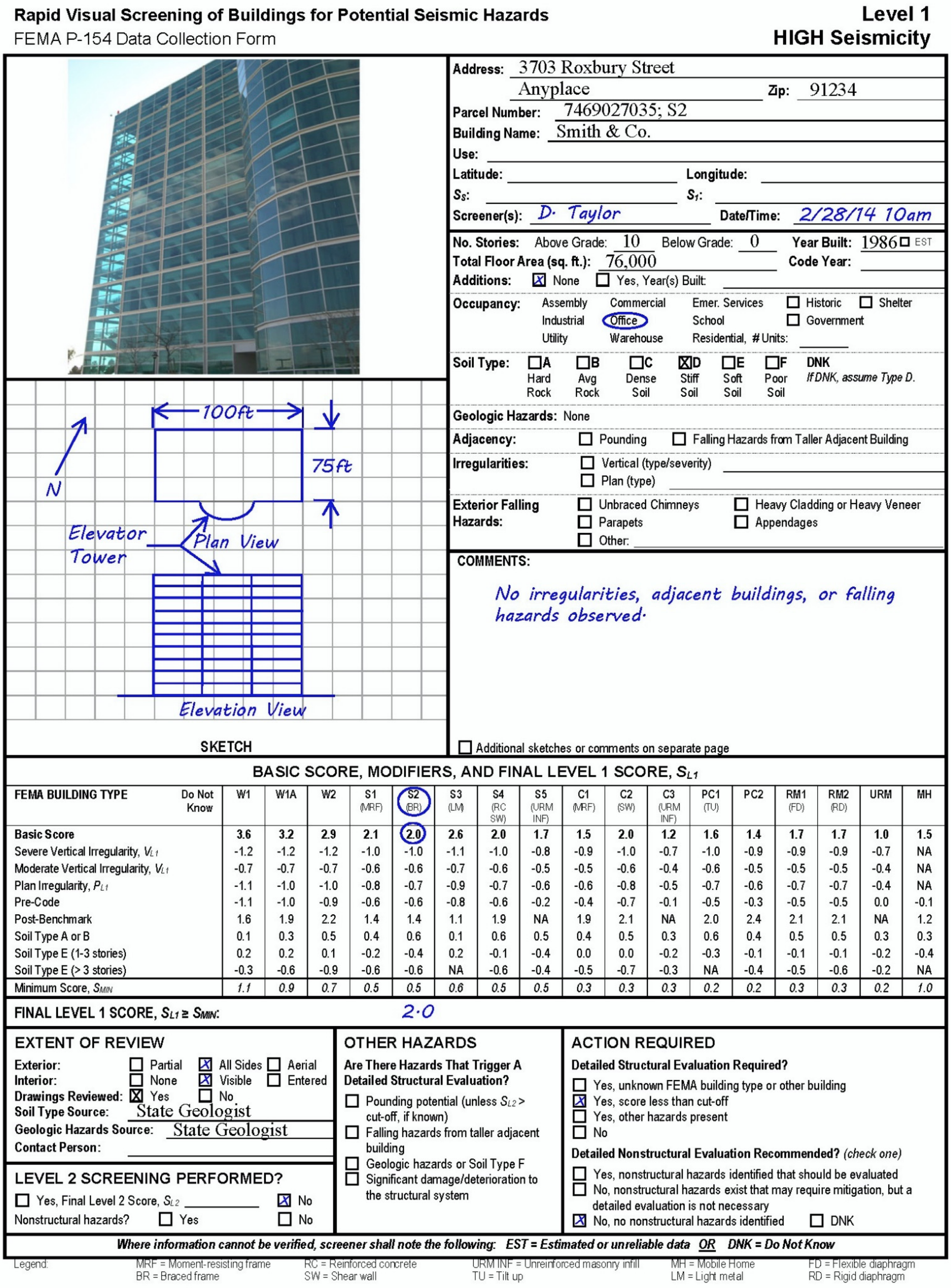
The screener completed the Extent of Review portion of the form, indicating that she viewed the exterior of the building from all sides, but was not able to enter the building to inspect the interior. The soil type source and geologic hazards source were entered during the pre-field phase.

The screener noted that no Level 2 screening was performed. She then reviewed the Other Hazards portion of the form and did not identify any other hazards that might trigger a detailed evaluation. Because this score was equal to the cut-off score of 2.0, the screener checked the "Yes" box in the Detailed Structural Evaluation Required field and "No" in the Detailed Nonstructural Evaluation Required field as no nonstructural hazards were identified.

Figure 7-7 shows the completed form for 3703 Roxbury, including the photograph that was added digitally at a later date.

7.2.8.2 Example 2: 3711 Roxbury Street

Upon arrival at the site, the screener observed the building as a whole (Figure 7-8). Unlike Example 1, there was little information in the building



Rapid Visual Screening of Buildings for Potential Seismic Hazards **Level 1**
FEMA P-154 Data Collection Form **HIGH Seismicity**

Address: 3703 Roxbury Street
Anyplace **Zip:** 91234
Parcel Number: 7469027035; S2
Building Name: Smith & Co.
Use:
Latitude: **Longitude:**
S_S: **S_1:**
Screener(s): D. Taylor **Date/Time:** 2/28/14 10am

No. Stories: Above Grade: 10 Below Grade: 0 **Year Built:** 1986 ☐ EST
Total Floor Area (sq. ft.): 76,000 **Code Year:**
Additions: ☒ None ☐ Yes, Year(s) Built:

Occupancy: Assembly Commercial Emer. Services ☐ Historic ☐ Shelter
Industrial [✓ Office] School ☐ Government
Utility Warehouse Residential, # Units:

Soil Type: ☐ **A** Hard Rock ☐ **B** Avg Rock ☐ **C** Dense Soil ☒ **D** Stiff Soil ☐ **E** Soft Soil ☐ **F** Poor Soil **DNK** *If DNK, assume Type D.*

Geologic Hazards: None

Adjacency: ☐ Pounding ☐ Falling Hazards from Taller Adjacent Building

Irregularities: ☐ Vertical (type/severity)
☐ Plan (type)

Exterior Falling Hazards: ☐ Unbraced Chimneys ☐ Heavy Cladding or Heavy Veneer
☐ Parapets ☐ Appendages
☐ Other:

COMMENTS:

No irregularities, adjacent buildings, or falling hazards observed.

☐ Additional sketches or comments on separate page

SKETCH

BASIC SCORE, MODIFIERS, AND FINAL LEVEL 1 SCORE, S_{L1}

FEMA BUILDING TYPE	Do Not Know	W1	W1A	W2	S1 (MRF)	[✓ S2 (BR)]	S3 (LM)	S4 (RC SW)	S5 (URM INF)	C1 (MRF)	C2 (SW)	C3 (URM INF)	PC1 (TU)	PC2	RM1 (FD)	RM2 (RD)	URM	MH
Basic Score		**3.6**	**3.2**	**2.9**	**2.1**	[✓ **2.0**]	**2.6**	**2.0**	**1.7**	**1.5**	**2.0**	**1.2**	**1.6**	**1.4**	**1.7**	**1.7**	**1.0**	**1.5**
Severe Vertical Irregularity, V_{L1}		-1.2	-1.2	-1.2	-1.0	-1.0	-1.1	-1.0	-0.8	-0.9	-1.0	-0.7	-1.0	-0.9	-0.9	-0.9	-0.7	NA
Moderate Vertical Irregularity, V_{L1}		-0.7	-0.7	-0.7	-0.6	-0.6	-0.7	-0.6	-0.5	-0.5	-0.6	-0.4	-0.6	-0.5	-0.5	-0.5	-0.4	NA
Plan Irregularity, P_{L1}		-1.1	-1.0	-1.0	-0.8	-0.7	-0.9	-0.7	-0.6	-0.6	-0.8	-0.5	-0.7	-0.6	-0.7	-0.7	-0.4	NA
Pre-Code		-1.1	-1.0	-0.9	-0.6	-0.6	-0.8	-0.6	-0.2	-0.4	-0.7	-0.1	-0.5	-0.3	-0.5	-0.5	0.0	-0.1
Post-Benchmark		1.6	1.9	2.2	1.4	1.4	1.1	1.9	NA	1.9	2.1	NA	2.0	2.4	2.1	2.1	NA	1.2
Soil Type A or B		0.1	0.3	0.5	0.4	0.6	0.1	0.6	0.5	0.4	0.5	0.3	0.6	0.4	0.5	0.5	0.3	0.3
Soil Type E (1-3 stories)		0.2	0.2	0.1	-0.2	-0.4	0.2	-0.1	-0.4	0.0	0.0	-0.2	-0.3	-0.1	-0.1	-0.1	-0.2	-0.4
Soil Type E (> 3 stories)		-0.3	-0.6	-0.9	-0.6	-0.6	NA	-0.6	-0.4	-0.5	-0.7	-0.3	NA	-0.4	-0.5	-0.6	-0.2	NA
Minimum Score, S_{MIN}		*1.1*	*0.9*	*0.7*	*0.5*	*0.5*	*0.6*	*0.5*	*0.5*	*0.3*	*0.3*	*0.3*	*0.2*	*0.2*	*0.3*	*0.3*	*0.2*	*1.0*

FINAL LEVEL 1 SCORE, $S_{L1} \geq S_{MIN}$: 2.0

EXTENT OF REVIEW

Exterior: ☐ Partial ☒ All Sides ☐ Aerial
Interior: ☐ None ☒ Visible ☐ Entered
Drawings Reviewed: ☒ Yes ☐ No
Soil Type Source: State Geologist
Geologic Hazards Source: State Geologist
Contact Person:

LEVEL 2 SCREENING PERFORMED?

☐ Yes, Final Level 2 Score, S_{L2} ☒ No
Nonstructural hazards? ☐ Yes ☐ No

OTHER HAZARDS

Are There Hazards That Trigger A Detailed Structural Evaluation?

☐ Pounding potential (unless S_{L2} > cut-off, if known)
☐ Falling hazards from taller adjacent building
☐ Geologic hazards or Soil Type F
☐ Significant damage/deterioration to the structural system

ACTION REQUIRED

Detailed Structural Evaluation Required?

☐ Yes, unknown FEMA building type or other building
☒ Yes, score less than cut-off
☐ Yes, other hazards present
☐ No

Detailed Nonstructural Evaluation Recommended? *(check one)*

☐ Yes, nonstructural hazards identified that should be evaluated
☐ No, nonstructural hazards exist that may require mitigation, but a detailed evaluation is not necessary
☒ No, no nonstructural hazards identified ☐ DNK

Where information cannot be verified, screener shall note the following: EST = Estimated or unreliable data OR DNK = Do Not Know

Legend:	MRF = Moment-resisting frame	RC = Reinforced concrete	URM INF = Unreinforced masonry infill	MH = Mobile Home	FD = Flexible diaphragm
	BR = Braced frame	SW = Shear wall	TU = Tilt up	LM = Light metal	RD = Rigid diaphragm

Figure 7-7 Completed Data Collection Form for Example 1, 3703 Roxbury Street.

Figure 7-8 Exterior view of 3711 Roxbury Street.

identification portion of the form (only street address, zip code, parcel number and soil type were provided). The screener determined the number of stories to be 12and the building use to be commercial and office. He paced off the building plan dimensions and estimated the plan size as 58 feet by 50 feet. Based on this information, the total square footage was estimated to be 34,800 square feet (12 stories by 50 feet by 58 feet), and the number of stories, use, and square footage were written on the form. Based on a review of information in Appendix D of this *Handbook*, the construction era was estimated to be in the 1940s. The screener wrote in the year of construction as 1945 and checked the "EST" box to note that the date was estimated. The screener circled both "Office" and "Commercial" to indicate the observed occupancies.

The screener noted that an adjacent 11-story building was separated from the building being screened by only 12 inches. The screener determined the minimum separation gap for pounding per the Level 1 Pounding Guide (1 1/2 inches per story for 11 stories equals 16.5 inches) and found that the actual separation was less than the minimum. In addition, the building being screened was at the end of the block. Based on these two conditions, the screener checked the "Pounding" box in the Adjacency section of the form.

The screener consulted the Vertical and Plan Irregularity Reference Guides and determined that the four individual towers extending above the base represented an out-of-plane offset. The screener noted this severe vertical irregularity,

Sketches of the plan and elevation views of the building were drawn in the "Sketch" portion of the form. The cornices at roof level were observed, and entered on the form.

Noting that it was a 12-story building, a review of the material in Table D-6 (Appendix D), indicated that the likely options for FEMA Building Type were S1, S2, S5, C1, C2, or C3. On more careful examination of the building exterior with the use of binoculars (see Figure 7-9), it was determined the building was Type C3, concrete frame with unreinforced masonry infill, and this alpha-numeric code, and accompanying Basic Score, were circled on the Data Collection Form.

Figure 7-9 Close-up view of 3711 Roxbury Street building showing exterior infill frame construction.

Because the four individual towers extending above the base represented a vertical irregularity, this modifier was circled. The screener checked the Quick Reference Guide and compared the estimated date of construction to the pre-code year for FEMA Building Type C3. Since 1945 was after the pre-code year of 1941, the screener did not circle the pre-code modifier.

Noting that the soil is Type E, as determined during the pre-field data acquisition phase, and that the number of stories was 12, the modifier for Soil Type E (> 3 stories) was circled. The total of the Basic Score plus applicable Score Modifiers was 1.2 - 0.7 - 0.3 = 0.2. Noting that this is less than the minimum score, S_{MIN} = 0.3, the screener indicated that the Final Level 1 Score, S_{L1}, was 0.3.

Under Extent of Review, the screener noted that he was not able to view all sides of the building by checking the "Partial" box under Exterior. He indicated that he was not able to view the interior of the building by checking "None" under Interior.

Under Other Hazards, he noted that pounding potential of the building with its neighbor triggers a Detailed Structural Evaluation.

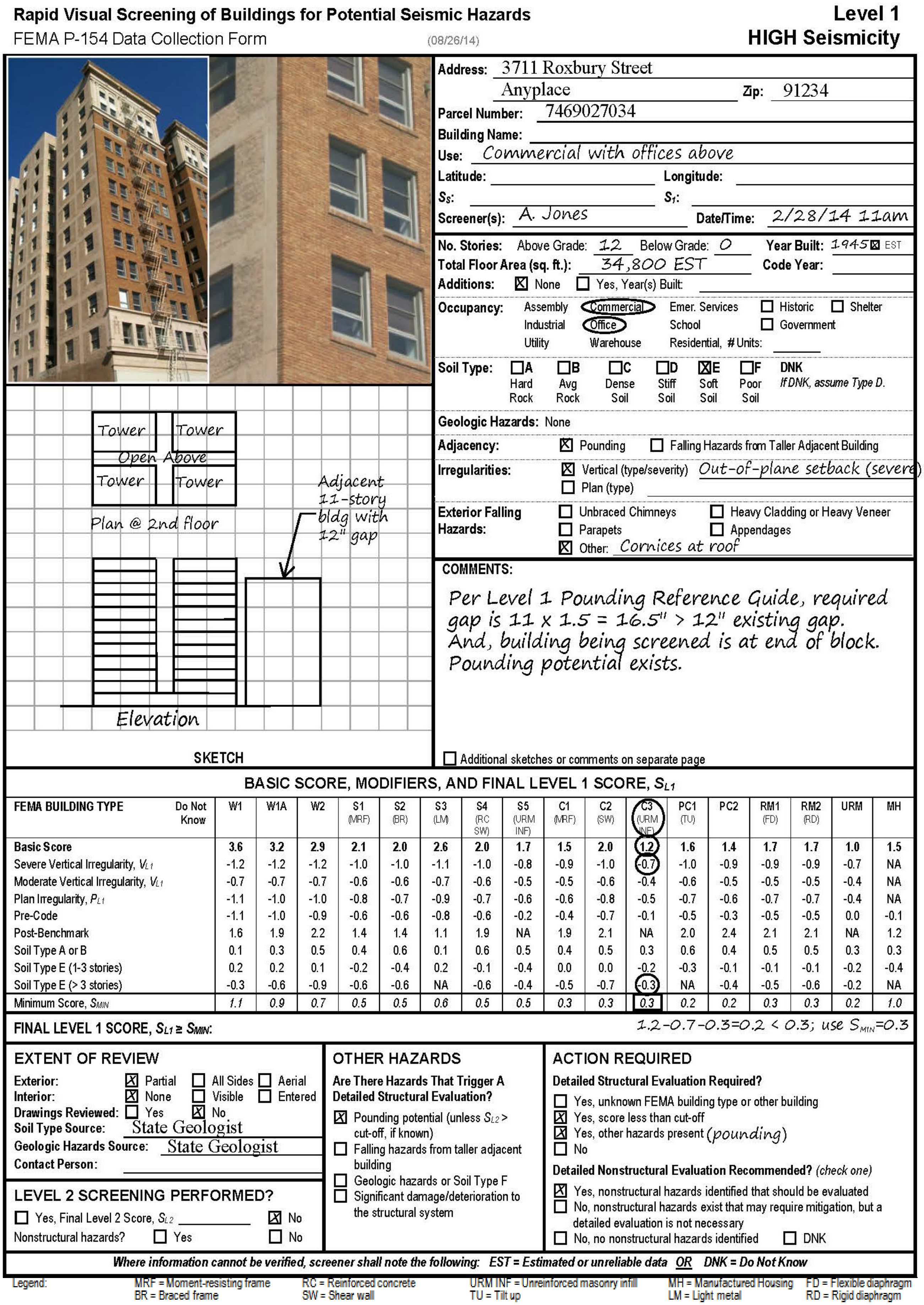
Because the building's Final Score was less than the cut-off score of 2.0, and because of the other hazards present (pounding), the building required a Detailed Structural Evaluation by an experienced seismic design professional. Because of the cornices, the building required a Detailed Nonstructural Evaluation. A completed version of the form, including photographs attached at a later date, is provided in Figure 7-10.

7.2.8.3 Example 3: 5020 Ebony Drive

Example 3 was a high-rise residential building (Figure 7-11) in a new part of the city in which new development had begun within the last few years. The building was not included in the electronic Building RVS Database; consequently, there was not a partially prepared Data Collection Form for this building. The screeners wrote the address of the building on a blank form along with their names and date and time of the screening.

Based on visual inspection, the screeners determined that the building had 22 stories above grade, including a tall occupied penthouse story, and 2 additional stories of parking below grade. They determined that it had no additions, estimated that it was designed after 2000, and concluded that its use was both commercial (in the first story) and residential in the upper stories. The screeners paced off the building plan dimensions to estimate the plan size to be approximately 270 feet by 180 feet. Based on this information and considering the symmetric but non-rectangular floor plan, the total square footage was estimated to be 712,800 square feet. The building uses (Commercial and Residential) were circled in the "Occupancy" portion.

The screeners photographed the building and drew a sketch of a portion of



Rapid Visual Screening of Buildings for Potential Seismic Hazards
FEMA P-154 Data Collection Form (08/26/14)

Level 1
HIGH Seismicity

Address: 3711 Roxbury Street
Anyplace **Zip:** 91234
Parcel Number: 7469027034
Building Name:
Use: Commercial with offices above
Latitude: **Longitude:**
S_S: **S_1:**
Screener(s): A. Jones **Date/Time:** 2/28/14 11am

No. Stories: Above Grade: 12 Below Grade: 0 **Year Built:** 1945 ☒ EST
Total Floor Area (sq. ft.): 34,800 EST **Code Year:**
Additions: ☒ None ☐ Yes, Year(s) Built:

Occupancy: Assembly [✓ Commercial] Emer. Services ☐ Historic ☐ Shelter
Industrial [✓ Office] School ☐ Government
Utility Warehouse Residential, # Units:

Soil Type: ☐ **A** Hard Rock ☐ **B** Avg Rock ☐ **C** Dense Soil ☐ **D** Stiff Soil ☒ **E** Soft Soil ☐ **F** Poor Soil **DNK** *If DNK, assume Type D.*

Geologic Hazards: None

Adjacency: ☒ Pounding ☐ Falling Hazards from Taller Adjacent Building

Irregularities: ☒ Vertical (type/severity) Out-of-plane setback (severe)
☐ Plan (type)

Exterior Falling Hazards: ☐ Unbraced Chimneys ☐ Heavy Cladding or Heavy Veneer
☐ Parapets ☐ Appendages
☒ Other: Cornices at roof

COMMENTS:

Per Level 1 Pounding Reference Guide, required gap is 11 x 1.5 = 16.5" > 12" existing gap. And, building being screened is at end of block. Pounding potential exists.

☐ Additional sketches or comments on separate page

Tower
Tower
Open Above
Tower
Tower
Plan @ 2nd floor

Adjacent 11-story bldg with 12" gap

Elevation

SKETCH

BASIC SCORE, MODIFIERS, AND FINAL LEVEL 1 SCORE, S_{L1}

FEMA BUILDING TYPE	Do Not Know	W1	W1A	W2	S1 (MRF)	S2 (BR)	S3 (LM)	S4 (RC SW)	S5 (URM INF)	C1 (MRF)	C2 (SW)	[✓ C3 (URM INF)]	PC1 (TU)	PC2	RM1 (FD)	RM2 (RD)	URM	MH
Basic Score		**3.6**	**3.2**	**2.9**	**2.1**	**2.0**	**2.6**	**2.0**	**1.7**	**1.5**	**2.0**	[✓ **1.2**]	**1.6**	**1.4**	**1.7**	**1.7**	**1.0**	**1.5**
Severe Vertical Irregularity, V_{L1}		-1.2	-1.2	-1.2	-1.0	-1.0	-1.1	-1.0	-0.8	-0.9	-1.0	[✓ -0.7]	-1.0	-0.9	-0.9	-0.9	-0.7	NA
Moderate Vertical Irregularity, V_{L1}		-0.7	-0.7	-0.7	-0.6	-0.6	-0.7	-0.6	-0.5	-0.5	-0.6	-0.4	-0.6	-0.5	-0.5	-0.5	-0.4	NA
Plan Irregularity, P_{L1}		-1.1	-1.0	-1.0	-0.8	-0.7	-0.9	-0.7	-0.6	-0.6	-0.8	-0.5	-0.7	-0.6	-0.7	-0.7	-0.4	NA
Pre-Code		-1.1	-1.0	-0.9	-0.6	-0.6	-0.8	-0.6	-0.2	-0.4	-0.7	-0.1	-0.5	-0.3	-0.5	-0.5	0.0	-0.1
Post-Benchmark		1.6	1.9	2.2	1.4	1.4	1.1	1.9	NA	1.9	2.1	NA	2.0	2.4	2.1	2.1	NA	1.2
Soil Type A or B		0.1	0.3	0.5	0.4	0.6	0.1	0.6	0.5	0.4	0.5	0.3	0.6	0.4	0.5	0.5	0.3	0.3
Soil Type E (1-3 stories)		0.2	0.2	0.1	-0.2	-0.4	0.2	-0.1	-0.4	0.0	0.0	-0.2	-0.3	-0.1	-0.1	-0.1	-0.2	-0.4
Soil Type E (> 3 stories)		-0.3	-0.6	-0.9	-0.6	-0.6	NA	-0.6	-0.4	-0.5	-0.7	[✓ -0.3]	NA	-0.4	-0.5	-0.6	-0.2	NA
Minimum Score, S_{MIN}		*1.1*	*0.9*	*0.7*	*0.5*	*0.5*	*0.6*	*0.5*	*0.5*	*0.3*	*0.3*	[✓ *0.3*]	*0.2*	*0.2*	*0.3*	*0.3*	*0.2*	*1.0*

FINAL LEVEL 1 SCORE, $S_{L1} \geq S_{MIN}$: 1.2-0.7-0.3=0.2 < 0.3; use S_{MIN}=0.3

EXTENT OF REVIEW

Exterior: ☒ Partial ☐ All Sides ☐ Aerial
Interior: ☒ None ☐ Visible ☐ Entered
Drawings Reviewed: ☐ Yes ☒ No
Soil Type Source: State Geologist
Geologic Hazards Source: State Geologist
Contact Person:

LEVEL 2 SCREENING PERFORMED?

☐ Yes, Final Level 2 Score, S_{L2} ______ ☒ No
Nonstructural hazards? ☐ Yes ☐ No

OTHER HAZARDS

Are There Hazards That Trigger A Detailed Structural Evaluation?

☒ Pounding potential (unless S_{L2} > cut-off, if known)
☐ Falling hazards from taller adjacent building
☐ Geologic hazards or Soil Type F
☐ Significant damage/deterioration to the structural system

ACTION REQUIRED

Detailed Structural Evaluation Required?

☐ Yes, unknown FEMA building type or other building
☒ Yes, score less than cut-off
☒ Yes, other hazards present (pounding)
☐ No

Detailed Nonstructural Evaluation Recommended? *(check one)*

☒ Yes, nonstructural hazards identified that should be evaluated
☐ No, nonstructural hazards exist that may require mitigation, but a detailed evaluation is not necessary
☐ No, no nonstructural hazards identified ☐ DNK

Where information cannot be verified, screener shall note the following: EST = Estimated or unreliable data <u>OR</u> DNK = Do Not Know

Legend:
MRF = Moment-resisting frame
BR = Braced frame
RC = Reinforced concrete
SW = Shear wall
URM INF = Unreinforced masonry infill
TU = Tilt up
MH = Manufactured Housing
LM = Light metal
FD = Flexible diaphragm
RD = Rigid diaphragm

Figure 7-10 Completed form for 3711 Roxbury Street.

Figure 7-11 Exterior view of 5020 Ebony Drive.

the plan view of the building in the space on the form allocated for a "Sketch."

The screeners did not know the soil type, but assumed Soil Type D, based on the instructions in the *Handbook* for when soil type is unknown, as well as their knowledge that an adjacent site only a quarter mile away was on Soil Type D.

The screeners observed the building's plan irregularity (reentrant corners) and noted it on the form.

Given the design date of 2000, the anchorage for the heavy cladding on the exterior of the building was assumed to have been designed to meet the anchorage requirements initially adopted in 1967 (per the information provided in the Quick Reference Guide). No other falling hazards were observed.

The window spacing in the upper stories and the column spacing at the first floor level indicated the building was either a steel moment frame building, or a concrete moment frame building. The screeners attempted to view the interior but were not provided with permission to do so. They elected to indicate that the building was either an S1 (steel moment-resisting frame) or C1 (concrete moment-resisting frame) type on the Data Collection Form and circled both types, along with their Basic Scores.

In addition, the screeners circled the Post-Benchmark Score Modifiers, given that the estimated design date (year 2000) occurred after the benchmark years for both FEMA Building Type S1 and FEMA Building Type C1 (per the information on the Quick Reference Guide), and the Score Modifiers for plan irregularity (in both the S1 and C1 columns).

By adding the circled numbers in both the S1 and C1 columns, scores of 2.7 and 2.8 were determined for the two FEMA Building Types. Using the lesser score of the two, the screener noted the Final Level 1 Score, S_{L1}, as 2.7. Because this is greater than the cut-off score of 2.0, a Detailed Structural Evaluation of the building by an experienced seismic design professional was not required. Before leaving the site, the screeners completed the Extent of Review, Other Hazards, and Action Required portions of the form. A completed version of the Data Collection Form is provided in Figure 7-12.

7.2.8.4 Example 4: 1450 Addison Avenue

The building at 1450 Addison Avenue (see Figure 7-13) is a one-story commercial building designed in 1990, per the information provided in the building identification portion of the Data Collection Form. By inspection, the screeners confirmed the address, number of stories, use (commercial), and year built, as shown on the form in Figure 7-14. The screeners paced off the building plan dimensions to estimate the plan size (estimated to be 10,125 square feet), confirming the square footage shown on the identification portion of the form. The L-shaped building was drawn on the form, along with the dimensions of the various legs.

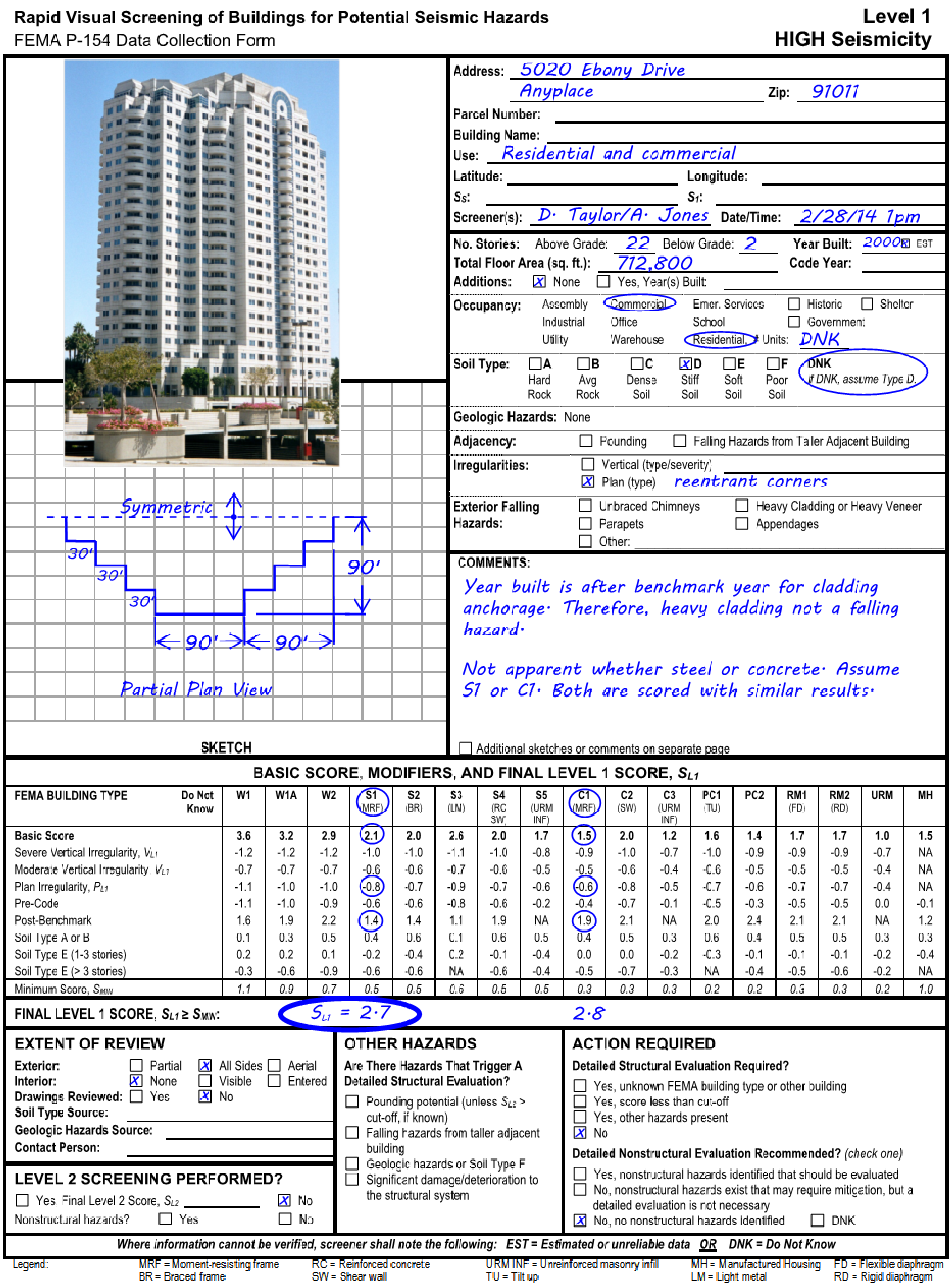
The building's commercial use was circled in the "Occupancy" portion. No falling hazards were observed.

The FEMA Building Type (W2) was circled on the form along with its Basic Score. Because the building was L-shaped in plan, the Score Modifier for plan irregularity was circled. Based on the age of the building, the Post-Benchmark Modifier was circled.

By adding the column of circled numbers, a Final Level 1 Score of 4.1 was determined. Because this score was greater than the cut-off score of 2.0, the building did not require a Detailed Structural Evaluation by an experienced seismic design professional. A completed version of the form is provided in Figure 7-14.

7.2.9 Step 9: Review by the Supervising Engineer

The quality assurance process was shortened due to the Supervising Engineer's presence in the field during the screenings. She decided to review



Rapid Visual Screening of Buildings for Potential Seismic Hazards
FEMA P-154 Data Collection Form

Level 1
HIGH Seismicity

Address: 5020 Ebony Drive
Anyplace **Zip:** 91011
Parcel Number:
Building Name:
Use: Residential and commercial
Latitude: **Longitude:**
S_S: **S_1:**
Screener(s): D. Taylor/A. Jones **Date/Time:** 2/28/14 1pm

No. Stories: Above Grade: 22 Below Grade: 2 **Year Built:** 2000 ☒ EST
Total Floor Area (sq. ft.): 712,800 **Code Year:**
Additions: ☒ None ☐ Yes, Year(s) Built:

Occupancy: Assembly [✓ Commercial] Emer. Services ☐ Historic ☐ Shelter
Industrial Office School ☐ Government
Utility Warehouse [✓ Residential] # Units: DNK

Soil Type: ☐ A Hard Rock ☐ B Avg Rock ☐ C Dense Soil ☒ D Stiff Soil ☐ E Soft Soil ☐ F Poor Soil [✓ DNK If DNK, assume Type D.]

Geologic Hazards: None
Adjacency: ☐ Pounding ☐ Falling Hazards from Taller Adjacent Building
Irregularities: ☐ Vertical (type/severity)
☒ Plan (type) reentrant corners
Exterior Falling Hazards: ☐ Unbraced Chimneys ☐ Heavy Cladding or Heavy Veneer
☐ Parapets ☐ Appendages
☐ Other:

COMMENTS:

Year built is after benchmark year for cladding anchorage. Therefore, heavy cladding not a falling hazard.

Not apparent whether steel or concrete. Assume S1 or C1. Both are scored with similar results.

☐ Additional sketches or comments on separate page

SKETCH

BASIC SCORE, MODIFIERS, AND FINAL LEVEL 1 SCORE, S_{L1}

FEMA BUILDING TYPE Do Not Know	W1	W1A	W2	[✓ S1 (MRF)]	S2 (BR)	S3 (LM)	S4 (RC SW)	S5 (URM INF)	[✓ C1 (MRF)]	C2 (SW)	C3 (URM INF)	PC1 (TU)	PC2	RM1 (FD)	RM2 (RD)	URM	MH
Basic Score	3.6	3.2	2.9	[✓ 2.1]	2.0	2.6	2.0	1.7	[✓ 1.5]	2.0	1.2	1.6	1.4	1.7	1.7	1.0	1.5
Severe Vertical Irregularity, V_{L1}	-1.2	-1.2	-1.2	-1.0	-1.0	-1.1	-1.0	-0.8	-0.9	-1.0	-0.7	-1.0	-0.9	-0.9	-0.9	-0.7	NA
Moderate Vertical Irregularity, V_{L1}	-0.7	-0.7	-0.7	-0.6	-0.6	-0.7	-0.6	-0.5	-0.5	-0.6	-0.4	-0.6	-0.5	-0.5	-0.5	-0.4	NA
Plan Irregularity, P_{L1}	-1.1	-1.0	-1.0	[✓ -0.8]	-0.7	-0.9	-0.7	-0.6	[✓ -0.6]	-0.8	-0.5	-0.7	-0.6	-0.7	-0.7	-0.4	NA
Pre-Code	-1.1	-1.0	-0.9	-0.6	-0.6	-0.8	-0.6	-0.2	-0.4	-0.7	-0.1	-0.5	-0.3	-0.5	-0.5	0.0	-0.1
Post-Benchmark	1.6	1.9	2.2	[✓ 1.4]	1.4	1.1	1.9	NA	[✓ 1.9]	2.1	NA	2.0	2.4	2.1	2.1	NA	1.2
Soil Type A or B	0.1	0.3	0.5	0.4	0.6	0.1	0.6	0.5	0.4	0.5	0.3	0.6	0.4	0.5	0.5	0.3	0.3
Soil Type E (1-3 stories)	0.2	0.2	0.1	-0.2	-0.4	0.2	-0.1	-0.4	0.0	0.0	-0.2	-0.3	-0.1	-0.1	-0.1	-0.2	-0.4
Soil Type E (> 3 stories)	-0.3	-0.6	-0.9	-0.6	-0.6	NA	-0.6	-0.4	-0.5	-0.7	-0.3	NA	-0.4	-0.5	-0.6	-0.2	NA
Minimum Score, S_{MIN}	*1.1*	*0.9*	*0.7*	*0.5*	*0.5*	*0.6*	*0.5*	*0.5*	*0.3*	*0.3*	*0.3*	*0.2*	*0.2*	*0.3*	*0.3*	*0.2*	*1.0*

FINAL LEVEL 1 SCORE, $S_{L1} \geq S_{MIN}$: S_{L1} = 2.7 2.8

EXTENT OF REVIEW
Exterior: ☐ Partial ☒ All Sides ☐ Aerial
Interior: ☒ None ☐ Visible ☐ Entered
Drawings Reviewed: ☐ Yes ☒ No
Soil Type Source:
Geologic Hazards Source:
Contact Person:

LEVEL 2 SCREENING PERFORMED?
☐ Yes, Final Level 2 Score, S_{L2} ☒ No
Nonstructural hazards? ☐ Yes ☐ No

OTHER HAZARDS
Are There Hazards That Trigger A Detailed Structural Evaluation?
☐ Pounding potential (unless S_{L2} > cut-off, if known)
☐ Falling hazards from taller adjacent building
☐ Geologic hazards or Soil Type F
☐ Significant damage/deterioration to the structural system

ACTION REQUIRED
Detailed Structural Evaluation Required?
☐ Yes, unknown FEMA building type or other building
☐ Yes, score less than cut-off
☐ Yes, other hazards present
☒ No
Detailed Nonstructural Evaluation Recommended? *(check one)*
☐ Yes, nonstructural hazards identified that should be evaluated
☐ No, nonstructural hazards exist that may require mitigation, but a detailed evaluation is not necessary
☒ No, no nonstructural hazards identified ☐ DNK

Where information cannot be verified, screener shall note the following: EST = Estimated or unreliable data OR DNK = Do Not Know

Legend:
MRF = Moment-resisting frame
BR = Braced frame
RC = Reinforced concrete
SW = Shear wall
URM INF = Unreinforced masonry infill
TU = Tilt up
MH = Manufactured Housing
LM = Light metal
FD = Flexible diaphragm
RD = Rigid diaphragm

Figure 7-12 Completed Data Collection form for 5020 Ebony Drive.

Figure 7-13 Exterior view of 1450 Addison Avenue.

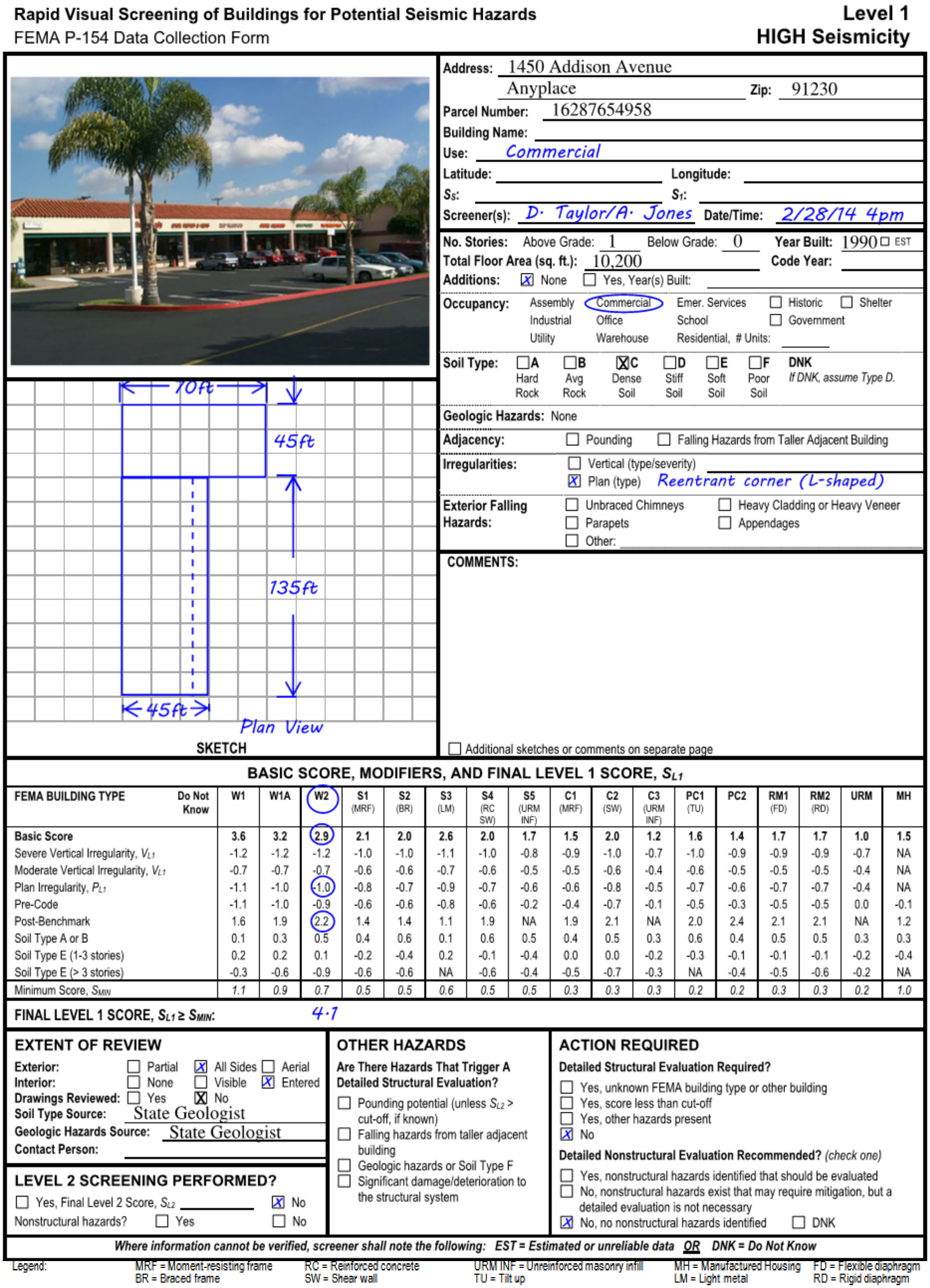
any form that included screener comments indicating some uncertainty. She also reviewed any form that had more than two FEMA Building Types circled. She spot checked 10% of the remaining forms. This resulted in approximately 250 reviews of individual forms.

The Supervising Engineer also reviewed the screening results after they were compiled into the RVS database to check for systematic errors. As expected, URMs generally received low scores, and new buildings generally received passing scores providing confidence that the scores were correctly calculated. These results were discussed with the Program Manager.

7.2.10 Step 10: Transferring the RVS Field Data to the Electronic Building RVS Database

The last step in the implementation of rapid visual screening for Anyplace, USA was transferring the information on the RVS Data Collection Forms into the relational electronic Building RVS Database. This required that all photos and sketches on the forms be scanned and numbered (for reference purposes), and that additional fields (and tables) be added to the database for those attributes not originally included in the database.

For quality control purposes, data were entered separately into two different versions of the electronic database, except photographs and sketches, which were scanned only once. A double-entry data verification process was then used, whereby the data from one database were compared to the same entries in the second database to identify those entries that were not exactly the



Rapid Visual Screening of Buildings for Potential Seismic Hazards
FEMA P-154 Data Collection Form

Level 1
HIGH Seismicity

Address: 1450 Addison Avenue
Anyplace **Zip:** 91230
Parcel Number: 16287654958
Building Name:
Use: Commercial
Latitude: **Longitude:**
S_S: **S_1:**
Screener(s): D. Taylor/A. Jones **Date/Time:** 2/28/14 4pm

No. Stories: Above Grade: 1 Below Grade: 0 **Year Built:** 1990 ☐ EST
Total Floor Area (sq. ft.): 10,200 **Code Year:**
Additions: ☒ None ☐ Yes, Year(s) Built:

Occupancy: Assembly [✓ Commercial] Emer. Services ☐ Historic ☐ Shelter
Industrial Office School ☐ Government
Utility Warehouse Residential, # Units:

Soil Type: ☐ A Hard Rock ☐ B Avg Rock ☒ C Dense Soil ☐ D Stiff Soil ☐ E Soft Soil ☐ F Poor Soil DNK *If DNK, assume Type D.*

Geologic Hazards: None

Adjacency: ☐ Pounding ☐ Falling Hazards from Taller Adjacent Building

Irregularities: ☐ Vertical (type/severity)
☒ Plan (type) Reentrant corner (L-shaped)

Exterior Falling Hazards: ☐ Unbraced Chimneys ☐ Heavy Cladding or Heavy Veneer
☐ Parapets ☐ Appendages
☐ Other:

COMMENTS:

☐ Additional sketches or comments on separate page

SKETCH

BASIC SCORE, MODIFIERS, AND FINAL LEVEL 1 SCORE, S_{L1}

FEMA BUILDING TYPE	**Do Not Know**	**W1**	**W1A**	**[✓ W2]**	**S1** (MRF)	**S2** (BR)	**S3** (LM)	**S4** (RC SW)	**S5** (URM INF)	**C1** (MRF)	**C2** (SW)	**C3** (URM INF)	**PC1** (TU)	**PC2**	**RM1** (FD)	**RM2** (RD)	**URM**	**MH**
Basic Score		**3.6**	**3.2**	**[✓ 2.9]**	**2.1**	**2.0**	**2.6**	**2.0**	**1.7**	**1.5**	**2.0**	**1.2**	**1.6**	**1.4**	**1.7**	**1.7**	**1.0**	**1.5**
Severe Vertical Irregularity, V_{L1}		-1.2	-1.2	-1.2	-1.0	-1.0	-1.1	-1.0	-0.8	-0.9	-1.0	-0.7	-1.0	-0.9	-0.9	-0.9	-0.7	NA
Moderate Vertical Irregularity, V_{L1}		-0.7	-0.7	-0.7	-0.6	-0.6	-0.7	-0.6	-0.5	-0.5	-0.6	-0.4	-0.6	-0.5	-0.5	-0.5	-0.4	NA
Plan Irregularity, P_{L1}		-1.1	-1.0	[✓ -1.0]	-0.8	-0.7	-0.9	-0.7	-0.6	-0.6	-0.8	-0.5	-0.7	-0.6	-0.7	-0.7	-0.4	NA
Pre-Code		-1.1	-1.0	-0.9	-0.6	-0.6	-0.8	-0.6	-0.2	-0.4	-0.7	-0.1	-0.5	-0.3	-0.5	-0.5	0.0	-0.1
Post-Benchmark		1.6	1.9	[✓ 2.2]	1.4	1.4	1.1	1.9	NA	1.9	2.1	NA	2.0	2.4	2.1	2.1	NA	1.2
Soil Type A or B		0.1	0.3	0.5	0.4	0.6	0.1	0.6	0.5	0.4	0.5	0.3	0.6	0.4	0.5	0.5	0.3	0.3
Soil Type E (1-3 stories)		0.2	0.2	0.1	-0.2	-0.4	0.2	-0.1	-0.4	0.0	0.0	-0.2	-0.3	-0.1	-0.1	-0.1	-0.2	-0.4
Soil Type E (> 3 stories)		-0.3	-0.6	-0.9	-0.6	-0.6	NA	-0.6	-0.4	-0.5	-0.7	-0.3	NA	-0.4	-0.5	-0.6	-0.2	NA
Minimum Score, S_{MIN}		*1.1*	*0.9*	*0.7*	*0.5*	*0.5*	*0.6*	*0.5*	*0.5*	*0.3*	*0.3*	*0.3*	*0.2*	*0.2*	*0.3*	*0.3*	*0.2*	*1.0*

FINAL LEVEL 1 SCORE, $S_{L1} \geq S_{MIN}$: 4.1

EXTENT OF REVIEW

Exterior: ☐ Partial ☒ All Sides ☐ Aerial
Interior: ☐ None ☐ Visible ☒ Entered
Drawings Reviewed: ☐ Yes ☒ No
Soil Type Source: State Geologist
Geologic Hazards Source: State Geologist
Contact Person:

LEVEL 2 SCREENING PERFORMED?

☐ Yes, Final Level 2 Score, S_{L2} ☒ No
Nonstructural hazards? ☐ Yes ☐ No

OTHER HAZARDS

Are There Hazards That Trigger A Detailed Structural Evaluation?

☐ Pounding potential (unless S_{L2} > cut-off, if known)
☐ Falling hazards from taller adjacent building
☐ Geologic hazards or Soil Type F
☐ Significant damage/deterioration to the structural system

ACTION REQUIRED

Detailed Structural Evaluation Required?

☐ Yes, unknown FEMA building type or other building
☐ Yes, score less than cut-off
☐ Yes, other hazards present
☒ No

Detailed Nonstructural Evaluation Recommended? *(check one)*

☐ Yes, nonstructural hazards identified that should be evaluated
☐ No, nonstructural hazards exist that may require mitigation, but a detailed evaluation is not necessary
☒ No, no nonstructural hazards identified ☐ DNK

Where information cannot be verified, screener shall note the following: EST = Estimated or unreliable data OR DNK = Do Not Know

Legend:
MRF = Moment-resisting frame
BR = Braced frame
RC = Reinforced concrete
SW = Shear wall
URM INF = Unreinforced masonry infill
TU = Tilt up
MH = Manufactured Housing
LM = Light metal
FD = Flexible diaphragm
RD = Rigid diaphragm

Figure 7-14 Completed Data Collection Form for 1450 Addison Avenue.

same. Non-identical entries were examined and corrected as necessary. The entire process, including scanning of sketches and photographs, required approximately 45 minutes per Data Collection Form.

After the electronic Building RVS Database was verified, it was imported into the city's GIS, thereby providing Anyplace with a state-of-the-art capability to identify and plot building groups based on any set of criteria desired by the city's policy makers. Photographs and sketches of individual buildings could also be shown in the GIS simply by clicking on the dot or symbol used to represent each building and selecting the desired image.

7.3 RVS Program Scenario B: Level 1 and Level 2 Screenings of K-12 School Buildings in Any State, USA

The state legislature, who is in this case the RVS Authority, is interested in understanding how many of the state's K-12 school buildings may be potentially hazardous in the event of an earthquake. They have partnered with the state's Structural Engineers Association to conduct RVS screenings of a sample of K-12 school buildings located throughout the state. A project team consisting of two structural engineers, one architect, and four members appointed by the State Superintendent has been assembled to plan and manage the program. The legislature plans to use the results of the RVS screenings to help prepare a preliminary budget for upgrading the schools.

Since the scope of the program was defined by the legislature, this step is not discussed here.

7.3.1 Step 1: Budget and Cost Estimation

The project team has determined that there are approximately 1,000 K-12 school buildings within the state. Rapid visual screening will be performed on a subset of these school buildings to obtain an initial estimate of the expected performance of the full building stock.

For this subset, the team plans to perform the following: (1) create an electronic record-keeping system including the capability for electronic scoring; (2) determine key seismic code adoption dates throughout the state; (3) acquire and review pre-field data from existing files; (4) review available building plans prior to field screening; (5) document building location and other information on the Data Collection Forms prior to field screening; and (6) perform Level 1 and Level 2 screenings including inspection of the interiors of buildings whenever possible.

The team has been granted a budget of $80,000 to perform the screening and present the results to the legislature. Based on this allowance, the team has decided to use eight engineers to screen 100 of the 1000 total school buildings in the state. The 100 school buildings are located across the state at 35 different school sites. Members of the project team are assumed to bill at a rate of $150 per hour. The screeners will all be experienced engineers and are assumed to bill at a rate of $120 per hour. Administrative tasks will be performed by personnel at a rate of $60 per hour. The RVS budget was developed and is shown in Table 7-3.

Table 7-3 RVS Budget for Any State, USA

Task	Hours			Cost
Task Description	Project Team $150/hr	Staff $60/hr	Screeners $120/hr	Task Cost
Select building subset	10			$1,500
Create record-keeping system including capability for electronic scoring	40			$6,000
Determine site-specific seismicity and soil type for each building and enter into record-keeping system (100 buildings x 10 minutes/building)		16		$960
Select and review Data Collection Form; establish code and benchmark years	40			$6,000
Acquisition and review of pre-field data (100 buildings x 50 minutes/building)	20	83		$7,980
Review construction documents (30 buildings x 30 minutes/building)	15			$2,250
Create individual Data Collection Forms from the database and distribute to screeners		20		$1,200
Training (two team members and 8 engineers attend 8 hour training)	16		64	$10,080
Field screening (55 minutes per building x 100 buildings, assumes Level 1 and Level 2 screenings performed with interior of the building typically accessed, plus 60 minutes of travel time each way to 35 sites)			162	$19,440
Quality assurance on completed forms (100 buildings x 15minutes/building); quality assurance on compiled data	36			$5,400
Enter field data into database + verification (100 buildings x 12minutes/building [2 people, 6 minutes each]); Photograph and sketch management (100 buildings x 12 minutes/building [once only])		40		$2,400
Calculate electronic scores	8			$1,200
Prepare of report to State Legislature	40			$6,000
Subtotal Cost				$70,410
Program management (10% of subtotal)				$7,041
Total Cost				$77,451

7.3.2 Step 2: Selection of Building Subset

The project team obtained an existing database of information on the state's schools that had been previously created by the state's Department of Education. For each K-12 school in the state, the survey identified the school district, school name, address, grade levels taught, and site number. For most of the schools, the individual buildings at the school site were further described including the date built and number of stories and, occasionally, the building material.

Using this information and by reviewing photos of the schools from maps available on the internet, the project team selected 100 buildings that were approximately representative of the full building stock with respect to date built, location, FEMA Building Type, and grade level.

7.3.3 Step 3: Pre-Field Planning

A record-keeping system was created for the RVS program using an Excel spreadsheet. The street address, name, and site number of each of the 100 schools were entered into the spreadsheet.

The site-specific hazard values, S_S and S_1, were determined using the USGS tool for each school location based on the school address (http://earthquake.usgs.gov/designmaps/usapp). The reported values of latitude and longitude and S_S and S_1 were entered into the spreadsheet for each school building.

V_s^{30} maps for the state were downloaded from the USGS website and were used to determine the soil type in different parts of the state (http://earthquake.usgs.gov/hazards/apps/vs30/). It was observed that the majority of the state has Soil Type B or C with some pockets of Soil Type D. The map was reviewed for each school building location, and the soil type was noted in the spreadsheet.

An existing state geologic hazards report indicated liquefaction potential existed in the westernmost portion of the state. The spreadsheet was updated to indicate liquefaction potential for the eight school buildings located within this hazard area.

Electronic scoring was integrated into the spreadsheet, allowing an electronic score to be calculated based on the site-specific soil type and seismic hazard and building information collected in the field.

7.3.4 Step 4: Selection and Review of the Data Collection Form

The spreadsheet included a calculation to determine seismicity region based on the site-specific seismic hazard values as determined during the pre-field planning step. A column was included in the spreadsheet to document the seismicity region at each site based on values of S_S and S_1 and the criteria in Table 2-2. Of the 100 school buildings, 62 were located in High seismicity, 36 were located in Moderately High seismicity, and 2 were located in Moderate seismicity. No schools were located in Very High or Low seismicity.

High, Moderately High, and Moderate seismicity Data Collection Forms were downloaded from www.atcouncil.org as pdf files. No modifications to the form were deemed necessary.

Next, the project team determined key seismic code adoption dates. The *International Building Code* (IBC) was adopted statewide in 2001, so benchmark years were set using the IBC column of Table 2-3. Prior to this, adoption and enforcement of seismic codes varied by local jurisdiction. The project team decided to use 1992 as the year that seismic codes were initially adopted and enforced.

Finally, the project team decided to use a cut-off score of 2.0.

7.3.5 Step 5: Qualifications and Training of Screeners

The project team selected eight experienced engineers from around the state to perform the screenings. The eight engineers, plus two members of the project team attended a one-day training session. They learned about the FEMA P-154 methodology and learned how to complete the Level 1 and Level 2 Data Collection Forms. Using photographs of actual buildings, they identified FEMA Building Types and building irregularities. Because of how common building additions are in older school buildings, special attention was paid during the training to screening buildings with additions. Buildings were assigned to screeners based on location to minimize the cost of travel time.

7.3.6 Step 6: Acquisition and Review of Pre-Field Data

In addition to the database of information that the project team had received from the state's Department of Education, permit files were also obtained at the local building departments and reviewed for information on the school buildings. From these permit files, the project team extracted information on building size, building age, number of stories, and, occasionally, FEMA Building Type.

Construction drawings were available for approximately a third of the school buildings. From these, irregularities could be identified and reviewed for severity.

In one county, schools had previously been screened using the second edition of FEMA 154. The completed *Second Edition* forms were used for additional information.

All of the information obtained during the pre-field data collection process was entered into the record-keeping spreadsheet. A routine was developed to automate the transfer of data from the spreadsheet into a pdf for each school building. Soil Type and Geologic Hazards were noted on the Data Collection Forms under the Extent of Review field.

7.3.7 Step 7: Field Screening of Buildings

Each building was assigned to a screener located nearest the building. The pre-filled forms were provided to the assigned screener. Each screener had three weeks to complete their assigned screenings and send the completed Data Collection Forms back to the project team.

Following are several examples illustrating rapid visual screening in the field and completion of the Level 1 and Level 2 Data Collection Forms. All of the examples are located in High seismicity. Some examples use forms containing relatively complete building identification information, including FEMA Building Type, obtained during the pre-field data acquisition and review process, while others use forms containing less complete building identification information.

7.3.7.1 Example 1: Main Building at Roosevelt Elementary School

The screener performed Level 1 and Level 2 screenings of the main classroom building at Roosevelt Elementary School (shown in Figure 7-15) using the provided Data Collection Form, which included pre-field information, such as address, number of stories, year built, and soils information.

The screener verified the pre-field information. She checked Soil Type D and indicated liquefaction potential, based on the pre-filled information in the "Extent of Review" portion of the form.

After walking around the building and through the interior of the building, she identified the building as a FEMA Building Type RM2 (reinforced masonry building with rigid floor and roof diaphragms) and sketched the

Figure 7-15 Exterior view of modern reinforced brick masonry building at Roosevelt Elementary School.

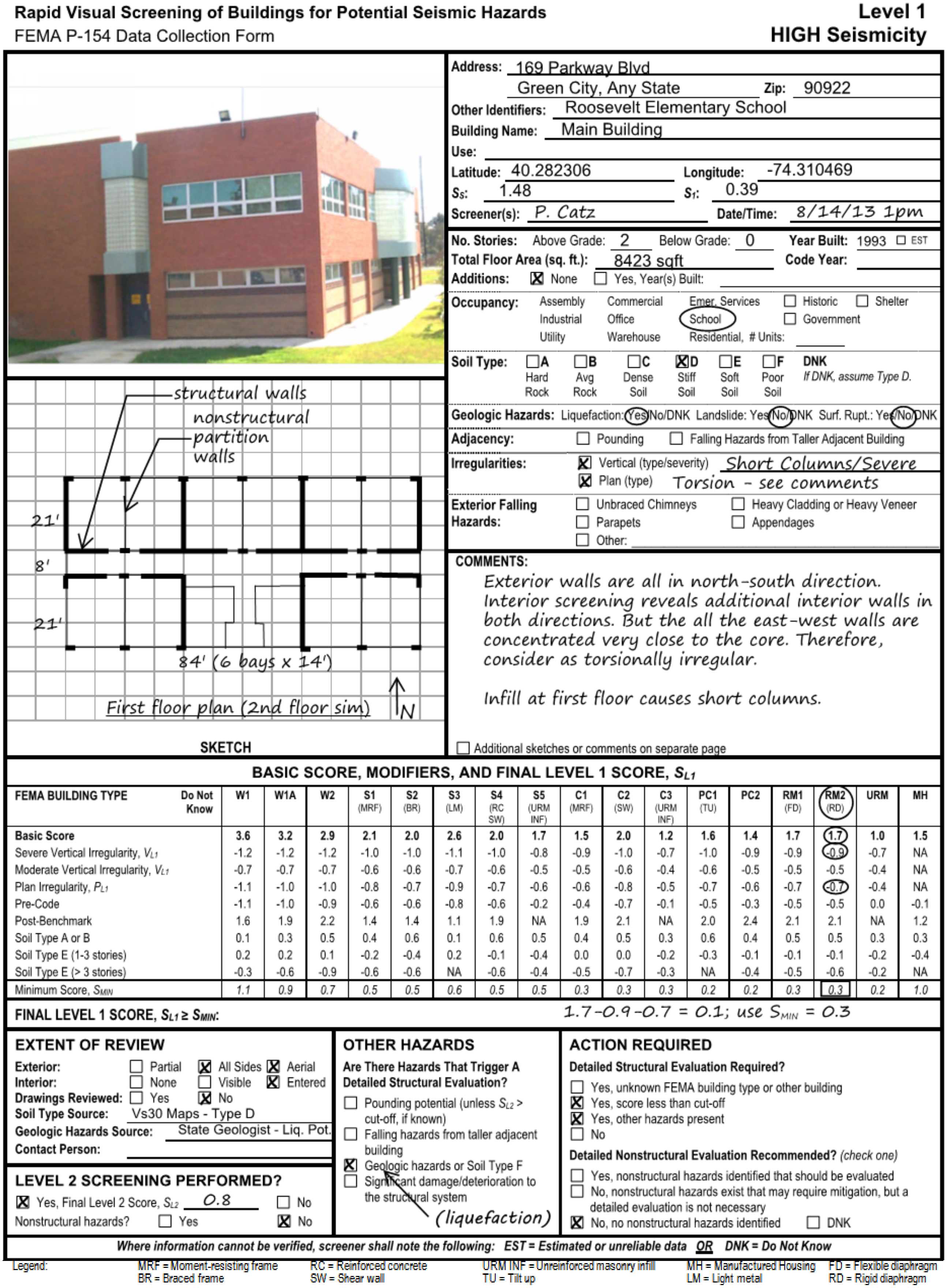
plan of the building. All of the interior walls were finished, but she was able to identify which walls were structural versus nonstructural by tapping on them. Those walls that sounded solid were deemed structural, and those that sounded hollow were deemed nonstructural. She added this information to the sketch.

Using the Vertical Irregularity Reference Guide, she identified the building as having a short column irregularity due to the presence of infill walls at the first floor that effectively shortened the length of the columns. Because the east-west walls were all concentrated at the center of the building, the screener identified the building as torsionally irregular. Considering the plan and vertical irregularities, the screener calculated a score of 0.1, but used S_{MIN} to set the Level 1 Final Score at 0.3.

The screener completed the Level 2 portion of the form, reviewing each of the Level 2 statements, and the nonstructural portion of the Level 2 form. The Level 2 Final Score, which included a more modest penalty for short columns and a positive modifier for redundancy, was calculated as +0.8. This score was transferred back onto the Level 1 form.

Under “Other Hazards,” the screener checked the “Geologic Hazards or Soil Type F” box to acknowledge that liquefaction potential at the site is a trigger for a Detailed Structural Evaluation. Under “Action Required,” the screener checked both “Yes, score less than cut-off” and “Yes, other hazards present” (because of the liquefaction potential). No exterior falling hazards were observed in either the Level 1 or the Level 2 screening.

The completed Level 1 Data Collection Form for the main classroom building is shown in Figure 7-16. The completed Level 2 Data Collection Form is shown in Figure 7-17. Additional buildings on site, including an auditorium structure and a cafeteria building, were screened separately.



Rapid Visual Screening of Buildings for Potential Seismic Hazards
FEMA P-154 Data Collection Form

Level 1
HIGH Seismicity

Address: 169 Parkway Blvd
Green City, Any State **Zip:** 90922
Other Identifiers: Roosevelt Elementary School
Building Name: Main Building
Use:
Latitude: 40.282306 **Longitude:** -74.310469
S_S: 1.48 S_1: 0.39
Screener(s): P. Catz **Date/Time:** 8/14/13 1pm

No. Stories: Above Grade: 2 Below Grade: 0 **Year Built:** 1993 ☐ EST
Total Floor Area (sq. ft.): 8423 sqft **Code Year:**
Additions: ☒ None ☐ Yes, Year(s) Built:

Occupancy: Assembly Commercial Emer. Services ☐ Historic ☐ Shelter
Industrial Office [✓ School] ☐ Government
Utility Warehouse Residential, # Units:

Soil Type: ☐ **A** Hard Rock ☐ **B** Avg Rock ☐ **C** Dense Soil ☒ **D** Stiff Soil ☐ **E** Soft Soil ☐ **F** Poor Soil **DNK** *If DNK, assume Type D.*

Geologic Hazards: Liquefaction: [✓ Yes]/No/DNK Landslide: Yes/[✓ No]/DNK Surf. Rupt.: Yes/[✓ No]/DNK

Adjacency: ☐ Pounding ☐ Falling Hazards from Taller Adjacent Building

Irregularities: ☒ Vertical (type/severity) Short Columns/Severe
☒ Plan (type) Torsion – see comments

Exterior Falling Hazards: ☐ Unbraced Chimneys ☐ Heavy Cladding or Heavy Veneer
☐ Parapets ☐ Appendages
☐ Other:

COMMENTS:

Exterior walls are all in north-south direction. Interior screening reveals additional interior walls in both directions. But the all the east-west walls are concentrated very close to the core. Therefore, consider as torsionally irregular.

Infill at first floor causes short columns.

☐ Additional sketches or comments on separate page

SKETCH

BASIC SCORE, MODIFIERS, AND FINAL LEVEL 1 SCORE, S_{L1}

FEMA BUILDING TYPE	**Do Not Know**	**W1**	**W1A**	**W2**	**S1** (MRF)	**S2** (BR)	**S3** (LM)	**S4** (RC SW)	**S5** (URM INF)	**C1** (MRF)	**C2** (SW)	**C3** (URM INF)	**PC1** (TU)	**PC2**	**RM1** (FD)	[✓ **RM2** (RD)]	**URM**	**MH**
Basic Score		**3.6**	**3.2**	**2.9**	**2.1**	**2.0**	**2.6**	**2.0**	**1.7**	**1.5**	**2.0**	**1.2**	**1.6**	**1.4**	**1.7**	[✓ **1.7**]	**1.0**	**1.5**
Severe Vertical Irregularity, V_{L1}		-1.2	-1.2	-1.2	-1.0	-1.0	-1.1	-1.0	-0.8	-0.9	-1.0	-0.7	-1.0	-0.9	-0.9	[✓ -0.9]	-0.7	NA
Moderate Vertical Irregularity, V_{L1}		-0.7	-0.7	-0.7	-0.6	-0.6	-0.7	-0.6	-0.5	-0.5	-0.6	-0.4	-0.6	-0.5	-0.5	-0.5	-0.4	NA
Plan Irregularity, P_{L1}		-1.1	-1.0	-1.0	-0.8	-0.7	-0.9	-0.7	-0.6	-0.6	-0.8	-0.5	-0.7	-0.6	-0.7	[✓ -0.7]	-0.4	NA
Pre-Code		-1.1	-1.0	-0.9	-0.6	-0.6	-0.8	-0.6	-0.2	-0.4	-0.7	-0.1	-0.5	-0.3	-0.5	-0.5	0.0	-0.1
Post-Benchmark		1.6	1.9	2.2	1.4	1.4	1.1	1.9	NA	1.9	2.1	NA	2.0	2.4	2.1	2.1	NA	1.2
Soil Type A or B		0.1	0.3	0.5	0.4	0.6	0.1	0.6	0.5	0.4	0.5	0.3	0.6	0.4	0.5	0.5	0.3	0.3
Soil Type E (1-3 stories)		0.2	0.2	0.1	-0.2	-0.4	0.2	-0.1	-0.4	0.0	0.0	-0.2	-0.3	-0.1	-0.1	-0.1	-0.2	-0.4
Soil Type E (> 3 stories)		-0.3	-0.6	-0.9	-0.6	-0.6	NA	-0.6	-0.4	-0.5	-0.7	-0.3	NA	-0.4	-0.5	-0.6	-0.2	NA
Minimum Score, S_{MIN}		*1.1*	*0.9*	*0.7*	*0.5*	*0.5*	*0.6*	*0.5*	*0.5*	*0.3*	*0.3*	*0.3*	*0.2*	*0.2*	*0.3*	[✓ *0.3*]	*0.2*	*1.0*

FINAL LEVEL 1 SCORE, $S_{L1} \geq S_{MIN}$: $1.7-0.9-0.7 = 0.1$; use $S_{MIN} = 0.3$

EXTENT OF REVIEW
Exterior: ☐ Partial ☒ All Sides ☒ Aerial
Interior: ☐ None ☐ Visible ☒ Entered
Drawings Reviewed: ☐ Yes ☒ No
Soil Type Source: Vs30 Maps - Type D
Geologic Hazards Source: State Geologist - Liq. Pot.
Contact Person:

LEVEL 2 SCREENING PERFORMED?
☒ Yes, Final Level 2 Score, S_{L2} 0.8 ☐ No
Nonstructural hazards? ☐ Yes ☒ No

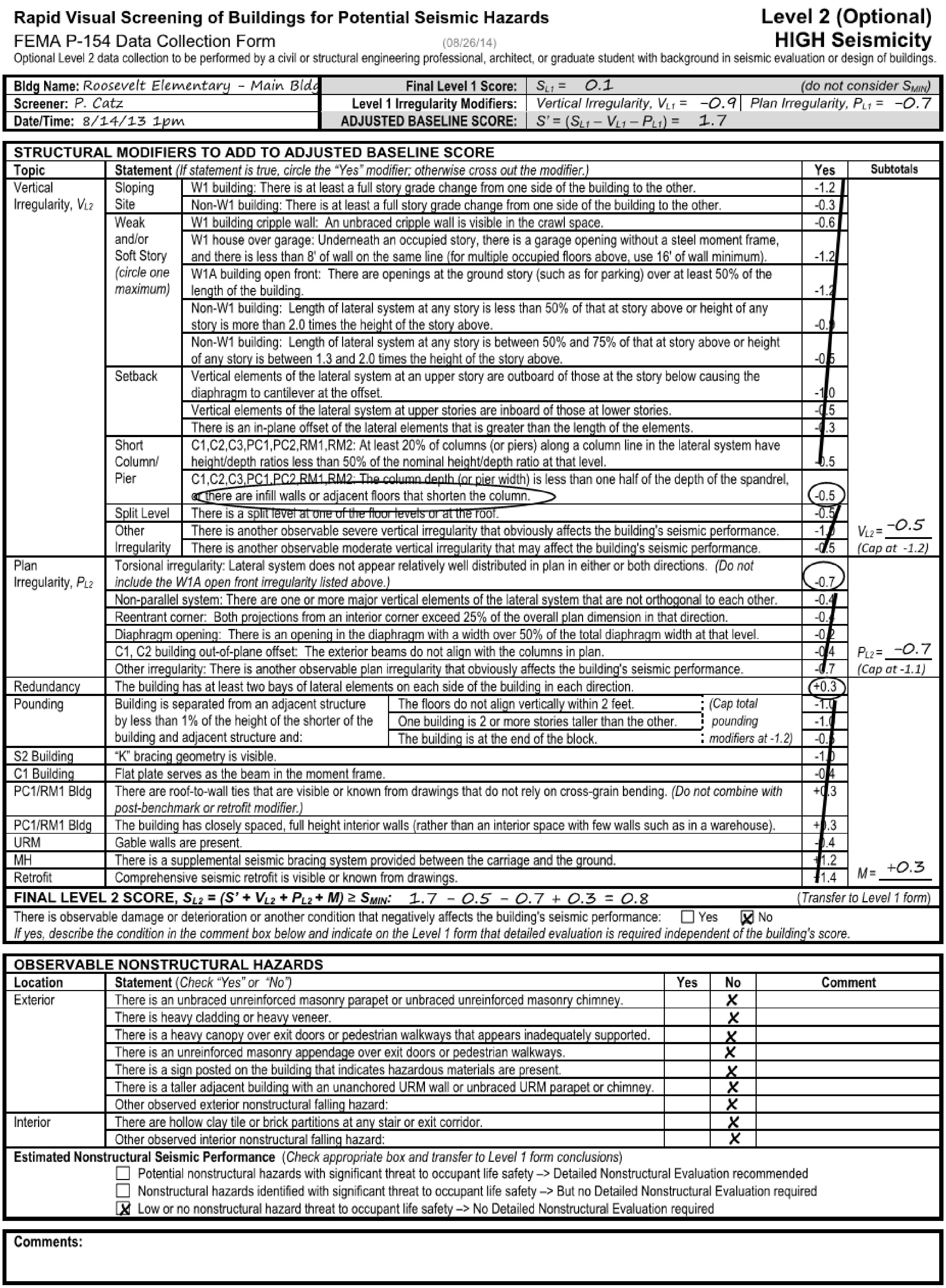
OTHER HAZARDS
Are There Hazards That Trigger A Detailed Structural Evaluation?
☐ Pounding potential (unless S_{L2} > cut-off, if known)
☐ Falling hazards from taller adjacent building
☒ Geologic hazards or Soil Type F
☐ Significant damage/deterioration to the structural system
(liquefaction)

ACTION REQUIRED
Detailed Structural Evaluation Required?
☐ Yes, unknown FEMA building type or other building
☒ Yes, score less than cut-off
☒ Yes, other hazards present
☐ No
Detailed Nonstructural Evaluation Recommended? *(check one)*
☐ Yes, nonstructural hazards identified that should be evaluated
☐ No, nonstructural hazards exist that may require mitigation, but a detailed evaluation is not necessary
☒ No, no nonstructural hazards identified ☐ DNK

Where information cannot be verified, screener shall note the following: EST = Estimated or unreliable data OR DNK = Do Not Know

Legend: MRF = Moment-resisting frame BR = Braced frame RC = Reinforced concrete SW = Shear wall URM INF = Unreinforced masonry infill TU = Tilt up MH = Manufactured Housing LM = Light metal FD = Flexible diaphragm RD = Rigid diaphragm

Figure 7-16 Completed Level 1 Data Collection Form for the main building at Roosevelt Elementary School.



Rapid Visual Screening of Buildings for Potential Seismic Hazards

FEMA P-154 Data Collection Form (08/26/14)

Level 2 (Optional)
HIGH Seismicity

Optional Level 2 data collection to be performed by a civil or structural engineering professional, architect, or graduate student with background in seismic evaluation or design of buildings.

Bldg Name: Roosevelt Elementary - Main Bldg	**Final Level 1 Score:**	S_{L1} = 0.1	*(do not consider S_{MIN})*
Screener: P. Catz	**Level 1 Irregularity Modifiers:**	*Vertical Irregularity, V_{L1}* = -0.9	*Plan Irregularity, P_{L1}* = -0.7
Date/Time: 8/14/13 1pm	**ADJUSTED BASELINE SCORE:**	$S' = (S_{L1} - V_{L1} - P_{L1})$ = 1.7	

STRUCTURAL MODIFIERS TO ADD TO ADJUSTED BASELINE SCORE

Topic	**Statement** *(If statement is true, circle the "Yes" modifier; otherwise cross out the modifier.)*		**Yes**	**Subtotals**
Vertical Irregularity, V_{L2}	Sloping Site	W1 building: There is at least a full story grade change from one side of the building to the other.	~~-1.2~~	
		Non-W1 building: There is at least a full story grade change from one side of the building to the other.	~~-0.3~~	
	Weak and/or Soft Story *(circle one maximum)*	W1 building cripple wall: An unbraced cripple wall is visible in the crawl space.	~~-0.6~~	
		W1 house over garage: Underneath an occupied story, there is a garage opening without a steel moment frame, and there is less than 8' of wall on the same line (for multiple occupied floors above, use 16' of wall minimum).	~~-1.2~~	
		W1A building open front: There are openings at the ground story (such as for parking) over at least 50% of the length of the building.	~~-1.2~~	
		Non-W1 building: Length of lateral system at any story is less than 50% of that at story above or height of any story is more than 2.0 times the height of the story above.	~~-0.9~~	
		Non-W1 building: Length of lateral system at any story is between 50% and 75% of that at story above or height of any story is between 1.3 and 2.0 times the height of the story above.	~~-0.5~~	
	Setback	Vertical elements of the lateral system at an upper story are outboard of those at the story below causing the diaphragm to cantilever at the offset.	~~-1.0~~	
		Vertical elements of the lateral system at upper stories are inboard of those at lower stories.	~~-0.5~~	
		There is an in-plane offset of the lateral elements that is greater than the length of the elements.	~~-0.3~~	
	Short Column/ Pier	C1,C2,C3,PC1,PC2,RM1,RM2: At least 20% of columns (or piers) along a column line in the lateral system have height/depth ratios less than 50% of the nominal height/depth ratio at that level.	~~-0.5~~	
		C1,C2,C3,PC1,PC2,RM1,RM2: The column depth (or pier width) is less than one half of the depth of the spandrel, or there are infill walls or adjacent floors that shorten the column.	[✓ -0.5]	
	Split Level	There is a split level at one of the floor levels or at the roof.	~~-0.5~~	
	Other Irregularity	There is another observable severe vertical irregularity that obviously affects the building's seismic performance.	~~-1.0~~	V_{L2} = -0.5
		There is another observable moderate vertical irregularity that may affect the building's seismic performance.	~~-0.5~~	*(Cap at -1.2)*
Plan Irregularity, P_{L2}	Torsional irregularity: Lateral system does not appear relatively well distributed in plan in either or both directions. *(Do not include the W1A open front irregularity listed above.)*		[✓ -0.7]	
	Non-parallel system: There are one or more major vertical elements of the lateral system that are not orthogonal to each other.		~~-0.4~~	
	Reentrant corner: Both projections from an interior corner exceed 25% of the overall plan dimension in that direction.		~~-0.4~~	
	Diaphragm opening: There is an opening in the diaphragm with a width over 50% of the total diaphragm width at that level.		~~-0.2~~	
	C1, C2 building out-of-plane offset: The exterior beams do not align with the columns in plan.		~~-0.4~~	P_{L2} = -0.7
	Other irregularity: There is another observable plan irregularity that obviously affects the building's seismic performance.		~~-0.7~~	*(Cap at -1.1)*
Redundancy	The building has at least two bays of lateral elements on each side of the building in each direction.		[✓ +0.3]	
Pounding	Building is separated from an adjacent structure by less than 1% of the height of the shorter of the building and adjacent structure and:	The floors do not align vertically within 2 feet. *(Cap total pounding modifiers at -1.2)*	~~-1.0~~	
		One building is 2 or more stories taller than the other.	~~-1.0~~	
		The building is at the end of the block.	~~-0.5~~	
S2 Building	"K" bracing geometry is visible.		~~-1.0~~	
C1 Building	Flat plate serves as the beam in the moment frame.		~~-0.4~~	
PC1/RM1 Bldg	There are roof-to-wall ties that are visible or known from drawings that do not rely on cross-grain bending. *(Do not combine with post-benchmark or retrofit modifier.)*		~~+0.3~~	
PC1/RM1 Bldg	The building has closely spaced, full height interior walls (rather than an interior space with few walls such as in a warehouse).		~~+0.3~~	
URM	Gable walls are present.		~~-0.4~~	
MH	There is a supplemental seismic bracing system provided between the carriage and the ground.		~~+1.2~~	
Retrofit	Comprehensive seismic retrofit is visible or known from drawings.		~~+1.4~~	M = +0.3

FINAL LEVEL 2 SCORE, $S_{L2} = (S' + V_{L2} + P_{L2} + M) \geq S_{MIN}$: 1.7 - 0.5 - 0.7 + 0.3 = 0.8 (*Transfer to Level 1 form*)

There is observable damage or deterioration or another condition that negatively affects the building's seismic performance: ☐ Yes ☒ No

If yes, describe the condition in the comment box below and indicate on the Level 1 form that detailed evaluation is required independent of the building's score.

OBSERVABLE NONSTRUCTURAL HAZARDS

Location	**Statement** (*Check "Yes" or "No"*)	**Yes**	**No**	**Comment**
Exterior	There is an unbraced unreinforced masonry parapet or unbraced unreinforced masonry chimney.		X	
	There is heavy cladding or heavy veneer.		X	
	There is a heavy canopy over exit doors or pedestrian walkways that appears inadequately supported.		X	
	There is an unreinforced masonry appendage over exit doors or pedestrian walkways.		X	
	There is a sign posted on the building that indicates hazardous materials are present.		X	
	There is a taller adjacent building with an unanchored URM wall or unbraced URM parapet or chimney.		X	
	Other observed exterior nonstructural falling hazard:		X	
Interior	There are hollow clay tile or brick partitions at any stair or exit corridor.		X	
	Other observed interior nonstructural falling hazard:		X	

Estimated Nonstructural Seismic Performance (*Check appropriate box and transfer to Level 1 form conclusions*)

☐ Potential nonstructural hazards with significant threat to occupant life safety –> Detailed Nonstructural Evaluation recommended
☐ Nonstructural hazards identified with significant threat to occupant life safety –> But no Detailed Nonstructural Evaluation required
☒ Low or no nonstructural hazard threat to occupant life safety –> No Detailed Nonstructural Evaluation required

Comments:

Figure 7-17 Completed Level 2 Data Collection Form for the main building at Roosevelt Elementary School.

7.3.7.2 Example 2: Main Building plus Addition at Washington Middle School

The screener performed Level 1 and Level 2 screenings of the main classroom building at Washington Middle School (shown in Figure 7-18) using the provided High seismicity Data Collection Form which included pre-field information such as address, number of stories, year built, and soils information. It also indicated that an addition was built in 1994.

Figure 7-18 Photo of exterior of Washington Middle School (from www.fema.gov).

The screener verified the pre-field information. He checked Soil Type C and indicated that no geologic hazards were present, based on the pre-filled information in the "Extent of Review" portion of the form.

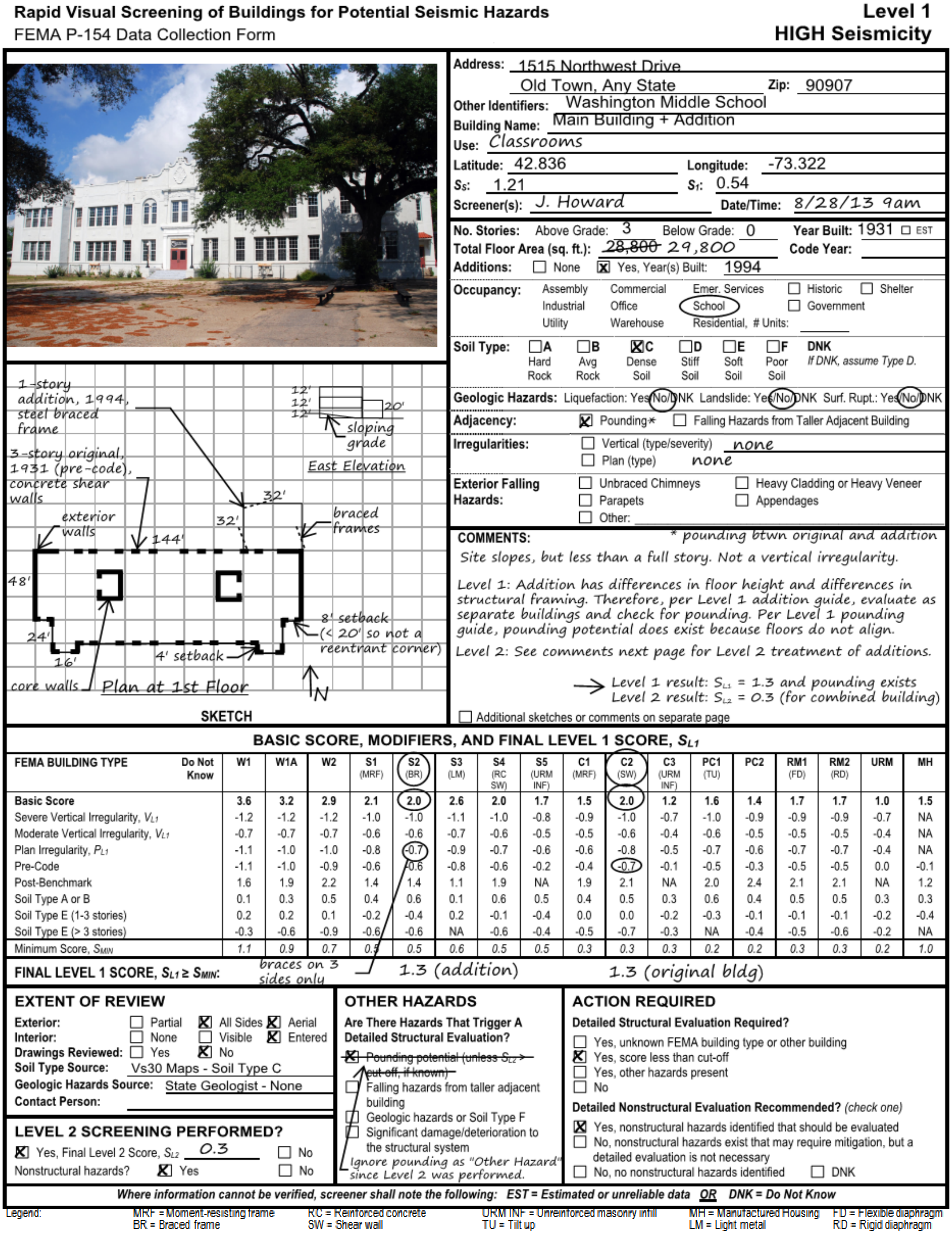
After walking around the building and through the interior of the building, he identified the original building as a C2 (concrete shear wall). He confirmed that the walls were concrete and not stucco over metal or wood framing by knocking on the walls and verifying that they were solid. He observed steel braces at the addition and concluded that it was an S2 (steel braced frame). He sketched a plan of the building, including the addition, and an elevation. He calculated the area of the building and found that the area provided on the form did not appear to include the area of the addition. He crossed out the provided area and wrote in a revised value.

The screener consulted the Level 1 Building Additions Reference Guide, which indicated that because the addition and the original building had different structural framing, they should be evaluated separately and pounding should be considered. He checked pounding using the Level 1 Pounding Reference Guide and found that pounding potential does exist because the roof of the addition does not align with the floor of the original building. While he could have used a separate form for the addition, he opted to use a single Level 1 form for both portions of the building. He calculated a Level 1 score for the original building, and a second Level 1 score for the addition. The screener did not observe any of the irregularities listed in the Vertical Irregularity Reference Guide in the main building. Because the addition has braced frames on only three sides, the screener identified the addition as torsionally irregular using the Plan Irregularity Reference Guide. Considering the original building is pre-code, the screener calculated the Level 1 Score for the original building as 1.3. Considering the plan irregularity and the soil type, the screener calculated the Level 1 Score for the addition as 1.3.

Prior to performing the Level 2 portion of the form, the screener consulted the Level 2 Building Additions Reference Guide. Based on the Level 2 guide, the screener treated the original plus addition as a single building. He applied (1) the reentrant corner modifier to account for the difference in the plan dimension between the original and the addition; (2) the setback modifier to account for the difference in height; and (3) the torsional irregularity modifier to account for the difference in structural systems. He also applied modifiers for split level (because the roof of the addition does not align with any of the original floor levels) and redundancy (because there are multiple bays of lateral elements in both directions on both sides of the building. He made sure to apply the appropriate caps to V_{L2} and P_{L2} as instructed on the Level 2 form. The Level 2 score was calculated as -0.3, so S_{MIN} (for the original building) was used as the Final Level 2 Score, S_{L2} = 0.3. This score was transferred back onto the Level 1 form.

No exterior falling hazards were observed in the Level 1 screening. During the Level 2 screening, however, the screener observed what appeared to be hollow clay tile partitions. He noted this on the Level 2 form.

The completed Level 1 Data Collection Form for the building is shown in Figure 7-19. The completed Level 2 Data Collection Form is shown in Figure 7-20. Additional buildings on site were screened separately.



Rapid Visual Screening of Buildings for Potential Seismic Hazards
FEMA P-154 Data Collection Form

Level 1
HIGH Seismicity

Address: 1515 Northwest Drive
Old Town, Any State **Zip:** 90907
Other Identifiers: Washington Middle School
Building Name: Main Building + Addition
Use: Classrooms
Latitude: 42.836 **Longitude:** -73.322
S_S: 1.21 **S_1:** 0.54
Screener(s): J. Howard **Date/Time:** 8/28/13 9am

No. Stories: Above Grade: 3 Below Grade: 0 **Year Built:** 1931 ☐ EST
Total Floor Area (sq. ft.): ~~28,800~~ 29,800 **Code Year:**
Additions: ☐ None ☒ Yes, Year(s) Built: 1994

Occupancy: Assembly Commercial Emer. Services ☐ Historic ☐ Shelter
Industrial Office [✓ School] ☐ Government
Utility Warehouse Residential, # Units:

Soil Type: ☐ A Hard Rock ☐ B Avg Rock ☒ C Dense Soil ☐ D Stiff Soil ☐ E Soft Soil ☐ F Poor Soil **DNK** *If DNK, assume Type D.*

Geologic Hazards: Liquefaction: Yes/[✓ No]/DNK Landslide: Yes/[✓ No]/DNK Surf. Rupt.: Yes/[✓ No]/DNK

Adjacency: ☒ Pounding* ☐ Falling Hazards from Taller Adjacent Building

Irregularities: ☐ Vertical (type/severity) none
☐ Plan (type) none

Exterior Falling Hazards: ☐ Unbraced Chimneys ☐ Heavy Cladding or Heavy Veneer
☐ Parapets ☐ Appendages
☐ Other:

COMMENTS: * pounding btwn original and addition

Site slopes, but less than a full story. Not a vertical irregularity.

Level 1: Addition has differences in floor height and differences in structural framing. Therefore, per Level 1 addition guide, evaluate as separate buildings and check for pounding. Per Level 1 pounding guide, pounding potential does exist because floors do not align.

Level 2: See comments next page for Level 2 treatment of additions.

→ Level 1 result: S_{L1} = 1.3 and pounding exists
Level 2 result: S_{L2} = 0.3 (for combined building)

☐ Additional sketches or comments on separate page

1-story addition, 1994, steel braced frame
3-story original, 1931 (pre-code), concrete shear walls
exterior walls
braced frames
core walls
12'
12'
12'
20'
sloping grade
East Elevation
32'
32'
144'
48'
24'
16'
8' setback (< 20' so not a reentrant corner)
4' setback
N
Plan at 1st Floor

SKETCH

BASIC SCORE, MODIFIERS, AND FINAL LEVEL 1 SCORE, S_{L1}

FEMA BUILDING TYPE	**Do Not Know**	**W1**	**W1A**	**W2**	**S1** (MRF)	[✓ **S2** (BR)]	**S3** (LM)	**S4** (RC SW)	**S5** (URM INF)	**C1** (MRF)	[✓ **C2** (SW)]	**C3** (URM INF)	**PC1** (TU)	**PC2**	**RM1** (FD)	**RM2** (RD)	**URM**	**MH**
Basic Score		**3.6**	**3.2**	**2.9**	**2.1**	[✓ **2.0**]	**2.6**	**2.0**	**1.7**	**1.5**	[✓ **2.0**]	**1.2**	**1.6**	**1.4**	**1.7**	**1.7**	**1.0**	**1.5**
Severe Vertical Irregularity, V_{L1}		-1.2	-1.2	-1.2	-1.0	-1.0	-1.1	-1.0	-0.8	-0.9	-1.0	-0.7	-1.0	-0.9	-0.9	-0.9	-0.7	NA
Moderate Vertical Irregularity, V_{L1}		-0.7	-0.7	-0.7	-0.6	-0.6	-0.7	-0.6	-0.5	-0.5	-0.6	-0.4	-0.6	-0.5	-0.5	-0.5	-0.4	NA
Plan Irregularity, P_{L1}		-1.1	-1.0	-1.0	-0.8	[✓ -0.7]	-0.9	-0.7	-0.6	-0.6	-0.8	-0.5	-0.7	-0.6	-0.7	-0.7	-0.4	NA
Pre-Code		-1.1	-1.0	-0.9	-0.6	-0.6	-0.8	-0.6	-0.2	-0.4	[✓ -0.7]	-0.1	-0.5	-0.3	-0.5	-0.5	0.0	-0.1
Post-Benchmark		1.6	1.9	2.2	1.4	1.4	1.1	1.9	NA	1.9	2.1	NA	2.0	2.4	2.1	2.1	NA	1.2
Soil Type A or B		0.1	0.3	0.5	0.4	0.6	0.1	0.6	0.5	0.4	0.5	0.3	0.6	0.4	0.5	0.5	0.3	0.3
Soil Type E (1-3 stories)		0.2	0.2	0.1	-0.2	-0.4	0.2	-0.1	-0.4	0.0	0.0	-0.2	-0.3	-0.1	-0.1	-0.1	-0.2	-0.4
Soil Type E (> 3 stories)		-0.3	-0.6	-0.9	-0.6	-0.6	NA	-0.6	-0.4	-0.5	-0.7	-0.3	NA	-0.4	-0.5	-0.6	-0.2	NA
Minimum Score, S_{MIN}		*1.1*	*0.9*	*0.7*	*0.5*	*0.5*	*0.6*	*0.5*	*0.5*	*0.3*	*0.3*	*0.3*	*0.2*	*0.2*	*0.3*	*0.3*	*0.2*	*1.0*

FINAL LEVEL 1 SCORE, $S_{L1} \geq S_{MIN}$: braces on 3 sides only 1.3 (addition) 1.3 (original bldg)

EXTENT OF REVIEW

Exterior: ☐ Partial ☒ All Sides ☒ Aerial
Interior: ☐ None ☐ Visible ☒ Entered
Drawings Reviewed: ☐ Yes ☒ No
Soil Type Source: Vs30 Maps - Soil Type C
Geologic Hazards Source: State Geologist - None
Contact Person:

LEVEL 2 SCREENING PERFORMED?

☒ Yes, Final Level 2 Score, S_{L2} 0.3 ☐ No
Nonstructural hazards? ☒ Yes ☐ No

OTHER HAZARDS

Are There Hazards That Trigger A Detailed Structural Evaluation?

☒ ~~Pounding potential (unless S_{L2} > cut-off, if known)~~
☐ Falling hazards from taller adjacent building
☐ Geologic hazards or Soil Type F
☐ Significant damage/deterioration to the structural system

Ignore pounding as "Other Hazard" since Level 2 was performed.

ACTION REQUIRED

Detailed Structural Evaluation Required?

☐ Yes, unknown FEMA building type or other building
☒ Yes, score less than cut-off
☐ Yes, other hazards present
☐ No

Detailed Nonstructural Evaluation Recommended? *(check one)*

☒ Yes, nonstructural hazards identified that should be evaluated
☐ No, nonstructural hazards exist that may require mitigation, but a detailed evaluation is not necessary
☐ No, no nonstructural hazards identified ☐ DNK

Where information cannot be verified, screener shall note the following: EST = Estimated or unreliable data <u>OR</u> DNK = Do Not Know

Legend:	MRF = Moment-resisting frame	RC = Reinforced concrete	URM INF = Unreinforced masonry infill	MH = Manufactured Housing	FD = Flexible diaphragm
	BR = Braced frame	SW = Shear wall	TU = Tilt up	LM = Light metal	RD = Rigid diaphragm

Figure 7-19 Completed Level 1 Data Collection Form for the main building (original plus addition) at Washington Middle School.

Rapid Visual Screening of Buildings for Potential Seismic Hazards

FEMA P-154 Data Collection Form

Optional Level 2 data collection to be performed by a civil or structural engineering professional, architect, or graduate student with background in seismic evaluation or design of buildings.

Level 2 (Optional)
HIGH Seismicity

Bldg Name: WMS - Main Building	**Final Level 1 Score:**	S_{L1} = 1.3	*(do not consider S_{MIN})*
Screener: J. Howard	**Level 1 Irregularity Modifiers:**	*Vertical Irregularity, V_{L1} =* 0	*Plan Irregularity, P_{L1} =* 0
Date/Time: 8/28/13 9am	**ADJUSTED BASELINE SCORE:**	*$S' = (S_{L1} - V_{L1} - P_{L1})$ =* 1.3	

STRUCTURAL MODIFIERS TO ADD TO ADJUSTED BASELINE SCORE

Topic	**Statement** *(If statement is true, circle the "Yes" modifier; otherwise cross out the modifier.)*		**Yes**	**Subtotals**
Vertical Irregularity, V_{L2}	Sloping Site	W1 building: There is at least a full story grade change from one side of the building to the other.	-1.2	
		Non-W1 building: There is at least a full story grade change from one side of the building to the other.	-0.3	
	Weak and/or Soft Story *(circle one maximum)*	W1 building cripple wall: An unbraced cripple wall is visible in the crawl space.	-0.6	
		W1 house over garage: Underneath an occupied story, there is a garage opening without a steel moment frame, and there is less than 8' of wall on the same line (for multiple occupied floors above, use 16' of wall minimum).	-1.2	
		W1A building open front: There are openings at the ground story (such as for parking) over at least 50% of the length of the building.	-1.2	
		Non-W1 building: Length of lateral system at any story is less than 50% of that at story above or height of any story is more than 2.0 times the height of the story above.	-0.9	
		Non-W1 building: Length of lateral system at any story is between 50% and 75% of that at story above or height of any story is between 1.3 and 2.0 times the height of the story above.	-0.5	
	Setback	Vertical elements of the lateral system at an upper story are outboard of those at the story below causing the diaphragm to cantilever at the offset.	-1.0	
		Vertical elements of the lateral system at upper stories are inboard of those at lower stories.	*[✓ -0.5]	
		There is an in-plane offset of the lateral elements that is greater than the length of the elements.	-0.3	
	Short Column/ Pier	C1,C2,C3,PC1,PC2,RM1,RM2: At least 20% of columns (or piers) along a column line in the lateral system have height/depth ratios less than 50% of the nominal height/depth ratio at that level.	-0.5	
		C1,C2,C3,PC1,PC2,RM1,RM2: The column depth (or pier width) is less than one half of the depth of the spandrel, or there are infill walls or adjacent floors that shorten the column.	-0.5	
	Split Level	There is a split level at one of the floor levels or at the roof.	[✓ -0.5]	
	Other Irregularity	There is another observable severe vertical irregularity that obviously affects the building's seismic performance.	-1.0	V_{L2} = -1.0
		There is another observable moderate vertical irregularity that may affect the building's seismic performance.	-0.5	*(Cap at -1.2)*
Plan Irregularity, P_{L2}	Torsional irregularity: Lateral system does not appear relatively well distributed in plan in either or both directions. *(Do not include the W1A open front irregularity listed above.)*		*[✓ -0.7]	
	Non-parallel system: There are one or more major vertical elements of the lateral system that are not orthogonal to each other.		-0.4	
	Reentrant corner: Both projections from an interior corner exceed 25% of the overall plan dimension in that direction.		*[✓ -0.4]	
	Diaphragm opening: There is an opening in the diaphragm with a width over 50% of the total diaphragm width at that level.		-0.2	
	C1, C2 building out-of-plane offset: The exterior beams do not align with the columns in plan.		-0.4	P_{L2} = -1.1
	Other irregularity: There is another observable plan irregularity that obviously affects the building's seismic performance.		-0.7	*(Cap at -1.1)*
Redundancy	The building has at least two bays of lateral elements on each side of the building in each direction.		[✓ +0.3]	
Pounding	Building is separated from an adjacent structure by less than 1% of the height of the shorter of the building and adjacent structure and:	The floors do not align vertically within 2 feet. *(Cap total pounding modifiers at -1.2)*	-1.0	
		One building is 2 or more stories taller than the other.	-1.0	
		The building is at the end of the block.	-0.5	
S2 Building	"K" bracing geometry is visible.		-1.0	
C1 Building	Flat plate serves as the beam in the moment frame.		-0.4	
PC1/RM1 Bldg	There are roof-to-wall ties that are visible or known from drawings that do not rely on cross-grain bending. *(Do not combine with post-benchmark or retrofit modifier.)*		+0.3	
PC1/RM1 Bldg	The building has closely spaced, full height interior walls (rather than an interior space with few walls such as in a warehouse).		+0.3	
URM	Gable walls are present.		-0.4	
MH	There is a supplemental seismic bracing system provided between the carriage and the ground.		+1.2	
Retrofit	Comprehensive seismic retrofit is visible or known from drawings.		+1.4	M = +0.3

FINAL LEVEL 2 SCORE, $S_{L2} = (S' + V_{L2} + P_{L2} + M) \geq S_{MIN}$: 1.3 − 1.0 − 1.1 + 0.3 = −0.5; use S_{MIN} = 0.3 (Transfer to Level 1 form)

There is observable damage or deterioration or another condition that negatively affects the building's seismic performance: ☐ Yes ☒ No

If yes, describe the condition in the comment box below and indicate on the Level 1 form that detailed evaluation is required independent of the building's score.

OBSERVABLE NONSTRUCTURAL HAZARDS

Location	**Statement** *(Check "Yes" or "No")*	**Yes**	**No**	**Comment**
Exterior	There is an unbraced unreinforced masonry parapet or unbraced unreinforced masonry chimney.		X	
	There is heavy cladding or heavy veneer.		X	
	There is a heavy canopy over exit doors or pedestrian walkways that appears inadequately supported.		X	
	There is an unreinforced masonry appendage over exit doors or pedestrian walkways.		X	
	There is a sign posted on the building that indicates hazardous materials are present.		X	
	There is a taller adjacent building with an unanchored URM wall or unbraced URM parapet or chimney.		X	
	Other observed exterior nonstructural falling hazard:		X	
Interior	There are hollow clay tile or brick partitions at any stair or exit corridor.	X		corridor appears to be hollow clay tile
	Other observed interior nonstructural falling hazard:		X	

Estimated Nonstructural Seismic Performance *(Check appropriate box and transfer to Level 1 form conclusions)*

☒ Potential nonstructural hazards with significant threat to occupant life safety –> Detailed Nonstructural Evaluation recommended
☐ Nonstructural hazards identified with significant threat to occupant life safety –> But no Detailed Nonstructural Evaluation required
☐ Low or no nonstructural hazard threat to occupant life safety –> No Detailed Nonstructural Evaluation required

Comments: * Addition has differences in horizontal dimension, floor height, and structural framing. Therefore, per Level 2 addition guide, evaluate as single building and consider reentrant corner, setback and torsional irregularities.

Figure 7-20 Completed Level 2 Data Collection Form for the main building (original plus addition) at Washington Middle School.

7.3.7.3 Example 3: Portable Classrooms at New City High School

While screening the main building and auditorium at New City High School, the screener noted a group of portable buildings being used as temporary classrooms. The screener decided to perform Level 1 and Level 2 screenings of these buildings using a blank Data Collection Form. He extracted soil type information and geologic hazards from the pre-filled Data Collection Form for the main building.

Figure 7-21 Exterior view portable classrooms at New City High School (from www.fema.gov).

The screener counted two rows of five portables, all of apparently identical size, use, and construction. Because of their uniformity, the screener opted to complete only one Data Collection Form for all ten of the buildings.

The screener was able to speak directly to the facilities manager of the high school, who recalled that the portables had been installed in 2006 with seismic bracing systems. The screener noted this information in the comments section of the form and included in the name of the facilities manager on the contact portion of the form. The screener attempted to confirm the existence of the bracing by looking under the portables, but all of the portables had continuous skirts that blocked his view.

Using FEMA Building Type MH (manufactured housing), the screener calculated a Level 1 Final Score of 1.8. He then completed the Level 2 portion of the form, which provides a positive modifier for MH buildings with seismic bracing systems. The resulting Level 2 Final Score was 3.0. Based on the Level 2 score, the screener indicated that additional detailed structural evaluation of the portables was not required. He reviewed each portable for potential falling hazards, but none were observed.

The completed Level 1 and Level 2 Data Collection Forms are shown in Figure 7-22 and 7-23, respectively.

7.3.8 Step 8: Review by the Supervising Engineer

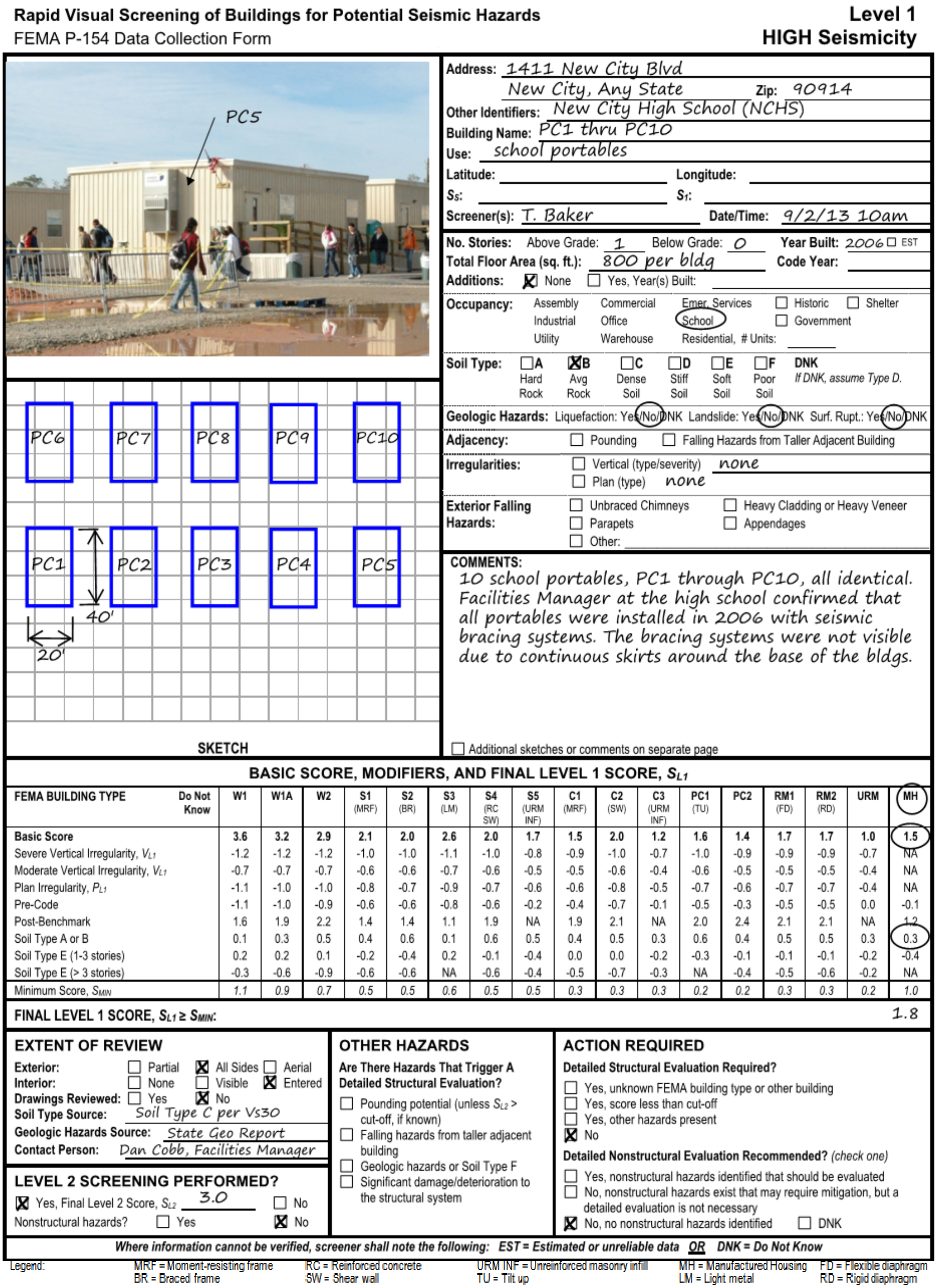
Following the completion of the field screening, the screeners scanned their completed forms and any additional notes or sketches. These scans, along with photographs of the buildings, were transmitted to the Supervising Engineers. The two engineers on the project team reviewed the forms, comparing the photographs and sketches to the building characteristics noted (such as number of stories, irregularities, and FEMA Building Type), at times correcting inconsistencies. The score calculations were double-checked with particular emphasis on reviewing that the proper Basic Score and Score Modifiers were applied and that the transfer of the Level 2 score to the Level 1 form was correct. Notes from screeners were carefully reviewed, particularly where the note indicated the screener's uncertainty. If a screener indicated uncertainty (such as building age or whether an observed condition qualified as an irregularity), the Supervising Engineers reviewed the photos and the sketches to make a determination. Finally, the Supervising Engineer checked that no "Other Hazards" were overlooked in determining whether to require a Detailed Structural Evaluation. In a few cases, the Supervising Engineer performed a follow-up screening to verify building age and FEMA Building Type.

When the reviewers were satisfied with the completed forms, the data recorded on the paper forms were entered into the record-keeping spreadsheet. Photographs, sketches, and additional pages of notes were scanned and saved to a file folder.

Electronic scores were calculated within the spreadsheet using the automation that had previously been developed.

7.3.9 Step 9: Report to State Legislature

The project team discussed the RVS results looking for patterns and inconsistencies. They presented the results in a report to the State Legislature. The report summarized methodology and criteria used in the screening program, and gave findings and conclusions, including scoring results and trends.



Rapid Visual Screening of Buildings for Potential Seismic Hazards
FEMA P-154 Data Collection Form

Level 1
HIGH Seismicity

Address: 1411 New City Blvd
New City, Any State **Zip:** 90914
Other Identifiers: New City High School (NCHS)
Building Name: PC1 thru PC10
Use: school portables
Latitude: **Longitude:**
S_S: **S_1:**
Screener(s): T. Baker **Date/Time:** 9/2/13 10am

No. Stories: Above Grade: 1 Below Grade: 0 **Year Built:** 2006 ☐ EST
Total Floor Area (sq. ft.): 800 per bldg **Code Year:**
Additions: ☒ None ☐ Yes, Year(s) Built:

Occupancy: Assembly Commercial Emer. Services ☐ Historic ☐ Shelter
Industrial Office [✓ School] ☐ Government
Utility Warehouse Residential, # Units:

Soil Type: ☐ A Hard Rock ☒ B Avg Rock ☐ C Dense Soil ☐ D Stiff Soil ☐ E Soft Soil ☐ F Poor Soil **DNK** *If DNK, assume Type D.*

Geologic Hazards: Liquefaction: Yes/[✓ No]/DNK Landslide: Yes/[✓ No]/DNK Surf. Rupt.: Yes/[✓ No]/DNK

Adjacency: ☐ Pounding ☐ Falling Hazards from Taller Adjacent Building

Irregularities: ☐ Vertical (type/severity) none
☐ Plan (type) none

Exterior Falling Hazards: ☐ Unbraced Chimneys ☐ Heavy Cladding or Heavy Veneer
☐ Parapets ☐ Appendages
☐ Other:

COMMENTS:
10 school portables, PC1 through PC10, all identical. Facilities Manager at the high school confirmed that all portables were installed in 2006 with seismic bracing systems. The bracing systems were not visible due to continuous skirts around the base of the bldgs.

SKETCH

☐ Additional sketches or comments on separate page

BASIC SCORE, MODIFIERS, AND FINAL LEVEL 1 SCORE, S_{L1}

FEMA BUILDING TYPE	**Do Not Know**	**W1**	**W1A**	**W2**	**S1** (MRF)	**S2** (BR)	**S3** (LM)	**S4** (RC SW)	**S5** (URM INF)	**C1** (MRF)	**C2** (SW)	**C3** (URM INF)	**PC1** (TU)	**PC2**	**RM1** (FD)	**RM2** (RD)	**URM**	[✓ **MH**]
Basic Score		**3.6**	**3.2**	**2.9**	**2.1**	**2.0**	**2.6**	**2.0**	**1.7**	**1.5**	**2.0**	**1.2**	**1.6**	**1.4**	**1.7**	**1.7**	**1.0**	[✓ **1.5**]
Severe Vertical Irregularity, V_{L1}		-1.2	-1.2	-1.2	-1.0	-1.0	-1.1	-1.0	-0.8	-0.9	-1.0	-0.7	-1.0	-0.9	-0.9	-0.9	-0.7	NA
Moderate Vertical Irregularity, V_{L1}		-0.7	-0.7	-0.7	-0.6	-0.6	-0.7	-0.6	-0.5	-0.5	-0.6	-0.4	-0.6	-0.5	-0.5	-0.5	-0.4	NA
Plan Irregularity, P_{L1}		-1.1	-1.0	-1.0	-0.8	-0.7	-0.9	-0.7	-0.6	-0.6	-0.8	-0.5	-0.7	-0.6	-0.7	-0.7	-0.4	NA
Pre-Code		-1.1	-1.0	-0.9	-0.6	-0.6	-0.8	-0.6	-0.2	-0.4	-0.7	-0.1	-0.5	-0.3	-0.5	-0.5	0.0	-0.1
Post-Benchmark		1.6	1.9	2.2	1.4	1.4	1.1	1.9	NA	1.9	2.1	NA	2.0	2.4	2.1	2.1	NA	1.2
Soil Type A or B		0.1	0.3	0.5	0.4	0.6	0.1	0.6	0.5	0.4	0.5	0.3	0.6	0.4	0.5	0.5	0.3	[✓ 0.3]
Soil Type E (1-3 stories)		0.2	0.2	0.1	-0.2	-0.4	0.2	-0.1	-0.4	0.0	0.0	-0.2	-0.3	-0.1	-0.1	-0.1	-0.2	-0.4
Soil Type E (> 3 stories)		-0.3	-0.6	-0.9	-0.6	-0.6	NA	-0.6	-0.4	-0.5	-0.7	-0.3	NA	-0.4	-0.5	-0.6	-0.2	NA
Minimum Score, S_{MIN}		*1.1*	*0.9*	*0.7*	*0.5*	*0.5*	*0.6*	*0.5*	*0.5*	*0.3*	*0.3*	*0.3*	*0.2*	*0.2*	*0.3*	*0.3*	*0.2*	*1.0*

FINAL LEVEL 1 SCORE, $S_{L1} \geq S_{MIN}$: 1.8

EXTENT OF REVIEW
Exterior: ☐ Partial ☒ All Sides ☐ Aerial
Interior: ☐ None ☐ Visible ☒ Entered
Drawings Reviewed: ☐ Yes ☒ No
Soil Type Source: Soil Type C per Vs30
Geologic Hazards Source: State Geo Report
Contact Person: Dan Cobb, Facilities Manager

LEVEL 2 SCREENING PERFORMED?
☒ Yes, Final Level 2 Score, S_{L2} 3.0 ☐ No
Nonstructural hazards? ☐ Yes ☒ No

OTHER HAZARDS
Are There Hazards That Trigger A Detailed Structural Evaluation?
- ☐ Pounding potential (unless S_{L2} > cut-off, if known)
- ☐ Falling hazards from taller adjacent building
- ☐ Geologic hazards or Soil Type F
- ☐ Significant damage/deterioration to the structural system

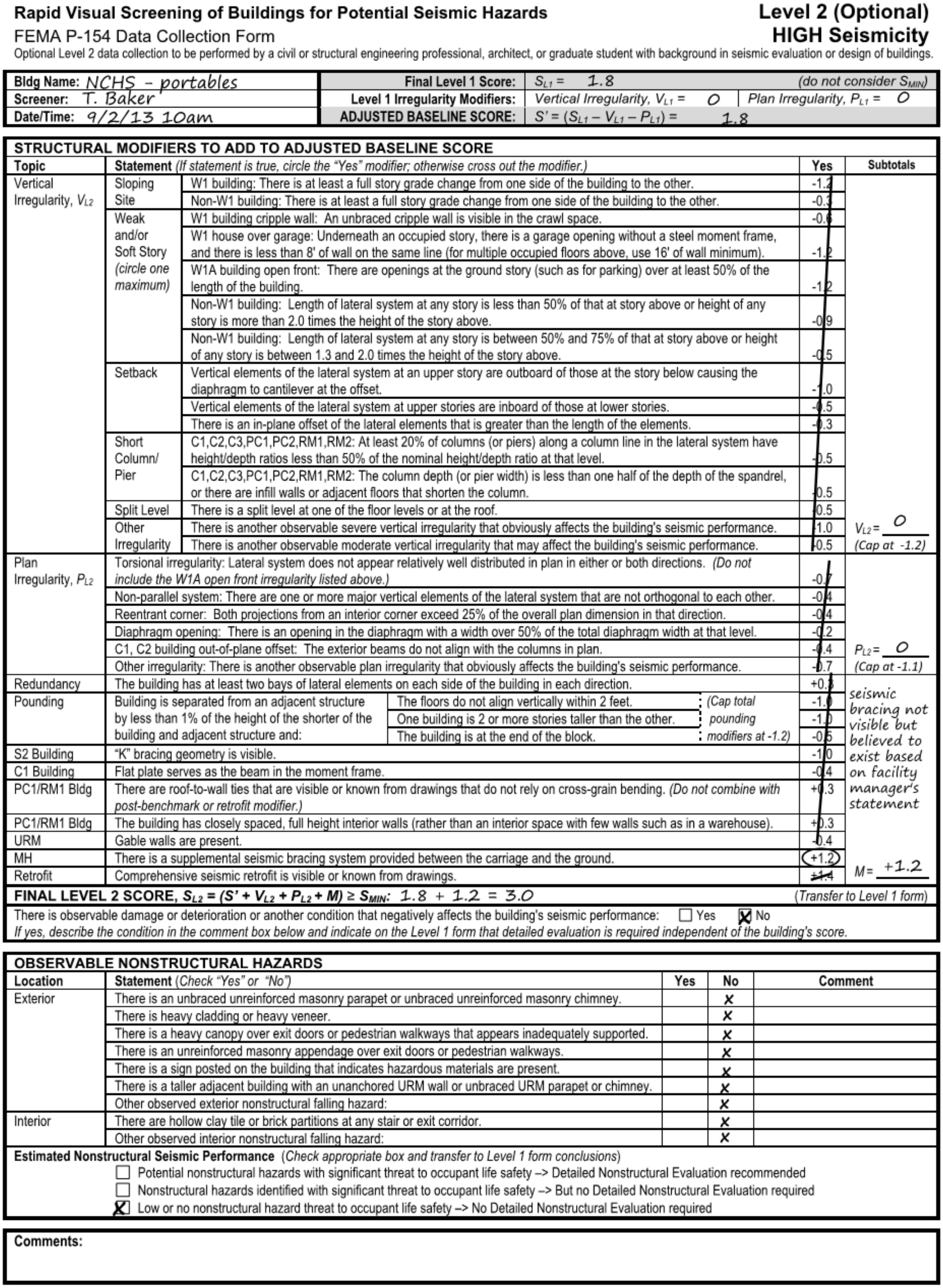
ACTION REQUIRED
Detailed Structural Evaluation Required?
- ☐ Yes, unknown FEMA building type or other building
- ☐ Yes, score less than cut-off
- ☐ Yes, other hazards present
- ☒ No

Detailed Nonstructural Evaluation Recommended? *(check one)*
- ☐ Yes, nonstructural hazards identified that should be evaluated
- ☐ No, nonstructural hazards exist that may require mitigation, but a detailed evaluation is not necessary
- ☒ No, no nonstructural hazards identified ☐ DNK

Where information cannot be verified, screener shall note the following: EST = Estimated or unreliable data OR DNK = Do Not Know

Legend:
MRF = Moment-resisting frame
BR = Braced frame
RC = Reinforced concrete
SW = Shear wall
URM INF = Unreinforced masonry infill
TU = Tilt up
MH = Manufactured Housing
LM = Light metal
FD = Flexible diaphragm
RD = Rigid diaphragm

Figure 7-22 Completed Level 1 Data Collection Form for portable classrooms at New City High School.



Rapid Visual Screening of Buildings for Potential Seismic Hazards **Level 2 (Optional)**

FEMA P-154 Data Collection Form **HIGH Seismicity**

Optional Level 2 data collection to be performed by a civil or structural engineering professional, architect, or graduate student with background in seismic evaluation or design of buildings.

Bldg Name: NCHS - portables	**Final Level 1 Score:**	S_{L1} = 1.8 *(do not consider S_{MIN})*
Screener: T. Baker	**Level 1 Irregularity Modifiers:**	*Vertical Irregularity, V_{L1} =* 0 | *Plan Irregularity, P_{L1} =* 0
Date/Time: 9/2/13 10am	**ADJUSTED BASELINE SCORE:**	*$S' = (S_{L1} - V_{L1} - P_{L1})$ =* 1.8

STRUCTURAL MODIFIERS TO ADD TO ADJUSTED BASELINE SCORE

Topic	**Statement** *(If statement is true, circle the "Yes" modifier; otherwise cross out the modifier.)*		**Yes**	**Subtotals**
Vertical Irregularity, V_{L2}	Sloping Site	W1 building: There is at least a full story grade change from one side of the building to the other.	~~-1.2~~	
		Non-W1 building: There is at least a full story grade change from one side of the building to the other.	~~-0.3~~	
	Weak and/or Soft Story *(circle one maximum)*	W1 building cripple wall: An unbraced cripple wall is visible in the crawl space.	~~-0.6~~	
		W1 house over garage: Underneath an occupied story, there is a garage opening without a steel moment frame, and there is less than 8' of wall on the same line (for multiple occupied floors above, use 16' of wall minimum).	~~-1.2~~	
		W1A building open front: There are openings at the ground story (such as for parking) over at least 50% of the length of the building.	~~-1.2~~	
		Non-W1 building: Length of lateral system at any story is less than 50% of that at story above or height of any story is more than 2.0 times the height of the story above.	~~-0.9~~	
		Non-W1 building: Length of lateral system at any story is between 50% and 75% of that at story above or height of any story is between 1.3 and 2.0 times the height of the story above.	~~-0.5~~	
	Setback	Vertical elements of the lateral system at an upper story are outboard of those at the story below causing the diaphragm to cantilever at the offset.	~~-1.0~~	
		Vertical elements of the lateral system at upper stories are inboard of those at lower stories.	~~-0.5~~	
		There is an in-plane offset of the lateral elements that is greater than the length of the elements.	~~-0.3~~	
	Short Column/ Pier	C1,C2,C3,PC1,PC2,RM1,RM2: At least 20% of columns (or piers) along a column line in the lateral system have height/depth ratios less than 50% of the nominal height/depth ratio at that level.	~~-0.5~~	
		C1,C2,C3,PC1,PC2,RM1,RM2: The column depth (or pier width) is less than one half of the depth of the spandrel, or there are infill walls or adjacent floors that shorten the column.	~~-0.5~~	
	Split Level	There is a split level at one of the floor levels or at the roof.	~~-0.5~~	
	Other Irregularity	There is another observable severe vertical irregularity that obviously affects the building's seismic performance.	~~-1.0~~	V_{L2} = 0
		There is another observable moderate vertical irregularity that may affect the building's seismic performance.	~~-0.5~~	*(Cap at -1.2)*
Plan Irregularity, P_{L2}	Torsional irregularity: Lateral system does not appear relatively well distributed in plan in either or both directions. *(Do not include the W1A open front irregularity listed above.)*		~~-0.7~~	
	Non-parallel system: There are one or more major vertical elements of the lateral system that are not orthogonal to each other.		~~-0.4~~	
	Reentrant corner: Both projections from an interior corner exceed 25% of the overall plan dimension in that direction.		~~-0.4~~	
	Diaphragm opening: There is an opening in the diaphragm with a width over 50% of the total diaphragm width at that level.		~~-0.2~~	
	C1, C2 building out-of-plane offset: The exterior beams do not align with the columns in plan.		~~-0.4~~	P_{L2} = 0
	Other irregularity: There is another observable plan irregularity that obviously affects the building's seismic performance.		~~-0.7~~	*(Cap at -1.1)*
Redundancy	The building has at least two bays of lateral elements on each side of the building in each direction.		~~+0.3~~	seismic bracing not visible but believed to exist based on facility manager's statement
Pounding	Building is separated from an adjacent structure by less than 1% of the height of the shorter of the building and adjacent structure and:	The floors do not align vertically within 2 feet. *(Cap total pounding modifiers at -1.2)*	~~-1.0~~	
		One building is 2 or more stories taller than the other.	~~-1.0~~	
		The building is at the end of the block.	~~-0.5~~	
S2 Building	"K" bracing geometry is visible.		~~-1.0~~	
C1 Building	Flat plate serves as the beam in the moment frame.		~~-0.4~~	
PC1/RM1 Bldg	There are roof-to-wall ties that are visible or known from drawings that do not rely on cross-grain bending. *(Do not combine with post-benchmark or retrofit modifier.)*		~~+0.3~~	
PC1/RM1 Bldg	The building has closely spaced, full height interior walls (rather than an interior space with few walls such as in a warehouse).		~~+0.3~~	
URM	Gable walls are present.		~~-0.4~~	
MH	There is a supplemental seismic bracing system provided between the carriage and the ground.		[✓ +1.2]	
Retrofit	Comprehensive seismic retrofit is visible or known from drawings.		~~+1.4~~	M = +1.2

FINAL LEVEL 2 SCORE, $S_{L2} = (S' + V_{L2} + P_{L2} + M) \geq S_{MIN}$: 1.8 + 1.2 = 3.0 *(Transfer to Level 1 form)*

There is observable damage or deterioration or another condition that negatively affects the building's seismic performance: ☐ Yes ☒ No

If yes, describe the condition in the comment box below and indicate on the Level 1 form that detailed evaluation is required independent of the building's score.

OBSERVABLE NONSTRUCTURAL HAZARDS

Location	**Statement** (*Check "Yes" or "No"*)	**Yes**	**No**	**Comment**
Exterior	There is an unbraced unreinforced masonry parapet or unbraced unreinforced masonry chimney.		✗	
	There is heavy cladding or heavy veneer.		✗	
	There is a heavy canopy over exit doors or pedestrian walkways that appears inadequately supported.		✗	
	There is an unreinforced masonry appendage over exit doors or pedestrian walkways.		✗	
	There is a sign posted on the building that indicates hazardous materials are present.		✗	
	There is a taller adjacent building with an unanchored URM wall or unbraced URM parapet or chimney.		✗	
	Other observed exterior nonstructural falling hazard:		✗	
Interior	There are hollow clay tile or brick partitions at any stair or exit corridor.		✗	
	Other observed interior nonstructural falling hazard:		✗	

Estimated Nonstructural Seismic Performance (*Check appropriate box and transfer to Level 1 form conclusions*)

- ☐ Potential nonstructural hazards with significant threat to occupant life safety –> Detailed Nonstructural Evaluation recommended
- ☐ Nonstructural hazards identified with significant threat to occupant life safety –> But no Detailed Nonstructural Evaluation required
- ☒ Low or no nonstructural hazard threat to occupant life safety –> No Detailed Nonstructural Evaluation required

Comments:

Figure 7-23 Completed Level 2 Data Collection Form for portable classrooms at New City High School.

7.3.10 *Example Level 1 and Level 2 Screening Using Electronic Scoring*

As an alternative to the use of paper-based scoring, the school buildings were also evaluated using electronic scoring. During the pre-field planning stage, site-specific seismic hazard values, S_s and S_1, were determined for each school site from the USGS online tool available at http://earthquake.usgs.gov/designmaps/usapp/.. Although all of the examples described below are located in High seismicity regions, the site-specific seismicity varies from site to site, resulting in variations in the difference between the paper-based score and the electronic score.

7.3.10.1 Example 1: Roosevelt Elementary School

The site-specific seismic hazard values, S_s and S_1, for Roosevelt Elementary School were determined to be 1.48g and 0.39g, respectively. The school is a two-story RM2 located on Soil Type D with Severe Vertical and Plan irregularities. Electronic scores for the school are calculated below using the guidance presented in Chapter 9 of FEMA P-155 (FEMA, 2015):

1. Building height, H = 2 stories x 12'/story = 24'
2. Building period, $T = 0.025 \text{ x } H^{0.75} = 0.27\text{sec}$
3. $S_S/S_1 = 1.48\text{g}/0.39\text{g} = 3.79 > T$; therefore, interpolate using S_S (adjusted for Soil Type CD). Linear interpolation will be used FEMA P-155 Chapter 9 discusses other types of interpolation that could be used.
4. Adjust S_S for Soil Type CD: $S_S = 1.48\text{g} > 1.25\text{g}$, therefore, $F_a = 1.0$.
5. $F_a \times S_S = 1.0 \times 1.48\text{g} = 1.48\text{g}$ (This is between High, $F_a \times S_S = 1.21\text{g}$ with Basic Score for RM2 = 1.7, and Very High, $F_a \times S_S = 2.25\text{g}$ with Basic Score for RM2 = 1.1.)
6. Electronic Basic Score is calculated with the following linear interpolation formula from Chapter 9 of FEMA P-155:

$$y = y_0 + (x - x_0)\frac{(y_1 - y_0)}{(x_1 - x_0)}$$

$$y = 1.1 + (1.48 - 2.25) \times (1.7 - 1.1) / (1.21 - 2.25) = 1.54$$

7. Similarly, the applicable electronic Level 1 modifiers are calculated as -0.85 (Severe Vertical Irregularity), -0.62 (Plan Irregularity), and 0.3 (Minimum Score).
8. Electronic Level 1 Score = 1.54 - 0.85 - 0.62 = 0.07 < S_{MIN} = 0.3; Use S_{L1} = 0.3.

9. The applicable electronic Level 2 modifiers are calculated as -0.47 (Short Column/Pier), -0.65 (Torsional Irregularity), and 0.27 (Redundancy).
10. Electronic Level 2 Score = 1.54 - 0.47 - 0.65 + 0.27 = 0.69 > S_{MIN}.

7.3.10.2 Example 2: Washington Middle School

The site-specific seismic hazard values, S_s and S_1, for Washington Middle School were determined to be 1.21g and 0.54g, respectively. This is close to the median values used in High seismicity. The main portion of the building is a three-story C2, while the addition is a one-story S2. The school is located on Soil Type C.

The Basic Score for Building Type C2 using electronic scoring and considering the above site-specific seismicity is 1.99, and the Pre-Code Score Modifier is -0.70. The resulting electronic Level 1 Score is 1.30. The Basic Score for Building Type S2 using electronic scoring and considering the site-specific seismicity is also 1.99, and the Plan Irregularity Score Modifier is -0.70. The resulting electronic Level 1 Score for the addition is 1.30. This is equal to the score for the main portion of the building. Hence, the Final Level 2 Score using electronic scoring is 1.30.

The Final Level 2 Score using electronic scoring considers the pre-code C2 building with irregularities due to the addition. Redundancy is also considered. The Final Level 2 Score is 1.99 (Basic Score) - 0.70 (Pre-Code) -0.50 (Vertical Setback) - 0.50 (Split Level) - 0.70 (Torsion) - 0.4 (Reentrant) + 0.30 (Redundancy) = -0.51. This is less than the minimum score, hence, the Final Level 2 Score is taken as 0.30.

7.3.10.3 Example 3: New City High School

The site-specific seismic hazard values, S_s and S_1, for New City High School were determined to be 1.05g and 0.36g, respectively. This indicates a lower seismicity than at Roosevelt Elementary School or Washington Middle School sites even though all are in High seismicity. The building is a one-story MH located on Soil Type B.

The Basic Score for Building Type MH using electronic scoring and considering Soil Type CD is 1.67. The Soil Type B Score Modifier is -0.42. The Final Level 1 Score using electronic scoring is 1.67 + 0.45 = 2.12.

The Final Level 2 Score is 2.12 (Basic Score plus Soil Type B) + 1.20 (Supplemental Seismic Bracing) = 3.32.

The Final Level 1 and Level 2 paper-based and electronic scores are summarized in Table 7-4. Where site-specific seismicity is similar to the median seismicity of the region, such as for Washington Middle School, the electronic scores will be similar to the paper-based scores. Where site-specific seismicity is greater than the median seismicity of the region, such as for Roosevelt Elementary School, the electronic scores will be smaller than the paper-based scores. Finally, where site-specific seismicity is less than the median seismicity of the region, such as for New City High School, the electronic scores will be greater than the paper-based scores.

Table 7-4 Summary of Paper-Based and Electronic Scores

School	Paper-Based Score		Electronic Score	
	Level 1 Score	Level 2 Score	Level 1 Score	Level 2 Score
Roosevelt Elementary School	0.3	0.8	0.3	0.7
Washington Middle School	1.3	0.3	1.3	0.3
New City High School	1.5	2.7	2.1	3.3

Appendix A

Maps Showing Seismicity Regions

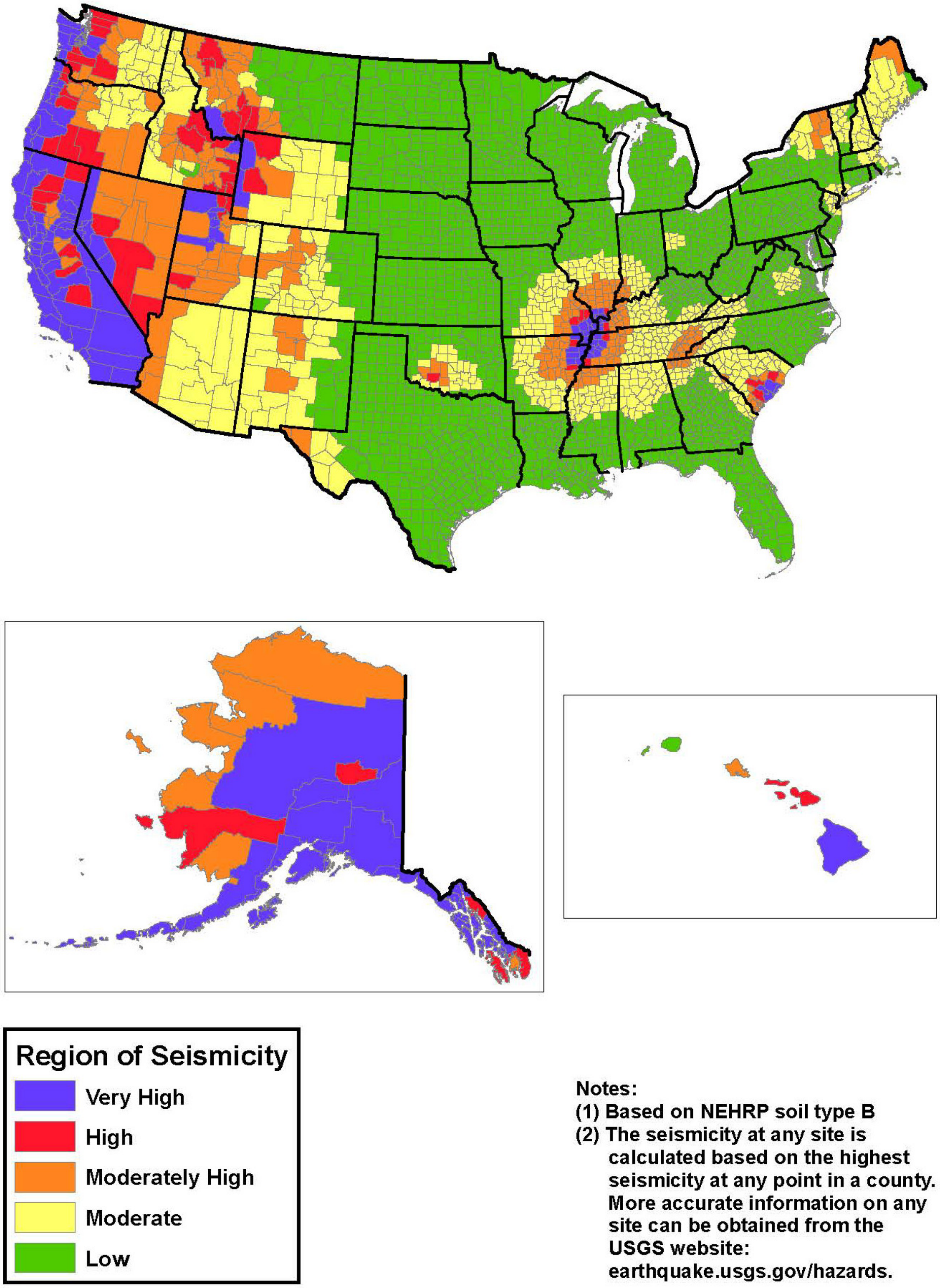
This appendix provides seismicity region designations of Low, Moderate, Moderately High, High, and Very High for all counties in the United States, based on an assumed Soil Type B throughout the county. The seismicity designation is based on the site-specific values of seismic hazard at a point in the county considering risk-targeted Maximum Considered Earthquake (MCE_R) ground motions. The determination is based on criteria set in Table 2-2 and repeated here as Table A-1. The designation at any county is based on the highest seismicity expected at any location in the county. A more accurate determination of the seismicity of a specific site can be made using the site-specific procedure described in Chapter 2.

Table A-1 Seismicity Region Determination from MCE_R Spectral Acceleration Response (from ASCE/SEI 41-13)

Seismicity Region		Spectral Acceleration Response, S_S (short-period, or 0.2 seconds)	Spectral Acceleration Response, S_1 (long-period, or 1.0 second)
🟩	Low	less than 0.250g	less than 0.100g
🟨	Moderate	greater than or equal to 0.250g but less than 0.500g	greater than or equal to 0.100g but less than 0.200g
🟧	Moderately High	greater than or equal to 0.500g but less than 1.000g	greater than or equal to 0.200g but less than 0.400g
🟥	High	greater than or equal to 1.000g but less than 1.500g	greater than or equal to 0.400g but less than 0.600g
🟪	Very High	greater than or equal to 1.500g	greater than or equal to 0.600g

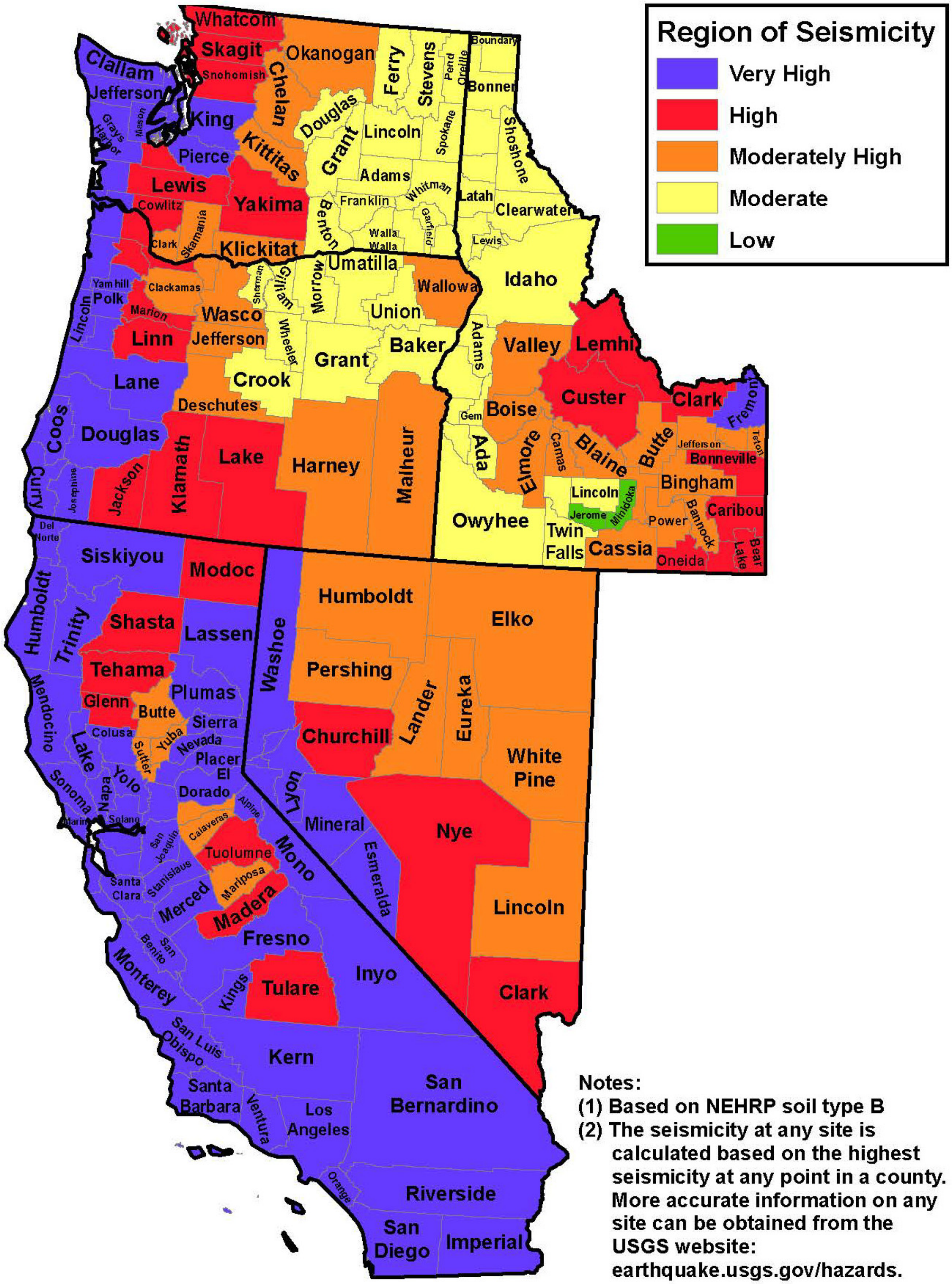
Notes: g = acceleration of gravity in horizontal direction

The maps have been developed by the U.S. Geological Survey. Figure A-1 provides a map of the seismicity regions in the entire United States. The following maps in Figure A-2 through Figure A-11 present seismicity regions in different geographical regions of the United States and its territories.



Notes:
(1) Based on NEHRP soil type B
(2) The seismicity at any site is calculated based on the highest seismicity at any point in a county. More accurate information on any site can be obtained from the USGS website: earthquake.usgs.gov/hazards.

Figure A-1 Very High, High, Moderately High, Moderate, and Low seismicity regions in the United States. A different RVS Data Collection Form has been developed for each of these regions.

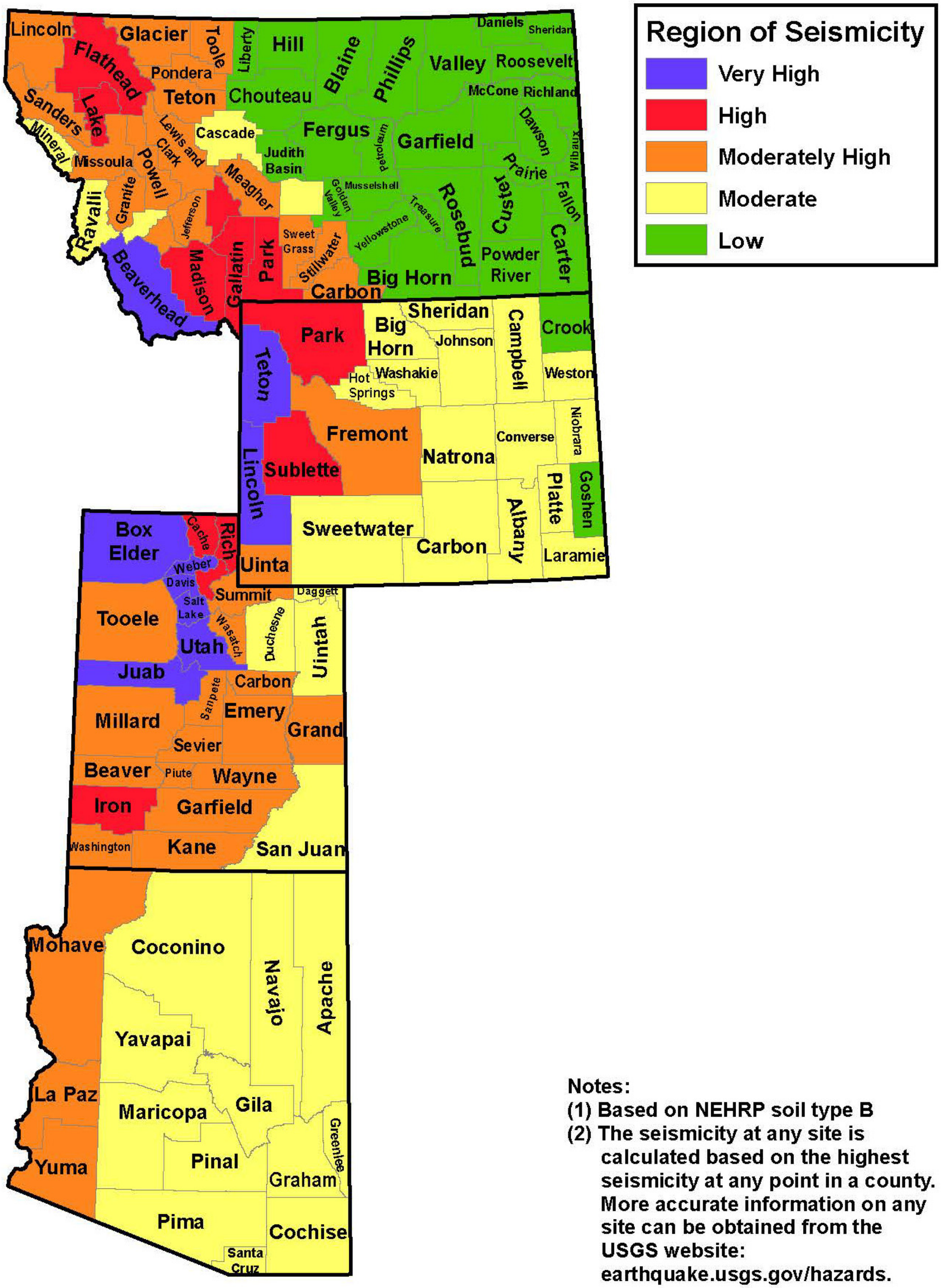


Notes:

(1) Based on NEHRP soil type B

(2) The seismicity at any site is calculated based on the highest seismicity at any point in a county. More accurate information on any site can be obtained from the USGS website: earthquake.usgs.gov/hazards.

Figure A-2 Seismicity regions in California, Idaho, Nevada, Oregon, and Washington.

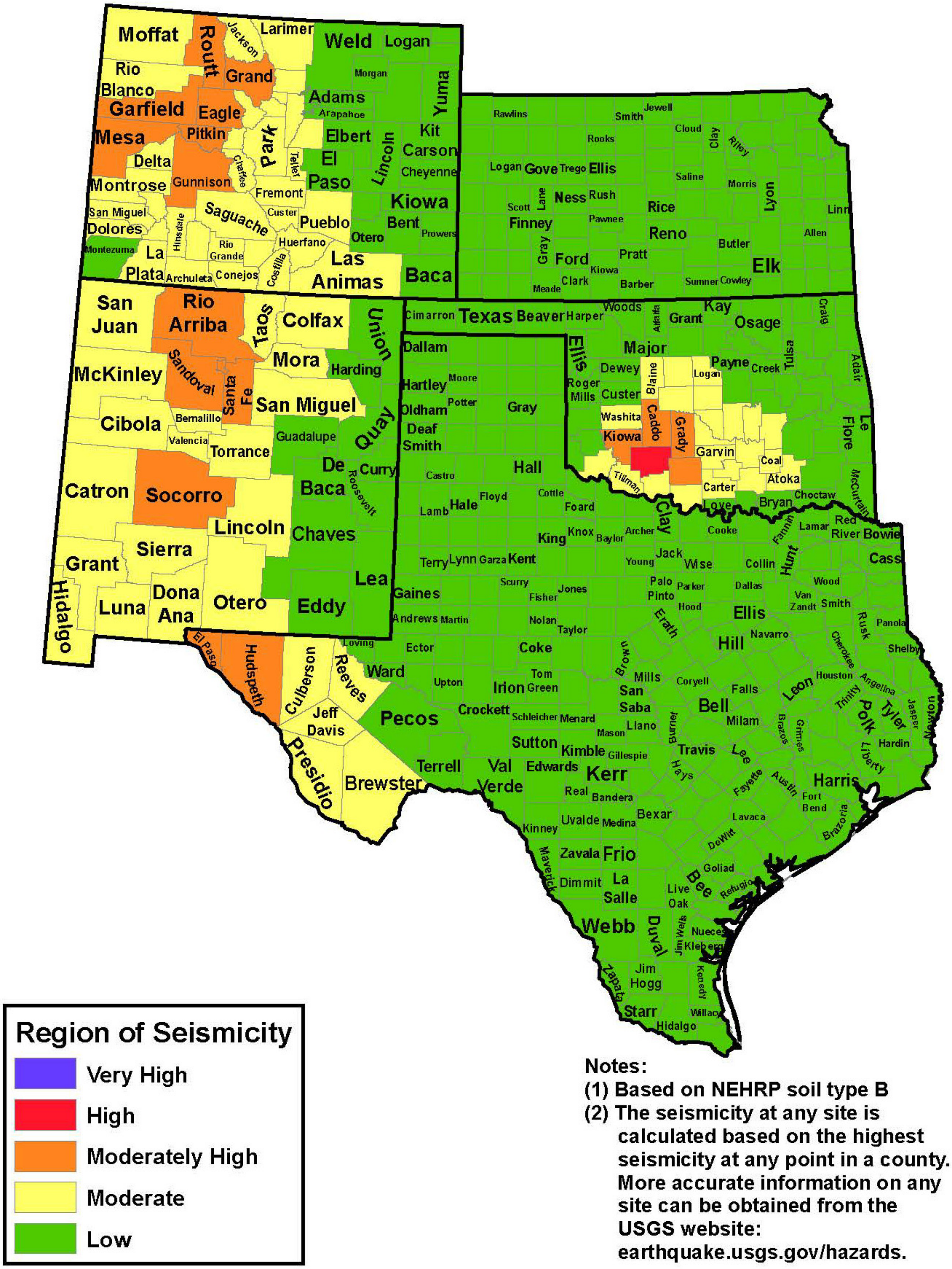


Notes:

(1) Based on NEHRP soil type B

(2) The seismicity at any site is calculated based on the highest seismicity at any point in a county. More accurate information on any site can be obtained from the USGS website: earthquake.usgs.gov/hazards.

Figure A-3 Seismicity regions in Arizona, Montana, Utah, and Wyoming.

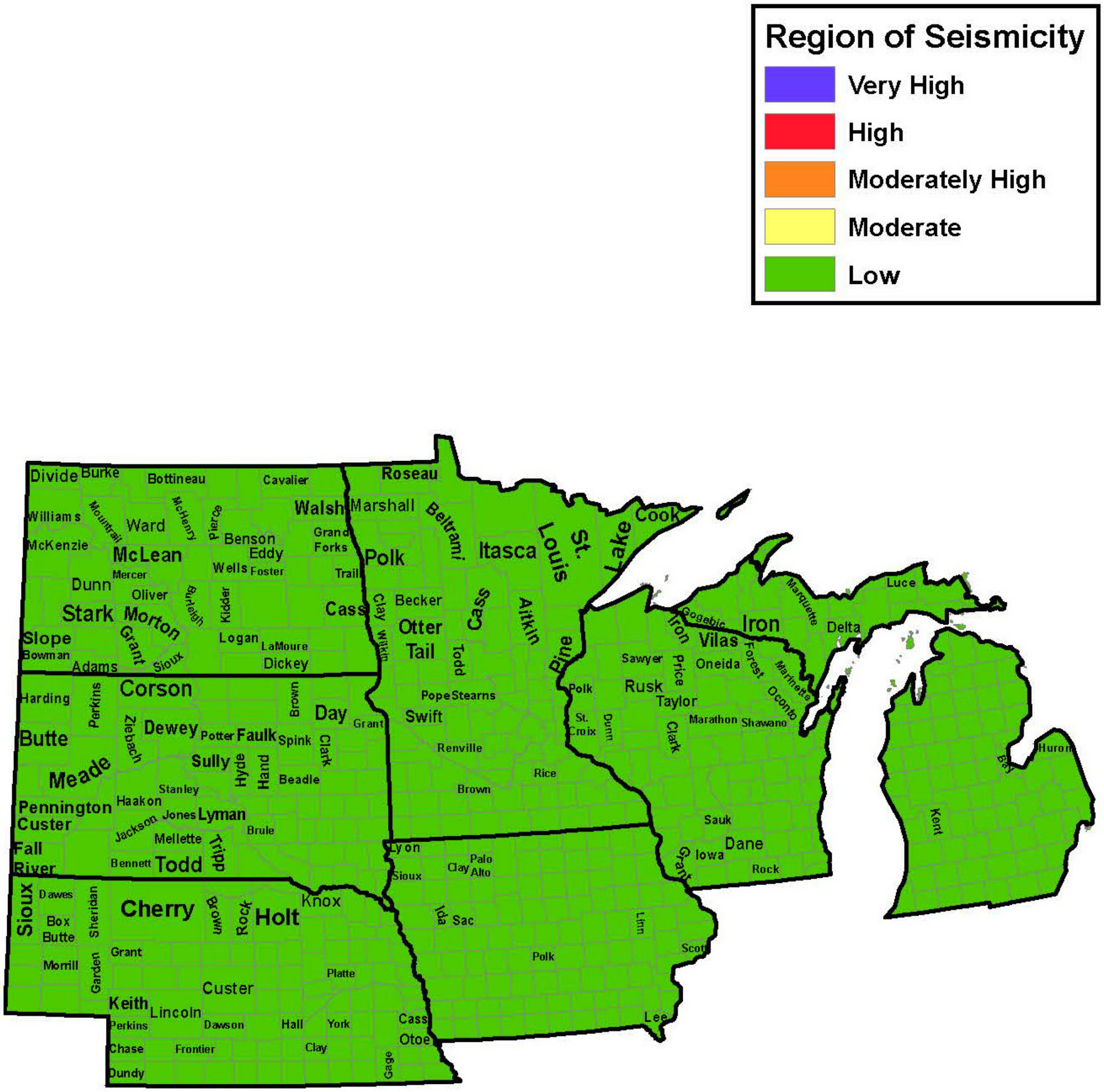


Notes:

(1) Based on NEHRP soil type B

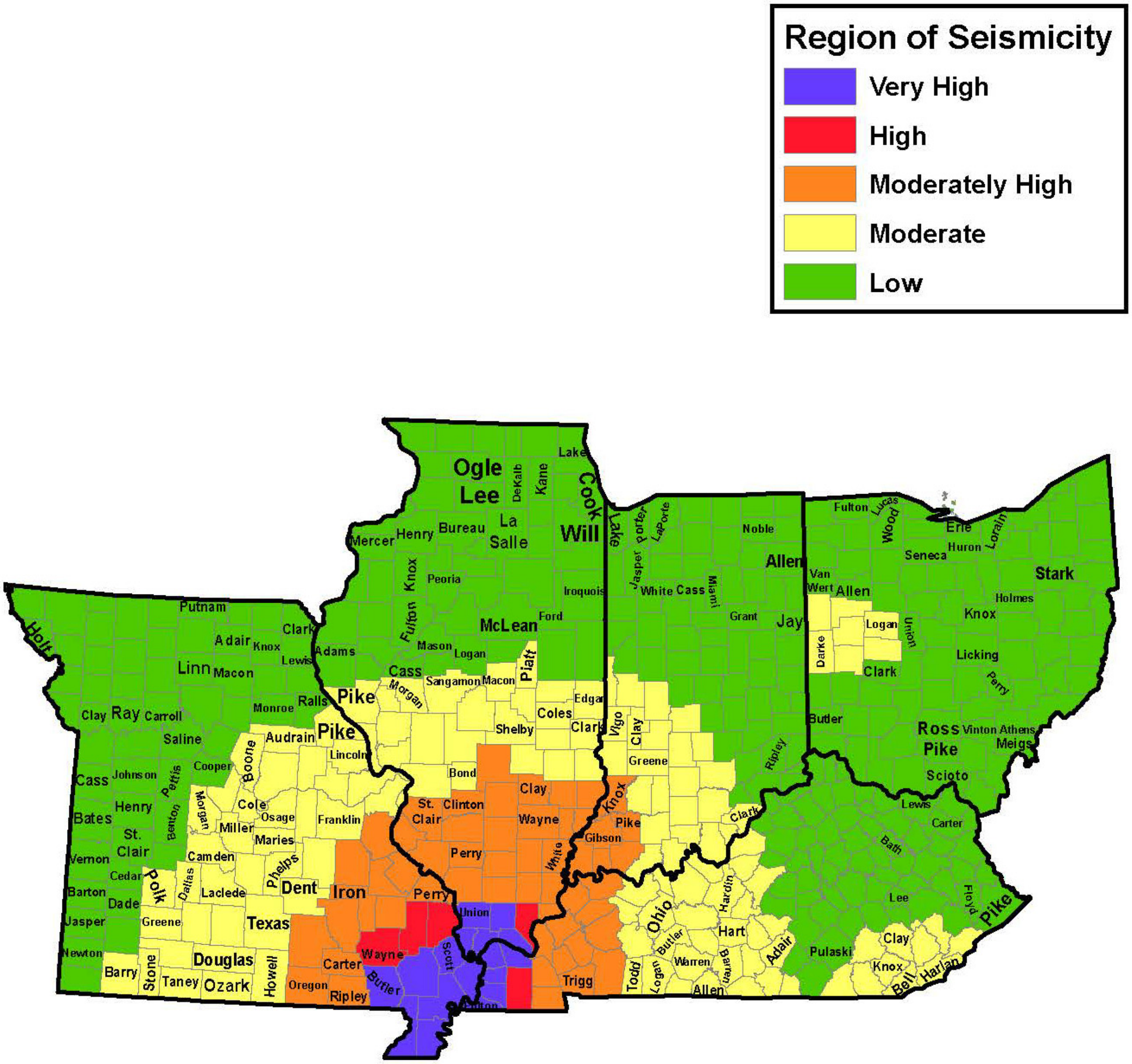
(2) The seismicity at any site is calculated based on the highest seismicity at any point in a county. More accurate information on any site can be obtained from the USGS website: earthquake.usgs.gov/hazards.

Figure A-4 Seismicity regions in Colorado, Kansas, New Mexico, Oklahoma, and Texas.



Notes:
(1) Based on NEHRP soil type B
(2) The seismicity at any site is calculated based on the highest seismicity at any point in a county. More accurate information on any site can be obtained from the USGS website: earthquake.usgs.gov/hazards.

Figure A-5 Seismicity regions in Iowa, Michigan, Nebraska, North Dakota, Minnesota, South Dakota, and Wisconsin.

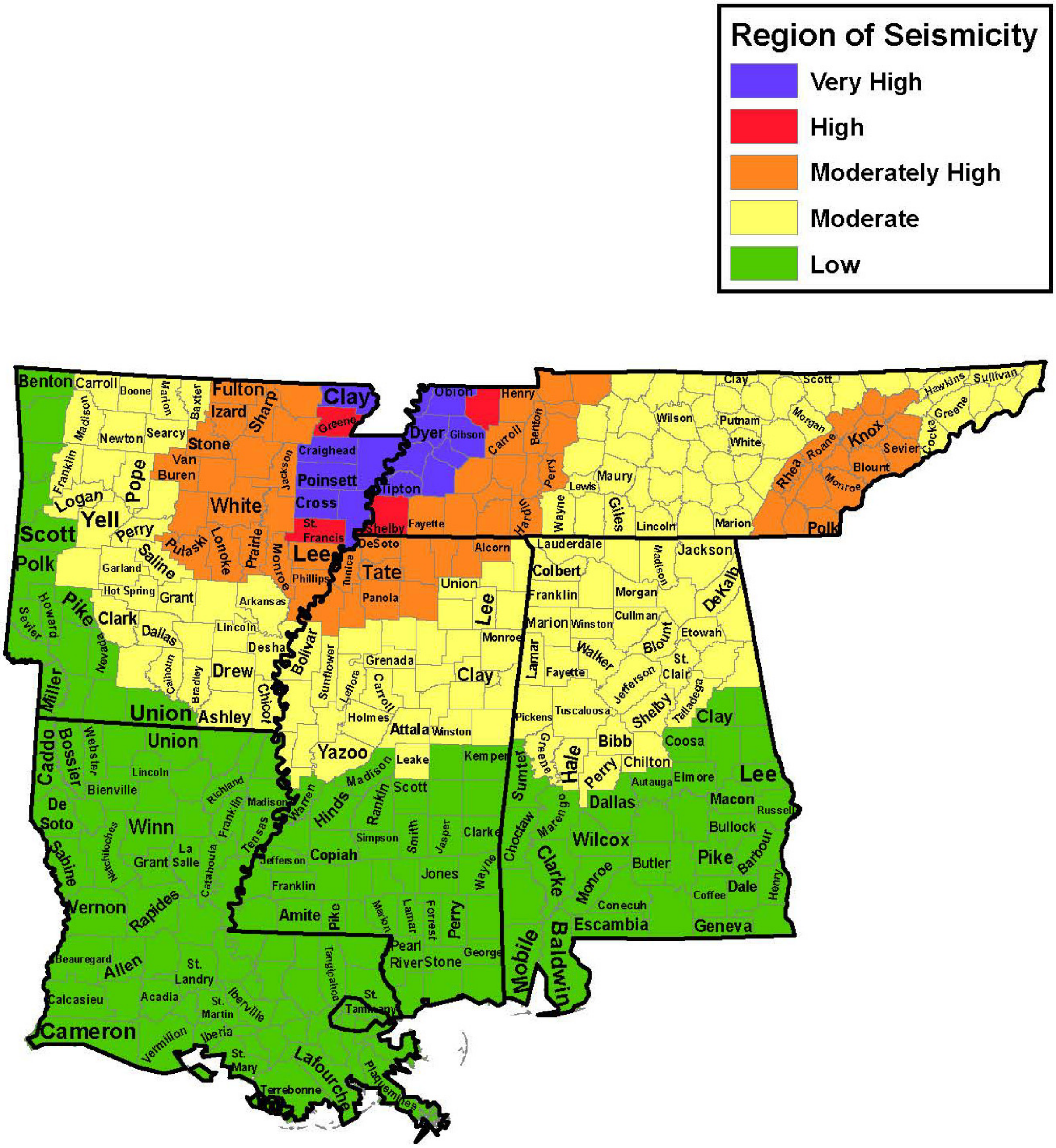


Notes:

(1) Based on NEHRP soil type B

(2) The seismicity at any site is calculated based on the highest seismicity at any point in a county. More accurate information on any site can be obtained from the USGS website: earthquake.usgs.gov/hazards.

Figure A-6 Seismicity regions in Illinois, Indiana, Kentucky, Missouri, and Ohio.

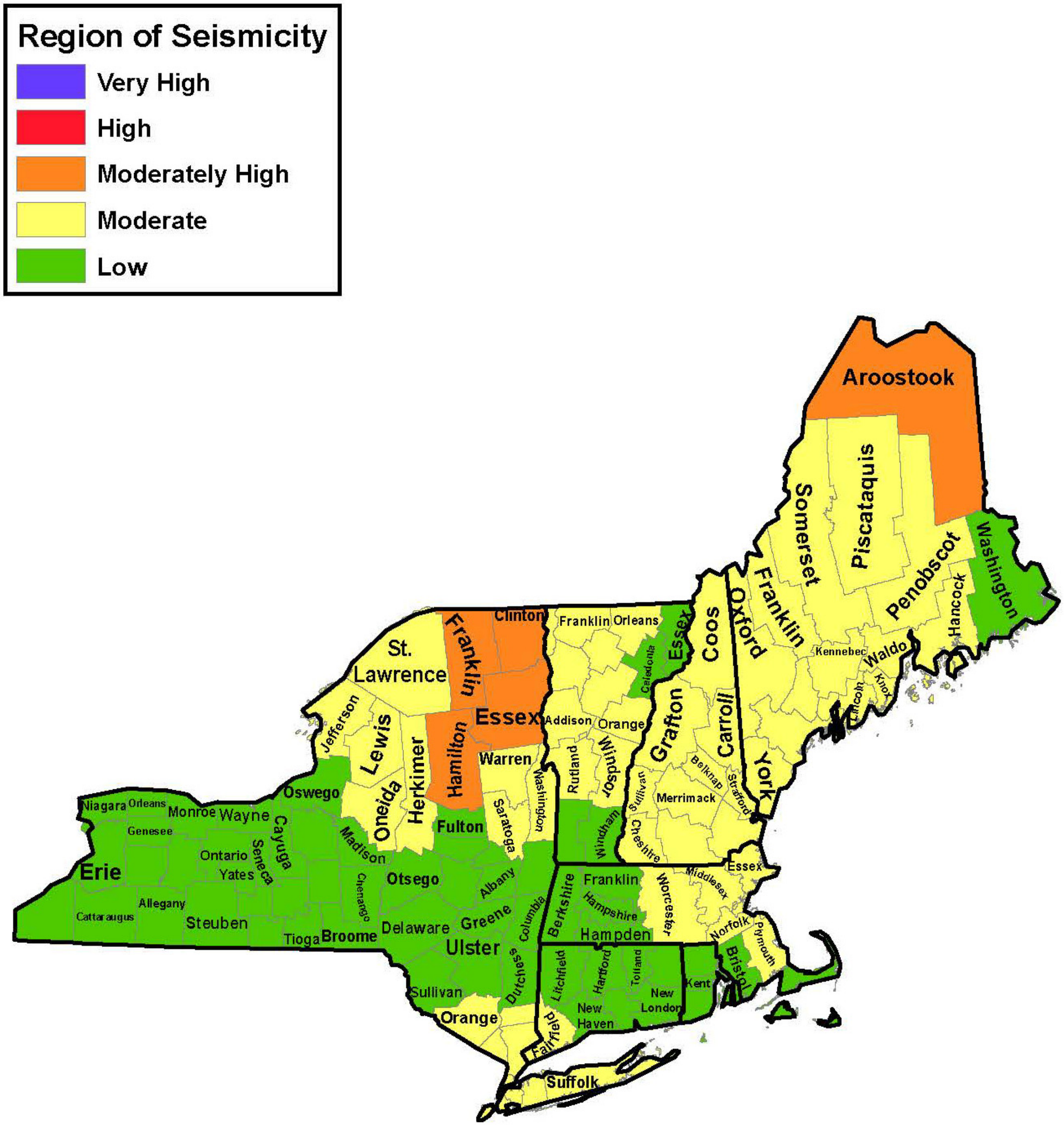


Notes:

(1) Based on NEHRP soil type B

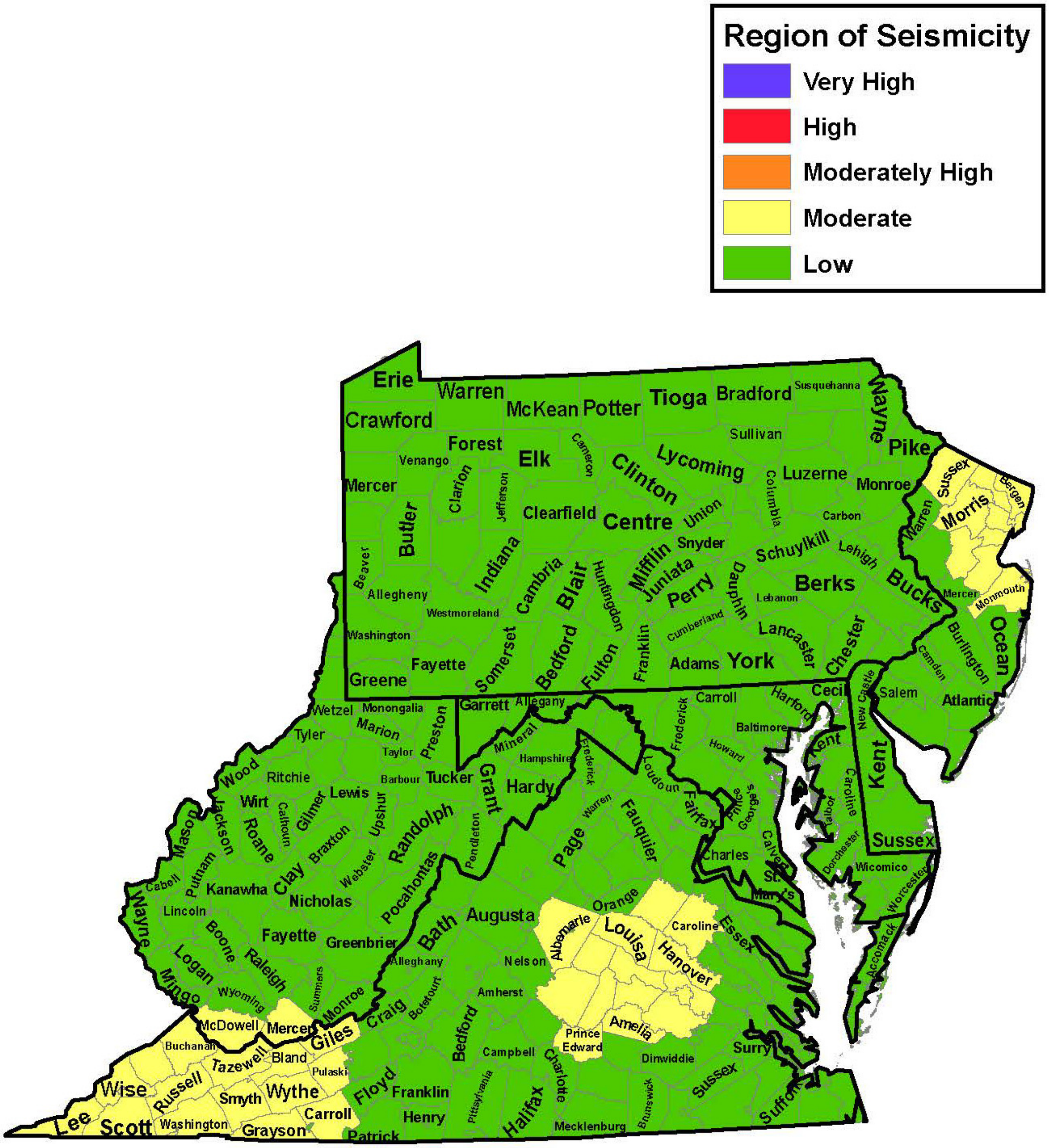
(2) The seismicity at any site is calculated based on the highest seismicity at any point in a county. More accurate information on any site can be obtained from the USGS website: earthquake.usgs.gov/hazards.

Figure A-7 Seismicity regions in Alabama, Arkansas, Louisiana, Mississippi, and Tennessee.



Notes:
(1) Based on NEHRP soil type B
(2) The seismicity at any site is calculated based on the highest seismicity at any point in a county. More accurate information on any site can be obtained from the USGS website: earthquake.usgs.gov/hazards.

Figure A-8 Seismicity regions in Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont.

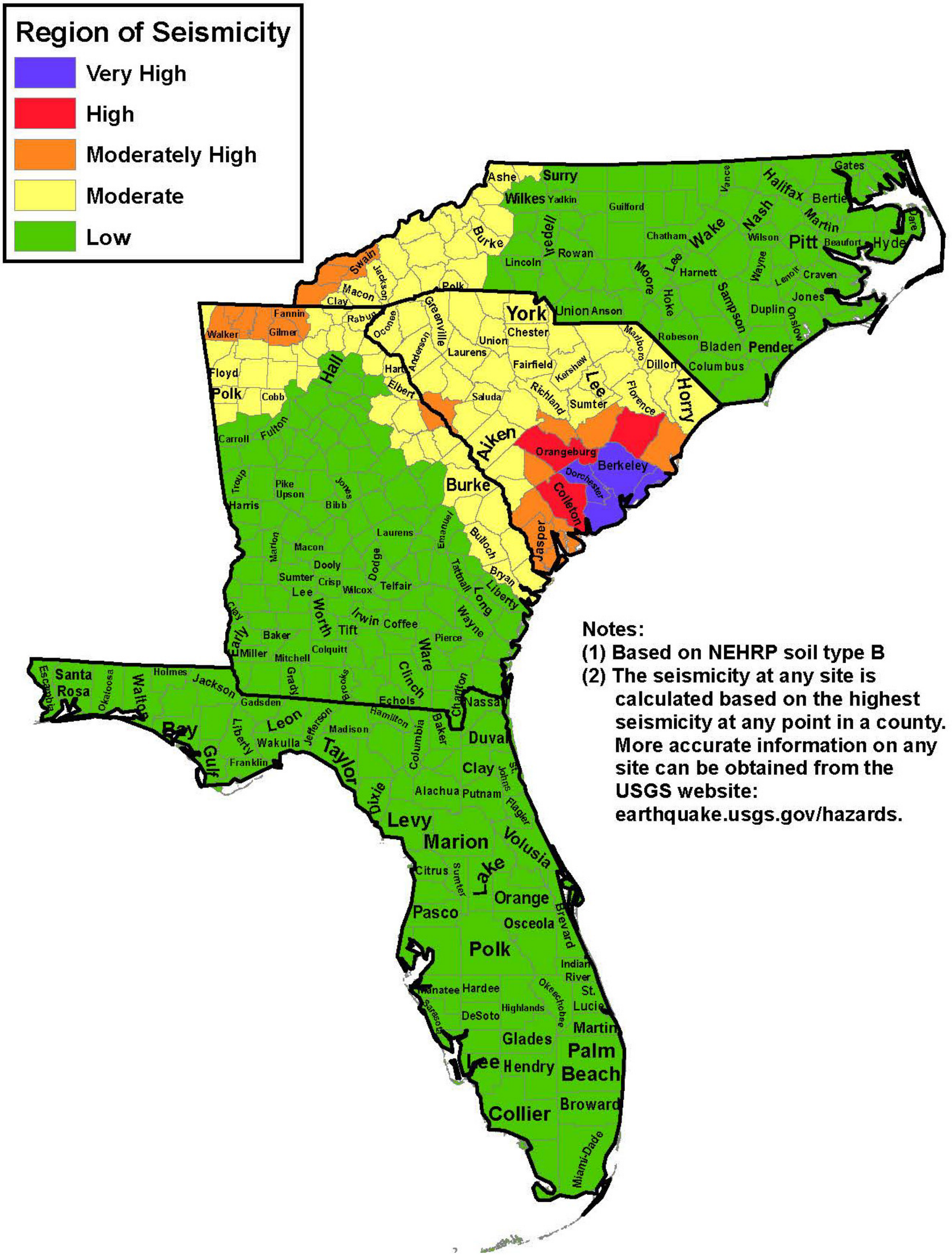


Notes:

(1) Based on NEHRP soil type B

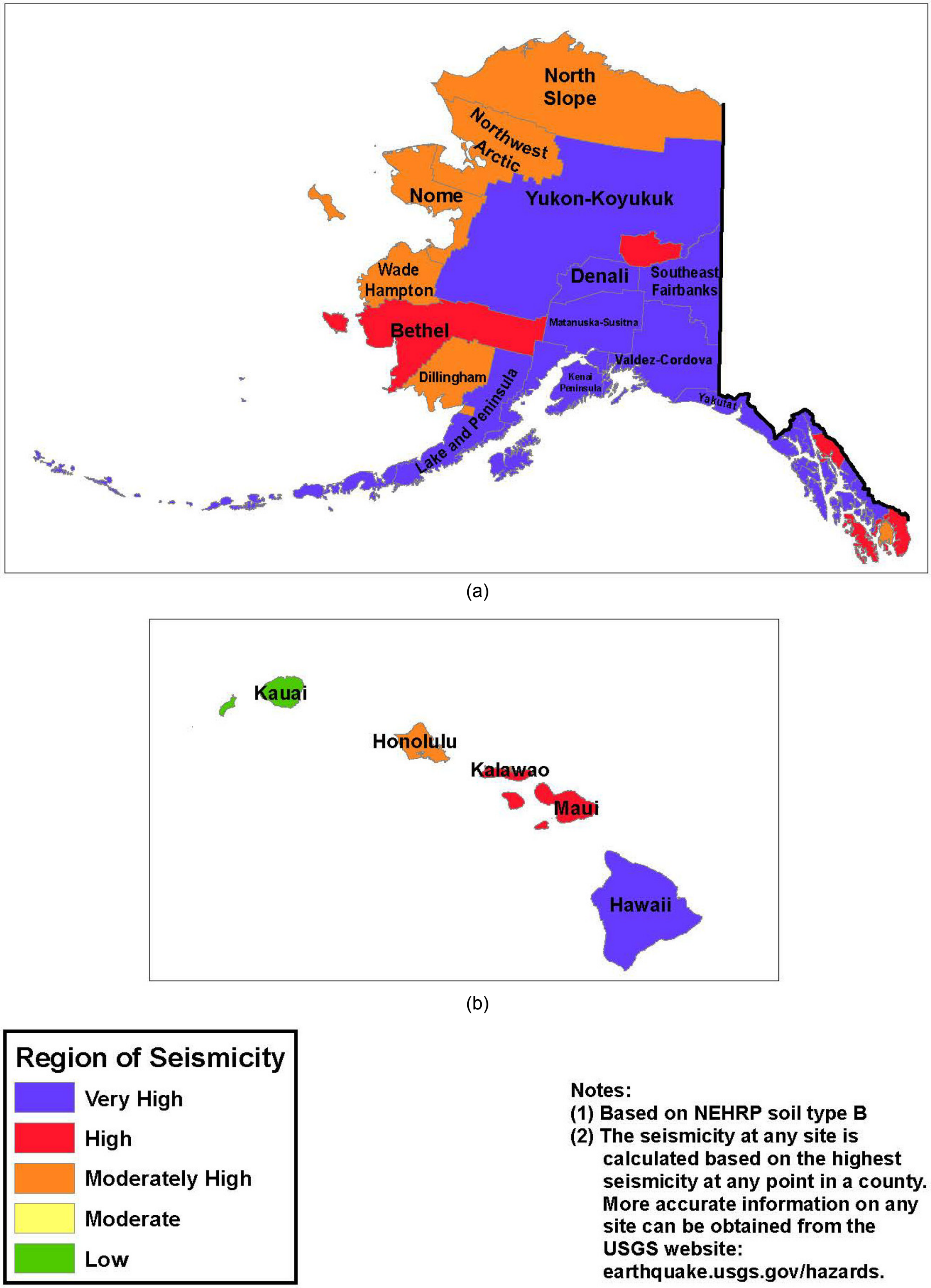
(2) The seismicity at any site is calculated based on the highest seismicity at any point in a county. More accurate information on any site can be obtained from the USGS website: earthquake.usgs.gov/hazards.

Figure A-9 Seismicity regions in Delaware, Maryland, New Jersey, Pennsylvania, Virginia, and West Virginia.



Notes:
(1) Based on NEHRP soil type B
(2) The seismicity at any site is calculated based on the highest seismicity at any point in a county. More accurate information on any site can be obtained from the USGS website: earthquake.usgs.gov/hazards.

Figure A-10 Seismicity regions in Georgia, North Carolina, South Carolina, and Florida.

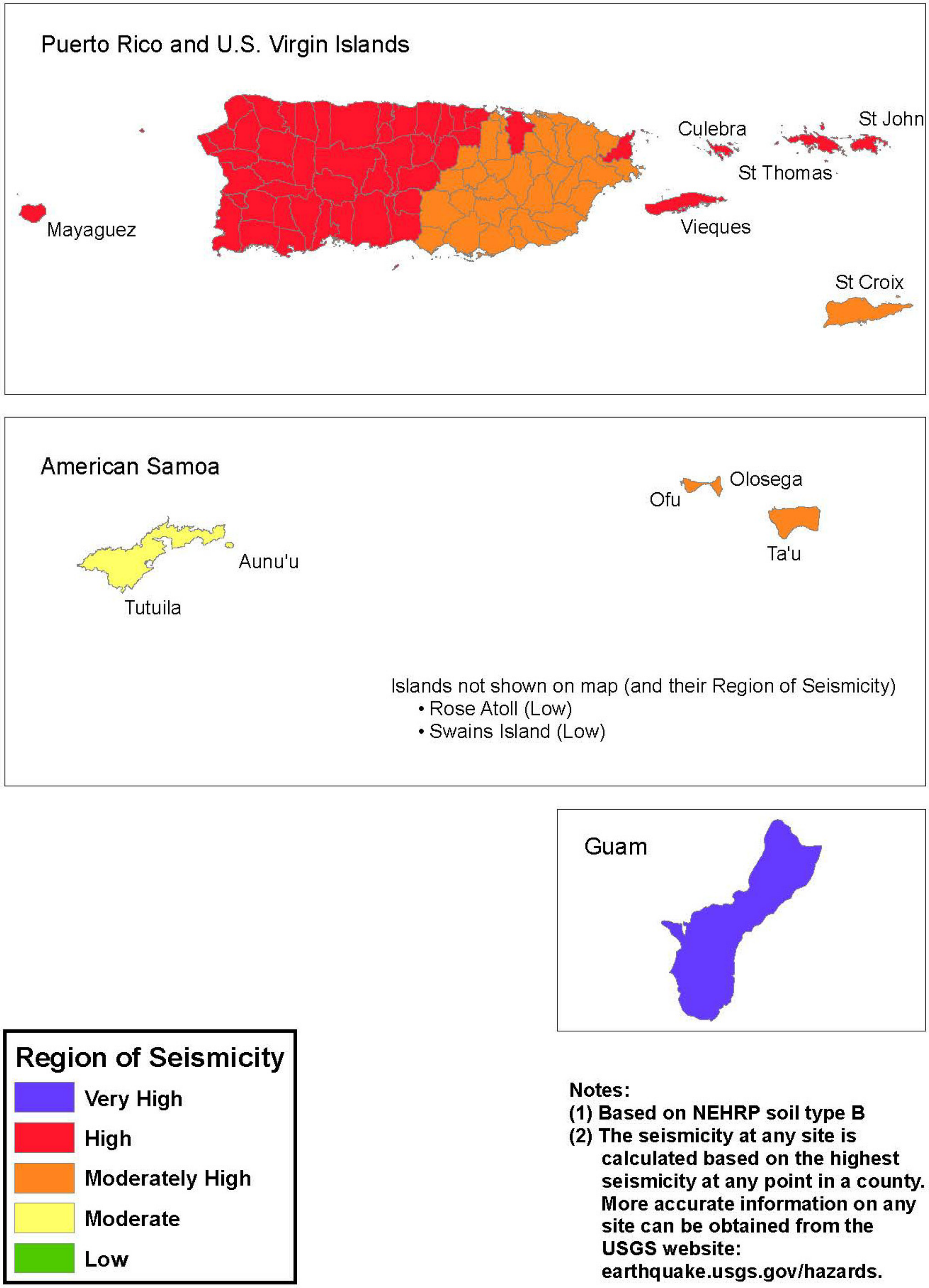


(a)

(b)

Notes:
(1) Based on NEHRP soil type B
(2) The seismicity at any site is calculated based on the highest seismicity at any point in a county. More accurate information on any site can be obtained from the USGS website: earthquake.usgs.gov/hazards.

Figure A-11 Seismicity regions in (a) Alaska and (b) Hawaii.



Notes:
(1) Based on NEHRP soil type B
(2) The seismicity at any site is calculated based on the highest seismicity at any point in a county. More accurate information on any site can be obtained from the USGS website: earthquake.usgs.gov/hazards.

Figure A-12 Seismicity regions in U.S. Territories.

Appendix B

Data Collection Forms and Reference Guides

B.1 Level 1 and Level 2 Forms for Very High, High, Moderately High, Moderate, and Low Seismicity

Electronic versions of these forms are also available for download at www.atcouncil.org.

Rapid Visual Screening of Buildings for Potential Seismic Hazards
FEMA P-154 Data Collection Form

Level 1
VERY HIGH Seismicity

PHOTOGRAPH

Address: ______________________________

______________________ **Zip:** __________

Other Identifiers: ______________________

Building Name: ______________________

Use: ______________________

Latitude: ______________ **Longitude:** ______________

***S*_S:** ______________ ***S*_1:** ______________

Screener(s): ______________ **Date/Time:** ______________

No. Stories: Above Grade: ______ Below Grade: ______ **Year Built:** ______ ☐ EST

Total Floor Area (sq. ft.): ______________ **Code Year:** ______

Additions: ☐ None ☐ Yes, Year(s) Built: ______________

Occupancy:
Assembly Commercial Emer. Services ☐ Historic ☐ Shelter
Industrial Office School ☐ Government
Utility Warehouse Residential, # Units: ______

Soil Type: ☐**A** Hard Rock ☐**B** Avg Rock ☐**C** Dense Soil ☐**D** Stiff Soil ☐**E** Soft Soil ☐**F** Poor Soil **DNK** *If DNK, assume Type D.*

Geologic Hazards: Liquefaction: Yes/No/DNK Landslide: Yes/No/DNK Surf. Rupt.: Yes/No/DNK

Adjacency: ☐ Pounding ☐ Falling Hazards from Taller Adjacent Building

Irregularities:
☐ Vertical (type/severity) ______________
☐ Plan (type) ______________

Exterior Falling Hazards:
☐ Unbraced Chimneys ☐ Heavy Cladding or Heavy Veneer
☐ Parapets ☐ Appendages
☐ Other: ______________

COMMENTS:

☐ Additional sketches or comments on separate page

SKETCH

BASIC SCORE, MODIFIERS, AND FINAL LEVEL 1 SCORE, S_{L1}

FEMA BUILDING TYPE **Do Not Know**	**W1**	**W1A**	**W2**	**S1** (MRF)	**S2** (BR)	**S3** (LM)	**S4** (RC SW)	**S5** (URM INF)	**C1** (MRF)	**C2** (SW)	**C3** (URM INF)	**PC1** (TU)	**PC2**	**RM1** (FD)	**RM2** (RD)	**URM**	**MH**
Basic Score	**2.1**	**1.9**	**1.8**	**1.5**	**1.4**	**1.6**	**1.4**	**1.2**	**1.0**	**1.2**	**0.9**	**1.1**	**1.0**	**1.1**	**1.1**	**0.9**	**1.1**
Severe Vertical Irregularity, V_{L1}	-0.9	-0.9	-0.9	-0.8	-0.7	-0.8	-0.7	-0.7	-0.7	-0.8	-0.6	-0.7	-0.7	-0.7	-0.7	-0.6	NA
Moderate Vertical Irregularity, V_{L1}	-0.6	-0.5	-0.5	-0.4	-0.4	-0.5	-0.4	-0.3	-0.4	-0.4	-0.3	-0.4	-0.4	-0.4	-0.4	-0.3	NA
Plan Irregularity, P_{L1}	-0.7	-0.7	-0.6	-0.5	-0.5	-0.6	-0.4	-0.4	-0.4	-0.5	-0.3	-0.5	-0.4	-0.4	-0.4	-0.3	NA
Pre-Code	-0.3	-0.3	-0.3	-0.3	-0.2	-0.3	-0.2	-0.1	-0.1	-0.2	0.0	-0.2	-0.1	-0.2	-0.2	0.0	0.0
Post-Benchmark	1.9	1.9	2.0	1.0	1.1	1.1	1.5	NA	1.4	1.7	NA	1.5	1.7	1.6	1.6	NA	0.5
Soil Type A or B	0.5	0.5	0.4	0.3	0.3	0.4	0.3	0.2	0.2	0.3	0.1	0.3	0.2	0.3	0.3	0.1	0.1
Soil Type E (1-3 stories)	0.0	-0.2	-0.4	-0.3	-0.2	-0.2	-0.2	-0.1	-0.1	-0.2	0.0	-0.2	-0.1	-0.2	-0.2	0.0	-0.1
Soil Type E (> 3 stories)	-0.4	-0.4	-0.4	-0.3	-0.3	NA	-0.3	-0.1	-0.1	-0.3	-0.1	NA	-0.1	-0.2	-0.2	0.0	NA
Minimum Score, S_{MIN}	*0.7*	*0.7*	*0.7*	*0.5*	*0.5*	*0.5*	*0.5*	*0.5*	*0.3*	*0.3*	*0.3*	*0.2*	*0.2*	*0.3*	*0.3*	*0.2*	*1.0*

FINAL LEVEL 1 SCORE, $S_{L1} \geq S_{MIN}$:

EXTENT OF REVIEW

Exterior: ☐ Partial ☐ All Sides ☐ Aerial
Interior: ☐ None ☐ Visible ☐ Entered
Drawings Reviewed: ☐ Yes ☐ No
Soil Type Source: ______________
Geologic Hazards Source: ______________
Contact Person: ______________

LEVEL 2 SCREENING PERFORMED?

☐ Yes, Final Level 2 Score, S_{L2} ______________ ☐ No
Nonstructural hazards? ☐ Yes ☐ No

OTHER HAZARDS

Are There Hazards That Trigger A Detailed Structural Evaluation?

☐ Pounding potential (unless S_{L2} > cut-off, if known)
☐ Falling hazards from taller adjacent building
☐ Geologic hazards or Soil Type F
☐ Significant damage/deterioration to the structural system

ACTION REQUIRED

Detailed Structural Evaluation Required?

☐ Yes, unknown FEMA building type or other building
☐ Yes, score less than cut-off
☐ Yes, other hazards present
☐ No

Detailed Nonstructural Evaluation Recommended? *(check one)*

☐ Yes, nonstructural hazards identified that should be evaluated
☐ No, nonstructural hazards exist that may require mitigation, but a detailed evaluation is not necessary
☐ No, no nonstructural hazards identified ☐ DNK

Where information cannot be verified, screener shall note the following: EST = Estimated or unreliable data <u>OR</u> DNK = Do Not Know

Legend:
MRF = Moment-resisting frame
BR = Braced frame
RC = Reinforced concrete
SW = Shear wall
URM INF = Unreinforced masonry infill
TU = Tilt up
MH = Manufactured Housing
LM = Light metal
FD = Flexible diaphragm
RD = Rigid diaphragm

Rapid Visual Screening of Buildings for Potential Seismic Hazards **Level 2 (Optional)**

FEMA P-154 Data Collection Form **VERY HIGH Seismicity**

Optional Level 2 data collection to be performed by a civil or structural engineering professional, architect, or graduate student with background in seismic evaluation or design of buildings.

Bldg Name:	**Final Level 1 Score:**	*S_{L1} =*	*(do not consider S_{MIN})*
Screener:	**Level 1 Irregularity Modifiers:**	*Vertical Irregularity, V_{L1} =*	*Plan Irregularity, P_{L1} =*
Date/Time:	**ADJUSTED BASELINE SCORE:**	*$S' = (S_{L1} - V_{L1} - P_{L1})$ =*	

STRUCTURAL MODIFIERS TO ADD TO ADJUSTED BASELINE SCORE

Topic	**Statement** *(If statement is true, circle the "Yes" modifier; otherwise cross out the modifier.)*		**Yes**	**Subtotals**
Vertical Irregularity, V_{L2}	Sloping Site	W1 building: There is at least a full story grade change from one side of the building to the other.	-0.9	
		Non-W1 building: There is at least a full story grade change from one side of the building to the other.	-0.2	
	Weak and/or Soft Story *(circle one maximum)*	W1 building cripple wall: An unbraced cripple wall is visible in the crawl space.	-0.5	
		W1 house over garage: Underneath an occupied story, there is a garage opening without a steel moment frame, and there is less than 8' of wall on the same line (for multiple occupied floors above, use 16' of wall minimum).	-0.9	
		W1A building open front: There are openings at the ground story (such as for parking) over at least 50% of the length of the building.	-0.9	
		Non-W1 building: Length of lateral system at any story is less than 50% of that at story above or height of any story is more than 2.0 times the height of the story above.	-0.7	
		Non-W1 building: Length of lateral system at any story is between 50% and 75% of that at story above or height of any story is between 1.3 and 2.0 times the height of the story above.	-0.4	
	Setback	Vertical elements of the lateral system at an upper story are outboard of those at the story below causing the diaphragm to cantilever at the offset.	-0.7	
		Vertical elements of the lateral system at upper stories are inboard of those at lower stories.	-0.4	
		There is an in-plane offset of the lateral elements that is greater than the length of the elements.	-0.2	
	Short Column/ Pier	C1,C2,C3,PC1,PC2,RM1,RM2: At least 20% of columns (or piers) along a column line in the lateral system have height/depth ratios less than 50% of the nominal height/depth ratio at that level.	-0.4	
		C1,C2,C3,PC1,PC2,RM1,RM2: The column depth (or pier width) is less than one half of the depth of the spandrel, or there are infill walls or adjacent floors that shorten the column.	-0.4	
	Split Level	There is a split level at one of the floor levels or at the roof.	-0.4	
	Other Irregularity	There is another observable severe vertical irregularity that obviously affects the building's seismic performance.	-0.7	*V_{L2} =* ______
		There is another observable moderate vertical irregularity that may affect the building's seismic performance.	-0.4	*(Cap at -0.9)*
Plan Irregularity, P_{L2}	Torsional irregularity: Lateral system does not appear relatively well distributed in plan in either or both directions. *(Do not include the W1A open front irregularity listed above.)*		-0.5	
	Non-parallel system: There are one or more major vertical elements of the lateral system that are not orthogonal to each other.		-0.2	
	Reentrant corner: Both projections from an interior corner exceed 25% of the overall plan dimension in that direction.		-0.2	
	Diaphragm opening: There is an opening in the diaphragm with a width over 50% of the total diaphragm width at that level.		-0.2	
	C1, C2 building out-of-plane offset: The exterior beams do not align with the columns in plan.		-0.2	*P_{L2} =* ______
	Other irregularity: There is another observable plan irregularity that obviously affects the building's seismic performance.		-0.5	*(Cap at -0.7)*
Redundancy	The building has at least two bays of lateral elements on each side of the building in each direction.		+0.2	
Pounding	Building is separated from an adjacent structure by less than 1.5% of the height of the shorter of the building and adjacent structure and:	The floors do not align vertically within 2 feet. *(Cap total pounding modifiers at -0.9)*	-0.7	
		One building is 2 or more stories taller than the other.	-0.7	
		The building is at the end of the block.	-0.4	
S2 Building	"K" bracing geometry is visible.		-0.7	
C1 Building	Flat plate serves as the beam in the moment frame.		-0.3	
PC1/RM1 Bldg	There are roof-to-wall ties that are visible or known from drawings that do not rely on cross-grain bending. *(Do not combine with post-benchmark or retrofit modifier.)*		+0.2	
PC1/RM1 Bldg	The building has closely spaced, full height interior walls (rather than an interior space with few walls such as in a warehouse).		+0.2	
URM	Gable walls are present.		-0.3	
MH	There is a supplemental seismic bracing system provided between the carriage and the ground.		+0.5	
Retrofit	Comprehensive seismic retrofit is visible or known from drawings.		+1.2	*M* = ______

FINAL LEVEL 2 SCORE, $S_{L2} = (S' + V_{L2} + P_{L2} + M) \geq S_{MIN}$: (*Transfer to Level 1 form*)

There is observable damage or deterioration or another condition that negatively affects the building's seismic performance: ☐ Yes ☐ No

If yes, describe the condition in the comment box below and indicate on the Level 1 form that detailed evaluation is required independent of the building's score.

OBSERVABLE NONSTRUCTURAL HAZARDS

Location	**Statement** (*Check "Yes" or "No"*)	**Yes**	**No**	**Comment**
Exterior	There is an unbraced unreinforced masonry parapet or unbraced unreinforced masonry chimney.			
	There is heavy cladding or heavy veneer.			
	There is a heavy canopy over exit doors or pedestrian walkways that appears inadequately supported.			
	There is an unreinforced masonry appendage over exit doors or pedestrian walkways.			
	There is a sign posted on the building that indicates hazardous materials are present.			
	There is a taller adjacent building with an unanchored URM wall or unbraced URM parapet or chimney.			
	Other observed exterior nonstructural falling hazard:			
Interior	There are hollow clay tile or brick partitions at any stair or exit corridor.			
	Other observed interior nonstructural falling hazard:			

Estimated Nonstructural Seismic Performance (*Check appropriate box and transfer to Level 1 form conclusions*)

☐ Potential nonstructural hazards with significant threat to occupant life safety → Detailed Nonstructural Evaluation recommended
☐ Nonstructural hazards identified with significant threat to occupant life safety → But no Detailed Nonstructural Evaluation required
☐ Low or no nonstructural hazard threat to occupant life safety → No Detailed Nonstructural Evaluation required

Comments:

Rapid Visual Screening of Buildings for Potential Seismic Hazards
FEMA P-154 Data Collection Form

Level 1
HIGH Seismicity

PHOTOGRAPH

Address: ____________________
____________________ **Zip:** ________
Other Identifiers: ____________________
Building Name: ____________________
Use: ____________________
Latitude: __________ **Longitude:** __________
S_S: __________ **S_1:** __________
Screener(s): __________ **Date/Time:** __________

No. Stories: Above Grade: ____ Below Grade: ____ **Year Built:** ____ ☐ EST
Total Floor Area (sq. ft.): __________ **Code Year:** ________
Additions: ☐ None ☐ Yes, Year(s) Built: __________

Occupancy: Assembly Commercial Emer. Services ☐ Historic ☐ Shelter
Industrial Office School ☐ Government
Utility Warehouse Residential, # Units: ____

Soil Type: ☐A Hard Rock ☐B Avg Rock ☐C Dense Soil ☐D Stiff Soil ☐E Soft Soil ☐F Poor Soil **DNK** *If DNK, assume Type D.*

Geologic Hazards: Liquefaction: Yes/No/DNK Landslide: Yes/No/DNK Surf. Rupt.: Yes/No/DNK

Adjacency: ☐ Pounding ☐ Falling Hazards from Taller Adjacent Building

Irregularities: ☐ Vertical (type/severity) __________
☐ Plan (type) __________

Exterior Falling Hazards: ☐ Unbraced Chimneys ☐ Heavy Cladding or Heavy Veneer
☐ Parapets ☐ Appendages
☐ Other: __________

COMMENTS:

SKETCH

☐ Additional sketches or comments on separate page

BASIC SCORE, MODIFIERS, AND FINAL LEVEL 1 SCORE, S_{L1}

FEMA BUILDING TYPE	Do Not Know	W1	W1A	W2	S1 (MRF)	S2 (BR)	S3 (LM)	S4 (RC SW)	S5 (URM INF)	C1 (MRF)	C2 (SW)	C3 (URM INF)	PC1 (TU)	PC2	RM1 (FD)	RM2 (RD)	URM	MH
Basic Score		**3.6**	**3.2**	**2.9**	**2.1**	**2.0**	**2.6**	**2.0**	**1.7**	**1.5**	**2.0**	**1.2**	**1.6**	**1.4**	**1.7**	**1.7**	**1.0**	**1.5**
Severe Vertical Irregularity, V_{L1}		-1.2	-1.2	-1.2	-1.0	-1.0	-1.1	-1.0	-0.8	-0.9	-1.0	-0.7	-1.0	-0.9	-0.9	-0.9	-0.7	NA
Moderate Vertical Irregularity, V_{L1}		-0.7	-0.7	-0.7	-0.6	-0.6	-0.7	-0.6	-0.5	-0.5	-0.6	-0.4	-0.6	-0.5	-0.5	-0.5	-0.4	NA
Plan Irregularity, P_{L1}		-1.1	-1.0	-1.0	-0.8	-0.7	-0.9	-0.7	-0.6	-0.6	-0.8	-0.5	-0.7	-0.6	-0.7	-0.7	-0.4	NA
Pre-Code		-1.1	-1.0	-0.9	-0.6	-0.6	-0.8	-0.6	-0.2	-0.4	-0.7	-0.1	-0.5	-0.3	-0.5	-0.5	0.0	-0.1
Post-Benchmark		1.6	1.9	2.2	1.4	1.4	1.1	1.9	NA	1.9	2.1	NA	2.0	2.4	2.1	2.1	NA	1.2
Soil Type A or B		0.1	0.3	0.5	0.4	0.6	0.1	0.6	0.5	0.4	0.5	0.3	0.6	0.4	0.5	0.5	0.3	0.3
Soil Type E (1-3 stories)		0.2	0.2	0.1	-0.2	-0.4	0.2	-0.1	-0.4	0.0	0.0	-0.2	-0.3	-0.1	-0.1	-0.1	-0.2	-0.4
Soil Type E (> 3 stories)		-0.3	-0.6	-0.9	-0.6	-0.6	NA	-0.6	-0.4	-0.5	-0.7	-0.3	NA	-0.4	-0.5	-0.6	-0.2	NA
Minimum Score, S_{MIN}		*1.1*	*0.9*	*0.7*	*0.5*	*0.5*	*0.6*	*0.5*	*0.5*	*0.3*	*0.3*	*0.3*	*0.2*	*0.2*	*0.3*	*0.3*	*0.2*	*1.0*

FINAL LEVEL 1 SCORE, $S_{L1} \geq S_{MIN}$:

EXTENT OF REVIEW

Exterior: ☐ Partial ☐ All Sides ☐ Aerial
Interior: ☐ None ☐ Visible ☐ Entered
Drawings Reviewed: ☐ Yes ☐ No
Soil Type Source: __________
Geologic Hazards Source: __________
Contact Person: __________

LEVEL 2 SCREENING PERFORMED?

☐ Yes, Final Level 2 Score, S_{L2} ________ ☐ No
Nonstructural hazards? ☐ Yes ☐ No

OTHER HAZARDS

Are There Hazards That Trigger A Detailed Structural Evaluation?
- ☐ Pounding potential (unless S_{L2} > cut-off, if known)
- ☐ Falling hazards from taller adjacent building
- ☐ Geologic hazards or Soil Type F
- ☐ Significant damage/deterioration to the structural system

ACTION REQUIRED

Detailed Structural Evaluation Required?
- ☐ Yes, unknown FEMA building type or other building
- ☐ Yes, score less than cut-off
- ☐ Yes, other hazards present
- ☐ No

Detailed Nonstructural Evaluation Recommended? *(check one)*
- ☐ Yes, nonstructural hazards identified that should be evaluated
- ☐ No, nonstructural hazards exist that may require mitigation, but a detailed evaluation is not necessary
- ☐ No, no nonstructural hazards identified ☐ DNK

Where information cannot be verified, screener shall note the following: EST = Estimated or unreliable data <u>OR</u> DNK = Do Not Know

Legend:	MRF = Moment-resisting frame	RC = Reinforced concrete	URM INF = Unreinforced masonry infill	MH = Manufactured Housing	FD = Flexible diaphragm
	BR = Braced frame	SW = Shear wall	TU = Tilt up	LM = Light metal	RD = Rigid diaphragm

Rapid Visual Screening of Buildings for Potential Seismic Hazards
Level 2 (Optional)
HIGH Seismicity

FEMA P-154 Data Collection Form

Optional Level 2 data collection to be performed by a civil or structural engineering professional, architect, or graduate student with background in seismic evaluation or design of buildings.

Bldg Name:	**Final Level 1 Score:**	S_{L1} =	*(do not consider S_{MIN})*
Screener:	**Level 1 Irregularity Modifiers:**	*Vertical Irregularity, V_{L1} =*	*Plan Irregularity, P_{L1} =*
Date/Time:	**ADJUSTED BASELINE SCORE:**	$S' = (S_{L1} - V_{L1} - P_{L1})$ =	

STRUCTURAL MODIFIERS TO ADD TO ADJUSTED BASELINE SCORE

Topic	**Statement** *(If statement is true, circle the "Yes" modifier; otherwise cross out the modifier.)*		**Yes**	**Subtotals**
Vertical Irregularity, V_{L2}	Sloping Site	W1 building: There is at least a full story grade change from one side of the building to the other.	-1.2	
		Non-W1 building: There is at least a full story grade change from one side of the building to the other.	-0.3	
	Weak and/or Soft Story *(circle one maximum)*	W1 building cripple wall: An unbraced cripple wall is visible in the crawl space.	-0.6	
		W1 house over garage: Underneath an occupied story, there is a garage opening without a steel moment frame, and there is less than 8' of wall on the same line (for multiple occupied floors above, use 16' of wall minimum).	-1.2	
		W1A building open front: There are openings at the ground story (such as for parking) over at least 50% of the length of the building.	-1.2	
		Non-W1 building: Length of lateral system at any story is less than 50% of that at story above or height of any story is more than 2.0 times the height of the story above.	-0.9	
		Non-W1 building: Length of lateral system at any story is between 50% and 75% of that at story above or height of any story is between 1.3 and 2.0 times the height of the story above.	-0.5	
	Setback	Vertical elements of the lateral system at an upper story are outboard of those at the story below causing the diaphragm to cantilever at the offset.	-1.0	
		Vertical elements of the lateral system at upper stories are inboard of those at lower stories.	-0.5	
		There is an in-plane offset of the lateral elements that is greater than the length of the elements.	-0.3	
	Short Column/ Pier	C1,C2,C3,PC1,PC2,RM1,RM2: At least 20% of columns (or piers) along a column line in the lateral system have height/depth ratios less than 50% of the nominal height/depth ratio at that level.	-0.5	
		C1,C2,C3,PC1,PC2,RM1,RM2: The column depth (or pier width) is less than one half of the depth of the spandrel, or there are infill walls or adjacent floors that shorten the column.	-0.5	
	Split Level	There is a split level at one of the floor levels or at the roof.	-0.5	
	Other Irregularity	There is another observable severe vertical irregularity that obviously affects the building's seismic performance.	-1.0	V_{L2} = ______
		There is another observable moderate vertical irregularity that may affect the building's seismic performance.	-0.5	*(Cap at -1.2)*
Plan Irregularity, P_{L2}	Torsional irregularity: Lateral system does not appear relatively well distributed in plan in either or both directions. *(Do not include the W1A open front irregularity listed above.)*		-0.7	
	Non-parallel system: There are one or more major vertical elements of the lateral system that are not orthogonal to each other.		-0.4	
	Reentrant corner: Both projections from an interior corner exceed 25% of the overall plan dimension in that direction.		-0.4	
	Diaphragm opening: There is an opening in the diaphragm with a width over 50% of the total diaphragm width at that level.		-0.2	
	C1, C2 building out-of-plane offset: The exterior beams do not align with the columns in plan.		-0.4	P_{L2} = ______
	Other irregularity: There is another observable plan irregularity that obviously affects the building's seismic performance.		-0.7	*(Cap at -1.1)*
Redundancy	The building has at least two bays of lateral elements on each side of the building in each direction.		+0.3	
Pounding	Building is separated from an adjacent structure by less than 1% of the height of the shorter of the building and adjacent structure and:	The floors do not align vertically within 2 feet. *(Cap total pounding modifiers at -1.2)*	-1.0	
		One building is 2 or more stories taller than the other.	-1.0	
		The building is at the end of the block.	-0.5	
S2 Building	"K" bracing geometry is visible.		-1.0	
C1 Building	Flat plate serves as the beam in the moment frame.		-0.4	
PC1/RM1 Bldg	There are roof-to-wall ties that are visible or known from drawings that do not rely on cross-grain bending. *(Do not combine with post-benchmark or retrofit modifier.)*		+0.3	
PC1/RM1 Bldg	The building has closely spaced, full height interior walls (rather than an interior space with few walls such as in a warehouse).		+0.3	
URM	Gable walls are present.		-0.4	
MH	There is a supplemental seismic bracing system provided between the carriage and the ground.		+1.2	
Retrofit	Comprehensive seismic retrofit is visible or known from drawings.		+1.4	M = ______

FINAL LEVEL 2 SCORE, $S_{L2} = (S' + V_{L2} + P_{L2} + M) \geq S_{MIN}$: (*Transfer to Level 1 form*)

There is observable damage or deterioration or another condition that negatively affects the building's seismic performance: ☐ Yes ☐ No

If yes, describe the condition in the comment box below and indicate on the Level 1 form that detailed evaluation is required independent of the building's score.

OBSERVABLE NONSTRUCTURAL HAZARDS

Location	**Statement** (*Check "Yes" or "No"*)	**Yes**	**No**	**Comment**
Exterior	There is an unbraced unreinforced masonry parapet or unbraced unreinforced masonry chimney.			
	There is heavy cladding or heavy veneer.			
	There is a heavy canopy over exit doors or pedestrian walkways that appears inadequately supported.			
	There is an unreinforced masonry appendage over exit doors or pedestrian walkways.			
	There is a sign posted on the building that indicates hazardous materials are present.			
	There is a taller adjacent building with an unanchored URM wall or unbraced URM parapet or chimney.			
	Other observed exterior nonstructural falling hazard:			
Interior	There are hollow clay tile or brick partitions at any stair or exit corridor.			
	Other observed interior nonstructural falling hazard:			

Estimated Nonstructural Seismic Performance (*Check appropriate box and transfer to Level 1 form conclusions*)

☐ Potential nonstructural hazards with significant threat to occupant life safety → Detailed Nonstructural Evaluation recommended
☐ Nonstructural hazards identified with significant threat to occupant life safety → But no Detailed Nonstructural Evaluation required
☐ Low or no nonstructural hazard threat to occupant life safety → No Detailed Nonstructural Evaluation required

Comments:

Rapid Visual Screening of Buildings for Potential Seismic Hazards
FEMA P-154 Data Collection Form

Level 1
MODERATELY HIGH Seismicity

PHOTOGRAPH

SKETCH

Address: ______________________________
______________________ **Zip:** __________
Other Identifiers: ______________________
Building Name: ______________________
Use: ______________________
Latitude: ______________ **Longitude:** ______________
S_S: ______________ **S_1:** ______________
Screener(s): ______________ **Date/Time:** ______________

No. Stories: Above Grade: ______ Below Grade: ______ **Year Built:** ______ ☐ EST
Total Floor Area (sq. ft.): ______________ **Code Year:** ______
Additions: ☐ None ☐ Yes, Year(s) Built: ______________

Occupancy: Assembly Industrial Utility Commercial Office Warehouse Emer. Services School Residential, # Units: ______ ☐ Historic ☐ Government ☐ Shelter

Soil Type: ☐**A** Hard Rock ☐**B** Avg Rock ☐**C** Dense Soil ☐**D** Stiff Soil ☐**E** Soft Soil ☐**F** Poor Soil **DNK** *If DNK, assume Type D.*

Geologic Hazards: Liquefaction: Yes/No/DNK Landslide: Yes/No/DNK Surf. Rupt.: Yes/No/DNK

Adjacency: ☐ Pounding ☐ Falling Hazards from Taller Adjacent Building

Irregularities: ☐ Vertical (type/severity) ______________
☐ Plan (type) ______________

Exterior Falling Hazards: ☐ Unbraced Chimneys ☐ Heavy Cladding or Heavy Veneer ☐ Parapets ☐ Appendages ☐ Other: ______________

COMMENTS:

☐ Additional sketches or comments on separate page

BASIC SCORE, MODIFIERS, AND FINAL LEVEL 1 SCORE, S_{L1}

FEMA BUILDING TYPE	Do Not Know	W1	W1A	W2	S1 (MRF)	S2 (BR)	S3 (LM)	S4 (RC SW)	S5 (URM INF)	C1 (MRF)	C2 (SW)	C3 (URM INF)	PC1 (TU)	PC2	RM1 (FD)	RM2 (RD)	URM	MH
Basic Score		**4.1**	**3.7**	**3.2**	**2.3**	**2.2**	**2.9**	**2.2**	**2.0**	**1.7**	**2.1**	**1.4**	**1.8**	**1.5**	**1.8**	**1.8**	**1.2**	**2.2**
Severe Vertical Irregularity, V_{L1}		-1.3	-1.3	-1.3	-1.1	-1.0	-1.2	-1.0	-0.9	-1.0	-1.1	-0.8	-1.0	-0.9	-1.0	-1.0	-0.8	NA
Moderate Vertical Irregularity, V_{L1}		-0.8	-0.8	-0.8	-0.7	-0.6	-0.8	-0.6	-0.6	-0.6	-0.6	-0.5	-0.6	-0.6	-0.6	-0.6	-0.5	NA
Plan Irregularity, P_{L1}		-1.3	-1.2	-1.1	-0.9	-0.8	-1.0	-0.8	-0.7	-0.7	-0.9	-0.6	-0.8	-0.7	-0.7	-0.7	-0.5	NA
Pre-Code		-0.8	-0.9	-0.9	-0.5	-0.5	-0.7	-0.6	-0.2	-0.4	-0.7	-0.1	-0.4	-0.3	-0.5	-0.5	-0.1	-0.3
Post-Benchmark		1.5	1.9	2.3	1.4	1.4	1.0	1.9	NA	1.9	2.1	NA	2.1	2.4	2.1	2.1	NA	1.2
Soil Type A or B		0.3	0.6	0.9	0.6	0.9	0.3	0.9	0.9	0.6	0.8	0.7	0.9	0.7	0.8	0.8	0.6	0.9
Soil Type E (1-3 stories)		0.0	-0.1	-0.3	-0.4	-0.5	0.0	-0.4	-0.5	-0.2	-0.2	-0.4	-0.5	-0.3	-0.4	-0.4	-0.3	-0.5
Soil Type E (> 3 stories)		-0.5	-0.8	-1.2	-0.7	-0.7	NA	-0.7	-0.6	-0.6	-0.8	-0.4	NA	-0.5	-0.6	-0.7	-0.3	NA
Minimum Score, S_{MIN}		*1.6*	*1.2*	*0.8*	*0.5*	*0.5*	*0.9*	*0.5*	*0.5*	*0.3*	*0.3*	*0.3*	*0.3*	*0.2*	*0.3*	*0.3*	*0.2*	*1.4*

FINAL LEVEL 1 SCORE, $S_{L1} \geq S_{MIN}$:

EXTENT OF REVIEW

Exterior: ☐ Partial ☐ All Sides ☐ Aerial
Interior: ☐ None ☐ Visible ☐ Entered
Drawings Reviewed: ☐ Yes ☐ No
Soil Type Source: ______________
Geologic Hazards Source: ______________
Contact Person: ______________

LEVEL 2 SCREENING PERFORMED?

☐ Yes, Final Level 2 Score, S_{L2} ________ ☐ No
Nonstructural hazards? ☐ Yes ☐ No

OTHER HAZARDS

Are There Hazards That Trigger A Detailed Structural Evaluation?

☐ Pounding potential (unless S_{L2} > cut-off, if known)
☐ Falling hazards from taller adjacent building
☐ Geologic hazards or Soil Type F
☐ Significant damage/deterioration to the structural system

ACTION REQUIRED

Detailed Structural Evaluation Required?

☐ Yes, unknown FEMA building type or other building
☐ Yes, score less than cut-off
☐ Yes, other hazards present
☐ No

Detailed Nonstructural Evaluation Recommended? *(check one)*

☐ Yes, nonstructural hazards identified that should be evaluated
☐ No, nonstructural hazards exist that may require mitigation, but a detailed evaluation is not necessary
☐ No, no nonstructural hazards identified ☐ DNK

Where information cannot be verified, screener shall note the following: EST = Estimated or unreliable data <u>OR</u> DNK = Do Not Know

Legend:

Legend:	MRF = Moment-resisting frame	RC = Reinforced concrete	URM INF = Unreinforced masonry infill	MH = Manufactured Housing	FD = Flexible diaphragm
	BR = Braced frame	SW = Shear wall	TU = Tilt up	LM = Light metal	RD = Rigid diaphragm

Rapid Visual Screening of Buildings for Potential Seismic Hazards

Level 2 (Optional)

FEMA P-154 Data Collection Form

MODERATELY HIGH Seismicity

Optional Level 2 data collection to be performed by a civil or structural engineering professional, architect, or graduate student with background in seismic evaluation or design of buildings.

Bldg Name:	**Final Level 1 Score:**	*S_{L1} =*	*(do not consider S_{MIN})*
Screener:	**Level 1 Irregularity Modifiers:**	*Vertical Irregularity, V_{L1} =*	*Plan Irregularity, P_{L1} =*
Date/Time:	**ADJUSTED BASELINE SCORE:**	*$S' = (S_{L1} – V_{L1} – P_{L1})$ =*	

STRUCTURAL MODIFIERS TO ADD TO ADJUSTED BASELINE SCORE

Topic	**Statement** *(If statement is true, circle the "Yes" modifier; otherwise cross out the modifier.)*		**Yes**	**Subtotals**
Vertical Irregularity, V_{L2}	Sloping Site	W1 building: There is at least a full story grade change from one side of the building to the other.	-1.3	
		Non-W1 building: There is at least a full story grade change from one side of the building to the other.	-0.3	
	Weak and/or Soft Story *(circle one maximum)*	W1 building cripple wall: An unbraced cripple wall is visible in the crawl space.	-0.6	
		W1 house over garage: Underneath an occupied story, there is a garage opening without a steel moment frame, and there is less than 8' of wall on the same line (for multiple occupied floors above, use 16' of wall minimum).	-1.3	
		W1A building open front: There are openings at the ground story (such as for parking) over at least 50% of the length of the building.	-1.3	
		Non-W1 building: Length of lateral system at any story is less than 50% of that at story above or height of any story is more than 2.0 times the height of the story above.	-1.0	
		Non-W1 building: Length of lateral system at any story is between 50% and 75% of that at story above or height of any story is between 1.3 and 2.0 times the height of the story above.	-0.5	
	Setback	Vertical elements of the lateral system at an upper story are outboard of those at the story below causing the diaphragm to cantilever at the offset.	-1.0	
		Vertical elements of the lateral system at upper stories are inboard of those at lower stories.	-0.5	
		There is an in-plane offset of the lateral elements that is greater than the length of the elements.	-0.3	
	Short Column/ Pier	C1,C2,C3,PC1,PC2,RM1,RM2: At least 20% of columns (or piers) along a column line in the lateral system have height/depth ratios less than 50% of the nominal height/depth ratio at that level.	-0.5	
		C1,C2,C3,PC1,PC2,RM1,RM2: The column depth (or pier width) is less than one half of the depth of the spandrel, or there are infill walls or adjacent floors that shorten the column.	-0.5	
	Split Level	There is a split level at one of the floor levels or at the roof.	-0.5	
	Other Irregularity	There is another observable severe vertical irregularity that obviously affects the building's seismic performance.	-1.0	V_{L2} = ______
		There is another observable moderate vertical irregularity that may affect the building's seismic performance.	-0.5	*(Cap at -1.3)*
Plan Irregularity, P_{L2}	Torsional irregularity: Lateral system does not appear relatively well distributed in plan in either or both directions. *(Do not include the W1A open front irregularity listed above.)*		-0.8	
	Non-parallel system: There are one or more major vertical elements of the lateral system that are not orthogonal to each other.		-0.4	
	Reentrant corner: Both projections from an interior corner exceed 25% of the overall plan dimension in that direction.		-0.4	
	Diaphragm opening: There is an opening in the diaphragm with a width over 50% of the total diaphragm width at that level.		-0.3	
	C1, C2 building out-of-plane offset: The exterior beams do not align with the columns in plan.		-0.4	P_{L2} = ______
	Other irregularity: There is another observable plan irregularity that obviously affects the building's seismic performance.		-0.8	*(Cap at -1.3)*
Redundancy	The building has at least two bays of lateral elements on each side of the building in each direction.		+0.3	
Pounding	Building is separated from an adjacent structure by less than 0.5% of the height of the shorter of the building and adjacent structure and:	The floors do not align vertically within 2 feet. *(Cap total pounding modifiers at -1.3)*	-1.0	
		One building is 2 or more stories taller than the other.	-1.0	
		The building is at the end of the block.	-0.5	
S2 Building	"K" bracing geometry is visible.		-1.0	
C1 Building	Flat plate serves as the beam in the moment frame.		-0.5	
PC1/RM1 Bldg	There are roof-to-wall ties that are visible or known from drawings that do not rely on cross-grain bending. *(Do not combine with post-benchmark or retrofit modifier.)*		+0.3	
PC1/RM1 Bldg	The building has closely spaced, full height interior walls (rather than an interior space with few walls such as in a warehouse).		+0.3	
URM	Gable walls are present.		-0.4	
MH	There is a supplemental seismic bracing system provided between the carriage and the ground.		+1.2	
Retrofit	Comprehensive seismic retrofit is visible or known from drawings.		+1.4	M = ______

FINAL LEVEL 2 SCORE, $S_{L2} = (S' + V_{L2} + P_{L2} + M) \geq S_{MIN}$: (*Transfer to Level 1 form*)

There is observable damage or deterioration or another condition that negatively affects the building's seismic performance: ☐ Yes ☐ No

If yes, describe the condition in the comment box below and indicate on the Level 1 form that detailed evaluation is required independent of the building's score.

OBSERVABLE NONSTRUCTURAL HAZARDS

Location	**Statement** (*Check "Yes" or "No"*)	**Yes**	**No**	**Comment**
Exterior	There is an unbraced unreinforced masonry parapet or unbraced unreinforced masonry chimney.			
	There is heavy cladding or heavy veneer.			
	There is a heavy canopy over exit doors or pedestrian walkways that appears inadequately supported.			
	There is an unreinforced masonry appendage over exit doors or pedestrian walkways.			
	There is a sign posted on the building that indicates hazardous materials are present.			
	There is a taller adjacent building with an unanchored URM wall or unbraced URM parapet or chimney.			
	Other observed exterior nonstructural falling hazard:			
Interior	There are hollow clay tile or brick partitions at any stair or exit corridor.			
	Other observed interior nonstructural falling hazard:			

Estimated Nonstructural Seismic Performance (*Check appropriate box and transfer to Level 1 form conclusions*)

☐ Potential nonstructural hazards with significant threat to occupant life safety → Detailed Nonstructural Evaluation recommended
☐ Nonstructural hazards identified with significant threat to occupant life safety → But no Detailed Nonstructural Evaluation required
☐ Low or no nonstructural hazard threat to occupant life safety → No Detailed Nonstructural Evaluation required

Comments:

Rapid Visual Screening of Buildings for Potential Seismic Hazards
FEMA P-154 Data Collection Form

Level 1
MODERATE Seismicity

PHOTOGRAPH

Address: ____________________
____________________ **Zip:** __________
Other Identifiers: ____________________
Building Name: ____________________
Use: ____________________
Latitude: __________ **Longitude:** __________
S_S: __________ **S_1:** __________
Screener(s): __________ **Date/Time:** __________

No. Stories: Above Grade: ______ Below Grade: ______ **Year Built:** ______ ☐ EST
Total Floor Area (sq. ft.): __________ **Code Year:** ______
Additions: ☐ None ☐ Yes, Year(s) Built: __________

Occupancy: Assembly Industrial Utility Commercial Office Warehouse Emer. Services School Residential, # Units: ______ ☐ Historic ☐ Government ☐ Shelter

Soil Type: ☐**A** Hard Rock ☐**B** Avg Rock ☐**C** Dense Soil ☐**D** Stiff Soil ☐**E** Soft Soil ☐**F** Poor Soil **DNK** *If DNK, assume Type D.*

Geologic Hazards: Liquefaction: Yes/No/DNK Landslide: Yes/No/DNK Surf. Rupt.: Yes/No/DNK

Adjacency: ☐ Pounding ☐ Falling Hazards from Taller Adjacent Building

Irregularities: ☐ Vertical (type/severity) __________
☐ Plan (type) __________

Exterior Falling Hazards: ☐ Unbraced Chimneys ☐ Parapets ☐ Other: __________ ☐ Heavy Cladding or Heavy Veneer ☐ Appendages

COMMENTS:

SKETCH

☐ Additional sketches or comments on separate page

BASIC SCORE, MODIFIERS, AND FINAL LEVEL 1 SCORE, S_{L1}

FEMA BUILDING TYPE	Do Not Know	W1	W1A	W2	S1 (MRF)	S2 (BR)	S3 (LM)	S4 (RC SW)	S5 (URM INF)	C1 (MRF)	C2 (SW)	C3 (URM INF)	PC1 (TU)	PC2	RM1 (FD)	RM2 (RD)	URM	MH
Basic Score		**5.1**	**4.5**	**3.8**	**2.7**	**2.6**	**3.5**	**2.5**	**2.7**	**2.1**	**2.5**	**2.0**	**2.1**	**1.9**	**2.1**	**2.1**	**1.7**	**2.9**
Severe Vertical Irregularity, V_{L1}		-1.4	-1.4	-1.4	-1.2	-1.2	-1.4	-1.1	-1.2	-1.1	-1.2	-1.0	-1.1	-1.0	-1.1	-1.1	-1.0	NA
Moderate Vertical Irregularity, V_{L1}		-0.9	-0.9	-0.9	-0.8	-0.7	-0.9	-0.7	-0.7	-0.7	-0.7	-0.6	-0.7	-0.6	-0.7	-0.7	-0.6	NA
Plan Irregularity, P_{L1}		-1.4	-1.3	-1.2	-1.0	-0.9	-1.2	-0.9	-0.9	-0.8	-1.0	-0.8	-0.9	-0.8	-0.8	-0.8	-0.7	NA
Pre-Code		-0.3	-0.5	-0.6	-0.3	-0.2	-0.2	-0.3	-0.3	-0.3	-0.4	-0.3	-0.2	-0.2	-0.2	-0.2	-0.1	-0.5
Post-Benchmark		1.4	2.0	2.5	1.5	1.5	0.8	2.1	NA	2.0	2.3	NA	2.1	2.5	2.3	2.3	NA	1.2
Soil Type A or B		0.7	1.2	1.8	1.1	1.4	0.6	1.5	1.6	1.1	1.5	1.3	1.6	1.3	1.4	1.4	1.3	1.6
Soil Type E (1-3 stories)		-1.2	-1.3	-1.4	-0.9	-0.9	-1.0	-0.9	-0.9	-0.7	-1.0	-0.7	-0.8	-0.7	-0.8	-0.8	-0.6	-0.9
Soil Type E (> 3 stories)		-1.8	-1.6	-1.3	-0.9	-0.9	NA	-0.9	-1.0	-0.8	-1.0	-0.8	NA	-0.7	-0.7	-0.8	-0.6	NA
Minimum Score, S_{MIN}		*1.6*	*1.2*	*0.9*	*0.6*	*0.6*	*0.8*	*0.6*	*0.6*	*0.3*	*0.3*	*0.3*	*0.3*	*0.2*	*0.3*	*0.3*	*0.2*	*1.5*

FINAL LEVEL 1 SCORE, $S_{L1} \geq S_{MIN}$:

EXTENT OF REVIEW

Exterior: ☐ Partial ☐ All Sides ☐ Aerial
Interior: ☐ None ☐ Visible ☐ Entered
Drawings Reviewed: ☐ Yes ☐ No
Soil Type Source: __________
Geologic Hazards Source: __________
Contact Person: __________

LEVEL 2 SCREENING PERFORMED?

☐ Yes, Final Level 2 Score, S_{L2} __________ ☐ No
Nonstructural hazards? ☐ Yes ☐ No

OTHER HAZARDS

Are There Hazards That Trigger A Detailed Structural Evaluation?

- ☐ Pounding potential (unless S_{L2} > cut-off, if known)
- ☐ Falling hazards from taller adjacent building
- ☐ Geologic hazards or Soil Type F
- ☐ Significant damage/deterioration to the structural system

ACTION REQUIRED

Detailed Structural Evaluation Required?

- ☐ Yes, unknown FEMA building type or other building
- ☐ Yes, score less than cut-off
- ☐ Yes, other hazards present
- ☐ No

Detailed Nonstructural Evaluation Recommended? *(check one)*

- ☐ Yes, nonstructural hazards identified that should be evaluated
- ☐ No, nonstructural hazards exist that may require mitigation, but a detailed evaluation is not necessary
- ☐ No, no nonstructural hazards identified ☐ DNK

Where information cannot be verified, screener shall note the following: EST = Estimated or unreliable data <u>OR</u> DNK = Do Not Know

Legend:	MRF = Moment-resisting frame	RC = Reinforced concrete	URM INF = Unreinforced masonry infill	MH = Manufactured Housing	FD = Flexible diaphragm
	BR = Braced frame	SW = Shear wall	TU = Tilt up	LM = Light metal	RD = Rigid diaphragm

Rapid Visual Screening of Buildings for Potential Seismic Hazards

FEMA P-154 Data Collection Form

Level 2 (Optional)
MODERATE Seismicity

Optional Level 2 data collection to be performed by a civil or structural engineering professional, architect, or graduate student with background in seismic evaluation or design of buildings.

Bldg Name:	**Final Level 1 Score:**	*S_{L1} =*	*(do not consider S_{MIN})*
Screener:	**Level 1 Irregularity Modifiers:**	*Vertical Irregularity, V_{L1} =*	*Plan Irregularity, P_{L1} =*
Date/Time:	**ADJUSTED BASELINE SCORE:**	*$S' = (S_{L1} - V_{L1} - P_{L1})$ =*	

STRUCTURAL MODIFIERS TO ADD TO ADJUSTED BASELINE SCORE

Topic	Statement *(If statement is true, circle the "Yes" modifier; otherwise cross out the modifier.)*		Yes	Subtotals
Vertical Irregularity, V_{L2}	Sloping Site	W1 building: There is at least a full story grade change from one side of the building to the other.	-1.4	
		Non-W1 building: There is at least a full story grade change from one side of the building to the other.	-0.4	
	Weak and/or Soft Story *(circle one maximum)*	W1 building cripple wall: An unbraced cripple wall is visible in the crawl space.	-0.7	
		W1 house over garage: Underneath an occupied story, there is a garage opening without a steel moment frame, and there is less than 8' of wall on the same line (for multiple occupied floors above, use 16' of wall minimum).	-1.4	
		W1A building open front: There are openings at the ground story (such as for parking) over at least 50% of the length of the building.	-1.4	
		Non-W1 building: Length of lateral system at any story is less than 50% of that at story above or height of any story is more than 2.0 times the height of the story above.	-1.1	
		Non-W1 building: Length of lateral system at any story is between 50% and 75% of that at story above or height of any story is between 1.3 and 2.0 times the height of the story above.	-0.6	
	Setback	Vertical elements of the lateral system at an upper story are outboard of those at the story below causing the diaphragm to cantilever at the offset.	-1.2	
		Vertical elements of the lateral system at upper stories are inboard of those at lower stories.	-0.6	
		There is an in-plane offset of the lateral elements that is greater than the length of the elements.	-0.4	
	Short Column/ Pier	C1,C2,C3,PC1,PC2,RM1,RM2: At least 20% of columns (or piers) along a column line in the lateral system have height/depth ratios less than 50% of the nominal height/depth ratio at that level.	-0.5	
		C1,C2,C3,PC1,PC2,RM1,RM2: The column depth (or pier width) is less than one half of the depth of the spandrel, or there are infill walls or adjacent floors that shorten the column.	-0.5	
	Split Level	There is a split level at one of the floor levels or at the roof.	-0.6	
	Other Irregularity	There is another observable severe vertical irregularity that obviously affects the building's seismic performance.	-1.2	*V_{L2}* = _______
		There is another observable moderate vertical irregularity that may affect the building's seismic performance.	-0.6	*(Cap at -1.4)*
Plan Irregularity, P_{L2}	Torsional irregularity: Lateral system does not appear relatively well distributed in plan in either or both directions. *(Do not include the W1A open front irregularity listed above.)*		-1.0	
	Non-parallel system: There are one or more major vertical elements of the lateral system that are not orthogonal to each other.		-0.5	
	Reentrant corner: Both projections from an interior corner exceed 25% of the overall plan dimension in that direction.		-0.5	
	Diaphragm opening: There is an opening in the diaphragm with a width over 50% of the total diaphragm width at that level.		-0.3	
	C1, C2 building out-of-plane offset: The exterior beams do not align with the columns in plan.		-0.4	*P_{L2}* = _______
	Other irregularity: There is another observable plan irregularity that obviously affects the building's seismic performance.		-1.0	*(Cap at -1.4)*
Redundancy	The building has at least two bays of lateral elements on each side of the building in each direction.		+0.4	
Pounding	Building is separated from an adjacent structure by less than 0.25% of the height of the shorter of the building and adjacent structure and:	The floors do not align vertically within 2 feet. *(Cap total pounding modifiers at -1.4)*	-1.2	
		One building is 2 or more stories taller than the other.	-1.2	
		The building is at the end of the block.	-0.6	
S2 Building	"K" bracing geometry is visible.		-1.2	
C1 Building	Flat plate serves as the beam in the moment frame.		-0.5	
PC1/RM1 Bldg	There are roof-to-wall ties that are visible or known from drawings that do not rely on cross-grain bending. *(Do not combine with post-benchmark or retrofit modifier.)*		+0.4	
PC1/RM1 Bldg	The building has closely spaced, full height interior walls (rather than an interior space with few walls such as in a warehouse).		+0.4	
URM	Gable walls are present.		-0.5	
MH	There is a supplemental seismic bracing system provided between the carriage and the ground.		+1.2	
Retrofit	Comprehensive seismic retrofit is visible or known from drawings.		+1.4	*M* = _______

FINAL LEVEL 2 SCORE, $S_{L2} = (S' + V_{L2} + P_{L2} + M) \geq S_{MIN}$: (*Transfer to Level 1 form*)

There is observable damage or deterioration or another condition that negatively affects the building's seismic performance: ☐ Yes ☐ No

If yes, describe the condition in the comment box below and indicate on the Level 1 form that detailed evaluation is required independent of the building's score.

OBSERVABLE NONSTRUCTURAL HAZARDS

Location	Statement (*Check "Yes" or "No"*)	Yes	No	Comment
Exterior	There is an unbraced unreinforced masonry parapet or unbraced unreinforced masonry chimney.			
	There is heavy cladding or heavy veneer.			
	There is a heavy canopy over exit doors or pedestrian walkways that appears inadequately supported.			
	There is an unreinforced masonry appendage over exit doors or pedestrian walkways.			
	There is a sign posted on the building that indicates hazardous materials are present.			
	There is a taller adjacent building with an unanchored URM wall or unbraced URM parapet or chimney.			
	Other observed exterior nonstructural falling hazard:			
Interior	There are hollow clay tile or brick partitions at any stair or exit corridor.			
	Other observed interior nonstructural falling hazard:			

Estimated Nonstructural Seismic Performance (*Check appropriate box and transfer to Level 1 form conclusions*)

☐ Potential nonstructural hazards with significant threat to occupant life safety →Detailed Nonstructural Evaluation recommended
☐ Nonstructural hazards identified with significant threat to occupant life safety →But no Detailed Nonstructural Evaluation required
☐ Low or no nonstructural hazard threat to occupant life safety → No Detailed Nonstructural Evaluation required

Comments:

Rapid Visual Screening of Buildings for Potential Seismic Hazards

FEMA P-154 Data Collection Form

Level 1
LOW Seismicity

PHOTOGRAPH

Address: ______________________________

______________________________ **Zip:** __________

Other Identifiers: ______________________________

Building Name: ______________________________

Use: ______________________________

Latitude: __________ **Longitude:** __________

S_S: __________ **S_1:** __________

Screener(s): __________ **Date/Time:** __________

No. Stories: Above Grade: _____ Below Grade: _____ **Year Built:** _____ ☐ EST

Total Floor Area (sq. ft.): __________ **Code Year:** __________

Additions: ☐ None ☐ Yes, Year(s) Built: __________

Occupancy:
Assembly Commercial Emer. Services ☐ Historic ☐ Shelter
Industrial Office School ☐ Government
Utility Warehouse Residential, # Units: _____

Soil Type:

☐**A**	☐**B**	☐**C**	☐**D**	☐**E**	☐**F**	**DNK**
Hard Rock	Avg Rock	Dense Soil	Stiff Soil	Soft Soil	Poor Soil	*If DNK, assume Type D.*

Geologic Hazards: Liquefaction: Yes/No/DNK Landslide: Yes/No/DNK Surf. Rupt.: Yes/No/DNK

Adjacency: ☐ Pounding ☐ Falling Hazards from Taller Adjacent Building

Irregularities:
☐ Vertical (type/severity) __________
☐ Plan (type) __________

Exterior Falling Hazards:
☐ Unbraced Chimneys ☐ Heavy Cladding or Heavy Veneer
☐ Parapets ☐ Appendages
☐ Other: __________

COMMENTS:

SKETCH

☐ Additional sketches or comments on separate page

BASIC SCORE, MODIFIERS, AND FINAL LEVEL 1 SCORE, S_{L1}

FEMA BUILDING TYPE	**Do Not Know**	**W1**	**W1A**	**W2**	**S1** (MRF)	**S2** (BR)	**S3** (LM)	**S4** (RC SW)	**S5** (URM INF)	**C1** (MRF)	**C2** (SW)	**C3** (URM INF)	**PC1** (TU)	**PC2**	**RM1** (FD)	**RM2** (RD)	**URM**	**MH**
Basic Score		**6.2**	**5.9**	**5.7**	**3.8**	**3.9**	**4.4**	**4.1**	**4.5**	**3.3**	**4.2**	**3.5**	**3.8**	**3.3**	**3.7**	**3.7**	**3.2**	**4.6**
Severe Vertical Irregularity, V_{L1}		-1.5	-1.5	-1.5	-1.4	-1.3	-1.6	-1.2	-1.3	-1.3	-1.2	-1.1	-1.3	-1.1	-1.1	-1.1	-1.2	NA
Moderate Vertical Irregularity, V_{L1}		-1.0	-0.9	-0.9	-0.9	-0.8	-1.0	-0.7	-0.7	-0.7	-0.7	-0.6	-0.8	-0.6	-0.6	-0.6	-0.7	NA
Plan Irregularity, P_{L1}		-1.6	-1.4	-1.3	-1.2	-1.1	-1.4	-1.0	-1.1	-1.0	-1.0	-0.9	-1.2	-0.9	-0.9	-0.9	-1.0	NA
Pre-Code		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Post-Benchmark		2.2	2.4	2.5	2.0	1.6	1.4	2.1	NA	2.3	2.2	NA	1.9	2.6	2.3	2.3	NA	1.8
Soil Type A or B		0.9	1.1	1.3	1.0	1.2	0.8	1.3	1.4	0.9	1.2	1.2	1.3	1.3	1.4	1.4	1.3	0.9
Soil Type E (1-3 stories)		-1.2	-1.7	-2.3	-1.2	-1.4	-1.0	-1.7	-2.0	-1.4	-2.0	-1.6	-1.7	-1.6	-1.7	-1.7	-1.5	-2.1
Soil Type E (> 3 stories)		-1.7	-2.0	-2.2	-1.2	-1.4	NA	-1.7	-1.9	-1.3	-1.9	-1.6	NA	-1.6	-1.6	-1.7	-1.4	NA
Minimum Score, S_{MIN}		*2.7*	*2.1*	*1.5*	*0.9*	*0.8*	*1.2*	*0.8*	*0.9*	*0.5*	*0.6*	*0.5*	*0.6*	*0.4*	*0.6*	*0.5*	*0.4*	*2.5*

FINAL LEVEL 1 SCORE, $S_{L1} \geq S_{MIN}$:

EXTENT OF REVIEW

Exterior: ☐ Partial ☐ All Sides ☐ Aerial
Interior: ☐ None ☐ Visible ☐ Entered
Drawings Reviewed: ☐ Yes ☐ No
Soil Type Source: __________
Geologic Hazards Source: __________
Contact Person: __________

LEVEL 2 SCREENING PERFORMED?

☐ Yes, Final Level 2 Score, S_{L2} __________ ☐ No
Nonstructural hazards? ☐ Yes ☐ No

OTHER HAZARDS

Are There Hazards That Trigger A Detailed Structural Evaluation?

☐ Pounding potential (unless S_{L2} > cut-off, if known)
☐ Falling hazards from taller adjacent building
☐ Geologic hazards or Soil Type F
☐ Significant damage/deterioration to the structural system

ACTION REQUIRED

Detailed Structural Evaluation Required?

☐ Yes, unknown FEMA building type or other building
☐ Yes, score less than cut-off
☐ Yes, other hazards present
☐ No

Detailed Nonstructural Evaluation Recommended? *(check one)*

☐ Yes, nonstructural hazards identified that should be evaluated
☐ No, nonstructural hazards exist that may require mitigation, but a detailed evaluation is not necessary
☐ No, no nonstructural hazards identified ☐ DNK

Where information cannot be verified, screener shall note the following: EST = Estimated or unreliable data OR DNK = Do Not Know

Legend:	MRF = Moment-resisting frame	RC = Reinforced concrete	URM INF = Unreinforced masonry infill	MH = Manufactured Housing	FD = Flexible diaphragm
	BR = Braced frame	SW = Shear wall	TU = Tilt up	LM = Light metal	RD = Rigid diaphragm

Rapid Visual Screening of Buildings for Potential Seismic Hazards **Level 2 (Optional)**

FEMA P-154 Data Collection Form **LOW Seismicity**

Optional Level 2 data collection to be performed by a civil or structural engineering professional, architect, or graduate student with background in seismic evaluation or design of buildings.

Bldg Name:	**Final Level 1 Score:**	S_{L1} =	*(do not consider S_{MIN})*
Screener:	**Level 1 Irregularity Modifiers:**	*Vertical Irregularity, V_{L1} =*	*Plan Irregularity, P_{L1} =*
Date/Time:	**ADJUSTED BASELINE SCORE:**	*$S' = (S_{L1} - V_{L1} - P_{L1})$ =*	

STRUCTURAL MODIFIERS TO ADD TO ADJUSTED BASELINE SCORE

Topic	**Statement** *(If statement is true, circle the "Yes" modifier; otherwise cross out the modifier.)*		**Yes**	**Subtotals**
Vertical Irregularity, V_{L2}	Sloping Site	W1 building: There is at least a full story grade change from one side of the building to the other.	-1.5	
		Non-W1 building: There is at least a full story grade change from one side of the building to the other.	-0.4	
	Weak and/or Soft Story *(circle one maximum)*	W1 building cripple wall: An unbraced cripple wall is visible in the crawl space.	-0.7	
		W1 house over garage: Underneath an occupied story, there is a garage opening without a steel moment frame, and there is less than 8' of wall on the same line (for multiple occupied floors above, use 16' of wall minimum).	-1.5	
		W1A building open front: There are openings at the ground story (such as for parking) over at least 50% of the length of the building.	-1.5	
		Non-W1 building: Length of lateral system at any story is less than 50% of that at story above or height of any story is more than 2.0 times the height of the story above.	-1.3	
		Non-W1 building: Length of lateral system at any story is between 50% and 75% of that at story above or height of any story is between 1.3 and 2.0 times the height of the story above.	-0.6	
	Setback	Vertical elements of the lateral system at an upper story are outboard of those at the story below causing the diaphragm to cantilever at the offset.	-1.3	
		Vertical elements of the lateral system at upper stories are inboard of those at lower stories.	-0.6	
		There is an in-plane offset of the lateral elements that is greater than the length of the elements.	-0.4	
	Short Column/ Pier	C1,C2,C3,PC1,PC2,RM1,RM2: At least 20% of columns (or piers) along a column line in the lateral system have height/depth ratios less than 50% of the nominal height/depth ratio at that level.	-0.6	
		C1,C2,C3,PC1,PC2,RM1,RM2: The column depth (or pier width) is less than one half of the depth of the spandrel, or there are infill walls or adjacent floors that shorten the column.	-0.6	
	Split Level	There is a split level at one of the floor levels or at the roof.	-0.6	
	Other Irregularity	There is another observable severe vertical irregularity that obviously affects the building's seismic performance.	-1.3	V_{L2} = ______
		There is another observable moderate vertical irregularity that may affect the building's seismic performance.	-0.6	*(Cap at -1.5)*
Plan Irregularity, P_{L2}	Torsional irregularity: Lateral system does not appear relatively well distributed in plan in either or both directions. *(Do not include the W1A open front irregularity listed above.)*		-1.1	
	Non-parallel system: There are one or more major vertical elements of the lateral system that are not orthogonal to each other.		-0.6	
	Reentrant corner: Both projections from an interior corner exceed 25% of the overall plan dimension in that direction.		-0.6	
	Diaphragm opening: There is an opening in the diaphragm with a width over 50% of the total diaphragm width at that level.		-0.4	
	C1, C2 building out-of-plane offset: The exterior beams do not align with the columns in plan.		-0.5	P_{L2} = ______
	Other irregularity: There is another observable plan irregularity that obviously affects the building's seismic performance.		-1.1	*(Cap at -1.6)*
Redundancy	The building has at least two bays of lateral elements on each side of the building in each direction.		+0.4	
Pounding	Building is separated from an adjacent structure by less than 0.1% of the height of the shorter of the building and adjacent structure and:	The floors do not align vertically within 2 feet. *(Cap total pounding modifiers at -1.5)*	-1.3	
		One building is 2 or more stories taller than the other.	-1.3	
		The building is at the end of the block.	-0.6	
S2 Building	"K" bracing geometry is visible.		-1.3	
C1 Building	Flat plate serves as the beam in the moment frame.		-0.6	
PC1/RM1 Bldg	There are roof-to-wall ties that are visible or known from drawings that do not rely on cross-grain bending. *(Do not combine with post-benchmark or retrofit modifier.)*		+0.4	
PC1/RM1 Bldg	The building has closely spaced, full height interior walls (rather than an interior space with few walls such as in a warehouse).		+0.4	
URM	Gable walls are present.		-0.6	
MH	There is a supplemental seismic bracing system provided between the carriage and the ground.		+1.8	
Retrofit	Comprehensive seismic retrofit is visible or known from drawings.		+1.6	*M* = ______

FINAL LEVEL 2 SCORE, $S_{L2} = (S' + V_{L2} + P_{L2} + M) \geq S_{MIN}$: (*Transfer to Level 1 form*)

There is observable damage or deterioration or another condition that negatively affects the building's seismic performance: ☐ Yes ☐ No

If yes, describe the condition in the comment box below and indicate on the Level 1 form that detailed evaluation is required independent of the building's score.

OBSERVABLE NONSTRUCTURAL HAZARDS

Location	**Statement** (*Check "Yes" or "No"*)	**Yes**	**No**	**Comment**
Exterior	There is an unbraced unreinforced masonry parapet or unbraced unreinforced masonry chimney.			
	There is heavy cladding or heavy veneer.			
	There is a heavy canopy over exit doors or pedestrian walkways that appears inadequately supported.			
	There is an unreinforced masonry appendage over exit doors or pedestrian walkways.			
	There is a sign posted on the building that indicates hazardous materials are present.			
	There is a taller adjacent building with an unanchored URM wall or unbraced URM parapet or chimney.			
	Other observed exterior nonstructural falling hazard:			
Interior	There are hollow clay tile or brick partitions at any stair or exit corridor.			
	Other observed interior nonstructural falling hazard:			

Estimated Nonstructural Seismic Performance (*Check appropriate box and transfer to Level 1 form conclusions*)

- ☐ Potential nonstructural hazards with significant threat to occupant life safety →Detailed Nonstructural Evaluation recommended
- ☐ Nonstructural hazards identified with significant threat to occupant life safety →But no Detailed Nonstructural Evaluation required
- ☐ Low or no nonstructural hazard threat to occupant life safety →No Detailed Nonstructural Evaluation required

Comments:

B.2 Quick Reference Guide

Table B-1 FEMA Building Types and Code Adoption and Enforcement Dates

FEMA Building Type		Year Seismic Codes Initially Adopted and Enforced	Benchmark Year when Codes Improved
W1	Light wood frame single- or multiple-family dwellings		
W1A	Light wood frame multi-unit, multi-story residential buildings with plan areas on each floor of greater than 3,000 square feet		
W2	Wood frame commercial and industrial buildings > 5,000 sqft		
S1	Steel moment-resisting frame		
S2	Braced steel frame		
S3	Light metal frame		
S4	Steel frame with cast-in-place concrete shear walls		
S5	Steel frame with unreinforced masonry infill walls		
C1	Concrete moment-resisting frame		
C2	Concrete shear wall		
C3	Concrete frame with unreinforced masonry infill walls		
PC1	Tilt-up construction		
PC2	Precast concrete frame		
RM1	Reinforced masonry with flexible floor and roof diaphragms		
RM2	Reinforced masonry with rigid floor and roof diaphragms		
URM	Unreinforced masonry bearing-wall buildings		
MH	Manufactured housing		
Anchorage of Heavy Cladding Year in which seismic anchorage requirements were adopted:			

Notes:

These tables shall be filled out by the Supervising Engineer. See Section 2.6.3 of the *Handbook* for additional information. If seismic codes have never been adopted and enforced in the jurisdiction, apply the Pre-Code Score Modifier regardless of the building's date of construction.

Pre-Code: Building designed and constructed prior to the year in which seismic codes were initially adopted and enforced in the jurisdiction; pre-code years are not applicable in regions of Low seismicity.

Post-Benchmark: Building designed and constructed after significant improvements in seismic code requirements (e.g., ductile detailing) were adopted and enforced; the benchmark year when codes improved may be different for each building type and jurisdiction.

Heavy Cladding: Heavy cladding on buildings designed and constructed prior to the year noted is considered an exterior falling hazard and should be noted as such on the Level 1 form.

B.3 Level 1 Building Addition Reference Guide

Table B-2 Level 1 Reference Guide for Reviewing Buildings with Horizontal Additions

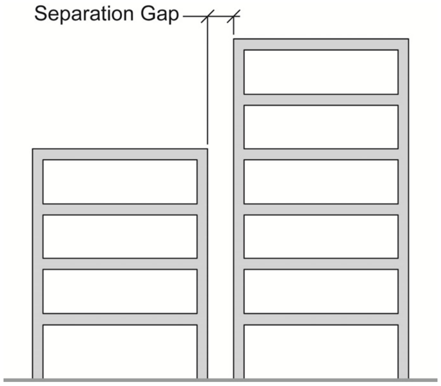
Building Addition Screening Criteria	Response	Screening Guidance
Criterion 1: Does the building have visible and aligned joints over the entire height of two exterior walls and across the roof?	Yes	Determine scores for each separate building defined by the joints and consider the potential for pounding using the adjacency guidelines in Section 3.9.
	No	See Criterion 2
Criterion 2: Does the building have any of the following characteristics: a) abrupt and noticeable differences in architectural style that occur on two sides of the building over the entire height of the exterior walls? b) visible differences in structural framing between distinct portions of the building? c) differences in floor elevation between portions of the building?	Yes	Screen as separate buildings defined by the differences noted in Criterion 2. Determine score for each portion and record the lower score.
	No	Screen as a single building.

B.4 Level 1 Pounding Reference Guide

Table B-3 Level 1 Pounding Reference Guide

Consider pounding when the separation between adjacent buildings is less than:

- 2″ times number of stories in shorter building (in Very High seismicity region)
- 1 1/2″ times number of stories in shorter building (in High seismicity region)
- 1″ times number of stories in shorter building (in Moderately High seismicity region)
- 1/2″ times number of stories in shorter building (in Moderate and Low seismicity regions)



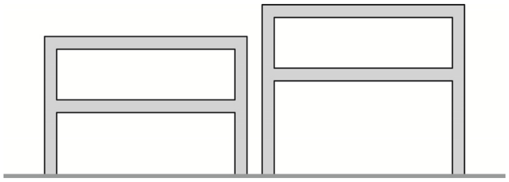
Examples:

a) Two 2-story buildings next to each other in High seismicity region:
Minimum Separation = 1 1/2″ x 2 = 3″

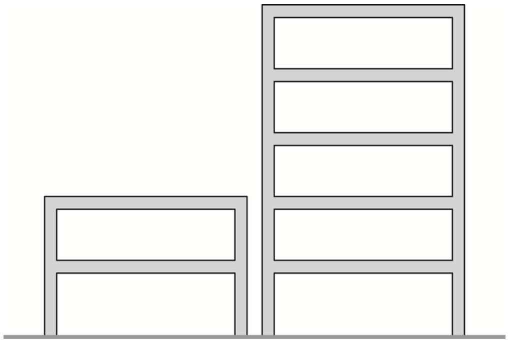
b) 6-story building next to a 4-story building in Moderate seismicity region: Minimum Separation = 1/2″ x 4 = 2″

AND one or more of the following conditions apply:

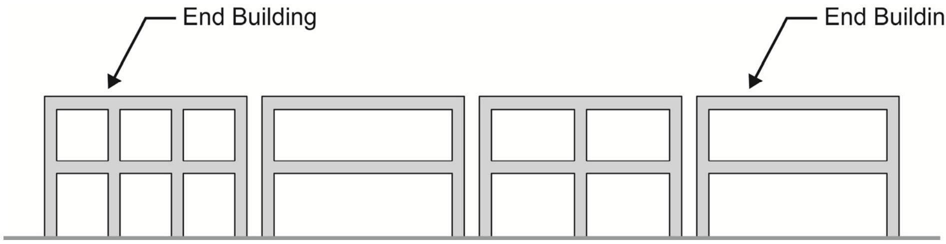
1. Floors of adjacent building do not align vertically within two feet:



2. One building is 2 or more stories taller than the other:



3. Building is at the end of the block:



B.5 Vertical Irregularity Reference Guide

Table B-4 Vertical Irregularity Reference Guide

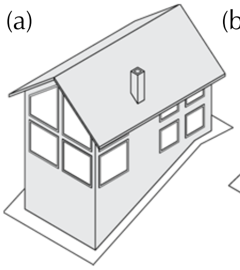
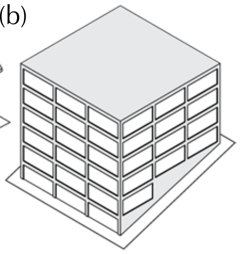
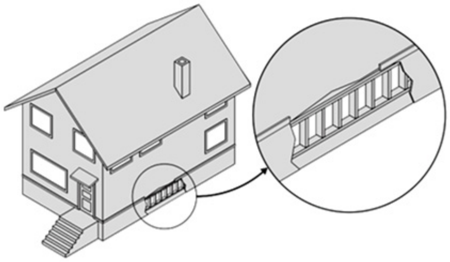
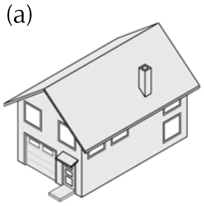
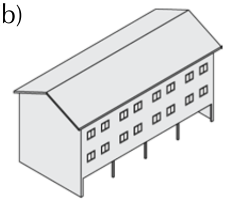
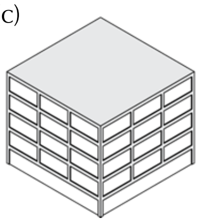
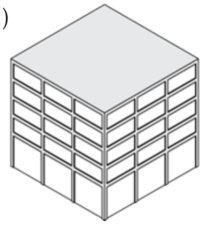
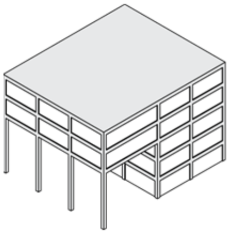
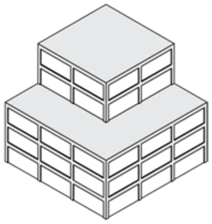
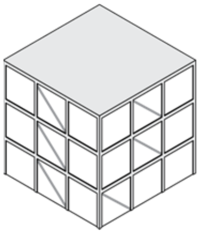
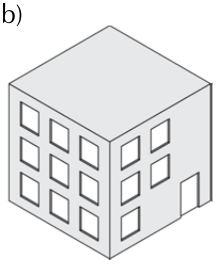
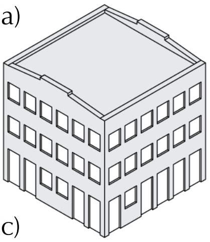
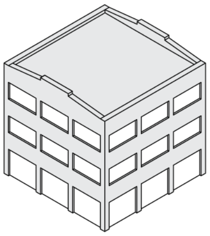
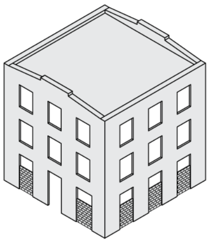
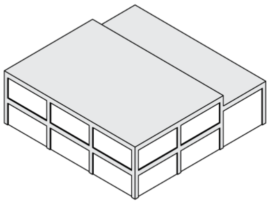
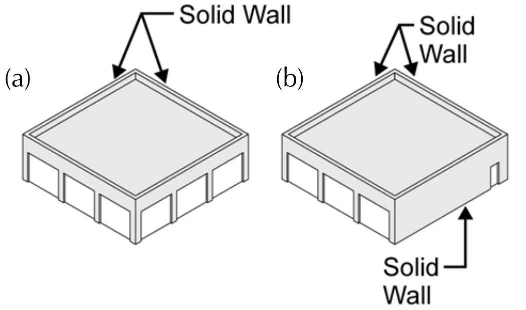
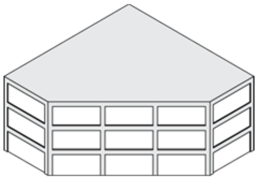
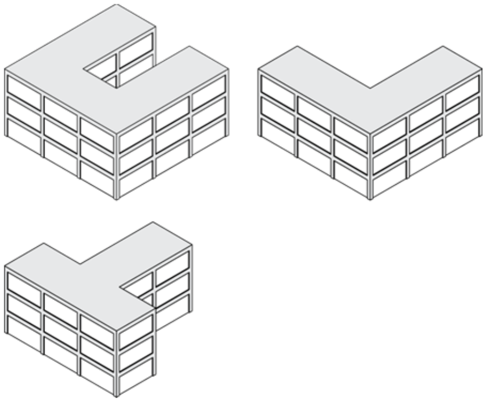
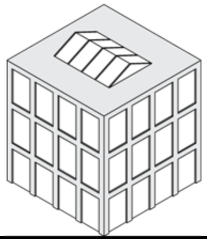
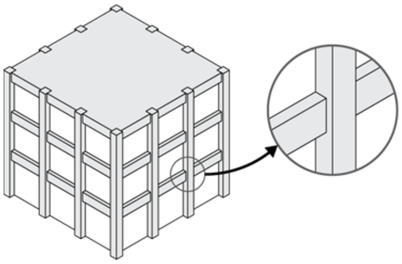
Vertical Irregularity		Severity	Level 1 Instructions
Sloping Site	(a)  (b) 	Varies	Apply if there is more than a one-story slope from one side of the building to the other. Evaluate as Severe for W1 buildings as shown in Figure (a); evaluate as Moderate for all other building types as shown in Figure (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	(a)  (b)  (c)  (d) 	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	(a)  (b) 	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	(a)  (b)  (c) 	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.

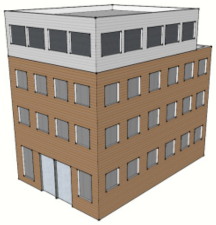
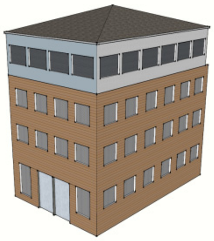
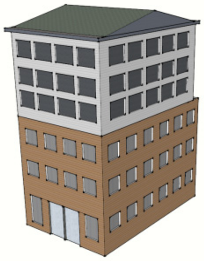
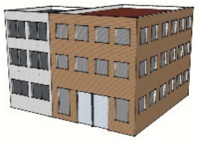
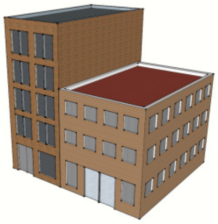
B.6 Plan Irregularity Reference Guide

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.

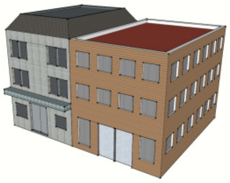
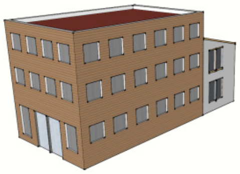
B.7 Level 2 Building Addition Reference Guide

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 also 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.

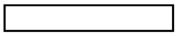
The above horizontal addition scenarios assume that there is not an obvious separation gap between the addition and the original building.

Appendix C

Review of Design and Construction Drawings

Drawing styles vary among engineering offices, but the conventions used are very consistent. The following are some of the common designations:

- Around the perimeter of the building, the exterior walls will be shown as a double line, if the space between the lines is empty, this will usually be a wood stud wall:



- Concrete walls will be shaded or dotted:

 or 

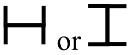
- Masonry walls will be cross hatched or double hatched:

 or 

- Horizontal beams and girders will be shown with a solid line for steel and wood, and a double solid or dotted line for concrete.
    - Steel framing will have a notation of shape, depth, and weight of the member. The designations will include W, S, I, B and several others followed by the depth in inches, an "x," and the weight in pounds per lineal foot. An example would be W8x10 (wide flange shape, 8" deep, 10 lbs/ft).
    - Wood framing will have the width and depth of the member. An example would be 4x10 (4" wide and 10" deep). Floor joists and roof rafters will be shown with the same call-out except not all members will be shown. A few at each end of the area being framed will show, and there will be an arrow showing the extent and the call-out of the size members.
    - Concrete framing will have the width and depth. Where steel and wood are shown as single line, concrete will be shown as a double line. An example of the call out would be 12x24 (12" wide and 24" deep). Additionally, or in lieu of the number call-out, the member might be given a letter and number (e.g., B-1, G-1) with a reference to a schedule for the size and reinforcing, where B stands for beam

and G stands for girder. Usually, beams are smaller than girders and span between girders while girders will be larger and frame between columns.

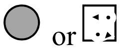
- Columns will be shown on the floor plans as their shape with a shading designation where appropriate:
    - Steel columns will be shown as an "H" rotated to the correct orientation for the location on the plan:

    - Wood columns will be an open square:

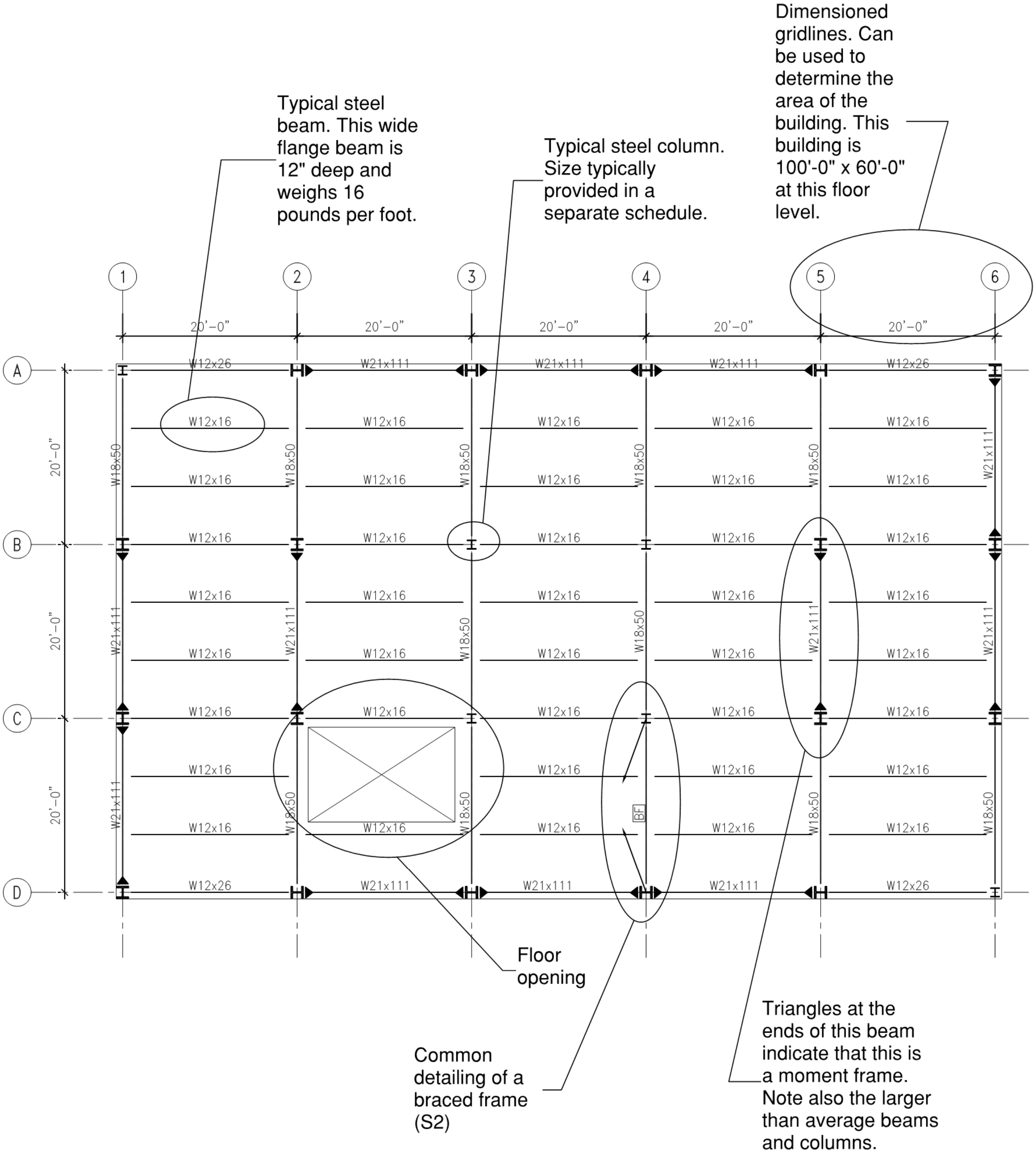
    - Concrete columns will be either a square or a circle depending on the column configuration. The square or circle will be shaded or dotted:

- Steel moment frames will show the columns with a heavy line between the columns representing the beam or girder. At each end of the beam or girder at the column will be a small shaded triangle, indicating that the connection between the beam or girder and the column is fully restrained

Figure C-1 shows an example of a framing plan for floor in a steel S1 or S2 building, and Figure C-2 shows an example for a concrete C2 building.



Dimensioned gridlines. Can be used to determine the area of the building. This building is 100'-0" x 60'-0" at this floor level.

Typical steel beam. This wide flange beam is 12" deep and weighs 16 pounds per foot.

Typical steel column. Size typically provided in a separate schedule.

Floor opening

Common detailing of a braced frame (S2)

Triangles at the ends of this beam indicate that this is a moment frame. Note also the larger than average beams and columns.

Figure C-1 Representative construction drawing of a floor plan for an S1 building. S2 detailing also shown.

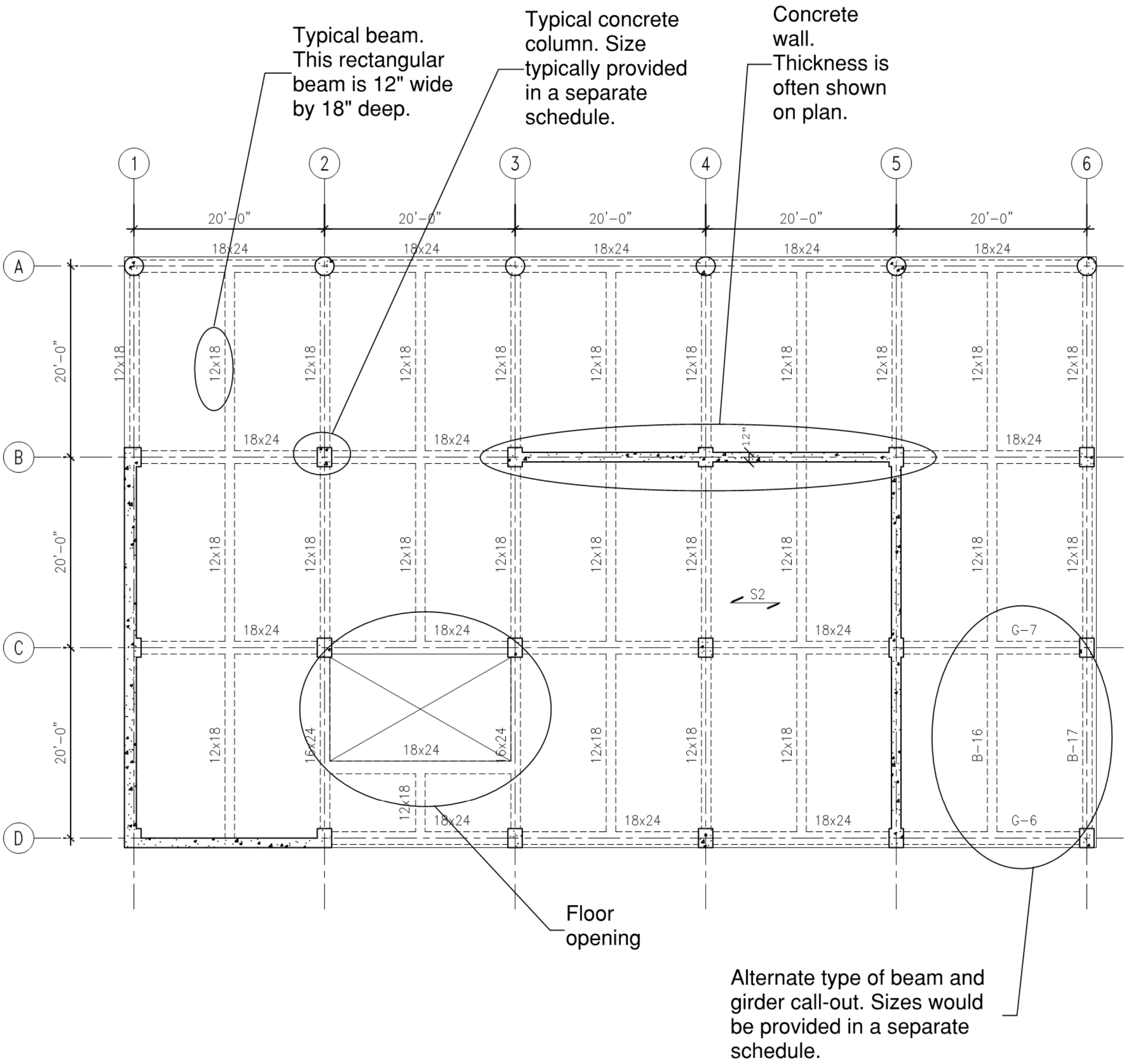


Figure C-2 Representative construction drawing of a floor plan for a C2 building.

Appendix D

Exterior Screening for Seismic System and Age

D.1 Introduction

A successful evaluation of a building is dependent on the screener's ability to identify accurately the construction materials, seismic force-resisting system, age, and other attributes that would modify its earthquake performance (e.g., vertical or plan irregularities). This appendix includes discussions of inspection techniques that can be used while viewing from the street.

D.2 What to Look For and How to Find It

It may be difficult to identify positively the FEMA Building Type from the street as building veneers often mask the structural skeleton. For example, a steel frame and a concrete frame may look similar from the outside. Features typical of a specific type of structure may give clues for successful identification. In some cases, there may be more than one type of frame present in the structure. Should this be the case, the predominant frame type should be indicated on the form.

Following are attributes that should be considered when trying to determine a building seismic force-resisting system from the street:

- *Age.* The approximate age of a building can indicate the possible FEMA Building Type, as well as indicating the seismic design code used during the building design process. Age is difficult to determine visually, but an approximation, accurate within perhaps a decade, can be estimated by looking at the architectural style and detail treatment of the building exterior, if the façade has not been renovated. If a building has been renovated, the apparent age is misleading. See Section D.3 for additional guidance.
- *Façade Pattern.* The type of structure can sometimes be deduced by the openness of the façade, or the size and pattern of window openings. The façade material often can give hints to the structure beneath. Newer façade materials likely indicate that modern construction types were used in the design and may indicate that certain building types can be eliminated.

- *Height.* The number of stories will indicate the possible type of construction. This is particularly useful for taller buildings, when combined with knowledge of local building practice. See Section D.4 for additional guidance.
- *Original Use.* The original use can, at times, give hints as to the FEMA Building Type. The original use can be inferred from the building character, if the building has not been renovated. The present use may be different from the original use. This is especially true in neighborhoods that have changed in character. A typical example of this is where a city's central business district has grown rapidly, and engulfed what were once industrial districts. A building's use may have changed to mixed office, commercial or residential (for office workers).

D.3 Identification of Building Age

The ability to identify the age of a building by considering its architectural style and construction materials requires an extensive knowledge of architectural history and past construction practice. It is beyond the scope of this *Handbook* to discuss the various styles and construction practices. Persons involved in or interested in buildings often have a general knowledge of architectural history relevant to their region. Interested readers should refer to in-depth texts for more specific information.

Photographs, architectural character, and age of residential, commercial, and mixed use and miscellaneous buildings, are illustrated in Tables D-1 through D-3, respectively. Photographs of several example steel frame and concrete frame buildings under construction are provided in Figure D-1. The screener should study these photographs and characteristics closely to assist in differentiating architectural styles and façade treatment of various periods. Façade renovation (see Photos b and c in Figure D-1) can clearly alter the original appearance. When estimating building age, the screener should look at the building from all sides as façade renovation often occurs only at the building front. A new building will seldom look like an old one. That is, a building is usually at least as old as it looks. Even when designed to look old, telltale signs of modern techniques can usually be seen in the type of windows, fixtures, and material used.

D.4 Identification of FEMA Building Type

The most common inspection that will be utilized with the RVS procedure will be the exterior or "sidewalk" or "streetside" survey. First, the evaluation should be as thorough as possible and performed in a logical manner. The street-facing front of the building is the starting point and the evaluation begins at the ground and progressively moves up the exterior wall to the roof or parapet line.

Table D-1 Photographs, Architectural Characteristics, and Age of Residential Buildings

Examples	Characteristics
 a. 1965 – 1980  b. 1965-1980  c. 1965-1980  d. 1960-1975 reinforced concrete shear wall  e. Pre-1933 URM (rehabilitated)	**Low-Rise Buildings (1-3 stories):** • Typically wood or masonry • May have ground floor or basement parking, a soft story • Older buildings typically have more architectural detail, ornamentation • 1950s and later are more modern, lacking ornamentation, typically with more horizontal lines Common FEMA Building Types: W1A, W2, C1, C2, RM1, RM2, URM **Mid-Rise (4-7 stories) and High-Rise Buildings (8 stories and higher):** • Typically, reinforced concrete (older, URM) • May have commercial ground floor, a soft story • Older buildings typically have more cornices, architectural detail, ornamentation • 1950s and later are lacking ornamentation, typically with stronger vertical or horizontal lines Common FEMA Building Types: W1A, RM1, RM2, URM

Table D-2 Illustrations, Architectural Characteristics, and Age of Commercial Structures

	Characteristics
 a. Pre-1930 (The New American Library, 1980)  b. 1910-1920 (Steel frame with unreinforced masonry infill that has been seismically rehabilitated)  c. 1920-1930  d. 1920-1930  e. 1890-1900	**Pre-1950:** • Building has flat roof with cornices, or several setbacks. • Ornate decorative work in concrete, terra cotta, cast stone or iron. • Large bell tower or clock tower is common. • Simple pattern of windows on all sides. • Floors are concrete slabs on steel or concrete beams. • Exterior is stone, terra cotta or concrete. Common FEMA Building Types: S2, S5, C2, C3

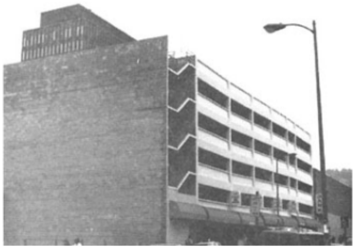
Table D-2 Illustrations, Architectural Characteristics, and Age of Commercial Structures (continued)

Examples	Characteristics
 f. 44 story, 1960s, L-shape on the left; 20 story, 1914, with setback on the right  g. 1950-1975  h. 1940-1950  i. 1950-1975  j. 1950-1975	**1950-1975:** • Flat roof, typically with no cornice. • Building is square or rectangular full height, fewer setbacks. • First story and top story can be taller than other stories. In some cases, the top story could be shorter than others. • Exterior finishes metal or glass, pre-cast stone or concrete. • Floors are concrete slab over steel or concrete beams. Common FEMA Building Types: S1, S2, S4, C1, C2

Table D-2 Illustrations, Architectural Characteristics, and Age of Commercial Structures (continued)

Examples	Characteristics
 k. Post-1975  l. Post-1975  m. Post-1975  n. Post-1975  o. Post-1975	**Post-1975:** • Flat roof, typically with no cornice. • Building is square or rectangular for its full height, fewer setbacks. • First story and top story can be taller than other stories. (In some cases, though, the top story could be shorter than others.) • Exterior finishes: metal or glass, pre-cast stone or concrete, with little ornamentation • Floors are concrete slabs over steel or concrete beams. Common FEMA Building Types: S1, S2, S4, C1, C2

Table D-3 Photographs, Architectural Characteristics, and Age of Miscellaneous Structures

Examples	Characteristics
 a. 1920-1930  b. 1920-1950  c. 1990-2000  d. 1990-2000; airport terminal  e. 1920-1930; windows create coupled shear walls.  f. Pre-1930  g. 1950 – 1965 parking structure  h. 1920-1930; theater and shops complex, reinforced concrete	Mixed use (residential with a commercial first floor), places of assembly, theatres, triangular buildings, halls, parking structures: • Long spans • Tall first story (for commercial use) - soft or weak story • Atria or irregular floor-to-floor layout

a. Building above is a high-rise steel dual system: moment frame (heavy columns and beams on upper façade) with bracing around elevator core. Fireproofing is being applied to steel at mid-height (inside the shroud) and precast façade elements are being attached to frame in lower stories.

b. Reinforced concrete frame under renovation: demolition of older façade units.

c. New precast façade units being applied to reinforced concrete frame buildings.

Figure D-1 Photos showing basic construction in steel-frame buildings and reinforced concrete-frame buildings.

For taller buildings, a pair of binoculars is useful. When a thorough inspection of the street-front elevation has been completed, the procedure is repeated on the next accessible wall. From the exterior, the screener should be able to determine the approximate age of the building, its original occupancy, and count the number of stories. With this information, Tables D-4 through D-7 provide the most likely structural system type, based on original occupancy and number of stories. These tables are based on expert judgment and would benefit from verification by design professionals and building regulatory personnel familiar with local design and construction

Table D-4 Most Likely FEMA Building Types for Pre-1930 Buildings

Original Occupancy	Number of Stories					
	1-2	**3**	**4-6**	**7-15**	**15-30**	**30+**
Residential	W1	W1A	W1A	S5		
	W1A	URM	S5	C3		
	URM		C3			
			URM			
Commercial	W2	W2	S1	S1	S1	
	S4	S4	S2	S2	S2	
	S5	S5	S4	S4	S4	
	C1	C1	S5	S5	S5	
	C2	C2	C1	C1	C1	
	C3	C3	C2	C2	C2	
	URM	URM	C3	C3	C3	
			URM			
Industrial	W2	W2				
	S1	S1				
	S2	S2				
	S3	S5				
	S5	C1				
	C1	C2				
	C2	C3				
	C3	URM				
	URM					

practices. Note that if it is not possible to identify immediately the FEMA Building Type for a pre-1930 building, the original occupancy and number of stories will provide some guidance. The building will need further inspection for precise identification.

In addition to using information on occupancy and number of stories, as provided in Tables D-4 through D-7, the following are some locations that the screener can look, without performing destructive investigations, to gain insight into the structure type:

- In newer frame construction the columns are often exposed on the exterior in the first story. If the columns are covered with a façade material, they are most likely steel columns, indicating a steel frame. If the frames are concrete, they are usually exposed and not covered with a façade. See Figures D-2 and D-3.

Table D-5 Most Likely FEMA Building Types for 1930-1945 Buildings

Original Occupancy	Number of Stories					
	1-2	3	4-6	7-15	15-30	30+
Residential	W1	W1A	W1A	S1		
	W1A	URM	S1	S2		
	URM		S2	S5		
			S5			
			URM			
Commercial	W2	W2	S1	S1	S1	S2
	S1	S1	S2	S2	S2	S5
	S2	S2	S5	S5	S5	
	S5	S5	C1	C1	C1	
	C1	C1	C2	C2	C2	
	C2	C2	C3	C3	C3	
	C3	C3	RM1			
	RM1	RM1	RM2			
	RM2	RM2	URM			
	URM	URM				
Industrial	S3	S3	C1			
	S5	S5	C2			
	C1	C1	C3			
	C2	C2				
	C3	C3				
	RM1	RM1				
	RM2	RM2				
	URM	URM				

Table D-6 Most Likely FEMA Building Types for 1945-1960 Buildings

Original Occupancy	Number of Stories					
	1-2	3	4-6	7-15	15-30	30+
Residential	W1	W1A	S1	S1	S1	S1
	W1A	RM	S2	S2	S2	S2
	RM	URM*	C1	C1	C1	C1
	URM*		C2	C2	C2	C2
			RM1			
			RM2			
			URM*			
Commercial	W2	W2	S1	S1	S1	S1
	S1	S1	S2	S2	S2	S2
	S2	S2	C1	C1	C1	C1
	C1	C1	C2	C2	C2	C2
	C2	C2	RM1			
	RM1	RM1	RM2			
	RM2	RM2	URM*			
	URM*	URM*				
Industrial	C1	S1	S1			
	C2	S2	S2			
	PC1	C1	C1			
	RM1	C2	C2			
	RM2	RM1	RM1			
	URM*	RM2	RM2			
		URM*	URM*			

*By this period, URM was generally not permitted in California or other high-seismicity regions, so that only in the central or eastern U.S. would buildings of this age be URM.

Table D-7 Most Likely FEMA Building Types for Post-1960 Buildings

Original Occupancy	Number of Stories					
	1-2	3	4-6	7-15	15-30	30+
Residential	W1,	W1A	W1A	S1		
	W1A	S1	S1	S2		
	S1	S2	S2	C1		
	S2	C1	C1	C2		
	C1	C2	C2	PC2		
	C2	PC2	PC2	RM1		
	PC2	RM1	RM1	RM2		
	RM1	RM2	RM2			
	RM2					
Commercial	W2	W2	W2	S1	S1	S1
	S1	S1	S1	S2	S2	S2
	S2	S2	S2	C1	C1	C1
	C1	C1	C1	C2	C2	C2
	C2	C2	C2	PC2	PC2	
	PC1	PC1	PC2	RM1		
	PC2	PC2	RM1	RM2		
	RM1	RM1	RM2			
	RM2	RM2				
Industrial	S1	S1	S1	S1	C1	
	S2	S2	S2	S2	C2	
	S3	C1	C1	C1	PC2	
	C1	C2	C2	C2		
	C2	PC1	PC2	PC2		
	PC1	PC2	RM1			
	PC2	RM1	RM2			
	RM1	RM2				
	RM2					

Figure D-2 Building with exterior columns covered with a façade material.

Figure D-3 Detail of the column façade of Figure D-2.

- Some structures use a combination of shear walls in the transverse direction and frames in the longitudinal direction. This can be seen from the exterior as the shear walls usually extend through the exterior longitudinal wall and are exposed there. This is most common in hotels and other residential structures where balconies are included. See Figure D-4.

Figure D-4 Building with both shear walls (in the short direction) and frames (in the long direction).

- An inspection of doorways and window framing can determine wall thickness. When the thickness exceeds approximately 12 inches, the wall is most likely unreinforced masonry (URM).
- If there are vertical joints in the wall, regularly spaced and extending to the full height, the wall is constructed of concrete, and if three or less stories in height, the FEMA Building Type is most likely a tilt-up (PC1). See Figure D-5.

Figure D-5 Regular, full-height joints in a building's wall indicate a concrete tilt-up.

- If the building is constructed of brick masonry without header courses (horizontal rows of visible brick ends), and the wall thickness is approximately 8 inches, the FEMA Building Type is most likely reinforced masonry (RM1 or RM2). See Figure D-6.

Figure D-6 Reinforced masonry wall showing no course of header bricks (a row of visible brick ends).

- If the exterior wall shows large concrete block units (approximately 8 to 12 inches high and 12 to 16 inches in length), either smooth or rough faced, the FEMA Building Type may be reinforced concrete block masonry (RM1 and RM2). See Figure D-7.

Figure D-7 Reinforced masonry building with exterior wall of concrete masonry units, or concrete blocks.

Because many buildings have been renovated, the screener should know where to look for clues to the original construction. Most renovations are done for commercial retail spaces, as businesses like to have an up-to-date image. Most exterior renovations are only to the front of the building or to walls that attract attention. Therefore, the original construction can often be seen at the sides, or the rear, where people generally do not look. If the original material is covered in these areas, it is often just painted or lightly plastered. In this case, the pattern of the older material can often still be seen.

Clues helping identify the original material are apparent if one is looking for them. Two examples are included here:

- Figure D-8 shows a building with a 1970s polished stone and glass façade. The side of the building indicates that it is a pre-1930 URM bearing-wall structure.

Figure D-8 A 1970s renovated façade hides a URM bearing wall structure.

- Figure D-9 shows a building façade with typical 1960s material. The side was painted. Showing through the paint, the horizontal board patterns in the poured-in-place concrete wall of pre-1940 construction could still be seen.

D.5 Characteristics of Exposed Construction Materials

Accurate identification of the FEMA Building Type often depends on the ability to recognize the exposed construction material. The screener should be familiar with how different materials look on existing buildings as well as how they have been installed.

Figure D-9 A concrete shear wall structure with a 1960s renovated façade.

Brief descriptions of some common materials are included here:

- *Unreinforced Masonry.* Unreinforced masonry walls, when they are not veneers, are typically several wythes thick (a wythe is a term denoting the width of one brick). Therefore, header bricks will be apparent in the exposed surface. Headers are bricks laid with the butt end on the exterior face, and function to tie wythes of bricks together. Header courses typically occur every six or seven courses. (See Figures D-10 and D-11.) Sometimes, URM infill walls will not have header bricks, and the wythes of brick are held together only by mortar. Needless to say, URM will look old, and most of the time show wear and weathering. URM may also have a soft sand-lime mortar which may be detected by scratching with a knife or key, unless the masonry has been repointed.

Figure D-10 URM wall showing header courses (identified by arrows) and two washer plates indicating wall anchors.

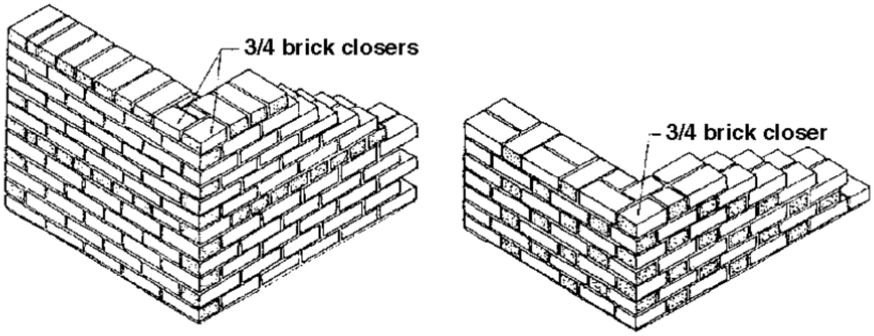


Figure D-11 Drawing of two types of masonry pattern showing header bricks (shown with stipples) (Allen, 1985).

- *Reinforced Masonry.* Most reinforced brick walls are constructed using the hollow grout method. Two wythes of bricks are laid with a hollow space in between. This space contains the reinforcement steel and is grouted afterward (see Figure D-12). This method of construction usually does not include header bricks in the wall surface.

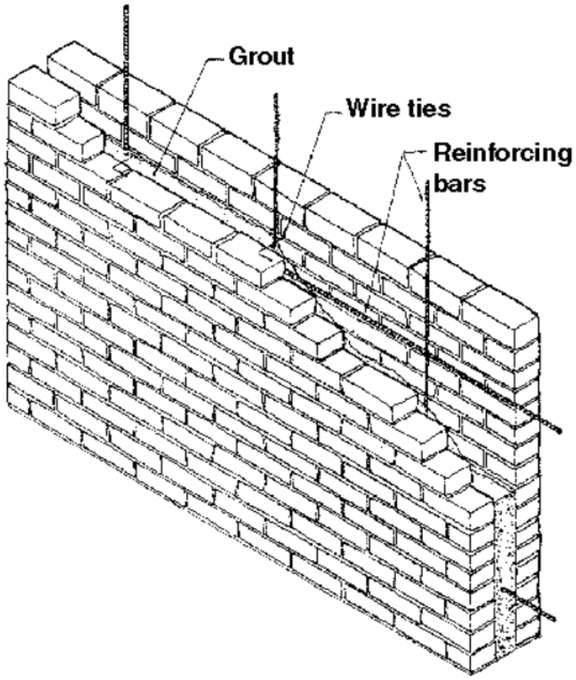


Figure D-12 Diagram of common reinforced masonry construction (Allen, 1985). Bricks are left out of the bottom course at intervals to create cleanout holes, then inserted before grouting.

- *Masonry Veneer.* Masonry veneers can be of several types, including prefabricated panels, thin brick texture tiles, and a single wythe of brick applied onto the structural backing. Figure D-13 shows brick veneer panels. Note the discontinuity of the brick pattern interrupted by the vertical gaps. This indicates that the surface is probably a veneer panel.

The scupper opening at the top of the wall, probably to let the rainwater on the roof to drain, also indicates that this is a thin veneer rather than a solid masonry wall. Good places to look for the evidence of veneer tile are at door or window openings where the edge of the tile will usually show.

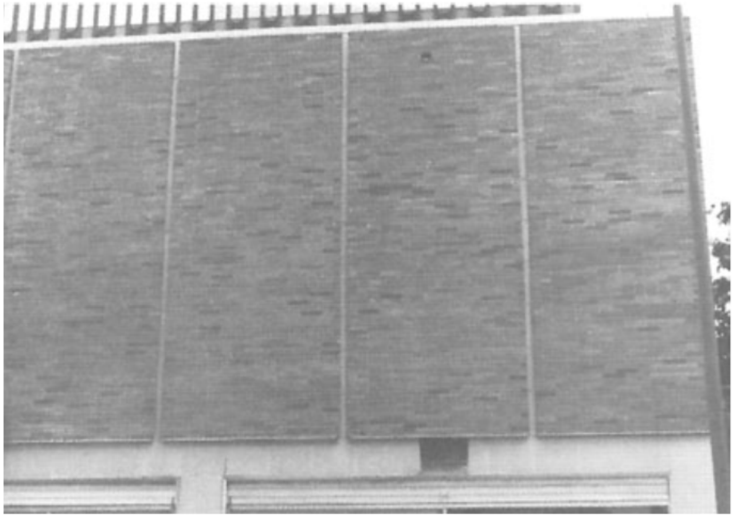


Figure D-13 Brick veneer panels.

- *Hollow Clay Tile.* The exposed area of a hollow clay tile masonry unit is approximately 6 inches by 10 inches and often has strip indentations running the length of the tile. They are fragile, unreinforced, have limited structural value, and usually are used for non-load-bearing walls, typically as infill within a concrete or steel frame. Figure D-14 shows a typical wall panel which has been punctured.

Figure D-14 Hollow clay tile wall with punctured tile.

- *False Masonry.* Masonry pattern sidings can be made from sheet metal, plastic, or asphalt material (see Figures D-15 and D-16). These sidings come in sheets and are attached to a structural backing, usually a wood frame. These sidings can be detected by looking at the edges and by their sound when tapped.

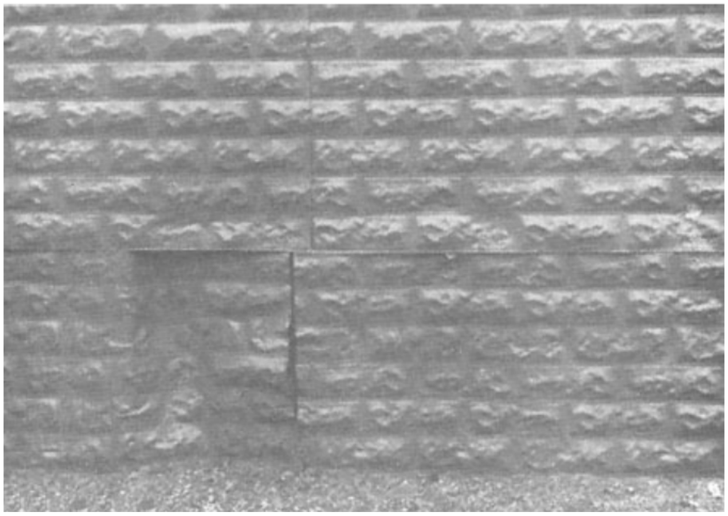


Figure D-15 Sheet metal siding with masonry pattern.

Figure D-16 Asphalt siding with brick pattern.

- *Cast-in-Place Concrete.* Cast-in-place concrete, before the 1940s, will likely show horizontal patterns from the wooden formwork. The formwork was constructed with wood planks, and therefore the concrete also will often show the wood grain pattern. Since the plank edges were not smooth, the surface will have horizontal lines approximately 4, 6, 8, 10, or 12 inches apart (see Figure D-17). Newer cast-in-place concrete comes in various finishes. The most economic finish is that in which the concrete is cast against plywood formwork, which will reflect the wood grain appearance of plywood, or against metal or plastic-covered wood forms, which normally do not show a distinctive pattern.

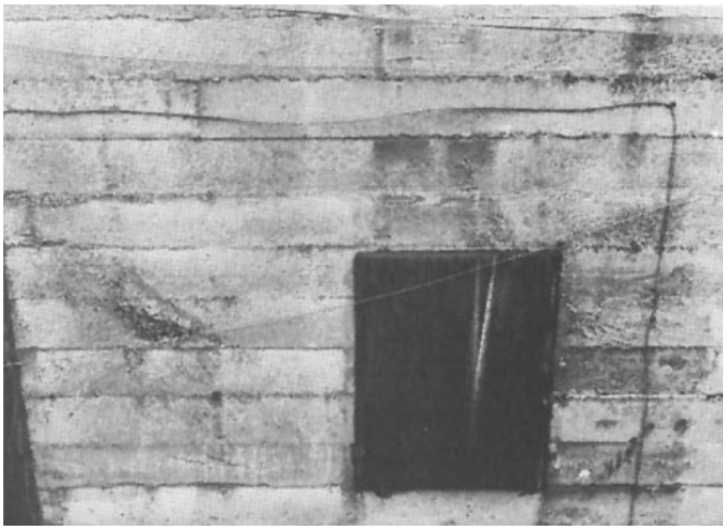


Figure D-17 Pre-1940 cast-in-place concrete with formwork pattern.

Appendix E

Characteristics and Earthquake Performance of FEMA Building Types Used in RVS

E.1 Introduction

For the purpose of the RVS, building structural framing types have been categorized into the 17 FEMA Building Types listed in Section 3.14 and shown in Table 3-1. This appendix provides additional information about each of these structural types, including detailed descriptions of their characteristics, common types of earthquake damage, and common seismic retrofitting techniques. See FEMA 547, *Techniques for the Seismic Rehabilitation of Existing Buildings* (FEMA, 2006), for detailed discussion of commonly employed seismic retrofit techniques.

E.2 Wood Frame (W1, W1A, W2)

E.2.1 Characteristics

Wood frame structures are usually detached residential dwellings, small apartments, commercial buildings or one-story industrial structures. They are rarely more than three stories tall, although older buildings may be as high as six stories, in rare instances.

W1 buildings are light wood frame residential and commercial buildings smaller than or equal to 5,000 square feet. These are most often single family homes, as shown in Figure E-1. W1A buildings are multistory, multi-unit residential wood frame buildings, as shown in Figure E-2. In these buildings, the upper floors are typically residential, while the first story can be used for residential, commercial, or parking space. W2 buildings are light wood frame buildings larger than 5,000 square feet as shown in Figure E-3.

Wood stud walls are typically constructed of 2-inch by 4-inch wood members vertically set about 16 inches apart. See Figures E-4 and E-5. These walls are braced by plywood or equivalent material, or by diagonals made of wood or steel. Many detached single family and low-rise multiple family residences in the United States are of stud wall wood frame construction.

Figure E-1 Single family residence (an example of the W1 identifier, light wood frame single- or multiple-family dwellings of one or more stories in height).

Figure E-2 Multi-unit, multistory residential wood frame structure with plan areas on each floor of greater than 3,000 square feet (W1A).

Figure E-3 Larger wood framed structure, typically with room-width spans (W2, commercial and industrial wood frame buildings greater than 5,000 square feet).

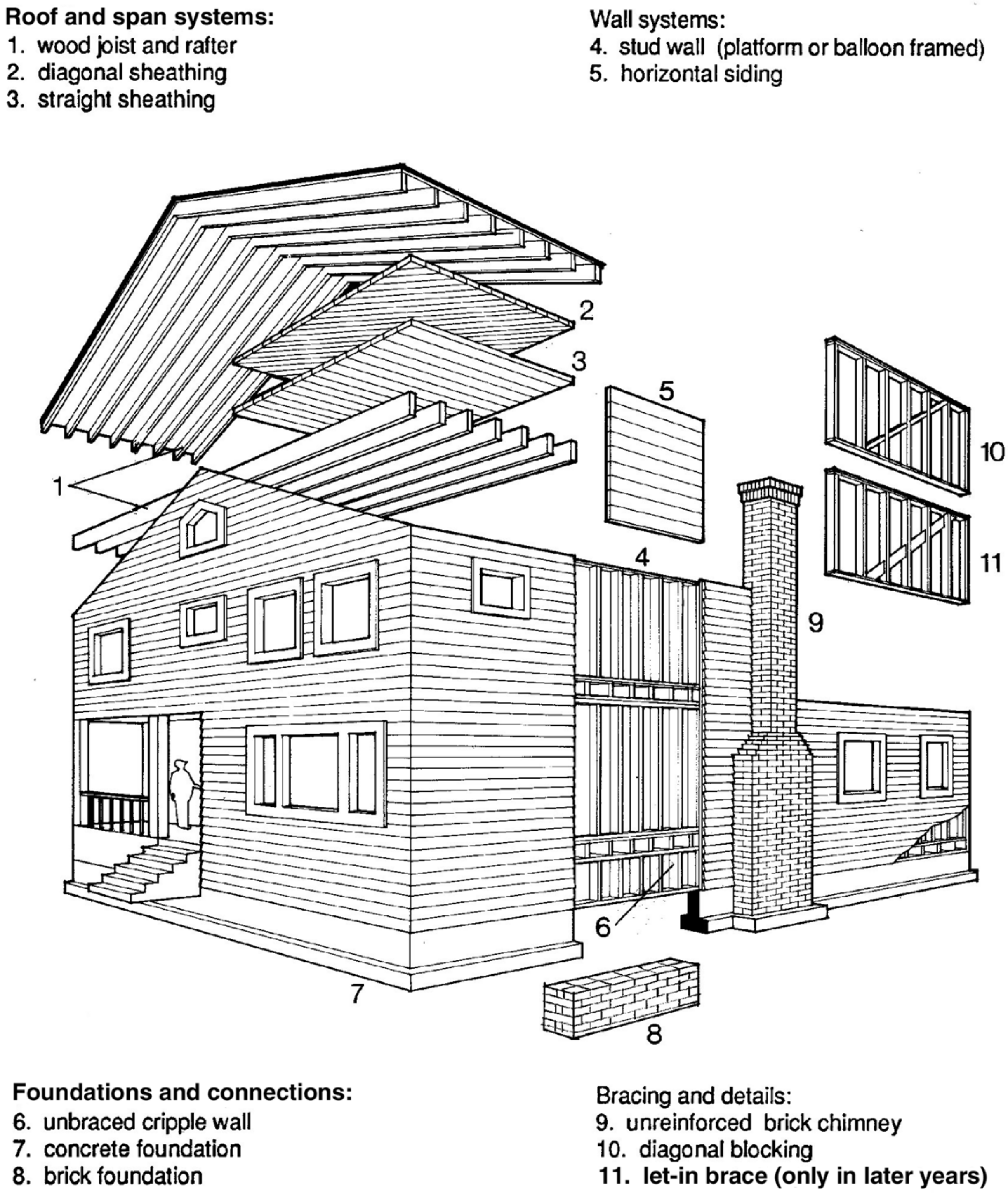


Figure E-4 Drawing of wood stud frame construction (Lagorio et al., 1986).

Figure E-5 Stud wall, wood framed house.

Post and beam construction, which consists of larger rectangular (6 inch by 6 inch and larger) or sometimes round wood columns framed together with large wood beams or trusses, is not common and is found mostly in older buildings. These buildings usually are not residential, but are larger buildings such as warehouses, churches, and theaters.

Timber pole buildings (Figures E-6 and E-7) are a less common form of construction found mostly in suburban and rural areas. Generally adequate seismically when first built, they are more often subject to wood deterioration due to the exposure of the columns, particularly near the ground surface. Together with an often-found "soft story" in this building type, this deterioration may contribute to unsatisfactory seismic performance.

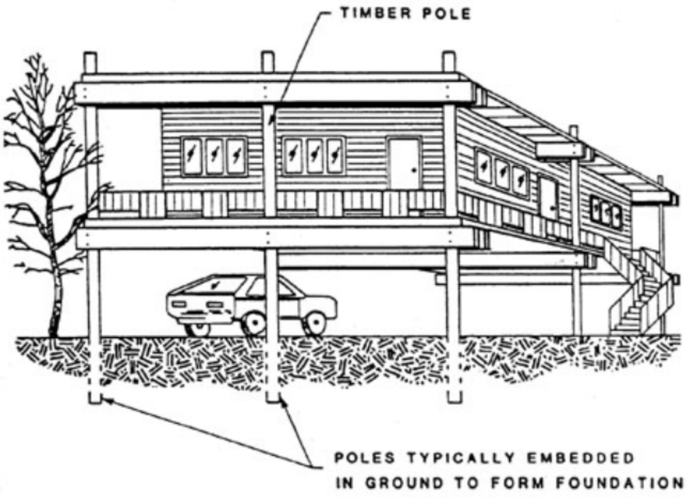


Figure E-6 Drawing of timber pole framed house (FEMA, 1987).

Figure E-7 Timber pole framed house.

In the western United States, it can be assumed that all single detached residential houses (i.e., houses with rear and sides separate from adjacent structures) are wood stud frame structures unless visual or supplemental information indicates otherwise (in the Southwestern United States, for example, some residential homes are constructed of adobe, rammed earth, and other non-wood materials). Many houses that appear to have brick exterior façades are actually wood frame with nonstructural brick veneer or brick-patterned synthetic siding.

In the central and eastern United States, brick walls are usually not veneer. For these houses, the brick must be examined closely to verify that it is real brick. The thickness of the exterior wall is estimated by looking at a window or door opening. If the wall is more than 9 inches from the interior finish to exterior surface, then it may be a brick wall. Also, if header bricks exist in the brick pattern, then it may be a brick wall. If these features all point to a brick wall, the house can be assumed to be a masonry building, and not a wood frame.

In wetter, humid climates it is common to find homes raised four feet or more above the outside grade with this space totally exposed (no foundation walls). This allows air flow under the house, to minimize decay and rot problems associated with high humidity and enclosed spaces. These houses are supported on wood posts and small precast concrete pads or piers. A common name for this construction is post and pier construction.

E.2.2 Typical Earthquake Damage

Stud wall buildings have performed well in past earthquakes due to inherent qualities of the structural system and because they are lightweight and low-rise. Cracks in any plaster or stucco may appear, but these seldom degrade the strength of the building and are classified as nonstructural damage. In fact, this type of damage helps dissipate the earthquake-induced energy of the shaking house. The most common type of structural damage in older buildings results from a lack of adequate connection between the house and the foundation. Houses can slide off their foundations if they are not properly bolted to the foundations. This movement (see Figure E-8) results in major damage to the building as well as to plumbing and electrical connections. Overturning of the entire structure is usually not a problem because of the low-rise geometry. In many municipalities, modern codes require wood structures to be adequately bolted to their foundations. However, the year that this practice was adopted will differ from community to community and should be checked.

Figure E-8 House off its foundation, 1983 Coalinga earthquake.

Many of the older wood stud frame buildings have no foundations or have weak foundations of unreinforced masonry or poorly reinforced concrete. These foundations have poor shear resistance to horizontal seismic forces and can fail.

Another problem in older buildings is the stability of cripple walls. Cripple walls are short stud walls between the foundation and the first floor level. Often these have no in- or out-of-plane bracing and thus may collapse when subjected to horizontal earthquake loading. If the cripple walls collapse, the house will sustain considerable damage and may collapse. In some older homes, plywood sheathing nailed to cripple studs may have been used to retrofit cripple walls. However, if the sheathing is not nailed adequately to the studs and foundation sill plate, the cripple walls will still collapse (see Figure E-9).

Figure E-9 Failed cripple stud wall, 1992 Big Bear earthquake.

Homes with post and pier perimeter foundations, which are constructed to provide adequate air flow under the structure to minimize the potential for decay, have little resistance to earthquake forces. When these buildings are subjected to strong earthquake ground motions, the posts may rotate or slip of the piers and the home will settle to the ground. As with collapsed cripple walls, this can be very expensive damage to repair and will result in the home building "red-tagged" per the ATC-20 post-earthquake safety evaluation procedures (ATC, 1995). See Figure E-9.

Garages often have a large door opening in the front wall with little or no bracing in the remainder of the wall. This wall has almost no resistance to lateral forces, which is a problem if a heavy load such as a second story is built on top of the garage. Homes built over garages have sustained damage in past earthquakes, with many collapses. Therefore, the house-over-garage configuration, which is found commonly in low-rise apartment complexes and some newer suburban detached dwellings, should be examined more carefully and perhaps retrofitted.

Unreinforced masonry chimneys present a life safety problem. They are often inadequately tied to the house, and therefore fall when strongly shaken. On the other hand, chimneys of reinforced masonry generally perform well.

Some wood frame structures, especially older buildings in the eastern United States, have masonry veneers that may represent another hazard. The veneer usually consists of one wythe of brick (a wythe is a term denoting the width of one brick) attached to the stud wall. In older buildings, the veneer is either insufficiently attached or has poor quality mortar, which often results in peeling of the veneer during moderate and large earthquakes.

W1A buildings can often have soft stories created by large openings at the ground floor for commercial space, parking, or other uses. As described in FEMA 547 (FEMA, 2006), "when an open front occurs, the diaphragm is required to transmit forces to other lines by rotation, creating torsional building behavior. This behavior is particularly critical when an exterior wall is provided at upper stories but discontinued in the first story, as this creates a significant discontinuity in the load path at the lowest story." W1A buildings with parking at the first floor are sometimes referred to as tuckunders. These buildings have collapsed in past earthquakes causing loss of life.

If adequately braced, post and beam buildings (not buildings with post and pier foundations) tend to perform well in earthquakes. However, walls often do not have sufficient bracing to resist horizontal motion and thus they may deform excessively.

E.2.3 Common Retrofit Techniques

In recent years, especially as a result of the Northridge earthquake, emphasis has been placed on addressing the common problems associated with light-wood framing. This work has concentrated mainly in the western United States with single-family residences.

The retrofit techniques focus on houses with continuous perimeter foundations and cripple walls. The retrofit work consists of bolting the house to the foundation and providing plywood or other wood sheathing materials to the cripple walls to strengthen them (see Figure E-10). This is the most cost-effective retrofit work that can be done on a single-family residence.

Figure E-10 Seismic strengthening of a cripple wall, with plywood sheathing.

Other common W1 retrofit techniques include bracing of masonry chimneys and improved anchorage to the foundation, particularly for homes on sloping hills.

W1A open front buildings can be strengthened by installing steel moment frames or by enhancing the existing walls and diaphragms.

W2 buildings can be strengthened with braced frames or by adding plywood to existing walls and diaphragms.

Little work has been done in retrofitting timber pole buildings or post and pier construction. In timber pole buildings retrofit techniques are focused on providing resistance to lateral forces by bracing (applying sheathing) to interior walls, thus creating a continuous load path to the ground. For homes with post and pier perimeter foundations, the work has focused on providing partial foundations and bracing to carry the earthquake loads.

E.3 Steel Frames (S1, S2)

E.3.1 Characteristics

Steel frame buildings generally may be classified as either moment-resisting frames or braced frames, based on their seismic force-resisting systems. Moment-resisting frames resist lateral loads and deformations by the bending stiffness of the beams and columns (there is no diagonal bracing). In concentric braced frames, the diagonal braces are connected, at each end, to the joints where beams and columns meet. The lateral forces or loads are resisted by the tensile and compressive strength of the bracing. In eccentric braced frames, the bracing is slightly offset from the main beam-to-column connections, and the short section of beam is expected to deform significantly in bending under major seismic forces, thereby dissipating a considerable portion of the energy of the vibrating building. Each type of steel frame is discussed below.

E.3.1.1 Moment-Resisting Steel Frame

Typical steel moment-resisting frame structures usually have similar bay widths in both the transverse and longitudinal direction, around 20-30 feet (Figure E-11). The load-bearing frame consists of beams and columns distributed throughout the building.

The floor diaphragms are usually concrete, sometimes over steel decking. Moment-resisting frame structures built since 1950 often incorporate prefabricated panels hung onto the structural frame as the exterior finish.

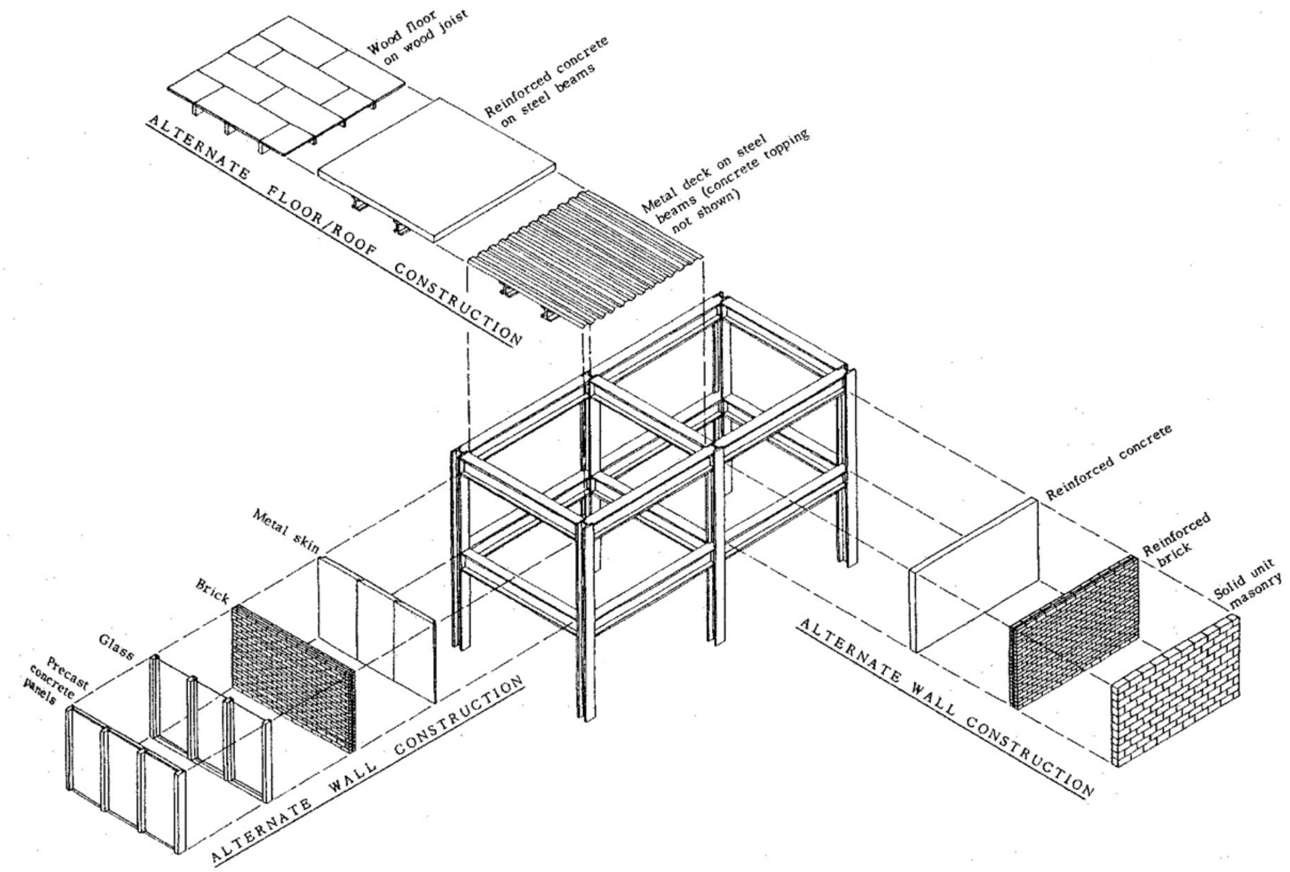


Figure E-11 Drawing of steel moment-resisting frame building (Steinbrugge, 1982).

These panels may be precast concrete, stone or masonry veneer, metal, glass or plastic.

This structural type is used for commercial, institutional, and other public buildings. It is seldom used for low-rise residential buildings.

Steel frame structures built before 1945 are usually clad or infilled with unreinforced masonry, such as bricks, hollow clay tiles and terra cotta tiles, and therefore should be classified as S5 structures (see Section E.6 for a detailed discussion). Other frame buildings of this period are encased in concrete. Wood or concrete floor diaphragms are common for these older buildings.

E.3.1.2 Braced Steel Frame

Braced steel frame structures (Figures E-12 and E-13) have been built since the late 1800s with similar usage and exterior finish as the steel moment-frame buildings. Braced frames are sometimes used for long and narrow buildings because of their stiffness. Although these buildings are braced with diagonal members, the bracing members usually cannot be detected from the building exterior.

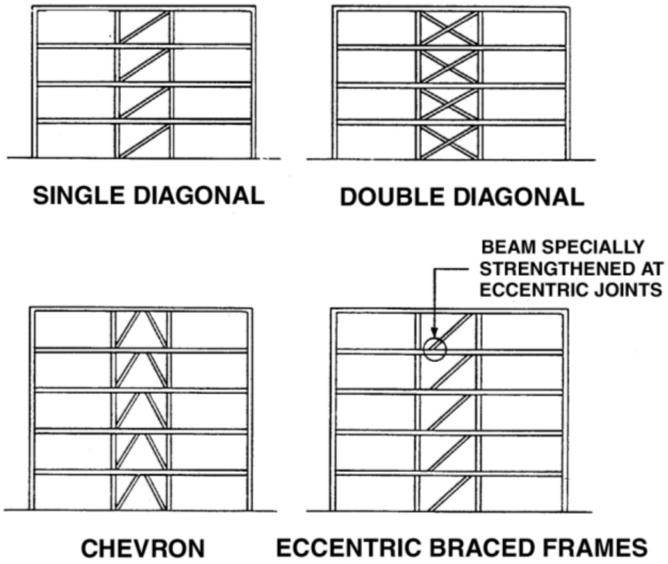


Figure E-12 Braced frame configurations (FEMA, 1987).

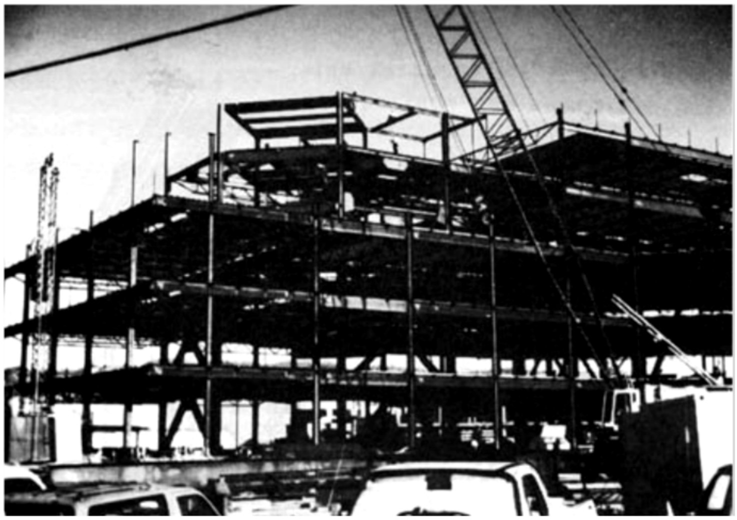


Figure E-13 Braced steel frame, with chevron and diagonal braces. The braces and steel frames are usually covered by finish material after the steel is erected.

From the building exterior, it is usually difficult to tell the difference between steel moment frames, braced frames, and frames with shear walls. In most modern buildings, the bracing or shear walls are located in the interior or covered by cladding material. Figure E-14 shows heavy diagonal bracing located at the side walls of a high rise building, which will be subsequently covered by finish materials and will not be apparent. In fact, it is difficult to differentiate steel frame structures and concrete frame structures from the exterior. Most of the time, the structural members are clad in finish material.

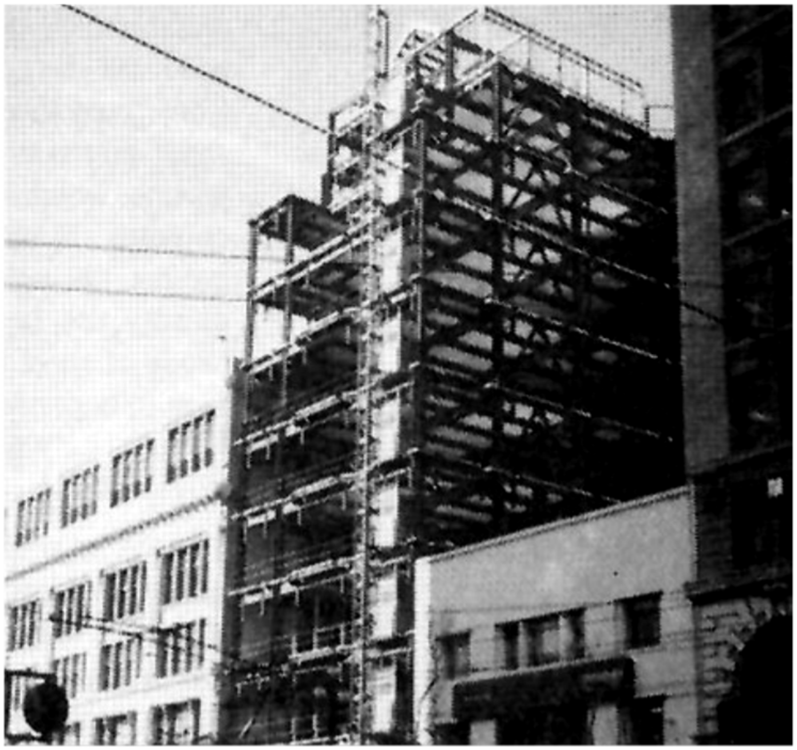


Figure E-14 Chevron bracing in steel building under construction.

In older buildings, steel members can also be encased in concrete. There are no positive ways of distinguishing these various frame types except in the two cases listed below:

- If a building can be determined to be a braced frame, it is probably a steel structure.
- If exposed steel beams and columns can be seen, then the steel frame structure is apparent. (Especially in older structures, a structural frame which appears to be concrete may actually be a steel frame encased in concrete.)

E.3.2 Typical Earthquake Damage

Steel frame buildings tend to be generally satisfactory in their earthquake resistance, because of their strength, flexibility and lightness. Collapse in earthquakes has been very rare, although steel frame buildings did collapse, for example, in the 1985 Mexico City earthquake. In the United States, these buildings have performed well, and probably will not collapse unless subjected to sufficiently severe ground shaking. The 1994 Northridge and 1995 Kobe earthquakes showed that steel frame buildings (in particular S1 moment-frame) were vulnerable to severe earthquake damage. Though none of the damaged buildings collapsed, they were rendered unsafe until repaired. The damage took the form of broken welded connections between the beams and columns. Cracks in the welds began inside the welds where the beam flanges were welded to the column flanges. These cracks, in some cases, broke the welds or propagated into the column flange, “tearing” the flange. The damage was found in those buildings that experienced ground accelerations of approximately 20% of gravity (20%g) or greater. Since 1994 Northridge, many cities that experienced large earthquakes in the recent past have instituted an inspection program to determine if any steel frames were damaged. Since steel frames are usually covered with a finish material, it is difficult to find damage to the joints. The process requires removal of the finishes and removal of fireproofing just to see the joint.

Possible damage includes the following:

- Nonstructural damage resulting from excessive deflections in frame structures can occur to elements such as interior partitions, equipment, and exterior cladding. Damage to nonstructural elements was the reason for the discovery of damage to moment frames as a result of the 1994 Northridge earthquake.
- Cladding and exterior finish material can fall if insufficiently or incorrectly connected.
- Plastic deformation of structural members can cause permanent displacements.
- Pounding with adjacent structures can occur.

E.3.3 Common Retrofit Techniques

As a result of the 1994 Northridge earthquake many steel frame buildings, primarily steel moment frames, have been retrofitted to address the problems discovered. The process is essentially to redo the connections, ensuring that cracks do not occur in the welds. There is careful inspection of the welding process and the electrodes during construction. Where possible, existing full penetration welds of the beams to the columns are changed so more fillet welding is used. This means that less heat is used in the welding process and consequently there is less potential for damage. Other methods include reducing welding to an absolute minimum by developing bolted connections or ensuring that the connection plates will yield (stretch permanently) before the welds will break. Other possibilities for retrofitting moment frames are to convert them to braced frames or add concrete shear walls. Sometimes older column splices will need strengthening as well.

The kind of damage discovered was not limited to moment frames, although they were the most affected. Some braced frames were found to have damage to the brace connections, especially at lower levels.

Structural types other than steel frames are sometimes retrofitted using steel frames, as shown for the concrete structure in Figure E-15.

Figure E-15 Retrofit of a concrete parking structure using exterior X-braced steel frames.

Probably the most common use of steel frames for retrofit is in unreinforced masonry bearing wall buildings (URM). Steel frames are typically used at the storefront windows as there is no available horizontal resistance provided by the windows in their plane. Frames can be used throughout the first floor perimeter when the floor area needs to be open, as in a restaurant. See Figure E-16. When a building is encountered with this type of retrofit scheme, the building is still considered a URM building, but on the Level 2 screening a Score Modifier for a comprehensive retrofit can be given.

E.4 Light Metal (S3)

E.4.1 Characteristics

Most light metal buildings existing today were built after 1950 (Figure E-17). They are used for agricultural structures, industrial factories, and warehouses.

They are typically one story in height, sometimes without interior columns, and often enclose a large floor area. Construction is typically of steel frames

Figure E-16 Use of a braced frame to rehabilitate an unreinforced masonry building.

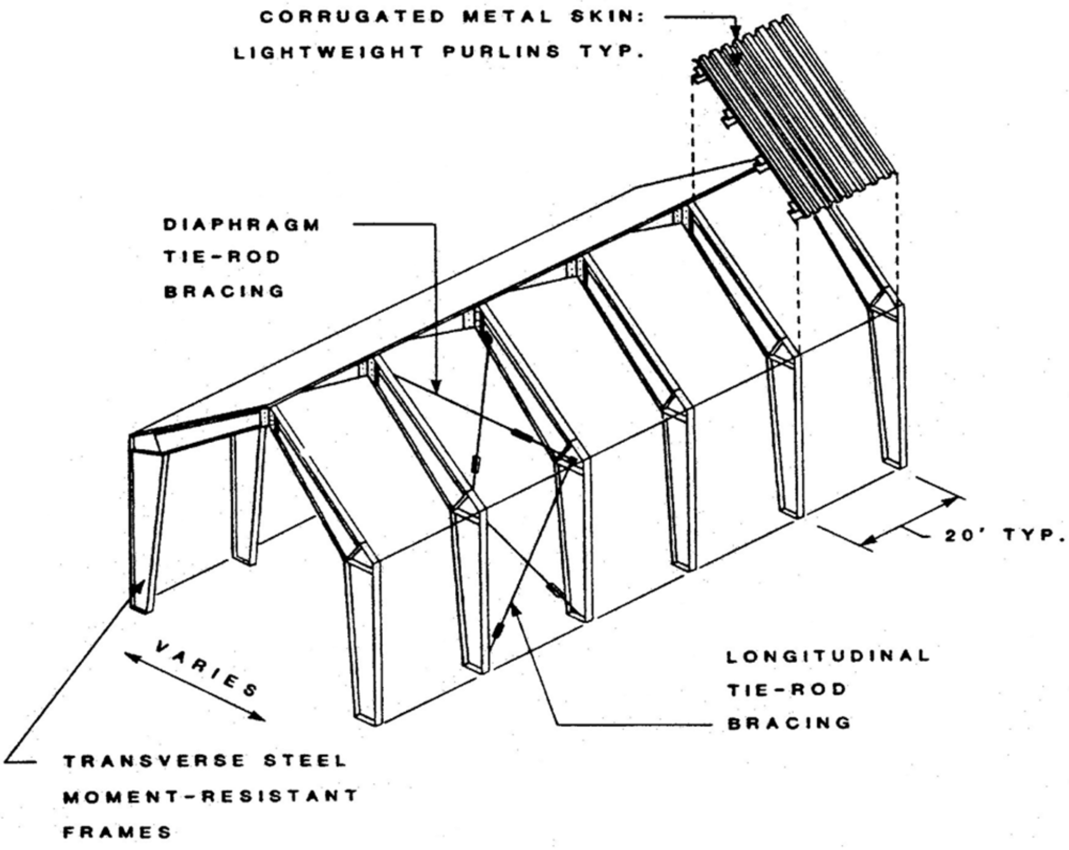


Figure E-17 Drawing of light metal construction.

spanning the short dimension of the building, resisting lateral forces as moment frames. Forces in the long direction are usually resisted by diagonal steel rod bracing. These buildings are usually clad with lightweight metal or asbestos-reinforced concrete siding, often corrugated.

To identify this construction type, the screener should look for the following characteristics:

- Light metal buildings are typically characterized by industrial corrugated sheet metal or asbestos-reinforced cement siding. The term, "metal building panels" should not be confused with "corrugated sheet metal siding." The former are prefabricated cladding units usually used for large office buildings. Corrugated sheet metal siding is a thin sheet material usually fastened to purlins, which in turn span between columns. If this sheet cladding is present, the screener should examine closely the fasteners used. If the heads of sheet metal screws can be seen in horizontal rows, the building is most likely a light metal structure.

  Because the typical structural system consists of moment frames in the transverse direction and frames braced with diagonal steel rods in the longitudinal direction, light metal buildings often have low-pitched roofs without parapets or overhangs (Figure E-18). Most of these buildings are prefabricated, so the buildings tend to be rectangular in plan, without many corners.

Figure E-18 Prefabricated metal building (S3, light metal building).

- These buildings generally have only a few windows, as it is difficult to detail a window in the sheet metal system.

- The screener should look for signs of a metal building, and should knock on the siding to see if it sounds hollow. Door openings should be inspected for exposed steel members. If a gap, or light, can be seen where the siding meets the ground, it is certainly light metal or wood frame. For the best indication, an interior inspection will confirm the structural skeleton, because most of these buildings do not have interior finishes.

E.4.2 Typical Earthquake Damage

Because these building are low-rise, lightweight, and constructed of steel members, they usually perform relatively well in earthquakes. Collapses do not usually occur. Some typical problems are listed below:

- Insufficient capacity of tension braces can lead to their elongation or failure, and, in turn, building damage.
- Inadequate connection to the foundation can allow the building columns to slide.
- Loss of the cladding can occur.

E.5 Steel Frame with Concrete Shear Wall (S4)

E.5.1 Characteristics

The construction of this structure type (Figure E-19) is similar to that of the steel moment-resisting frame in that a matrix of steel columns and girders is distributed throughout the structure. The joints, however, are not designed for moment resistance, and the lateral forces are resisted by concrete shear walls.

It is often difficult to differentiate visually between a steel frame with concrete shear walls and one without, because interior shear walls will often be covered by interior finishes and will look like interior nonstructural partitions. For the purposes of an RVS, unless the shear wall is identifiable from the exterior (i.e., a raw concrete finish was part of the architectural aesthetic of the building, and was left exposed), this building cannot be identified accurately. Figure E-20 shows a structure with such an exposed shear wall. Figure E-21 is a close-up of shear wall damage.

E.5.2 Typical Earthquake Damage

The shear walls can be part of the elevator and service core or part of the exterior or interior walls. This type of structure performs as well in earthquakes as other steel buildings. Some typical types of damage, other than nonstructural damage and pounding, are:

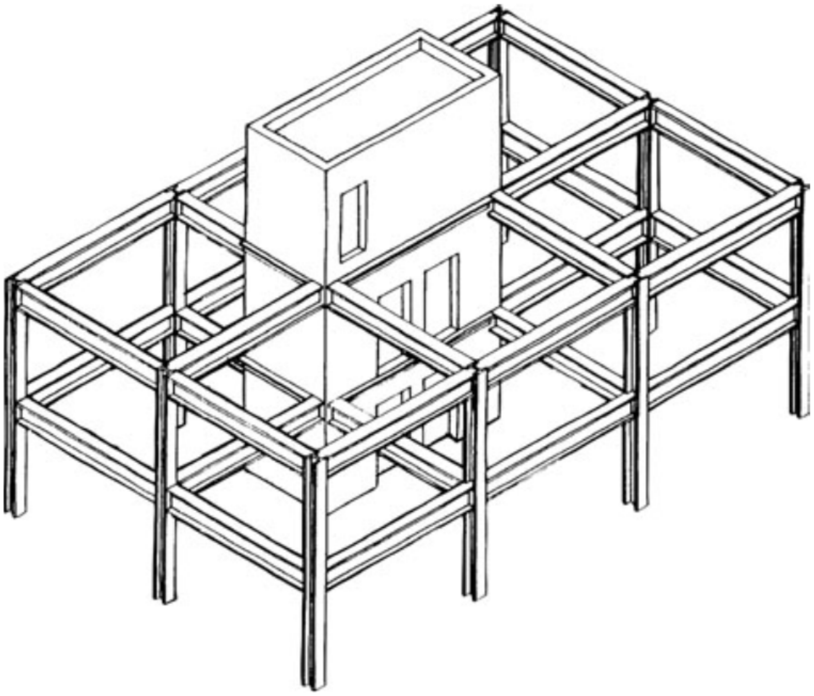


Figure E-19 Drawing of steel frame with interior concrete shear walls (Steinbrugge, 1982).

Figure E-20 Concrete shear wall on building exterior.

Figure E-21 Close-up of exterior shear wall damage during a major earthquake.

- Shear cracking and distress that occur around openings in concrete shear walls.
- Wall shear failures that occur at stresses below expected capacity due to wall construction joints acting as weak planes.
- Wall bending failures that occur due to insufficient chord steel lap lengths.

E.5.3 Common Retrofit Techniques

Retrofit techniques for S4 buildings are similar to those for concrete shear wall buildings (C2).

E.6 Steel Frame with Unreinforced Masonry Infill (S5)

E.6.1 Characteristics

This construction type (Figures E-22 and E-23) consists of a steel structural frame and walls "infilled" with unreinforced masonry (URM). In older buildings, the floor diaphragms are often wood. Later buildings have reinforced concrete floors. Because of the masonry infill, the structure tends to be stiff. Because the steel frame in an older building is covered by unreinforced masonry for fire protection, it is easy to confuse this type of building with URM bearing wall structures. Further, because the steel columns are relatively thin, they may be hidden in walls.

An apparently solid masonry wall may enclose a series of steel columns and girders. These infill walls are usually two or three wythes thick. Therefore,

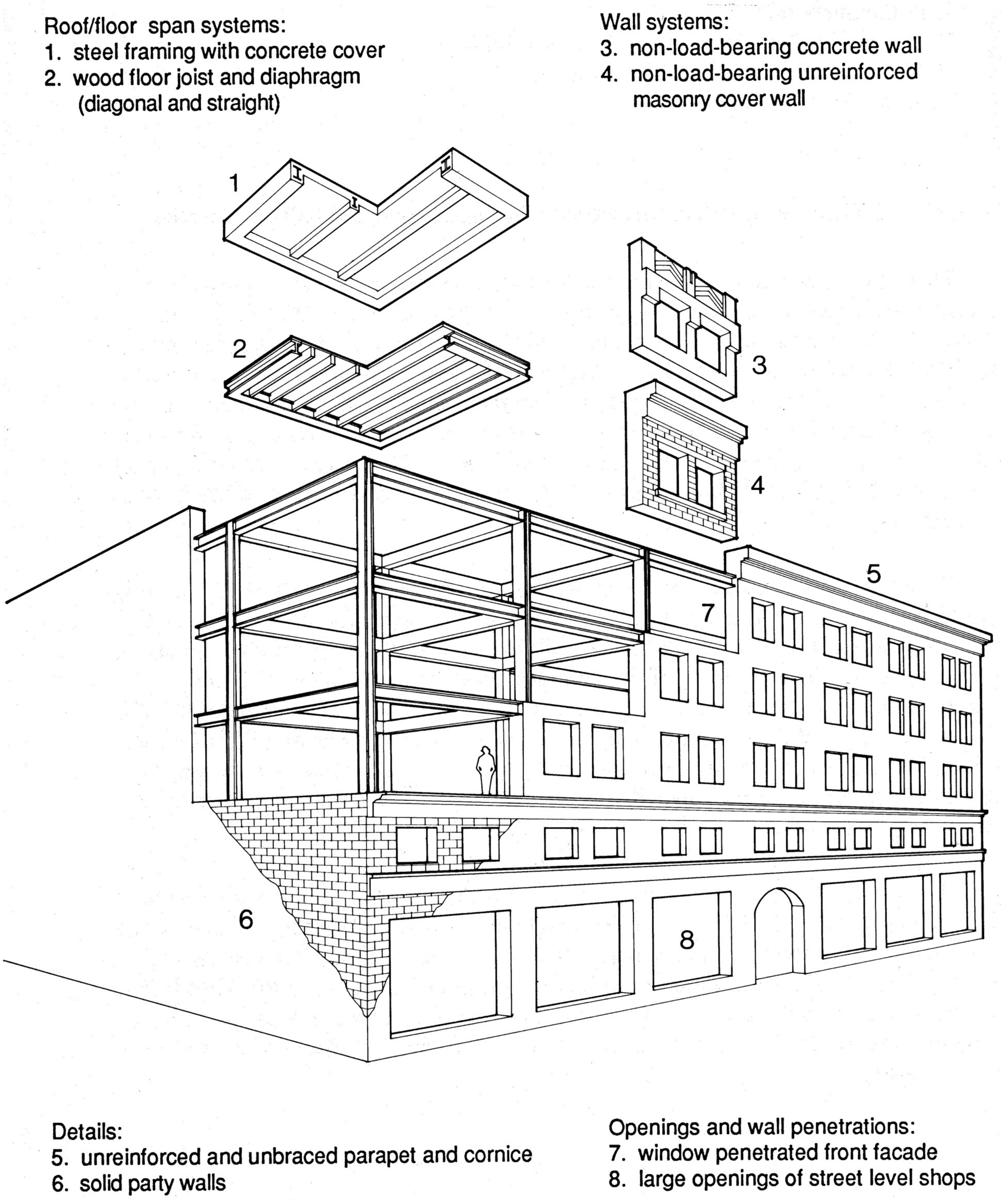


Figure E-22 Drawing of steel frame with URM infill (Lagorio et al., 1986).

Figure E-23 Example of steel frame with URM infill walls (S5).

header bricks will sometimes be present and thus mislead the screener into thinking the building is a URM bearing wall structure, rather than infill. Often in these structures the infill and veneer masonry is exposed. Otherwise, masonry may be obscured by cladding in buildings, especially those that have undergone renovation.

When a masonry building is encountered, the screener should first attempt to determine if the masonry is reinforced, by checking the date of construction, although this is only a rough guide. A clearer indication of a steel frame structure with URM infill is when the building exhibits the characteristics of a frame structure of type S1 or S2. One can assume all frame buildings clad in brick and constructed prior to about 1940 are of this type.

Older frame buildings may be of several types: steel frame encased with URM, steel frame encased with concrete, and concrete frame. Sometimes older buildings have decorative cladding such as terra cotta or stone veneer. Veneers may obscure all evidence of URM. In that case, the structural type cannot be determined. However, if there is evidence that a large amount of concrete is used in the building (for example, a rear wall constructed of concrete), then it is unlikely that the building has URM infill.

When the screener cannot be sure if the building is a frame or has bearing walls, two clues may help: the thickness of the walls and the height. Because infill walls are constructed of two or three wythes of bricks, they should be approximately 9 inches thick (2 wythes). Furthermore, the thickness of the wall will not increase in the lower stories, because the structural frame is carrying the load. For buildings over six stories tall, URM is infill or veneer, because URM bearing wall structures are seldom this tall and, if so, they will have extremely thick walls in the lower stories.

E.6.2 Typical Earthquake Damage

In major earthquakes, the infill walls may suffer substantial cracking and deterioration from in-plane or out-of-plane deformation, thus reducing the in-plane wall stiffness. This in turn puts additional demand on the frame. Some of the walls may fail while others remain intact, which may result in torsion or soft story problems.

The hazard from falling masonry is significant as these buildings can be taller than 20 stories. As described below, typical damage results from a variety of factors.

- Infill walls tend to buckle and fall out-of-plane when subjected to strong lateral forces. Because infill walls are non-load-bearing, they tend to be thin (around 9”) and cannot rely on the additional shear strength that accompanies vertical compressive loads.
- Veneer masonry around columns or beams is usually poorly anchored to the structural members and can disengage and fall.
- Interior infill partitions and other nonstructural elements can be severely damaged and collapse.
- If stories above the first are infilled, but the first is not, then a soft story exists, and the difference in stiffness creates a large demand at the ground floor columns, causing structural damage.
- When the earthquake forces are sufficiently high, the steel frame itself can fail locally. Connections between members are usually not designed for high lateral loads (except in tall buildings) and this can lead to damage of these connections. Complete collapse has seldom occurred, but cannot be ruled out.

E.6.3 Common Retrofit Techniques

Retrofit techniques for this structural type have focused on the expected damage. By far the most significant problem, and that which is addressed in most retrofit schemes, is failure of the infill wall out of its plane. This failure presents a significant life safety hazard to individuals on the exterior of the building, especially those who manage to exit the building during the earthquake. To remedy this problem, anchorage connections are developed to tie the masonry infill to the floors and roof of the structure.

Another significant problem is the inherent lack of shear strength throughout the building. Some of the retrofit techniques employed include the following:

- Shotcrete (with pneumatically placed concrete) the interior faces of the masonry wall, creating reinforced concrete shear elements.
- Provide cross bracing in steel frames or fully strengthen the connections to create moment frames. In this latter case, the frames are still not sufficient to resist all the lateral forces, and reliance on the infill walls is necessary to provide adequate strength.

E.7 Concrete Moment-Resisting Frame (C1)

E.7.1 Characteristics

Concrete moment-resisting frame construction consists of concrete beams and columns that resist both lateral and vertical loads (see Figure E-24). There may be a few bays infilled with masonry, but if there is more extensive infill, it would be categorized as a C3 building type. A fundamental factor in the seismic performance of concrete moment-resisting frames is the presence or absence of ductile detailing. Hence, several construction subtypes fall under this category:

- nonductile reinforced-concrete frames with unreinforced infill walls,
- nonductile reinforced-concrete frames with reinforced infill walls,
- nonductile reinforced-concrete frames, and
- ductile reinforced-concrete frames.

Ductile detailing refers to the presence of special steel reinforcing within concrete beams and columns. The special reinforcement provides confinement of the concrete, permitting good performance in the members beyond the elastic capacity, primarily in bending. Due to this confinement, disintegration of the concrete is delayed, and the concrete retains its strength for more cycles of loading (i.e., the ductility is increased). See Figure E-25 for a dramatic example of ductility in concrete.

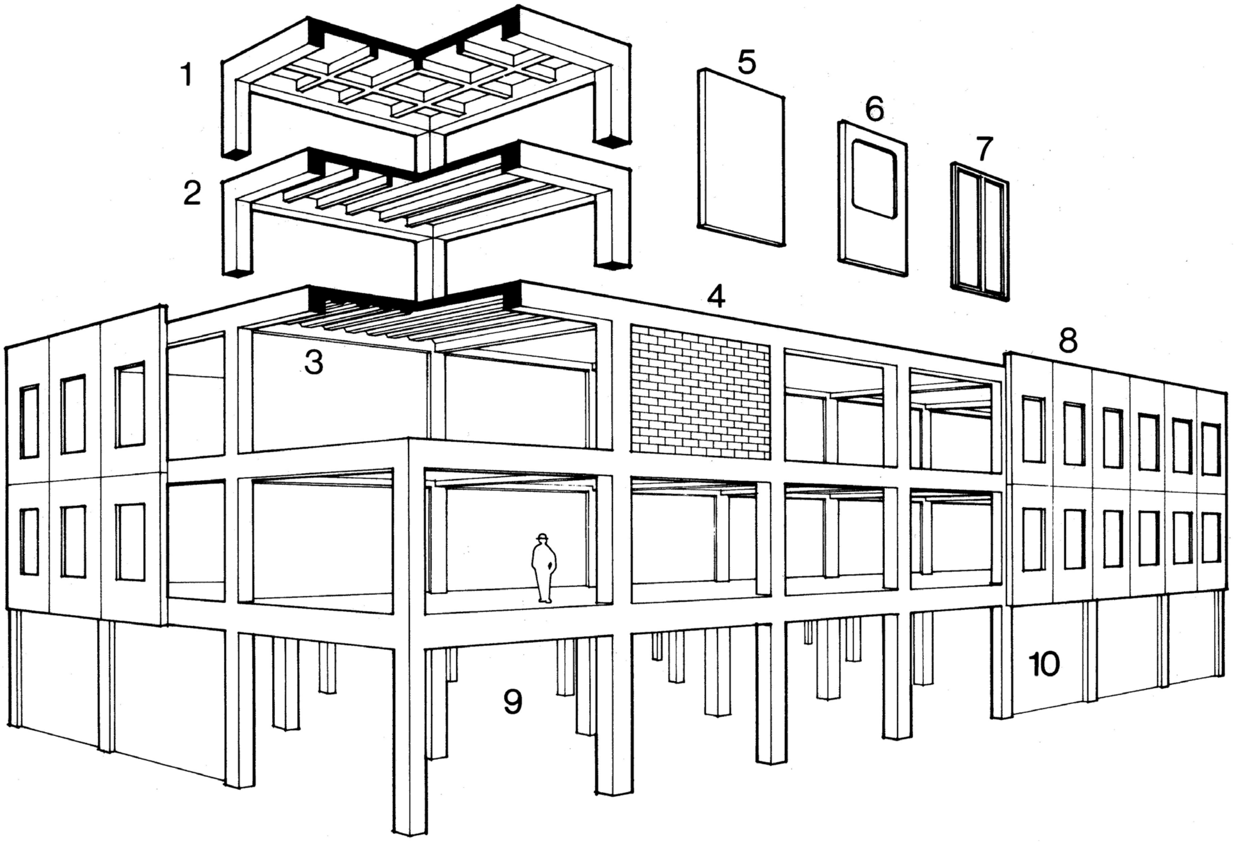


Figure E-24 Drawing of concrete moment-resisting frame building (Lagorio et al., 1986).

Figure E-25 Extreme example of ductility in concrete, 1994 Northridge earthquake.

Ductile detailing (Figure E-26) has been practiced in high-seismicity areas since 1967, when ductility requirements were first introduced into the *Uniform Building Code* (the adoption and enforcement of ductility requirements in a given jurisdiction may be later, however). Prior to that time, nonductile or ordinary concrete moment-resisting frames were the norm (and still are, for moderate seismic areas). In high-seismicity areas, additional tie reinforcing was required following the 1971 San Fernando earthquake and appeared in the *Uniform Building Code* in 1976. Additional code requirements to improve ductility were added following the 1994 Northridge earthquake.

In many low-seismicity areas of the United States, nonductile concrete frames of the first three types continue to be built. This group includes large multistory commercial, institutional, and residential buildings constructed using flat slab frames, waffle slab frames, and the standard beam-and-column frames.

These structures generally are more massive than steel-frame buildings, are underreinforced (i.e., have insufficient reinforcing steel embedded in the concrete) and display low ductility.

This building type is difficult to differentiate from steel moment-resisting frames unless the structural concrete has been left relatively exposed (see Figure E-27). Although a steel frame may be encased in concrete and appear to be a concrete frame, this is seldom the case for modern buildings (post 1940s). For the purpose of the RVS procedures, it can be assumed that all exposed concrete frames are concrete and not steel frames.

Figure E-26 Example of ductile reinforced concrete column, 1994 Northridge earthquake; horizontal ties would need to be closer for greater demands.

Figure E-27 Concrete moment-resisting frame building (C1) with exposed concrete, deep beams, wide columns (and with architectural window framing).

E.7.2 Typical Earthquake Damage

Under high amplitude cyclic loading, lack of confinement will result in rapid disintegration of nonductile concrete members, with ensuing brittle failure and possible building collapse (see Figure E-28).

Causes and types of damage include:

- Excessive tie spacing in columns can lead to a lack of concrete confinement and shear failure.
- Placement of inadequate rebar splices all at the same location in a column can lead to column failure.
- Insufficient shear strength in columns can lead to shear failure prior to the full development of moment hinge capacity.
- Insufficient shear tie anchorage can prevent the column from developing its full shear capacity.
- Lack of continuous beam reinforcement can result in unexpected hinge formation during load reversal.
- Inadequate reinforcing of beam-column joints or the positioning of beam bar splices at columns can lead to failures.

Figure E-28 Locations of failures at beam-to-column joints in nonductile frames, 1994 Northridge earthquake.

- The relatively low stiffness of the frame can lead to substantial nonstructural damage.
- Pounding damage with adjacent buildings can occur.

E.7.3 Common Retrofit Techniques

Retrofit techniques for reinforced concrete frame buildings depend on the extent to which the frame meets ductility requirements. The costs associated with the upgrading an existing, conventional beam-column framing system to meet the minimum standards for ductility are high, and this approach is usually not cost-effective. The most practical and cost-effective solution is to add a system of shear walls or braced frames to provide the required seismic resistance (ATC, 1992).

In some cases, where only added ductility is needed, columns and/or beams are wrapped with steel jackets or fiber reinforced polymer material. Occasionally, this has also been done by added concrete.

The outside cover of concrete (a couple of inches) is removed, exposing the reinforcing ties. Additional ties are added with their ends embedded into the core of the column. The exterior concrete is then replaced. This process results in a detail that provides a reasonable amount of ductility but not as much as there would have been had the ductility been provided in the original design.

E.8 Concrete Shear Wall (C2)

E.8.1 Characteristics

This category consists of buildings with a perimeter concrete bearing wall structural system or frame structures with shear walls (Figure E-29). The structure, including the usual concrete floor diaphragms, is typically cast in place. Before the 1940s, bearing wall systems were used in schools, churches, and industrial buildings. Concrete shear wall buildings constructed since the early 1950s are institutional, commercial, and residential buildings, ranging from one to more than thirty stories. Frame buildings with shear walls tend to be commercial and industrial. A common example of the latter type is a warehouse with interior frames and perimeter concrete walls. Residential buildings of this type are often mid-rise towers. The shear walls in these newer buildings can be located along the perimeter, as interior partitions, or around the service core.

Frame structures with interior shear walls are difficult to identify positively. When the building is clearly a box-like bearing wall structure, it is probably a

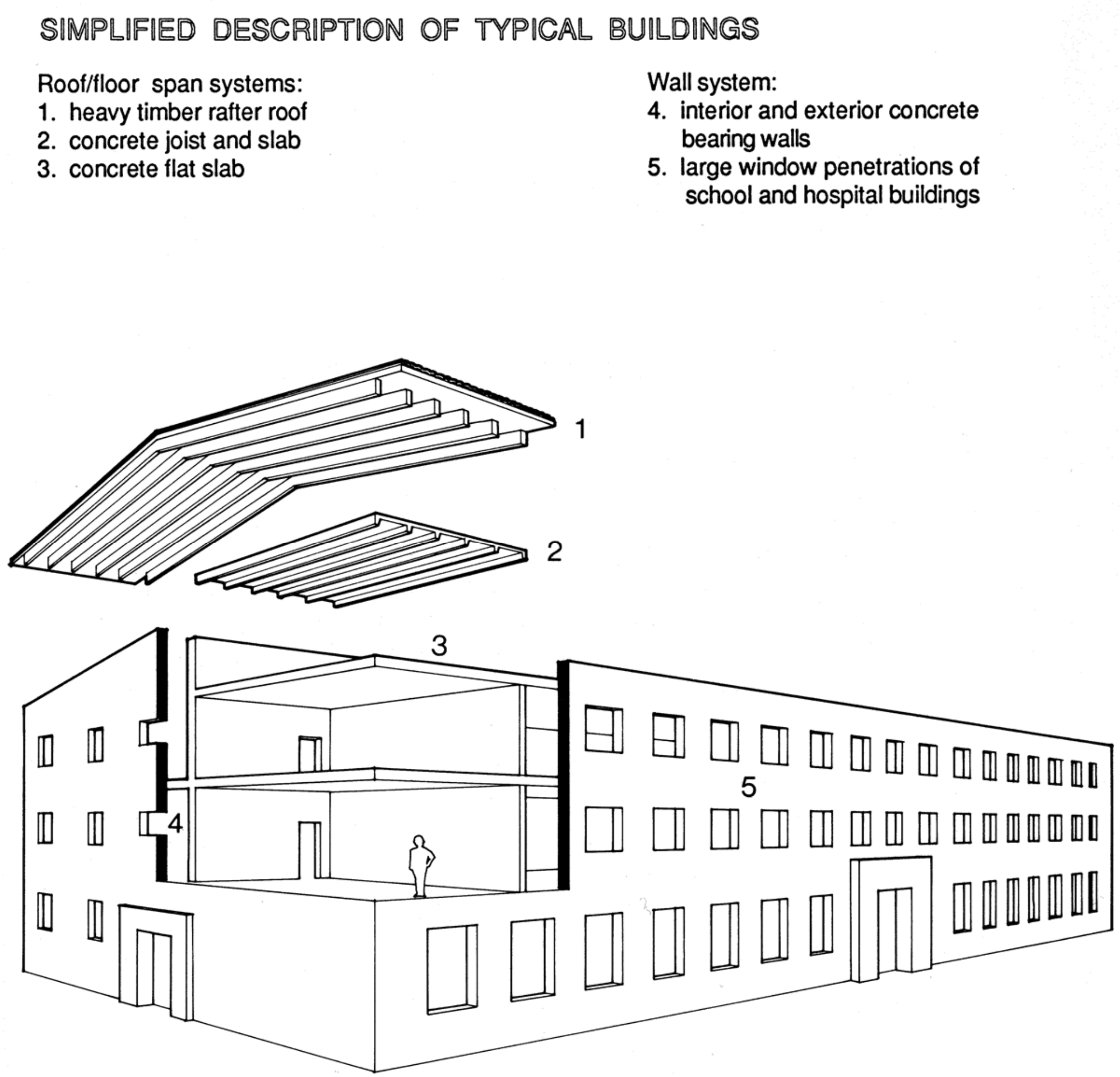


Figure E-29 Drawing of concrete shear wall building (Lagorio et al., 1986).

shear wall structure. Concrete shear wall buildings are usually cast in place.

The screener should look for signs of cast-in-place concrete. In concrete bearing wall structures, the wall thickness ranges from 6 to 10 inches and is thin in comparison to that of masonry bearing wall structures.

E.8.2 Typical Types of Earthquake Damage

This building type generally performs better than concrete frame buildings. The buildings are heavy compared with steel frame buildings, but they are also stiff due to the presence of the shear walls. Damage commonly observed in taller buildings is caused by vertical discontinuities, pounding, and irregular configuration. Other damage specific to this building type includes the following.

- During large seismic events, shear cracking and distress can occur around openings in concrete shear walls and in spandrel beams and link beams between shear walls (see Figures E-30 and E-31).
- Shear failure can occur at wall construction joints usually at a load level below the expected capacity.
- Bending failures can result from insufficient vertical chord steel and insufficient lap lengths at the ends of the walls.

Figure E-30 Tall concrete shear wall building: walls connected by damaged spandrel beams.

Figure E-31 Shear wall damage, 1989 Loma Prieta earthquake.

E.8.3 Common Retrofit Techniques

Reinforced concrete shear wall buildings can be rehabilitated in a variety of ways. Techniques include: (1) reinforcing existing walls in shear by applying a layer of shotcrete or poured concrete; (2) where feasible, filling existing window or door openings with concrete to add shear strength and eliminate critical bending stresses at the edge of openings; (3) reinforcing narrow overstressed shear panels in in-plane bending by adding reinforced boundary elements; and (4) enhancing the shear strength of the shear walls with a fiber reinforcing polymer overlay.

E.9 Concrete Frame with Unreinforced Masonry Infill (C3)

E.9.1 Characteristics

These buildings (Figures E-32 and E-33) have been, and continue to be, built in regions where unreinforced masonry (URM) has not been eliminated by code. These buildings were generally built before 1940 in high-seismicity regions and may continue to be built in other regions. Several construction subtypes fall under this category: nonductile reinforced-concrete frames with unreinforced infill walls, and nonductile reinforced-concrete frames with reinforced infill walls.

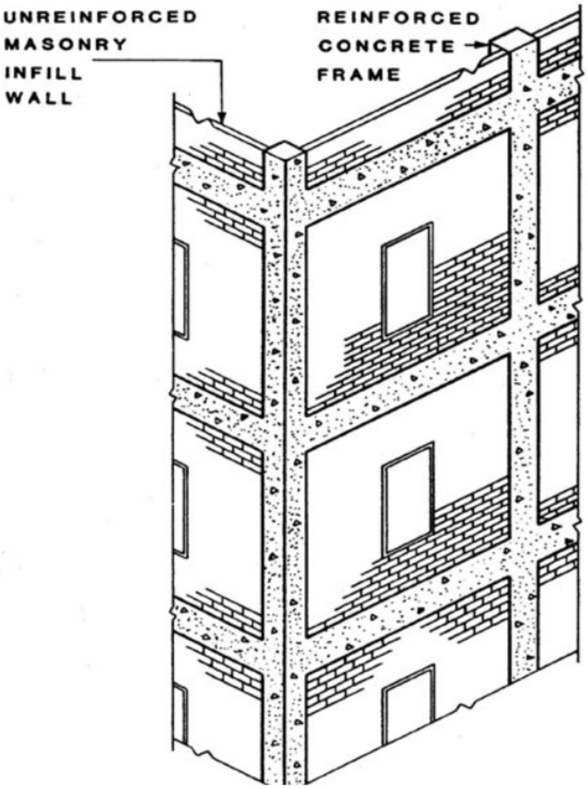


Figure E-32 Concrete frame with URM infill.

Figure E-33 C3 building and detail showing concrete frame with URM infill (left wall), and face brick (right wall).

The first step in identification is to determine if the structure is old enough to contain URM. In contrast to steel frames with URM infill, concrete frames with URM infill usually show clear evidence of the concrete frames. This is particularly true for industrial buildings and can usually be observed at the side or rear of commercial buildings. The concrete columns and beams are relatively large and are usually not covered by masonry but left exposed.

A case in which URM infill cannot be readily identified is the commercial building with large windows on all sides; these buildings may have interior URM partitions. Another difficult case occurs when the exterior walls are covered by decorative tile or stone veneer. The infill material can be URM or a thin concrete infill.

E.9.2 Typical Earthquake Damage

The hazards of these buildings, which in the western United States are often older, are similar to and perhaps more severe than those of the newer concrete frames. Where URM infill is present, a falling hazard exists. The failure mechanisms of URM infill in a concrete frame are generally the same as URM infill in a steel frame.

E.9.3 Common Retrofit Techniques

Retrofit of unreinforced masonry infill in a concrete frame is identical to that of the URM infill in a steel frame. See Section E.6.3. Anchorage of the wall panels for out-of-plane forces is the key component, followed by providing sufficient shear strength in the building.

E.10 Tilt-up Structures (PC1)

E.10.1 Characteristics

In traditional tilt-up buildings (Figures E-34 through E-36), concrete wall panels are cast on the ground and then tilted upward into their final positions. More recently, wall panels are fabricated off-site and trucked to the site.

Tilt-up buildings are an inexpensive form of light industrial and commercial construction and have become increasingly popular in the western and central United States since the 1940s. They are typically one and sometimes two stories high and typically have a simple rectangular plan. The walls are the seismic force-resisting system. The roof can be a plywood diaphragm carried on wood purlins and glued laminated (glulam) wood beams or a light steel deck and joist system, supported in the interior of the building on steel pipe columns. The wall panels are attached to concrete cast-in-place pilasters or to steel columns, or the joint is simply closed with a later concrete pour. These joints are typically spaced about 20 feet apart.

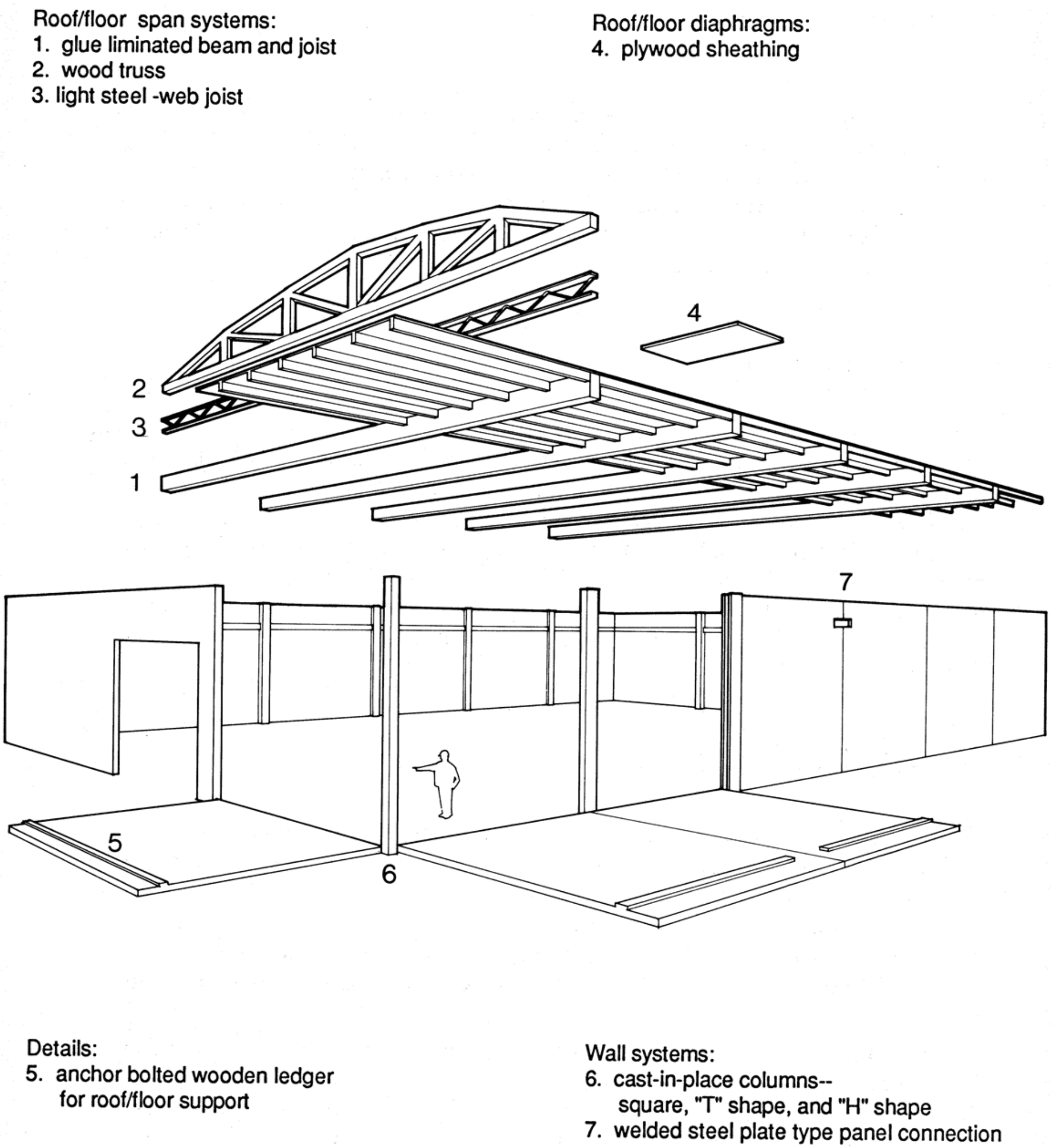


Figure E-34 Drawing of tilt-up construction typical of the western United States. Tilt-up construction in the eastern United States may incorporate a steel frame (Lagorio et al., 1986).

The major defect in existing tilt-ups is a lack of positive anchorage between wall and diaphragm, which has been corrected since about 1973 in the western United States.

In the western United States, it can be assumed that all one-story concrete industrial warehouses with flat roofs built after 1950 are tilt-ups unless supplementary information indicates otherwise.

Figure E-35 Tilt-up industrial building, 1970s.

Figure E-36 Tilt-up industrial building, mid- to late-1980s.

E.10.2 Typical Earthquake Damage

Before 1973 in the western United States, many tilt-up buildings did not have sufficiently strong connections or anchors between the walls and the roof and floor diaphragms. The anchorage typically was nothing more than the nailing of the plywood roof sheathing to the wood ledgers supporting the framing.

During an earthquake, the weak anchorage broke the ledgers, resulting in the panels falling and the supported framing collapsing. When mechanical anchors were used, they pulled out of the walls or split the wood members to which they were attached, causing the floors or roofs to collapse. See Figures E-37 and E-38. The connections between the concrete panels are also vulnerable to failure. Without these connections, the building loses much of its lateral-force-resisting capacity. For these reasons, many tilt-up buildings were damaged in the 1971 San Fernando earthquake. Since 1973, tilt-up construction practices have changed in California and other high-seismicity regions, requiring positive wall-diaphragm connection (Such requirements may not have yet been made in other regions of the country). However, a large number of these older, pre-1970s-vintage tilt-up buildings still exist and have not been rehabilitated to correct this wall-anchor defect. Damage to these buildings was observed again in the 1987 Whittier earthquake, 1989 Loma Prieta earthquake, and the 1994 Northridge earthquake. These buildings are a prime source of seismic hazard. In areas of low or moderate seismicity, inadequate wall anchor details continue to be used. Severe ground shaking in such an area may produce major damage in tilt-up buildings.

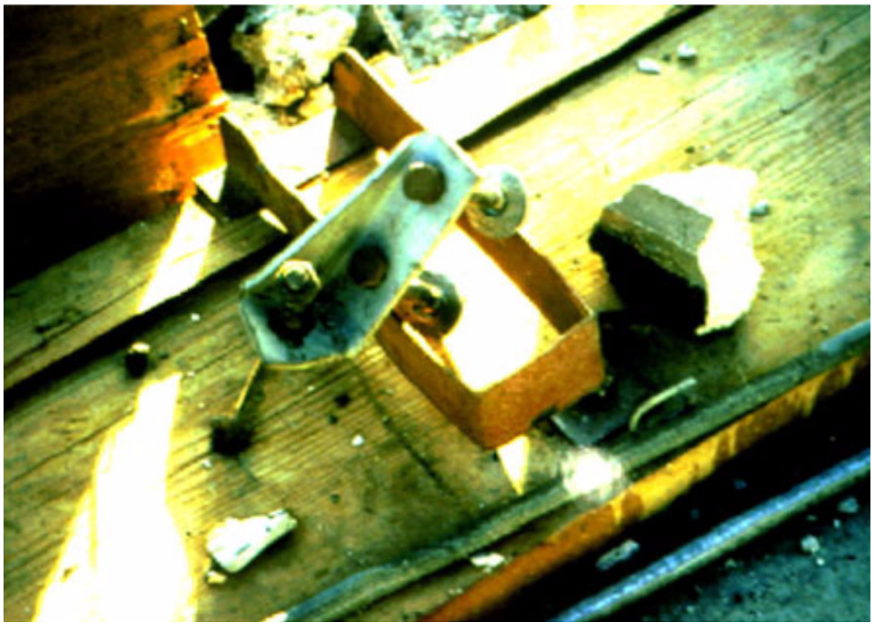


Figure E-37 Tilt-up construction anchorage failure.

E.10.3 Common Retrofit Techniques

The retrofit of tilt-up buildings is relatively easy and inexpensive. The most common form of retrofit is to provide a positive anchorage connection at the roof and wall intersection (see Figure E-39). This is usually done by using pre-fabricated metal hardware attached to the framing member and to a bolt that is installed through the wall. On the outside of the wall a large washer plate is used.

Figure E-38 Result of failure of the roof beam anchorage to the wall in tilt-up building.

Accompanying the anchorage retrofit is the addition of ties across the building to develop the anchorage forces from the wall panels fully into the diaphragm.

This is accomplished by interconnecting framing members from one side of the building to the other, and then increasing the connections of the diaphragm (usually wood) to develop the additional forces.

E.11 Precast Concrete Frame (PC2)

E.11.1 Characteristics

Precast concrete frame construction, first developed in the 1930s, was not widely used until the 1960s. The precast frame (Figure E-40) is essentially a post and beam system in concrete where columns, beams and slabs are prefabricated and assembled on site. Various types of members are used. Vertical-load-carrying elements may be "T"sections, cross shapes, or arches and are often more than one story in height. Beams are often "T" sections and double T sections, or rectangular sections. Prestressing of the members, including pretensioning and post-tensioning, is often employed. The identification of this structure type cannot rely solely on construction date, although most precast concrete frame structures were constructed after 1960. Some typical characteristics are the following:

- Precast concrete, in general, is of a higher quality and precision compared to cast-in-place concrete. It is also available in a greater range of textures and finishes. Many newer concrete and steel buildings have precast concrete panels and column covers as an exterior finish (See Figure E-41).

Figure E-39 Newly installed anchorage of roof beam to wall in tilt-up building.

Thus, the presence of precast concrete does not necessarily mean that it is a precast concrete frame.

- Precast concrete frames are, in essence, post and beam construction in concrete. Therefore, when a concrete structure displays the features of a post-and-beam system, it is most likely that it is a precast concrete frame. It is usually not economical for a conventional cast-in-place concrete frame to look like a post-and-beam system. Features of a precast concrete post-and-beam system include:

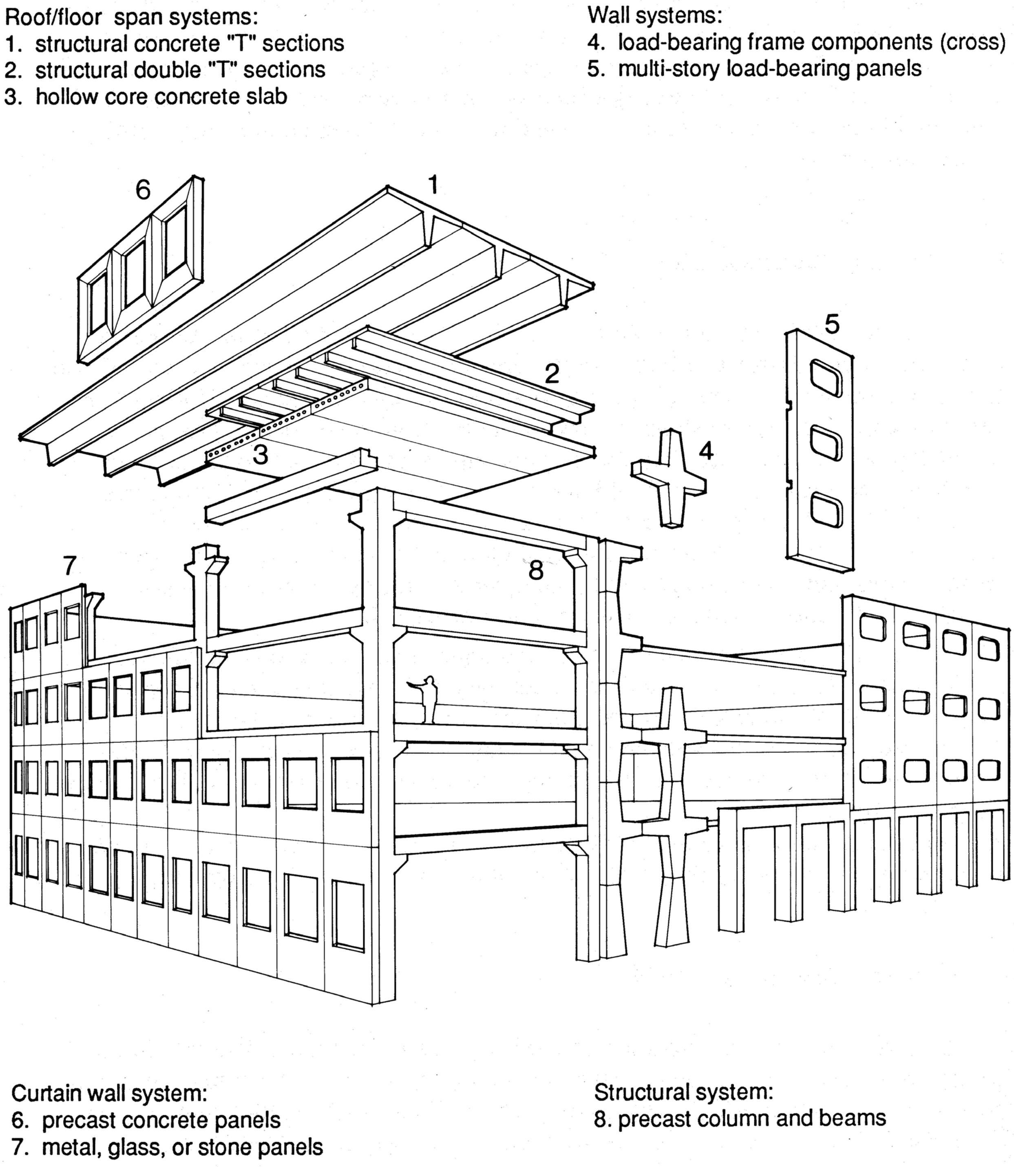


Figure E-40 Drawing of precast concrete frame building (Lagorio et al., 1986).

Figure E-41 Typical precast column cover on a steel or concrete moment frame.

- exposed ends of beams and girders that project beyond their supports or project away from the building surface,
- the absence of small joists, and
- beams sitting on top of girders rather than meeting at a monolithic joint (see Figure E-42).

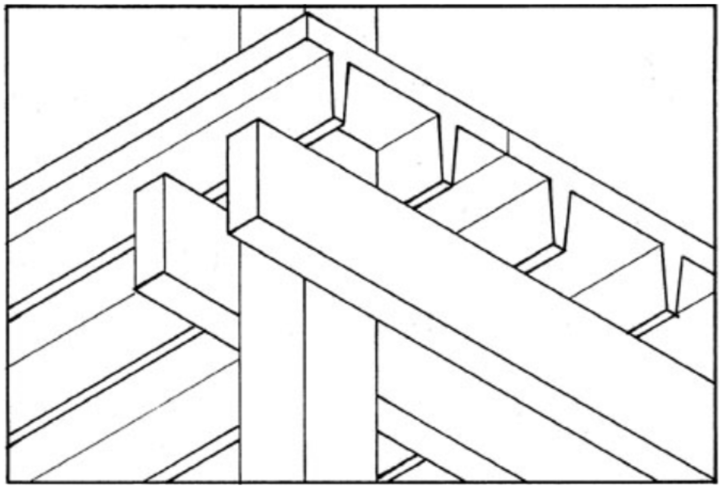


Figure E-42 Exposed precast double-Tee sections and overlapping beams are indicative of precast frames.

The presence of precast structural components is usually a good indication of this system, although these components are also used in mixed construction. Precast structural components come in a variety of shapes and sizes. The most common types are sometimes difficult to detect from the street. Less common but more obvious examples include the following.

- *T-sections or double T's*. These are deep beams with thin webs and flanges and with large span capacities. (Figure E-43 shows one end of a double-T beam as it is lowered onto its seat.)

Figure E-43 Example of precast double "T" section during installation.

- *Cross or T-shaped units of partial columns and beams*. These are structural units for constructing moment-resisting frames. They are usually joined together by field welding of steel connectors cast into the concrete. Joints should be clearly visible at the mid-span of the beams or the mid-height of the columns. See Figure E-44.
- *Precast arches*. Precast arches and pedestals are popular in the architecture of these buildings.
- *Column*. When a column displays a precast finish without an indication that it has a cover (i.e., no vertical seam can be found), the column is likely to be a precast structural column.

It is possible that a precast concrete frame may not show any of the above features.

E.11.2 Typical Earthquake Damage

The earthquake performance of this structural type varies widely and is sometimes poor. This type of building can perform well if the detailing used to connect the structural elements has sufficient strength and ductility (toughness). Because structures of this type often employ cast-in-place

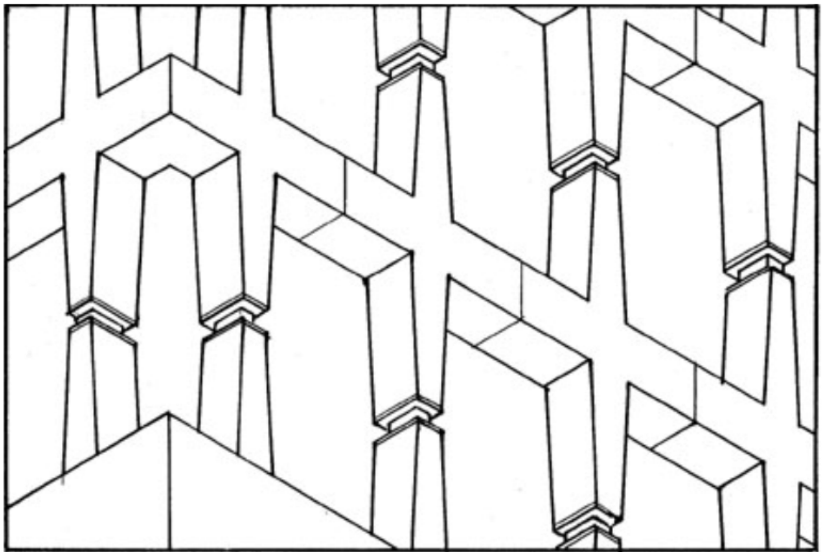


Figure E-44 Precast structural cross; installation joints are at sections where bending is minimum during high seismic demand.

concrete or reinforced masonry (brick or block) shear walls for lateral-load resistance, they experience the same types of damage as other shear wall building types. Some of the problem areas specific to precast frames are listed below.

- Poorly designed connections between prefabricated elements can fail.
- Accumulated stresses can result due to shrinkage and creep and due to stresses incurred in transportation.
- Loss of vertical support can occur due to inadequate bearing area and insufficient connection between floor elements and columns.
- Corrosion of the metal connectors between prefabricated elements can occur.

E.11.3 Common Retrofit Techniques

Seismic retrofit techniques for precast concrete frame buildings are varied, depending on the elements being strengthened. Inadequate shear capacity of floor diaphragms can be addressed by adding reinforced concrete topping to an untopped system when possible, or adding new shear walls to reduce the seismic shear forces in the diaphragm. Corbels with inadequate vertical shear or bending strength can be strengthened by adding epoxied horizontal shear dowels through the corbel and into the column. Alternatively, vertical shear capacity can be increased by adding a structural steel bolster under the corbel, bolted to the column, or a new steel column or reinforced concrete column can be added (ATC, 1992).

E.12 Reinforced Masonry (RM1 and RM2)

E.12.1 Characteristics

Reinforced masonry buildings are mostly low-rise structures with perimeter bearing walls, often with wood diaphragms (RM1 buildings) although precast concrete is sometimes used (RM2 buildings). Floor and roof assemblies usually consist of timber joists and beams, glued laminated beams, or light steel joists. The bearing walls consist of grouted and reinforced hollow or solid masonry units. Interior supports, if any, are often wood or steel columns, wood stud frames, or masonry walls. Occupancy varies from small commercial buildings to residential and industrial buildings. Generally, they are less than five stories in height although many taller masonry buildings exist. Reinforced masonry structures are usually basically rectangular structures (See Figure E-45).

Figure E-45 Modern reinforced brick masonry.

To identify reinforced masonry, one must determine separately if the building is masonry and if it is reinforced. To obtain information on how to recognize a masonry structure, see Appendix D, which describes the characteristics of construction materials. The best way of assessing the reinforcement condition is to compare the date of construction with the date of code requirement for the reinforcement of masonry in the local jurisdiction.

The screener also needs to determine if the building is veneered with masonry or is a masonry building. Wood siding is seldom applied over masonry. If the front façade appears to be reinforced masonry whereas the side has wood siding, it is probably a wood frame that has undergone façade renovation.

The back of the building should be checked for signs of the original construction type.

If it can be determined that the bearing walls are constructed of concrete blocks, they may be reinforced. Load-bearing structures using these blocks are probably reinforced if the local code required it. Concrete blocks come in a variety of sizes and textures. The most common size is 8 inches wide by 16 inches long by 8 inches high. Their presence is obvious if the concrete blocks are left as the finish surface.

E.12.2 Typical Earthquake Damage

Reinforced masonry buildings can perform well in moderate earthquakes if they are adequately reinforced and grouted, and if sufficient diaphragm anchorage exists. A major problem is control of the workmanship during construction. Poor construction practice can result in ungrouted and unreinforced walls. Even where construction practice is adequate, insufficient reinforcement in the design can be responsible for heavy damage of the walls. The lack of positive connection of the floor and roof diaphragms to the wall is also a problem. Some older reinforced masonry buildings have wall-to-diaphragm tension ties that rely on cross-grain bending of the perimeter ledger to resist loads, a particularly poor detail for resisting earthquake loading.

E.12.3 Common Retrofit Techniques

Techniques for seismic retrofit of reinforced masonry bearing wall buildings are varied, depending on the element. Techniques for retrofitting masonry walls include: (1) applying a layer of concrete or shotcrete to the existing walls; (2) adding vertical reinforcing and grouting into ungrouted block walls; and (3) filling in large or critical openings with reinforced concrete or masonry dowelled to the surrounding wall. Wood or steel deck diaphragms in RM1 buildings can be rehabilitated by adding an additional layer of plywood to strengthen and stiffen an existing wood diaphragm, by shear welding between sections of an existing steel deck or adding flat sheet steel reinforcement, or by adding additional vertical elements (for example, shear walls or braced frames) to decrease diaphragm spans and stresses. Wall-to-diaphragm ties in wood frame construction relying on cross-grain bending can be strengthened with additional wall anchors and blocking back into the diaphragm to supplant the existing weak ties. Precast floor diaphragms in RM2 buildings can be strengthened by adding a layer of concrete topping reinforced with mesh (if the supporting structure has the capacity to carry the additional vertical dead load), or by adding new shear walls to reduce the diaphragm span (ATC, 1992).

E.13 Unreinforced Masonry (URM)

E.13.1 Characteristics

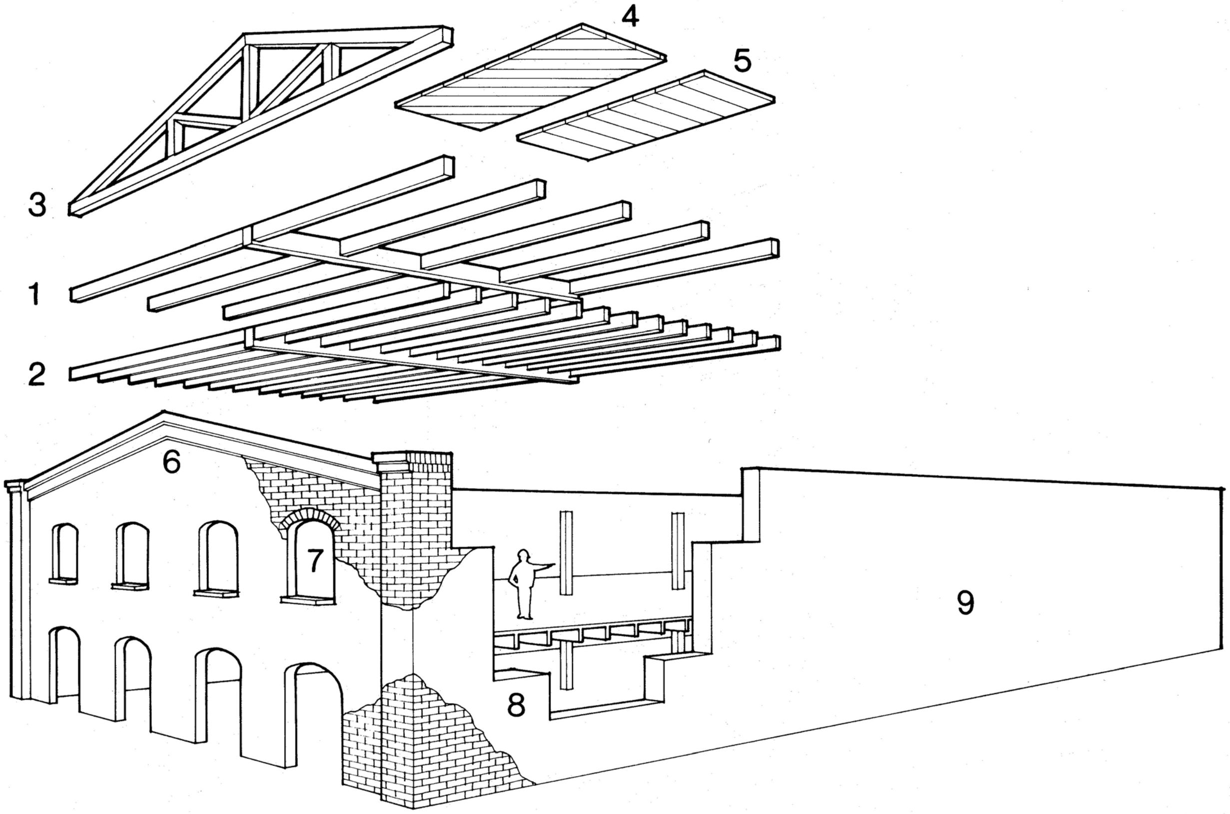
Most unreinforced masonry (URM) bearing wall structures in the western United States (Figures E-46 through E-50) were built before 1934, although this construction type was permitted in some jurisdictions having moderate or high seismicity until the late 1940s or early 1950s (in some jurisdictions URM may still be a common type of construction, even today). These buildings usually range from one to six stories in height and function as commercial, residential, or industrial buildings. The construction varies according to the type of use, although wood floor and roof diaphragms are common. Smaller commercial and residential buildings usually have light wood floor joists and roof joists supported on the typical perimeter URM wall and interior, wood, load-bearing partitions. Larger buildings, such as industrial warehouses, have heavier floors and interior columns, usually of wood. The bearing walls of these industrial buildings tend to be thick, often as much as 25 inches or more at the base. Wall thicknesses of residential, commercial, and office buildings range from 9 inches at upper stories to 17 inches at lower stories.

The first step in identifying buildings of this type is to determine if the structure has bearing walls. Second, the screener should determine the approximate age of the building. Some indications of unreinforced masonry are listed below.

- Weak mortar was used to bond the masonry units together in much of the early unreinforced masonry construction in the United States. As the poor earthquake performance of this mortar type became known in the 1930s, and as cement mortar became available, this weaker mortar was not used and thus is not found in more recent masonry buildings. If this soft mortar is present, it is probably URM. Soft mortar can be scratched with a hard instrument such as a penknife, screwdriver, or a coin. This scratch testing, if permitted, should be done in a wall area where the original structural material is exposed, such as the sides or back of a building. Newer masonry may be used in renovations and it may look very much like the old. Older mortar joints can also be repointed (i.e., regular maintenance of the masonry mortar), or repaired with newer mortar during renovation. The original construction may also have used a high-quality mortar. Thus, even if the existence of soft mortar cannot be detected, it may still be URM.

Roof/floor span systems:
1. wood post and beam (heavy timber)
2. wood post, beam, and joist (mill construction)
3. wood truss-- pitch and curve

Roof/floor diaphragms:
4. diagonal sheathing
5. straight sheathing



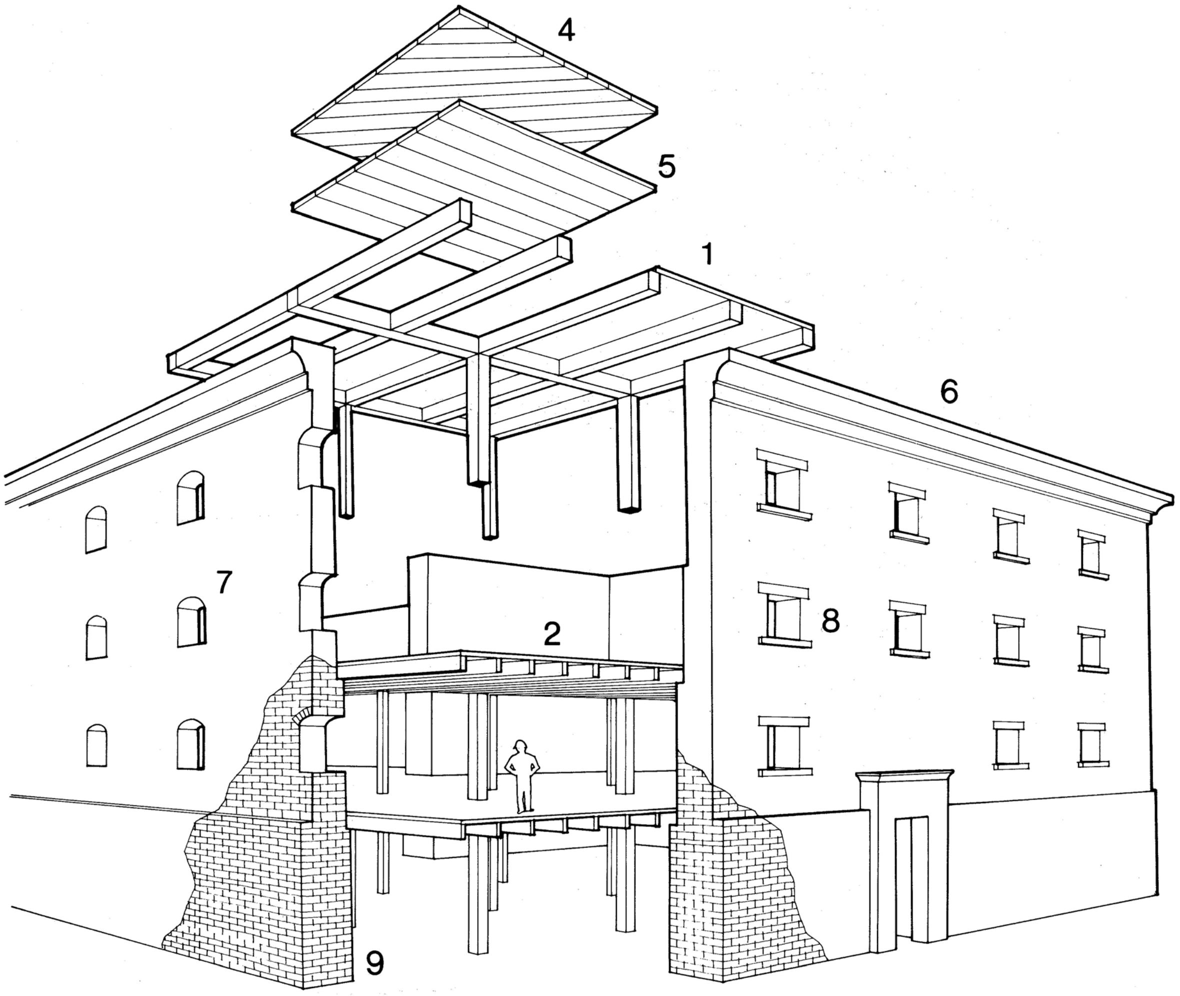
Details:
6. typical unbraced parapet and cornice
7. flat arch window opennings

Wall systems:
8. bearing wall-- four or more wythes of brick
9. typical long solid party wall

Figure E-46 Drawing of unreinforced masonry bearing wall building, two-story (Lagorio et al., 1986).

Roof/floor span systems:
1. wood post and beam (heavy timber)
2. wood post, beam, and joist (mill construction)
3. wood truss-- pitch and curve

Roof/floor diaphragms:
4. diagonal sheathing
5. straight sheathing



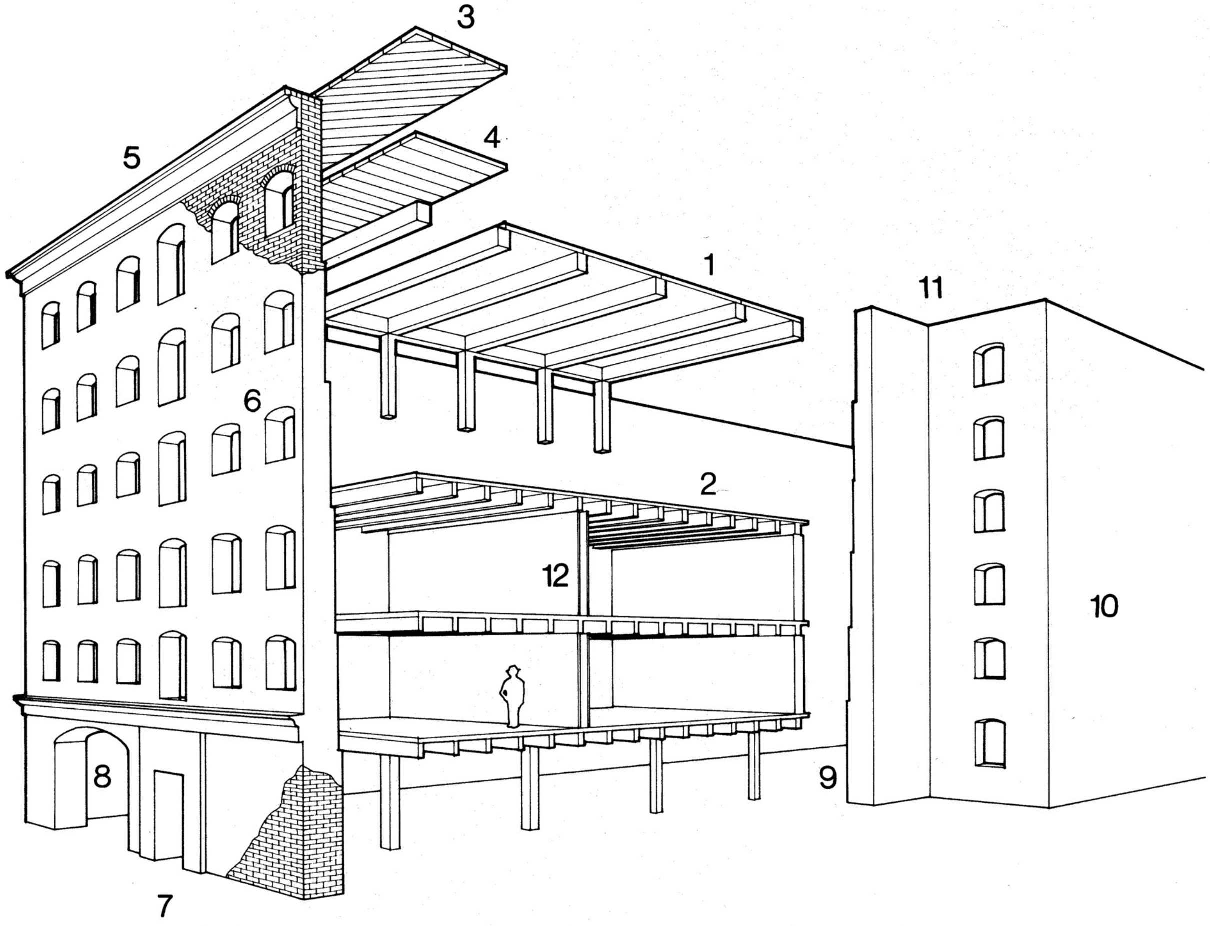
Details:
6. typical unbraced parapet and cornice
7. flat arch window opennings
8. small window penetrations (if bldg is originally a warehouse)

Wall systems:
9. bearing wall-- four to eight wythes of brick

Figure E-47 Drawing of unreinforced masonry bearing wall building, four-story (Lagorio et al., 1986).

Roof/floor span systems:
1. wood post and beam (heavy timber)
2. wood post, beam, and joist (mill construction)

Roof/floor diaphragms:
3. diagonal sheathing
4. straight sheathing



Details:
5. typical unbraced parapet and cornice
6. flat arch window opennings
7. typical penetrated facade of residential buildings
8. large opennings of ground floor shops

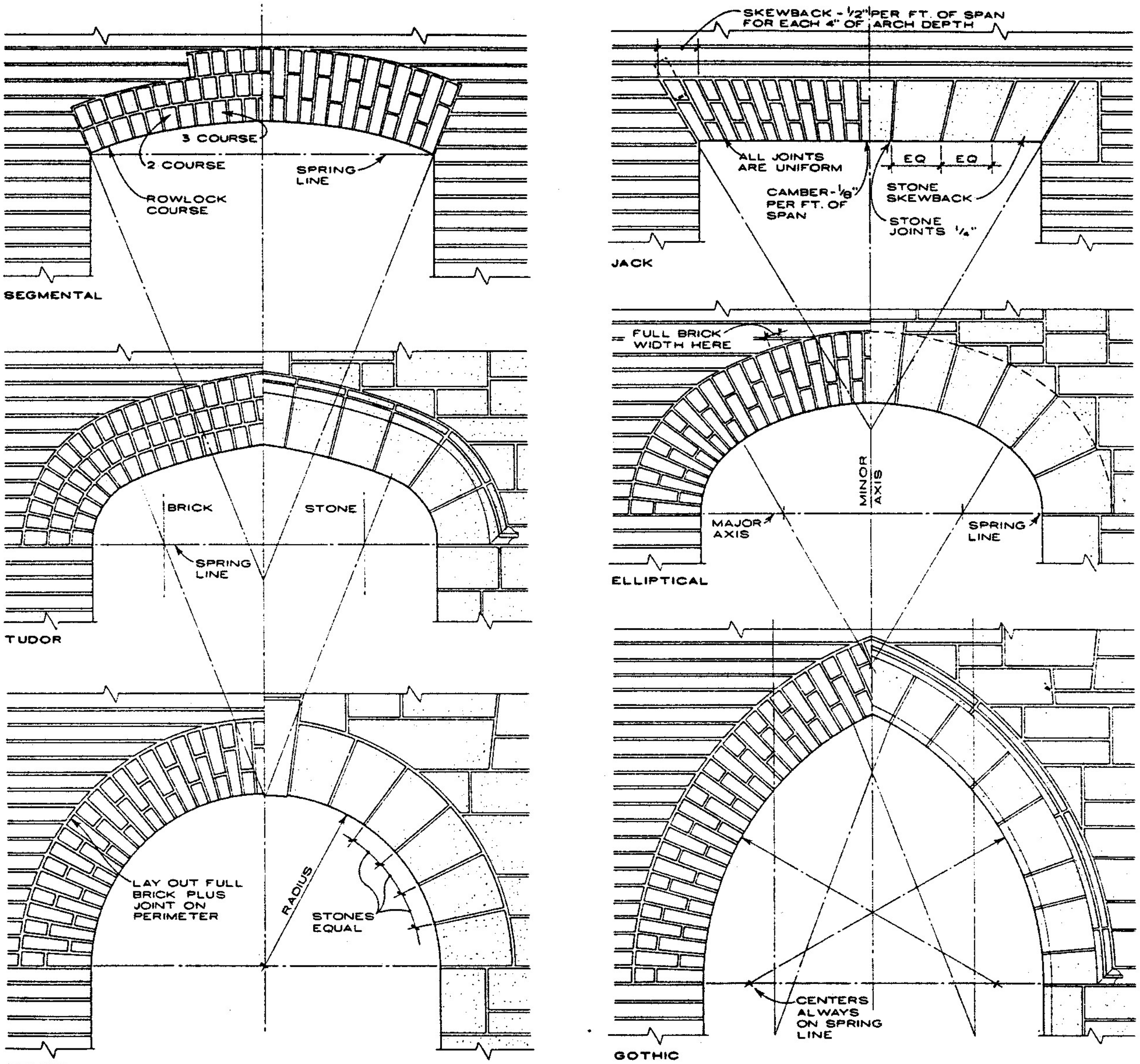
Wall systems:
9. bearing wall-- four to eight wythes of brick
10. typical long solid party wall
11. light/ventilation wells in residential bldg
12. non-structural wood stud partition walls

Figure E-48 Drawing of unreinforced masonry bearing wall building, six-story (Lagorio et al., 1986).

Figure E-49 East Coast URM bearing wall building.

Figure E-50 West Coast URM bearing wall building.

- An architectural characteristic of older brick bearing wall structures is the arch and flat arch window heads (see Figure E-51). These arrangements of masonry units function as a header to carry the load above the opening to either side. Although masonry-veneered wood frame structures may have these features, they are much more widely used in URM bearing wall structures, as they were the most economical method of spanning over a window opening at the time of construction. Other methods of spanning are also used, including steel and stone lintels, but these methods are generally more costly and usually employed in the front façade only.



NOTE: Stone joints may be handled in a variety of ways. This is one illustration.

Figure E-51 Drawings of typical window head features in URM bearing wall buildings (Packard, 1981).

- Some structures of this type will have anchor plates visible at the floor and roof lines, approximately 6-10 feet on center around the perimeter of the building. Anchor plates are usually square or diamond-shaped steel plates approximately 6 inches by 6 inches, with a bolt and nut at the center. Their presence indicates anchor ties have been placed to tie the walls to the floors and roof. These are either from the original construction or from retrofit under local ordinances. Unless the anchors are 6 feet on center or less, they are not considered effective in earthquakes. If they are closely spaced, and appear to be recently installed, it indicates that the building has been rehabilitated. In either case, when these anchors are present all around the building, the original construction is URM bearing wall.

- When a building has many exterior solid walls constructed from hollow clay tile, and no columns of another material can be detected, it is probably not a URM bearing wall but probably a wood or metal frame structure with URM infill.
- One way to distinguish a reinforced masonry building from an unreinforced masonry building is to examine the brick pattern closely. Reinforced masonry usually does not show header bricks in the wall surface.

If a building does not display the above features, or if the exterior is covered by other finish material, the building may still be URM.

E.13.2 Typical Earthquake Damage

Unreinforced masonry structures are recognized as the most hazardous structural type. They have been observed to fail in many modes during past earthquakes. Typical problems include the following.

- *Unbraced parapets.* Parapets cantilevering up from the roof line are typically not braced and are usually the first element to fail in an earthquake. See Figure E-52 for parapet damage.

Figure E-52 Parapet failure leaving an uneven roof line, due to inadequate anchorage, 1989 Loma Prieta earthquake.

- *Insufficient wall-to-diaphragm ties.* Because the perimeter walls are not positively anchored to the floors and roof, they tend to fall out under out-of-plane loading. The collapse of bearing walls can lead to major building collapses. Some of these buildings have anchors as a part of the original construction or as a retrofit. These older anchors exhibit questionable performance.

- *Inadequate URM wall out-of-plane capacity*. URM walls that are adequately tied to the floor and roof diaphragms span between the diaphragms under out-of-plane loads perpendicular to the face of the wall. Walls with high height-to-thickness ratios are more susceptible to out-of-plane failures.
- *Inadequate URM wall in-plane capacity.* The mortar used in older URM buildings was often made of lime and sand, with little or no cement, and had limited shear strength. Wall lines with large openings further reduce capacity. URM bearing walls can be heavily damaged and collapse under large loads. See Figure E-53.

Figure E-53 Damaged URM building, 1992 Big Bear earthquake.

- *Inadequate diaphragm strength and stiffness*. The strength and stiffness of wood diaphragms in wood buildings can be inadequate to take the large loads generated by the heavy masonry walls. They may lack the strength to transfer out-of-plane wall loads back through the diaphragm to the in-plane walls. And the displacements at mid-span of the diaphragm may amplifying the out-of-plane loads on the walls and exceed the in-plane capacity of interior partitions. At open front situations, the diaphragm may be inadequate to transfer the load from URM perimeter walls above the open front back to other walls that can deliver the loads to the foundations.

- *Slender Walls.* Some of these buildings have tall story heights and thin walls. This condition, especially in non-load-bearing walls, will result in buckling out-of-plane under severe lateral load. Failure of a non-load-bearing wall represents a falling hazard, whereas the collapse of a load-bearing wall will lead to partial or total collapse of the structure.

E.13.3 Common Retrofit Techniques

Over the last 20 years or more, jurisdictions in California have required that unreinforced masonry bearing wall buildings be rehabilitated or demolished. To minimize the economical impact on owners of having to rehabilitate their buildings, many jurisdictions implemented phased programs such that the critical items were dealt with first. The following are the key elements included in a typical retrofit program.

- Parapet and chimneys are braced back to the roof.
- Roof and floor diaphragms are connected to the walls for both anchorage forces (out of the plane of the wall) and shear forces (in the plane of the wall). Anchorage connections are placed at 6 feet spacing or less, depending on the force requirements. Shear connections are usually placed at around 2 feet center to center. Anchors consist of bolts installed through the wall, with 6-inch-square washer plates, and connected to hardware attached to the wood framing. Shear connections usually are bolts embedded in the masonry walls in oversized holes filled with either a non-shrink grout or an epoxy adhesive. See Figure E-54.

Figure E-54 Two existing anchors above three new wall anchors at floor line using decorative washer plates.

- In cases when the height-to-thickness ratio of the walls exceeds the limits of stability, retrofit consists of reducing the spans of the wall to a level that their thickness can support or adding vertical wood or steel posts ("strongbacks") that are anchored to the wall and span between diaphragms.
- If the building has an open storefront in the first story, resulting in a soft story, part of the storefront is enclosed with new masonry or a steel frame is provided there, with new foundations.
- Walls are retrofitted by either closing openings with reinforced masonry or with reinforced shotcrete. Loads to the perimeter walls can be reduced by adding interior steel braces.
- Inadequate diaphragms can be strengthened with plywood overlays and blocking.

E.14 Manufactured Housing (MH)

E.14.1 Characteristics

The Manufactured Housing building type has been added to the third edition of FEMA P-154. Manufactured Housing is part of a larger class of prefabricated structures that includes modular buildings.

Manufactured homes are built in a factory and transported to the site. Mobile home is an older term for a manufactured home, though mobile home remains in widespread use. Construction requirements for manufactured homes are administered by the U.S. Department of Housing and Urban Development (HUD), per HUD's Manufactured Home Construction and Safety Standards. HUD regulation of manufactured housing began in 1976. HUD standards are published in the Code of Federal Regulations under 24 CFR Part 3280, and they define a manufactured home as:

> *"a structure, transportable in one or more sections, which in the traveling mode is 8 body feet or more in width or 40 body feet or more in length or which when erected on-site is 320 or more square feet, and which is built on a permanent chassis and designed to be used as a dwelling with or without a permanent foundation when connected to the required utilities."*

Manufactured homes come in different sizes. A single-wide can be up to 18 feet in width. A double-wide is 20 feet or more in width; it is towed to the site in two separate units, which are then joined together. Some homes are built with additional units to create an even larger structure. Manufactured homes are typically one story. Floors and roofs are usually constructed with plywood or oriented strand board, and the outside surfaces are covered with sheet metal.

At the site, the *HAZUS-MH MR4 Technical Manual* (FEMA, 2009a) notes that "manufactured homes are typically placed on isolated piers, jack stands, or masonry block foundations (usually without any positive anchorage)." Earthquake resistant bracing systems (ERBS) are available. A 1995 HUD brochure (National Conference, 1996) notes that "Some bracing systems simply provide a frame that catches the home if, during an earthquake, the home falls off its pier. Other more elaborate bracing systems actually minimize both horizontal and vertical movement of the home through connections between the bracing system, the home, and the footings."

Modular buildings are also factory built in units or modules, but they do not have a permanent chassis or axles and must be transported to the site on flatbed trucks. Using a crane, the modules are set on a foundation and joined together to make a final structure. They may be multistory. Modular buildings are governed by local building codes.

Prefabricated structures are used not just as residences, but also for schools and other occupancies, as well as temporary buildings with many uses. Portable classrooms are often used on school properties to provide additional temporary space. In California, permanent foundations are required when the classroom exceeds 2,160 square feet or has more than one story, per the Division of State Architect's IR 16-1 "Design and Construction Requirements for Relocatable Buildings" (DSA, 2011).

The focus for the Manufactured Housing screening category is on buildings that are mobile, raised up off the ground, not anchored to the ground, and may or may not have an ERBS. This includes mobile homes and modular buildings, such as those used for portable classrooms, when they are not permanently anchored.

Prefabricated structures that are anchored to a foundation and are wood framed are screened using the RVS procedure for W1 buildings; similarly, prefabricated structures built with a steel superstructure and anchored to a foundation are screened with the RVS procedure for S1 buildings.

In a rapid visual screening, it may not always be possible to determine whether a permanent foundation or an ERBS exists, as there is often a cripple wall or skirt wall covering the underlying conditions. Unanchored Manufactured Housing should be assumed unless a permanent foundation or ERBS can be seen.

E.14.2 Typical Earthquake Damage

The lightweight superstructure of Manufactured Housing as defined above is somewhat seismically resilient as it must be designed to be transported and to resist wind loads. Typical superstructure earthquake damage can include cracking of partitions and ceilings and racking of walls. Complete failure of the superstructure due to racking is relatively unlikely. The primary issue of concern and source of significant damage is due to the lack of a permanent foundation connection or an ERBS. In moderate shaking, the building can fall off its supports, and jack stands can penetrate the floor. Connecting utility lines can be severed, and escaping gas can cause fires. Falling objects, structural damage, and fire can lead to injuries and fatalities. The cost and disruption from damage can be significant.

E.14.3 Common Retrofit Techniques

Because the superstructure of Manufactured Housing is relatively seismically resilient, it is rare for it to undergo seismic retrofitting. However, the addition of an ERBS is a common retrofit technique if it was not done at the time of original installation on the site.

Appendix F

Guidance on Assessing Damage and Deterioration

F.1 Introduction

The scoring system in FEMA P-154 RVS is established assuming that the building is constructed of sound materials. Deterioration of structural elements can have a significant impact on the expected performance of a building and therefore needs to be captured when performing a survey when possible. Determination of the potential impact on performance is difficult at best since not all damage and deterioration is visible, nor is it easy to assess.

Chapter 3 provides guidelines for assessing damage and deterioration during a Level 1 screening.

The following sections describe some of the important conditions to consider when evaluating this hazard. The key question is whether the level of deterioration and damage rises to the level of “significant” and thus triggers a Detailed Structural Evaluation. This is best determined by an experienced engineer, but the guidance below is provided to assist the screener in conducting RVS.

F.2 Guidance on Assessing Damage and Deterioration of Wood

Conditions, such as decay, shrinkage, splitting, fire damage, or sagging, may affect the overall capacity of the seismic force-resisting system. Metal accessory deterioration, or broken or loose connections, can also contribute to lateral weaknesses.

Evidence of moisture damage on the building surfaces is a good clue that hidden damage may exist. Rusted nails, bolts, and fasteners can have a major impact on the capacity to transfer the loads as intended.

Wood structural panels or shear walls should be checked for evidence of sill plate damage when the sill is accessible (Figure F-1). Rusted nails or evidence of decay on the wood framing will suggest that its strength has been compromised.

Figure F-1 Wood decay in cripple wall.

Wood post and bracing systems should be checked for rot, splitting and steel corrosion (Figures F-2 and F-3). Since these can generally be considered to provide primary lateral resistance, their integrity is essential to the seismic resistance of the structure and can warrant a more detailed evaluation to assure safety.

Figure F-2 Damaged wood post.

Figure F-3 Rotted timber column.

Fire-damaged members are often not directly observed; however, when discovered, their effect should be considered. Reduction of member sizes and significant charring should be noted and flagged for additional investigation.

Steel bolts and other metal fasteners that show evidence of deterioration should be evaluated when they are part of the primary seismic force-resisting system.

Checking and splitting of wood, water stains on wood elements, and light rust on metal connection hardware, are common and do not warrant checking a detailed evaluation. However, if there is noticeable loss of cross section in wood members or large areas of softness from dryrot or insect damage, and if there are a substantial number of broken connections or connections with substantial loss of cross section from rust, then this is considered significant, and a Detailed Structural Evaluation is recommended.

F.3 Guidance on Assessing Damage and Deterioration of Steel

Rusting and corrosion of steel members and connections can be an important indicator of the potential for poor performance in a building's lateral force-resisting system (Figure F-4). Reduced member size, pitting, scaling, and other detrimental effects of water intrusion should be evaluated.

Steel members exhibiting notable size reductions or pitting should be captured in the survey. While the primary concern is for elements comprising the seismic force-resisting system, it is helpful to comment on any member that has this defect.

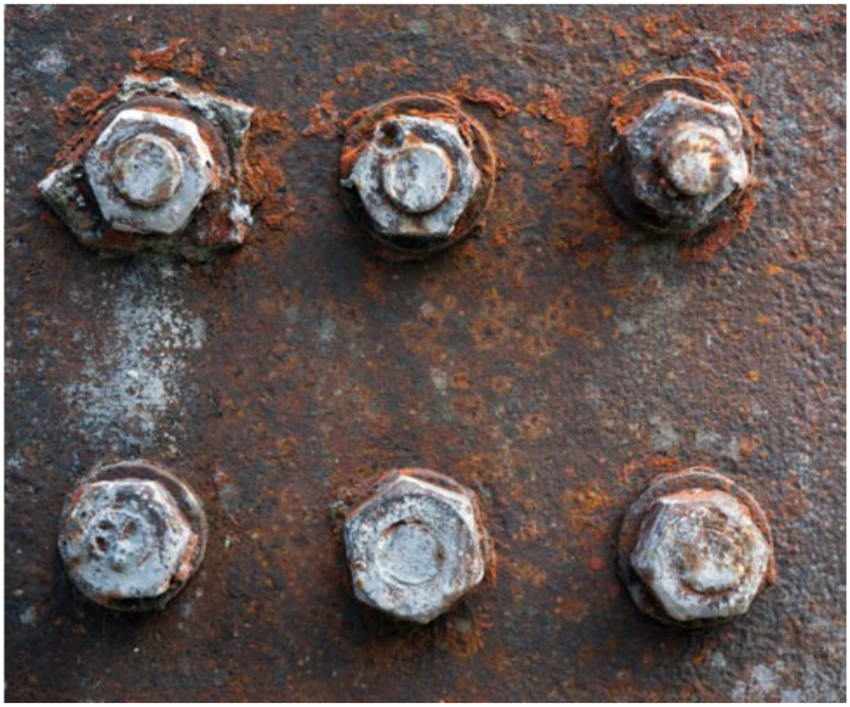


Figure F-4 Corroded steel fasteners.

Some other considerations include cracking or missing bolts. For the purposes of RVS, this is most important when it occurs in the seismic force-resisting system.

Steel surface rusting or corrosion may appear severe, but if it does not significantly reduce the member section then it should not be considered sufficient to trigger a detailed evaluation. On the other hand, significant loss of section in important members of the lateral system or significant loss of section at connections or substantial missing bolts or other connectors is sufficient to trigger a Detailed Structural Evaluation.

F.4 Guidance on Assessing Damage and Deterioration of Concrete

Deterioration of concrete materials either as cover for reinforcing steel or due to cracking should be considered detrimental to the capacity of the individual members.

Spalling of concrete cover over reinforcing steel can be evidence of moisture and corrosion issues (Figure F-5). While not always a problem for a member's reduction in capacity, it can be an indicator of hidden reinforcing steel corrosion that would reduce member strength.

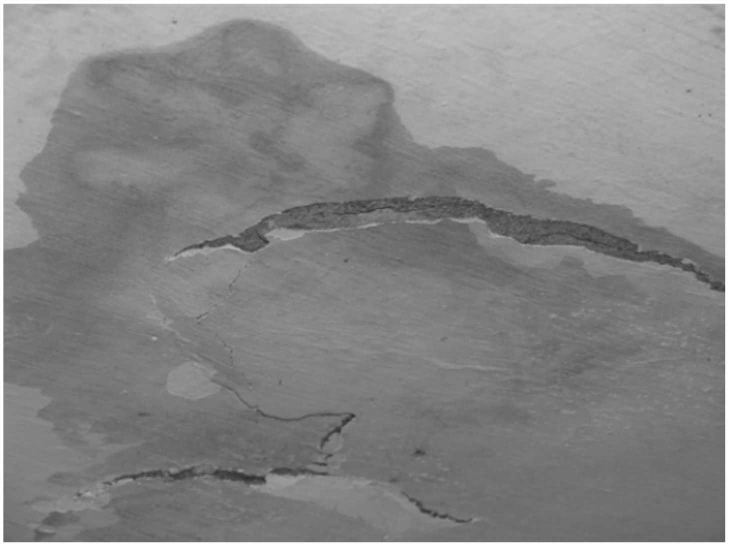


Figure F-5 Spalled concrete cover.

The benefits of reinforcing steel in concrete members can be significantly reduced when the steel is compromised through corrosion and deterioration. Exposed reinforcing steel does not bond to concrete and therefore is ineffective in transferring forces and consequently should be further evaluated (Figure F-6).

Figure F-6 Exposed reinforcing steel.

Post-tensioning anchor corrosion can also lead to failure of concrete sections. If these connections can be examined and they show evidence of significant loss of section, then this should be reason for further examination of the structure.

Precast concrete walls and precast members generally rely upon mechanical anchorages to fasten them into a system. Examination of these steel elements for corrosion and loss of section can also lead to concerns about their capacity to perform adequately during an earthquake. If excessive rust is observed, then this should be flagged and commented upon on the screening forms.

Long-term creep, shrinkage or temperature extremes can produce cracking near connections. For simplicity in rapid visual screening, concrete crack widths of 1/8" or greater should be considered significant and reported on the forms.

Concrete walls and columns can also have cracking which may affect the overall strength of a building (Figure F-7). Crack width and crack type are both important considerations. For example, flexural cracks or temperature and shrinkage cracking are typically not considered to be of serious concern. Cracks representative of shear demands, on the other hand, can be of more substantial concern. FEMA 306 report, *Evaluation and Repair of Earthquake Damaged Concrete and Masonry Wall Buildings* (FEMA, 1999a), provides excellent additional guidance, but is beyond the level of effort intended for RVS. For the purposes of the rapid visual screening, crack widths of 1/8" or greater that appear to go fully through the structural elements and are at least 25% of the length or width of a member are sufficient to warrant a Detailed Structural Evaluation.

Figure F-7 Concrete cracks.

F.5 Guidance on Assessing Damage and Deterioration of Reinforced Masonry

Reinforced masonry can exhibit cracking from a variety of sources (Figure F-8). Temperature extremes, inadequate control joints, foundation settlement and other causes can produce diagonal or joint line cracking that should be examined and evaluated. Crack widths greater than 1/8” or greater over at least 25% of the length of a member are sufficient to warrant a Detailed Structural Evaluation.

Figure F-8 “Stair-step” cracking.

F.6 Guidance on Assessing Damage and Deterioration of Unreinforced Masonry

Cracking in unreinforced masonry walls can be detrimental to the overall expected performance of these types of buildings. Diagonal “stair-step” or through-brick cracking with widths greater than 1/8” should be captured for additional investigation by checking the “Significant Damage/Deterioration to the Structural System” box (Figure F-9). Cracks over at least 25% of the length of a member are sufficient to warrant a Detailed Structural Evaluation.

Figure F-9 Masonry joint separations.

Appendix G

Earthquakes and How Buildings Resist Them

G.1 The Nature of Earthquakes

In a global sense, earthquakes result from motion between plates comprising the earth's crust (see Figure G-1). These plates are driven by the convective motion of the material in the earth's mantle between the core and the crust, which in turn is driven by heat generated at the earth's core. Just as in a heated pot of water, heat from the earth's core causes material to rise to the earth's surface. Forces between the rising material and the earth's crustal plates cause the plates to move. The resulting relative motions of the plates are associated with the generation of earthquakes. Where the plates spread apart, molten material fills the void. An example is the ridge on the ocean floor, at the middle of the Atlantic Ocean. This material quickly cools and, over millions of years, is driven by newer, viscous, fluid material across the ocean floor.

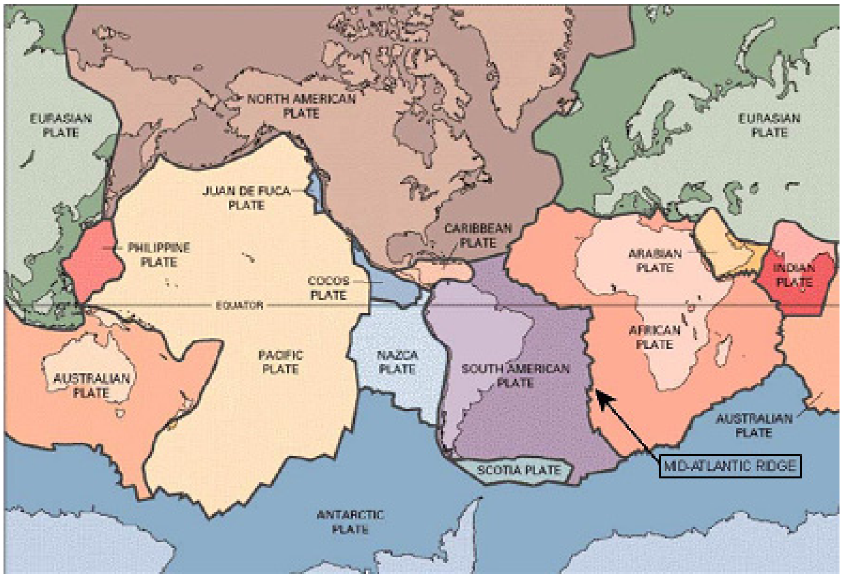


Figure G-1 The separate tectonic plates comprising the earth's crust superimposed on a map of the world.

These large pieces of the earth's surface, termed tectonic plates, move very slowly and irregularly. Forces build up for decades, centuries, or millennia at the interfaces (or faults) between plates, until a large releasing movement suddenly occurs. This sudden, violent motion produces the nearby shaking that is felt as an earthquake. Strong shaking produces strong horizontal forces on structures, which can cause direct damage to buildings, bridges, and other man-made structures as well as triggering fires, landslides, road damage, tidal waves (tsunamis), and other damaging phenomena.

A fault is like a "tear" in the earth's crust and its fault surface may be from one to over one hundred miles deep. In some cases, faults are the physical expression of the boundary between adjacent tectonic plates and thus are hundreds of miles long. In addition, there are shorter faults, parallel to, or branching out from, a main fault zone. Generally, the longer a fault, the larger magnitude earthquake it can generate. Beyond the main tectonic plates, there are many smaller sub-plates, platelets and simple blocks of crust which can move or shift due to the jostling of their neighbors and the major plates. The known existence of these many sub-plates implies that smaller but still damaging earthquakes are possible almost anywhere.

With the present understanding of the earthquake generating mechanism, the times, sizes, and locations of earthquakes cannot be reliably predicted. Generally, earthquakes will be concentrated in the vicinity of faults, and certain faults are more likely than others to produce a large event, but the earthquake generating process is not understood well enough to predict the exact time of earthquake occurrence. Therefore, communities must be prepared for an earthquake to occur at any time.

Four major factors can affect the severity of ground shaking and thus potential damage at a site. These are the magnitude of the earthquake, the type of earthquake, the distance from the source of the earthquake to the site, and the hardness or softness of the rock or soil at the site. Larger earthquakes will shake longer and harder, and thus cause more damage. Experience has shown that the ground motion can be felt for several seconds to a minute or longer. In preparing for earthquakes, both horizontal (side to side) and vertical shaking must be considered.

There are many ways to describe the size and severity of an earthquake and associated ground shaking. Perhaps the most familiar are earthquake magnitude and Modified Mercalli Intensity (MMI, often simply termed "intensity"). Earthquake magnitude is technically known as the Richter magnitude, a numerical description of the maximum amplitude of ground movement measured by a seismograph (adjusted to a standard setting). On the Richter scale, the largest recorded earthquakes have had magnitudes of about 9.5. It is a logarithmic scale, and a unit increase in magnitude corresponds to a ten-fold increase in the adjusted ground displacement amplitude, and to approximately a thirty-fold increase in total potential strain energy released by the earthquake.

Modified Mercalli Intensity (MMI) is a subjective scale defining the level of shaking at specific sites on a scale of I to XII. (MMI is expressed in Roman numerals, to connote its approximate nature.) For example, slight shaking that causes few instances of fallen plaster or cracks in chimneys constitutes MMI VI. It is difficult to find a reliable precise relationship between magnitude, which is a description of the earthquake's total energy level, and intensity, which is a subjective description of the level of shaking of the earthquake at specific sites, because shaking intensity can vary with building type, design and construction practice, soil type and distance from the event. The following analogy may be worth remembering: earthquake magnitude and intensity are similar to a light bulb and the light it emits. A particular light bulb has only one energy level, or wattage (e.g., 100 watts, analogous to an earthquake's magnitude). Near the light bulb, the light intensity is very bright (perhaps 100 foot-candles, analogous to MMI IX), while farther away the intensity decreases (e.g., 10 foot-candles, MMI V).

A particular earthquake has only one magnitude value, whereas it has intensity values that differ throughout the surrounding land. MMI is a subjective measure of seismic intensity at a site, and cannot be measured using a scientific instrument. Rather, MMI is estimated by scientists based on observations, such as the degree of disturbance to the ground, the degree of damage to typical buildings and the behavior of people. A more objective measure of seismic shaking at a site, which can be measured by instruments, is a simple structure's acceleration in response to the ground motion. In this *Handbook*, the level of ground shaking is described by the spectral response acceleration.

G.2 Seismicity of the United States

Figure G-2 shows the seismicity of the United States based on the 2014 seismicity catalog of the USGS National Seismic Hazard Mapping Project. The data are based on Petersen et al. (2014), Wesson et al. (2007), and Klein et al. (2001).

It is evident that some parts of the country have experienced more earthquakes than others. The boundary between the North American and Pacific tectonic plates lies along the west coast of the United States and south of Alaska. The San Andreas fault in California and the Aleutian Trench off the coast of Alaska are part of this boundary. These active seismic zones have generated earthquakes with Richter magnitudes greater than 8. Many

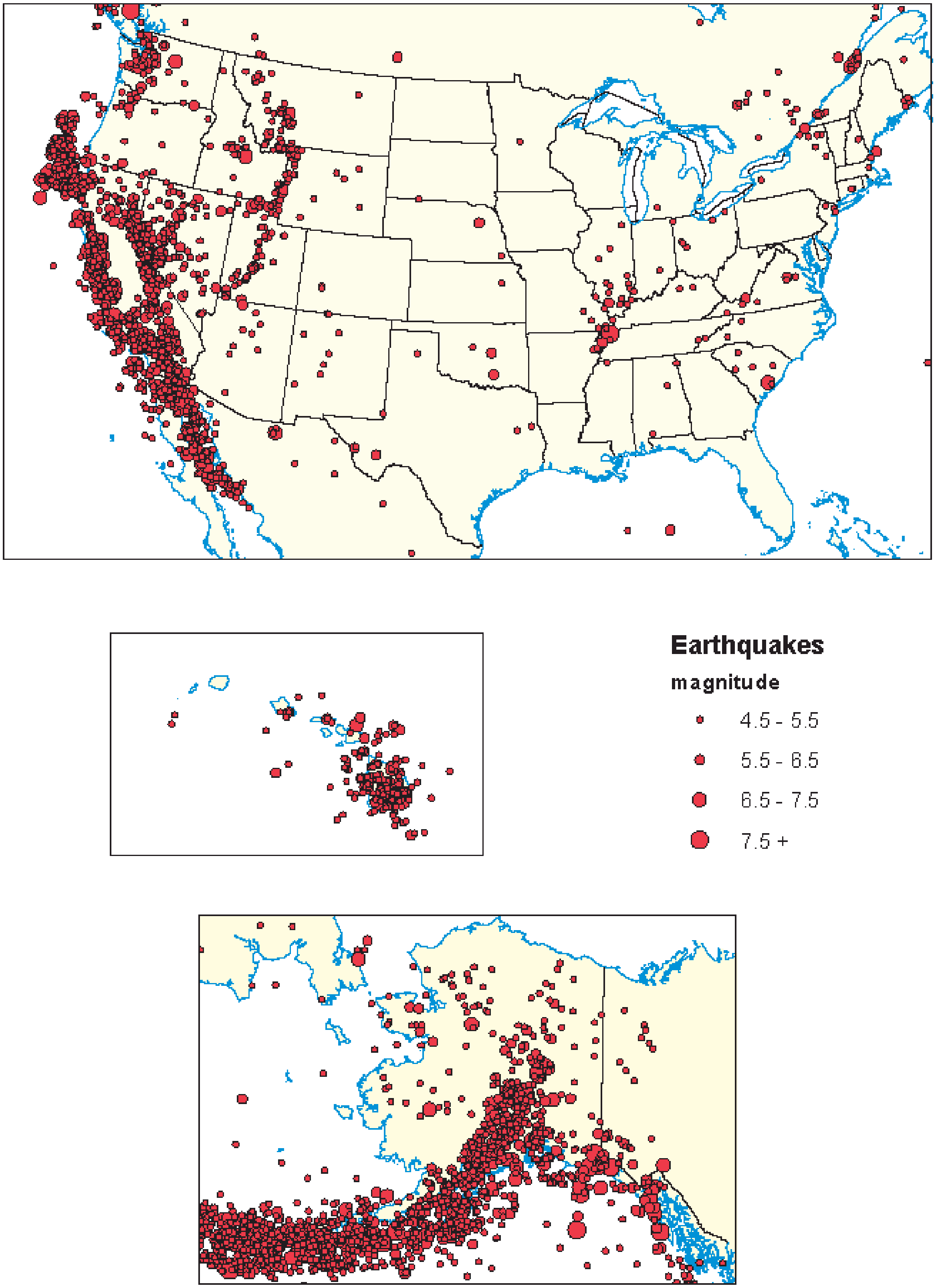


Figure G-2 Seismicity data for the United States showing earthquake locations with varying size of circles depending on the magnitude.

other smaller fault zones exist throughout the western United States that are also participating intermittently in releasing the stresses and strains that are built up as the tectonic plates try to move past one another. Because earthquakes always occur along faults, the seismic hazard will be greater for those population centers close to active fault zones.

In California, the earthquake hazard is so significant that special study zones have been created by the legislature, and named Alquist-Priola Special Study Zones. These zones cover the larger known faults and require special geotechnical studies to be performed in order to establish design parameters.

On the east coast of the United States, the sources of earthquakes are less understood. There is no plate boundary and few locations of faults are known. Therefore, it is difficult to make statements about where earthquakes are most likely to occur. Several significant historical earthquakes have occurred, such as in Charleston, South Carolina, in 1886, New Madrid, Missouri, in 1811 and 1812, and Mineral, Virginia in 2011, indicating that there is potential for large earthquakes. However, most earthquakes in the Eastern United States are smaller magnitude events. Because of regional geologic differences, specifically, the hardness of the crustal rock, Eastern and Central United States earthquakes are felt at much greater distances from their sources than those in the western United States, sometimes at distances up to a thousand miles.

G.3 Earthquake Effects

Many different types of damage can occur in buildings. Damage can be divided into two categories: structural and nonstructural, both of which can be hazardous to building occupants. Structural damage means degradation of the building's structural support systems (i.e., vertical- and lateral-force-resisting systems), such as the building frames and walls. Nonstructural damage refers to any damage that does not affect the integrity of the structural support systems. Examples of nonstructural damage are collapsed chimneys, broken windows, or fallen ceilings. The type of damage to be expected is a complex issue that depends on the structural type and age of the building, its configuration, construction materials, the site conditions, the proximity of the building to neighboring buildings, and the type of non-structural elements.

When strong earthquake shaking occurs, a building is shaken mostly from side to side, and also up and down. That is, while the ground is violently moving from side to side, taking the building foundation with it, the building structure tends to stay at rest, similar to a passenger standing on a bus that accelerates quickly. Once the building starts moving, it tends to continue in the same direction, but the ground moves back in the opposite direction (as if the bus driver first accelerated quickly, then suddenly braked). Thus, the building gets thrown back and forth by the motion of the ground, with some parts of the building lagging behind the foundation movement, and then moving in the opposite direction. The force F that an upper floor level or roof level of the building should successfully resist is related to its mass m and its acceleration a, according to Newton's law, $F = ma$. The heavier the building, the more the force is exerted. Therefore, a tall, heavy, reinforced-concrete building will be subject to more force than a lightweight, one-story, wood frame house, given the same acceleration.

Damage can be due either to structural members (beams, columns, and walls) being overloaded or differential movements between different parts of the structure. If the structure is sufficiently strong to resist these forces or differential movements, little damage will result. If the structure cannot resist these forces or differential movements, structural members will be damaged, and collapse may occur.

Building damage is related to the duration and the severity of the ground shaking. Larger earthquakes tend to shake longer and harder and therefore cause more damage to structures. Earthquakes with Richter magnitudes less than 5 rarely cause significant damage to buildings, since acceleration levels (except when the site is on the fault) and duration of shaking for these earthquakes are relatively small.

In addition to damage caused by ground shaking, damage can be caused by buildings pounding against one another, ground failure that causes the degradation of the building foundation, landslides, fires and tidal waves (tsunamis). Most of these indirect forms of damage are not addressed in this *Handbook*.

Generally, the farther from the source of an earthquake, the less severe is the motion. The rate at which motion decreases with distance is a function of the regional geology, inherent characteristics and details of the earthquake, and its source location. The underlying geology of the site can also have a significant effect on the amplitude of the ground motion there. Soft, loose soils tend to amplify the ground motion and in many cases a resonance effect can make it last longer. In such circumstances, building damage can be accentuated. In the San Francisco earthquake of 1906, damage was greater in the areas where buildings were constructed on loose, man-made fill and less at the tops of the rocky hills. Even more dramatic was the 1985 Mexico City earthquake. This earthquake occurred 250 miles from the city, but very soft soils beneath the city amplified the ground shaking enough to cause weak mid-rise buildings to collapse (see Figure G-3). Resonance of the building frequency with the amplified ground shaking frequency played a significant role. Sites with rock close to or at the surface will be less likely to amplify motion. The type of motion felt also changes with distance from the earthquake. Close to the source the motion tends to be violent rapid shaking, whereas farther away the motion is normally more of a swaying nature. Buildings will respond differently to the rapid shaking than to the swaying motion.

Figure G-3 Mid-rise building collapse, 1985 Mexico City earthquake.

Each building has its own vibrational characteristics that depend on building height and structural type. Similarly, each earthquake has its own vibrational characteristics that depend on the geology of the site, distance from the source, and the type and site of the earthquake source mechanism. Sometimes a natural resonant frequency of the building and a prominent frequency of the earthquake motion are similar and cause a sympathetic response, termed resonance. This causes an increase in the amplitude of the building's vibration and consequently increases the potential for damage.

Resonance was a major problem in the 1985 Mexico City earthquake, in which the total collapse of many mid-rise buildings (Figure G-7) caused many fatalities. Tall buildings at large distances from the earthquake source have a small, but finite, probability of being subjected to ground motions containing frequencies that can cause resonance. Similar effects were seen in the 2010 Chile earthquake where a number of tall concrete buildings in Santiago were damaged, even though the epicenter was hundreds of miles away.

Where taller, more flexible, buildings are susceptible to distant earthquakes (swaying motion) shorter and stiffer buildings are more susceptible to nearby earthquakes (rapid shaking).

The level of damage that results from a major earthquake depends on how well a building has been designed and constructed (see Section G.4). The exact type of damage cannot be predicted because no two buildings undergo identical motion. However, there are some general trends that have been observed in many earthquakes.

- Newer buildings generally sustain less damage than older buildings designed to earlier codes.
- Common problems in wood frame construction are the collapse of unreinforced chimneys (Figure G-4), houses sliding off their foundations (Figure G-5), collapse of wood frame cripple walls (Figure G-6), and collapse of post and pier foundations (Figure G-7). Although such damage may be costly to repair, it is not usually life threatening.

Figure G-4 Collapsed chimney with damaged roof, 1987 Whittier Narrows earthquake.

Figure G-5 House that slid off foundation, 1994 Northridge earthquake.

Figure G-6 Collapsed cripple stud walls dropped this house to the ground, 1992 Landers and Big Bear earthquakes.

Figure G-7 Photo of house settled to the ground due to collapse of its post and pier foundation.

The collapse of load bearing walls that support the floor and roof framing for the structure is a common form of damage in unreinforced masonry structures (Figure G-8). This damage commonly occurs due to lack of an adequate structural connection between the floor and roof framing and the heavy masonry walls.

Similar types of damage have occurred in many older tilt-up buildings (Figure G-9).

From a life-safety perspective, vulnerable buildings need to be clearly identified, and then strengthened or demolished.

Figure G-8 Collapse of unreinforced masonry bearing wall, 1933 Long Beach earthquake.

Figure G-9 Collapse of a tilt-up bearing wall, 1994 Northridge earthquake.

G.4 How Buildings Resist Earthquakes

As described above, buildings experience horizontal distortion when subjected to earthquake motion. When these distortions get large, the damage can be catastrophic. Therefore, most buildings are designed with lateral force-resisting systems (or seismic force-resisting systems), to resist the effects of earthquake forces. In many cases, seismic systems make a building stiffer against horizontal forces, and thus minimize the amount of relative lateral movement and consequently the damage.

The combined action of seismic systems along the width and length of a building can typically resist earthquake motion from any direction. Seismic systems differ from building to building because the type of system is controlled to some extent by the basic layout and structural elements of the building. Basically, seismic systems consist of axial-, shear- and bending-resistant elements.

In wood frame, stud-wall buildings, plywood siding is typically used to prevent excessive lateral deflection in the plane of the wall. Without the extra strength provided by the plywood or other structural sheathing, walls would distort excessively or "rack," resulting in broken windows and stuck doors. In older wood frame houses, this resistance to lateral loads may be provided by either wood or steel diagonal bracing.

The earthquake-resisting systems in modern steel buildings take many forms. Many types of diagonal bracing configurations have been used, such as single diagonal braces, X-bracing, V-bracing, or inverted V-bracing. In braced frames, horizontal loads are resisted through tension and compression forces in the braces with resulting changed forces in the beams and columns. Steel buildings are sometimes constructed with moment-resistant frames in one direction and braced frames in the other.

Moment-resisting steel frames are capable of resisting lateral loads. In this type of construction the connections between the beams and the columns are designed to resist the rotation of the column relative to the beam. Thus, the beam and the column work together and resist lateral movement and lateral displacement by bending.

In concrete structures, shear walls are sometimes used to provide lateral resistance in the plane of the wall, in addition to moment-resisting frames. Ideally, these shear walls are continuous reinforced-concrete walls extending from the foundation to the roof of the building. They can be exterior walls or interior walls. They are interconnected with the rest of the concrete frame, and thus resist the horizontal motion of one floor relative to another. Shear walls can also be constructed of reinforced masonry, using bricks or concrete blocks.

Glossary, Abbreviations, and Symbols

Glossary

Adjusted Baseline Score: The score used at the beginning of the Level 2 page of the Data Collection Form that takes the Final Score on the Level 1 page and subtracts the plan and vertical irregularity Score Modifiers.

Basic Score: Each FEMA Building Type has a Basic Score for each seismicity region that provides a relative comparison of expected seismic performance.

Benchmark Year: The year that substantially improved seismic codes were adopted and enforced. See Chapter 2.

Collapse: Collapse is defined in FEMA P-154 as when the gravity load-carrying system (such as beams, columns, floors, shear walls) loses the ability to carry its own weight and the weight of whatever else it supports. That failure leads to severe structural deformation of a potentially life-threatening nature, especially falling of all or portions of the structure.

Construction Documents: Drawings and specifications prepared by the design team that are used by the contractor to build the building. This includes architectural and structural drawings. These are sometimes referred to as working drawings.

Cut-off Score: A Final Score established by the RVS Authority to divide screened buildings into two categories: those that are expected to have acceptable seismic performance, and those that may be seismically hazardous and should be studied further. See Chapter 2 and Chapter 5.

Data Collection Form: The form used to document the rapid visual screening. The first page provides the Level 1 screening. The second page covers the optional Level 2 screening. Data Collection Forms are available for the Low, Moderate, Moderately High, High, and Very High seismicity regions.

Detailed Nonstructural Evaluation: Following a rapid visual screening in FEMA P-154, if potential nonstructural seismic deficiencies are identified, a Detailed Nonstructural Evaluation is recommended. FEMA E-74 (FEMA, 2012) can be used to conduct the evaluation.

Detailed Structural Evaluation: Following a rapid visual screening in FEMA P-154, if the Final Score is below the cut-off score; the FEMA Building Type is unknown; or there or other hazards such as pounding potential with adjacent buildings, falling hazards from adjacent buildings, geologic hazards, Soil Type F soil, or significant damage/deterioration, then a Detailed Structural Evaluation is recommended. ASCE/SEI 41-13 (ASCE, 2014) can be used to conduct the evaluation.

FEMA Building Type: A set of standardized building types developed in FEMA publications to cover the common building types found in the United States. This is also known in some publications as FEMA Model Building Type and Model Building Type. See Chapter 3 and Appendix E for more detail.

Final Score: The Final Score is derived by adding to or subtracting Score Modifiers from the Basic Score for the FEMA Building Type. Final Scores typically range from 0 to 7, with higher scores corresponding to better expected seismic performance and a lower potential for collapse. The Final Score can also be used to estimate of the probability of building collapse. The score is an estimate of the negative of the logarithm (base 10) of the probability of collapse should severe ground shaking occur with at the MCE_R level. See FEMA P-155.

Gable Wall: A generally triangularly-shaped wall at the exterior of a building under a roof.

Geographic Information System (GIS): A system designed to capture, store, manipulate, analyze, manage, and present all types of geographical data. GIS can provide valuable information about the buildings to be screened.

High Seismicity Region: A region of high seismicity as defined by Table 2-2.

Level 1 Form: The first page of the Data Collection Form. It must be completed during the rapid visual screening.

Level 1 Screener: Individual that conducts Level 1 screenings of buildings who can be an appropriately trained civil or structural engineer, architect, design professional, building official, construction contractor, facility manager, firefighter, architectural or engineering student, or another individual with a general familiarity or background in building design or construction. See Chapter 2.

Level 2 Form: The second page of the Data Collection Form. Completion is optional.

Level 2 Screener: Individual that conducts both Level 1 and Level 2 screenings of buildings who can be an appropriately trained civil or structural engineering professional, architect, or graduate student with background in seismic evaluation or design of buildings. See Chapter 2.

Low Seismicity Region: A region of low seismicity as defined per Table 2-2.

MCE_R: Risk-targeted maximum considered earthquake ground motions, as specified in ASCE/SEI 7-10 (ASCE, 2010) and ASCE/SEI 41-13. These ground motions are the basis for the *Third Edition* scores.

Moderate Seismicity Region: A region of moderate seismicity as defined in Table 2-2.

Moderately High Seismicity Region: A region of moderately high seismicity as defined in Table 2-2. The Moderately High seismicity region has stronger seismicity than the Moderate seismicity region and less seismicity than the High seismicity region.

Post-Benchmark Score Modifier: A Score Modifier applied to buildings build after the benchmark year.

Pre-Code Score Modifier: A Score Modifier that is used to identify a building built before the pre-code year.

Pre-Code Year: The year that seismic codes were initially adopted and enforced. See Chapter 2.

Pre-Field Activities: The portion work in a rapid visual screening program that occurs before the actual field screening. It includes pre-field planning, selection and modification of Data Collection Forms, selection and training of screening personnel, and acquisition and review of pre-field data. See Chapter 2.

Pre-Field Planning: A subset of pre-field activities that includes selection and development of a record-keeping system, development of an electronic scoring tool if desired, compilation and development of seismic hazard maps.

Program Manager: The entity that will manage the RVS program on behalf of the RVS Authority, such as a building department, qualified technical branch of government, or outside consultant. See Chapter 2.

ROVER (Rapid Observation of Vulnerability and Estimation of Risk): Free mobile software for pre- and post-earthquake building safety screening, developed by FEMA. See Chapter 1.

Rapid Visual Screening (RVS) Authority: The entity that has decided to conduct an RVS program and will use the results. This could include a state legislature, city council, school district, or private building owner. See Chapter 2.

Sanborn Map: Maps, published for the insurance industry, that provide information about building attributes including year built, size and structural type. See Chapter 2.

Score Modifier: Values that are added (or subtracted) from the Basic Score to arrive at a Final Score. The Score Modifiers are related to observed seismic performance attributes.

Seismic Force-Resisting System: That part of the structural system that has been considered in the design to provide the required resistance to the seismic forces.

Soil Type: Soil is classified in FEMA P-154 in accordance with ASCE/SEI 7-10. There are six types of soil, ranging from Type A to Type F. Site Class is an analogous term. See Chapter 2.

Supervising Engineer: The individual that will provide the technical expertise necessary to run the RVS program. See Chapter 2.

Very High Seismicity Region: A region of seismicity as defined in Table 2-2.

Abbreviations

RVS	Rapid Visual Screening
URM	Unreinforced Masonry

Symbols

M	The sum of all Level 2 modifiers except P_{L2} and V_{L2}. See Chapter 4.
P_{L1}	Level 1 Plan Irregularity Modifier. See Chapter 3.
P_{L2}	Level 2 Plan Irregularity Modifier. See Chapter 4.
S'	Adjusted baseline Score (used in the calculation of the Final Level 2 Score). See Chapter 4.
S_1	The spectral acceleration response at a period of 1.0 seconds. See Chapter 2.
S_{L1}	Final Level 1 Score. See Chapter 3.
S_{L2}	Final Level 2 Score. See Chapter 4.
S_{MIN}	Minimum Score. See Chapter 3.
S_S	The spectral acceleration response at a period of 0.2 seconds. See Chapter 2.

V_{L1}	Level 1 Vertical Irregularity Modifier. See Chapter 3.
V_{L2}	Level 2 Vertical Irregularity Modifier. See Chapter 4.
V_S^{30}	Shear wave velocity in the upper 30 meters of soil. It is used to determine the soil type. See Chapters 2 and 6.

Illustration Credits

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Kit Wong	3-40, 3-41, D-6, D-8, D-9, D-10, D-13, D-14, D-15, D-16, D-17, E-42, E-44; Figures in Table D-1 a and b, Table D-3 f and g
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U.S. DEPARTMENT OF HOMELAND SECURITY

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FEMA P-154
Catalog No. 08211-2