# Simplified Seismic Assessment of Detached, Single-Family, Wood-Frame Dwellings

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# Simplified Seismic Assessment of Detached, Single-Family, Wood-Frame Dwellings

Prepared by

APPLIED TECHNOLOGY COUNCIL
201 Redwood Shores Parkway, Suite 240
Redwood City, California 94065
www.ATCouncil.org

Prepared for

FEDERAL EMERGENCY MANAGEMENT AGENCY
Michael Mahoney, Project Officer
John Gillengerten, Subject Matter Expert
Washington, D.C.

TASK ORDER CONTRACT MANAGEMENT
Christopher Rojahn (Project Executive Director)
Thomas R. McLane (Project Manager)
Jon A. Heintz (Project Quality Control Monitor)
William T. Holmes (Project Technical Monitor)

PROJECT REVIEW PANEL
Barry Welliver (Chair)
Susan Dowty
Gary J. Ehrlich
Mark Legg
Philip Line
James E. Russell

PROJECT MANAGEMENT COMMITTEE
Ronald T. Eguchi (Project Technical Director)
Kelly E. Cobeen
Douglas C. Hohbach
Nicolas Luco
Charles Real
Jonathan P. Stewart

STOCHASTIC ANALYSIS TEAM
Surya Gunturi
Kate Stillwell
Kamban Parasuraman

May 2012

## Notice

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Cover Photos: Source: FEMA G225-CD, *Seismic Retrofit Training for Building Contractors & Inspectors*, 2006.

# Foreword

The Federal Emergency Management Agency (FEMA) has the goal of reducing the ever-increasing cost that disasters inflict on our country. Preventing losses before they happen by designing and building to withstand anticipated forces from these hazards is one of the key components of mitigation, and is the only truly effective way of reducing the cost of disasters. As part of its responsibilities under the National Earthquake Hazards Reduction Program (NEHRP), and in accordance with the National Earthquake Hazards Reduction Act of 1977 (PL 94-125) as amended, FEMA is charged with supporting activities necessary to improve technical quality in the field of earthquake engineering. The primary method of addressing this charge has been supporting the investigation of seismic technical issues as they are identified by FEMA, the development and publication of technical design and construction guidance products, the dissemination of these products, and support of training and related outreach efforts.

In recent earthquake events, typical wood-frame residential structures were observed to have suffered more damage than had traditionally been thought, damage due primarily to their flexibility. This risk is magnified by the sheer numbers of these buildings that exist in moderate and high seismic regions in our country.

This residential seismic rating system was originally developed by the Applied Technology Council (ATC) for the City of Los Angeles using FEMA disaster funds following the 1994 Northridge earthquake. At a recent workshop on seismic rating systems, one of the recommendations was to update and expand that original ATC-50 assessment system for national use. FEMA supported the development of this expanded residential rating system (FEMA P-50) and its accompanying retrofit guidelines (FEMA P-50-1) to be applicable in all high seismic areas of the country. FEMA supported this work not to promote the use of a residential rating system, but to provide a tool that communities or other entities could then use to encourage the seismic retrofitting of residential structures, thereby reducing future earthquake losses.

FEMA wishes to express its gratitude to the Project Management Committee of Ronald T. Eguchi (Project Technical Director), Kelly E. Cobeen, Douglas C. Hohbach, Nicolas Luco, Charles Real, and Jonathan P. Stewart for their efforts in preparing this document. We also wish to thank the Project

Review Panel of Barry Welliver (Chair), Susan Dowty, Gary J. Ehrlich, Mark Legg, Philip Line, and James E. Russell, who provided expert review and guidance throughout the developmental effort. Thanks are also due to Surya Gunturi, Kate Stillwell, and Kamban Parasuraman, who conducted an independent analysis to develop damage ranges for each Seismic Performance Grade.

Federal Emergency Management Agency

# Preface

In September 2011 the Applied Technology Council (ATC), with funding from the Federal Emergency Management Agency (FEMA) under Task Order Contract HSFEHQ-08-D-0726, commenced the updating of the ATC-50 report, *Simplified Seismic Assessment of Detached, Single-Family, Wood-Frame Dwellings* (ATC, 2002a), which had been written for use in Los Angeles, California. The project's purpose was to make the ATC-50 document nationally applicable and, at the same time, take advantage of web-based information and other technological developments that have occurred since 2002. The update effort was one of several projects in a task order series to develop written guidance for FEMA on the creation, update, and maintenance of seismic evaluation and rehabilitation documents for existing buildings.

The ATC-50 report was originally developed in 2002 (first printing) and expanded in 2007 (second printing) to include additional supporting documentation. The original project was prompted by high economic losses resulting from damage to single-family, wood-frame dwellings during the 1994 Northridge earthquake, and focused on the development and testing of standardized procedures for voluntary seismic evaluation and retrofit. In addition to the ATC-50 report, two additional documents were also prepared in the original project: (1) the ATC-50-1 report, *Seismic Rehabilitation Guidelines for Detached, Single-Family, Wood-Frame Dwellings* (ATC, 2002b); and (2) the ATC-50-2 report, *Safer at Home in Earthquakes: A Proposed Earthquake Safety Program* (ATC, 2002c).

The current work involved a review and update of:

1. Information on the Simplified Seismic Assessment Form pertaining to the dwelling's structural and nonstructural systems and the site conditions, including the organization and completeness of all assessment items on the form, and the numerical scores for all penalties related to such assessment items.
2. Information on the Simplified Seismic Assessment Form pertaining to the dwelling's seismic hazard exposure, including the organization and completeness of all conditions on the form, and the numerical scores for all penalties related to such conditions. Furthermore, significant effort was made to replace the original paper-based, zip code hazard data with location-specific data available through online websites.

3. The procedures and data for calculating a Seismic Performance Grade in the Simplified Seismic Assessment Form, including the matrix of Performance Grades as a function of Structural Score and Seismic Hazard Score, and the ranges of expected damage for each grade.

In a separate related FEMA-funded project, ATC also updated the ATC-50-1 report for consistency with this FEMA P-50 document and the updated Simplified Seismic Assessment Form. That document is now available as FEMA P-50-1, *Seismic Retrofit Guidelines for Detached, Single-Family, Wood-Frame Dwellings* (FEMA, 2012).

ATC is indebted to the ATC Project Management Committee, which consisted of Ronald T. Eguchi (Project Technical Director), Kelly E. Cobeen, Douglas C. Hohbach, Nicolas Luco, Charles Real, and Jonathan P. Stewart, for their efforts in researching and preparing this report, and to the Project Review Panel, which consisted of Barry Welliver (Chair), Susan Dowty, Gary J. Ehrlich, Mark Legg, Philip Line, and James E. Russell, who provided expert review and guidance throughout the developmental effort. Surya Gunturi, Kate Stillwell, and Kamban Parasuraman served on the Stochastic Analysis Team, who conducted an independent analysis to develop damage ranges for each Seismic Performance Grade. Thomas R. McLane served as Project Manager, and Peter Mork provided report production services. The affiliations of these individuals are provided in the list of Project Participants.

Special recognition is given to the California Earthquake Authority (CEA), who provided funding for (1) the independent development of damage ranges for each Seismic Performance Grade, and (2) the incorporation of that information in this document. The input and guidance of CEA's Janiele Maffei and Shawna Ackerman are also highly appreciated.

ATC also gratefully acknowledges the input, support, and guidance provided by Michael Mahoney (FEMA Project Officer), Jennifer Lynette (FEMA Region IX), and John Gillengerten (FEMA Subject Matter Expert).

Christopher Rojahn
ATC Executive Director

# Table of Contents

**Foreword** ........ iii

**Preface** ........ v

**List of Figures** ........ xi

**List of Tables** ........ xv

**1. Introduction** ........ 1
- 1.1 Background ........ 1
- 1.2 Purpose and Scope of the FEMA P-50 Report ........ 1
- 1.3 Intended Users of the Report ........ 2
- 1.4 Relationship to Other Documents ........ 2
- 1.5 Contents and Organization of the Report ........ 3

**2. Simplified Seismic Assessment** ........ 5
- 2.1 Overview of the Simplified Seismic Assessment Form ........ 5
  - 2.1.1 Applicability ........ 5
  - 2.1.2 Major Sections of the Form ........ 9
  - 2.1.3 Sections A through E: Assessment of the Dwelling Structure and Site ........ 10
  - 2.1.4 Section F: Identification of Seismic Hazards ........ 11
  - 2.1.5 Section G: Determination of the Seismic Performance Grade ........ 11
  - 2.1.6 Section H: Improving the Seismic Performance Grade ........ 11
  - 2.1.7 Disclaimer ........ 12
- 2.2 Scoring Approach for the Structural System ........ 12
  - 2.2.1 Penalty Points and Structural Score ........ 12
  - 2.2.2 Weighting of Penalty Points ........ 13
- 2.3 Output of Evaluation ........ 13
- 2.4 Seismic Performance Grades ........ 13
  - 2.4.1 Grade A (including A, A-) ........ 14
  - 2.4.2 Grade B (including B+, B, B-) ........ 15
  - 2.4.3 Grade C (including C+, C, C-) ........ 15
  - 2.4.4 Grade D (including D+, D, D-) ........ 15
  - 2.4.5 Basis for Seismic Performance Grades ........ 16
- 2.5 Limitations of Simplified Assessment ........ 17

**3. Assessment of Structural Elements** ........ 21
- 3.1 Assessment of Foundation System (Section A) ........ 21
  - 3.1.1 Exterior Footing (Assessment Item A-1) ........ 22
  - 3.1.2 Lowest Floor Construction (Assessment Item A-2) ........ 22
  - 3.1.3 Framing Support at Crawlspace Interior (Assessment Item A-3) ........ 23

3.1.4 Top of Footing or Foundation Wall (Assessment Item A-4) .......... 24
3.1.5 Dwelling Anchorage to Foundation (Assessment Item A-5) .......... 25
3.2 Assessment of Superstructure Framing and Configuration (Section B) .......... 28
3.2.1 Dwelling Configuration Irregularities (Assessment Item B-1) .......... 28
3.2.2 Summed Exterior Wall Length (Assessment Item B-2) .......... 29
3.2.3 Roofing Weight (Assessment Item B-3) .......... 30
3.2.4 Narrow Walls at Garage Door (Assessment Item B-4) .......... 31
3.2.5 Exterior Wall Finish (Assessment Item B-5) .......... 32
3.2.6 Interior Remodeling (Assessment Item B-6) .......... 34
3.2.7 Number of Stories (Assessment Item B-7) .......... 34
3.2.8 Perimeter Bracing Below Lowest Framed Floor (Assessment Item B-8) .......... 34
3.3 General Condition Assessment (Section C) .......... 36
3.3.1 Overall Condition (Assessment Item C-1) .......... 37
3.3.2 Framing Alterations (Assessment Item C-2) .......... 37
3.3.3 Exterior Stucco Condition (Assessment Item C-3) .......... 38
3.3.4 Foundation Condition (Assessment Item C-4) .......... 38
3.3.5 Quality of Construction (Assessment Item C-5) .......... 39

**4. Assessment of Nonstructural Elements, Dwelling Age and Size .......... 41**
4.1 Chimneys (Assessment Item D-1) .......... 41
4.2 Water Heater (Assessment Item D-2) .......... 42
4.3 Gas Shutoff (Assessment Item D-3) .......... 43
4.4 Stairs, Decks and Porch Roofs (Assessment Item D-4) .......... 43
4.5 Age of Dwelling (Assessment Item D-5) .......... 44
4.6 Floor Area (Assessment Item D-6) .......... 45
4.7 FEMA Resources .......... 45

**5. Assessment of Local Site Conditions .......... 47**
5.1 Site Slope (Assessment Item E-1) .......... 47
5.2 Site Cut and Fill (Assessment Item E-2) .......... 48
5.3 Foundation Condition and Differential Foundation Settlement (Assessment Items E-3 and E-4) .......... 48
5.4 Slope Stability (Assessment Item E-5) .......... 49
5.5 Drainage (Assessment Item E-6) .......... 50

**6. Regional Seismic Hazards .......... 51**
6.1 Regionalization of Hazards .......... 51
6.2 Ground Shaking Hazards .......... 52
6.3 Liquefaction Hazards .......... 52
6.4 Seismic Landslide Hazards .......... 54
6.5 Surface Fault Rupture Hazards .......... 55
6.6 Total Regional Seismic Hazard Points .......... 56
6.7 Hazards Not Considered .......... 57

**7. Seismic Performance Grade ............................................................59**
7.1 Determination of Structural Score ............................................59
7.2 Determination of Seismic Hazard Score ...................................59
7.3 Determination of Seismic Performance Grade ..........................59

**8. Improving the Seismic Performance Grade ...................................61**
8.1 Effect of Seismic Retrofit on the Structural Score ....................61
8.2 Effect of Retrofit on the Seismic Performance Grade ...............63
8.3 Resources for Seismic Retrofit ..................................................63
8.4 Reassessment of the Seismic Performance Grade .....................65

**9. Implementing a Simplified Seismic Assessment Program.............67**
9.1 Role of Simplified Assessment in Seismic Loss Reduction.......67
9.2 Program Implementation ...........................................................68
9.3 Qualifications of Inspectors.......................................................68
9.4 Field Inspections........................................................................69
9.5 Future Development of the Methodology .................................69

**Appendix A: Simplified Seismic Assessment Form .................................71**

**Appendix B: Examples Using the Simplified Seismic Assessment Form ......................................................................................79**
B.1 Hillside Home.............................................................................79
B.2 Seismically Retrofitted Dwelling ...............................................86
B.3 Home with Unbraced Cripple Wall ...........................................93
B.4 Slab-on-Grade Dwelling..........................................................100
B.5 Split-level Dwelling ................................................................107

**Appendix C: Seismic Performance of Wood-Frame Dwellings............115**
C.1. Introduction ............................................................................115
C.2 Characteristics and Seismic Vulnerabilities of Wood-Frame Dwellings ................................................................................115
  C.2.1 Cripple-Wall Dwellings .............................................116
  C.2.2 Slab-on-Grade Dwellings...........................................118
  C.2.3 Basement Dwellings and Crawlspace Dwellings with Foundation Stem Walls ......................................121
  C.2.4 Perimeter Post-and-Pier Foundation Dwellings ..........123
  C.2.5 Split-Level Dwellings, Multi-Level Hillside Dwellings ..................................................................124
  C.2.6 Exterior Wall Strength................................................126
C.3 Studies of the Performance of Wood-Frame Dwellings in Recent California Earthquakes ................................................127
  C.3.1 1971 San Fernando Earthquake..................................127
  C.3.2 1989 Loma Prieta Earthquake ....................................129
  C.3.3 1994 Northridge Earthquake ......................................129
C.4 Comparative Analysis and Interpretation of Data from the 1971 San Fernando and 1994 Northridge Earthquakes ............130
  C.4.1 Effects of Number of Stories......................................130
  C.4.2 Effects of Age of Construction...................................133
  C.4.3 Loss Ratio as a Function of MMI, Year Built and Building Square Footage ............................................133

C.4.4 Summary of Findings: Factors that Significantly Affect Damageability .......... 135
C.4.5 Recommendations for Improved Collection of Dwelling Earthquake Performance Data .......... 136

**Appendix D: Development of Damage Ranges for Seismic Performance Grades .......... 137**
D.1 Prototype Structures .......... 138
D.2 Site Selection .......... 138
D.3 Model Methodology .......... 138
D.4 Analysis and Results .......... 143
D.5 Sensitivity Analyses .......... 146
D.5.1 Sensitivity of Damage Ratios to Soil Conditions .......... 146
D.5.2 Sensitivity of Damage Ratios to Structure Definition .......... 147
D.1 Structure Definitions in Analyzed Portfolio .......... 148

**Appendix E: Basis of Structural Score Methodology .......... 161**
E.1 Background .......... 161
E.2 ATC-50 Development .......... 161
E.2.1 Categorization .......... 161
E.2.2 Application of Past Earthquake Data .......... 162
E.2.3 Initial Weighting Assessments .......... 162
E.2.4 Final Weighting Assignments .......... 163
E.3 FEMA P-50 Development .......... 163
E.3.1 General .......... 163
E.3.2 Vulnerabilities Causing Extensive Damage .......... 164
E.3.3 Other Revisions .......... 164

**References .......... 165**

**Project Participants .......... 169**

# List of Figures

Figure 2-1 Map of Western United States showing distribution of earthquake ground shaking by Seismic Design Category, as specified in the *International Residential Code*. ...............6

Figure 2-2 Map of Eastern United States showing distribution of earthquake ground shaking by Seismic Design Category, as specified in the *International Residential Code* ...............7

Figure 2-3 Map of Alaska showing distribution of earthquake ground shaking by Seismic Design Category, as specified in the *International Residential Code* ...................................8

Figure 2-4 Map of Hawaii showing distribution of earthquake ground shaking by Seismic Design Category, as specified in the *International Residential Code* ...................................9

Figure 3-1 Assessment item A-1 ..........................................................22

Figure 3-2 Assessment item A-2 ..........................................................22

Figure 3-3 Assessment item A-3 ..........................................................23

Figure 3-4 Assessment item A-4 ..........................................................25

Figure 3-5 Assessment item A-5 ..........................................................26

Figure 3-6 Assessment item B-1...........................................................28

Figure 3-7 Assessment item B-2...........................................................30

Figure 3-8 Assessment item B-3...........................................................30

Figure 3-9 Assessment item B-4...........................................................31

Figure 3-10 Assessment item B-5...........................................................32

Figure 3-11 Assessment item B-6...........................................................34

Figure 3-12 Assessment item B-7...........................................................34

Figure 3-13 Assessment item B-8...........................................................35

Figure 3-14 Assessment item C-1...........................................................37

Figure 3-15 Assessment item C-2...........................................................37

Figure 3-16 Assessment item C-3...........................................................38

Figure 3-17 Assessment item C-4 .......... 38

Figure 3-18 Assessment item C-5 .......... 39

Figure 4-1 Assessment item D-1 .......... 41

Figure 4-2 Assessment item D-2. .......... 42

Figure 4-3 Assessment item D-3 .......... 43

Figure 4-4 Assessment item D-4 .......... 43

Figure 4-5 Assessment item D-5 .......... 44

Figure 4-6 Assessment item D-6 .......... 45

Figure 5-1 Assessment item E-1 .......... 48

Figure 5-2 Assessment item E-2 .......... 48

Figure 5-3 Assessment item E-3 .......... 49

Figure 5-4 Assessment item E-4 .......... 49

Figure 5-5 Assessment item E-5 .......... 49

Figure 5-6 Assessment item E-6 .......... 50

Figure 6-1 Section F of the Simplified Seismic Assessment Form .......... 52

Figure 7-1 Section G of the Simplified Seismic Assessment Form. .......... 60

Figure 8-1 Section H of the Simplified Seismic Assessment Form .......... 62

Figure C-1 Drawing of wood stud frame construction .......... 116

Figure C-2 Typical one-story cripple-wall crawl-space house .......... 117

Figure C-3 Typical older one and one-half-story cripple-wall crawl-space house .......... 117

Figure C-4 Section through typical cripple-wall crawl-space house .......... 118

Figure C-5 Typical earthquake damage to a cripple-wall house .......... 119

Figure C-6 Typical one-story slab-on-grade house .......... 119

Figure C-7 Section through typical one-story slab-on-grade house .......... 120

Figure C-8 Section through a typical one-story basement house .......... 121

Figure C-9 Section through a variation of the basement dwelling where the perimeter foundation walls enclose a crawl space .......... 122

Figure C-10 Damage to a basement-type dwelling where the sill plate slid on the top of the foundation wall........................123

Figure C-11 Post-and-pier foundation house on sloping site.................123

Figure C-12 Post-and-pier house on flat site..........................................124

Figure C-13 Earthquake-damaged perimeter post-and-pier foundation. ........................................................................125

Figure C-14 Split-level house, where the section of flooring above the garage is at a lower level than the main second-floor level...........................................................................125

Figure C-15 Cracking damage to stucco first-floor walls ......................126

Figure C-16 Damage and racking displacement in the first floor walls.....................................................................................126

Figure D-1 Generalized portfolio loss estimation analysis methodology ......................................................................142

Figure D-2 Average 500-year return period damage ratio across different hazard zones........................................................145

Figure D-3 Average 500-year return period damage ratio across different scoring category ..................................................145

Figure D.1-1 Site locations for hazard zone C & D0 ..............................158

Figure D.1-2 Site locations for hazard zone D1 ......................................158

Figure D.1-3 Site locations for hazard zone D2 ......................................159

Figure D.1-4 Site locations for hazard zone E0.......................................159

Figure D.1-5 Site locations for hazard zone E1.......................................160

# List of Tables

Table 6-1 Table 1 of the Simplified Seismic Assessment Form ..........53

Table 6-2 Table 2 of the Simplified Seismic Assessment Form ..........54

Table 6-3 Table 3 of the Simplified Seismic Assessment Form ..........55

Table 6-4 Table 4 of the Simplified Seismic Assessment Form ..........56

Table 7-1 Table 5 of the Simplified Seismic Assessment Form ..........60

Table C-1 Contribution of Specific Building Characteristics to Damage ..........128

Table C-2 Loss Ratios for Dwellings Damaged during the 1971 San Fernando Earthquake ..........129

Table C-3 Number of Buildings in Damage Ranges: Single-Family Wood Frame Dwellings by Intensity, Vintage, and Square Foot Range ..........131

Table C-4 Mean Loss Ratio for Dwellings in 1994 Northridge Earthquake as Function of MMI and Year Built ..........133

Table C-5 Mean Loss Ratio for Dwellings in 1994 Northridge Earthquake as Function of MMI and Year Built (Dwellings under 1600 sq ft) ..........134

Table C-6 Mean Loss Ratio of Dwellings in 1994 Northridge Earthquake as Function of MMI and Year Built (Dwellings between 1600 and 2500 sq ft) ..........134

Table C-7 Mean Loss Ratio of Dwellings in 1994 Northridge Earthquake as Function of MMI and Year Built (Dwellings over 2500 sq ft) ..........135

Table D-1 Summary of Prototype Structures ..........138

Table D-2 Site Locations and Details ..........139

Table D-3 Number of Site-Structure Combinations Within Each Structural Score and Regional Hazard Score ..........143

Table D-4 500-year Return Period Damage Ratio Variation Within Each Structural Score and Regional Hazard Score ..........143

Table D.1-1 Variations of Structural Configurations Proposed as Prototype Structures for FEMA P-50 Benchmarking ....... 149

Table D.1-2 Assignment of FEMA P-50 Penalty Assessment Items to Prototype Structures ..................................................... 150

Table D.1-3 Final Portfolio of Structural Configurations Used in the FEMA P-50 Analysis .................................................. 152

Table D.1-4 Definitions of each Value for Secondary Structural Modifiers Used in the EQECAT Model............................ 156

Table E-1 Initial Weights Assigned to Assessment Categories ......... 162

# Chapter 1

# Introduction

## 1.1 Background

This FEMA P-50 document is an update of the ATC-50 report, *Simplified Seismic Assessment Procedures for Detached, Single-Family, Wood-Frame Dwellings* (ATC, 2002a, first printing), which was originally developed for the City of Los Angeles. Expanded in 2007 to include additional supporting documentation (ATC, 2007a, second printing), the ATC-50 report provides inspection procedures and a four-page Simplified Seismic Assessment Form to evaluate detached, single-family, wood-frame dwellings, and to assign to each a Seismic Performance Grade. The procedure only applies to dwellings in Los Angeles and considers the potential for damage or collapse in a manner that is useful to owners, purchasers, insurers, lenders, contractors, design professionals, and regulatory officials.

Since the publication of the first and second printings of the ATC-50 report in 2002 and 2007, respectively, a wealth of new information has become available, including geo-located databases that provide easily accessible, and in some cases, site-specific hazard information. Additional studies and perspectives have also been developed that contribute to the improvement of the Structural Scoring system developed for the original ATC-50 document.

## 1.2 Purpose and Scope of the FEMA P-50 Report

As in the original ATC-50 document, the project specifications dictated that the revised simplified seismic assessment methodology:

- use existing technologies and information,
- consider attributes of typical wood-frame dwellings,
- focus on features that are known to affect the seismic performance, and
- enable an inspector to assign a grade that represents the approximate level of damage expected when a specified severity of ground shaking occurs.

Based on these criteria, the update development team enhanced the original seismic evaluation and grading system that assigns weighted numeric penalties for observed seismic deficiencies. As before, the resulting Structural

Score is combined with information on regional seismic hazards to assign a Seismic Performance Grade that reflects the performance that is generally expected in future damaging seismic events. A revised Simplified Seismic Assessment Form, an expanded version of the original grading form, has been developed for rapid use in the field. The form is self-contained, concise, and updatable.

The revised Simplified Seismic Assessment Form satisfies the following criteria:

1. The form is easy to use and apply, presents simple assessment items and offers simple, multiple-choice responses.
2. The focus of the form is the identification of seismic deficiencies and the establishment of a Seismic Performance Grade that reflects expected performance in future damaging earthquakes.
3. The methodology enables an inspector to assess the dwelling and complete the form on site usually in less than one hour.
4. The form provides a list of conditions that, if seismically retrofitted, would enable the owner to improve the Seismic Performance Grade.

Because of the limited nature of the FEMA P-50 simplified seismic assessment methodology, the performance implied by a specific grade could vary widely, depending upon the characteristics of the dwelling, the soil conditions of the site, the proximity of the site to the earthquake source zone, and the presence of possible secondary hazards, such as fault rupture, liquefaction and landslide.

## 1.3 Intended Users of the Report

The intended users of the report include building owners, building officials, home inspectors, design professionals, home builders, emergency planners, insurers, lenders, and any other persons involved in implementing or using results from the FEMA P-50 simplified seismic assessment methodology.

## 1.4 Relationship to Other Documents

The overall goal of the FEMA P-50 document is to provide guidelines for reducing damage to detached, single-family, wood-frame dwellings in future earthquakes. This report and the accompanying Simplified Seismic Assessment Form address the first part of the process, that is, identifying those structures that are in need of seismic resistance improvement. To complete the process, it is important that identified seismic deficiencies be linked to specific seismic retrofit procedures, which are the subject of Chapter 8 of this document. One available resource document is the companion FEMA P-50-1 report, *Seismic Retrofit Guidelines for Detached, Single-Family, Wood-Frame Dwellings* (FEMA, 2012). This linkage is included directly in the FEMA P-50-1 seismic retrofit procedures. The inspector is encouraged to provide the homeowner with a copy of the FEMA P-50-1 report so that the homeowner can review and assess seismic retrofit options.

## 1.5 Contents and Organization of the Report

This report has been organized to include concise, practical information in the body of the report, with supporting technical information and examples provided in the appendices.

Chapter 1 provides an overview of the purpose and scope of the project, identifies the intended audience, and discusses how this report relates to the seismic retrofit guidelines that were prepared as part of the original ATC-50 study, i.e., the ATC-50-1 report, *Seismic Rehabilitation Guidelines for Detached, Single-Family, Wood-Frame Dwellings* (ATC, 2002b, first printing; ATC, 2007b, second printing), which has been updated and is now available as the FEMA P-50-1 report, *Seismic Retrofit Guidelines for Detached, Single-Family, Wood-Frame Dwellings* (FEMA, 2012).

Chapter 2 introduces the Simplified Seismic Assessment Form, discusses the major sections of the form, the scoring approach, and the output of the evaluation. This chapter also discusses the limitations of the simplified assessment approach.

Chapters 3 through 7 provide guidance to the inspector on how to complete each section of the Simplified Seismic Assessment Form. Chapter 3 discusses the assessment of structural elements and construction quality. The assessment of nonstructural elements, dwelling age, and dwelling size are addressed in Chapter 4, and in Chapter 5, the assessment of local site effects is discussed. Chapter 6 describes how the regional seismic hazard score is developed, explaining the use of online websites to denote the level of expected ground shaking as well as the more localized secondary hazards of surface fault rupture, liquefaction, and landslide. In Chapter 7, instructions are provided on how to calculate both the Structural Score and the overall Seismic Performance Grade, which is based on the Structural Score and the Seismic Hazard Score.

Chapter 8 addresses ways for the homeowner to improve the Seismic Performance Grade. The primary option is seismic retrofit following the FEMA P-50-1 *Guidelines*, but the homeowner may also elect to have the dwelling evaluated by a licensed design professional.

Finally, Chapter 9 discusses issues relating to the implementation of the methodology, including inspector qualifications and equipment needed.

Following Chapter 9 are five appendices. Appendix A contains a full-sized, reproducible version of the Simplified Seismic Assessment Form. Five examples of the application of the Simplified Seismic Assessment Form are provided in Appendix B. Appendix C provides information about the performance of wood-frame dwellings during past earthquakes, and Appendix D contains newly developed information on estimated damage ranges for each Seismic Performance Grade. Finally, Appendix E provides the basis for the building characteristics and penalties used to determine the Structural Score.

## Chapter 2

# Simplified Seismic Assessment

The purpose of Chapter 2 is to introduce and provide a general description of the applicability and contents of the FEMA P-50 Simplified Seismic Assessment Form. Descriptions and discussions are also provided for the assessment scoring system, the assigned Seismic Performance Grades, use of assessment results, and limitations of the assessment method.

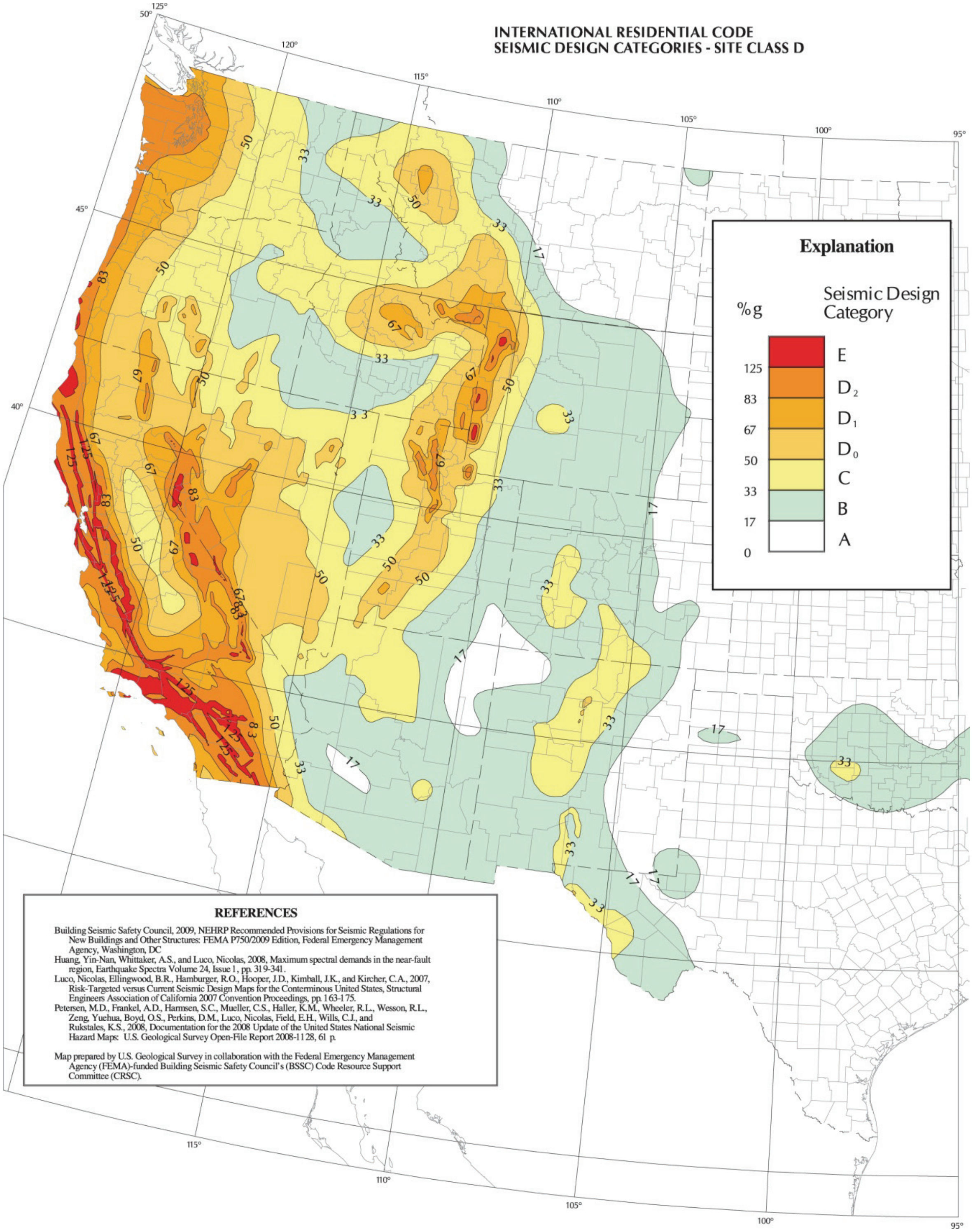
## 2.1 Overview of the Simplified Seismic Assessment Form

The FEMA P-50 Simplified Seismic Assessment Form is a self-contained six-page document containing the information necessary for an inspector to assess and document the anticipated seismic performance of detached single-family wood-frame dwellings. Full-sized, reproducible copies of the form are provided in Appendix A. It is recommended that the form be used in combination with the commentary provided in Chapters 3 through 6.

### *2.1.1 Applicability*

The FEMA P-50 Simplified Seismic Assessment Form has been developed specifically for detached, single-family, light-frame dwellings constructed of wood framing systems. The potential seismic vulnerabilities (weaknesses) and related penalty points included in the assessment form and the methodology for evaluating seismic hazards are applicable for dwellings located in regions where the seismic hazard (expressed in terms of design spectral acceleration response at a 0.2-second building period, $S_{DS}$) is 0.33 times gravity or greater. This corresponds to locations where Seismic Design Categories C through E, as specified in the *International Residential Code* (ICC, 2009b), are applicable (see maps, Figures 2-1 through 2-4. These are regions of moderate-to-high seismic hazard; in regions of lower seismic hazard, the likelihood of significant damage due to earthquakes is thought to be low. Further detail on seismic hazards is provided in Chapter 6.

While the form has been developed for detached, single-family dwellings, the form can be used for duplexes and two-family units with overall configurations and structural systems similar to detached, single-family dwellings.



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Petersen, M.D., Frankel, A.D., Harmsen, S.C., Mueller, C.S., Haller, K.M., Wheeler, R.L., Wesson, R.L., Zeng, Yuehua, Boyd, O.S., Perkins, D.M., Luco, Nicolas, Field, E.H., Wills, C.J., and Rukstales, K.S., 2008, Documentation for the 2008 Update of the United States National Seismic Hazard Maps: U.S. Geological Survey Open-File Report 2008-1128, 61 p.

Map prepared by U.S. Geological Survey in collaboration with the Federal Emergency Management Agency (FEMA)-funded Building Seismic Safety Council's (BSSC) Code Resource Support Committee (CRSC).

Figure 2-1 Map of Western United States showing distribution of earthquake ground shaking by Seismic Design Category, as specified in the *International Residential Code*. Ground shaking contours are specified in terms of horizontal acceleration response (g) of short-period (0.2-second) structures, for Soil-Site Class D. The Simplified Seismic Assessment Form only applies in regions where Seismic Design Categories C, $D_0$, $D_1$, $D_2$, and E are applicable. (Source: U. S. Geological Survey.)

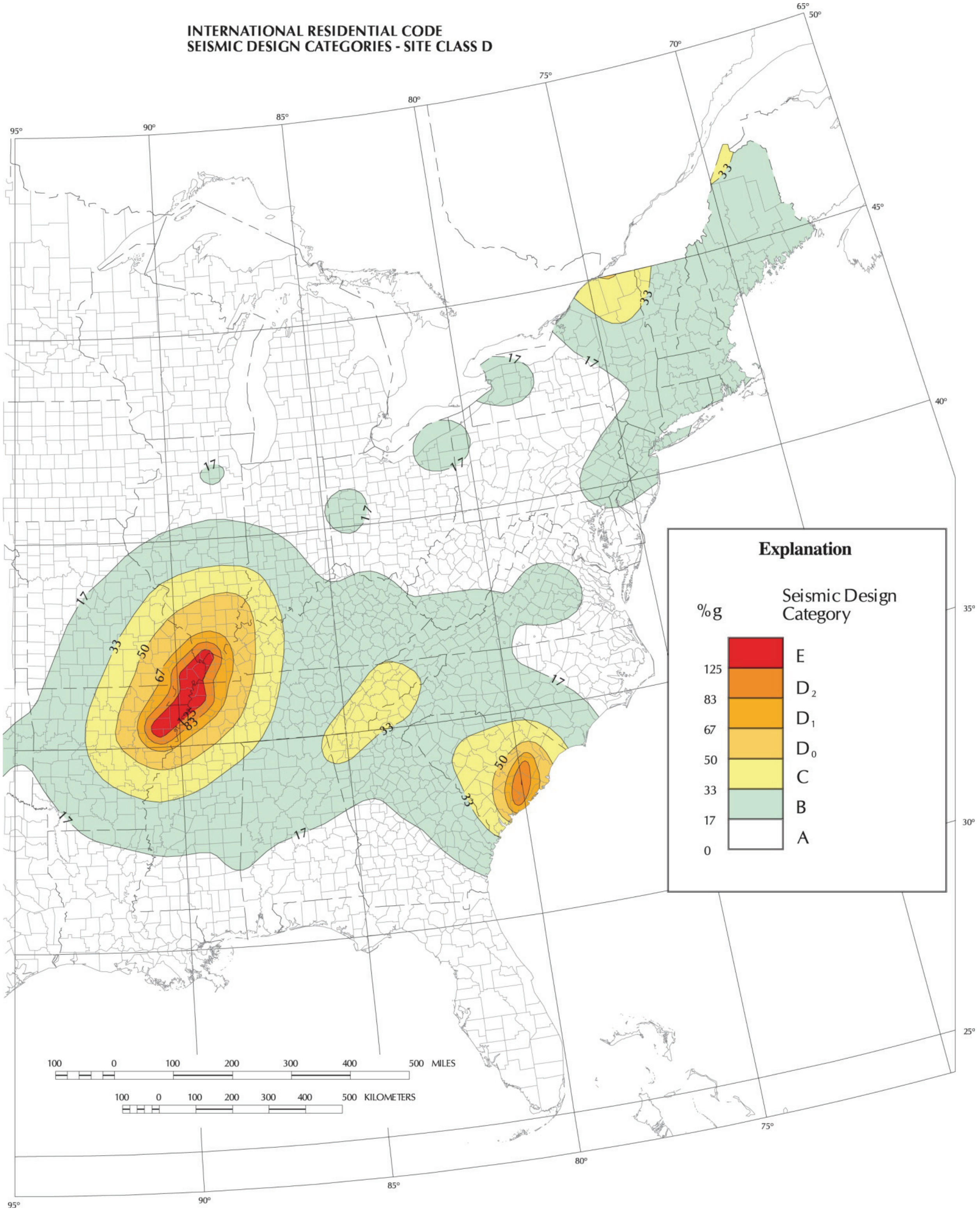
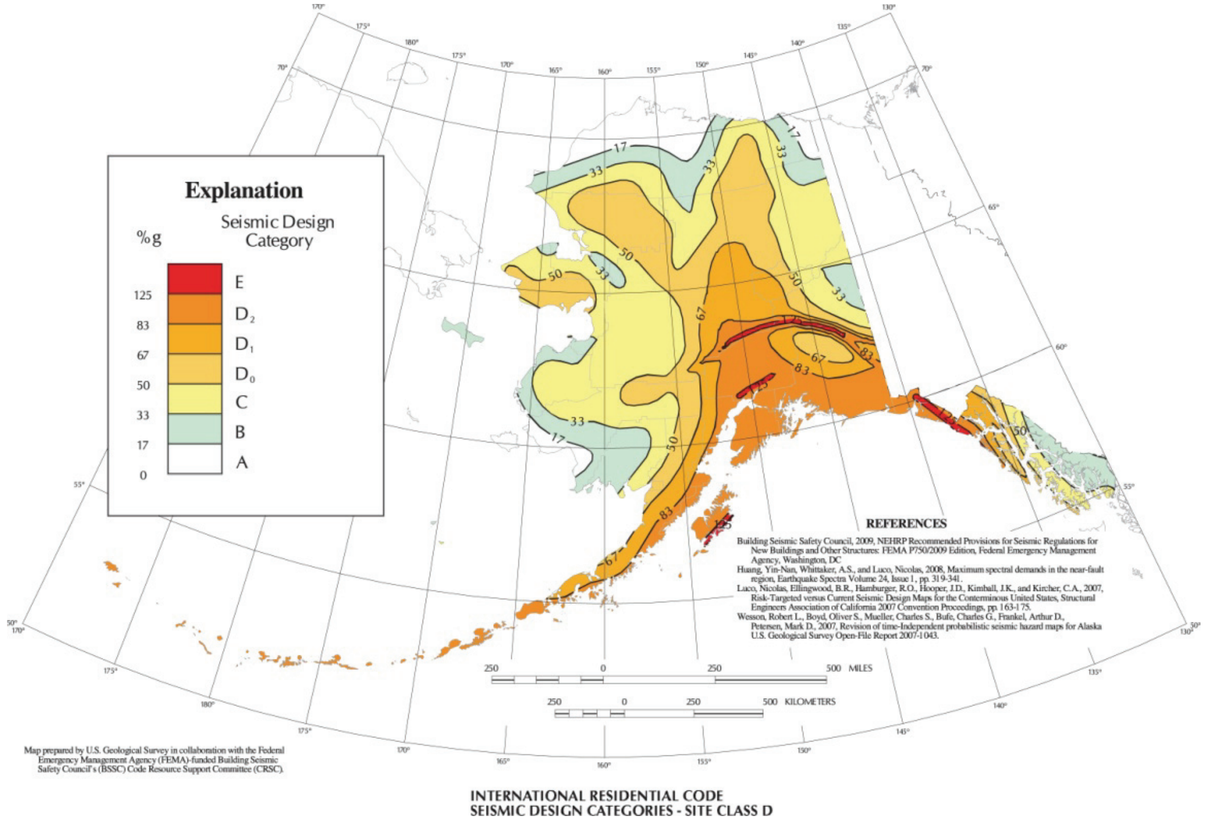


Figure 2-2 Map of Eastern United States showing distribution of earthquake ground shaking by Seismic Design Category, as specified in the *International Residential Code*. Ground shaking contours are specified in terms of horizontal acceleration response (g) of short-period (0.2-second) structures, for Soil-Site Class D. The Simplified Seismic Assessment Form only applies in regions where Seismic Design Categories C, $D_0$, $D_1$, $D_2$, and E are applicable. (Source: U. S. Geological Survey.)



**REFERENCES**

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Luco, Nicolas, Ellingwood, B.R., Hamburger, R.O., Hooper, J.D., Kimball, J.K., and Kircher, C.A., 2007, Risk-Targeted versus Current Seismic Design Maps for the Conterminous United States, Structural Engineers Association of California 2007 Convention Proceedings, pp. 163-175.

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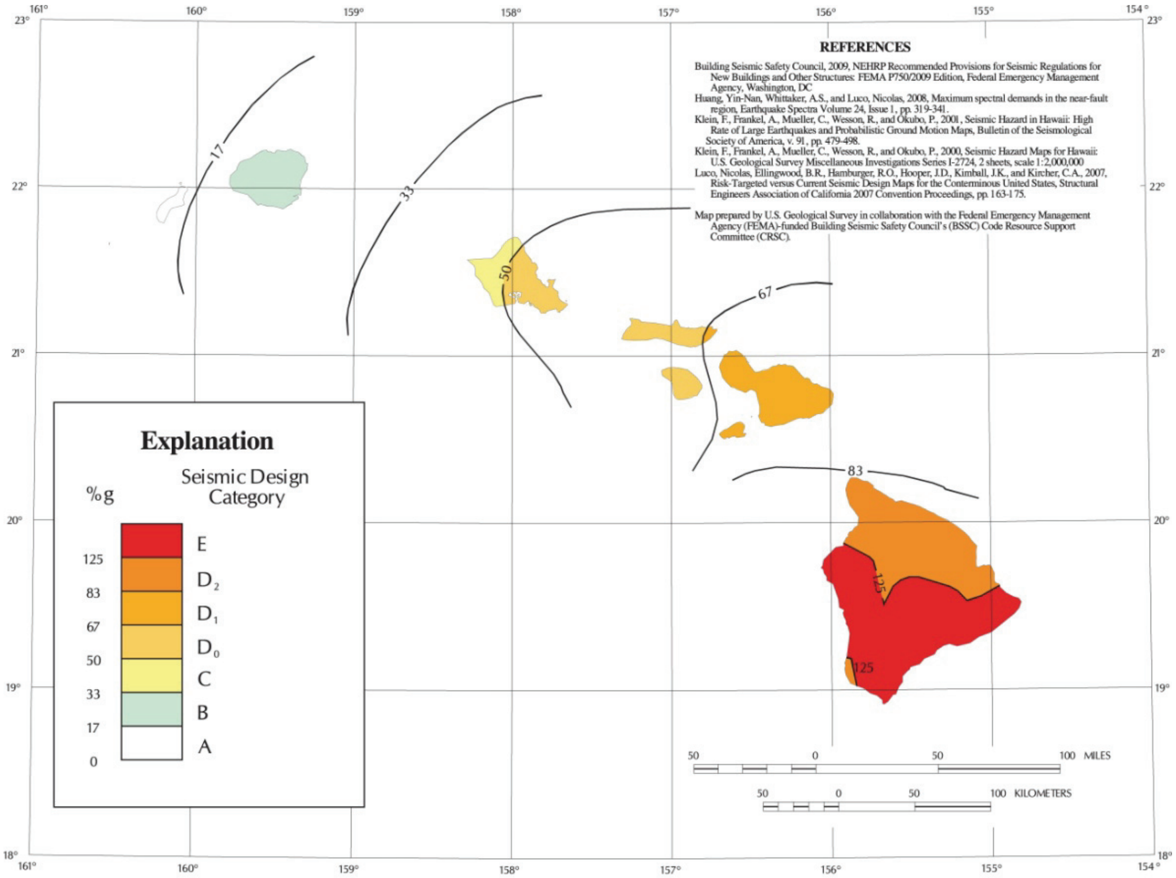
Map prepared by U.S. Geological Survey in collaboration with the Federal Emergency Management Agency (FEMA)-funded Building Seismic Safety Council's (BSSC) Code Resource Support Committee (CRSC).

Figure 2-3 Map of Alaska showing distribution of earthquake ground shaking by Seismic Design Category, as specified in the *International Residential Code*. Ground shaking contours are specified in terms of horizontal acceleration response (g) of short-period (0.2-second) structures, for Soil-Site Class D. The Simplified Seismic Assessment Form only applies in regions where Seismic Design Categories C, $D_0$, $D_1$, $D_2$, and E are applicable. (Source: U. S. Geological Survey.)

Dwellings types NOT addressed by the Simplified Seismic Assessment Form include dwellings constructed primarily of steel, masonry (other than veneer and chimneys), concrete, or other non-wood materials. Manufactured housing, installed on temporary or permanent foundations, cannot be evaluated using the FEMA P-50 Simplified Seismic Assessment Form; however, modular wood-frame dwellings (including panelized construction) are required to meet the same building code as site-built dwellings, and so can be evaluated using the Simplified Seismic Assessment Form.

Also not addressed by the assessment form are earthquake-related damages to dwelling utilities, such as water, sewer, gas and electricity. Similarly, the form does not address specific damage caused by electrical, mechanical, and plumbing failures in the dwelling, other than overturning of water heaters and associated rupture of gas lines.

Hazards such as tsunamis, tornadoes, windstorms, and wildfires are beyond the scope of the assessment.



REFERENCES

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Klein, F., Frankel, A., Mueller, C., Wesson, R., and Okubo, P., 2001, Seismic Hazard in Hawaii: High Rate of Large Earthquakes and Probabilistic Ground Motion Maps, Bulletin of the Seismological Society of America, v. 91, pp. 479-498.

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Luco, Nicolas, Ellingwood, B.R., Hamburger, R.O., Hooper, J.D., Kimball, J.K., and Kircher, C.A., 2007, Risk-Targeted versus Current Seismic Design Maps for the Conterminous United States, Structural Engineers Association of California 2007 Convention Proceedings, pp. 163-175.

Map prepared by U.S. Geological Survey in collaboration with the Federal Emergency Management Agency (FEMA)-funded Building Seismic Safety Council's (BSSC) Code Resource Support Committee (CRSC).

INTERNATIONAL RESIDENTIAL CODE
SEISMIC DESIGN CATEGORIES - SITE CLASS D

Figure 2-4 Map of Hawaii showing distribution of earthquake ground shaking by Seismic Design Category, as specified in the *International Residential Code*. Ground shaking contours are specified in terms of horizontal acceleration response (g) of short-period (0.2-second) structures, for Soil-Site Class D. The Simplified Seismic Assessment Form only applies in regions where Seismic Design Categories C, $D_0$, $D_1$, $D_2$, and E are applicable. (Source: U. S. Geological Survey.)

### *2.1.2 Major Sections of the Form*

The form is divided into eight sections, A through H. The first five sections, A through E, identify potential seismic vulnerabilities (weaknesses) relating to the dwelling and the site. Section F addresses seismic hazards, Section G is used to determine the Seismic Performance Grade, and Section H is used to identify those conditions that could be improved by seismic retrofit to improve the Seismic Performance Grade.

Detailed discussions of the major sections and instructions on how to complete them are provided in Chapters 3 through 8.

### 2.1.3 Sections A through E: Assessment of the Dwelling Structure and Site

Sections A through E address the following dwelling and site-related issues:

- *Section A*: Foundation systems,
- *Section B*: Superstructure framing and configuration,
- *Section C*: General condition assessment,
- *Section D*: Nonstructural elements, age, and size, and
- *Section E*: Local site conditions.

Each section contains a series of assessment items that address potential seismic vulnerabilities for a detached, single-family, wood-frame dwelling (see Figure 2-5). Multiple-choice responses allow the inspector to identify

**FEMA P-50** **Simplified Seismic Assessment Form**
**For Detached, Single-Family, Wood-Frame Dwellings**
(Please print all information)

**Grade**

Street Address
Community/Area/City
ZIP Code
Date

Owner
Inspector
Inspection Form # (optional)

For each question, circle only one answer. Circle the one with higher penalty if more than one answer applies. Exception: question B-1

**A. Foundation** (If the dwelling has a crawl space, the inspector should view all the areas that are accessible.)

**Penalty**

*A-1 The exterior footing is:
  a. continuous concrete or reinforced masonry [0]
  b. other footing conditions [4.2]

A-2 The lowest floor of the dwelling is:
  a. slab-on-grade [0]
  b. wood framed over crawl space or basement [2.9]
  c. combination of slab-on-grade and wood framed floor over crawl space or basement [2.9]

*A-3 At the dwelling crawlspace or basement interior, the lowest floor framing is supported on:
  a. continuous stem walls or a combination of continuous stem walls and beams on posts bearing on concrete footings/piers [0]
  b. beams on posts bearing on piers/pad footings [0.8]
  c. beams on posts supported directly on soil [2.2]
  d. not applicable: slab-on-grade [0]

A-4 For a foundation on a slope of 3 horizontal to 1 vertical or steeper, the top of the footing or foundation stem wall on which wall studs or posts are supported is:
  a. sloped parallel to the ground slope [3.7]
  b. stepped [1.8]
  c. at a constant elevation with no steps [0.6]
  d. not applicable [0]

**Penalty**

*A-5 At the dwelling perimeter walls, where the foundation system supports a wood framed floor:
  a. the foundation sill plate (mudsill) is bolted to the foundation with average anchor bolt spacing of 72 in. or less [0]
  b. the foundation sill plate is fastened to the foundation with retrofit anchors equivalent to 72 in. or less anchor bolt spacing [0]
  c. the anchor bolts have average spacing that is > 72 in. but <= 108 in. [1.7]
  d. the anchor bolts have > 108 in. average spacing [4.6]
  e. the foundation sill plates have extensive decay, splitting, or inadequate edge distance at one-third or more of the anchor bolt locations such that significant slip of the sill plate could occur [10.0]
  f. the anchor bolts have significant corrosion at one third or more of the anchor bolt locations such that significant slip of the sill plate could occur [10.0]
  g. there are no foundation anchor bolts [15.0]
  h. there are no foundation sill plates to connect to the foundation [15.0]
  i. not applicable [ 0 ]

**Total** ☐

**B. Superstructure Framing and Configuration** (Every accessible area such as the attic and under-floor area that reveals structural elements must be inspected.)

**Penalty**

B-1 The dwelling has: (circle all that apply, a to e)
  a. unsymmetrical wall strength (torsion problems) yes [1.6]
  b. reentrant corners (seen in plan view) yes [0.3]
  c. split-level floor construction yes [2.0]
  d. out-of-plane offsets of more than 4 ft. in exterior walls yes [0.4]
  e. non-orthogonal seismic resisting systems yes [0.6]
  f. none of the above, or built in accordance with 1994 UBC, 2000 IBC, 2000 IRC or later edition yes [0]

*B-2 For exterior walls at the lowest occupied story, the summed length of full story height wall sections (between openings, excluding < 2'-8" panels) on any face is less than:
  a. 20% of the length of the wall, if a single story yes [3.2]
  b. 25% of the length of the wall, if two stories yes [3.2]
  c. 40% of the length of the wall, if three stories or more yes [3.2]
  d. none of the above [0]

*B-3 If the roofing is heavy (i.e., clay or concrete tile) the dwelling is:
  a. single story [1.6]
  b. multi-story [3.5]
  c. not applicable: roofing is light. [0]

**Penalty**

*B-4 For an attached garage with a second floor above, the narrow walls at the side of the garage door openings have:
  a. wood structural panels on each narrow wall pier [0]
  b. structural steel frames around or alongside the door [0]
  c. prefabricated narrow shear walls, installed in accordance with manufacturer's recommendations [0]
  d. none of the conditions specified in conditions a, b, or c above (that are visable) [3.0]
  e. not applicable (single story) or built in accordance with 1997 UBC, 2000 IBC, 2000 IRC or later edition [0]

*B-5 The exterior wall covering is primarily:
  a. siding known to be over plywood or OSB sheathing [0]
  b. siding not known to be over plywood or OSB sheathing [2.5]
  c. plywood (T1-11) or diagonal wood siding [0]
  d stucco [1.0]
  e. masonry veneer not more than 10 feet above the supporting foundation [2.5]
  f. masonry veneer more than 10 feet above the supporting foundation [3.5]

*Assessment item that may be improved by seismic retrofit; **see page 6, Section H**

**Simplified Seismic Assessment Form** **Page 1**

Figure 2-5 Page 1 of Simplified Seismic Assessment Form, which contains Section A, Foundation systems, and a portion of Section B, Superstructure framing and configuration. Note assessment items (e.g., in Section A) and the corresponding condition options, with associated penalties. Appendix A contains all six pages of the Simplified Seismic Assessment Form.

the condition most applicable to the dwelling. *Where multiple conditions apply, the inspector is directed to circle the response with the highest penalty points.* Item B-1 is the only exception to this approach; for B-1, all applicable items are to be circled. All assessment items on the form must be answered or completed. Responses to the items in these five sections provide the basis for establishing a Structural Score, which is determined in Section G.

Chapter 3 provides detailed discussions of Sections A, B and C of the form. Chapter 4 provides a detailed discussion of Section D. Chapter 5 provides a detailed discussion of Section E.

### 2.1.4 Section F: Identification of Seismic Hazards

Section F, which addresses seismic hazards affecting the site, uses the dwelling location (street address or degrees latitude and longitude) as a basis for determining the seismic hazard exposure. The Seismic Hazard Score is determined considering the following seismic hazard-related conditions: earthquake ground shaking potential, soil liquefaction potential, fault rupture potential, and earthquake-induced landslide potential. The resulting Seismic Hazard Score is used in Section G, in combination with the Structural Score, to determine the Seismic Performance Grade. See Chapter 6 for detailed discussion of Section F.

### 2.1.5 Section G: Determination of the Seismic Performance Grade

In Section G, the inspector determines the Seismic Performance Grade, which indicates the anticipated seismic performance of the assessed dwelling. The Seismic Performance Grade is determined from Table 5 of Appendix A, based on the Structural Score and the Seismic Hazard Score. Chapter 7 provides a detailed discussion of how the Seismic Performance Grade is assigned.

Section G also contains brief descriptions for each Seismic Performance Grade. Additional information is provided in Section 2.4. It is recommended that the inspector explain these descriptions to the homeowner.

### 2.1.6 Section H: Improving the Seismic Performance Grade

The purpose of Section H is to provide the homeowner with information on approaches to improving the Seismic Performance Grade.

The Seismic Performance Grade (Section G) may be (1) improved as a result of seismic retrofit or (2) improved by a more in-depth seismic evaluation of the dwelling and the site by a qualified licensed design professional. Either of these will result in review and revision of the simplified seismic assessment. Guidance on these topics is provided in Chapter 8 of this document.

Seismic retrofit of dwellings with moderate to low Seismic Performance Grades is strongly encouraged. Assessment items in Sections A through E that can be retrofitted to increase the Structural Score and Seismic Performance Grade are designated by an asterisk (*) next to the item number. In Section H the inspector adds up penalty points that can be regained through retrofit, both for a sub-group identified as “priority” retrofits, and for all possible retrofits. Retrofits identified as “priority” are based on expert opinion that the particular retrofit involves a moderate cost and high benefit-to-cost ratio. From this information, the improved Structural Score and Seismic Performance Grade are determined for both groups of retrofits. The intent of this section is to demonstrate to homeowners that their dwelling can be readily retrofitted to gain a quantifiable improvement in seismic performance. See Chapters 3 through 6 and 8 for further discussion of retrofitting.

It may also be possible to retrofit dwellings against damage due to liquefaction and earthquake-induced landslide, addressed in Section F of the assessment form. Because of the expense, retrofit for these items is not frequently undertaken.

A more in-depth survey by a qualified licensed design professional may lead to revision of the simplified seismic assessment, potentially resulting in an increase in the Seismic Performance Grade. This could involve a structural engineer further evaluating items that lead to the Structural Score, or a geotechnical (soils) engineer further evaluating site soil conditions and the ability of the foundation system to resist earthquake seismic hazards. This approach to improving the Seismic Performance Grade is discussed in more detail in Section 8.4.

### *2.1.7 Disclaimer*

The final section of the form contains a disclaimer advising all parties of applicable limitations. See Section 2.5 for a complete discussion.

## 2.2 Scoring Approach for the Structural System

### *2.2.1 Penalty Points and Structural Score*

The scoring approach focuses on assignment of penalty points based on identified potential seismic vulnerabilities (weaknesses). Each dwelling starts with 100 points before inspection, and each identified potential seismic vulnerability lowers the score from 100.

The maximum possible number of penalty points is 100, which would result in a Structural Score of 0. Seismic retrofit of identified weaknesses eliminates penalty points, restoring the score closer to 100.

### 2.2.2 Weighting of Penalty Points

Not all deficiencies have the same impact on seismic performance. Therefore relative scores or weights are defined for the various deficiencies. In general, the more serious the seismic vulnerability, the larger the number of penalty points assigned to it.

The penalty points assigned, however, are not necessarily a direct reflection of the damage that can result from the vulnerability. In particular, assessment Items A-5 and B-8 have been associated with extensive damage in some dwellings, including up to a total loss. In addition, assessment Items D-1, D-2, and D-3 have occasionally been associated with extensive damage due to fire following earthquake.

The basis for the weighting of the assessment categories and the number of penalty points assigned to each assessment item is described in Appendix E.

## 2.3 Output of Evaluation

The following information is provided to the homeowner at the end of the assessment (in Sections G and H of the form).

- Total penalty points (0 to 100) and identification of potential seismic vulnerabilities that caused the points to be assigned.
- A Structural Score for the dwelling (1 to 100). A higher score is more desirable.
- A Seismic Hazard Score (1 to 12). A lower score reflects a lower hazard, and is more desirable.
- A Seismic Performance Grade, expressed as a letter grade from A to D. An A grade is most desirable, and a D grade is least desirable.

## 2.4 Seismic Performance Grades

The assigned Seismic Performance Grade, A through D, provides an indication of the generally anticipated seismic performance of the assessed dwelling, given its specific structural characteristics and geographical location, relative to the overall group of detached single-family wood-frame dwellings. This section provides a description of the generally anticipated performance for each Seismic Performance Grade. Note that a lower grade can be a result of either a less favorable Structural Score or a high Seismic Hazard

Score. The lowest grades will occur when both of these conditions exist. Conversely, a higher Structural Score and/or a lower Seismic Hazard Score will result in higher grades.

Also provided for each Seismic Performance Grade is a range of earthquake damage ratios. Damage ratios are expressed in terms of a range of damage as a percentage of replacement cost of the dwelling (land value excluded). These damage ratio estimates were obtained from a stochastic model utilizing prototype structures with a range of representative Structural Scores sited in various seismically representative regions of California.

Reported damage ratios are those with a 1/500 likelihood of being exceeded in any given year. The measure of damage was selected so that its likelihood aligns with the likelihood of the largest of the anticipated seismic events[1]. However, these damage ratios do not represent the expected damage incurred by any specific earthquake event nor do they represent actual costs of repair, which will vary.

See Section 2.5 for discussion of variability in ground shaking for anticipated seismic events. See Appendix D for a detailed explanation of the damage ranges.

### 2.4.1 Grade A (including A, A-)

This is the best grade a dwelling can receive. An A grade indicates that the dwelling is generally expected, but not certain, to have excellent seismic performance during the anticipated seismic events[1].

A dwelling with excellent performance should be anticipated to potentially sustain minor structural damage as well as damage to finish materials from the anticipated seismic events, with potential earthquake damage of 0% to 10% of replacement cost. Dwellings graded A should not include vulnerabilities identified in Assessment Items A-5 or B-8, potentially leading to extensive damage.

It is likely, but not certain, that the dwelling will be in a structural condition that will allow continued occupancy following the anticipated seismic events.

For dwellings receiving an A grade, seismic retrofit measures may be considered for improved performance, but are not as imperative as with lower grades.

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[1] The anticipated seismic events are described by the earthquake ground motion contours illustrated in the *International Residential Code* Seismic Design Category maps in Figures 2-1 to 2-4.

### 2.4.2 Grade B (including B+, B, B-)

This is the second best grade a dwelling can receive. The grade B indicates that the dwelling is generally expected, but not certain, to have good seismic performance during the anticipated seismic events.

A good performing dwelling should be anticipated to potentially sustain moderate structural damage and damage to finish materials in the anticipated seismic events, with potential earthquake damage of 0% to 50% of replacement cost.

Dwellings graded B could have vulnerabilities identified in Assessment Items A-5 and B-8, potentially leading to extensive damage.

It is likely but not certain that the dwelling will be in a structural condition after the anticipated seismic events such that it can remain occupied after a postearthquake inspection by a knowledgeable professional or after minor structural repairs are completed.

For dwellings receiving a B grade, seismic retrofit measures should be considered for improved performance, particularly if they have vulnerabilities identified with extensive damage.

### 2.4.3 Grade C (including C+, C, C-)

The grade C indicates that the dwelling is generally expected but not certain to have fair seismic performance during the anticipated seismic events, and may experience moderate to major structural damage and damage to the finish materials, with potential earthquake damage of 10% to 60% of replacement cost.

Most likely, the dwelling will require some structural repairs after the anticipated seismic events before continued safe occupancy.

For dwellings receiving a C grade, seismic retrofit work is strongly encouraged.

### 2.4.4 Grade D (including D+, D, D-)

This is the lowest grade a dwelling can receive. The grade D means that the dwelling is expected but not certain to have poor seismic performance during the anticipated seismic events and may experience severe damage to both the structure and the finish materials, with potential earthquake damage of 20% to 100% of replacement cost.

Most likely, the dwelling will require significant structural repairs after the anticipated seismic events, before continued safe occupancy.

For dwellings receiving a D grade, seismic retrofit work is strongly encouraged.

### *2.4.5 Basis for Seismic Performance Grades*

The Seismic Performance Grades in Table 5 of Appendix A are intended to provide a description of possible extent of damage and ability to reoccupy a dwelling following a major earthquake. The damage ranges associated with each Seismic Performance Grade have an annual probability of exceedance of 1/500, which represents the probability of occurrence of significant earthquake ground motions for which the homeowner may have to repair damage. And although the damage ranges presented do not technically represent a single event, they are seen by the authors as a reasonable approximation of the single event.

With regard to the letter grades, the assignment of the Seismic Performance Grades, A through D, is based largely on the results of the earlier ATC-50 study, which focused on the earthquake performance of dwellings in the Los Angeles area. ATC-50 assigned letter grades based on expert judgment, seismic damage data from the 1971 San Fernando and 1994 Northridge earthquakes, and a pilot study. The pilot study of 400 dwellings was conducted where the boundaries of each letter grade relative to hazard and structural scores were established so that a split of roughly 50-50 was achieved between D and C grades and B and A grades. In the current development (FEMA P-50), this distribution has been slightly modified to reflect the damage ratio data and to be representative of dwelling and seismic hazard conditions throughout the United States. These changes have been driven by the expert judgment and opinion of the Project Management Committee and have been reviewed by the Project Review Panel (see list of Project Participants).

To develop damage ranges for the grades appearing in Table 5 of Appendix A, EQECAT used proprietary software[2] to conduct analyses for 76 dwelling models with a range of structural characteristics intended to span the grading system. The dwelling models make use of existing EQECAT Modifiers developed for the California Earthquake Authority (CEA) and others to approximate the vulnerability. Analyses were run at each of 100 sites—some in hazard zone C and $D_0$, some in $D_1$, some in $D_2$, $E_0$ and $E_1$. The total number of site/dwelling-model pairs was 7600. The analysis was conducted using a synthetic catalog of earthquakes intended to match the National Seismic Hazard Mapping Project model (Petersen et al., 2008), and covering the full range of events deemed credible by the U. S. Geological Survey. Loss

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[2] WORLDCATenterprise$^{TM}$ (WCe) Version 3.16

curves were plotted, 500-year losses (expressed as a damage ratio = repair cost / dwelling value) were extracted, and the results were re-binned to depict damage ratio as a function of Seismic Hazard Score and Structural Score.

Although the study to develop loss ranges for each Seismic Performance Grade focused on the earthquake performance of single-family, wood-frame dwellings in California, its application to areas outside of California is judged to be appropriate. Because a broad set of ground motion scenarios were selected for this analysis (i.e., from very low to high seismic hazard levels) and because deficiencies that also occur in dwellings outside of California were considered, the results are considered applicable to other areas of the United States that are also subjected to moderate and high seismic hazards. Furthermore, the selection of damage ratios for each Seismic Performance Grade was based on choosing the lowest and highest values associated with that grade. Therefore, the ranges presented in Table 5 of Appendix A are broad, encompassing damage expected in non-California construction.

A more detailed discussion of (1) the methodology used to develop the expected loss ranges for each Seismic Performance Grade, and (2) the results from that study are presented in Appendix D.

## 2.5 Limitations of Simplified Assessment

Because of the limited nature of the FEMA P-50 simplified seismic assessment methodology, the performance implied by a Seismic Performance Grade could vary widely. Variability is inherent in the seismic hazard, site soil hazards, dwelling performance, and dwelling evaluation following an earthquake. Anticipated ground shaking is primarily dependent on probabilistic models, with inherent variability. Variability can also depend on the proximity of the site to the earthquake source zone, and the presence of possible secondary hazards, such as fault rupture, liquefaction and earthquake-induced landslide. Variability in performance and in evaluation by post-earthquake safety evaluators must be anticipated and will impact ability to reoccupy the dwelling. Determination of ability to occupy a dwelling following an earthquake also requires consideration of a number of aspects beyond the structural aspects considered by this assessment.

Another limitation of the seismic assessment is not being able to visually inspect enclosed construction (shear walls, connections, steel frames, deep foundations), or evaluate site soil conditions and other factors affecting seismic performance. This limitation prompted the developers of the procedure and form to use the word “simplified” in the title of the form. The intent is to convey to the homeowner that it is possible to have a subsequent seismic assessment that is not simplified.  A more detailed assessment could include review of plans, calculations, site and soil conditions, and limited destructive testing that may reveal substantially different conditions.  Such an assessment may result in a higher or lower Structural Score, Seismic Hazard Score, and resulting Seismic Performance Grade. See Section 8.4 for discussion of more detailed assessments.

A disclaimer statement is provided in the last section of the assessment form. The intent of this disclaimer is to advise all parties, including the homeowner, that the Applied Technology Council, and the other FEMA P-50 project sponsors make no warranty, expressed or implied, as to the ability of the evaluated property to withstand earthquakes or associated hazards, nor to the completeness of the form or its accuracy, in that many aspects of earthquake engineering are uncertain.  The text of the disclaimer is provided below.

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## Chapter 3

# Assessment of Structural Elements

This chapter describes portions of the Simplified Seismic Assessment Form that address structural elements that directly or indirectly alter the earthquake performance of a dwelling. The assessment categories are based on data describing the performance of wood-frame dwellings in previous earthquakes. The structural evaluation is divided into three major assessment categories: Foundation (Section A), Superstructure Framing and Configuration (Section B), and General Condition Assessment (Section C).

Sections A through C include three broad categories of assessed structural conditions. One category includes vulnerabilities (weaknesses) shown in past earthquakes to cause extensive damage to the dwelling and possibly cause risk to the safety of the occupants. Assessment items A-5 and B-8 are examples of this category. The second category includes dwelling configuration characteristics such as weight and geometry that, based on past earthquake experience and expert opinion, are thought to increase earthquake damage and cost of repair. The third category includes condition issues such as wood decay and foundation deterioration that are judged to potentially increase the extent of damage in an earthquake.

### 3.1 Assessment of Foundation System (Section A)

There are five assessment items in Section A, with a maximum possible penalty of 28 points. This section addresses the type of foundation and the connection between the foundation system and the wood-frame dwelling.

A slab-on-grade dwelling on a flat lot can pass this section without any penalties. A raised foundation system on a sloped lot with no anchor bolts will be penalized the most.

The figures provided in the following subsections replicate each assessment item from Section A of the Simplified Seismic Assessment Form, along with optional condition responses and associated penalty points. Commentary addressing how the assessment item is to be answered and why the assessment item is included is also provided.

### 3.1.1 Exterior Footing (Assessment Item A-1)

Assessment item A-1, optional condition responses, and associated penalty points are shown in Figure 3-1. The exterior footing type has affected the extent of footing damage in past earthquakes. The footing should be observed from the dwelling perimeter, crawlspace, or basement.

| | | Penalty |
|---|---|---|
| *A-1 | The exterior footing is: | |
| | a. continuous concrete or reinforced masonry | [0] |
| | b. other footing conditions | [4.2] |

Figure 3-1 Assessment item A-1. *denotes assessment item that may be improved by seismic retrofit.

Considerations for assignment of conditions a and b include:

a. *Continuous concrete and reinforced masonry exterior footings are included in condition a. Also included are foundations with continuous perimeter grade beams or tie-beams. These foundation types have been better earthquake performers, suffering less damage than the foundation types in condition b, so are not penalized.*

b. *All other exterior footing types are to be included in condition b and assigned penalty points. Included in condition b are continuous footings of other materials such as unreinforced brick or stone masonry. Also included are discontinuous footings such as isolated post-and-pier systems, isolated drilled pier systems without tie-beams, and partially continuous perimeter footings. These footing materials and types have been identified in past earthquakes as poorer performers, resulting in increased damage.*

Penalty points can be regained with retrofit to include continuous concrete or reinforced masonry foundations.

### 3.1.2 Lowest Floor Construction (Assessment Item A-2)

This assessment item (see Figure 3-2) is intended to apply to the lowest occupied floor, not including basements.

| | | Penalty |
|---|---|---|
| A-2 | The lowest floor of the dwelling is: | |
| | a. slab-on-grade | [0] |
| | b. wood framed over crawl space or basement | [2.9] |
| | c. combination of slab-on-grade and wood framed floor over crawl space or basement | [2.9] |

Figure 3-2 Assessment item A-2.

Considerations for assignment of conditions a through c include:

a. *Where the dwelling lowest floor is a slab-on-grade, there will be no crawlspace. Wood-frame dwellings supported directly on slab-on-grade floor systems avoid vulnerabilities inherent in wood-framed lowest floor systems, and therefore are not penalized.*

b. *A framed lowest floor increases the potential vulnerability of the dwelling by increasing the number of resisting elements and connections required to transfer earthquake loads from the lowest floor framing to the foundation. The assigned penalty points recognize this increased potential vulnerability.*

c. *A number of wood-frame dwellings have a combination of slab-on-grade and framed lowest floors. Where this occurs the penalty still applies because framed floor portions of the dwelling have increased potential for vulnerability. This combination is common with split-level and hillside homes.*

Retrofit to regain penalty points for this assessment item is not practical.

### *3.1.3 Framing Support at Crawlspace Interior (Assessment Item A-3)*

This item (see Figure 3-3) is intended to be assessed based on observed conditions in the dwelling crawlspace or basement. Items a-c describe various methods for supporting floor framing. Where more than one support system is present, select the system that is predominant.

| | | | **Penalty** |
|---|---|---|---|
| *A-3 | At the crawlspace or basement interior, the lowest floor framing is supported on: | | |
| | a. | continuous stem walls or a combination of continuous stem walls and beams on posts bearing on concrete footings/piers | [0] |
| | b. | beams on posts bearing on piers/pad footings | [0.8] |
| | c. | beams on posts supported directly on soil | [2.2] |
| | d. | not applicable: slab-on-grade | [0] |

Figure 3-3 Assessment item A-3. *denotes assessment item that may be improved by seismic retrofit.

Considerations for assignment of conditions a through d include:

a. *Condition a applies where continuous footings are typical at the building interior. This system is given no penalty because framing supports are least likely to shift off of the foundations.*

*b. Condition b commonly occurs in older wood-frame dwellings (often called post-and-pier system). There is increased possibility that supporting posts can shift off of pier or pad footings, potentially causing damage.*

*c. Condition c reflects a condition in which the supporting post bears directly on the ground. Where this occurs, the possibility of damage and loss of support to the floor above is increased due to exposure to decay and termites.*

*d. Condition d applies where the lowest floor is slab-on-grade or where there are no interior floor framing supports.*

The damage caused due to loss of floor support due to shifting posts can vary from very minor, where repair requires replacement of the affected post, to major where significant finish and structural damage requires repair.

Retrofit is encouraged where posts sit directly on the ground without foundations (condition c); support on the ground exposes the framing to potential decay and termite damage, as well as loss of support during an earthquake. Retrofit involves providing new concrete pad footings. Retrofit of this condition is given a “priority” designation in Section H of the Simplified Seismic Assessment Form (see Chapter 8). Where this condition is retrofitted, 1.4 penalty points can be gained back, with a resulting penalty of 0.8.

Where posts are supported on pier or pad footings, it is a good idea to verify or improve connection of the post to the beam above and footing below to help avoid shifting posts and loss of support; connections should be kept flexible, allowing the posts to tilt. This improvement does not reduce penalty points.

Retrofit to add continuous interior footings is not common and not considered a priority.

### *3.1.4 Top of Footing or Foundation Wall (Assessment Item A-4)*

Assessment item A-4, optional condition responses, and associated penalty points are shown in Figure 3-4. In dwellings on sloping lots (those with slope angles greater than three units horizontal to one unit vertical—approximately 18 degrees from horizontal), the configuration of the foundation-wall system that supports the lowest framed floor can have a significant effect on the dwelling’s earthquake performance. It is intended that these conditions be observed below the lowest framed floor either from the crawlspace(s), or possibly exposed at the building exterior.

| | | Penalty |
|---|---|---|
| A-4 | For a foundation on a slope of 3 horizontal to 1 vertical or steeper, the top of the footing or foundation stem wall on which wall studs or posts are supported is: | |
| | a. sloped parallel to the ground slope | [3.7] |
| | b. stepped | [1.8] |
| | c. at a constant elevation with no steps | [0.6] |
| | d. not applicable | [0] |

Figure 3-4 Assessment item A-4.

Considerations for assignment of conditions a through d include:

a. *If the top of the footing or foundation wall (and therefore sill plate) is parallel to the slope, the vertical stud and post supports below the lowest floor framing will butt onto the sill plate at an angle that is not 90 degrees, creating a potentially unstable situation where studs or posts slide along the sill plate. This configuration is assigned the highest penalty.*

b. *A lesser penalty is assigned for dwellings on steep-sloping lots in which the foundation has horizontal surfaces stepping up to the highest level.*

c. *An even smaller penalty is assigned for dwellings on steep-sloping lots that have foundation stem walls with a constant top elevation (without steps) that support the lowest floor framing.*

d. *Condition d is applicable where no crawlspace exists or where the site slope is less than 3 horizontal to 1 vertical.*

Retrofit to regain penalty points for this assessment item is not practical. Where condition a occurs, fastening of wall studs to the sloped foundation sill plate using toenails or connectors is encouraged, but does not reduce penalty points.

### 3.1.5 Dwelling Anchorage to Foundation (Assessment Item A-5)

Assessment item A-5, optional condition responses, and associated penalty points are shown in Figure 3-5. Fastening of wood foundation sill plates (mudsills) to the supporting foundation is extremely important to the earthquake performance of wood-frame dwellings. Anchorage is most commonly achieved with 1/2-inch or 5/8-inch diameter anchor bolts; however, other fastener and connector types are sometimes used. Lack of such anchorage permits the dwelling to slide off the foundation, potentially resulting in complete loss and hazard to occupants. Poor performance has repeatedly been observed in past earthquakes for dwellings that are not anchored to the foundation. This assessment item is intended to be observed from the crawlspace.

Many older dwellings were constructed without anchor bolts. The year at which anchor bolts started being commonly installed varies by community. See Appendix Section C.2 for illustration of common dwelling and anchor bolt configurations.

| | | Penalty |
|---|---|---|
| *A-5 | At the dwelling perimeter walls, where the foundation system supports a wood framed floor: | |
| a. | the foundation sill plate (mudsill) is bolted to the foundation with average anchor bolt spacing of 72 inches or less | [0] |
| b. | the foundation sill plate is fastened to the foundation with retrofit anchors equivalent to 72 inch or less anchor bolt spacing | [0] |
| c. | the anchor bolts have average spacing that is greater than 72 inches but less than or equal to 108 inches | [1.7] |
| d. | the anchor bolts have greater than 108 inch average spacing | [4.6] |
| e. | the foundation sill plates have extensive decay, splitting, or inadequate bolt edge distance at one-third or more of the anchor bolt locations such that significant slip of the sill plate could occur | [10.0] |
| f. | the anchor bolts have significant corrosion at one-third or more of the anchor bolt locations such that significant slip of the sill plates could occur | [10.0] |
| g. | there are no foundation anchor bolts | [15.0] |
| h. | there are no foundation sill plates to connect to the foundation | [15.0] |
| i. | not applicable | [0] |

Figure 3-5 Assessment item A-5. *denotes assessment item that may be improved by seismic retrofit.

Considerations for assignment of conditions a through i include:

a. *Condition a applies where anchor bolts are provided and spaced at 72 inches (six feet) on center or closer. This is a common bolt spacing for dwellings constructed in accordance with conventional construction provisions. For engineered dwellings, bolt spacing may be closer.*

b. *For condition b, retrofit anchors are provided in place of anchor bolts. Retrofit anchors are used where overhead clearance does not permit drill or roto-hammer access to install anchor bolts. Retrofit anchors should be spaced to provide a per-foot capacity equal to anchor bolts at 72 inches, or at a spacing determined using retrofit standards, manufacturer's literature or engineering calculations.*

c. *Condition c applies where the dwelling may be vulnerable to increased damage due to excessive spacing of anchor bolts.*

*d.* *Condition d describes a condition of higher vulnerability where the anchor bolt spacing is so large that it is no longer systematic. There may be sections of mudsill with only one bolt and portions of the dwelling may be particularly vulnerable to slipping off the foundation.*

*e.* *Condition e occurs where, although anchor bolts are present, decay or splitting of the foundation sill plate or placement of the anchor bolts very close to the sill plate edge may cause the anchor bolts to be ineffective. This is limited to extensive decay or splitting that would permit significant sill plate slip (i.e., on the order of inches), and to where one third or more of the anchor bolts are affected, resulting in the possibility of wide-spread sill plate movement. For anchor bolt placement, it applies where one-third or more of the anchor bolts are centered less than 3/4-inch from the edge of the sill plate.*

*f.* *Similar to the condition described in e, condition f is intended to apply where anchor bolt corrosion is significant enough to cause wide-spread sill plate slip over a significant portion of the dwelling. There can be significant corrosion of the anchor bolt at the underside of the sill plate while only mild to moderate corrosion is visible at the anchor bolt top. Many highly corroded anchor bolts can be identified by applying torque with a standard wrench; highly corroded anchors will break off.*

*g.* *Condition g applies where there is no anchorage of the wood-frame dwelling to the foundation, leaving the dwelling highly vulnerable to sliding off the foundation. If the foundation sill plate is anchored to the foundation with fasteners or connectors other than anchor bolts or retrofit anchors, reassessment of the anchorage by a licensed design professional is likely to be necessary to determine adequacy of anchorage. See Section 8.4 for discussion.*

*h.* *Condition h describes a highly vulnerable condition where no mudsills exist (such as post and pier condition) where the dwelling is highly vulnerable to sliding relative to the foundation.*

*i.* *Condition i is intended to address any configuration where a raised wood-frame floor does not exist, and therefore no penalty points are applied. It is impossible to observe the foundation bolts for dwellings with slab-on-grade floors, because the bolts are totally concealed by the concrete and wall coverings (with the possible exception of the garage). In observations of earthquake damage to date, slab-on-grade dwellings have not been observed to slide off their foundations. This may be be-*

*cause use of anchor bolts became very common in the time period where slab-on-grade foundations came into common use.*

Penalty points can be regained with retrofit of sill plate anchorage to the foundation. This retrofit generally provides significant benefit at a moderate cost and is highly encouraged. Retrofit of this condition is given a “priority” designation in Section H of the Simplified Seismic Assessment Form (see Chapter 8).

## 3.2 Assessment of Superstructure Framing and Configuration (Section B)

This section covers everything above the foundation system, including cripple walls. There are a total of eight assessment items in this section with a maximum possible penalty of 36.7 points. The inspector will typically require more training in assessment of the superstructure than any other part of the form. The figures provided in the following subsections replicate each assessment item pertaining to assessment of Superstructure Framing and Configuration (Section B of the Simplified Seismic Assessment Form), along with optional condition responses and associated penalty points. Commentary addressing how the assessment item is to be answered and why the assessment item is included is also provided.

### *3.2.1 Dwelling Configuration Irregularities (Assessment Item B-1)*

Assessment item B-1 (see Figure 3-6) addresses overall irregularities and asymmetry in the dwelling configuration. Earthquake design requirements that came into effect with the adoption of the 1994 *Uniform Building Code* (UBC), the 2000 *International Building Code* (IBC), or the *International Residential Code* (IRC) are thought to provide adequate strength even when these irregularities occur. The assessment item is unique on the form in that

| | | | **Penalty** |
|---|---|---|---|
| B-1 | The dwelling has: (circle all that apply, a to e) | | |
| | a. | unsymmetrical wall strength (torsion problems). | yes [1.6] |
| | b. | reentrant corners (seen in plan view) | yes [0.3] |
| | c. | split-level floor construction | yes [2.0] |
| | d. | out-of-plane offsets of more than 4 ft. in exterior walls | yes [0.4] |
| | e. | non-orthogonal seismic resisting systems | yes [0.6] |
| | f. | none of the above, or built in accordance with 1994 UBC, 2000 IBC, 2000 IRC or later edition | yes [0] |

Figure 3-6 Assessment item B-1.

it is possible for a single home to acquire up to five different penalties from this single assessment item.

Considerations for assignment of conditions a through f include:

a. *Condition a applies where the walls on one exterior face of the dwelling have significantly greater summed full story height wall length (excluding openings) than the summed length on the opposing exterior face. This will be applicable to many dwellings. Summed lengths in the range of 50 percent more wall length than the opposite face of the dwelling should be considered significantly greater.*

b. *Condition b applies in any dwelling where the dwelling perimeter in plan (aerial) view is more complex than a single rectangle. This will be applicable to most dwellings.*

c. *Condition c applies where a single floor of the dwelling has more than one elevation (i.e., vertical offsets in the floor level). This configuration has been associated with greater earthquake damage. See Appendix Section C.2.5 for discussion of split-level dwellings.*

d. *Condition d applies where exterior walls of the dwelling jog in and out, with the jogs being more than four feet. This will be applicable to many dwellings.*

e. *Condition e applies where the majority of the bracing walls are at an angle other than 90 degrees to each other. This condition is unusual, but seen in some housing developments.*

f. *Condition f identifies code editions in which specific limitations were put on irregular structures. Dwellings designed and constructed using the 1994 Uniform Building Code (UBC), 2000 International Building Code (IBC), 2000 International Residential Code (IRC) or more recent editions of the noted building codes are thought to be less vulnerable to building damage due to dwelling configuration. It is suggested that the code and edition be reviewed and modified if necessary for the community being considered.*

Retrofit to regain penalty points for this assessment item is not practical.

### 3.2.2 Summed Exterior Wall Length (Assessment Item B-2)

This assessment item (see Figure 3-7) is intended to be applied to the lowest occupied story of the dwelling and assessed for each of the four dwelling faces. Full story height wall sections provide bracing for the horizontal forces of the earthquake. Adequate bracing wall length is very important for the earthquake performance of exterior walls. Therefore, various penalties are assessed for conditions that suggest inadequate bracing wall length. This is evaluated by measuring the overall out-to-out length of the wall and subtracting out the length of door and window openings, as well as any section of wall between openings that is less than 2'-8" long. A structure is penalized if there is an insufficient percentage of full-height wall. A face of the dwelling with a garage door opening need not be penalized where an adequate percentage of full height wall is provided overall on that wall face.

| | | Penalty |
|---|---|---|
| *B-2 | For exterior walls at the lowest occupied story, the summed length of full-story height wall sections (between openings, excluding < 2’-8” panels) on any face is less than: | |
| a. | 20% of the length of the wall, if a single story | yes [3.2] |
| b. | 25% of the length of the wall, if two stories | yes [3.2] |
| c. | 40% of the length of the wall, if three stories or more | yes [3.2] |
| d. | none of the above | [0] |

Figure 3-7 Assessment item B-2. *denotes assessment item that may be improved by seismic retrofit.

The exterior wall criteria listed are the same as those required in *Uniform Building Code* conventional construction provisions through the 1997 edition for Seismic Zones 2B, 3 and 4. The criteria do not consider the additional bracing provided by the interior walls.

Penalty points can be regained with retrofit to provide the required summed length of wall. This retrofit can require elimination of existing door or window openings; however, engineered retrofit designs can provide additional bracing without affecting openings.

### *3.2.3 Roofing Weight (Assessment Item B-3)*

Assessment item B-3, optional condition responses, and associated penalty points are shown in Figure 3-8. Heavy roofing materials increase the earthquake load that must be resisted, thereby increasing the likelihood and extent of damage. Light roofing materials would generally include composition

| | | Penalty |
|---|---|---|
| *B-3 | If the roofing is heavy (i.e., clay or concrete tile) the dwelling is: | |
| a. | single story | [1.6] |
| b. | multi-story | [3.5] |
| c. | not applicable: roofing is light | [0] |

Figure 3-8 Assessment item B-3. *denotes assessment item that may be improved by seismic retrofit.

shingle, wood shingle, metal roofing (e.g., standing seam roofs, stamped roofing, corrugated steel), and rolled or membrane roofing. Heavy roofing would commonly include concrete and clay tile. Although it is not specifically penalized, having more than one reroof over an existing roof can also increase the roof weight, and therefore earthquake loading.

Penalty points can be regained with retrofit to replace heavy roofing with a lighter roofing type.

### 3.2.4 Narrow Walls at Garage Door (Assessment Item B-4)

At the front wall of a garage, it is common for the garage door opening to take up most of the wall length, often leaving narrow wall piers at each side of the opening as the only earthquake bracing. The limited bracing wall length makes this portion of the dwelling more vulnerable to earthquake damage. This is particularly true where a second floor occurs over the garage. This assessment item (see figure 3-9) penalizes dwellings with a second floor over the garage in which bracing of the narrow walls was not addressed during construction.

| | | | Penalty |
|---|---|---|---|
| *B-4 | For an attached garage with a second floor above, the narrow walls at the side of the garage door openings have: | | |
| | a. | wood structural panels on each narrow wall pier | [0] |
| | b. | structural steel frames around or alongside the door | [0] |
| | c. | prefabricated narrow shear walls, installed in accordance with manufacturer's recommendations | [0] |
| | d. | none of the conditions specified in conditions a, b, or c above (that are visible) | [3.0] |
| | e. | not applicable (single story) or built in accordance with 1997 UBC, 2000 IBC, 2000 IRC or later edition | [0] |

Figure 3-9 Assessment item B-4. *denotes assessment item that may be improved by seismic retrofit.

Considerations for assignment of conditions a through e include:

a. *Condition a indicates that narrow wall piers at the side of the garage door opening are sheathed using either plywood or oriented strand board (OSB). No differentiation is made between walls that do and do not have tie-down hardware, because it is assumed that hardware, if present, may not be readily observed.*

b. *Condition b indicates a structural steel moment frame (with at least two columns connected to a beam with rigid welded connections). The frames are most commonly constructed with I-shaped wide flange sections, but can also use tube and c-shaped sections.*

c. *Condition c includes pre-manufactured shear wall elements, commonly using wood, plywood and/or cold-formed steel sections. Such elements should be specifically rated for earthquake bracing, and installed in accordance with the manufacturer's instructions. Manufactured walls not properly installed should be penalized 3 points.*

d. *Condition d applies where none of the approaches to bracing conditions a-c are identified, and indicates a potentially vulnerable condition.*

e. *Condition e indicates the use of a building code and edition in which narrow wall piers were restricted and prescriptive provisions were included for narrow wall piers. This includes the 1997 Uniform Building Code (UBC), 2000 International Building Code (IBC) or 2000 International Residential Code (IRC). It is suggested that the code and edition be reviewed and modified if necessary for the community being considered.*

Penalty points can be regained with retrofit of the garage front condition. Retrofit of this condition is given a "priority" designation in Section H of the Simplified Seismic Assessment Form (see Chapter 8).

### *3.2.5 Exterior Wall Finish (Assessment Item B-5)*

The earthquake strength and resilience of various types of exterior wall sheathing and finish materials varies significantly. This assessment item (see Figure 3-10) penalizes materials that are less strong and less resilient.

| | | | **Penalty** |
|---|---|---|---|
| *B-5 | The exterior wall covering is primarily: | | |
| | a. | siding known to be over plywood or OSB sheathing | [0] |
| | b. | siding not known to be over plywood or OSB sheathing | [2.5] |
| | c. | plywood (T1-11) or diagonal wood siding | [0] |
| | d. | stucco | [1.0] |
| | e. | masonry veneer not more than 10 feet above the supporting foundation | [2.5] |
| | f. | masonry veneer more than 10 feet above the supporting foundation | [3.5] |

Figure 3-10 Assessment item B-5. *denotes assessment item that may be improved by seismic retrofit.

Considerations for assignment of conditions a through f include:

a. *Condition a applies where exterior horizontal, vertical, or non-plywood-panel siding is known to be applied over plywood or oriented strand board (OSB) sheathing. The existence of plywood or oriented strand* *board (OSB) sheathing may be known because the sheathing can be observed in some locations, or because plans from construction indicate the presence of plywood or OSB. This is more likely to occur with recently constructed dwellings.*

b. *Condition b applies where exterior horizontal, vertical, or non-plywood-panel siding is used and plywood or OSB sheathing is NOT known to be installed underneath the siding. Exterior siding can include wood, aluminum, fiber-cement board, vinyl, and other siding products; unless the siding product is specifically know to be rated by the manufacturer for earthquake bracing, these penalty points should be assigned. This is a common condition in older dwellings.*

c. *Condition c applies where T1-11 or similar plywood siding materials are used; where properly installed, these materials provide good earthquake bracing. It is recommended that panel edge nailing for T1-11 siding be checked including adequacy of nailing at vertical tongue and groove edges (a single nail may be relied on to secure both abutting vertical edges, and this nailing is often not adequate for bracing wall use) and existence of edge nailing at horizontal panel edges. Where nailing is inadequate, 2.5 penalty points are to be assigned.*

d. *Condition d applies where stucco is used. Stucco is both stronger and stiffer than other exterior wall-finish materials. Cracking of stucco finishes is very common in earthquakes, and the penalty points reflect the likelihood that repair of cracking will be required.*

e. *Masonry veneer has often been damaged in past earthquakes. When veneer is damaged, it cracks along joints and often separates from and falls off of the supporting wall. Both exterior and interior veneer should be included.*

f. *Masonry veneer that extends more than 10 feet above the supporting foundation is more vulnerable to earthquake damage than veneer at 10 feet or less. Condition f includes veneer in gable end walls, which has been observed to be particularly vulnerable in past earthquakes. In addition, the hazard posed to occupants increases with the increased height of veneer.*

Penalty points can be regained with retrofit involving removal of brittle finish materials and replacing with stronger and more resilient materials.

### *3.2.6 Interior Remodeling (Assessment Item B-6)*

Assessment item B-6, optional condition responses, and associated penalty points are shown in Figure 3-11. Dwellings with few interior walls tend to sustain more damage than dwellings with more interior walls. The removal of an interior wall can significantly reduce the earthquake resistance of a dwelling. This change would not be reflected in the answer to assessment item B-2 regarding the length of exterior walls.

| | | | **Penalty** |
|---|---|---|---|
| B-6 | There is evidence of interior remodeling that has removed interior walls: | yes | [1.0] |
| | | no/not applicable | [0] |

Figure 3-11 Assessment item B-6.

Retrofit to regain penalty points for this assessment item is generally not practical.

### *3.2.7 Number of Stories (Assessment Item B-7)*

Multi-story dwellings create larger earthquake forces and have historically suffered more damage. Retrofit to regain penalty points for this assessment item (see figure 3-12) is not practical.

| | | | **Penalty** |
|---|---|---|---|
| B-7 | The number of stories is: | | |
| | a. | one.(1) | [0] |
| | b. | two (2) | [1.8] |
| | c. | 3 or more | [3.6] |

Figure 3-12 Assessment item B-7.

### *3.2.8 Perimeter Bracing Below Lowest Framed Floor (Assessment Item B-8)*

This assessment item (see Figure 3-13) focuses on the system occurring between the lowest framed floor level and ground (foundation). As described in Appendix Section C.2, configurations include cripple wall dwellings, post-and pier dwellings, split-level dwellings and hillside dwellings. Where the bracing system between the lowest framed floor and ground is not adequate, extensive damage to the dwelling can occur, up to total loss. This damage can also endanger occupants of the dwelling.

Cripple wall and post-and-pier dwelling configurations have contributed significantly to wood-frame dwelling damage in a number of past earthquakes. In addition, hillside dwellings lacking the bracing described in assessment

| | | Penalty |
|---|---|---|
| *B-8 | At the dwelling perimeter, the lowest framed floor is supported on: | |
| | a. beam and column (post-and-pier) system with no sheathed exterior walls | [14.0] |
| | b. perimeter cripple walls with no plywood or OSB sheathing | [14.0] |
| | c. original or retrofitted perimeter cripple walls with plywood or OSB sheathing where cripple walls are one story or less in height | [1.0 ] |
| | d. original or retrofitted perimeter cripple walls with plywood or OSB sheathing where cripple walls are greater than one story in height | [4.0] |
| | e. wood or steel diagonal braces not detailed in accordance with 1997 UBC, 2000 IBC or later edition | [7.0] |
| | f. plywood or OSB sheathed perimeter skirt walls that do not extend to and anchor to the foundation | [7.0] |
| | g. none of the above | [0] |

Figure 3-13 Assessment item B-8. *denotes assessment item that may be improved by seismic retrofit.

item B-8, were significantly damaged during the 1994 Northridge Earthquake.

Considerations for assignment of conditions a through g include:

a. *Condition a applies where the crawlspace is exposed, not enclosed by cripple walls or concrete or masonry foundation walls. This condition is applicable whether the site is level or sloped and at any height between the framed floor and foundation. This system is significantly vulnerable to earthquake damage. See Appendix Section C.2 for discussion of applicable dwelling types.*

b. *Condition b includes perimeter cripple walls braced with anything other than plywood or oriented strand board (OSB) sheathing. Other bracing materials, including stucco and straight and diagonal wood sheathing, are vulnerable to earthquake damage when used below the lowest framed floor (in contrast these material perform well in occupied stories as addressed in assessment item B-5).*

c. *Dwellings with cripple walls originally constructed with or retrofitted with plywood or oriented strand board (OSB) sheathing on the perimeter cripple walls are thought to be good performers. This condition is limited to cripple walls of one story (approximately eight feet) or less in height because the greater flexibility of tall walls can result in increased damage. Modern provisions for bracing of cripple walls appeared in the 1997 Uniform Building Code (UBC) and 2000 International Building Code (IBC). Modern provisions for earthquake retrofit of cripple walls* *were made widely available in the 1997 Uniform Code for Building Conservation (UCBC) and the 2003 International Existing Building Code (IEBC). Construction or retrofit under these or more recent code editions should mitigate poor behavior. The code and edition should be reviewed and modified if required for the community being considered.*

*d. Dwellings with perimeter cripple walls originally constructed with or retrofitted with plywood or oriented strand board (OSB) sheathing and of more than one story (approximately eight feet) in height are given a small penalty because the greater flexibility of tall walls can result in damage.*

*e. Condition e applies to beam and column systems braced with steel or wood diagonal brace members that do not have detailing allowing the full capacity of the diagonal brace members to be developed. Prior to the 1997 Uniform Building Code (UBC) or the 2000 International Building Code (IBC), it was uncommon to design brace connections to develop the brace member capacity. This code edition designation should be reviewed and modified if required for the community being considered.*

*f. Condition f applies to dwellings that have sheathed walls that are not attached to the foundations. In some regions, post and pier systems have been enclosed by "skirt" walls without adequate top and bottom connections. This is particularly applicable to hillside dwellings.*

*g. Condition g applies to slab-on-grade dwellings and dwellings in which basement walls or foundation stem walls extend up to the underside of floor framing. These dwellings do not exhibit the vulnerabilities described in conditions a through f.*

Penalty points can be regained with retrofit of these perimeter wall configurations. This retrofit generally provides significant benefit at a moderate cost and is highly encouraged. Retrofit of this condition is given a "priority" designation in Section H of the Simplified Seismic Assessment Form (see Chapter 8).

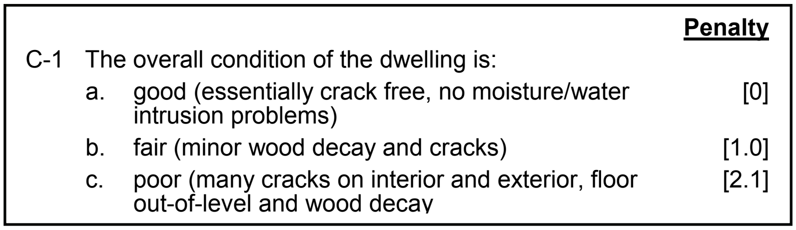
## 3.3 General Condition Assessment (Section C)

The condition of existing structural elements contributes to their performance. Most of the assessment items in Section C are directed towards identifying signs of poor maintenance and material degradation. There are a total of five assessment items in this section with a maximum possible penalty of 8.6 points. Conditions to look for include cracking, wood decay, moisture damage around the foundation, stucco damage, and evidence of framing alterations that could affect earthquake performance.

The figures provided in the following subsections replicate each assessment item pertaining to Condition Assessment (Section C of the Simplified Seismic Assessment Form), along with optional condition responses and associated penalty points. Limited commentary is also provided.

### *3.3.1 Overall Condition (Assessment Item C-1)*

Assessment of overall condition is (see Figure 3-14) to be based on the condition of readily visible finish materials (wall, ceiling, floor) and observed foundations and framing. Water intrusion into a dwelling can cause wood decay and encourage termite infestation in the earthquake-resisting structural elements. Very local (minor) water and decay problems are not uncommon in older dwellings and should not result in penalty points. The intent of this item is to capture condition issues that are significant and wide-spread enough to affect ability to resist earthquake loading.



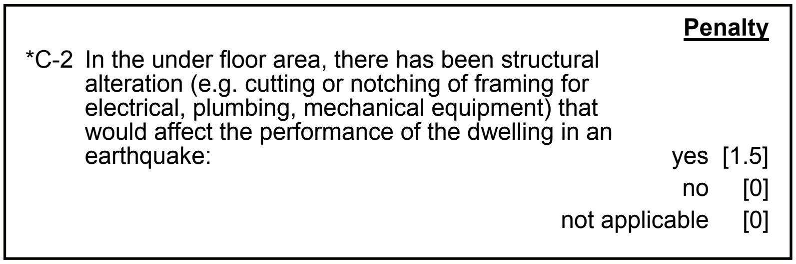
| | | | |
|---|---|---|---|
| | | | **Penalty** |
| C-1 | The overall condition of the dwelling is: | | |
| | a. | good (essentially crack free, no moisture/water intrusion problems) | [0] |
| | b. | fair (minor wood decay and cracks) | [1.0] |
| | c. | poor (many cracks on interior and exterior, floor out-of-level and wood decay | [2.1] |

Figure 3-14 Assessment item C-1.

While improvement of the dwelling condition is encouraged, retrofit/ repair to regain penalty points for this item is not practical.

### *3.3.2 Framing Alterations (Assessment Item C-2)*

Assessment of framing alterations (see Figure 3-15) is based on conditions observed in the crawlspace or basement. As in assessment item C-1, the intent of this item is to capture modifications to structural framing that are significant enough to affect earthquake performance. The primary focus should



| | | | |
|---|---|---|---|
| | | | **Penalty** |
| *C-2 | In the under floor area, there has been structural alteration (e.g. cutting or notching of framing for electrical, plumbing, mechanical equipment) that would affect the performance of the dwelling in an earthquake: | yes | [1.5] |
| | | no | [0] |
| | | not applicable | [0] |

Figure 3-15 Assessment item C-2. *denotes assessment item that may be improved by seismic retrofit.

be framing members that resist earthquake loading; however, other alterations thought to significantly affect possible damage in an earthquake should be included.

Penalty points can be regained with retrofit/ repair of the damaged structural framing.

### 3.3.3 Exterior Stucco Condition (Assessment Item C-3)

Deterioration of the stucco decreases its effectiveness for earthquake bracing, and can also permit increased water intrusion and wider deterioration of the dwelling. This assessment item (see Figure 3-16) is intended to capture wide-spread condition issues with the stucco.

| | | Penalty |
|---|---|---|
| *C-3 | There is evidence of: stucco detachment, bowing of stucco, corroded wire mesh, extensive cracking at finished grade above the bottom of the stucco: | |
| | a. extensive | [2.0] |
| | b. minor | [1.0] |
| | c. none | [0] |

Figure 3-16 Assessment item C-3. *denotes condition that may be improved by seismic retrofit.

Penalty points can be regained with retrofit/repair of the damaged stucco.

### 3.3.4 Foundation Condition (Assessment Item C-4)

A concrete foundation weakened by deterioration is more likely than a strong foundation to be damaged during an earthquake. This assessment item (see Figure 3-17) is intended to capture wide-spread condition issues with the foundation.

| | | Penalty |
|---|---|---|
| *C-4 | At the foundation level, there is: | |
| | a. significant deterioration visible (corrosion, material breakdown) | [1.3] |
| | b. some deterioration visible | [0.6] |
| | c. no deterioration visible | [0] |

Figure 3-17 Assessment item C-4. *denotes assessment item that may be improved by seismic retrofit.

Penalty points for this item can be regained with repair of the deterioration. The practicality of repair will vary with the nature and extent of deterioration.

### 3.3.5 Quality of Construction (Assessment Item C-5)

Assessment item C-5 (see Figure 3-18) deals with the quality of the original construction rather than the extent of deterioration that may or have occurred since the dwelling was built.

| | | Penalty |
|---|---|---|
| C-5 | Throughout the dwelling, the quality of construction appears to be: | |
| | a. good | [0.0] |
| | b. average | [0.8] |
| | c. poor | [1.7] |

Figure 3-18 Assessment item C-5.

This assessment item calls for the inspector to rate the overall quality as good, fair, or poor. The answer will be based on the inspector's judgment, and there will almost certainly be some variation among inspectors. Some of the construction flaws to consider are

- poor quality materials, and
- poor workmanship.

Materials and workmanship identified as good quality should generally meet the requirements of the building code enforced at the time of construction.

Retrofit to regain penalty points for this item is not practical.

## Chapter 4

# Assessment of Nonstructural Elements, Dwelling Age and Size

Past earthquakes have shown that damage to nonstructural elements, including chimneys, and water heaters, can in some cases cost more than structural damage. This chapter describes those portions of the Simplified Seismic Assessment Form (Section D) that address the assessment of nonstructural elements. Also included in this section are questions and statements relating to the age and size of the dwelling. Section D of the Simplified Seismic Assessment Form includes six assessment items. A maximum of 10 penalty points can be assigned in this section of the form.

The figures provided in the following sections replicate each assessment item from Section D of the Simplified Seismic Assessment Form, along with optional condition responses and associated penalty points. Limited commentary addressing how the assessment item is to be answered and why the assessment item is included is also provided.

### 4.1 Chimneys (Assessment Item D-1)

Assessment item D-1 (see Figure 4-1) pertains to masonry and concrete chimneys. Unreinforced masonry chimneys, in particular, have been a major source of damage in previous moderate to major earthquakes and have on occasion caused fatalities. In addition to the chimney damage itself, the fallen chimney can damage the roof and surrounding areas.

| | | **Penalty** |
|---|---|---|
| *D-1 | The chimney inspection revealed: | |
| a. | properly connected anchor straps tying the masonry/concrete chimney(s) at side of house to the floor, ceiling and roof framing]: | yes [1.0] |
| | | no [2.0] |
| b. | chimney occurs at dwelling interior | [1.0] |
| c. | dwelling has no masonry/concrete chimney | [0] |

Figure 4-1 Assessment item D-1. *denotes assessment item that may be improved by seismic retrofit.

Considerations for assignment of conditions a through c include:

*a.* *Building code provisions for new buildings require chimneys to be strapped to the dwelling interior framing at each floor, ceiling and roof level. This strapping may not eliminate damage, but should reduce the hazard caused by falling masonry or concrete. Where the chimney is strapped, the reduced penalty of 1.0 points recognizes that damage may still occur.*

*b.* *Chimneys at the dwelling interior are surrounded by floor, ceiling and roof framing on all sides, reducing the hazard from falling masonry or concrete. The penalty of 1.0 point reflects this lower hazard, and that damage is still possible.*

*c.* *Condition C applies where there is no concrete or masonry chimney. Light-frame chimneys with metal flues (with or without masonry veneer) are to be included in this item.*

Not reflected in conditions a and b are chimneys that extend a significant distance above the roof line. Such chimneys may be vulnerable to failure at the roof line and to falling. Where the chimney height above the chimney exceeds twice the least horizontal chimney dimension, engineering evaluation is recommended.

Varying approaches exist for mitigating chimney performance. See Chapter 8 for further guidance.

## 4.2 Water Heater (Assessment Item D-2)

Assessment item D-2 (see Figure 4-2) pertains to water heaters, which have overturned and caused significant water and fire damage in past earthquakes. To avoid penalty points, a gas water heater must have anchor straps and flexible water and gas connections. An electric water heater must have approved straps; a flexible water connection is also recommended. Anchor straps need to be installed tight enough to greatly limit the ability of the water heater to move towards or away from surrounding walls. The base of the water heater should also be anchored to the floor or pedestal on which it stands. Anchor straps are considered approved if they meet the requirements of the state or

|  |  | Penalty |
|---|---|---|
| *D-2 | The gas water heater has approved anchor straps and water and gas connections: | yes [0] |
|  |  | no [1.0] |
|  | The electric water heater has approved anchor straps: | yes [0] |
|  |  | no [0.7] |

Figure 4-2 Assessment item D-2. *denotes assessment item that may be improved by seismic retrofit.

local guidelines, where available, or otherwise meet the requirements of referenced FEMA publications.

Retrofit of water heaters is easy and inexpensive. Retrofit of this condition is given a “priority” designation in Section H of the Simplified Seismic Assessment Form (see Chapter 8).

## 4.3 Gas Shutoff (Assessment Item D-3)

Broken gas lines create risk for fire, explosion, and asphyxiation. In the assessment of this item (Figure 4-3) a penalty is assessed for any dwelling that does not have earthquake-activated shut-off valves on the gas line. (Gas shut-off valves are commonly located immediately on the residence side of the gas meter).

| | | | Penalty |
|---|---|---|---|
| *D-3 | An earthquake-activated gas shut-off valve is installed: | yes | [0] |
| | | no | [1.0 |
| | | not applicable | [0] |

Figure 4-3 Assessment item D-3. *denotes assessment item that may be improved by seismic retrofit.

Retrofit by installation of shut-off valves is given a “priority” designation in Section H of the Simplified Seismic Assessment Form (see Chapter 8). Homeowners should check with the local building department and gas company to see if gas shut-off valves are allowed.

## 4.4 Stairs, Decks and Porch Roofs (Assessment Item D-4)

Most exterior stairs, decks and porch roofs rely on the dwelling to provide earthquake bracing, while an estimated small percentage of these dwelling components has internal bracing walls or diagonal braces that provide independent bracing. Penalties for this assessment item (Figure 4-4) apply to the former group that relies on the dwelling to provide earthquake bracing. These

| | | | Penalty |
|---|---|---|---|
| *D-4 | The dwelling has exterior stairs, decks or porch roofs, without internal earthquake bracing, that are attached to the dwelling with: | | |
| | a. | two or more connections tying the stair, deck or porch to the dwelling interior framing | [0] |
| | b. | nails or screws that would be loaded in withdrawal if the stair deck or porch moved away from the dwelling | [1.0] |
| | c. | other connection configurations | [1.0] |

Figure 4-4 Assessment item D-4. *denotes assessment item that may be improved by seismic retrofit.

dwelling components have been sources of damage and local collapse in past earthquakes; while they are not known to have posed a hazard to occupants, they have the potential to do so.

Considerations for assignment of conditions include:

a. *Where exterior stairs, decks and porch roofs have connections that engage interior framing and do not rely on withdrawal capacity of fasteners, there is no penalty applied. For porch roofs, continuity of roof finishes (other than tile roofs) from the dwelling to the porch roof can provide this positive connection. A minimum of two connection points is required for each section of stair, deck or roof. Additional connection points should be provided for larger and more complex configurations.*

b. *Many exterior stairs, decks and porch roofs are supported on a ledger, fastened to the face of the dwelling wall. Often the ledger fastening is limited to nails, screws or bolts that only engage the exterior wall finish or blocking or rim joists under the finish. These connections are vulnerable to fastener withdrawal, causing the ledger to separate from the dwelling, possibly resulting in collapse of the stairs, deck or roof. Separation and collapse can also occur due to separation of blocking or rim joists that have nominal connection to other dwelling framing.*

c. *Condition c is intended to address other connection configurations that are not in conformance with condition a, and are therefore vulnerable.*

Retrofit involves providing positive anchorage to the dwelling. Retrofit of this condition is given a “priority” designation in Section H of the Simplified Seismic Assessment Form (see Chapter 8).

## 4.5 Age of Dwelling (Assessment Item D-5)

Penalties for older dwellings (Figure 4-5) cover many aspects of earthquake performance. Older dwellings have been shown in some post-earthquake evaluations to be more vulnerable to damage than newer dwellings, as discussed in Appendix C. In addition, older dwellings are more likely to have

| | | Penalty |
|---|---|---|
| D-5 | The dwelling was built: (if remodel/added area >50% of total area, use addition date): | |
| | a. before 1920 | [3.0] |
| | b. 1921 to 1977 | [2.0] |
| | c. 1978 to 1993 | [1.0] |
| | d. 1994 or later | [0] |

Figure 4-5 Assessment item D-5.

vulnerable configurations, as addressed in assessment items A-5, B-4 and B-8. The form lists four age categories for this assessment item. Some degree of penalty is assigned for all homes built before 1995.

## 4.6 Floor Area (Assessment Item D-6)

Homes with larger floor plan areas have historically sustained more damage than smaller homes, all other conditions being equal. The approximate areas of all the floor levels of the house and any attached garage are to be summed. Three size categories are provided for this assessment item (Figure 4-6). Dwellings larger than 1600 square feet are assigned a penalty.

| | | | **Penalty** |
|---|---|---|---|
| D-6 | The approximate total floor area (sq. ft.) of the dwelling and attached garage is: | | |
| | a. | < 1600 | [0] |
| | b. | 1601 - 2500 | [1.0] |
| | c. | ≥ 2501 | [2.0] |

Figure 4-6 Assessment item D-6.

## 4.7 FEMA Resources

FEMA has two significant documents that provide information on effective methods for reducing risks associated with residential nonstructural earthquake damage:

1. FEMA E-74, *Reducing the Risks of Nonstructural Earthquake Damage***,** *A Practical Guide, Fourth Edition* (http://www.fema.gov/plan/prevent/earthquake/fema74/index.shtm)

   FEMA E-74, Chapter 6, “Seismic Protection of Nonstructural Components,” recommends a combination of common-sense and additional protective measures that involve the installation of seismic anchorage and bracing to reduce nonstructural hazards. It provides examples of how to anchor the following residential nonstructural components:

   - Architectural Component Examples (http://www.fema.gov/plan/prevent/earthquake/fema74/chapter6_3.shtm)
     - Anchored veneer
     - Glazing
     - Glass block
     - Interior partition walls, light
     - Stone, tile, and masonry veneer

    - Suspended acoustic lay-in tile ceiling systems
    - Ceilings applied directly to structure
    - Unreinforced masonry chimney
    - Stairways
  - Mechanical, Electrical, and Plumbing (MEP) Component Examples (http://www.fema.gov/plan/prevent/earthquake/fema74/chapter6_4.shtm)
    - Water heaters
    - Recessed light fixtures
    - Surface-mounted lighting
    - Pendant light fixtures
  - Furniture, Fixtures, and Equipment (FF&E) and Content Examples (http://www.fema.gov/plan/prevent/earthquake/fema74/chapter6_5.shtm)
    - Light duty shelving
    - Bookshelves
    - Desktop computers and accessories
    - Televisions and video monitors, wall-mounted
    - File cabinets
    - Miscellaneous furniture and fixtures
    - Shelf-mounted items
    - Desktop, countertop items
    - Fragile artwork

2. FEMA 232, *Homebuilders' Guide to Earthquake-Resistant Design and Construction* (http://www.fema.gov/library/viewRecord.do?id=2103)

   FEMA 232, Chapter 8, “Anchorage of Home Contents,” provides guidance on anchorage of home contents, including the following residential nonstructural components: water heaters, drawer and cabinet latches, wood stoves, desktop computers and office equipment, and miscellaneous furniture.

   See Chapter 8 for further discussion of retrofit.

## Chapter 5

# Assessment of Local Site Conditions

Section E of the Simplified Seismic Assessment Form deals with the site topography, drainage and other site-related issues that can affect the performance of the structure in future earthquakes.

The following conditions could inhibit good seismic performance:

- Instability of slopes and surface material above or below a structure;
- Foundation instability caused by local liquefaction of sandy soils with shallow groundwater (addressed as a regional seismic hazard);
- Differential settlement of foundation soils from seismic compression or shear deformation, especially for structures sited on cut-and-fill lots.

In addition to potential site design and construction oversights by the original site developer, these factors can be exacerbated by deterioration of slopes due to circumstances beyond the site developer's control: rain and site drainage and elevation of the ground water table.

This section of the form includes six assessment items. The maximum number of penalty points for local site conditions is 16.7.

The figures provided in the following sections replicate each assessment item from Section E of the Simplified Seismic Assessment Form, along with optional condition responses and associated penalty points. Commentary addressing how the assessment item is to be answered and why the assessment item is included is also provided.

### 5.1 Site Slope (Assessment Item E-1)

Steep slopes (steeper than one vertical unit to three horizontal units) are penalized, as shown in Figure 5-1, while lots on flat or low slopes are not. Dwellings located on steep sites have the potential for increased earthquake damage from a variety of sources including increased likelihood of soil movement and more complex foundation configurations.

| | | Penalty |
|---|---|---|
| E-1 | The dwelling is located primarily on: | |
| | a. a flat lot or slope (≤ 3:1) | [ 0 ] |
| | b. steep slope (>3:1) | [3.0] |

Figure 5-1 Assessment item E-1.

## 5.2 Site Cut and Fill (Assessment Item E-2)

Compacted fill materials can be subject to ground failure during earthquakes from shear (sliding) deformations and volume change (seismic compression). This ground failure has been shown to produce particularly damaging relative displacements at the contact between cut and fill areas on a lot. Those relative displacements can cause damage to foundations, slabs-on-grade, and sometimes the dwelling structure. Conditions that affect penalty points for this assessment item are shown in Figure 5-2.

| | | Penalty |
|---|---|---|
| E-2 | The dwelling is located on a cut-and-fill pad, which was developed: | |
| | a. without a geotechnical investigation | [2.7] |
| | b. with a geotechnical investigation | [1.3] |
| | c. dwelling is *not* on cut-and-fill pad | [ 0 ] |

Figure 5-2 Assessment item E-2.

*A cut-and-fill lot is assessed an additional penalty if the lot was developed without a geotechnical investigation. The geotechnical investigation should correspond to use of engineered grading plans and engineered fills, installed with some level of quality control. Use of geotechnical reports and engineered fills started being required by national building codes in approximately 2000, but was required considerably earlier in local areas. It should be possible to determine whether cut and fill work was done with a geotechnical report using building department records.*

## 5.3 Foundation Condition and Differential Foundation Settlement (Assessment Items E-3 and E-4)

Cracks in foundation elements are not uncommon and can occur simply from normal shrinkage of concrete. When cracking becomes extensive and differential settlement is significant, the cracking and settlement is likely associated with soil deformations. Soil deformations can occur in the absence of earthquake loading from seasonal shrinkage and swell of clayey foundation soils, hydro-compression in relatively deep fills, and creep of slopes. The conditions that give rise to pre-earthquake deformations can also contribute to earthquake-induced deformations, possibly including liquefaction, seismic compression, and seismic slope displacement. Moreover, a foundation cracked prior to the earthquake is moderately more vulnerable to further cracking and movement during the earthquake.

Assessment item E-3 (Figure 5-3) addresses the issue of foundation cracking, and assessment item E-4 (Figure 5-4) addresses evidence of differential settlement.

| | | | Penalty |
|---|---|---|---|
| *E-3 | The exterior footing has: | | |
| | a. | no visible cracks or a few minor cracks | [ 0 ] |
| | b. | minor cracks in several areas | [1.0] |
| | c. | extensive cracking | [2.7] |
| | d. | not applicable | [ 0 ] |

Figure 5-3 Assessment item E-3. *denotes assessment item that may be improved by seismic retrofit.

| | | | Penalty |
|---|---|---|---|
| E-4 | The evidence of differential settlement in or around the dwelling is: | | |
| | a. | extensive | [2.5] |
| | b. | minor | [1.0] |
| | c. | none visible | [ 0 ] |

Figure 5-4 Assessment item E-4.

The practicality of retrofit for the conditions addressed by these assessment items will depend on the extent and nature of the foundation cracking. Penalty points are assigned for cracked foundations and foundations with evidence of differential settlement.

## 5.4 Slope Stability (Assessment Item E-5)

There is a penalty if slopes above or below the house appear to be unstable. Examples include tilting of trees and fence posts in the down-slope direction and bulges in slopes. Penalty points for this assessment item (Figure 5-5) should be assigned where the deformation is proximate to the structure and is of large enough scale that hazard to the dwelling is plausible.

| | | | Penalty |
|---|---|---|---|
| E-5: | The slope above or below the structure appears to be unstable: | yes | [3.2] |
| | | no | [ 0 ] |
| | | not applicable | [ 0 ] |

Figure 5-5 Assessment item E-5.

## 5.5 Drainage (Assessment Item E-6)

Poor drainage of surface water away from the foundation can weaken the supporting soil. On a larger scale, excessive water can promote soil liquefaction if the soil is sandy. Liquefaction is often associated with severe building damage. For this assessment item (Figure 5-6), the inspector looks for the presence or absence of roof gutters and downspouts and the degree to which water is diverted away from the foundation either naturally or with downspouts and drains.

| | | **Penalty** |
|---|---|---|
| *E-6: General condition of site drainage: | | |
| a. | roof gutters and downspouts collecting and conducting water away from foundation | [ 0 ] |
| b. | water collecting at/near perimeter footing with no positive slope away from dwelling | [2.6] |
| c. | no roof gutters but drainage appears to be adequate or roof gutters with downspouts that empty into splash blocks | [1.3] |

Figure 5-6 Assessment item E-6. *denotes assessment item that may be improved by seismic retrofit.

Retrofit of site drainage is encouraged because it is relatively inexpensive and can reduce future deterioration of the dwelling, with or without an earthquake. Retrofit of this condition is given a “priority” designation in Section H of the Simplified Seismic Assessment Form (see Chapter 8).

## Chapter 6

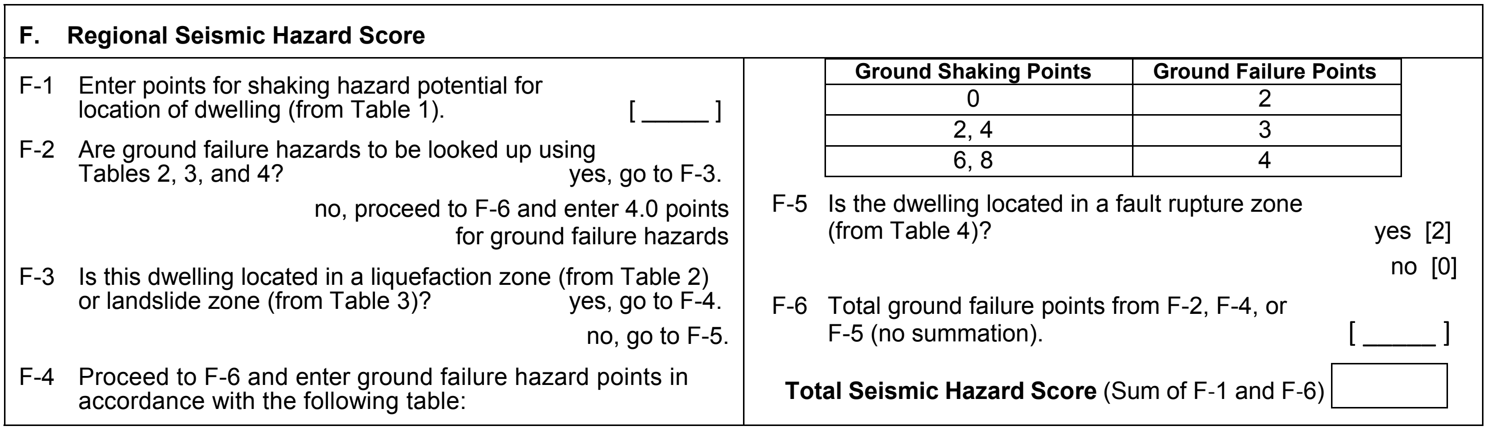
# Regional Seismic Hazards

Section F of the Simplified Seismic Assessment Form (Figure 6-1) addresses regional seismic hazards that could affect the site. These regional seismic hazards are due to conditions that are outside the homeowner's control. Effects considered are: (1) the potential for earthquake ground shaking at the location of the dwelling; (2) whether the dwelling is in a location that makes it prone to surface fault rupture; (3) whether the dwelling is located in an area that is susceptible to soil liquefaction because of the underlying soil conditions and water table; or (4) whether the location is vulnerable to seismic slope instability (landslide).

The site's Seismic Hazard Score is computed in this section as a combination of the penalty points for the various seismic hazards affecting the site, as described below. A higher number of seismic hazard penalty points is less desirable—it translates into an increased risk of damage during an earthquake. It is not possible to reduce the number of seismic hazard penalty points by seismic rehabilitation of the dwelling. However, reassessment of the seismic hazard by a qualified licensed design professional might lead to a reduced seismic hazard score through better knowledge of site soils and the dwelling foundation system. See Section 8.4.

## 6.1 Regionalization of Hazards

Seismic hazards have strong regional variations in both potential for ground shaking and ground failure (fault rupture, liquefaction, landslide). In keeping with the goal that the assessment form be simple to use, the project team adopted the use of web-based resources to enable the efficient look-up of the inputs required in the form. Those web-based resources are described below for seismic hazards related to ground shaking, liquefaction, landslides, and surface fault rupture. Note that because the resources for assessing ground failure potential are less simple to use, Question F-2 of the form (see Figure 6-1) presents the option to skip the look-up of ground failure hazards and instead simply assign the maximum number of ground failure hazard points (four). However, four ground failure hazard points can change the seismic performance grade determined for the dwelling by as much as a full letter grade or more (e.g., B+ to C).



**F. Regional Seismic Hazard Score**

F-1 Enter points for shaking hazard potential for location of dwelling (from Table 1). [_____]

F-2 Are ground failure hazards to be looked up using Tables 2, 3, and 4? yes, go to F-3.
no, proceed to F-6 and enter 4.0 points for ground failure hazards

F-3 Is this dwelling located in a liquefaction zone (from Table 2) or landslide zone (from Table 3)? yes, go to F-4.
no, go to F-5.

F-4 Proceed to F-6 and enter ground failure hazard points in accordance with the following table:

| Ground Shaking Points | Ground Failure Points |
|---|---|
| 0 | 2 |
| 2, 4 | 3 |
| 6, 8 | 4 |

F-5 Is the dwelling located in a fault rupture zone (from Table 4)? yes [2]
no [0]

F-6 Total ground failure points from F-2, F-4, or F-5 (no summation). [_____]

**Total Seismic Hazard Score** (Sum of F-1 and F-6) ☐

Figure 6-1 Section F of the Simplified Seismic Assessment Form.

## 6.2 Ground Shaking Hazards

Potential ground shaking intensities for building code applications are mapped by the U.S. Geological Survey (USGS) in collaboration with building code committees. Several ground motion parameters are mapped, but a parameter referred to as $S_{DS}$ is used here for ground shaking hazard scoring, consistent with the *International Residential Code*. Also consistent with building codes, by default $S_{DS}$ is evaluated for stiff soil conditions ("Site Class D").

Table 1 of the assessment form, repeated here as Table 6-1, and the web application referenced therein, can be used to assign ground shaking hazard points. The ground motion values obtained from the procedure described in Table 1 account for the occurrence of many different earthquakes affecting the dwelling site. Thus, they serve as proxies for the ground shaking hazard potential, a fundamental component of the risk of damage in an earthquake.

In Table 1, the ground-motion parameter $S_{DS}$ is looked up as a real number in units of g, the acceleration of gravity. After conversion to a percentage of g (by multiplying by 100), points are assigned on a scale between zero and eight. Those seismic hazard points are then entered into the table as the response to Question F-1.

## 6.3 Liquefaction Hazards

Analysis of data from past earthquakes reveals that regions with increased susceptibility to soil liquefaction sustain higher levels of damage than comparable areas without liquefaction (Youd and Perkins, 1987; Bray and Stewart, 2000).

On liquefiable soil, dwellings are shaken and damaged as though on firm ground until liquefaction occurs. Once liquefaction occurs, the structure may be subject to differential ground displacements (laterally or vertically)

**Table 6-1 Table 1 of the Simplified Seismic Assessment Form**

**Table 1. Assignment of Ground Shaking Hazard Score**

1. Use the USGS Seismic Design Maps Web Application (http://earthquake.usgs.gov/designmaps/usapp)[1] to look up ground shaking parameter $S_{DS}$:
    a. Press the 'Launch Application' button.
    b. In the web application, select '2012 IBC' for the Building Code Reference Document.
    c. Select 'Site Class D – "Stiff Soil" (Default)' for the Site Soil Classification.
    d. Enter the site address or latitude and longitude.
    e. Press the 'Compute Values' button.
    f. Read parameter $S_{DS}$ from the summary report. Enter here: _______ g
    g. Multiply value from 1f by 100: ______%g
2. Using the value from 1g, assign ground shaking points according to the following table (these points are assigned in Item F-1):

| Value of $S_{DS}$ (% g) | Ground Shaking Hazard Points |
|---|---|
| 33 - 66.99 | 0 |
| 67 - 82.99 | 2 |
| 83 - 124.99 | 4 |
| 125 - 187.99 | 6 |
| 188 - 250 | 8 |

[1] Note:If you are using the USGS application for the first time, or have recently cleared your web browser cookies, you may have to register for immediate use. Also, if you are using an anti-virus software program, you may have to enable some links to this site, e.g., if you receive a message that says "only secure content is displayed, "you must click on "show all content."

beneath the foundations, or the foundation may suffer a bearing failure into the weakened soil.

Table 2 of the assessment form, repeated here as Table 6-2, describes the process by which the possible presence of liquefaction hazards at a particular site can be identified. As shown in Table 2, liquefaction hazards are identified from one of the following map types:

1. *Liquefaction susceptibility maps* indicate areas potentially susceptible to liquefaction based on geologic conditions (young sediments) and shallow ground water. Liquefaction may or may not be likely to occur depending on ground shaking hazards.

2. *Liquefaction potential maps* combine liquefaction susceptibility with anticipated ground motions levels (evaluated for scenario earthquakes or from Probabilistic Seismic Hazard Analysis) to identify areas where liquefaction is likely to be triggered.

3. *Liquefaction potential index (LPI) maps* describe, in a general way, the expected level of liquefaction-induced ground deformation as represented by a numerical index known as the LPI.

**Table 6-2 Table 2 of the Simplified Seismic Assessment Form**

**Table 2. Assignment of Site as Being Within a Liquefaction Zone**

1. If site is in California, locate site on the California Emergency Management Agency (Cal EMA) MyPlan web site (myplan.calema.ca.gov).
    a. Enter address in 'Find Location' window.
    b. Select 'liquefaction' in menu bar to right of map.
    c. Zoom as needed to see map details.
    d. If site is located within green zone on map, answer to Question F-3 is 'yes'.
    e. If site located in non-liquefaction and non-seismic landslide zone on map (generally pale yellow), answer to Question F-3 is 'no'.
    f. Site not mapped if background is stippled. Go to Step (2).
2. If site is not on Cal EMA web site, determine site liquefaction potential/susceptibility using available web resources. See www.ATCouncil.org/pdfs/FEMAP-50LiquefactionInfo.pdf for a list of such resources. Map types shown in these web resources are:
    a. Liquefaction susceptibility maps. Answer to F-3 is 'yes' if site is in a zone of moderate-to-high liquefaction susceptibility. Answer is 'no' if in a low susceptibility or non-susceptible zone.
    b. Liquefaction potential maps. Answer to F-3 is 'yes' if site is in a liquefaction potential zone. Answer is 'no' if in a low or null potential zone.
    c. Liquefaction potential index (LPI) maps. Answer to F-3 is 'yes' if site is has mapped LPI ≥ 5 and no if mapped LPI < 5.
3. If the location of the site has not been mapped, Question F-3 can be answered as 'yes' if other local information suggests liquefaction potential and 'no' if such information suggests no such hazards.
4. If no maps are available and no information on site conditions is available, answer question F-2 as 'no'.

The type of map that is available to identify liquefaction hazards is regionally dependent, but liquefaction susceptibility and potential maps are the most common. Question F-3 should be answered as 'Yes' if the site is in a liquefaction susceptible zone (for Map Type 1), in a liquefaction potential zone (for Map Type 2) or in a zone with LPI > 5 (Map Type 3).

For sites that are in a liquefaction zone, the scoring depends on the ground shaking hazard potential. This is to account for the fact that liquefaction triggering is more likely, and its effects are more likely to be severe, when the ground shaking is strong. Two, three, or four points are assigned based on the ground shaking hazard points, as listed in Question F-4. Those ground failure hazard points are then entered as the response to Question F-6.

## 6.4 Seismic Landslide Hazards

Landslides caused by earthquakes can damage dwellings as a result of differential displacements beneath the foundations, or in some cases, earth materials impacting the structure.

Table 3 of the assessment form, repeated here as Table 6-3, describes the process by which the possible presence of seismic landslide hazards at a particular site can be identified. Two types of seismic landslide maps are most common. The first combines information on ground slope, geologic condi-

**Table 6-3 Table 3 of the Simplified Seismic Assessment Form**

**Table 3. Assignment of Site as Being Within a Seismic Landslide Zone**

1. If site is in California, attempt to locate site on the Cal EMA MyPlanweb site (myplan.calema.ca.gov).
    a. Enter address in 'Find Location' window.
    b. Select 'landslide' in menu bar to right of map.
    c. Zoom as needed to see map details.
    d. If site is located within brown zone on map, answer to Question F-3 is 'yes'.
    e. If site located in non-seismic landslide zone on map (generally pale yellow), answer to Question F-3 is 'no'.
    f. Site not mapped if background is stippled. Go to Step (2).
2. If site is not on Cal EMA web site, determine site landslide potential/susceptibility using available web resources. See www.ATCouncil.org/pdf/FEMAP-50LandslideInfo.pdf for a list of such resources. Map types shown in these web resources are:
    a. Seismic landslide susceptibility maps. Answer to F-3 is 'yes' if site is in a zone of moderate to high seismic landslide susceptibility. Answer is 'no' if in a low susceptibility or non-susceptible zone.
    b. Seismic landslide potential maps. Answer to F-3 is 'yes' if site is in a seismic landslide potential zone. Answer is 'no' if in a low or null potential zone.
3. If the location of the site has not been mapped, Question F-3 can be answered as 'yes' if other local information suggests high landslide potential and 'no' if such information suggests no such hazards (e.g., flat site).
4. If no maps are available and no information on site conditions is available, answer question F-2 as 'no'.

tions (used to infer shear strength), and ground shaking to identify zones of landslide hazard potential (e.g., Jibson et al., 2000). The second type of map is based principally on field mapping to identify locations where seismic landslide potential is judged to be high (often based on occurrence of past landslides).

The type of map that is available to identify seismic landslide hazards is regionally dependent, with landslide hazard potential maps (Map Type 1) being most common in California. Question F-3 should be answered as 'Yes' if the site is in a seismic landslide potential zone (Map Type 1) or a historic seismic landslide zone (for Map Type 2).

For sites that are in a seismic landslide zone, the scoring depends on the ground shaking hazard potential. This is to account for the fact that landslide hazards are more severe when the ground shaking is strong. Two, three, or four points are assigned based on the ground shaking hazard points, as listed in Question F-4. Those ground failure hazard points are then entered as the response to Question F-6.

## 6.5 Surface Fault Rupture Hazards

Surface fault rupture occurs when earthquake fault displacements extend to the ground surface, which is common for events of magnitude greater than about 7, but may or may not occur at lower magnitudes. Few dwellings are located over faults, so the potential for fault rupture beneath any single dwelling is low. However, when fault rupture occurs beneath a dwelling, the damage can be severe.

Table 4 of the assessment form, repeated here as Table 6-4, describes the process by which the presence of active faults, and therefore locations of potential surface rupture, near a dwelling can be identified. A primary source of information for California sites is the California Emergency Management Agency (Cal EMA) web site. As shown in Table 4, in California, fault rupture zones are mapped for faults that are active within Holocene time (within the last 10,000 years). Nationwide, the U. S. Geological Survey has prepared maps of faults active in Quaternary time (within the last 1.6 million years).

**Table 6-4 Table 4 of the Simplified Seismic Assessment Form**

**Table 4. Assignment of Site as Being Within a Surface Fault Rupture Zone**

1. If site is in California, locate site on the Cal EMA MyPlanweb site (myplan.calema.ca.gov).
    a. Enter address in ‘Find Location’ window.
    b. Select ‘Fault Lines’ in menu bar to right of map.
    c. Zoom as needed to see map details.
    d. If site is located within gray zone on map, answer to Question F-5 is ‘yes’.
    e. If site located in non-gray zone, answer to Question F-5 is ‘no’.
    f. Site not mapped if background is stippled. Go to Step (2).
2. If site is not on Cal EMA web site, locate site using USGS Quaternary faults web site (http://geohazards.usgs.gov/qfaults/map.php).
    a. Select applicable state or region.
    b. Zoom in on site and determine whether site is near a Quaternary fault that has been active within 15,000 years (marked as red or yellow on map).
    c. Faults are only marked for map scales marked at the 1 km (or larger) level. At this level of zoom, Question F-5 can be answered as ‘yes’ if the mapped fault trace is within approximately 0.25 km of the site and ‘no’ otherwise.

Question F-5 should be answered as ‘Yes’, and two ground failure hazard points entered as the response to Question F-6, if the dwelling is in a California fault rupture hazard zone or within about 250 m of a Quaternary fault active within the past 15,000 years for locations elsewhere in the United States. Note that this question (F-5) is skipped if the dwelling has already been deemed to be located in a liquefaction or landslide zone. In that case, any additional ground failure hazard associated with fault rupture is considered to be negligible.

## 6.6 Total Regional Seismic Hazard Points

The inspector sums the seismic hazard points from ground shaking (F-1) and ground failure (F-6) to determine the Seismic Hazard Score. The sum is entered in the box provided in Section F and in the appropriate box in Section G.

## 6.7 Hazards Not Considered

There are other less probable hazards associated with earthquakes that have not been addressed in this form. These include flooding due to dam failures or to seiche, lurching of softer soil, tsunami inundation, and the release of toxic materials. The losses from these sources are considered remote and difficult to quantify for a specific dwelling.

## Chapter 7

# Seismic Performance Grade

Section G of the Simplified Seismic Assessment Form (Figure 7-1) is used to determine the Seismic Performance Grade, which depends on the Structural Score and the Seismic Hazard Score. The first step is to compute the Structural Score and the second is to combine that score with the Seismic Hazard Score to determine the Seismic Performance Grade.

### 7.1 Determination of Structural Score

The Structural Score is calculated by (1) inserting the penalty points from Sections A through E in the spaces provided in item 1 of Section G, (2) summing the penalties and inserting the sum in the first box, and (3) subtracting this sum of all penalty points from 100 and inserting the difference in the second box. The higher the Structural Score, the better the dwelling is expected to perform in future earthquakes.

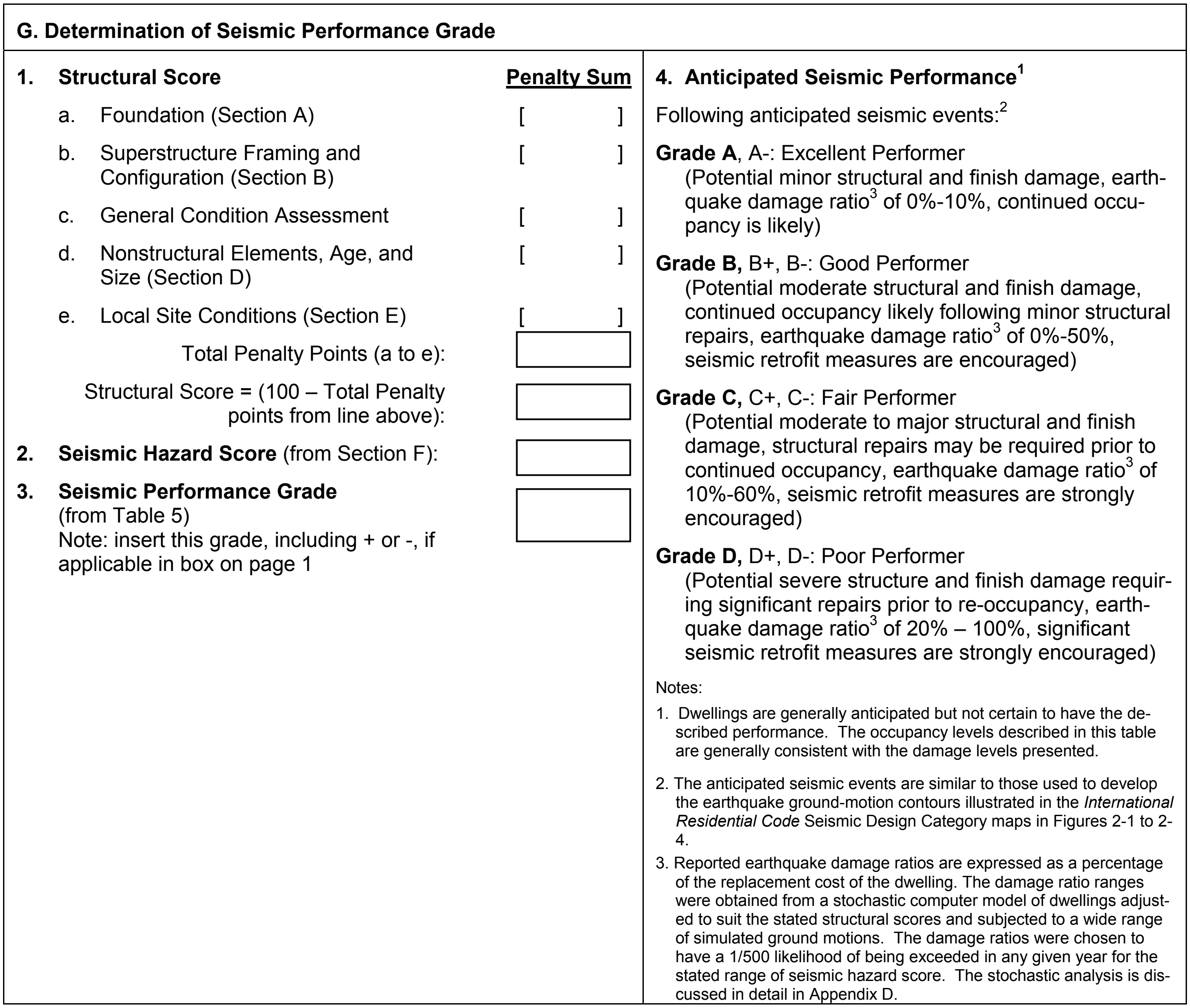
### 7.2 Determination of Seismic Hazard Score

The Seismic Hazard Score is taken from the Total Seismic Hazard Score box of Section F and inserted in the third box in Section G.

### 7.3 Determination of Seismic Performance Grade

The Seismic Performance Grade is determined from Table 5 on the form, reproduced here as Table 7-1. The grade for a given dwelling is determined by (a) finding the row that includes the Structural Score, (b) finding the column that includes the Seismic Hazard Score, and (c) identifying the cell that is the intersection of the row and column from items a and b above. The Seismic Performance Grade printed in this cell is recorded in the large box in Section G and also in the box on page 1 of the form in the upper right-hand corner.

The grade provides important information to the homeowner regarding the earthquake vulnerability of the dwelling. With one exception (an A+ grade is not possible), grades are subdivided to include "+" and "-" descriptors that indicate the dwelling is expected to incur damage at the higher and lower ends, respectively, of the damage range for that grade. Qualitative and quantitative definitions for the various grades are provided in Section 2.4. Section G of the form contains a condensed version of these definitions.



**G. Determination of Seismic Performance Grade**

| | | **Penalty Sum** |
|---|---|---|
| **1.** | **Structural Score** | |
| a. | Foundation (Section A) | [ ] |
| b. | Superstructure Framing and Configuration (Section B) | [ ] |
| c. | General Condition Assessment | [ ] |
| d. | Nonstructural Elements, Age, and Size (Section D) | [ ] |
| e. | Local Site Conditions (Section E) | [ ] |
| | Total Penalty Points (a to e): | ☐ |
| | Structural Score = (100 – Total Penalty points from line above): | ☐ |
| **2.** | **Seismic Hazard Score** (from Section F): | ☐ |
| **3.** | **Seismic Performance Grade** (from Table 5)<br>Note: insert this grade, including + or -, if applicable in box on page 1 | ☐ |

**4. Anticipated Seismic Performance**[1]

Following anticipated seismic events:[2]

**Grade A**, A-: Excellent Performer
(Potential minor structural and finish damage, earthquake damage ratio[3] of 0%-10%, continued occupancy is likely)

**Grade B,** B+, B-: Good Performer
(Potential moderate structural and finish damage, continued occupancy likely following minor structural repairs, earthquake damage ratio[3] of 0%-50%, seismic retrofit measures are encouraged)

**Grade C,** C+, C-: Fair Performer
(Potential moderate to major structural and finish damage, structural repairs may be required prior to continued occupancy, earthquake damage ratio[3] of 10%-60%, seismic retrofit measures are strongly encouraged)

**Grade D,** D+, D-: Poor Performer
(Potential severe structure and finish damage requiring significant repairs prior to re-occupancy, earthquake damage ratio[3] of 20% – 100%, significant seismic retrofit measures are strongly encouraged)

Notes:

1. Dwellings are generally anticipated but not certain to have the described performance. The occupancy levels described in this table are generally consistent with the damage levels presented.
2. The anticipated seismic events are similar to those used to develop the earthquake ground-motion contours illustrated in the *International Residential Code* Seismic Design Category maps in Figures 2-1 to 2-4.
3. Reported earthquake damage ratios are expressed as a percentage of the replacement cost of the dwelling. The damage ratio ranges were obtained from a stochastic computer model of dwellings adjusted to suit the stated structural scores and subjected to a wide range of simulated ground motions. The damage ratios were chosen to have a 1/500 likelihood of being exceeded in any given year for the stated range of seismic hazard score. The stochastic analysis is discussed in detail in Appendix D.

Figure 7-1 Section G of the Simplified Seismic Assessment Form.

**Table 7-1 Table 5 of the Simplified Seismic Assessment Form**

**Table 5. Seismic Performance Grade Based on Structural Score and Regional Seismic Hazard Score**

| **Seismic Hazard Score** | | **0 - 1** | **2 - 3** | **4 - 5** | **6 - 7** | **8 - 10** | **11 - 12** |
|---|---|---|---|---|---|---|---|
| **Structural Score** | **1.0 - 45.9** | B- | C+ | C | D | D- | D- |
| | **46.0 - 64.9** | B+ | B | C+ | D+ | D | D- |
| | **65.0 - 74.9** | A- | B+ | B | C | C- | D+ |
| | **75.0 - 84.9** | A- | A- | B+ | B- | C | C |
| | **85.0 - 100** | A | A | A- | B+ | B | B- |

## Chapter 8

# Improving the Seismic Performance Grade

The purpose of Section H (see Figure 8-1) is to provide the homeowner with information that will assist in deciding if the dwelling should be seismically retrofitted. Initially the inspector should advise the homeowner that the Structural Score and the Seismic Performance Grade may possibly (1) be improved as a result of seismic retrofit or (2) be altered by a more in-depth seismic evaluation of the dwelling and the site by a qualified licensed design professional.

### 8.1 Effect of Seismic Retrofit on the Structural Score

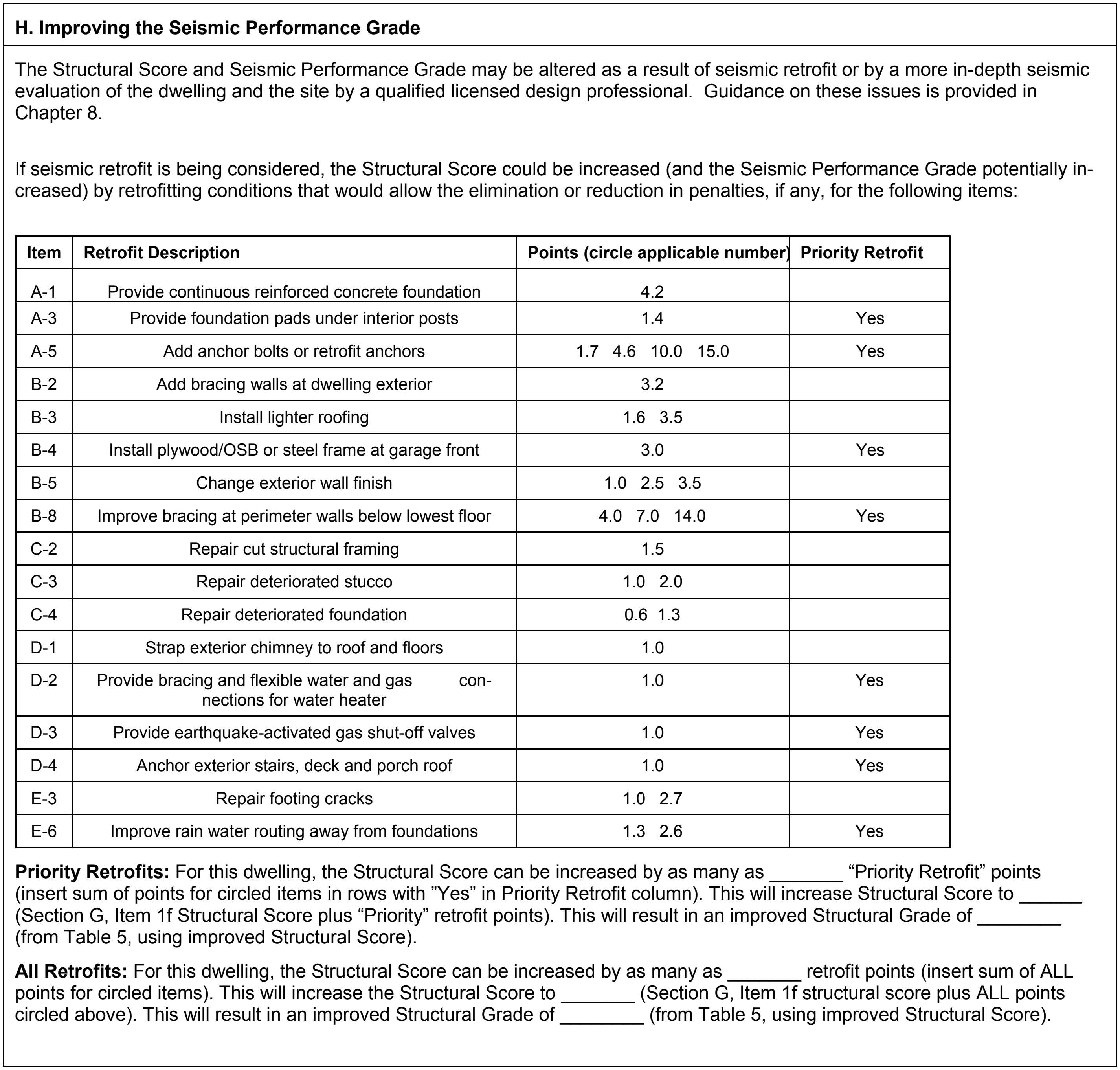
Seismic retrofit undertaken in response to the findings of a FEMA P-50 simplified seismic assessment translates directly into reduced penalty points and an increased Structural Score. Retrofit can significantly improve the Structural Score.

In Section H the inspector tallies the penalty points that can be regained through retrofit (items denoted with an asterisk (*) in Sections A through E). In many cases the full number of penalty points assigned by the assessment form can be regained.

The total number of penalty points that can be regained through seismic retrofit is inserted in the spaces provided at the bottom of Section H. The regained penalty points identified in Section H are added to the Structural Score from the second box in Section G, and the improved Structural Performance Grade with retrofit based on the improved Structural Score with retrofit is determined from Table 5.

This process is performed twice in Section H; one time for priority retrofit items (indicated as a priority with a "yes" in the right-hand column) and a second time for all retrofit items (summing all circled points in Section H). Items are identified as priority based on expert opinion that they involve a moderate cost and high benefit-to-cost ratio.

In some cases, it may not be possible to increase the Seismic Performance Grade by seismic retrofit. Regardless of improvement to the Structural Score,



**H. Improving the Seismic Performance Grade**

The Structural Score and Seismic Performance Grade may be altered as a result of seismic retrofit or by a more in-depth seismic evaluation of the dwelling and the site by a qualified licensed design professional. Guidance on these issues is provided in Chapter 8.

If seismic retrofit is being considered, the Structural Score could be increased (and the Seismic Performance Grade potentially increased) by retrofitting conditions that would allow the elimination or reduction in penalties, if any, for the following items:

| Item | Retrofit Description | Points (circle applicable number) | Priority Retrofit |
|---|---|---|---|
| A-1 | Provide continuous reinforced concrete foundation | 4.2 | |
| A-3 | Provide foundation pads under interior posts | 1.4 | Yes |
| A-5 | Add anchor bolts or retrofit anchors | 1.7 4.6 10.0 15.0 | Yes |
| B-2 | Add bracing walls at dwelling exterior | 3.2 | |
| B-3 | Install lighter roofing | 1.6 3.5 | |
| B-4 | Install plywood/OSB or steel frame at garage front | 3.0 | Yes |
| B-5 | Change exterior wall finish | 1.0 2.5 3.5 | |
| B-8 | Improve bracing at perimeter walls below lowest floor | 4.0 7.0 14.0 | Yes |
| C-2 | Repair cut structural framing | 1.5 | |
| C-3 | Repair deteriorated stucco | 1.0 2.0 | |
| C-4 | Repair deteriorated foundation | 0.6 1.3 | |
| D-1 | Strap exterior chimney to roof and floors | 1.0 | |
| D-2 | Provide bracing and flexible water and gas connections for water heater | 1.0 | Yes |
| D-3 | Provide earthquake-activated gas shut-off valves | 1.0 | Yes |
| D-4 | Anchor exterior stairs, deck and porch roof | 1.0 | Yes |
| E-3 | Repair footing cracks | 1.0 2.7 | |
| E-6 | Improve rain water routing away from foundations | 1.3 2.6 | Yes |

**Priority Retrofits:** For this dwelling, the Structural Score can be increased by as many as _______ "Priority Retrofit" points (insert sum of points for circled items in rows with "Yes" in Priority Retrofit column). This will increase Structural Score to ______ (Section G, Item 1f Structural Score plus "Priority" retrofit points). This will result in an improved Structural Grade of ________ (from Table 5, using improved Structural Score).

**All Retrofits:** For this dwelling, the Structural Score can be increased by as many as _______ retrofit points (insert sum of ALL points for circled items). This will increase the Structural Score to _______ (Section G, Item 1f structural score plus ALL points circled above). This will result in an improved Structural Grade of ________ (from Table 5, using improved Structural Score).

Figure 8-1 Section H of the Simplified Seismic Assessment Form.

seismic retrofit is still encouraged, and particularly for assessment items A-5 and B-8.

Consider an example from Appendix B. Example B.3 describes a dwelling with a Structural Score of 50.9. The two largest penalties come from assessment item A-5 (no foundation sill plate anchorage to the foundation) and assessment item B-8 (a cripple wall with no plywood or OSB sheathing). If these two items alone were remedied through seismic retrofit, the Structural Score would increase by 29 points, to 79.9.  If all priority items were retrofit, the Structural Score would increase by 31.3 points to 82.2. If the homeowner took advantage of all possible seismic retrofit opportunities, the Structural Score would rise by 38.6 points to 89.5.

## 8.2 Effect of Retrofit on the Seismic Performance Grade

Because the Seismic Performance Grade is dependent upon both the Structural Score and Seismic Hazard Score, and because the Seismic Hazard Score cannot usually be altered, the Seismic Performance Grade is generally improved as a result of an increase in the Structural Score. A large enough increase in the Structural Score moves the dwelling to a lower row of Table 5 (see Appendix A), and possibly to a higher grade.

Consider again the example in Section B.3. With the original Structural Score of 50.9, this results in a grade of D, which means that the dwelling is expected (not guaranteed) to be a poor performer, and is expected to experience severe damage in the anticipated seismic events, possibly being damaged beyond economical repair and needing to be demolished. If the cripple wall and anchor bolts are retrofit, the Seismic Performance Grade climbs to C, which means that the dwelling is expected (not guaranteed) to be a fair performer and to experience only minor to moderate damage in an earthquake.  If all possible deficiencies are retrofit, the grade becomes a B. In addition to reducing damage, Grade B dwellings can most likely be occupied after the earthquake, although they may need cosmetic and minor repairs.

## 8.3 Resources for Seismic Retrofit

The follow information identifies general resources and design provisions that provide guidance for retrofit of items identified on the assessment form.

General resource FEMA P-50-1, *Seismic Retrofit Guidelines for Detached, Single-Family, Wood-Frame Dwellings*, a companion to this FEMA P-50 publication, is a recommended starting point for those contemplating seismic retrofit. It covers a broad range of information ranging from fundamentals of wood-frame dwelling construction, retrofit strategies, hiring of licensed design professionals and contractors, and discussion on how to approach retrofit for each applicable assessment item. FEMA P-50-1 also discusses details of some retrofit measures.

Design provisions for retrofit fall into two general categories. The first category is prescriptive provisions, otherwise known as conventional construction. These are provisions that are detailed to a level such that design by an engineer or architect is not required. It is intended that both the design and construction can be performed by a contractor or possibly the homeowner. While not required, engineered provisions (discussed below) can sometimes improve performance or reduce retrofit cost.

The second category is engineered provisions. These require design by engineering methods and involvement of a qualified licensed design professional. When hiring a licensed design professional to provide engineered design, it is important that it is a professional that has experience in design of seismic retrofits for dwellings.

In addition to FEMA P-50-1, the following are resources of potential interest for those pursuing seismic retrofit:

**International Code Council Publications**

- The *International Existing Building Code* (IEBC), Appendix Chapter A-3, provides prescriptive design provisions for anchor bolts and cripple wall bracing.
- The *International Residential Code* (IRC) provides prescriptive provisions for new construction that can be adapted for retrofit.
- The *International Building Code* (IBC) provides engineered design guidance that can be applied to any retrofit.

**American Society of Civil Engineers Publication**

- S*eismic Rehabilitation of Existing Buildings* (ASCE-41) provides engineered design methodologies for seismic retrofit of all building types.

**FEMA Publications**

- FEMA G-225, *Seismic Retrofit Training for Building Contractors and Inspectors* provides training on the details of retrofit construction.
- FEMA P-593, *Seismic Rehabilitation Training for One- and Two-Family Dwellings* provides training to identify vulnerabilities and to design anchor bolting and bracing retrofit using prescriptive provisions http://www.fema.gov/library/viewRecord.do?id=4554
- FEMA E-74, *Reducing the Risks of Nonstructural Earthquake Damage***,** *A Practical Guide, Fourth Edition* (http://www.fema.gov/plan/prevent/ earthquake/fema74/index.shtm) provides retrofit guidance for a number of items addressed in Section D of the assessment form.

- FEMA 547, *Techniques for the Seismic Rehabilitation of Existing Buildings* provides guidance on engineered approaches to seismic retrofit http://www.fema.gov/library/viewRecord.do?id=2393

**Other State and Local Resources**

- California Department of General Services Division of the State Architect *Guidelines for Bracing of Residential Water Heaters* http://www.documents.dgs.ca.gov/dsa/pubs/waterheaterbracing_11_30_05.pdf
- City of Seattle *Earthquake Home Retrofit Handbook, How to Complete the Home Assessment Checklist* http://www.seattle.gov/emergency/library/mitigation/HR%20Book%202%20-%20assessment.pdf
- Association of Bay Area Governments (ABAG) *Standard Plan Set for Residential Seismic Retrofitting* http://www.abag.ca.gov/bayarea/eqmaps/fixit/plansets.html
- City of Los Angeles, Department of Building and Safety, Anchor Bolting/Bracing Foundation Plan, *Earthquake Hazard Reduction in Existing Wood Frame Residential Buildings With Weak Cripple Walls and Unbolted Sill Plates* http://www.ci.la.ca.us/ladbs/rpt_code_pub/anchor_bolting.pdf
- City of Los Angeles, Department of Building and Safety, Document No. P/BC 2008 070, *Reconstruction and Replacement of Earthquake Damaged Chimneys* http://ladbs.org/LADBSWeb/LADBS_Forms/InformationBulletins/IB-P-BC2008-070EQDamagedChimney.pdf

Other retrofit resources prepared by local jurisdictions are available. It is recommended that persons interested in retrofit contact the local building department to identify any locally available resources.

## 8.4 Reassessment of the Seismic Performance Grade

The Seismic Performance Grade on the Simplified Seismic Assessment Form can be reassessed and, if appropriate, revised as a result of further investigation by a qualified licensed design professional.  The process of performing a further investigation to reassess the Seismic Performance Grade would be as follows: A homeowner has had the dwelling assessed and has been given a copy of the completed assessment form with the assigned Seismic Performance Grade. The homeowner believes the dwelling has better seismic resistance than indicated by the grade. The homeowner engages a qualified licensed design professional to perform further assessment of the dwelling, and revise as necessary the conditions selected for various assessment items on the Simplified Seismic Assessment Form. This assessment would be more comprehensive than done for original completion of the assessment form, and may include: review of available drawings and specifications from original construction, review of soils reports or soils testing, and removal of finish materials to observe hidden conditions. A revision to assigned penalty points can be made where existing construction is better understood or where existing construction overcomes the vulnerability assumed in the assessment form.

At the conclusion of this assessment, the design professional reviews the original assessment form and develops an engineering report indicating how penalty points for assessment items should be revised (eliminated or revised to penalty assignments that better reflect the observed conditions). The engineering report should contain a summary section that shows the penalty points for each assessment item on the assessment form, re-calculates the Structural Score or Seismic Hazard Score and assigns a new Seismic Performance Grade based on the further assessment. The engineering report with an attached copy of the original assessment form replaces the original form as a record of the assessment process. A licensed engineer or architect experienced in structural engineering can provide reassessment of the Structural Score. A licensed engineer experienced in geotechnical engineering can provide reassessment of the Seismic Hazard Score. See FEMA P-50-1 Chapter 4 for examples of reassessed items

## Chapter 9

# Implementing a Program of Simplified Seismic Assessment

Systematic implementation of a program for simplified seismic assessment of detached, single-family wood-frame dwellings, at the community or state-wide level, has the real potential for substantially reducing economic losses from moderate-to-major earthquakes. The beneficiaries extend beyond homeowners, who would be provided with important knowledge on the expected seismic performance of their dwellings as well as clear advice on seismic retrofit needs. Other beneficiaries of such a program would include those in the market place with a financial stake in the seismic performance of single family dwellings—lenders, landlords, insurers and local governmental entities.

Following are brief discussions on various issues relating to the implementation of simplified seismic assessment programs using the methodology and Simplified Seismic Assessment Form described in this document.

### 9.1 Role of Simplified Assessment in Seismic Loss Reduction

Perhaps the most important function of the Simplified Seismic Assessment Form is to provide individual homeowners with information about the expected seismic performance of their dwellings. Once advised of the outcome of simplified seismic assessment, in the form of a Seismic Performance Grade and the associated damage and economic loss descriptions, homeowners would be provided with either the comfort of knowing their home is expected to perform well in the next major earthquake, or in the case of lower ratings (grades), decide to retrofit their dwelling to improve its performance, obtain earthquake insurance, or both. Determination of a Seismic Performance Grade could also be relatively easily added to the scope of services provided by home inspectors during a property transaction.

Since mortgage lenders can be significantly exposed to default by a homeowner when a residence suffers disproportionate damage in an earthquake, the requirement that the seismic rating (Seismic Performance Grade) be above a designated threshold (e.g., B grade) could be used as one of the conditions for obtaining a mortgage loan.

The methodology could also be used by cities to rank their wood-frame dwelling inventory and to establish a seismic retrofitting program. For example, such a program could require that all D grade homes be upgraded to a specified higher grade.

While there may be some significant obstacles to treating the completed Simplified Seismic Assessment Form as an official record, it may be in the public interest to make official approval of permits for additions or alterations, or approval of a sale contingent on identifying or improving the Seismic Performance Grade.

## 9.2 Program Implementation

The ATC-50-2 report, *Safer at Home in Earthquakes: A Proposed Earthquake Safety Program* (ATC, 2007b), describes various program implementation options, including incentives and other market-making mechanisms, including roles for government and private organizations, to encourage voluntary simplified assessments and seismic retrofitting of homes to minimize loss of life and damage in future earthquakes.

In the current policy and economic environment, two paths towards potential widespread adoption of the Simplified Seismic Assessment Form have been identified:

1. Home inspectors can be encouraged to obtain training in the use of the form and offer it as a service to homeowners.
2. Mortgage lenders can be encouraged to ask for evaluations as a condition for obtaining a loan.

A seismic assessment program may also have utility for the earthquake insurance industry, with higher rated dwellings potentially eligible for a premium discount.

An informational campaign would help to engage these potential program audiences.

## 9.3 Qualifications of Inspectors

The primary qualification needed to perform simplified seismic assessment of detached, single-family, wood-frame dwellings is knowledge of the basics of wood-frame home construction, including familiarity with the building materials used and construction techniques. Some understanding of fundamental statics is also needed, as it relates to the structure's load path, load transfer, and lateral-load-resisting elements. Specific training in the methodology described in this report is also needed. It is likely that a one-day training seminar, with related field work, will be sufficient for those with the relevant background, such as home inspectors.

## 9.4 Field Inspections

The Simplified Seismic Assessment Form was designed so that all of the structural questions can be answered by visual inspection. There are some questions that will require items such as a flashlight or a tape measure. In addition , since observation of crawl spaces and attics will often be part of the inspection, knee pads, a dust mask and a step ladder may be necessary. A properly trained inspector likely can complete a simplified seismic assessment of a typical dwelling in approximately 60 minutes. Additional time will be required to determine the Seismic Hazard Score, with the amount of time dependent on how familiar the inspector is with the available seismic hazard information for the region.

## 9.5 Future Development of the Methodology

Future development of the methodology includes: (1) periodic updating of the existing Simplified Seismic Assessment Form to incorporate new seismic hazard data and dwelling seismic performance data, (2) improvements to facilitate implementation, such as new high-technology applications and other tools, (3) adaptation of the methodology to other regions, and (4) adaptation of the methodology to other similar structural types.

## Appendix A

# Simplified Seismic Assessment Form

# FEMA P-50 Simplified Seismic Assessment Form
# For Detached, Single-Family, Wood-Frame Dwellings

(Please print all information)

☐ **Grade**

Street Address ______ Community/Area/City ______ ZIP Code ______ Date ______

Owner ______ Inspector ______ Inspection Form # (optional) ______

For each question, circle only one answer. Circle the one with higher penalty if more than one answer applies. Exception: question B-1

## A. Foundation (If the dwelling has a crawl space, the inspector should view all the areas that are accessible.)

| | | Penalty |
|---|---|---|
| *A-1 | The exterior footing is: | |
| a. | continuous concrete or reinforced masonry | [0] |
| b. | other footing conditions | [4.2] |
| A-2 | The lowest floor of the dwelling is: | |
| a. | slab-on-grade | [0] |
| b. | wood framed over crawl space or basement | [2.9] |
| c. | combination of slab-on-grade and wood framed floor over crawl space or basement | [2.9] |
| *A-3 | At the dwelling crawlspace or basement interior, the lowest floor framing is supported on: | |
| a. | continuous stem walls or a combination of continuous stem walls and beams on posts bearing on concrete footings/piers | [0] |
| b. | beams on posts bearing on piers/pad footings | [0.8] |
| c. | beams on posts supported directly on soil | [2.2] |
| d. | not applicable: slab-on-grade | [0] |
| A-4 | For a foundation on a slope of 3 horizontal to 1 vertical or steeper, the top of the footing or foundation stem wall on which wall studs or posts are supported is: | |
| a. | sloped parallel to the ground slope | [3.7] |
| b. | stepped | [1.8] |
| c. | at a constant elevation with no steps | [0.6] |
| d. | not applicable | [0] |

| | | Penalty |
|---|---|---|
| *A-5 | At the dwelling perimeter walls, where the foundation system supports a wood framed floor: | |
| a. | the foundation sill plate (mudsill) is bolted to the foundation with average anchor bolt spacing of 72 in. or less | [0] |
| b. | the foundation sill plate is fastened to the foundation with retrofit anchors equivalent to 72 in. or less anchor bolt spacing | [0] |
| c. | the anchor bolts have average spacing that is > 72 in. but <= 108 in. | [1.7] |
| d. | the anchor bolts have > 108 in. average spacing | [4.6] |
| e. | the foundation sill plates have extensive decay, splitting, or inadequate edge distance at one-third or more of the anchor bolt locations such that significant slip of the sill plate could occur | [10.0] |
| f. | the anchor bolts have significant corrosion at one third or more of the anchor bolt locations such that significant slip of the sill plate could occur | [10.0] |
| g. | there are no foundation anchor bolts | [15.0] |
| h. | there are no foundation sill plates to connect to the foundation | [15.0] |
| i. | not applicable | [ 0 ] |
| | **Total** | ☐ |

## B. Superstructure Framing and Configuration (Every accessible area such as the attic and under-floor area that reveals structural elements must be inspected.)

| | | | Penalty |
|---|---|---|---|
| B-1 | The dwelling has: (circle all that apply, a to e) | | |
| a. | unsymmetrical wall strength (torsion problems) | yes | [1.6] |
| b. | reentrant corners (seen in plan view) | yes | [0.3] |
| c. | split-level floor construction | yes | [2.0] |
| d. | out-of-plane offsets of more than 4 ft. in exterior walls | yes | [0.4] |
| e. | non-orthogonal seismic resisting systems | yes | [0.6] |
| f. | none of the above, or built in accordance with 1994 UBC, 2000 IBC, 2000 IRC or later edition | yes | [0] |
| *B-2 | For exterior walls at the lowest occupied story, the summed length of full story height wall sections (between openings, excluding < 2'-8" panels) on any face is less than: | | |
| a. | 20% of the length of the wall, if a single story | yes | [3.2] |
| b. | 25% of the length of the wall, if two stories | yes | [3.2] |
| c. | 40% of the length of the wall, if three stories or more | yes | [3.2] |
| d. | none of the above | | [0] |
| *B-3 | If the roofing is heavy (i.e., clay or concrete tile) the dwelling is: | | |
| a. | single story | | [1.6] |
| b. | multi-story | | [3.5] |
| c. | not applicable: roofing is light. | | [0] |

| | | Penalty |
|---|---|---|
| *B-4 | For an attached garage with a second floor above, the narrow walls at the side of the garage door openings have: | |
| a. | wood structural panels on each narrow wall pier | [0] |
| b. | structural steel frames around or alongside the door | [0] |
| c. | prefabricated narrow shear walls, installed in accordance with manufacturer's recommendations | [0] |
| d. | none of the conditions specified in conditions a, b, or c above (that are visable) | [3.0] |
| e. | not applicable (single story) or built in accordance with 1997 UBC, 2000 IBC, 2000 IRC or later edition | [0] |
| *B-5 | The exterior wall covering is primarily: | |
| a. | siding known to be over plywood or OSB sheathing | [0] |
| b. | siding not known to be over plywood or OSB sheathing | [2.5] |
| c. | plywood (T1-11) or diagonal wood siding | [0] |
| d | stucco | [1.0] |
| e. | masonry veneer not more than 10 feet above the supporting foundation | [2.5] |
| f. | masonry veneer more than 10 feet above the supporting foundation | [3.5] |

*Assessment item that may be improved by seismic retrofit; **see page 6, Section H**

## B. Superstructure Framing and Configuration (Every accessible area such as the attic and under-floor area that reveals structural elements must be inspected.) *(continued)*

**Penalty**

B-6 There is evidence of interior remodeling that has removed interior walls: yes [1.0]
no/ not applicable [0]

B-7 The number of stories is:
- a. one (1) [0]
- b. two (2) [1.8]
- c. 3 or more [3.6]

*B-8 At the dwelling perimeter, the main lowest framed floor is supported on:
- a. beam and column (post-and-pier) system with no sheathed exterior walls [14.0]
- b. perimeter cripple walls with no plywood or OSB sheathing [14.0]
- c. original or retrofitted perimeter cripple walls with plywood or OSB sheathing where cripple walls are one story or less in height [1.0 ]
- d. original or retrofitted perimeter cripple walls with plywood or OSB sheathing where cripple walls are greater than one story in height [4.0]
- e. wood or steel diagonal braces not detailed in accordance with 1997 UBC, 2000 IBC or later edition [7.0]
- f. plywood or OSB sheathed perimeter skirt walls that do not extend to and anchor to the foundation [7.0]
- g. none of the above [0]

**Total**

## C. General Condition Assessment

**Penalty**

C-1 The overall condition of the dwelling is:
- a. good (essentially crack free, no moisture/water intrusion problems) [ 0 ]
- b. fair (minor wood decay and cracks) [1.0]
- c. poor (many cracks on interior and exterior, floor out-of-level and wood decay) [2.1]

*C-2 In the under floor area, there has been structural alteration (e.g. cutting or notching of framing for electrical, plumbing, mechanical equipment) that would affect the performance of the dwelling in an earthquake: yes [1.5]
no [0]
not applicable [0]

*C-3: There is evidence of: stucco detachment, bowing of stucco, corroded wire mesh, extensive cracking at finished grade above the bottom of the stucco:
- a. extensive [2.0]
- b. minor [1.0]
- c. none [0]

**Penalty**

*C-4 At the foundation level, there is:
- a. significant deterioration visible (corrosion, material breakdown) [1.3]
- b. some deterioration visible [0.6]
- c. no deterioration visible [0]

C-5 Throughout the dwelling, the quality of construction appears to be:
- a. good [0]
- b. average [0.8]
- c. poor [1.7]

**Total**

## D. Nonstructural Elements, Age, and Size

**Penalty**

*D-1 The chimney inspection revealed:
- a. properly connected anchor straps tying the masonry/concrete chimney(s) at side of house to the floor, ceiling and roof framing yes [1.0]
  no [2.0]
- b. chimney occurs at dwelling interior [1.0]
- c. dwelling has no masonry/concrete chimney [0]

*D-2 The gas water heater has effective anchor straps and water and gas connections: yes [0]
no [1.0]

The electric water heater has approved anchor straps: yes [0]
no [0.7]

*D-3 An earthquake-activated gas shut-off valve is installed: yes [0]
no [1.0]
not applicable [0]

**Penalty**

*D-4 The dwelling has exterior stairs, decks or porch roofs, without internal earthquake bracing, that are attached to the dwelling with:
- a. two or more connections tying the stair, deck or porch to the dwelling interior framing [0]
- b. nails or screws that would be loaded in withdrawal if the stair deck or porch moved away from the dwelling [1.0]
- c. other connection configurations [1.0]

D-5 The dwelling was built: (if remodel/added area >50% of total area, use addition date):
- a. before 1920 [3.0]
- b. 1921 to 1977 [2.0]
- c. 1978 to 1993 [1.0]
- d. 1994 or later [0]

D-6 The approximate total floor area (sq. ft.) of the dwelling and attached garage is:
- a. < 1600. [0]
- b. 1601 - 2500 [1.0]
- c. ≥ 2501 [2.0]

**Total**

*Assessment item that may be improved by seismic retrofit; **see page 6, Section H**

## E. Local Site Conditions

**Penalty**

E-1 The dwelling is located primarily on:
  a. a flat lot or slope (≤ 3:1) [0]
  b. steep slope (> 3:1) [3.0]

E-2 The dwelling is located on a cut-and-fill pad, which was developed:
  a. without a geotechnical investigation [2.7]
  b. with a geotechnical investigation [1.3]
  c. dwelling is *not* on cut-and-fill pad [0]

*E-3 The exterior concrete footing has:
  a. no visible cracks or a few minor cracks [0]
  b. minor cracks in several areas [1.0]
  c. extensive cracking [2.7]
  d. not applicable [0]

**Penalty**

E-4 The evidence of differential settlement in or around the dwelling is:
  a. extensive [2.5]
  b. minor [1.0]
  c. none visible [0]

E-5: The slope above or below the structure appears to be unstable:
  yes [3.2]
  no [0]
  not applicable [0]

*E-6: General condition of site drainage:
  a. roof gutters and downspouts collecting and conducting water away from foundation [0]
  b. water collecting at/near perimeter footing with no positive slope away from dwelling [2.6]
  c. no roof gutters but drainage appears to be adequate or roof gutters with downspouts that empty into splash blocks [1.3]

**Total** ☐

## F. Regional Seismic Hazard Score

F-1 Enter points for shaking hazard potential for location of dwelling (from Table 1). [ _____ ]

F-2 Are ground failure hazards to be looked up using Tables 2, 3, and 4? yes, go to F-3.
no, proceed to F-6 and enter 4.0 points for ground failure hazards

F-3 Is this dwelling located in a liquefaction zone (from Table 2) or landslide zone (from Table 3)? yes, go to F-4.
no, go to F-5.

F-4 Proceed to F-6 and enter ground failure hazard points in accordance with the following table:

| Ground Shaking Points | Ground Failure Points |
|---|---|
| 0 | 2 |
| 2, 4 | 3 |
| 6, 8 | 4 |

F-5 Is the dwelling located in a fault rupture zone (from Table 4)?
  yes [2]
  no [0]

F-6 Total ground failure points from F-2, F-4, or F-5 (no summation). [ _____ ]

**Total Seismic Hazard Score** (Sum of F-1 and F-6) ☐

### Table 1. Assignment of Ground Shaking Hazard Score

1. Use the USGS Seismic Design Maps Web Application (http://earthquake.usgs.gov/designmaps/usapp)[1] to look up ground shaking parameter $S_{DS}$:
   a. Press the ‘Launch Application’ button.
   b. In the web application, select ‘2012 IBC’ for the Building Code Reference Document.
   c. Select ‘Site Class D – “Stiff Soil” (Default)’ for the Site Soil Classification.
   d. Enter the site address or latitude and longitude.
   e. Press the ‘Compute Values’ button.
   f. Read parameter $S_{DS}$ from the summary report. Enter here: _______ g
   g. Multiply value from 1f by 100: ______%g
2. Using the value from 1g, assign ground shaking points according to the following table (these points are assigned in Item F-1):

| Value of $S_{DS}$ (% g) | Ground Shaking Hazard Points |
|---|---|
| 33 - 66.99 | 0 |
| 67 - 82.99 | 2 |
| 83 - 124.99 | 4 |
| 125 - 187.99 | 6 |
| 188 - 250 | 8 |

[1] Note:If you are using the USGS application for the first time, or have recently cleared your web browser cookies, you may have to register for immediate use. Also, if you are using an anti-virus software program, you may have to enable some links to this site, e.g., if you receive a message that says “only secure content is displayed, ”you must click on “show all content.”

* Assessment item that may be improved by seismic retrofit; **see page 6, Section H**

### Table 2. Assignment of Site as Being Within a Liquefaction Zone

1. If site is in California, locate site on the California Emergency Management Agency (Cal EMA) MyPlan web site (myplan.calema.ca.gov).
    a. Enter address in ‘Find Location’ window.
    b. Select ‘liquefaction’ in menu bar to right of map.
    c. Zoom as needed to see map details.
    d. If site is located within green zone on map, answer to Question F-3 is ‘yes’.
    e. If site located in non-liquefaction and non-seismic landslide zone on map (generally pale yellow), answer to Question F-3 is ‘no’.
    f. Site not mapped if background is stippled. Go to Step (2).
2. If site is not on Cal EMA web site, determine site liquefaction potential/susceptibility using available web resources. See www.ATCouncil.org/pdfs/FEMAP-50LiquefactionInfo.pdf for a list of such resources. Map types shown in these web resources are:
    a. Liquefaction susceptibility maps. Answer to F-3 is ‘yes’ if site is in a zone of moderate-to-high liquefaction susceptibility. Answer is ‘no’ if in a low susceptibility or non-susceptible zone.
    b. Liquefaction potential maps. Answer to F-3 is ‘yes’ if site is in a liquefaction potential zone. Answer is ‘no’ if in a low or null potential zone.
    c. Liquefaction potential index (LPI) maps. Answer to F-3 is ‘yes’ if site is has mapped LPI ≥ 5 and no if mapped LPI < 5.
3. If the location of the site has not been mapped, Question F-3 can be answered as ‘yes’ if other local information suggests liquefaction potential and ‘no’ if such information suggests no such hazards.
4. If no maps are available and no information on site conditions is available, answer question F-2 as ‘no’.

### Table 3. Assignment of Site as Being Within a Seismic Landslide Zone

1. If site is in California, attempt to locate site on the Cal EMA MyPlanweb site (myplan.calema.ca.gov).
    a. Enter address in ‘Find Location’ window.
    b. Select ‘landslide’ in menu bar to right of map.
    c. Zoom as needed to see map details.
    d. If site is located within brown zone on map, answer to Question F-3 is ‘yes’.
    e. If site located in non-seismic landslide zone on map (generally pale yellow), answer to Question F-3 is ‘no’.
    f. Site not mapped if background is stippled. Go to Step (2).
2. If site is not on Cal EMA web site, determine site landslide potential/susceptibility using available web resources. See www.ATCouncil.org/pdf/FEMAP-50LandslideInfo.pdf for a list of such resources. Map types shown in these web resources are:
    a. Seismic landslide susceptibility maps. Answer to F-3 is ‘yes’ if site is in a zone of moderate to high seismic landslide susceptibility. Answer is ‘no’ if in a low susceptibility or non-susceptible zone.
    b. Seismic landslide potential maps. Answer to F-3 is ‘yes’ if site is in a seismic landslide potential zone. Answer is ‘no’ if in a low or null potential zone.
3. If the location of the site has not been mapped, Question F-3 can be answered as ‘yes’ if other local information suggests high landslide potential and ‘no’ if such information suggests no such hazards (e.g., flat site).
4. If no maps are available and no information on site conditions is available, answer question F-2 as ‘No’.

### Table 4. Assignment of Site as Being Within a Surface Fault Rupture Zone

1. If site is in California, locate site on the Cal EMA MyPlanweb site (myplan.calema.ca.gov).
    a. Enter address in ‘Find Location’ window.
    b. Select ‘Fault Lines’ in menu bar to right of map.
    c. Zoom as needed to see map details.
    d. If site is located within gray zone on map, answer to Question F-5 is ‘yes’.
    e. If site located in non-gray zone, answer to Question F-5 is ‘no’.
    f. Site not mapped if background is stippled. Go to Step (2).
2. If site is not on Cal EMA web site, locate site using USGS Quaternary faults web site (http://geohazards.usgs.gov/qfaults/map.php).
    a. Select applicable state or region.
    b. Zoom in on site and determine whether site is near a Quaternary fault that has been active within 15,000 years (marked as red or yellow on map).
    c. Faults are only marked for map scales marked at the 1 km (or larger) level. At this level of zoom, Question F-5 can be answered as ‘yes’ if the mapped fault trace is within approximately 0.25 km of the site and ‘no’ otherwise.

**Table 5. Seismic Performance Grade Based on Structural Score and Regional Seismic Hazard Score**

| Seismic Hazard Score | | 0 - 1 | 2 - 3 | 4 - 5 | 6 - 7 | 8 - 10 | 11 - 12 |
|---|---|---|---|---|---|---|---|
| **Structural Score** | **1.0 - 45.9** | B- | C+ | C | D | D- | D- |
| | **46.0 - 64.9** | B+ | B | C+ | D+ | D | D- |
| | **65.0 - 74.9** | A- | B+ | B | C | C- | D+ |
| | **75.0 - 84.9** | A- | A- | B+ | B- | C | C |
| | **85.0 - 100** | A | A | A- | B+ | B | B- |

## G. Determination of Seismic Performance Grade

1. **Structural Score** **Penalty Sum**

a. Foundation (Section A) [ ]

b. Superstructure Framing and Configuration (Section B) [ ]

c. General Condition Assessment [ ]

d. Nonstructural Elements, Age, and Size (Section D) [ ]

e. Local Site Conditions (Section E) [ ]

Total Penalty Points (a to e): ☐

Structural Score = (100 – Total Penalty points from line above): ☐

2. **Seismic Hazard Score** (from Section F): ☐

3. **Seismic Performance Grade** (from Table 5) ☐
Note: insert this grade, including + or -, if applicable in box on page 1

4. **Anticipated Seismic Performance**[1]

Following anticipated seismic events:[2]

**Grade A**, A-: Excellent Performer
(Potential minor structural and finish damage, earthquake damage ratio[3] of 0%-10%, continued occupancy is likely)

**Grade B,** B+, B-: Good Performer
(Potential moderate structural and finish damage, continued occupancy likely following minor structural repairs, earthquake damage ratio[3] of 0%-50%, seismic retrofit measures are encouraged)

**Grade C,** C+, C-: Fair Performer
(Potential moderate to major structural and finish damage, structural repairs may be required prior to continued occupancy, earthquake damage ratio[3] of 10%-60%, seismic retrofit measures are strongly encouraged)

**Grade D,** D+, D-: Poor Performer
(Potential severe structure and finish damage requiring significant repairs prior to re-occupancy, earthquake damage ratio[3] of 20% – 100%, significant seismic retrofit measures are strongly encouraged)

Notes:

1. Dwellings are generally anticipated but not certain to have the described performance. The occupancy levels described in this table are generally consistent with the damage levels presented.

2. The anticipated seismic events are similar to those used to develop the earthquake ground-motion contours illustrated in the *International Residential Code* Seismic Design Category maps in Figures 2-1 to 2-4.

3. Reported earthquake damage ratios are expressed as a percentage of the replacement cost of the dwelling. The damage ratio ranges were obtained from a stochastic computer model of dwellings adjusted to suit the stated structural scores and subjected to a wide range of simulated ground motions. The damage ratios were chosen to have a 1/500 likelihood of being exceeded in any given year for the stated range of seismic hazard score. The stochastic analysis is discussed in detail in Appendix D.

## H. Improving the Seismic Performance Grade

The Structural Score and Seismic Performance Grade may be altered as a result of seismic retrofit or by a more in-depth seismic evaluation of the dwelling and the site by a qualified licensed design professional. Guidance on these issues is provided in Chapter 8.

If seismic retrofit is being considered, the Structural Score could be increased (and the Seismic Performance Grade potentially increased) by retrofitting conditions that would allow the elimination or reduction in penalties, if any, for the following items:

| Item | Retrofit Description | Points (circle applicable number) | Priority Retrofit |
|---|---|---|---|
| A-1 | Provide continuous reinforced concrete foundation | 4.2 | |
| A-3 | Provide foundation pads under interior posts | 1.4 | Yes |
| A-5 | Add anchor bolts or retrofit anchors | 1.7 4.6 10.0 15.0 | Yes |
| B-2 | Add bracing walls at dwelling exterior | 3.2 | |
| B-3 | Install lighter roofing | 1.6 3.5 | |
| B-4 | Install plywood/OSB or steel frame at garage front | 3.0 | Yes |
| B-5 | Change exterior wall finish | 1.0 2.5 3.5 | |
| B-8 | Improve bracing at perimeter walls below lowest floor | 4.0 7.0 14.0 | Yes |
| C-2 | Repair cut structural framing | 1.5 | |
| C-3 | Repair deteriorated stucco | 1.0 2.0 | |
| C-4 | Repair deteriorated foundation | 0.6 1.3 | |
| D-1 | Strap exterior chimney to roof and floors | 1.0 | |
| D-2 | Provide bracing and flexible water and gas connections for water heater | 1.0 | Yes |
| D-3 | Provide earthquake-activated gas shut-off valves | 1.0 | Yes |
| D-4 | Anchor exterior stairs, deck and porch roof | 1.0 | Yes |
| E-3 | Repair footing cracks | 1.0 2.7 | |
| E-6 | Improve rain water routing away from foundations | 1.3 2.6 | Yes |

**Priority Retrofits:** For this dwelling, the Structural Score can be increased by as many as _______ "Priority Retrofit" points (insert sum of points for circled items in rows with "Yes" in Priority Retrofit column). This will increase Structural Score to ______ (Section G, Item 1f Structural Score plus "Priority" retrofit points). This will result in an improved Structural Grade of ________ (from Table 5, using improved Structural Score).

**All Retrofits:** For this dwelling, the Structural Score can be increased by as many as _______ retrofit points (insert sum of ALL points for circled items). This will increase the Structural Score to _______ (Section G, Item 1f structural score plus ALL points circled above). This will result in an improved Structural Grade of ________ (from Table 5, using improved Structural Score).

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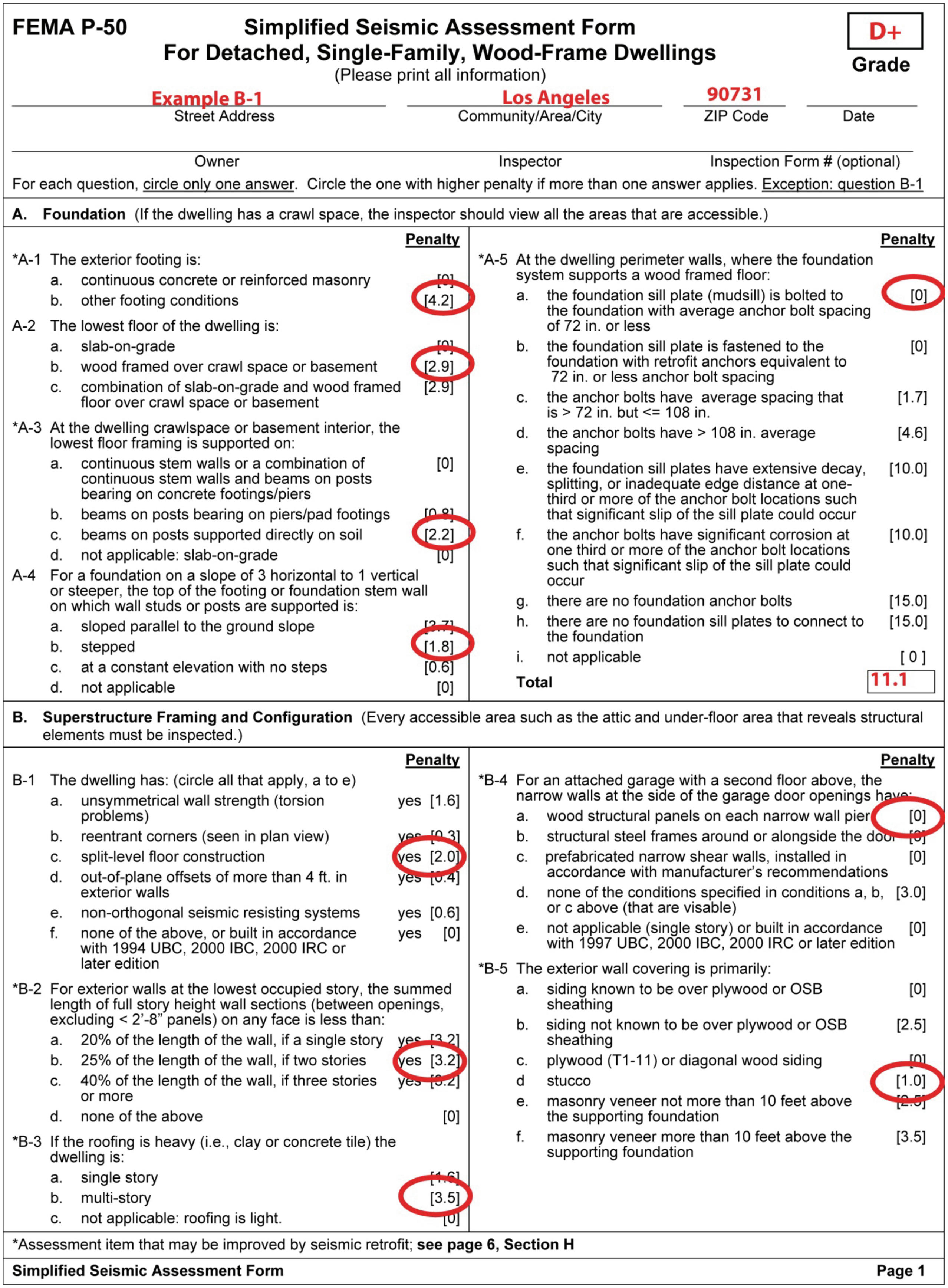
## Appendix B

# Examples Using the Simplified Seismic Assessment Form

### Example B.1: Hillside Home

### Location: Los Angeles, California 90731

This house is a hillside home located on a steep slope. The house is approximately 37 years old with split-level floors and several other irregularities. Despite the presence of anchor bolts at the foundation, there are many other penalized elements in the dwelling.



**FEMA P-50**

## Simplified Seismic Assessment Form For Detached, Single-Family, Wood-Frame Dwellings

(Please print all information)

D+
**Grade**

Example B-1
Street Address

Los Angeles
Community/Area/City

90731
ZIP Code

Date

Owner

Inspector

Inspection Form # (optional)

For each question, circle only one answer. Circle the one with higher penalty if more than one answer applies. Exception: question B-1

### A. Foundation (If the dwelling has a crawl space, the inspector should view all the areas that are accessible.)

**Penalty**

*A-1 The exterior footing is:
- a. continuous concrete or reinforced masonry [0]
- b. other footing conditions [✓ [4.2]]

A-2 The lowest floor of the dwelling is:
- a. slab-on-grade [0]
- b. wood framed over crawl space or basement [✓ [2.9]]
- c. combination of slab-on-grade and wood framed floor over crawl space or basement [2.9]

*A-3 At the dwelling crawlspace or basement interior, the lowest floor framing is supported on:
- a. continuous stem walls or a combination of continuous stem walls and beams on posts bearing on concrete footings/piers [0]
- b. beams on posts bearing on piers/pad footings [0.8]
- c. beams on posts supported directly on soil [✓ [2.2]]
- d. not applicable: slab-on-grade [0]

A-4 For a foundation on a slope of 3 horizontal to 1 vertical or steeper, the top of the footing or foundation stem wall on which wall studs or posts are supported is:
- a. sloped parallel to the ground slope [3.7]
- b. stepped [✓ [1.8]]
- c. at a constant elevation with no steps [0.6]
- d. not applicable [0]

**Penalty**

*A-5 At the dwelling perimeter walls, where the foundation system supports a wood framed floor:
- a. the foundation sill plate (mudsill) is bolted to the foundation with average anchor bolt spacing of 72 in. or less [✓ [0]]
- b. the foundation sill plate is fastened to the foundation with retrofit anchors equivalent to 72 in. or less anchor bolt spacing [0]
- c. the anchor bolts have average spacing that is > 72 in. but <= 108 in. [1.7]
- d. the anchor bolts have > 108 in. average spacing [4.6]
- e. the foundation sill plates have extensive decay, splitting, or inadequate edge distance at one-third or more of the anchor bolt locations such that significant slip of the sill plate could occur [10.0]
- f. the anchor bolts have significant corrosion at one third or more of the anchor bolt locations such that significant slip of the sill plate could occur [10.0]
- g. there are no foundation anchor bolts [15.0]
- h. there are no foundation sill plates to connect to the foundation [15.0]
- i. not applicable [ 0 ]

**Total** 11.1

### B. Superstructure Framing and Configuration (Every accessible area such as the attic and under-floor area that reveals structural elements must be inspected.)

**Penalty**

B-1 The dwelling has: (circle all that apply, a to e)
- a. unsymmetrical wall strength (torsion problems) yes [1.6]
- b. reentrant corners (seen in plan view) yes [0.3]
- c. split-level floor construction [✓ yes [2.0]]
- d. out-of-plane offsets of more than 4 ft. in exterior walls yes [0.4]
- e. non-orthogonal seismic resisting systems yes [0.6]
- f. none of the above, or built in accordance with 1994 UBC, 2000 IBC, 2000 IRC or later edition yes [0]

*B-2 For exterior walls at the lowest occupied story, the summed length of full story height wall sections (between openings, excluding < 2'-8" panels) on any face is less than:
- a. 20% of the length of the wall, if a single story yes [3.2]
- b. 25% of the length of the wall, if two stories [✓ yes [3.2]]
- c. 40% of the length of the wall, if three stories or more yes [3.2]
- d. none of the above [0]

*B-3 If the roofing is heavy (i.e., clay or concrete tile) the dwelling is:
- a. single story [1.6]
- b. multi-story [✓ [3.5]]
- c. not applicable: roofing is light. [0]

**Penalty**

*B-4 For an attached garage with a second floor above, the narrow walls at the side of the garage door openings have:
- a. wood structural panels on each narrow wall pier [✓ [0]]
- b. structural steel frames around or alongside the door [0]
- c. prefabricated narrow shear walls, installed in accordance with manufacturer's recommendations [0]
- d. none of the conditions specified in conditions a, b, or c above (that are visable) [3.0]
- e. not applicable (single story) or built in accordance with 1997 UBC, 2000 IBC, 2000 IRC or later edition [0]

*B-5 The exterior wall covering is primarily:
- a. siding known to be over plywood or OSB sheathing [0]
- b. siding not known to be over plywood or OSB sheathing [2.5]
- c. plywood (T1-11) or diagonal wood siding [0]
- d stucco [✓ [1.0]]
- e. masonry veneer not more than 10 feet above the supporting foundation [2.5]
- f. masonry veneer more than 10 feet above the supporting foundation [3.5]

*Assessment item that may be improved by seismic retrofit; **see page 6, Section H**

**Simplified Seismic Assessment Form** **Page 1**

## B. Superstructure Framing and Configuration (Every accessible area such as the attic and under-floor area that reveals structural elements must be inspected.) *(continued)*

**Penalty**

B-6 There is evidence of interior remodeling that has removed interior walls:
yes [1.0]
[✓ no/ not applicable [0]]

B-7 The number of stories is:
- a. one (1) [0]
- b. two (2) [1.8]
- [✓ c. 3 or more [3.6]]

*B-8 At the dwelling perimeter, the main lowest framed floor is supported on:
- a. beam and column (post-and-pier) system with no sheathed exterior walls [14.0]
- [✓ b. perimeter cripple walls with no plywood or OSB sheathing [14.0]]
- c. original or retrofitted perimeter cripple walls with plywood or OSB sheathing where cripple walls are one story or less in height [1.0 ]
- d. original or retrofitted perimeter cripple walls with plywood or OSB sheathing where cripple walls are greater than one story in height [4.0]
- e. wood or steel diagonal braces not detailed in accordance with 1997 UBC, 2000 IBC or later edition [7.0]
- f. plywood or OSB sheathed perimeter skirt walls that do not extend to and anchor to the foundation [7.0]
- g. none of the above [0]

**Total** 27.3

## C. General Condition Assessment

**Penalty**

C-1 The overall condition of the dwelling is:
- a. good (essentially crack free, no moisture/water intrusion problems) [ 0 ]
- [✓ b. fair (minor wood decay and cracks) [1.0]]
- c. poor (many cracks on interior and exterior, floor out-of-level and wood decay) [2.1]

*C-2 In the under floor area, there has been structural alteration (e.g. cutting or notching of framing for electrical, plumbing, mechanical equipment) that would affect the performance of the dwelling in an earthquake:
yes [1.5]
[✓ no [0]]
not applicable [0]

*C-3: There is evidence of: stucco detachment, bowing of stucco, corroded wire mesh, extensive cracking at finished grade above the bottom of the stucco:
- a. extensive [2.0]
- b. minor [1.0]
- [✓ c. none [0]]

**Penalty**

*C-4 At the foundation level, there is:
- a. significant deterioration visible (corrosion, material breakdown) [1.3]
- b. some deterioration visible [0.6]
- [✓ c. no deterioration visible [0]]

C-5 Throughout the dwelling, the quality of construction appears to be:
- a. good [0]
- [✓ b. average [0.8]]
- c. poor [1.7]

**Total** 1.8

## D. Nonstructural Elements, Age, and Size

**Penalty**

*D-1 The chimney inspection revealed:
- a. properly connected anchor straps tying the masonry/concrete chimney(s) at side of house to the floor, ceiling and roof framing
  yes [1.0]
  [✓ no [2.0]]
- b. chimney occurs at dwelling interior [1.0]
- c. dwelling has no masonry/concrete chimney [0]

*D-2 The gas water heater has effective anchor straps and water and gas connections:
[✓ yes [0]]
no [1.0]

The electric water heater has approved anchor straps:
yes [0]
no [0.7]

*D-3 An earthquake-activated gas shut-off valve is installed:
yes [0]
[✓ no [1.0]]
not applicable [0]

**Penalty**

*D-4 The dwelling has exterior stairs, decks or porch roofs, without internal earthquake bracing, that are attached to the dwelling with:
- [✓ a. two or more connections tying the stair, deck or porch to the dwelling interior framing [0]]
- b. nails or screws that would be loaded in withdrawal if the stair deck or porch moved away from the dwelling [1.0]
- c. other connection configurations [1.0]

D-5 The dwelling was built: (if remodel/added area >50% of total area, use addition date):
- a. before 1920 [3.0]
- b. 1921 to 1977 [2.0]
- [✓ c. 1978 to 1993 [1.0]]
- d. 1994 or later [0]

D-6 The approximate total floor area (sq. ft.) of the dwelling and attached garage is:
- a. < 1600. [0]
- b. 1601 - 2500 [1.0]
- [✓ c. ≥ 2501 [2.0]]

**Total** 6.0

*Assessment item that may be improved by seismic retrofit; **see page 6, Section H**

**Simplified Seismic Assessment Form** **Page 2**

## E. Local Site Conditions

**Penalty**

E-1 The dwelling is located primarily on:
- a. a flat lot or slope (≤ 3:1) [✓ [0]]
- b. steep slope (> 3:1) [3.0]

E-2 The dwelling is located on a cut-and-fill pad, which was developed:
- a. without a geotechnical investigation [2.7]
- b. with a geotechnical investigation [✓ [1.3]]
- c. dwelling is *not* on cut-and-fill pad [0]

*E-3 The exterior concrete footing has:
- a. no visible cracks or a few minor cracks [✓ [0]]
- b. minor cracks in several areas [1.0]
- c. extensive cracking [2.7]
- d. not applicable [0]

**Penalty**

E-4 The evidence of differential settlement in or around the dwelling is:
- a. extensive [2.5]
- b. minor [1.0]
- c. none visible [✓ [0]]

E-5: The slope above or below the structure appears to be unstable:
- yes [3.2]
- [✓ no [0]]
- not applicable [0]

*E-6: General condition of site drainage:
- a. roof gutters and downspouts collecting and conducting water away from foundation [✓ [0]]
- b. water collecting at/near perimeter footing with no positive slope away from dwelling [2.6]
- c. no roof gutters but drainage appears to be adequate or roof gutters with downspouts that empty into splash blocks [1.3]

**Total** 1.3

## F. Regional Seismic Hazard Score

F-1 Enter points for shaking hazard potential for location of dwelling (from Table 1). [ 4 ]

F-2 Are ground failure hazards to be looked up using Tables 2, 3, and 4?
- [✓ yes,] go to F-3.
- no, proceed to F-6 and enter 4.0 points for ground failure hazards

F-3 Is this dwelling located in a liquefaction zone (from Table 2) or landslide zone (from Table 3)?
- yes, go to F-4.
- [✓ no,] go to F-5.

F-4 Proceed to F-6 and enter ground failure hazard points in accordance with the following table:

| Ground Shaking Points | Ground Failure Points |
|---|---|
| 0 | 2 |
| 2, 4 | 3 |
| 6, 8 | 4 |

F-5 Is the dwelling located in a fault rupture zone (from Table 4)?
- [✓ yes [2]]
- no [0]

F-6 Total ground failure points from F-2, F-4, or F-5 (no summation). [ 2 ]

**Total Seismic Hazard Score** (Sum of F-1 and F-6) 6

### Table 1. Assignment of Ground Shaking Hazard Score

1. Use the USGS Seismic Design Maps Web Application (http://earthquake.usgs.gov/designmaps/usapp)[1] to look up ground shaking parameter $S_{DS}$:
   - a. Press the ‘Launch Application’ button.
   - b. In the web application, select ‘2012 IBC’ for the Building Code Reference Document.
   - c. Select ‘Site Class D – “Stiff Soil” (Default)’ for the Site Soil Classification.
   - d. Enter the site address or latitude and longitude.
   - e. Press the ‘Compute Values’ button.
   - f. Read parameter $S_{DS}$ from the summary report. Enter here: 1.03 g
   - g. Multiply value from 1f by 100: 103 %g
2. Using the value from 1g, assign ground shaking points according to the following table (these points are assigned in Item F-1):

| Value of $S_{DS}$ (% g) | Ground Shaking Hazard Points |
|---|---|
| 33 - 66.99 | 0 |
| 67 - 82.99 | 2 |
| 83 - 124.99 | [✓ 4] |
| 125 - 187.99 | 6 |
| 188 - 250 | 8 |

[1] Note:If you are using the USGS application for the first time, or have recently cleared your web browser cookies, you may have to register for immediate use. Also, if you are using an anti-virus software program, you may have to enable some links to this site, e.g., if you receive a message that says “only secure content is displayed, ”you must click on “show all content.”

* Assessment item that may be improved by seismic retrofit; **see page 6, Section H**

### Table 2. Assignment of Site as Being Within a Liquefaction Zone

1. If site is in California, locate site on the California Emergency Management Agency (Cal EMA) MyPlan web site (myplan.calema.ca.gov).
    a. Enter address in ‘Find Location’ window.
    b. Select ‘liquefaction’ in menu bar to right of map.
    c. Zoom as needed to see map details.
    d. If site is located within green zone on map, answer to Question F-3 is ‘yes’.
    e. If site located in non-liquefaction and non-seismic landslide zone on map (generally pale yellow), answer to Question F-3 is ‘no’.
    f. Site not mapped if background is stippled. Go to Step (2).
2. If site is not on Cal EMA web site, determine site liquefaction potential/susceptibility using available web resources. See www.ATCouncil.org/pdfs/FEMAP-50LiquefactionInfo.pdf for a list of such resources. Map types shown in these web resources are:
    a. Liquefaction susceptibility maps. Answer to F-3 is ‘yes’ if site is in a zone of moderate-to-high liquefaction susceptibility. Answer is ‘no’ if in a low susceptibility or non-susceptible zone.
    b. Liquefaction potential maps. Answer to F-3 is ‘yes’ if site is in a liquefaction potential zone. Answer is ‘no’ if in a low or null potential zone.
    c. Liquefaction potential index (LPI) maps. Answer to F-3 is ‘yes’ if site is has mapped LPI ≥ 5 and no if mapped LPI < 5.
3. If the location of the site has not been mapped, Question F-3 can be answered as ‘yes’ if other local information suggests liquefaction potential and ‘no’ if such information suggests no such hazards.
4. If no maps are available and no information on site conditions is available, answer question F-2 as ‘no’.

### Table 3. Assignment of Site as Being Within a Seismic Landslide Zone

1. If site is in California, attempt to locate site on the Cal EMA MyPlanweb site (myplan.calema.ca.gov).
    a. Enter address in ‘Find Location’ window.
    b. Select ‘landslide’ in menu bar to right of map.
    c. Zoom as needed to see map details.
    d. If site is located within brown zone on map, answer to Question F-3 is ‘yes’.
    e. If site located in non-seismic landslide zone on map (generally pale yellow), answer to Question F-3 is ‘no’.
    f. Site not mapped if background is stippled. Go to Step (2).
2. If site is not on Cal EMA web site, determine site landslide potential/susceptibility using available web resources. See www.ATCouncil.org/pdf/FEMAP-50LandslideInfo.pdf for a list of such resources. Map types shown in these web resources are:
    a. Seismic landslide susceptibility maps. Answer to F-3 is ‘yes’ if site is in a zone of moderate to high seismic landslide susceptibility. Answer is ‘no’ if in a low susceptibility or non-susceptible zone.
    b. Seismic landslide potential maps. Answer to F-3 is ‘yes’ if site is in a seismic landslide potential zone. Answer is ‘no’ if in a low or null potential zone.
3. If the location of the site has not been mapped, Question F-3 can be answered as ‘yes’ if other local information suggests high landslide potential and ‘no’ if such information suggests no such hazards (e.g., flat site).
4. If no maps are available and no information on site conditions is available, answer question F-2 as ‘No’.

### Table 4. Assignment of Site as Being Within a Surface Fault Rupture Zone

1. If site is in California, locate site on the Cal EMA MyPlanweb site (myplan.calema.ca.gov).
    a. Enter address in ‘Find Location’ window.
    b. Select ‘Fault Lines’ in menu bar to right of map.
    c. Zoom as needed to see map details.
    d. If site is located within gray zone on map, answer to Question F-5 is ‘yes’.
    e. If site located in non-gray zone, answer to Question F-5 is ‘no’.
    f. Site not mapped if background is stippled. Go to Step (2).
2. If site is not on Cal EMA web site, locate site using USGS Quaternary faults web site (http://geohazards.usgs.gov/qfaults/map.php).
    a. Select applicable state or region.
    b. Zoom in on site and determine whether site is near a Quaternary fault that has been active within 15,000 years (marked as red or yellow on map).
    c. Faults are only marked for map scales marked at the 1 km (or larger) level. At this level of zoom, Question F-5 can be answered as ‘yes’ if the mapped fault trace is within approximately 0.25 km of the site and ‘no’ otherwise.

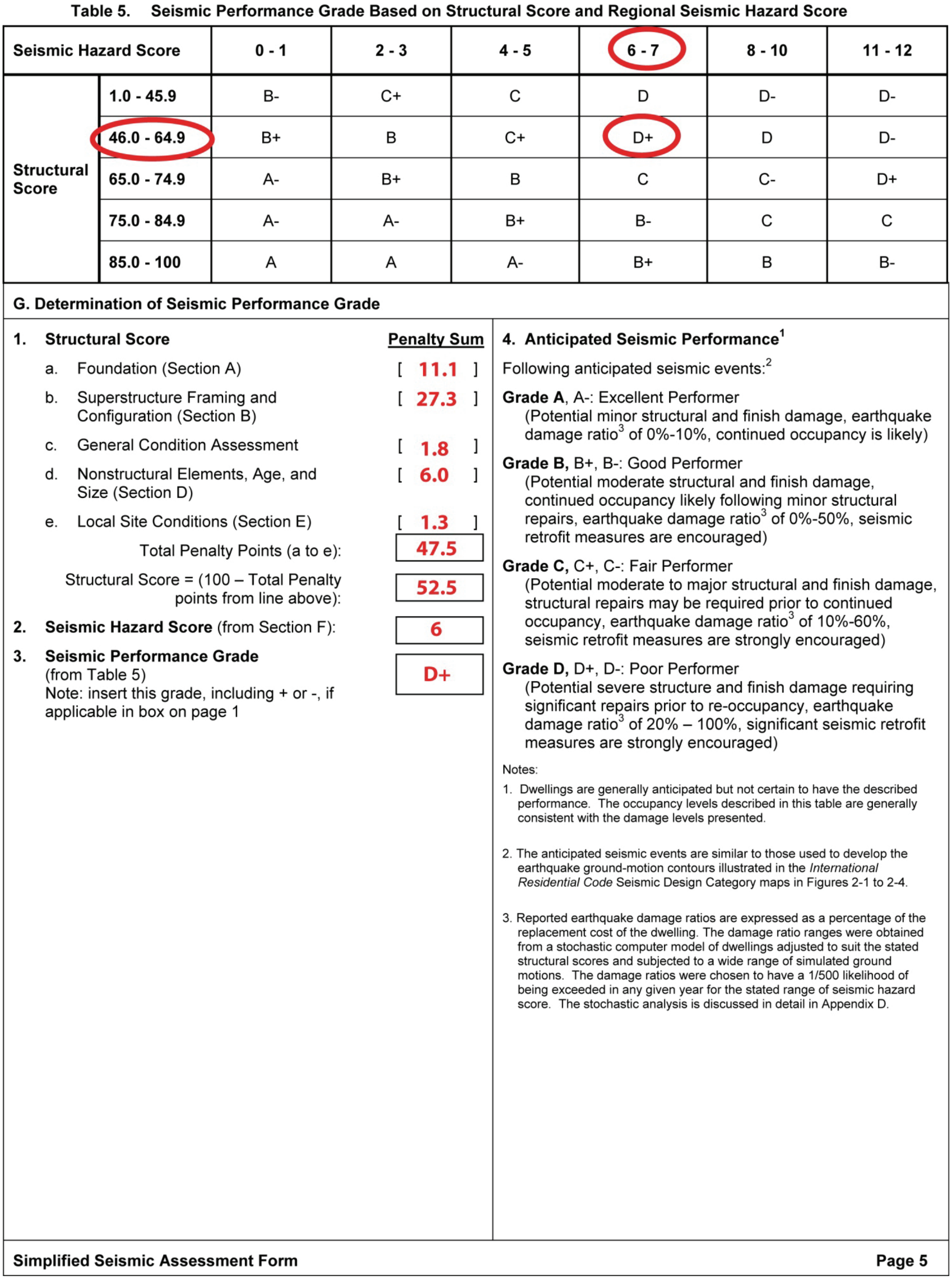


**Table 5. Seismic Performance Grade Based on Structural Score and Regional Seismic Hazard Score**

| **Seismic Hazard Score** | | **0 - 1** | **2 - 3** | **4 - 5** | **[✓ 6 - 7]** | **8 - 10** | **11 - 12** |
|---|---|---|---|---|---|---|---|
| **Structural Score** | **1.0 - 45.9** | B- | C+ | C | D | D- | D- |
| | **[✓ 46.0 - 64.9]** | B+ | B | C+ | [✓ D+] | D | D- |
| | **65.0 - 74.9** | A- | B+ | B | C | C- | D+ |
| | **75.0 - 84.9** | A- | A- | B+ | B- | C | C |
| | **85.0 - 100** | A | A | A- | B+ | B | B- |

**G. Determination of Seismic Performance Grade**

1. **Structural Score** — **Penalty Sum**

a. Foundation (Section A) [ 11.1 ]

b. Superstructure Framing and Configuration (Section B) [ 27.3 ]

c. General Condition Assessment [ 1.8 ]

d. Nonstructural Elements, Age, and Size (Section D) [ 6.0 ]

e. Local Site Conditions (Section E) [ 1.3 ]

Total Penalty Points (a to e): 47.5

Structural Score = (100 – Total Penalty points from line above): 52.5

2. **Seismic Hazard Score** (from Section F): 6

3. **Seismic Performance Grade** (from Table 5) D+

Note: insert this grade, including + or -, if applicable in box on page 1

4. **Anticipated Seismic Performance**[1]

Following anticipated seismic events:[2]

**Grade A**, A-: Excellent Performer
(Potential minor structural and finish damage, earthquake damage ratio[3] of 0%-10%, continued occupancy is likely)

**Grade B,** B+, B-: Good Performer
(Potential moderate structural and finish damage, continued occupancy likely following minor structural repairs, earthquake damage ratio[3] of 0%-50%, seismic retrofit measures are encouraged)

**Grade C,** C+, C-: Fair Performer
(Potential moderate to major structural and finish damage, structural repairs may be required prior to continued occupancy, earthquake damage ratio[3] of 10%-60%, seismic retrofit measures are strongly encouraged)

**Grade D,** D+, D-: Poor Performer
(Potential severe structure and finish damage requiring significant repairs prior to re-occupancy, earthquake damage ratio[3] of 20% – 100%, significant seismic retrofit measures are strongly encouraged)

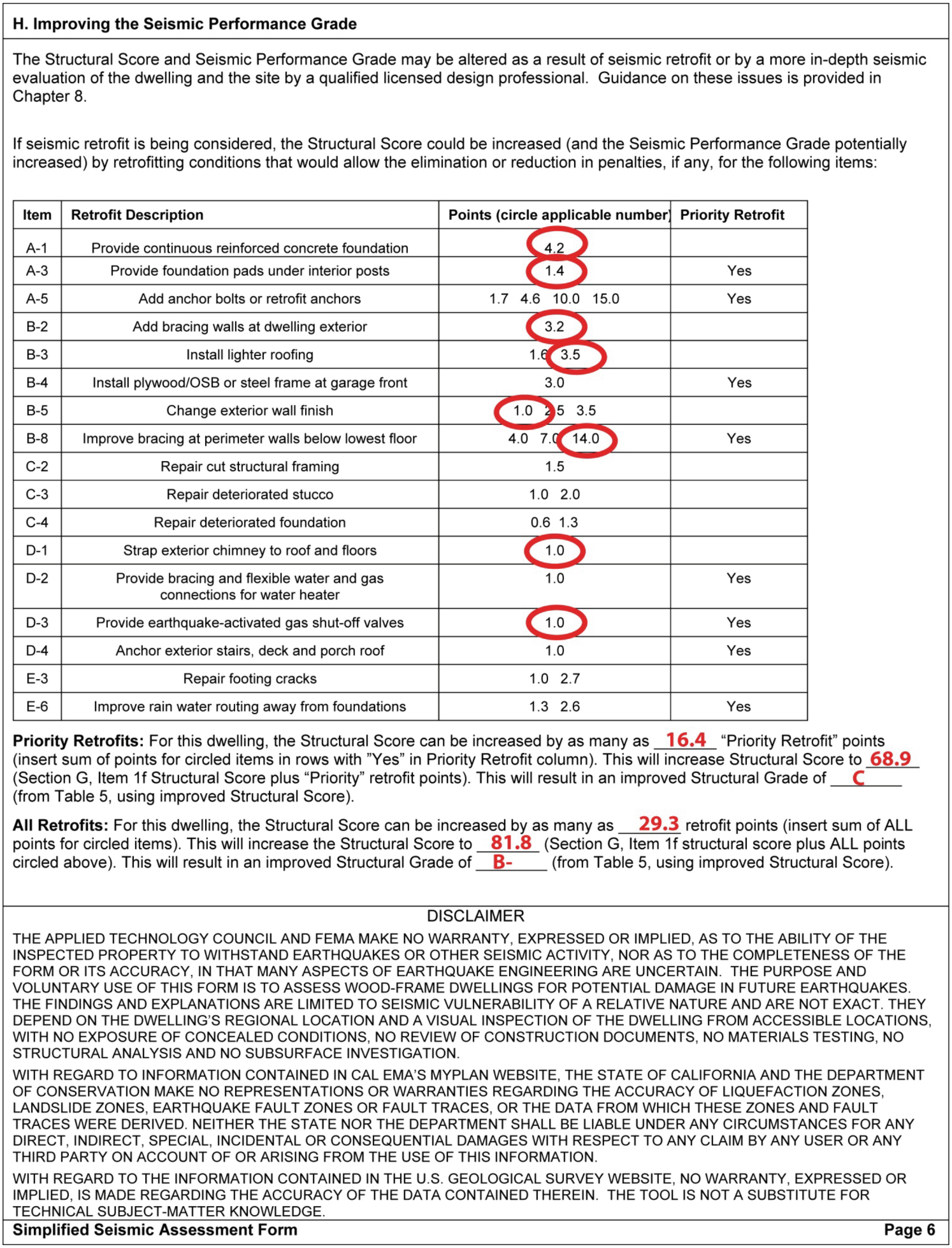
Notes:

1. Dwellings are generally anticipated but not certain to have the described performance. The occupancy levels described in this table are generally consistent with the damage levels presented.

2. The anticipated seismic events are similar to those used to develop the earthquake ground-motion contours illustrated in the *International Residential Code* Seismic Design Category maps in Figures 2-1 to 2-4.

3. Reported earthquake damage ratios are expressed as a percentage of the replacement cost of the dwelling. The damage ratio ranges were obtained from a stochastic computer model of dwellings adjusted to suit the stated structural scores and subjected to a wide range of simulated ground motions. The damage ratios were chosen to have a 1/500 likelihood of being exceeded in any given year for the stated range of seismic hazard score. The stochastic analysis is discussed in detail in Appendix D.

**Simplified Seismic Assessment Form** **Page 5**



**H. Improving the Seismic Performance Grade**

The Structural Score and Seismic Performance Grade may be altered as a result of seismic retrofit or by a more in-depth seismic evaluation of the dwelling and the site by a qualified licensed design professional. Guidance on these issues is provided in Chapter 8.

If seismic retrofit is being considered, the Structural Score could be increased (and the Seismic Performance Grade potentially increased) by retrofitting conditions that would allow the elimination or reduction in penalties, if any, for the following items:

| Item | Retrofit Description | Points (circle applicable number) | Priority Retrofit |
|---|---|---|---|
| A-1 | Provide continuous reinforced concrete foundation | [✓ 4.2] | |
| A-3 | Provide foundation pads under interior posts | [✓ 1.4] | Yes |
| A-5 | Add anchor bolts or retrofit anchors | 1.7 4.6 10.0 15.0 | Yes |
| B-2 | Add bracing walls at dwelling exterior | [✓ 3.2] | |
| B-3 | Install lighter roofing | 1.6 [✓ 3.5] | |
| B-4 | Install plywood/OSB or steel frame at garage front | 3.0 | Yes |
| B-5 | Change exterior wall finish | [✓ 1.0] 2.5 3.5 | |
| B-8 | Improve bracing at perimeter walls below lowest floor | 4.0 7.0 [✓ 14.0] | Yes |
| C-2 | Repair cut structural framing | 1.5 | |
| C-3 | Repair deteriorated stucco | 1.0 2.0 | |
| C-4 | Repair deteriorated foundation | 0.6 1.3 | |
| D-1 | Strap exterior chimney to roof and floors | [✓ 1.0] | |
| D-2 | Provide bracing and flexible water and gas connections for water heater | 1.0 | Yes |
| D-3 | Provide earthquake-activated gas shut-off valves | [✓ 1.0] | Yes |
| D-4 | Anchor exterior stairs, deck and porch roof | 1.0 | Yes |
| E-3 | Repair footing cracks | 1.0 2.7 | |
| E-6 | Improve rain water routing away from foundations | 1.3 2.6 | Yes |

**Priority Retrofits:** For this dwelling, the Structural Score can be increased by as many as **16.4** "Priority Retrofit" points (insert sum of points for circled items in rows with "Yes" in Priority Retrofit column). This will increase Structural Score to **68.9** (Section G, Item 1f Structural Score plus "Priority" retrofit points). This will result in an improved Structural Grade of **C** (from Table 5, using improved Structural Score).

**All Retrofits:** For this dwelling, the Structural Score can be increased by as many as **29.3** retrofit points (insert sum of ALL points for circled items). This will increase the Structural Score to **81.8** (Section G, Item 1f structural score plus ALL points circled above). This will result in an improved Structural Grade of **B-** (from Table 5, using improved Structural Score).

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**Simplified Seismic Assessment Form** **Page 6**

## Example B.2: Seismically Retrofitted Dwelling
## Location: Los Angeles, California 90043

This house in southern Los Angeles was built prior to 1977 but was seismically rehabilitated after the 1994 Northridge earthquake.

**FEMA P-50**

## Simplified Seismic Assessment Form
## For Detached, Single-Family, Wood-Frame Dwellings

(Please print all information)

**Grade** B

Street Address: Example B-2
Community/Area/City: Los Angeles
ZIP Code: 90043
Date:

Owner:
Inspector:
Inspection Form # (optional):

For each question, circle only one answer. Circle the one with higher penalty if more than one answer applies. Exception: question B-1

### A. Foundation (If the dwelling has a crawl space, the inspector should view all the areas that are accessible.)

|  |  | **Penalty** |
|---|---|---|
| *A-1 | The exterior footing is: |  |
| a. | continuous concrete or reinforced masonry | [✓ [0]] |
| b. | other footing conditions | [4.2] |
| A-2 | The lowest floor of the dwelling is: |  |
| a. | slab-on-grade | [0] |
| b. | wood framed over crawl space or basement | [✓ [2.9]] |
| c. | combination of slab-on-grade and wood framed floor over crawl space or basement | [2.9] |
| *A-3 | At the dwelling crawlspace or basement interior, the lowest floor framing is supported on: |  |
| a. | continuous stem walls or a combination of continuous stem walls and beams on posts bearing on concrete footings/piers | [0] |
| b. | beams on posts bearing on piers/pad footings | [✓ [0.8]] |
| c. | beams on posts supported directly on soil | [2.2] |
| d. | not applicable: slab-on-grade | [0] |
| A-4 | For a foundation on a slope of 3 horizontal to 1 vertical or steeper, the top of the footing or foundation stem wall on which wall studs or posts are supported is: |  |
| a. | sloped parallel to the ground slope | [3.7] |
| b. | stepped | [1.8] |
| c. | at a constant elevation with no steps | [0.6] |
| d. | not applicable | [✓ [0]] |

|  |  | **Penalty** |
|---|---|---|
| *A-5 | At the dwelling perimeter walls, where the foundation system supports a wood framed floor: |  |
| a. | the foundation sill plate (mudsill) is bolted to the foundation with average anchor bolt spacing of 72 in. or less | [0] |
| b. | the foundation sill plate is fastened to the foundation with retrofit anchors equivalent to 72 in. or less anchor bolt spacing | [0] |
| c. | the anchor bolts have average spacing that is > 72 in. but <= 108 in. | [✓ [1.7]] |
| d. | the anchor bolts have > 108 in. average spacing | [4.6] |
| e. | the foundation sill plates have extensive decay, splitting, or inadequate edge distance at one-third or more of the anchor bolt locations such that significant slip of the sill plate could occur | [10.0] |
| f. | the anchor bolts have significant corrosion at one third or more of the anchor bolt locations such that significant slip of the sill plate could occur | [10.0] |
| g. | there are no foundation anchor bolts | [15.0] |
| h. | there are no foundation sill plates to connect to the foundation | [15.0] |
| i. | not applicable | [ 0 ] |
|  | **Total** | 5.4 |

### B. Superstructure Framing and Configuration (Every accessible area such as the attic and under-floor area that reveals structural elements must be inspected.)

|  |  | **Penalty** |
|---|---|---|
| B-1 | The dwelling has: (circle all that apply, a to e) |  |
| a. | unsymmetrical wall strength (torsion problems) | [✓ yes [1.6]] |
| b. | reentrant corners (seen in plan view) | yes [0.3] |
| c. | split-level floor construction | yes [2.0] |
| d. | out-of-plane offsets of more than 4 ft. in exterior walls | yes [0.4] |
| e. | non-orthogonal seismic resisting systems | yes [0.6] |
| f. | none of the above, or built in accordance with 1994 UBC, 2000 IBC, 2000 IRC or later edition | yes [0] |
| *B-2 | For exterior walls at the lowest occupied story, the summed length of full story height wall sections (between openings, excluding < 2'-8" panels) on any face is less than: |  |
| a. | 20% of the length of the wall, if a single story | yes [3.2] |
| b. | 25% of the length of the wall, if two stories | yes [3.2] |
| c. | 40% of the length of the wall, if three stories or more | yes [3.2] |
| d. | none of the above | [✓ [0]] |
| *B-3 | If the roofing is heavy (i.e., clay or concrete tile) the dwelling is: |  |
| a. | single story | [1.6] |
| b. | multi-story | [3.5] |
| c. | not applicable: roofing is light. | [✓ [0]] |

|  |  | **Penalty** |
|---|---|---|
| *B-4 | For an attached garage with a second floor above, the narrow walls at the side of the garage door openings have: |  |
| a. | wood structural panels on each narrow wall pier | [0] |
| b. | structural steel frames around or alongside the door | [0] |
| c. | prefabricated narrow shear walls, installed in accordance with manufacturer's recommendations | [0] |
| d. | none of the conditions specified in conditions a, b, or c above (that are visable) | [3.0] |
| e. | not applicable (single story) or built in accordance with 1997 UBC, 2000 IBC, 2000 IRC or later edition | [✓ [0]] |
| *B-5 | The exterior wall covering is primarily: |  |
| a. | siding known to be over plywood or OSB sheathing | [0] |
| b. | siding not known to be over plywood or OSB sheathing | [✓ [2.5]] |
| c. | plywood (T1-11) or diagonal wood siding | [0] |
| d | stucco | [1.0] |
| e. | masonry veneer not more than 10 feet above the supporting foundation | [2.5] |
| f. | masonry veneer more than 10 feet above the supporting foundation | [3.5] |

*Assessment item that may be improved by seismic retrofit; **see page 6, Section H**

**Simplified Seismic Assessment Form** **Page 1**

## B. Superstructure Framing and Configuration (Every accessible area such as the attic and under-floor area that reveals structural elements must be inspected.) *(continued)*

**Penalty**

B-6 There is evidence of interior remodeling that has removed interior walls:
yes [1.0]
no/ not applicable [✓ [0]]

B-7 The number of stories is:
- a. one (1) [✓ [0]]
- b. two (2) [1.8]
- c. 3 or more [3.6]

*B-8 At the dwelling perimeter, the main lowest framed floor is supported on:
- a. beam and column (post-and-pier) system with no sheathed exterior walls [14.0]
- b. perimeter cripple walls with no plywood or OSB sheathing [14.0]
- c. original or retrofitted perimeter cripple walls with plywood or OSB sheathing where cripple walls are one story or less in height [1.0 ]
- d. original or retrofitted perimeter cripple walls with plywood or OSB sheathing where cripple walls are greater than one story in height [4.0]
- e. wood or steel diagonal braces not detailed in accordance with 1997 UBC, 2000 IBC or later edition [✓ [7.0]]
- f. plywood or OSB sheathed perimeter skirt walls that do not extend to and anchor to the foundation [7.0]
- g. none of the above [0]

**Total** 11.1

## C. General Condition Assessment

**Penalty**

C-1 The overall condition of the dwelling is:
- a. good (essentially crack free, no moisture/water intrusion problems) [ 0 ]
- b. fair (minor wood decay and cracks) [✓ [1.0]]
- c. poor (many cracks on interior and exterior, floor out-of-level and wood decay) [2.1]

*C-2 In the under floor area, there has been structural alteration (e.g. cutting or notching of framing for electrical, plumbing, mechanical equipment) that would affect the performance of the dwelling in an earthquake:
yes [1.5]
[✓ no [0]]
not applicable [0]

*C-3: There is evidence of: stucco detachment, bowing of stucco, corroded wire mesh, extensive cracking at finished grade above the bottom of the stucco:
- a. extensive [2.0]
- b. minor [1.0]
- c. none [✓ [0]]

**Penalty**

*C-4 At the foundation level, there is:
- a. significant deterioration visible (corrosion, material breakdown) [1.3]
- b. some deterioration visible [✓ [0.6]]
- c. no deterioration visible [0]

C-5 Throughout the dwelling, the quality of construction appears to be:
- a. good [0]
- b. average [✓ [0.8]]
- c. poor [1.7]

**Total** 2.4

## D. Nonstructural Elements, Age, and Size

**Penalty**

*D-1 The chimney inspection revealed:
- a. properly connected anchor straps tying the masonry/concrete chimney(s) at side of house to the floor, ceiling and roof framing
  yes [1.0]
  [✓ no [2.0]]
- b. chimney occurs at dwelling interior [1.0]
- c. dwelling has no masonry/concrete chimney [0]

*D-2 The gas water heater has effective anchor straps and water and gas connections:
yes [0]
[✓ no [1.0]]

The electric water heater has approved anchor straps:
yes [0]
no [0.7]

*D-3 An earthquake-activated gas shut-off valve is installed:
yes [0]
[✓ no [1.0]]
not applicable [0]

**Penalty**

*D-4 The dwelling has exterior stairs, decks or porch roofs, without internal earthquake bracing, that are attached to the dwelling with:
- a. two or more connections tying the stair, deck or porch to the dwelling interior framing [✓ [0]]
- b. nails or screws that would be loaded in withdrawal if the stair deck or porch moved away from the dwelling [1.0]
- c. other connection configurations [1.0]

D-5 The dwelling was built: (if remodel/added area >50% of total area, use addition date):
- a. before 1920 [3.0]
- b. 1921 to 1977 [✓ [2.0]]
- c. 1978 to 1993 [1.0]
- d. 1994 or later [0]

D-6 The approximate total floor area (sq. ft.) of the dwelling and attached garage is:
- a. < 1600. [✓ [0]]
- b. 1601 - 2500 [1.0]
- c. ≥ 2501 [2.0]

**Total** 6.0

*Assessment item that may be improved by seismic retrofit; **see page 6, Section H**

## E. Local Site Conditions

**Penalty**

E-1 The dwelling is located primarily on:
- a. a flat lot or slope (≤ 3:1) [✓ [0]]
- b. steep slope (> 3:1) [3.0]

E-2 The dwelling is located on a cut-and-fill pad, which was developed:
- a. without a geotechnical investigation [2.7]
- b. with a geotechnical investigation [1.3]
- c. dwelling is *not* on cut-and-fill pad [✓ [0]]

*E-3 The exterior concrete footing has:
- a. no visible cracks or a few minor cracks [0]
- b. minor cracks in several areas [✓ [1.0]]
- c. extensive cracking [2.7]
- d. not applicable [0]

**Penalty**

E-4 The evidence of differential settlement in or around the dwelling is:
- a. extensive [2.5]
- b. minor [1.0]
- c. none visible [✓ [0]]

E-5: The slope above or below the structure appears to be unstable:
- yes [3.2]
- no [0]
- [✓ not applicable [0]]

*E-6: General condition of site drainage:
- a. roof gutters and downspouts collecting and conducting water away from foundation [0]
- b. water collecting at/near perimeter footing with no positive slope away from dwelling [2.6]
- c. no roof gutters but drainage appears to be adequate or roof gutters with downspouts that empty into splash blocks [✓ [1.3]]

**Total** 2.3

## F. Regional Seismic Hazard Score

F-1 Enter points for shaking hazard potential for location of dwelling (from Table 1). [ 4 ]

F-2 Are ground failure hazards to be looked up using Tables 2, 3, and 4?
- [✓ yes, go to F-3.]
- no, proceed to F-6 and enter 4.0 points for ground failure hazards

F-3 Is this dwelling located in a liquefaction zone (from Table 2) or landslide zone (from Table 3)?
- yes, go to F-4.
- [✓ no, go to F-5.]

F-4 Proceed to F-6 and enter ground failure hazard points in accordance with the following table:

| Ground Shaking Points | Ground Failure Points |
|---|---|
| 0 | 2 |
| 2, 4 | 3 |
| 6, 8 | 4 |

F-5 Is the dwelling located in a fault rupture zone (from Table 4)?
- yes [2]
- [✓ no [0]]

F-6 Total ground failure points from F-2, F-4, or F-5 (no summation). [ 0 ]

**Total Seismic Hazard Score** (Sum of F-1 and F-6) 4

### Table 1. Assignment of Ground Shaking Hazard Score

1. Use the USGS Seismic Design Maps Web Application (http://earthquake.usgs.gov/designmaps/usapp)[1] to look up ground shaking parameter $S_{DS}$:
   - a. Press the 'Launch Application' button.
   - b. In the web application, select '2012 IBC' for the Building Code Reference Document.
   - c. Select 'Site Class D – "Stiff Soil" (Default)' for the Site Soil Classification.
   - d. Enter the site address or latitude and longitude.
   - e. Press the 'Compute Values' button.
   - f. Read parameter $S_{DS}$ from the summary report. Enter here: 1.24 g
   - g. Multiply value from 1f by 100: 124 %g
2. Using the value from 1g, assign ground shaking points according to the following table (these points are assigned in Item F-1):

| Value of $S_{DS}$ (% g) | Ground Shaking Hazard Points |
|---|---|
| 33 - 66.99 | 0 |
| 67 - 82.99 | 2 |
| 83 - 124.99 | [✓ 4] |
| 125 - 187.99 | 6 |
| 188 - 250 | 8 |

[1] Note:If you are using the USGS application for the first time, or have recently cleared your web browser cookies, you may have to register for immediate use. Also, if you are using an anti-virus software program, you may have to enable some links to this site, e.g., if you receive a message that says "only secure content is displayed, "you must click on "show all content."

* Assessment item that may be improved by seismic retrofit; **see page 6, Section H**

### Table 2. Assignment of Site as Being Within a Liquefaction Zone

1. If site is in California, locate site on the California Emergency Management Agency (Cal EMA) MyPlan web site (myplan.calema.ca.gov).
   a. Enter address in ‘Find Location’ window.
   b. Select ‘liquefaction’ in menu bar to right of map.
   c. Zoom as needed to see map details.
   d. If site is located within green zone on map, answer to Question F-3 is ‘yes’.
   e. If site located in non-liquefaction and non-seismic landslide zone on map (generally pale yellow), answer to Question F-3 is ‘no’.
   f. Site not mapped if background is stippled. Go to Step (2).
2. If site is not on Cal EMA web site, determine site liquefaction potential/susceptibility using available web resources. See www.ATCouncil.org/pdfs/FEMAP-50LiquefactionInfo.pdf for a list of such resources. Map types shown in these web resources are:
   a. Liquefaction susceptibility maps. Answer to F-3 is ‘yes’ if site is in a zone of moderate-to-high liquefaction susceptibility. Answer is ‘no’ if in a low susceptibility or non-susceptible zone.
   b. Liquefaction potential maps. Answer to F-3 is ‘yes’ if site is in a liquefaction potential zone. Answer is ‘no’ if in a low or null potential zone.
   c. Liquefaction potential index (LPI) maps. Answer to F-3 is ‘yes’ if site is has mapped LPI ≥ 5 and no if mapped LPI < 5.
3. If the location of the site has not been mapped, Question F-3 can be answered as ‘yes’ if other local information suggests liquefaction potential and ‘no’ if such information suggests no such hazards.
4. If no maps are available and no information on site conditions is available, answer question F-2 as ‘no’.

### Table 3. Assignment of Site as Being Within a Seismic Landslide Zone

1. If site is in California, attempt to locate site on the Cal EMA MyPlanweb site (myplan.calema.ca.gov).
   a. Enter address in ‘Find Location’ window.
   b. Select ‘landslide’ in menu bar to right of map.
   c. Zoom as needed to see map details.
   d. If site is located within brown zone on map, answer to Question F-3 is ‘yes’.
   e. If site located in non-seismic landslide zone on map (generally pale yellow), answer to Question F-3 is ‘no’.
   f. Site not mapped if background is stippled. Go to Step (2).
2. If site is not on Cal EMA web site, determine site landslide potential/susceptibility using available web resources. See www.ATCouncil.org/pdf/FEMAP-50LandslideInfo.pdf for a list of such resources. Map types shown in these web resources are:
   a. Seismic landslide susceptibility maps. Answer to F-3 is ‘yes’ if site is in a zone of moderate to high seismic landslide susceptibility. Answer is ‘no’ if in a low susceptibility or non-susceptible zone.
   b. Seismic landslide potential maps. Answer to F-3 is ‘yes’ if site is in a seismic landslide potential zone. Answer is ‘no’ if in a low or null potential zone.
3. If the location of the site has not been mapped, Question F-3 can be answered as ‘yes’ if other local information suggests high landslide potential and ‘no’ if such information suggests no such hazards (e.g., flat site).
4. If no maps are available and no information on site conditions is available, answer question F-2 as ‘No’.

### Table 4. Assignment of Site as Being Within a Surface Fault Rupture Zone

1. If site is in California, locate site on the Cal EMA MyPlanweb site (myplan.calema.ca.gov).
   a. Enter address in ‘Find Location’ window.
   b. Select ‘Fault Lines’ in menu bar to right of map.
   c. Zoom as needed to see map details.
   d. If site is located within gray zone on map, answer to Question F-5 is ‘yes’.
   e. If site located in non-gray zone, answer to Question F-5 is ‘no’.
   f. Site not mapped if background is stippled. Go to Step (2).
2. If site is not on Cal EMA web site, locate site using USGS Quaternary faults web site (http://geohazards.usgs.gov/qfaults/map.php).
   a. Select applicable state or region.
   b. Zoom in on site and determine whether site is near a Quaternary fault that has been active within 15,000 years (marked as red or yellow on map).
   c. Faults are only marked for map scales marked at the 1 km (or larger) level. At this level of zoom, Question F-5 can be answered as ‘yes’ if the mapped fault trace is within approximately 0.25 km of the site and ‘no’ otherwise.

Table 5. Seismic Performance Grade Based on Structural Score and Regional Seismic Hazard Score

| Seismic Hazard Score | | 0 - 1 | 2 - 3 | [✓ 4 - 5] | 6 - 7 | 8 - 10 | 11 - 12 |
|---|---|---|---|---|---|---|---|
| Structural Score | 1.0 - 45.9 | B- | C+ | C | D | D- | D- |
| | 46.0 - 64.9 | B+ | B | C+ | D+ | D | D- |
| | [✓ 65.0 - 74.9] | A- | B+ | [✓ B] | C | C- | D+ |
| | 75.0 - 84.9 | A- | A- | B+ | B- | C | C |
| | 85.0 - 100 | A | A | A- | B+ | B | B- |

## G. Determination of Seismic Performance Grade

**1. Structural Score** **Penalty Sum**

a. Foundation (Section A) [ 5.4 ]

b. Superstructure Framing and Configuration (Section B) [ 11.1 ]

c. General Condition Assessment [ 2.4 ]

d. Nonstructural Elements, Age, and Size (Section D) [ 6.0 ]

e. Local Site Conditions (Section E) [ 2.3 ]

Total Penalty Points (a to e): 27.2

Structural Score = (100 – Total Penalty points from line above): 72.8

**2. Seismic Hazard Score** (from Section F): 4

**3. Seismic Performance Grade** (from Table 5)
Note: insert this grade, including + or -, if applicable in box on page 1 B

**4. Anticipated Seismic Performance**[1]

Following anticipated seismic events:[2]

**Grade A**, A-: Excellent Performer
(Potential minor structural and finish damage, earthquake damage ratio[3] of 0%-10%, continued occupancy is likely)

**Grade B,** B+, B-: Good Performer
(Potential moderate structural and finish damage, continued occupancy likely following minor structural repairs, earthquake damage ratio[3] of 0%-50%, seismic retrofit measures are encouraged)

**Grade C,** C+, C-: Fair Performer
(Potential moderate to major structural and finish damage, structural repairs may be required prior to continued occupancy, earthquake damage ratio[3] of 10%-60%, seismic retrofit measures are strongly encouraged)

**Grade D,** D+, D-: Poor Performer
(Potential severe structure and finish damage requiring significant repairs prior to re-occupancy, earthquake damage ratio[3] of 20% – 100%, significant seismic retrofit measures are strongly encouraged)

Notes:

1. Dwellings are generally anticipated but not certain to have the described performance. The occupancy levels described in this table are generally consistent with the damage levels presented.

2. The anticipated seismic events are similar to those used to develop the earthquake ground-motion contours illustrated in the *International Residential Code* Seismic Design Category maps in Figures 2-1 to 2-4.

3. Reported earthquake damage ratios are expressed as a percentage of the replacement cost of the dwelling. The damage ratio ranges were obtained from a stochastic computer model of dwellings adjusted to suit the stated structural scores and subjected to a wide range of simulated ground motions. The damage ratios were chosen to have a 1/500 likelihood of being exceeded in any given year for the stated range of seismic hazard score. The stochastic analysis is discussed in detail in Appendix D.

**H. Improving the Seismic Performance Grade**

The Structural Score and Seismic Performance Grade may be altered as a result of seismic retrofit or by a more in-depth seismic evaluation of the dwelling and the site by a qualified licensed design professional. Guidance on these issues is provided in Chapter 8.

If seismic retrofit is being considered, the Structural Score could be increased (and the Seismic Performance Grade potentially increased) by retrofitting conditions that would allow the elimination or reduction in penalties, if any, for the following items:

| Item | Retrofit Description | Points (circle applicable number) | Priority Retrofit |
|---|---|---|---|
| A-1 | Provide continuous reinforced concrete foundation | 4.2 | |
| A-3 | Provide foundation pads under interior posts | 1.4 | Yes |
| A-5 | Add anchor bolts or retrofit anchors | [✓ 1.7] 4.6 10.0 15.0 | Yes |
| B-2 | Add bracing walls at dwelling exterior | 3.2 | |
| B-3 | Install lighter roofing | 1.6 3.5 | |
| B-4 | Install plywood/OSB or steel frame at garage front | 3.0 | Yes |
| B-5 | Change exterior wall finish | 1.0 [✓ 2.5] 3.5 | |
| B-8 | Improve bracing at perimeter walls below lowest floor | 4.0 [✓ 7.0] 10.0 | Yes |
| C-2 | Repair cut structural framing | 1.5 | |
| C-3 | Repair deteriorated stucco | 1.0 2.0 | |
| C-4 | Repair deteriorated foundation | [✓ 0.6] 1.3 | |
| D-1 | Strap exterior chimney to roof and floors | [✓ 1.0] | |
| D-2 | Provide bracing and flexible water and gas connections for water heater | [✓ 1.0] | Yes |
| D-3 | Provide earthquake-activated gas shut-off valves | [✓ 1.0] | Yes |
| D-4 | Anchor exterior stairs, deck and porch roof | 1.0 | Yes |
| E-3 | Repair footing cracks | [✓ 1.0] 1.7 | |
| E-6 | Improve rain water routing away from foundations | [✓ 1.3] 2.6 | Yes |

**Priority Retrofits:** For this dwelling, the Structural Score can be increased by as many as 12 "Priority Retrofit" points (insert sum of points for circled items in rows with "Yes" in Priority Retrofit column). This will increase Structural Score to 84.8 (Section G, Item 1f Structural Score plus "Priority" retrofit points). This will result in an improved Structural Grade of B+ (from Table 5, using improved Structural Score).

**All Retrofits:** For this dwelling, the Structural Score can be increased by as many as 17.1 retrofit points (insert sum of ALL points for circled items). This will increase the Structural Score to 89.9 (Section G, Item 1f structural score plus ALL points circled above). This will result in an improved Structural Grade of A- (from Table 5, using improved Structural Score).

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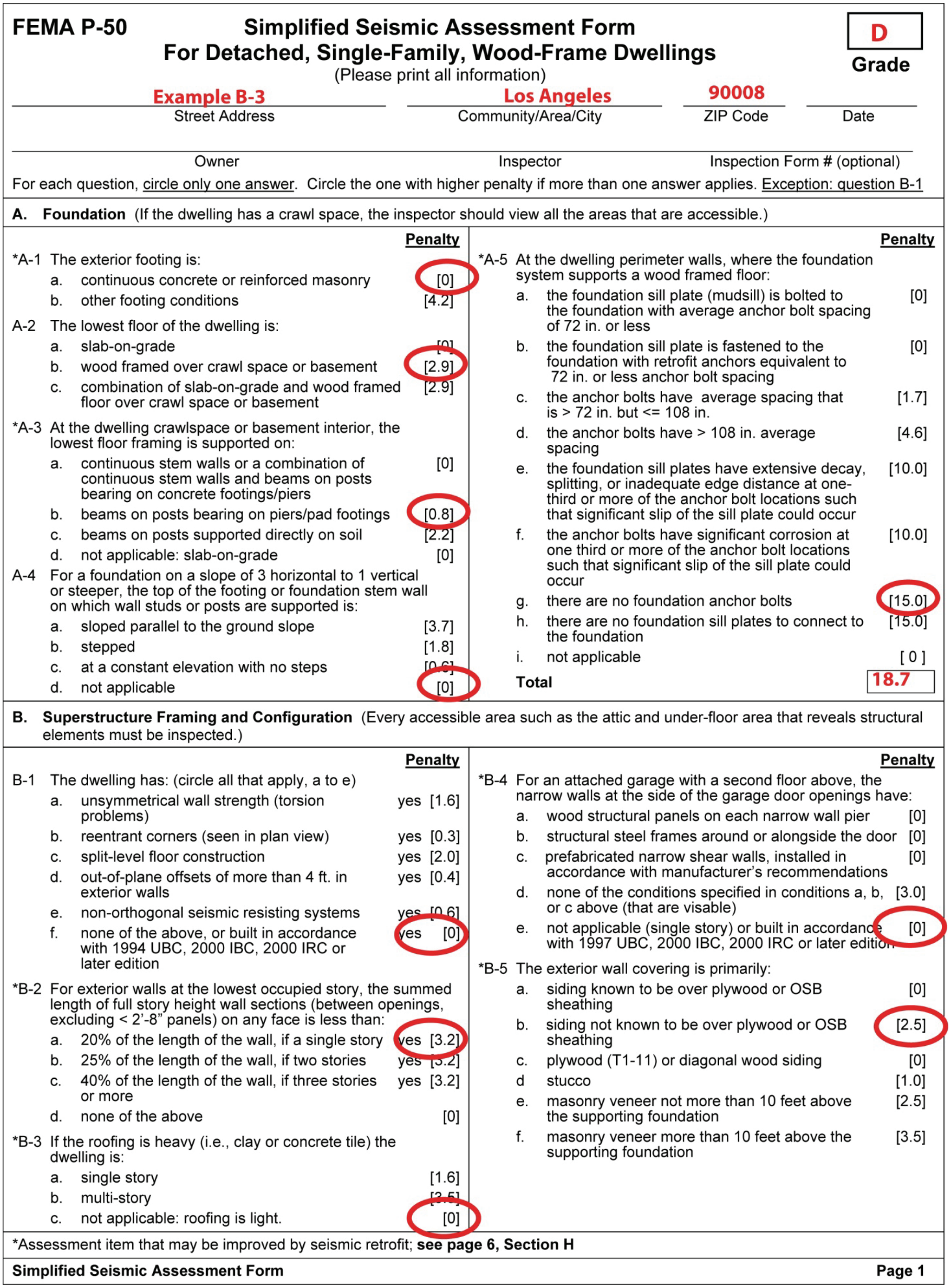
## Example B.3: Home with Unbraced Cripple Wall
## Location: Los Angeles, California 90008

This single-story home has a raised floor supported by an unbraced cripple wall. Additionally, the cripple wall is not bolted to the foundation.



**FEMA P-50** **Simplified Seismic Assessment Form**
**For Detached, Single-Family, Wood-Frame Dwellings**
(Please print all information)

**D**
**Grade**

Street Address: Example B-3
Community/Area/City: Los Angeles
ZIP Code: 90008
Date:

Owner:
Inspector:
Inspection Form # (optional):

For each question, circle only one answer. Circle the one with higher penalty if more than one answer applies. Exception: question B-1

**A. Foundation** (If the dwelling has a crawl space, the inspector should view all the areas that are accessible.)

**Penalty**

*A-1 The exterior footing is:
- a. continuous concrete or reinforced masonry [✓ [0]]
- b. other footing conditions [4.2]

A-2 The lowest floor of the dwelling is:
- a. slab-on-grade [0]
- b. wood framed over crawl space or basement [✓ [2.9]]
- c. combination of slab-on-grade and wood framed floor over crawl space or basement [2.9]

*A-3 At the dwelling crawlspace or basement interior, the lowest floor framing is supported on:
- a. continuous stem walls or a combination of continuous stem walls and beams on posts bearing on concrete footings/piers [0]
- b. beams on posts bearing on piers/pad footings [✓ [0.8]]
- c. beams on posts supported directly on soil [2.2]
- d. not applicable: slab-on-grade [0]

A-4 For a foundation on a slope of 3 horizontal to 1 vertical or steeper, the top of the footing or foundation stem wall on which wall studs or posts are supported is:
- a. sloped parallel to the ground slope [3.7]
- b. stepped [1.8]
- c. at a constant elevation with no steps [0.6]
- d. not applicable [✓ [0]]

**Penalty**

*A-5 At the dwelling perimeter walls, where the foundation system supports a wood framed floor:
- a. the foundation sill plate (mudsill) is bolted to the foundation with average anchor bolt spacing of 72 in. or less [0]
- b. the foundation sill plate is fastened to the foundation with retrofit anchors equivalent to 72 in. or less anchor bolt spacing [0]
- c. the anchor bolts have average spacing that is > 72 in. but <= 108 in. [1.7]
- d. the anchor bolts have > 108 in. average spacing [4.6]
- e. the foundation sill plates have extensive decay, splitting, or inadequate edge distance at one-third or more of the anchor bolt locations such that significant slip of the sill plate could occur [10.0]
- f. the anchor bolts have significant corrosion at one third or more of the anchor bolt locations such that significant slip of the sill plate could occur [10.0]
- g. there are no foundation anchor bolts [✓ [15.0]]
- h. there are no foundation sill plates to connect to the foundation [15.0]
- i. not applicable [ 0 ]

**Total** 18.7

**B. Superstructure Framing and Configuration** (Every accessible area such as the attic and under-floor area that reveals structural elements must be inspected.)

**Penalty**

B-1 The dwelling has: (circle all that apply, a to e)
- a. unsymmetrical wall strength (torsion problems) yes [1.6]
- b. reentrant corners (seen in plan view) yes [0.3]
- c. split-level floor construction yes [2.0]
- d. out-of-plane offsets of more than 4 ft. in exterior walls yes [0.4]
- e. non-orthogonal seismic resisting systems yes [0.6]
- f. none of the above, or built in accordance with 1994 UBC, 2000 IBC, 2000 IRC or later edition [✓ yes [0]]

*B-2 For exterior walls at the lowest occupied story, the summed length of full story height wall sections (between openings, excluding < 2'-8" panels) on any face is less than:
- a. 20% of the length of the wall, if a single story [✓ yes [3.2]]
- b. 25% of the length of the wall, if two stories yes [3.2]
- c. 40% of the length of the wall, if three stories or more yes [3.2]
- d. none of the above [0]

*B-3 If the roofing is heavy (i.e., clay or concrete tile) the dwelling is:
- a. single story [1.6]
- b. multi-story [3.5]
- c. not applicable: roofing is light. [✓ [0]]

**Penalty**

*B-4 For an attached garage with a second floor above, the narrow walls at the side of the garage door openings have:
- a. wood structural panels on each narrow wall pier [0]
- b. structural steel frames around or alongside the door [0]
- c. prefabricated narrow shear walls, installed in accordance with manufacturer's recommendations [0]
- d. none of the conditions specified in conditions a, b, or c above (that are visable) [3.0]
- e. not applicable (single story) or built in accordance with 1997 UBC, 2000 IBC, 2000 IRC or later edition [✓ [0]]

*B-5 The exterior wall covering is primarily:
- a. siding known to be over plywood or OSB sheathing [0]
- b. siding not known to be over plywood or OSB sheathing [✓ [2.5]]
- c. plywood (T1-11) or diagonal wood siding [0]
- d stucco [1.0]
- e. masonry veneer not more than 10 feet above the supporting foundation [2.5]
- f. masonry veneer more than 10 feet above the supporting foundation [3.5]

*Assessment item that may be improved by seismic retrofit; **see page 6, Section H**

**Simplified Seismic Assessment Form** **Page 1**

## B. Superstructure Framing and Configuration (Every accessible area such as the attic and under-floor area that reveals structural elements must be inspected.) *(continued)*

**Penalty**

B-6 There is evidence of interior remodeling that has removed interior walls:
- yes [1.0]
- no/ not applicable [✓ [0]]

B-7 The number of stories is:
- a. one (1) [✓ [0]]
- b. two (2) [1.8]
- c. 3 or more [3.6]

*B-8 At the dwelling perimeter, the main lowest framed floor is supported on:
- a. beam and column (post-and-pier) system with no sheathed exterior walls [14.0]
- b. perimeter cripple walls with no plywood or OSB sheathing [✓ [14.0]]
- c. original or retrofitted perimeter cripple walls with plywood or OSB sheathing where cripple walls are one story or less in height [1.0 ]
- d. original or retrofitted perimeter cripple walls with plywood or OSB sheathing where cripple walls are greater than one story in height [4.0]
- e. wood or steel diagonal braces not detailed in accordance with 1997 UBC, 2000 IBC or later edition [7.0]
- f. plywood or OSB sheathed perimeter skirt walls that do not extend to and anchor to the foundation [7.0]
- g. none of the above [0]

**Total** 19.7

## C. General Condition Assessment

**Penalty**

C-1 The overall condition of the dwelling is:
- a. good (essentially crack free, no moisture/water intrusion problems) [ 0 ]
- b. fair (minor wood decay and cracks) [✓ [1.0]]
- c. poor (many cracks on interior and exterior, floor out-of-level and wood decay) [2.1]

*C-2 In the under floor area, there has been structural alteration (e.g. cutting or notching of framing for electrical, plumbing, mechanical equipment) that would affect the performance of the dwelling in an earthquake:
- yes [1.5]
- [✓ no [0]]
- not applicable [0]

*C-3: There is evidence of: stucco detachment, bowing of stucco, corroded wire mesh, extensive cracking at finished grade above the bottom of the stucco:
- a. extensive [2.0]
- b. minor [1.0]
- c. none [✓ [0]]

*C-4 At the foundation level, there is:
- a. significant deterioration visible (corrosion, material breakdown) [1.3]
- b. some deterioration visible [✓ [0.6]]
- c. no deterioration visible [0]

C-5 Throughout the dwelling, the quality of construction appears to be:
- a. good [0]
- b. average [✓ [0.8]]
- c. poor [1.7]

**Total** 2.4

## D. Nonstructural Elements, Age, and Size

**Penalty**

*D-1 The chimney inspection revealed:
- a. properly connected anchor straps tying the masonry/concrete chimney(s) at side of house to the floor, ceiling and roof framing
  - yes [1.0]
  - [✓ no [2.0]]
- b. chimney occurs at dwelling interior [1.0]
- c. dwelling has no masonry/concrete chimney [0]

*D-2 The gas water heater has effective anchor straps and water and gas connections:
- [✓ yes [0]]
- no [1.0]

The electric water heater has approved anchor straps:
- yes [0]
- no [0.7]

*D-3 An earthquake-activated gas shut-off valve is installed:
- yes [0]
- [✓ no [1.0]]
- not applicable [0]

*D-4 The dwelling has exterior stairs, decks or porch roofs, without internal earthquake bracing, that are attached to the dwelling with:
- a. two or more connections tying the stair, deck or porch to the dwelling interior framing [✓ [0]]
- b. nails or screws that would be loaded in withdrawal if the stair deck or porch moved away from the dwelling [1.0]
- c. other connection configurations [1.0]

D-5 The dwelling was built: (if remodel/added area >50% of total area, use addition date):
- a. before 1920 [3.0]
- b. 1921 to 1977 [✓ [2.0]]
- c. 1978 to 1993 [1.0]
- d. 1994 or later [0]

D-6 The approximate total floor area (sq. ft.) of the dwelling and attached garage is:
- a. < 1600. [0]
- b. 1601 - 2500 [✓ [1.0]]
- c. ≥ 2501 [2.0]

**Total** 6.0

*Assessment item that may be improved by seismic retrofit; **see page 6, Section H**

## E. Local Site Conditions

**Penalty**

E-1 The dwelling is located primarily on:
  a. a flat lot or slope (≤ 3:1) [✓ [0]]
  b. steep slope (> 3:1) [3.0]

E-2 The dwelling is located on a cut-and-fill pad, which was developed:
  a. without a geotechnical investigation [2.7]
  b. with a geotechnical investigation [1.3]
  c. dwelling is *not* on cut-and-fill pad [✓ [0]]

*E-3 The exterior concrete footing has:
  a. no visible cracks or a few minor cracks [✓ [0]]
  b. minor cracks in several areas [1.0]
  c. extensive cracking [2.7]
  d. not applicable [0]

**Penalty**

E-4 The evidence of differential settlement in or around the dwelling is:
  a. extensive [2.5]
  b. minor [✓ [1.0]]
  c. none visible [0]

E-5: The slope above or below the structure appears to be unstable:
  yes [3.2]
  [✓ no [0]]
  not applicable [0]

*E-6: General condition of site drainage:
  a. roof gutters and downspouts collecting and conducting water away from foundation [0]
  b. water collecting at/near perimeter footing with no positive slope away from dwelling [2.6]
  c. no roof gutters but drainage appears to be adequate or roof gutters with downspouts that empty into splash blocks [✓ [1.3]]

**Total** 2.3

## F. Regional Seismic Hazard Score

F-1 Enter points for shaking hazard potential for location of dwelling (from Table 1). [ 6 ]

F-2 Are ground failure hazards to be looked up using Tables 2, 3, and 4?
  [✓ yes, go to F-3.]
  no, proceed to F-6 and enter 4.0 points for ground failure hazards

F-3 Is this dwelling located in a liquefaction zone (from Table 2) or landslide zone (from Table 3)?
  [✓ yes, go to F-4.]
  no, go to F-5.

F-4 Proceed to F-6 and enter ground failure hazard points in accordance with the following table:

| Ground Shaking Points | Ground Failure Points |
|---|---|
| 0 | 2 |
| 2, 4 | 3 |
| 6, 8 | [✓ 4] |

F-5 Is the dwelling located in a fault rupture zone (from Table 4)?
  yes [2]
  no [0]

F-6 Total ground failure points from F-2, F-4, or F-5 (no summation). [ 4 ]

**Total Seismic Hazard Score** (Sum of F-1 and F-6) 10

### Table 1. Assignment of Ground Shaking Hazard Score

1. Use the USGS Seismic Design Maps Web Application (http://earthquake.usgs.gov/designmaps/usapp)[1] to look up ground shaking parameter $S_{DS}$:
   a. Press the ‘Launch Application’ button.
   b. In the web application, select ‘2012 IBC’ for the Building Code Reference Document.
   c. Select ‘Site Class D – “Stiff Soil” (Default)’ for the Site Soil Classification.
   d. Enter the site address or latitude and longitude.
   e. Press the ‘Compute Values’ button.
   f. Read parameter $S_{DS}$ from the summary report. Enter here: 1.29 g
   g. Multiply value from 1f by 100: 129 %g
2. Using the value from 1g, assign ground shaking points according to the following table (these points are assigned in Item F-1):

| Value of $S_{DS}$ (% g) | Ground Shaking Hazard Points |
|---|---|
| 33 - 66.99 | 0 |
| 67 - 82.99 | 2 |
| 83 - 124.99 | 4 |
| 125 - 187.99 | [✓ 6] |
| 188 - 250 | 8 |

[1] Note:If you are using the USGS application for the first time, or have recently cleared your web browser cookies, you may have to register for immediate use. Also, if you are using an anti-virus software program, you may have to enable some links to this site, e.g., if you receive a message that says “only secure content is displayed, ”you must click on “show all content.”

* Assessment item that may be improved by seismic retrofit; **see page 6, Section H**

**Simplified Seismic Assessment Form** **Page 3**

**Table 2. Assignment of Site as Being Within a Liquefaction Zone**

1. If site is in California, locate site on the California Emergency Management Agency (Cal EMA) MyPlan web site (myplan.calema.ca.gov).
   a. Enter address in 'Find Location' window.
   b. Select 'liquefaction' in menu bar to right of map.
   c. Zoom as needed to see map details.
   d. If site is located within green zone on map, answer to Question F-3 is 'yes'.
   e. If site located in non-liquefaction and non-seismic landslide zone on map (generally pale yellow), answer to Question F-3 is 'no'.
   f. Site not mapped if background is stippled. Go to Step (2).
2. If site is not on Cal EMA web site, determine site liquefaction potential/susceptibility using available web resources. See www.ATCouncil.org/pdfs/FEMAP-50LiquefactionInfo.pdf for a list of such resources. Map types shown in these web resources are:
   a. Liquefaction susceptibility maps. Answer to F-3 is 'yes' if site is in a zone of moderate-to-high liquefaction susceptibility. Answer is 'no' if in a low susceptibility or non-susceptible zone.
   b. Liquefaction potential maps. Answer to F-3 is 'yes' if site is in a liquefaction potential zone. Answer is 'no' if in a low or null potential zone.
   c. Liquefaction potential index (LPI) maps. Answer to F-3 is 'yes' if site is has mapped LPI ≥ 5 and no if mapped LPI < 5.
3. If the location of the site has not been mapped, Question F-3 can be answered as 'yes' if other local information suggests liquefaction potential and 'no' if such information suggests no such hazards.
4. If no maps are available and no information on site conditions is available, answer question F-2 as 'no'.

**Table 3. Assignment of Site as Being Within a Seismic Landslide Zone**

1. If site is in California, attempt to locate site on the Cal EMA MyPlanweb site (myplan.calema.ca.gov).
   a. Enter address in 'Find Location' window.
   b. Select 'landslide' in menu bar to right of map.
   c. Zoom as needed to see map details.
   d. If site is located within brown zone on map, answer to Question F-3 is 'yes'.
   e. If site located in non-seismic landslide zone on map (generally pale yellow), answer to Question F-3 is 'no'.
   f. Site not mapped if background is stippled. Go to Step (2).
2. If site is not on Cal EMA web site, determine site landslide potential/susceptibility using available web resources. See www.ATCouncil.org/pdf/FEMAP-50LandslideInfo.pdf for a list of such resources. Map types shown in these web resources are:
   a. Seismic landslide susceptibility maps. Answer to F-3 is 'yes' if site is in a zone of moderate to high seismic landslide susceptibility. Answer is 'no' if in a low susceptibility or non-susceptible zone.
   b. Seismic landslide potential maps. Answer to F-3 is 'yes' if site is in a seismic landslide potential zone. Answer is 'no' if in a low or null potential zone.
3. If the location of the site has not been mapped, Question F-3 can be answered as 'yes' if other local information suggests high landslide potential and 'no' if such information suggests no such hazards (e.g., flat site).
4. If no maps are available and no information on site conditions is available, answer question F-2 as 'No'.

**Table 4. Assignment of Site as Being Within a Surface Fault Rupture Zone**

1. If site is in California, locate site on the Cal EMA MyPlanweb site (myplan.calema.ca.gov).
   a. Enter address in 'Find Location' window.
   b. Select 'Fault Lines' in menu bar to right of map.
   c. Zoom as needed to see map details.
   d. If site is located within gray zone on map, answer to Question F-5 is 'yes'.
   e. If site located in non-gray zone, answer to Question F-5 is 'no'.
   f. Site not mapped if background is stippled. Go to Step (2).
2. If site is not on Cal EMA web site, locate site using USGS Quaternary faults web site (http://geohazards.usgs.gov/qfaults/map.php).
   a. Select applicable state or region.
   b. Zoom in on site and determine whether site is near a Quaternary fault that has been active within 15,000 years (marked as red or yellow on map).
   c. Faults are only marked for map scales marked at the 1 km (or larger) level. At this level of zoom, Question F-5 can be answered as 'yes' if the mapped fault trace is within approximately 0.25 km of the site and 'no' otherwise.

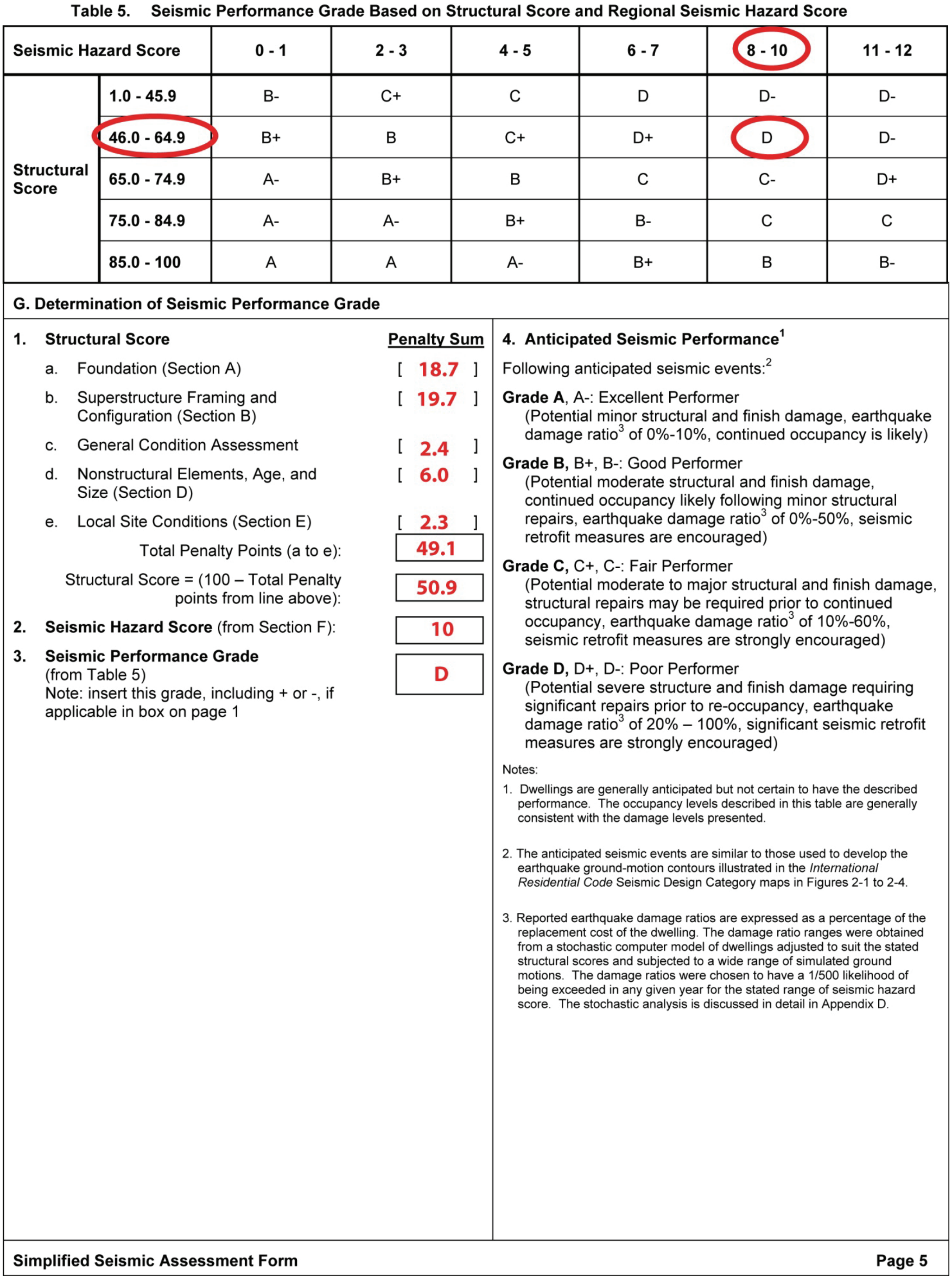


**Table 5. Seismic Performance Grade Based on Structural Score and Regional Seismic Hazard Score**

| Seismic Hazard Score | | 0 - 1 | 2 - 3 | 4 - 5 | 6 - 7 | [✓ 8 - 10] | 11 - 12 |
|---|---|---|---|---|---|---|---|
| Structural Score | 1.0 - 45.9 | B- | C+ | C | D | D- | D- |
| | [✓ 46.0 - 64.9] | B+ | B | C+ | D+ | [✓ D] | D- |
| | 65.0 - 74.9 | A- | B+ | B | C | C- | D+ |
| | 75.0 - 84.9 | A- | A- | B+ | B- | C | C |
| | 85.0 - 100 | A | A | A- | B+ | B | B- |

**G. Determination of Seismic Performance Grade**

1. **Structural Score** **Penalty Sum**

   a. Foundation (Section A) [ 18.7 ]

   b. Superstructure Framing and Configuration (Section B) [ 19.7 ]

   c. General Condition Assessment [ 2.4 ]

   d. Nonstructural Elements, Age, and Size (Section D) [ 6.0 ]

   e. Local Site Conditions (Section E) [ 2.3 ]

   Total Penalty Points (a to e): 49.1

   Structural Score = (100 – Total Penalty points from line above): 50.9

2. **Seismic Hazard Score** (from Section F): 10

3. **Seismic Performance Grade** (from Table 5) D
   Note: insert this grade, including + or -, if applicable in box on page 1

4. **Anticipated Seismic Performance**[1]

Following anticipated seismic events:[2]

**Grade A**, A-: Excellent Performer
(Potential minor structural and finish damage, earthquake damage ratio[3] of 0%-10%, continued occupancy is likely)

**Grade B,** B+, B-: Good Performer
(Potential moderate structural and finish damage, continued occupancy likely following minor structural repairs, earthquake damage ratio[3] of 0%-50%, seismic retrofit measures are encouraged)

**Grade C,** C+, C-: Fair Performer
(Potential moderate to major structural and finish damage, structural repairs may be required prior to continued occupancy, earthquake damage ratio[3] of 10%-60%, seismic retrofit measures are strongly encouraged)

**Grade D,** D+, D-: Poor Performer
(Potential severe structure and finish damage requiring significant repairs prior to re-occupancy, earthquake damage ratio[3] of 20% – 100%, significant seismic retrofit measures are strongly encouraged)

Notes:

1. Dwellings are generally anticipated but not certain to have the described performance. The occupancy levels described in this table are generally consistent with the damage levels presented.

2. The anticipated seismic events are similar to those used to develop the earthquake ground-motion contours illustrated in the *International Residential Code* Seismic Design Category maps in Figures 2-1 to 2-4.

3. Reported earthquake damage ratios are expressed as a percentage of the replacement cost of the dwelling. The damage ratio ranges were obtained from a stochastic computer model of dwellings adjusted to suit the stated structural scores and subjected to a wide range of simulated ground motions. The damage ratios were chosen to have a 1/500 likelihood of being exceeded in any given year for the stated range of seismic hazard score. The stochastic analysis is discussed in detail in Appendix D.

**Simplified Seismic Assessment Form** **Page 5**

## H. Improving the Seismic Performance Grade

The Structural Score and Seismic Performance Grade may be altered as a result of seismic retrofit or by a more in-depth seismic evaluation of the dwelling and the site by a qualified licensed design professional. Guidance on these issues is provided in Chapter 8.

If seismic retrofit is being considered, the Structural Score could be increased (and the Seismic Performance Grade potentially increased) by retrofitting conditions that would allow the elimination or reduction in penalties, if any, for the following items:

| Item | Retrofit Description | Points (circle applicable number) | Priority Retrofit |
|---|---|---|---|
| A-1 | Provide continuous reinforced concrete foundation | 4.2 | |
| A-3 | Provide foundation pads under interior posts | 1.4 | Yes |
| A-5 | Add anchor bolts or retrofit anchors | 1.7 4.6 10.0 [✓ 15.0] | Yes |
| B-2 | Add bracing walls at dwelling exterior | [✓ 3.2] | |
| B-3 | Install lighter roofing | 1.6 3.5 | |
| B-4 | Install plywood/OSB or steel frame at garage front | 3.0 | Yes |
| B-5 | Change exterior wall finish | 1.0 [✓ 2.5] 3.5 | |
| B-8 | Improve bracing at perimeter walls below lowest floor | 4.0 7.0 [✓ 14.0] | Yes |
| C-2 | Repair cut structural framing | 1.5 | |
| C-3 | Repair deteriorated stucco | 1.0 2.0 | |
| C-4 | Repair deteriorated foundation | [✓ 0.6] 1.3 | |
| D-1 | Strap exterior chimney to roof and floors | [✓ 1.0] | |
| D-2 | Provide bracing and flexible water and gas connections for water heater | 1.0 | Yes |
| D-3 | Provide earthquake-activated gas shut-off valves | [✓ 1.0] | Yes |
| D-4 | Anchor exterior stairs, deck and porch roof | 1.0 | Yes |
| E-3 | Repair footing cracks | 1.0 2.7 | |
| E-6 | Improve rain water routing away from foundations | [✓ 1.3] 2.6 | Yes |

**Priority Retrofits:** For this dwelling, the Structural Score can be increased by as many as 31.3 "Priority Retrofit" points (insert sum of points for circled items in rows with "Yes" in Priority Retrofit column). This will increase Structural Score to 82.2 (Section G, Item 1f Structural Score plus "Priority" retrofit points). This will result in an improved Structural Grade of C (from Table 5, using improved Structural Score).

**All Retrofits:** For this dwelling, the Structural Score can be increased by as many as 38.6 retrofit points (insert sum of ALL points for circled items). This will increase the Structural Score to 89.5 (Section G, Item 1f structural score plus ALL points circled above). This will result in an improved Structural Grade of B (from Table 5, using improved Structural Score).

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# Example B.4: Slab-on-Grade Dwelling

## Location: Los Angeles, California 91605

This house is located in the Panorama City area of Los Angeles. Because of the slab-on-grade floor construction, it received no penalties in the foundation section of the form. The house was built after 1977, and received relatively low penalties on the other sections of the form.

.

**FEMA P-50**

# Simplified Seismic Assessment Form For Detached, Single-Family, Wood-Frame Dwellings

(Please print all information)

**B+**
**Grade**

Street Address: Example B-4
Community/Area/City: Los Angeles
ZIP Code: 91605
Date:

Owner:
Inspector:
Inspection Form # (optional):

For each question, circle only one answer. Circle the one with higher penalty if more than one answer applies. Exception: question B-1

## A. Foundation (If the dwelling has a crawl space, the inspector should view all the areas that are accessible.)

**Penalty**

*A-1 The exterior footing is:
- a. continuous concrete or reinforced masonry [✓ [0]]
- b. other footing conditions [4.2]

A-2 The lowest floor of the dwelling is:
- a. slab-on-grade [✓ [0]]
- b. wood framed over crawl space or basement [2.9]
- c. combination of slab-on-grade and wood framed floor over crawl space or basement [2.9]

*A-3 At the dwelling crawlspace or basement interior, the lowest floor framing is supported on:
- a. continuous stem walls or a combination of continuous stem walls and beams on posts bearing on concrete footings/piers [0]
- b. beams on posts bearing on piers/pad footings [0.8]
- c. beams on posts supported directly on soil [2.2]
- d. not applicable: slab-on-grade [✓ [0]]

A-4 For a foundation on a slope of 3 horizontal to 1 vertical or steeper, the top of the footing or foundation stem wall on which wall studs or posts are supported is:
- a. sloped parallel to the ground slope [3.7]
- b. stepped [1.8]
- c. at a constant elevation with no steps [0.6]
- d. not applicable [✓ [0]]

**Penalty**

*A-5 At the dwelling perimeter walls, where the foundation system supports a wood framed floor:
- a. the foundation sill plate (mudsill) is bolted to the foundation with average anchor bolt spacing of 72 in. or less [✓ [0]]
- b. the foundation sill plate is fastened to the foundation with retrofit anchors equivalent to 72 in. or less anchor bolt spacing [0]
- c. the anchor bolts have average spacing that is > 72 in. but <= 108 in. [1.7]
- d. the anchor bolts have > 108 in. average spacing [4.6]
- e. the foundation sill plates have extensive decay, splitting, or inadequate edge distance at one-third or more of the anchor bolt locations such that significant slip of the sill plate could occur [10.0]
- f. the anchor bolts have significant corrosion at one third or more of the anchor bolt locations such that significant slip of the sill plate could occur [10.0]
- g. there are no foundation anchor bolts [15.0]
- h. there are no foundation sill plates to connect to the foundation [15.0]
- i. not applicable [ 0 ]

**Total** 0

## B. Superstructure Framing and Configuration (Every accessible area such as the attic and under-floor area that reveals structural elements must be inspected.)

**Penalty**

B-1 The dwelling has: (circle all that apply, a to e)
- a. unsymmetrical wall strength (torsion problems) [✓ yes [1.6]]
- b. reentrant corners (seen in plan view) yes [0.3]
- c. split-level floor construction yes [2.0]
- d. out-of-plane offsets of more than 4 ft. in exterior walls yes [0.4]
- e. non-orthogonal seismic resisting systems yes [0.6]
- f. none of the above, or built in accordance with 1994 UBC, 2000 IBC, 2000 IRC or later edition yes [0]

*B-2 For exterior walls at the lowest occupied story, the summed length of full story height wall sections (between openings, excluding < 2'-8" panels) on any face is less than:
- a. 20% of the length of the wall, if a single story [✓ yes [3.2]]
- b. 25% of the length of the wall, if two stories yes [3.2]
- c. 40% of the length of the wall, if three stories or more yes [3.2]
- d. none of the above [0]

*B-3 If the roofing is heavy (i.e., clay or concrete tile) the dwelling is:
- a. single story [1.6]
- b. multi-story [3.5]
- c. not applicable: roofing is light. [✓ [0]]

**Penalty**

*B-4 For an attached garage with a second floor above, the narrow walls at the side of the garage door openings have:
- a. wood structural panels on each narrow wall pier [0]
- b. structural steel frames around or alongside the door [0]
- c. prefabricated narrow shear walls, installed in accordance with manufacturer's recommendations [0]
- d. none of the conditions specified in conditions a, b, or c above (that are visable) [3.0]
- e. not applicable (single story) or built in accordance with 1997 UBC, 2000 IBC, 2000 IRC or later edition [✓ [0]]

*B-5 The exterior wall covering is primarily:
- a. siding known to be over plywood or OSB sheathing [0]
- b. siding not known to be over plywood or OSB sheathing [2.5]
- c. plywood (T1-11) or diagonal wood siding [0]
- d stucco [✓ [1.0]]
- e. masonry veneer not more than 10 feet above the supporting foundation [2.5]
- f. masonry veneer more than 10 feet above the supporting foundation [3.5]

*Assessment item that may be improved by seismic retrofit; **see page 6, Section H**

**Simplified Seismic Assessment Form** **Page 1**

### B. Superstructure Framing and Configuration (Every accessible area such as the attic and under-floor area that reveals structural elements must be inspected.) *(continued)*

**Penalty**

B-6 There is evidence of interior remodeling that has removed interior walls:
yes [1.0]
[✓ no/ not applicable [0]]

B-7 The number of stories is:
- a. one (1) [✓ [0]]
- b. two (2) [1.8]
- c. 3 or more [3.6]

*B-8 At the dwelling perimeter, the main lowest framed floor is supported on:
- a. beam and column (post-and-pier) system with no sheathed exterior walls [14.0]
- b. perimeter cripple walls with no plywood or OSB sheathing [14.0]
- c. original or retrofitted perimeter cripple walls with plywood or OSB sheathing where cripple walls are one story or less in height [1.0 ]
- d. original or retrofitted perimeter cripple walls with plywood or OSB sheathing where cripple walls are greater than one story in height [4.0]
- e. wood or steel diagonal braces not detailed in accordance with 1997 UBC, 2000 IBC or later edition [7.0]
- f. plywood or OSB sheathed perimeter skirt walls that do not extend to and anchor to the foundation [7.0]
- g. none of the above [✓ [0]]

**Total** 5.8

### C. General Condition Assessment

**Penalty**

C-1 The overall condition of the dwelling is:
- a. good (essentially crack free, no moisture/water intrusion problems) [ 0 ]
- b. fair (minor wood decay and cracks) [✓ [1.0]]
- c. poor (many cracks on interior and exterior, floor out-of-level and wood decay) [2.1]

*C-2 In the under floor area, there has been structural alteration (e.g. cutting or notching of framing for electrical, plumbing, mechanical equipment) that would affect the performance of the dwelling in an earthquake:
yes [1.5]
[✓ no [0]]
not applicable [0]

*C-3: There is evidence of: stucco detachment, bowing of stucco, corroded wire mesh, extensive cracking at finished grade above the bottom of the stucco:
- a. extensive [2.0]
- b. minor [1.0]
- c. none [✓ [0]]

**Penalty**

*C-4 At the foundation level, there is:
- a. significant deterioration visible (corrosion, material breakdown) [1.3]
- b. some deterioration visible [0.6]
- c. no deterioration visible [✓ [0]]

C-5 Throughout the dwelling, the quality of construction appears to be:
- a. good [0]
- b. average [✓ [0.8]]
- c. poor [1.7]

**Total** 1.8

### D. Nonstructural Elements, Age, and Size

**Penalty**

*D-1 The chimney inspection revealed:
- a. properly connected anchor straps tying the masonry/concrete chimney(s) at side of house to the floor, ceiling and roof framing
  yes [1.0]
  no [2.0]
- b. chimney occurs at dwelling interior [1.0]
- c. dwelling has no masonry/concrete chimney [✓ [0]]

*D-2 The gas water heater has effective anchor straps and water and gas connections:
yes [0]
[✓ no [1.0]]

The electric water heater has approved anchor straps:
yes [0]
no [0.7]

*D-3 An earthquake-activated gas shut-off valve is installed:
yes [0]
[✓ no [1.0]]
not applicable [0]

**Penalty**

*D-4 The dwelling has exterior stairs, decks or porch roofs, without internal earthquake bracing, that are attached to the dwelling with:
- a. two or more connections tying the stair, deck or porch to the dwelling interior framing [✓ [0]]
- b. nails or screws that would be loaded in withdrawal if the stair deck or porch moved away from the dwelling [1.0]
- c. other connection configurations [1.0]

D-5 The dwelling was built: (if remodel/added area >50% of total area, use addition date):
- a. before 1920 [3.0]
- b. 1921 to 1977 [2.0]
- c. 1978 to 1993 [✓ [1.0]]
- d. 1994 or later [0]

D-6 The approximate total floor area (sq. ft.) of the dwelling and attached garage is:
- a. < 1600. [0]
- b. 1601 - 2500 [✓ [1.0]]
- c. ≥ 2501 [2.0]

**Total** 4.0

*Assessment item that may be improved by seismic retrofit; **see page 6, Section H**

## E. Local Site Conditions

**Penalty**

E-1 The dwelling is located primarily on:
- a. a flat lot or slope (≤ 3:1) [✓ [0]]
- b. steep slope (> 3:1) [3.0]

E-2 The dwelling is located on a cut-and-fill pad, which was developed:
- a. without a geotechnical investigation [2.7]
- b. with a geotechnical investigation [1.3]
- c. dwelling is *not* on cut-and-fill pad [✓ [0]]

*E-3 The exterior concrete footing has:
- a. no visible cracks or a few minor cracks [✓ [0]]
- b. minor cracks in several areas [1.0]
- c. extensive cracking [2.7]
- d. not applicable [0]

**Penalty**

E-4 The evidence of differential settlement in or around the dwelling is:
- a. extensive [2.5]
- b. minor [✓ [1.0]]
- c. none visible [0]

E-5: The slope above or below the structure appears to be unstable:
- yes [3.2]
- no [0]
- [✓ not applicable [0]]

*E-6: General condition of site drainage:
- a. roof gutters and downspouts collecting and conducting water away from foundation [0]
- b. water collecting at/near perimeter footing with no positive slope away from dwelling [2.6]
- c. no roof gutters but drainage appears to be adequate or roof gutters with downspouts that empty into splash blocks [✓ [1.3]]

**Total** 2.3

## F. Regional Seismic Hazard Score

F-1 Enter points for shaking hazard potential for location of dwelling (from Table 1). [ 6 ]

F-2 Are ground failure hazards to be looked up using Tables 2, 3, and 4?
- [✓ yes, go to F-3.]
- no, proceed to F-6 and enter 4.0 points for ground failure hazards

F-3 Is this dwelling located in a liquefaction zone (from Table 2) or landslide zone (from Table 3)?
- yes, go to F-4.
- [✓ no, go to F-5.]

F-4 Proceed to F-6 and enter ground failure hazard points in accordance with the following table:

| Ground Shaking Points | Ground Failure Points |
|---|---|
| 0 | 2 |
| 2, 4 | 3 |
| 6, 8 | 4 |

F-5 Is the dwelling located in a fault rupture zone (from Table 4)?
- yes [2]
- [✓ no [0]]

F-6 Total ground failure points from F-2, F-4, or F-5 (no summation). [ 0 ]

**Total Seismic Hazard Score** (Sum of F-1 and F-6) 6

### Table 1. Assignment of Ground Shaking Hazard Score

1. Use the USGS Seismic Design Maps Web Application (http://earthquake.usgs.gov/designmaps/usapp)[1] to look up ground shaking parameter $S_{DS}$:
   - a. Press the 'Launch Application' button.
   - b. In the web application, select '2012 IBC' for the Building Code Reference Document.
   - c. Select 'Site Class D – "Stiff Soil" (Default)' for the Site Soil Classification.
   - d. Enter the site address or latitude and longitude.
   - e. Press the 'Compute Values' button.
   - f. Read parameter $S_{DS}$ from the summary report. Enter here: 1.35 g
   - g. Multiply value from 1f by 100: 135 %g
2. Using the value from 1g, assign ground shaking points according to the following table (these points are assigned in Item F-1):

| Value of $S_{DS}$ (% g) | Ground Shaking Hazard Points |
|---|---|
| 33 - 66.99 | 0 |
| 67 - 82.99 | 2 |
| 83 - 124.99 | 4 |
| 125 - 187.99 | [✓ 6] |
| 188 - 250 | 8 |

[1] Note:If you are using the USGS application for the first time, or have recently cleared your web browser cookies, you may have to register for immediate use. Also, if you are using an anti-virus software program, you may have to enable some links to this site, e.g., if you receive a message that says "only secure content is displayed, "you must click on "show all content."

* Assessment item that may be improved by seismic retrofit; **see page 6, Section H**

### Table 2. Assignment of Site as Being Within a Liquefaction Zone

1. If site is in California, locate site on the California Emergency Management Agency (Cal EMA) MyPlan web site (myplan.calema.ca.gov).
   a. Enter address in 'Find Location' window.
   b. Select 'liquefaction' in menu bar to right of map.
   c. Zoom as needed to see map details.
   d. If site is located within green zone on map, answer to Question F-3 is 'yes'.
   e. If site located in non-liquefaction and non-seismic landslide zone on map (generally pale yellow), answer to Question F-3 is 'no'.
   f. Site not mapped if background is stippled. Go to Step (2).
2. If site is not on Cal EMA web site, determine site liquefaction potential/susceptibility using available web resources. See www.ATCouncil.org/pdfs/FEMAP-50LiquefactionInfo.pdf for a list of such resources. Map types shown in these web resources are:
   a. Liquefaction susceptibility maps. Answer to F-3 is 'yes' if site is in a zone of moderate-to-high liquefaction susceptibility. Answer is 'no' if in a low susceptibility or non-susceptible zone.
   b. Liquefaction potential maps. Answer to F-3 is 'yes' if site is in a liquefaction potential zone. Answer is 'no' if in a low or null potential zone.
   c. Liquefaction potential index (LPI) maps. Answer to F-3 is 'yes' if site is has mapped LPI ≥ 5 and no if mapped LPI < 5.
3. If the location of the site has not been mapped, Question F-3 can be answered as 'yes' if other local information suggests liquefaction potential and 'no' if such information suggests no such hazards.
4. If no maps are available and no information on site conditions is available, answer question F-2 as 'no'.

### Table 3. Assignment of Site as Being Within a Seismic Landslide Zone

1. If site is in California, attempt to locate site on the Cal EMA MyPlanweb site (myplan.calema.ca.gov).
   a. Enter address in 'Find Location' window.
   b. Select 'landslide' in menu bar to right of map.
   c. Zoom as needed to see map details.
   d. If site is located within brown zone on map, answer to Question F-3 is 'yes'.
   e. If site located in non-seismic landslide zone on map (generally pale yellow), answer to Question F-3 is 'no'.
   f. Site not mapped if background is stippled. Go to Step (2).
2. If site is not on Cal EMA web site, determine site landslide potential/susceptibility using available web resources. See www.ATCouncil.org/pdf/FEMAP-50LandslideInfo.pdf for a list of such resources. Map types shown in these web resources are:
   a. Seismic landslide susceptibility maps. Answer to F-3 is 'yes' if site is in a zone of moderate to high seismic landslide susceptibility. Answer is 'no' if in a low susceptibility or non-susceptible zone.
   b. Seismic landslide potential maps. Answer to F-3 is 'yes' if site is in a seismic landslide potential zone. Answer is 'no' if in a low or null potential zone.
3. If the location of the site has not been mapped, Question F-3 can be answered as 'yes' if other local information suggests high landslide potential and 'no' if such information suggests no such hazards (e.g., flat site).
4. If no maps are available and no information on site conditions is available, answer question F-2 as 'No'.

### Table 4. Assignment of Site as Being Within a Surface Fault Rupture Zone

1. If site is in California, locate site on the Cal EMA MyPlanweb site (myplan.calema.ca.gov).
   a. Enter address in 'Find Location' window.
   b. Select 'Fault Lines' in menu bar to right of map.
   c. Zoom as needed to see map details.
   d. If site is located within gray zone on map, answer to Question F-5 is 'yes'.
   e. If site located in non-gray zone, answer to Question F-5 is 'no'.
   f. Site not mapped if background is stippled. Go to Step (2).
2. If site is not on Cal EMA web site, locate site using USGS Quaternary faults web site (http://geohazards.usgs.gov/qfaults/map.php).
   a. Select applicable state or region.
   b. Zoom in on site and determine whether site is near a Quaternary fault that has been active within 15,000 years (marked as red or yellow on map).
   c. Faults are only marked for map scales marked at the 1 km (or larger) level. At this level of zoom, Question F-5 can be answered as 'yes' if the mapped fault trace is within approximately 0.25 km of the site and 'no' otherwise.

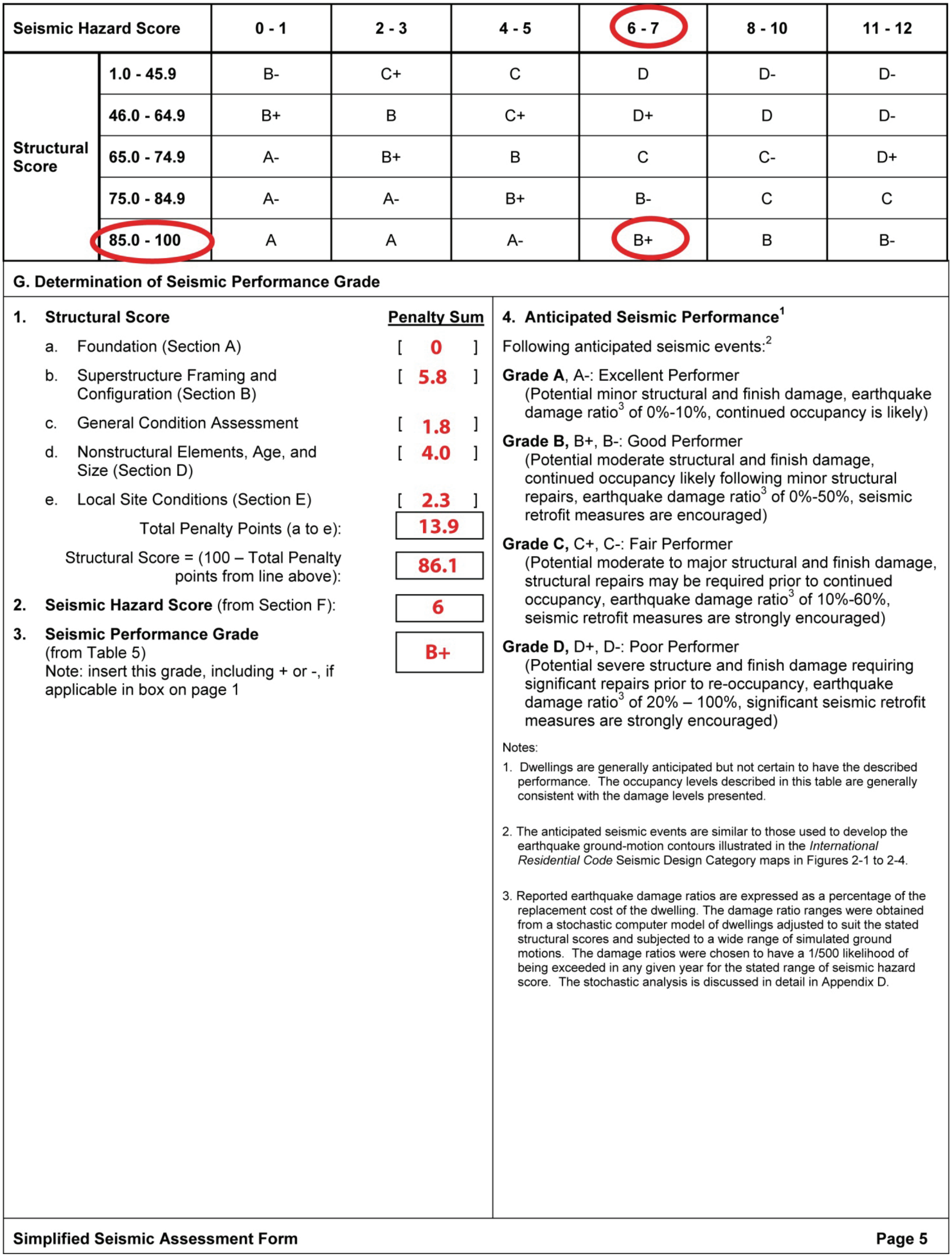

**Table 5. Seismic Performance Grade Based on Structural Score and Regional Seismic Hazard Score**

| **Seismic Hazard Score** | | **0 - 1** | **2 - 3** | **4 - 5** | **[✓ 6 - 7]** | **8 - 10** | **11 - 12** |
|---|---|---|---|---|---|---|---|
| **Structural Score** | **1.0 - 45.9** | B- | C+ | C | D | D- | D- |
| | **46.0 - 64.9** | B+ | B | C+ | D+ | D | D- |
| | **65.0 - 74.9** | A- | B+ | B | C | C- | D+ |
| | **75.0 - 84.9** | A- | A- | B+ | B- | C | C |
| | **[✓ 85.0 - 100]** | A | A | A- | [✓ B+] | B | B- |

**G. Determination of Seismic Performance Grade**

**1. Structural Score** **Penalty Sum**

a. Foundation (Section A) [ 0 ]

b. Superstructure Framing and Configuration (Section B) [ 5.8 ]

c. General Condition Assessment [ 1.8 ]

d. Nonstructural Elements, Age, and Size (Section D) [ 4.0 ]

e. Local Site Conditions (Section E) [ 2.3 ]

Total Penalty Points (a to e): 13.9

Structural Score = (100 – Total Penalty points from line above): 86.1

**2. Seismic Hazard Score** (from Section F): 6

**3. Seismic Performance Grade** (from Table 5) B+

Note: insert this grade, including + or -, if applicable in box on page 1

**4. Anticipated Seismic Performance**[1]

Following anticipated seismic events:[2]

**Grade A**, A-: Excellent Performer
(Potential minor structural and finish damage, earthquake damage ratio[3] of 0%-10%, continued occupancy is likely)

**Grade B,** B+, B-: Good Performer
(Potential moderate structural and finish damage, continued occupancy likely following minor structural repairs, earthquake damage ratio[3] of 0%-50%, seismic retrofit measures are encouraged)

**Grade C,** C+, C-: Fair Performer
(Potential moderate to major structural and finish damage, structural repairs may be required prior to continued occupancy, earthquake damage ratio[3] of 10%-60%, seismic retrofit measures are strongly encouraged)

**Grade D,** D+, D-: Poor Performer
(Potential severe structure and finish damage requiring significant repairs prior to re-occupancy, earthquake damage ratio[3] of 20% – 100%, significant seismic retrofit measures are strongly encouraged)

Notes:

1. Dwellings are generally anticipated but not certain to have the described performance. The occupancy levels described in this table are generally consistent with the damage levels presented.

2. The anticipated seismic events are similar to those used to develop the earthquake ground-motion contours illustrated in the *International Residential Code* Seismic Design Category maps in Figures 2-1 to 2-4.

3. Reported earthquake damage ratios are expressed as a percentage of the replacement cost of the dwelling. The damage ratio ranges were obtained from a stochastic computer model of dwellings adjusted to suit the stated structural scores and subjected to a wide range of simulated ground motions. The damage ratios were chosen to have a 1/500 likelihood of being exceeded in any given year for the stated range of seismic hazard score. The stochastic analysis is discussed in detail in Appendix D.

**Simplified Seismic Assessment Form** **Page 5**

## H. Improving the Seismic Performance Grade

The Structural Score and Seismic Performance Grade may be altered as a result of seismic retrofit or by a more in-depth seismic evaluation of the dwelling and the site by a qualified licensed design professional. Guidance on these issues is provided in Chapter 8.

If seismic retrofit is being considered, the Structural Score could be increased (and the Seismic Performance Grade potentially increased) by retrofitting conditions that would allow the elimination or reduction in penalties, if any, for the following items:

| Item | Retrofit Description | Points (circle applicable number) | Priority Retrofit |
|---|---|---|---|
| A-1 | Provide continuous reinforced concrete foundation | 4.2 | |
| A-3 | Provide foundation pads under interior posts | 1.4 | Yes |
| A-5 | Add anchor bolts or retrofit anchors | 1.7 4.6 10.0 15.0 | Yes |
| B-2 | Add bracing walls at dwelling exterior | [✓ 3.2] | |
| B-3 | Install lighter roofing | 1.6 3.5 | |
| B-4 | Install plywood/OSB or steel frame at garage front | 3.0 | Yes |
| B-5 | Change exterior wall finish | [✓ 1.0] 2.5 3.5 | |
| B-8 | Improve bracing at perimeter walls below lowest floor | 4.0 7.0 14.0 | Yes |
| C-2 | Repair cut structural framing | 1.5 | |
| C-3 | Repair deteriorated stucco | 1.0 2.0 | |
| C-4 | Repair deteriorated foundation | 0.6 1.3 | |
| D-1 | Strap exterior chimney to roof and floors | 1.0 | |
| D-2 | Provide bracing and flexible water and gas connections for water heater | [✓ 1.0] | Yes |
| D-3 | Provide earthquake-activated gas shut-off valves | [✓ 1.0] | Yes |
| D-4 | Anchor exterior stairs, deck and porch roof | 1.0 | Yes |
| E-3 | Repair footing cracks | 1.0 2.7 | |
| E-6 | Improve rain water routing away from foundations | [✓ 1.3] 2.6 | Yes |

**Priority Retrofits:** For this dwelling, the Structural Score can be increased by as many as 3.3 "Priority Retrofit" points (insert sum of points for circled items in rows with "Yes" in Priority Retrofit column). This will increase Structural Score to 89.4 (Section G, Item 1f Structural Score plus "Priority" retrofit points). This will result in an improved Structural Grade of B+ (from Table 5, using improved Structural Score).

**All Retrofits:** For this dwelling, the Structural Score can be increased by as many as 7.5 retrofit points (insert sum of ALL points for circled items). This will increase the Structural Score to 93.6 (Section G, Item 1f structural score plus ALL points circled above). This will result in an improved Structural Grade of B+ (from Table 5, using improved Structural Score).

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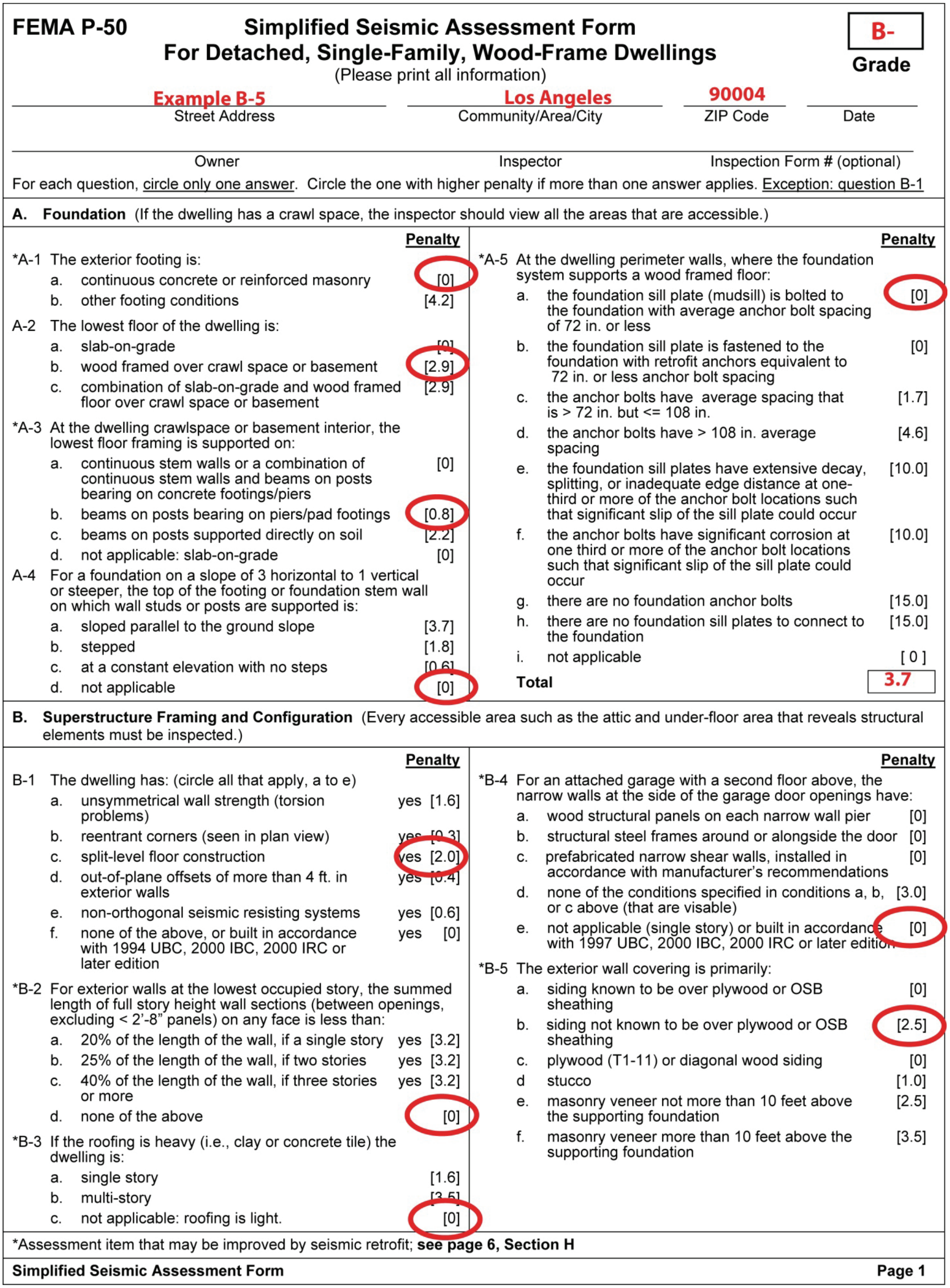
## Example B.5: Split-level Dwelling
## S Location: Los Angeles, California 90004

This dwelling received a penalty for the split-level floor diaphragms. However, it scored reasonably well in most sections, especially Local Site Conditions, and it is equipped with an earthquake activated gas shut-off valve.

.



**FEMA P-50**

## Simplified Seismic Assessment Form For Detached, Single-Family, Wood-Frame Dwellings

(Please print all information)

**B-** Grade

Example B-5 — Street Address
Los Angeles — Community/Area/City
90004 — ZIP Code
Date

Owner
Inspector
Inspection Form # (optional)

For each question, circle only one answer. Circle the one with higher penalty if more than one answer applies. Exception: question B-1

### A. Foundation (If the dwelling has a crawl space, the inspector should view all the areas that are accessible.)

**Penalty**

*A-1 The exterior footing is:
- a. continuous concrete or reinforced masonry [✓ [0]]
- b. other footing conditions [4.2]

A-2 The lowest floor of the dwelling is:
- a. slab-on-grade [0]
- b. wood framed over crawl space or basement [✓ [2.9]]
- c. combination of slab-on-grade and wood framed floor over crawl space or basement [2.9]

*A-3 At the dwelling crawlspace or basement interior, the lowest floor framing is supported on:
- a. continuous stem walls or a combination of continuous stem walls and beams on posts bearing on concrete footings/piers [0]
- b. beams on posts bearing on piers/pad footings [✓ [0.8]]
- c. beams on posts supported directly on soil [2.2]
- d. not applicable: slab-on-grade [0]

A-4 For a foundation on a slope of 3 horizontal to 1 vertical or steeper, the top of the footing or foundation stem wall on which wall studs or posts are supported is:
- a. sloped parallel to the ground slope [3.7]
- b. stepped [1.8]
- c. at a constant elevation with no steps [0.6]
- d. not applicable [✓ [0]]

**Penalty**

*A-5 At the dwelling perimeter walls, where the foundation system supports a wood framed floor:
- a. the foundation sill plate (mudsill) is bolted to the foundation with average anchor bolt spacing of 72 in. or less [✓ [0]]
- b. the foundation sill plate is fastened to the foundation with retrofit anchors equivalent to 72 in. or less anchor bolt spacing [0]
- c. the anchor bolts have average spacing that is > 72 in. but <= 108 in. [1.7]
- d. the anchor bolts have > 108 in. average spacing [4.6]
- e. the foundation sill plates have extensive decay, splitting, or inadequate edge distance at one-third or more of the anchor bolt locations such that significant slip of the sill plate could occur [10.0]
- f. the anchor bolts have significant corrosion at one third or more of the anchor bolt locations such that significant slip of the sill plate could occur [10.0]
- g. there are no foundation anchor bolts [15.0]
- h. there are no foundation sill plates to connect to the foundation [15.0]
- i. not applicable [ 0 ]

**Total** 3.7

### B. Superstructure Framing and Configuration (Every accessible area such as the attic and under-floor area that reveals structural elements must be inspected.)

**Penalty**

B-1 The dwelling has: (circle all that apply, a to e)
- a. unsymmetrical wall strength (torsion problems) yes [1.6]
- b. reentrant corners (seen in plan view) yes [0.3]
- c. split-level floor construction [✓ yes [2.0]]
- d. out-of-plane offsets of more than 4 ft. in exterior walls yes [0.4]
- e. non-orthogonal seismic resisting systems yes [0.6]
- f. none of the above, or built in accordance with 1994 UBC, 2000 IBC, 2000 IRC or later edition yes [0]

*B-2 For exterior walls at the lowest occupied story, the summed length of full story height wall sections (between openings, excluding < 2'-8" panels) on any face is less than:
- a. 20% of the length of the wall, if a single story yes [3.2]
- b. 25% of the length of the wall, if two stories yes [3.2]
- c. 40% of the length of the wall, if three stories or more yes [3.2]
- d. none of the above [✓ [0]]

*B-3 If the roofing is heavy (i.e., clay or concrete tile) the dwelling is:
- a. single story [1.6]
- b. multi-story [3.5]
- c. not applicable: roofing is light. [✓ [0]]

**Penalty**

*B-4 For an attached garage with a second floor above, the narrow walls at the side of the garage door openings have:
- a. wood structural panels on each narrow wall pier [0]
- b. structural steel frames around or alongside the door [0]
- c. prefabricated narrow shear walls, installed in accordance with manufacturer's recommendations [0]
- d. none of the conditions specified in conditions a, b, or c above (that are visable) [3.0]
- e. not applicable (single story) or built in accordance with 1997 UBC, 2000 IBC, 2000 IRC or later edition [✓ [0]]

*B-5 The exterior wall covering is primarily:
- a. siding known to be over plywood or OSB sheathing [0]
- b. siding not known to be over plywood or OSB sheathing [✓ [2.5]]
- c. plywood (T1-11) or diagonal wood siding [0]
- d stucco [1.0]
- e. masonry veneer not more than 10 feet above the supporting foundation [2.5]
- f. masonry veneer more than 10 feet above the supporting foundation [3.5]

*Assessment item that may be improved by seismic retrofit; **see page 6, Section H**

**Simplified Seismic Assessment Form** **Page 1**

## B. Superstructure Framing and Configuration (Every accessible area such as the attic and under-floor area that reveals structural elements must be inspected.) *(continued)*

**Penalty**

B-6 There is evidence of interior remodeling that has removed interior walls: [✓ yes [1.0]]
no/ not applicable [0]

B-7 The number of stories is:
- a. one (1) [0]
- b. [✓ two (2) [1.8]]
- c. 3 or more [3.6]

*B-8 At the dwelling perimeter, the main lowest framed floor is supported on:
- a. beam and column (post-and-pier) system with no sheathed exterior walls [14.0]
- b. perimeter cripple walls with no plywood or OSB sheathing [14.0]
- c. original or retrofitted perimeter cripple walls with plywood or OSB sheathing where cripple walls are one story or less in height [1.0 ]
- d. original or retrofitted perimeter cripple walls with plywood or OSB sheathing where cripple walls are greater than one story in height [4.0]
- e. wood or steel diagonal braces not detailed in accordance with 1997 UBC, 2000 IBC or later edition [7.0]
- f. plywood or OSB sheathed perimeter skirt walls that do not extend to and anchor to the foundation [7.0]
- g. [✓ none of the above [0]]

**Total** 7.3

## C. General Condition Assessment

**Penalty**

C-1 The overall condition of the dwelling is:
- a. good (essentially crack free, no moisture/water intrusion problems) [ 0 ]
- b. [✓ fair (minor wood decay and cracks) [1.0]]
- c. poor (many cracks on interior and exterior, floor out-of-level and wood decay) [2.1]

*C-2 In the under floor area, there has been structural alteration (e.g. cutting or notching of framing for electrical, plumbing, mechanical equipment) that would affect the performance of the dwelling in an earthquake:
yes [1.5]
[✓ no [0]]
not applicable [0]

*C-3: There is evidence of: stucco detachment, bowing of stucco, corroded wire mesh, extensive cracking at finished grade above the bottom of the stucco:
- a. extensive [2.0]
- b. minor [1.0]
- c. [✓ none [0]]

*C-4 At the foundation level, there is:
- a. significant deterioration visible (corrosion, material breakdown) [1.3]
- b. [✓ some deterioration visible [0.6]]
- c. no deterioration visible [0]

C-5 Throughout the dwelling, the quality of construction appears to be:
- a. good [0]
- b. [✓ average [0.8]]
- c. poor [1.7]

**Total** 2.4

## D. Nonstructural Elements, Age, and Size

**Penalty**

*D-1 The chimney inspection revealed:
- a. properly connected anchor straps tying the masonry/concrete chimney(s) at side of house to the floor, ceiling and roof framing yes [1.0]
  no [2.0]
- b. chimney occurs at dwelling interior [1.0]
- c. [✓ dwelling has no masonry/concrete chimney [0]]

*D-2 The gas water heater has effective anchor straps and water and gas connections: [✓ yes [0]]
no [1.0]

The electric water heater has approved anchor straps: yes [0]
no [0.7]

*D-3 An earthquake-activated gas shut-off valve is installed: [✓ yes [0]]
no [1.0]
not applicable [0]

*D-4 The dwelling has exterior stairs, decks or porch roofs, without internal earthquake bracing, that are attached to the dwelling with:
- a. [✓ two or more connections tying the stair, deck or porch to the dwelling interior framing [0]]
- b. nails or screws that would be loaded in withdrawal if the stair deck or porch moved away from the dwelling [1.0]
- c. other connection configurations [1.0]

D-5 The dwelling was built: (if remodel/added area >50% of total area, use addition date):
- a. [✓ before 1920 [3.0]]
- b. 1921 to 1977 [2.0]
- c. 1978 to 1993 [1.0]
- d. 1994 or later [0]

D-6 The approximate total floor area (sq. ft.) of the dwelling and attached garage is:
- a. < 1600. [0]
- b. 1601 - 2500 [1.0]
- c. [✓ ≥ 2501 [2.0]]

**Total** 5.0

*Assessment item that may be improved by seismic retrofit; **see page 6, Section H**

**Simplified Seismic Assessment Form** **Page 2**

## E. Local Site Conditions

**Penalty**

E-1 The dwelling is located primarily on:
  [✓ a. a flat lot or slope (≤ 3:1) [0]]
  b. steep slope (> 3:1) [3.0]

E-2 The dwelling is located on a cut-and-fill pad, which was developed:
  a. without a geotechnical investigation [2.7]
  b. with a geotechnical investigation [1.3]
  [✓ c. dwelling is *not* on cut-and-fill pad [0]]

*E-3 The exterior concrete footing has:
  [✓ a. no visible cracks or a few minor cracks [0]]
  b. minor cracks in several areas [1.0]
  c. extensive cracking [2.7]
  d. not applicable [0]

**Penalty**

E-4 The evidence of differential settlement in or around the dwelling is:
  a. extensive [2.5]
  b. minor [1.0]
  [✓ c. none visible [0]]

E-5: The slope above or below the structure appears to be unstable:
  yes [3.2]
  [✓ no [0]]
  not applicable [0]

*E-6: General condition of site drainage:
  a. roof gutters and downspouts collecting and conducting water away from foundation [0]
  b. water collecting at/near perimeter footing with no positive slope away from dwelling [2.6]
  [✓ c. no roof gutters but drainage appears to be adequate or roof gutters with downspouts that empty into splash blocks [1.3]]

**Total** 1.3

## F. Regional Seismic Hazard Score

F-1 Enter points for shaking hazard potential for location of dwelling (from Table 1). [ 6 ]

F-2 Are ground failure hazards to be looked up using Tables 2, 3, and 4?
  [✓ yes], go to F-3.
  no, proceed to F-6 and enter 4.0 points for ground failure hazards

F-3 Is this dwelling located in a liquefaction zone (from Table 2) or landslide zone (from Table 3)?
  yes, go to F-4.
  [✓ no], go to F-5.

F-4 Proceed to F-6 and enter ground failure hazard points in accordance with the following table:

| Ground Shaking Points | Ground Failure Points |
|---|---|
| 0 | 2 |
| 2, 4 | 3 |
| 6, 8 | 4 |

F-5 Is the dwelling located in a fault rupture zone (from Table 4)?
  yes [2]
  [✓ no [0]]

F-6 Total ground failure points from F-2, F-4, or F-5 (no summation). [ 0 ]

**Total Seismic Hazard Score** (Sum of F-1 and F-6) 6

### Table 1. Assignment of Ground Shaking Hazard Score

1. Use the USGS Seismic Design Maps Web Application (http://earthquake.usgs.gov/designmaps/usapp)[1] to look up ground shaking parameter $S_{DS}$:
   a. Press the 'Launch Application' button.
   b. In the web application, select '2012 IBC' for the Building Code Reference Document.
   c. Select 'Site Class D – "Stiff Soil" (Default)' for the Site Soil Classification.
   d. Enter the site address or latitude and longitude.
   e. Press the 'Compute Values' button.
   f. Read parameter $S_{DS}$ from the summary report. Enter here: 1.66 g
   g. Multiply value from 1f by 100: 166 %g

2. Using the value from 1g, assign ground shaking points according to the following table (these points are assigned in Item F-1):

| Value of $S_{DS}$ (% g) | Ground Shaking Hazard Points |
|---|---|
| 33 - 66.99 | 0 |
| 67 - 82.99 | 2 |
| 83 - 124.99 | 4 |
| 125 - 187.99 | [✓ 6] |
| 188 - 250 | 8 |

[1] Note:If you are using the USGS application for the first time, or have recently cleared your web browser cookies, you may have to register for immediate use. Also, if you are using an anti-virus software program, you may have to enable some links to this site, e.g., if you receive a message that says "only secure content is displayed, "you must click on "show all content."

* Assessment item that may be improved by seismic retrofit; **see page 6, Section H**

**Table 2. Assignment of Site as Being Within a Liquefaction Zone**

1. If site is in California, locate site on the California Emergency Management Agency (Cal EMA) MyPlan web site (myplan.calema.ca.gov).
    a. Enter address in 'Find Location' window.
    b. Select 'liquefaction' in menu bar to right of map.
    c. Zoom as needed to see map details.
    d. If site is located within green zone on map, answer to Question F-3 is 'yes'.
    e. If site located in non-liquefaction and non-seismic landslide zone on map (generally pale yellow), answer to Question F-3 is 'no'.
    f. Site not mapped if background is stippled. Go to Step (2).
2. If site is not on Cal EMA web site, determine site liquefaction potential/susceptibility using available web resources. See www.ATCouncil.org/pdfs/FEMAP-50LiquefactionInfo.pdf for a list of such resources. Map types shown in these web resources are:
    a. Liquefaction susceptibility maps. Answer to F-3 is 'yes' if site is in a zone of moderate-to-high liquefaction susceptibility. Answer is 'no' if in a low susceptibility or non-susceptible zone.
    b. Liquefaction potential maps. Answer to F-3 is 'yes' if site is in a liquefaction potential zone. Answer is 'no' if in a low or null potential zone.
    c. Liquefaction potential index (LPI) maps. Answer to F-3 is 'yes' if site is has mapped LPI ≥ 5 and no if mapped LPI < 5.
3. If the location of the site has not been mapped, Question F-3 can be answered as 'yes' if other local information suggests liquefaction potential and 'no' if such information suggests no such hazards.
4. If no maps are available and no information on site conditions is available, answer question F-2 as 'no'.

**Table 3. Assignment of Site as Being Within a Seismic Landslide Zone**

1. If site is in California, attempt to locate site on the Cal EMA MyPlanweb site (myplan.calema.ca.gov).
    a. Enter address in 'Find Location' window.
    b. Select 'landslide' in menu bar to right of map.
    c. Zoom as needed to see map details.
    d. If site is located within brown zone on map, answer to Question F-3 is 'yes'.
    e. If site located in non-seismic landslide zone on map (generally pale yellow), answer to Question F-3 is 'no'.
    f. Site not mapped if background is stippled. Go to Step (2).
2. If site is not on Cal EMA web site, determine site landslide potential/susceptibility using available web resources. See www.ATCouncil.org/pdf/FEMAP-50LandslideInfo.pdf for a list of such resources. Map types shown in these web resources are:
    a. Seismic landslide susceptibility maps. Answer to F-3 is 'yes' if site is in a zone of moderate to high seismic landslide susceptibility. Answer is 'no' if in a low susceptibility or non-susceptible zone.
    b. Seismic landslide potential maps. Answer to F-3 is 'yes' if site is in a seismic landslide potential zone. Answer is 'no' if in a low or null potential zone.
3. If the location of the site has not been mapped, Question F-3 can be answered as 'yes' if other local information suggests high landslide potential and 'no' if such information suggests no such hazards (e.g., flat site).
4. If no maps are available and no information on site conditions is available, answer question F-2 as 'No'.

**Table 4. Assignment of Site as Being Within a Surface Fault Rupture Zone**

1. If site is in California, locate site on the Cal EMA MyPlanweb site (myplan.calema.ca.gov).
    a. Enter address in 'Find Location' window.
    b. Select 'Fault Lines' in menu bar to right of map.
    c. Zoom as needed to see map details.
    d. If site is located within gray zone on map, answer to Question F-5 is 'yes'.
    e. If site located in non-gray zone, answer to Question F-5 is 'no'.
    f. Site not mapped if background is stippled. Go to Step (2).
2. If site is not on Cal EMA web site, locate site using USGS Quaternary faults web site (http://geohazards.usgs.gov/qfaults/map.php).
    a. Select applicable state or region.
    b. Zoom in on site and determine whether site is near a Quaternary fault that has been active within 15,000 years (marked as red or yellow on map).
    c. Faults are only marked for map scales marked at the 1 km (or larger) level. At this level of zoom, Question F-5 can be answered as 'yes' if the mapped fault trace is within approximately 0.25 km of the site and 'no' otherwise.

Table 5. **Seismic Performance Grade Based on Structural Score and Regional Seismic Hazard Score**

| **Seismic Hazard Score** | | **0 - 1** | **2 - 3** | **4 - 5** | **[✓ 6 - 7]** | **8 - 10** | **11 - 12** |
|---|---|---|---|---|---|---|---|
| **Structural Score** | **1.0 - 45.9** | B- | C+ | C | D | D- | D- |
| | **46.0 - 64.9** | B+ | B | C+ | D+ | D | D- |
| | **65.0 - 74.9** | A- | B+ | B | C | C- | D+ |
| | **[✓ 75.0 - 84.9]** | A- | A- | B+ | [✓ B-] | C | C |
| | **85.0 - 100** | A | A | A- | B+ | B | B- |

## G. Determination of Seismic Performance Grade

**1. Structural Score** — **Penalty Sum**

a. Foundation (Section A) [ 3.7 ]

b. Superstructure Framing and Configuration (Section B) [ 7.3 ]

c. General Condition Assessment [ 2.4 ]

d. Nonstructural Elements, Age, and Size (Section D) [ 5.0 ]

e. Local Site Conditions (Section E) [ 1.3 ]

Total Penalty Points (a to e): 19.7

Structural Score = (100 – Total Penalty points from line above): 80.3

**2. Seismic Hazard Score** (from Section F): 6

**3. Seismic Performance Grade** (from Table 5)
Note: insert this grade, including + or -, if applicable in box on page 1

B-

**4. Anticipated Seismic Performance**[1]

Following anticipated seismic events:[2]

**Grade A**, A-: Excellent Performer
(Potential minor structural and finish damage, earthquake damage ratio[3] of 0%-10%, continued occupancy is likely)

**Grade B,** B+, B-: Good Performer
(Potential moderate structural and finish damage, continued occupancy likely following minor structural repairs, earthquake damage ratio[3] of 0%-50%, seismic retrofit measures are encouraged)

**Grade C,** C+, C-: Fair Performer
(Potential moderate to major structural and finish damage, structural repairs may be required prior to continued occupancy, earthquake damage ratio[3] of 10%-60%, seismic retrofit measures are strongly encouraged)

**Grade D,** D+, D-: Poor Performer
(Potential severe structure and finish damage requiring significant repairs prior to re-occupancy, earthquake damage ratio[3] of 20% – 100%, significant seismic retrofit measures are strongly encouraged)

Notes:

1. Dwellings are generally anticipated but not certain to have the described performance. The occupancy levels described in this table are generally consistent with the damage levels presented.

2. The anticipated seismic events are similar to those used to develop the earthquake ground-motion contours illustrated in the *International Residential Code* Seismic Design Category maps in Figures 2-1 to 2-4.

3. Reported earthquake damage ratios are expressed as a percentage of the replacement cost of the dwelling. The damage ratio ranges were obtained from a stochastic computer model of dwellings adjusted to suit the stated structural scores and subjected to a wide range of simulated ground motions. The damage ratios were chosen to have a 1/500 likelihood of being exceeded in any given year for the stated range of seismic hazard score. The stochastic analysis is discussed in detail in Appendix D.

**H. Improving the Seismic Performance Grade**

The Structural Score and Seismic Performance Grade may be altered as a result of seismic retrofit or by a more in-depth seismic evaluation of the dwelling and the site by a qualified licensed design professional. Guidance on these issues is provided in Chapter 8.

If seismic retrofit is being considered, the Structural Score could be increased (and the Seismic Performance Grade potentially increased) by retrofitting conditions that would allow the elimination or reduction in penalties, if any, for the following items:

| Item | Retrofit Description | Points (circle applicable number) | Priority Retrofit |
|---|---|---|---|
| A-1 | Provide continuous reinforced concrete foundation | 4.2 | |
| A-3 | Provide foundation pads under interior posts | 1.4 | Yes |
| A-5 | Add anchor bolts or retrofit anchors | 1.7 4.6 10.0 15.0 | Yes |
| B-2 | Add bracing walls at dwelling exterior | 3.2 | |
| B-3 | Install lighter roofing | 1.6 3.5 | |
| B-4 | Install plywood/OSB or steel frame at garage front | 3.0 | Yes |
| B-5 | Change exterior wall finish | 1.0 [✓ 2.5] 3.5 | |
| B-8 | Improve bracing at perimeter walls below lowest floor | 4.0 7.0 14.0 | Yes |
| C-2 | Repair cut structural framing | 1.5 | |
| C-3 | Repair deteriorated stucco | 1.0 2.0 | |
| C-4 | Repair deteriorated foundation | [✓ 0.6] 1.3 | |
| D-1 | Strap exterior chimney to roof and floors | 1.0 | |
| D-2 | Provide bracing and flexible water and gas connections for water heater | 1.0 | Yes |
| D-3 | Provide earthquake-activated gas shut-off valves | 1.0 | Yes |
| D-4 | Anchor exterior stairs, deck and porch roof | 1.0 | Yes |
| E-3 | Repair footing cracks | 1.0 2.7 | |
| E-6 | Improve rain water routing away from foundations | [✓ 1.3] 2.6 | Yes |

**Priority Retrofits:** For this dwelling, the Structural Score can be increased by as many as 1.3 “Priority Retrofit” points (insert sum of points for circled items in rows with ”Yes” in Priority Retrofit column). This will increase Structural Score to 81.6 (Section G, Item 1f Structural Score plus “Priority” retrofit points). This will result in an improved Structural Grade of B- (from Table 5, using improved Structural Score).

**All Retrofits:** For this dwelling, the Structural Score can be increased by as many as 4.4 retrofit points (insert sum of ALL points for circled items). This will increase the Structural Score to 84.7 (Section G, Item 1f structural score plus ALL points circled above). This will result in an improved Structural Grade of B+ (from Table 5, using improved Structural Score).

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# Appendix C

# Seismic Performance of Wood-Frame Dwellings

## C.1 Introduction

The FEMA P-50 methodology for simplified seismic assessment of detached, single-family, wood-frame dwellings is based on the earthquake-resisting properties of such structures and studies of their performance in past California earthquakes. This appendix summarizes the characteristics and seismic vulnerabilities of single-family, wood-frame dwellings, performance trends derived from several databases containing seismic performance statistics of large numbers of wood-frame dwellings in the 1971 San Fernando, 1989 Loma Prieta, and 1994 Northridge earthquakes in California, and conclusions that can be drawn from this information. The companion publication FEMA P-50-1, *Seismic Retrofit Guidelines for Detached, Single-Family, Wood-Frame Dwellings*, provides additional discussion of common building configurations and construction.

Where discussion in this chapter relates to specific items in the Simplified Seismic Assessment Form, this is indicated by the applicable form assessment item designation.

## C.2 Characteristics and Seismic Vulnerabilities of Wood-Frame Dwellings

Wood-frame dwellings typically have from one to three stories and typically are constructed of wood stud walls constructed of 2-inch by 4-inch wood members vertically set about 16 inches apart (see Figure C-1). Four predominant configurations occur for supporting a wood-frame dwelling on its foundation:

- cripple-wall with a crawl space,
- slab-on-grade,
- basement and crawlspace with foundation stem wall, and
- post and pier.

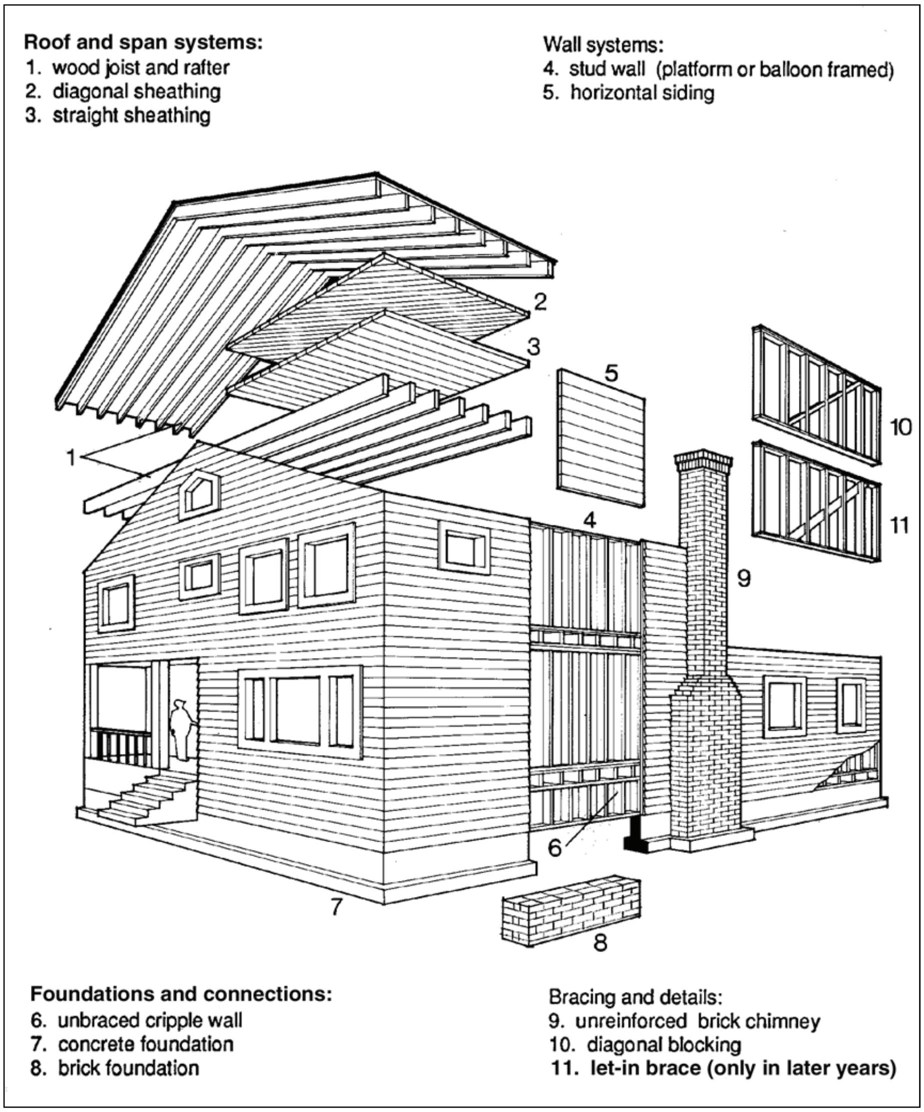

Figure C-1 Drawing of wood stud frame construction (courtesy of Lagorio, Friedman, and Wong, 1986).

A fifth configuration, the spilt-level dwelling, is usually a combination of a slab-on-grade and a cripple-wall dwelling.

Following are descriptions of these configurations. For each dwelling configuration, seismic vulnerabilities are also described.

### *C.2.1 Cripple-Wall Dwellings*

Cripple-wall dwellings are typically one- and two-story structures (Figures C-2 and C-3) with a perimeter foundation of unreinforced or reinforced concrete, brick masonry, or concrete block. The perimeter foundation typically comprises a stem wall supported by a wider footing. The stem wall

Figure C-2 Typical one-story cripple-wall crawl-space house (from ATC, 2002a).

Figure C-3 Typical older one and one-half-story cripple-wall crawl-space house (from ATC, 2002a).

supports the bottom sill plate of a short stud wall called a cripple, or pony, wall. The cripple wall encloses the crawlspace, and supports the perimeter of the first floor. The construction of wood stud walls and floors then continues up to the roof. The minimum height of the crawl space is usually 18 inches. On a sloping site, the maximum crawl space height depends on the slope. Typically, the crawl space remains an unfinished utility space. Figure C-4 shows a section through a typical cripple-wall crawl-space dwelling. Note that, away from the perimeter cripple wall, the floor joists are supported by floor beams resting on posts set into pier footings.

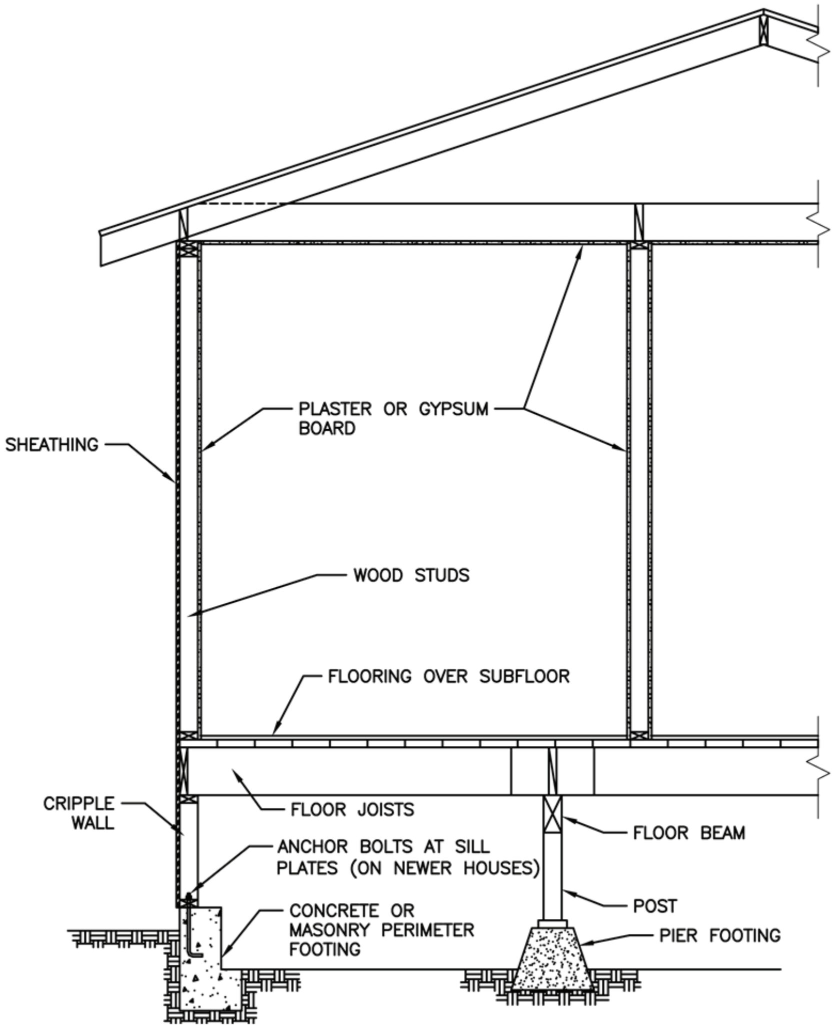

Figure C-4 Section through typical cripple-wall crawl-space house (from ATC, 2002b).

Two common seismic vulnerabilities in cripple-wall dwellings are the insufficient strength of the cripple wall exterior sheathing [Form assessment item B-8] and the lack of anchor bolts between the cripple wall sill and the foundation [Form item A-5]. Figure C-5 shows typical earthquake damage to the cripple wall. It is also common for crawlspace posts to shake out, leaving the beams and joists with no support [Form item B-8, exterior posts, Form item A-3, interior posts].

### *C.2.2 Slab-on-Grade Dwellings*

Slab-on-grade dwellings (see example in Figure C-6) have foundations formed by cast-in-place concrete slabs that lie directly on leveled soil. Most of the foundation consists of a ground floor concrete slab of about four-inch

Figure C-5 Typical earthquake damage to a cripple-wall house (from ATC, 2002a).

Figure C-6 Typical one-story slab-on-grade house (from ATC, 2002a).

thickness. At the perimeter, and often at the location of selected interior load-bearing walls, the slab is thickened to 12″ to 18″ to form a footing. The slab and thickened footings are usually reinforced with steel reinforcing bars or two-way wire fabric. Sometimes, the slab is reinforced with sleeved pre-stressing steel tendons that are post-tensioned and anchored after the concrete has cured. Anchor bolts cast into the slabs and footings or shot-in nails connect the bearing and lateral-force-resisting wood-frame stud walls to the slab. Interior stud walls are sheathed with gypsum board or plaster. Exterior walls are sheathed with gypsum board or plaster on the interior faces, and stucco, sawn wood siding, panel sheathing, or other material on the exterior faces. Similar wood-frame construction proceeds upwards for the desired number of stories, with wood joists supporting the elevated floors. A transverse section through a typical one-story slab-on-grade dwelling is shown in Figure C-7.

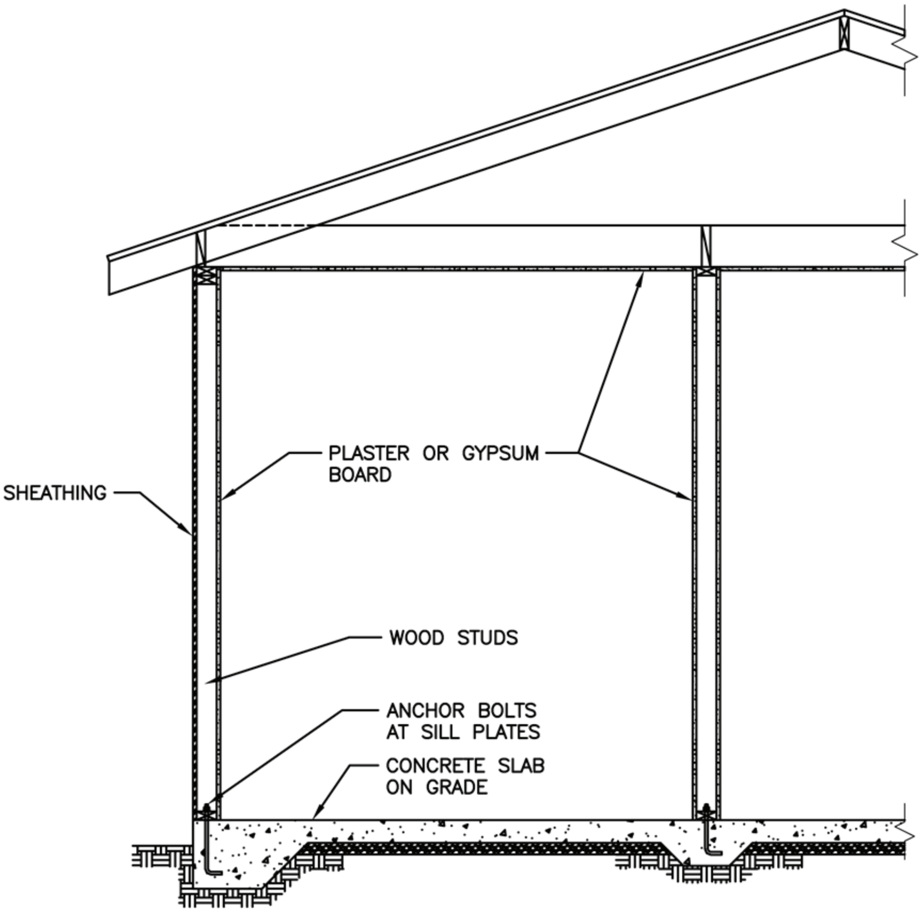

Figure C-7 Section through typical one-story slab-on-grade house (from ATC, 2002b).

### *C.2.3 Basement Dwellings and Crawlspace Dwellings with Foundation Stem Walls*

Dwellings with basements (basement dwellings) typically have full-height perimeter concrete basement walls. A concrete slab is usually placed between these walls to form the basement floor. A wood sill plate supporting the first floor joists is placed on the top of the perimeter basement wall, and the wood-frame construction then proceeds upwards for the desired number of stories. A section through a typical one-story basement dwelling is shown in Figure C-8.

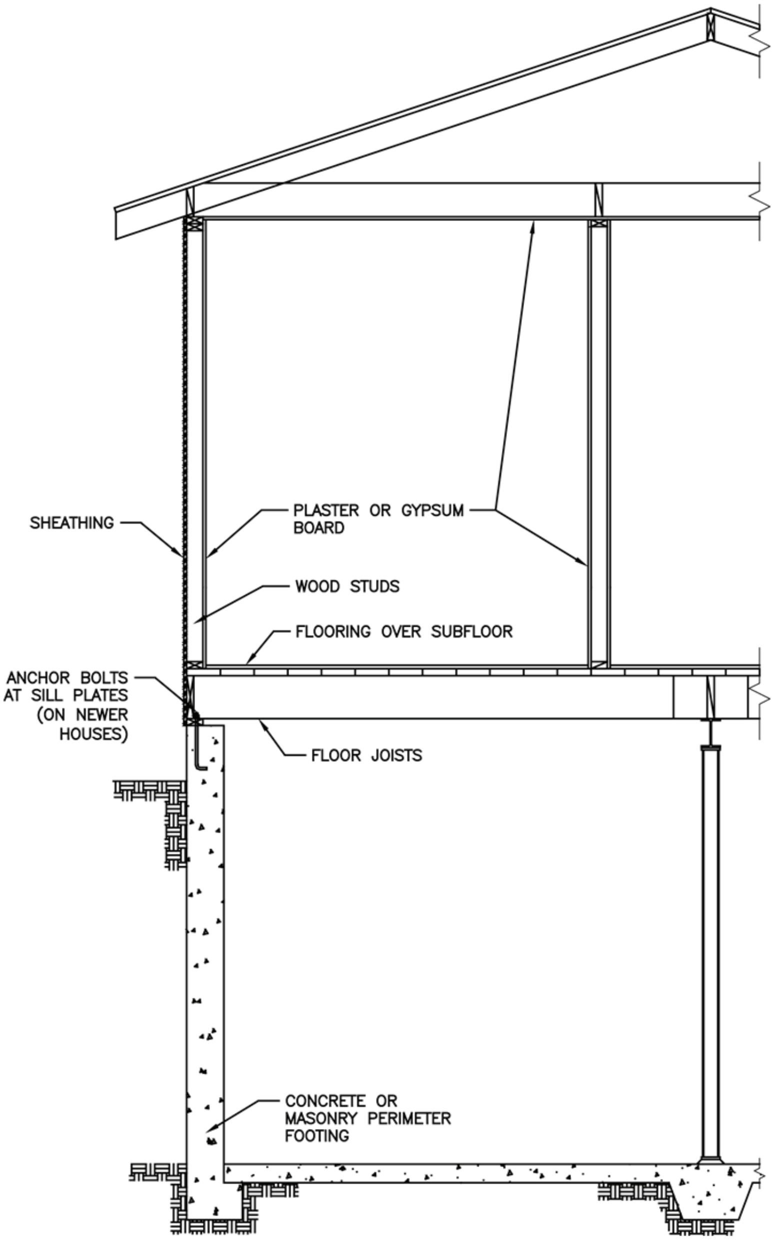

Figure C-8 Section through a typical one-story basement house (from ATC, 2002b).

A section through a crawl space dwelling with foundation stem walls is shown in Figure C-9. The perimeter walls are shorter, and they enclose a crawl space rather than a full-height basement. This configuration differs from a cripple-wall dwelling in that the perimeter foundation walls are made of concrete rather than wood framing.

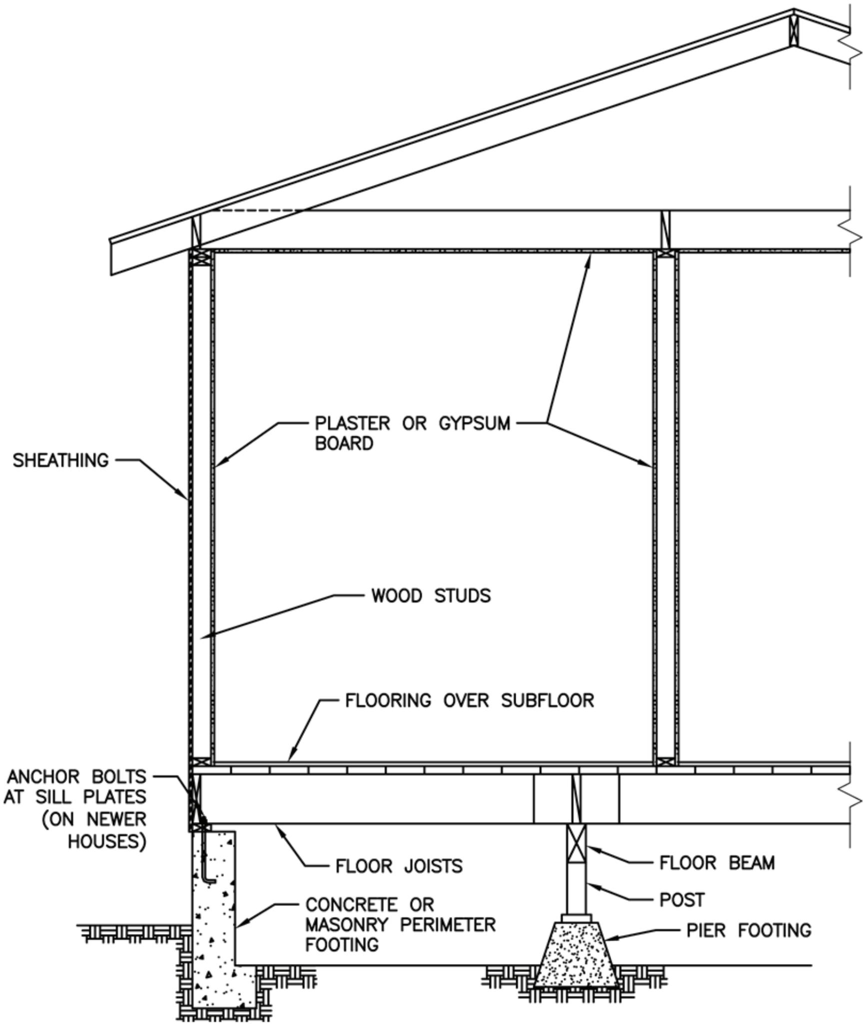

Figure C-9 Section through a variation of the basement dwelling where the perimeter foundation walls enclose a crawl space (from ATC, 2002b).

A common seismic vulnerability in basement and foundation stem wall dwellings is the lack of anchor bolts between the sill plate and the basement wall [Form item A-5]. A dwelling of this type that was damaged in the Cape Mendocino earthquake of 1992 is shown in Figure C-10; in this case the sill plate slid along the top of the basement wall.

Figure C-10 Damage to a basement-type dwelling where the sill plate slid on the top of the foundation wall (from ATC, 2002a).

### C.2.4 Perimeter Post-and-Pier Foundation Dwellings

Dwellings with post-and-pier foundation can be located either on sloping sites (Figure C-11) or flat sites (Figure C-12). Dwellings of this type have

Figure C-11 Post-and-pier foundation house on sloping site (from ATC, 2002a).

Figure C-12 Post-and-pier house on flat site (from ATC, 2002a).

individual footings spaced along the dwelling perimeter and along interior lines. These footings may be shallow foundations or deep drilled piers, and may or may not be tied together by grade beams at ground level. The footings support wood, steel, or concrete posts. The posts are provided with some degree of lateral-force resistance by diagonal bracing or by rigid connections to the girders supported by the posts. The first-floor joists and the dwelling superstructure are supported by these girders.

A common seismic vulnerability in post-and-pier dwellings is the lack of seismic strength in the post-and-pier foundation system [Form items A-1 through A-5 and B-8]. Earthquake damage to a post-and-pier foundation is shown in Figure C-13. Dwellings on steep hillsides, as shown in Figure C-11, are particularly vulnerable to damage.

### *C.2.5 Split-Level Dwellings, Multi-Level Hillside Dwellings*

Dwellings where adjacent floor levels are separated by less than a full-story height are usually designated split-level dwellings. One typical configuration is shown in Figure C-14. The right part of the dwelling is of two-story slab-on-grade wood-frame construction, with the garage space occupying the lower floor. The attached portion on the left side is of one-story cripple-wall construction. Other split-level dwellings may have all slab-on-grade ground floors at different elevations, and may not have living spaces over the garage. These dwellings may be on either flat or sloped sites. On flat sites, the two lower levels may be at nearly the same elevation.

Figure C-13 Earthquake-damaged perimeter post-and-pier foundation (from ATC, 2002a). The diagonally braced post has slid off the pier footing.

Figure C-14 Split-level house, where the section of flooring above the garage is at a lower level than the main second-floor level (from ATC, 2002a).

A common seismic vulnerability in split-level dwellings with living spaces over the garage is inadequate strength of the walls at each side of the garage door to resist seismic forces from the dwelling portion above [Form item B-4]. Damage that was in part initiated by this vulnerability is shown in Figure C-14. Another common vulnerability is insufficient strength of the cripple wall under the single-story portion of the dwelling, when present, causing damage similar to that of Figure C-5 [Form item B-8]. This configuration is also penalized under form item B-1, split-level floor construction.

### C.2.6 Exterior Wall Strength

A common seismic vulnerability in dwellings is the insufficient lateral-force-resisting strength of the first floor exterior and interior walls due to the large number of door and window openings in these walls [Form item B-2] and the limited strength of the sheathing materials [Form item B-5]. Typical earthquake damage to the first-story walls is shown in Figures C-15 and C-16.

Figure C-15 Cracking damage to stucco first-floor walls (from ATC, 2002a).

Figure C-16 Damage and racking displacement in the first floor walls (from ATC, 2002a.

## C.3 Studies of the Performance of Wood-Frame Dwellings in Recent California Earthquakes

Studies of the performance of wood-frame dwellings in several relatively recent California earthquakes provide useful information for predicting the future performance of such dwellings in earthquakes. It is important to recognize, however, that as engineering practices, codes and regulations are improved, there will likely be a corresponding improvement in the performance of newly designed and constructed dwellings. Descriptions of selected relevant studies of dwelling damage in three relatively recent damaging earthquakes in California (1971 San Fernando earthquake, 1989 Loma Prieta earthquake, and 1994 Northridge earthquake) follow (Sections C.3.1, C.3.2, and C.3.3). Section C.4 contains comparative analyses and interpretations of these data. This information has been extracted from the ATC-50 report, *Simplified Seismic Assessment of Detached, Single-Family, Wood-Frame Dwellings* (ATC, 2002b), predecessor to this document.

### *C.3.1 1971 San Fernando Earthquake*

Seismic performance data for dwellings in the San Fernando Valley were collected after the 1971 San Fernando earthquake by the Department of Housing and Urban Development (HUD) and the Insurance Services Office.

**HUD Data.** The HUD database is based on a limited survey of 169 residential dwellings affected by the 1971 San Fernando earthquake. Information was gathered on (1) building location; (2) the number of stories (especially split level and including the configuration below the first floor); (3) presence of connection of ledger or wood sill plate to footings; (4) interior partition finish (e.g., metal lath and plaster, gypsum lath and plaster, or gypsum board); (5) serious previous deterioration of the structure; (6) presence of an unreinforced masonry chimney; (7) fill, cut-and-fill lot, or other poor soil or site condition; (8) unbraced wood cripple studs in exterior wall framing; (9) damageability, as indicated by the owner's estimate of actual itemized repair costs; (10) damageability, as indicated by the repair cost estimate on the building permit; and (11) replacement cost of the residence.

The survey was not random, nor even representative. Split-level dwellings were over-represented: 22.5% of residences surveyed were split-level, as contrasted to 0.5% in the general area. Another 18.9% were noted as being one and two-story, as opposed to 3.0% in the general population. Moreover, the buildings surveyed had higher damage ratios (defined as the ratio of repair cost to replacement cost) than was typical of dwellings in the same earthquake intensity zones (Wiggins and Taylor, 1986).

To draw practical conclusions, the HUD survey data statistics were adjusted by Wiggins and Taylor (1986) to remove biases and to determine which parameters (building characteristics) had the largest influence on damage. The authors developed a "point" rating system that was used to assign points to each building in the sample set, based on building characteristics, the loss ratio (repair cost divided by replacement cost), and ground shaking intensity. Using this information, a multiple regression analysis was carried out to define the contribution of each survey parameter (building characteristic) to building economic loss. Table C-1 shows the results of the multiple regression analysis, indicating the contribution of those parameters having the highest correlation with damage. In this study Wiggins and Taylor found that those parameters that did not have a significant effect on predicting the damageability level included the number of stories, age, physical condition, and presence of unreinforced or poorly reinforced masonry chimneys.

**Table C-1 Contribution of Specific Building Characteristics to Damage (from Wiggins and Taylor, 1986)[1]**

| Building Characteristic | Relative Contribution to Damage |
|---|---|
| No visible connection between wood sill or ledger to footings | 23% |
| Wood stud and cripple walls as exterior wall framing | 21% |
| Fill (engineered or not, pre-1963) or Cut and Fill | 11% |
| Interior partition finish of gypsum lath and plaster or metal lath and plaster | 7% |
| Configuration below first floor | 1% |
| Other factors | 37% |
| **Total** | **100%** |

[1] Based on a study of dwellings surveyed by HUD after 1971 San Fernando earthquake.

**Insurance Services Office Data.** K.V. Steinbrugge of the Insurance Services Office developed more comprehensive but less detailed loss estimates for the 1971 San Fernando earthquake. Loss ratios (ratio of damageability, or repair cost, to replacement cost) for dwellings included in the Steinbrugge (1982) study of the San Fernando Valley earthquake are summarized in Table C-2.

Table C-2 indicates that pre-1940 dwellings performed worse than dwellings built in 1940 and thereafter and that one-and-two-story dwellings performed worse than two-story dwellings, which performed worse than one-story dwellings. One major limitation of these data is that these estimates are not correlated to ground-shaking intensities.

### *C.3.2 1989 Loma Prieta Earthquake*

One of the principal investigations of dwelling performance during the 1989 Loma Prieta earthquake was a study conducted by the U.S. Geological Survey, which analyzed losses to single-family dwellings associated with ground deformation in the Marina and South of Market districts. This study encompasses a different approach from the regression analysis of the San Fernando Valley earthquake by Wiggins and Taylor (1986), which specifically excluded damage due to ground failure. The USGS study evaluated earthquake damage data for four San Francisco zip codes based on numerous data sources, including a City of San Francisco rapid evaluation screening analysis using the ATC-20 *Procedures for Postearthquake Safety Evaluation of Buildings* (ATC, 1989), Federal Emergency Management Agency damage survey reports, Small Business Administration loss data relative to loans to small business and individuals adversely affected by the earthquake, loss data for applicants to the Individual and Family Grant Program of the State of California, and loss data provided by insurers to the California Department of Insurance.

**Table C-2 Loss Ratios[1] for Dwellings Damaged during the 1971 San Fernando Earthquake (after Steinbrugge, 1982)**

| Number of Stories | Pre-1940 | 1940 and Thereafter | All Buildings |
|---|---|---|---|
| One story | 0.080 | 0.044 | 0.046 |
| One and two stories | 0.303 | 0.165 | 0.172 |
| Two stories | 0.220 | 0.120 | 0.125 |
| All dwellings | 0.092 | 0.050 | 0.052 |

[1] Repair cost divided by replacement cost.

Multiple regression analyses of the USGS data by Taylor et al. (1994) were performed to evaluate the contribution to damage by various building characteristics. Neither age nor height of the dwelling was found to have a significant impact on the observed damage ratios. Data from regions where settlement occurred suggested that this phenomena had a small but statistically significant effect on the observed damage ratios. Settlement explained nearly 10% of the observed damage.

### *C.3.3 1994 Northridge Earthquake*

The performance of dwellings during the 1994 Northridge earthquake is documented in two large data sets: (1) a data set derived from insurance data collected by the California Department of Insurance (CDI); and (2) a data set of ATC-20 building safety inspection postings (ATC, 1989) compiled for the Office of Emergency Services (OES), State of California (ABS Consulting et al., 1995). The CDI data set is composed of various subsets, one of which has specific loss and replacement value information on individual dwellings. The OES data set includes data on Modified Mercalli Intensity, peak ground acceleration, site condition (hard rock, soft rock, soft soil), year built, square footage, and structure type (e.g., wood frame, concrete). These data are documented in *The Northridge Earthquake of January 17, 1994: Report of Data Collection and Analysis*, *Part A: Damage and Inventory Data* (ABS Consulting et al., 1995). Partial results are summarized in Table C-3.

## C.4 Comparative Analysis and Interpretation of Data from the 1971 San Fernando and 1994 Northridge Earthquakes

As part of the seismic grading system development process, the ATC-50 development team analyzed and compared dwelling performance data from the 1971 San Fernando earthquake (Wiggins and Taylor, 1986,and Steinbrugge, 1982) and the 1994 Northridge earthquake (ABS Consulting et al., 1995) to identify building characteristics having the greatest impact on damageability. The following parameters and topics were investigated:

- Effects of the number of stories,
- Effects of age of construction, and
- Loss ratios as a function of Modified Mercalli Intensity (MMI), year built, and building square footage.

Following are the development team's findings and conclusions pertaining to each of these parameters and topics.

### *C.4.1 Effects of Number of Stories*

For the 1971 San Fernando Valley earthquake, the Steinbrugge (1982) data set and the HUD data set were used to draw provisional conclusions on the effects of the number of stories on the damageability of low-rise dwellings.

Regression analysis of the HUD data by Wiggins and Taylor (1986) indicates that the loss ratio depends to some extent on the number of stories, with one-story structures being slightly better performers. The Steinbrugge (1982) data set (see Table C-2) suggests more strongly that the number of stories is a significant predictor of damageability, with one-story dwellings being the best performers.

**Table C-3** Number of Buildings in Damage Ranges: Single-Family Wood Frame Dwellings by Intensity, Vintage, and Square Foot Range (from ABS Consulting et al., 1995)

| Damage Range | MMI = VI | | | MMI = VII | | | MMI = VIII | | | MMI = IX | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Square footage: | | | Square footage: | | | Square footage: | | | Square footage: | | | |
| | <1600 | 1600-2500 | >2500 | <1600 | 1600-2500 | >2500 | <1600 | 1600-2500 | >2500 | <1600 | 1600-2500 | >2500 | |
| *Year Built: pre-1941** | | | | | | | | | | | | | |
| 0.05-0.3 | 39 | 7 | 3 | 64 | 37 | 48 | 55 | 27 | 11 | 2 | 1 | | *294* |
| 0.3-1.25 | 143 | 58 | 7 | 418 | 326 | 224 | 312 | 149 | 62 | 6 | 3 | | 1,708 |
| 1.25-3.5 | 231 | 53 | 13 | 599 | 487 | 241 | 556 | 216 | 65 | 15 | 10 | 1 | 2,487 |
| 3.5-7.5 | 259 | 42 | 6 | 611 | 379 | 144 | 489 | 193 | 71 | 27 | 10 | 1 | 2,232 |
| 7.5-20 | 287 | 37 | 2 | 1,056 | 262 | 27 | 892 | 176 | 40 | 46 | 11 | | 2,836 |
| 20-65 | 43 | 3 | | 213 | 29 | 9 | 271 | 28 | 10 | 26 | 4 | 1 | 637 |
| 65-100 | 9 | | | 50 | 8 | 4 | 104 | 20 | 10 | 4 | 3 | | 212 |
| N/A | 432 | 95 | 14 | 623 | 384 | 226 | 819 | 178 | 39 | 9 | 2 | | 2,821 |
| Total | 1,443 | 295 | 45 | 3,634 | 1,912 | 923 | 3,498 | 987 | 308 | 135 | 44 | 3 | 13,227 |
| *Year Built: 1941-1950* | | | | | | | | | | | | | |
| 0.05-0.3 | 7 | 4 | 1 | 36 | 16 | 5 | 73 | 29 | 12 | 2 | | | 185 |
| 0.3-1.25 | 44 | 11 | | 151 | 86 | 31 | 425 | 143 | 31 | 24 | 8 | 2 | 956 |
| 1.25-3.5 | 44 | 11 | 1 | 192 | 69 | 14 | 671 | 229 | 35 | 38 | 6 | 4 | 1,314 |
| 3.5-7.5 | 32 | 10 | | 109 | 49 | 9 | 630 | 207 | 47 | 40 | 17 | 6 | 1,156 |
| 7.5-20 | 18 | 1 | | 124 | 28 | 2 | 739 | 191 | 38 | 47 | 10 | 5 | 1,203 |
| 20-65 | 1 | | | 25 | 5 | 1 | 156 | 34 | 17 | 14 | 3 | 2 | 258 |
| 65-100 | 1 | | | 3 | | | 21 | 6 | 3 | | 2 | 2 | 38 |
| N/A | 118 | 40 | 3 | 296 | 100 | 30 | 778 | 170 | 27 | 23 | 5 | | 1,590 |
| Total | 265 | 77 | 5 | 936 | 353 | 92 | 3,493 | 1,009 | 210 | 188 | 51 | 21 | 6,700 |
| *Year Built: 1951-1960* | | | | | | | | | | | | | |
| 0.05-0.3 | 5 | 6 | 3 | 42 | 25 | 5 | 195 | 109 | 28 | 20 | 15 | | 453 |
| 0.3-1.25 | 19 | 16 | 5 | 137 | 91 | 10 | 1,004 | 649 | 79 | 185 | 145 | 16 | 2,356 |
| 1.25-3.5 | 15 | 18 | 4 | 152 | 77 | 13 | 1,431 | 939 | 104 | 245 | 252 | 29 | 3,279 |
| 3.5-7.5 | 10 | 9 | 2 | 110 | 50 | 2 | 1,362 | 928 | 95 | 275 | 234 | 44 | 3,121 |
| 7.5-20 | 7 | 3 | | 108 | 28 | | 1,777 | 802 | 92 | 343 | 270 | 36 | 3,466 |
| 20-65 | 2 | | | 7 | 1 | | 302 | 152 | 24 | 86 | 45 | 16 | 635 |
| 65-100 | | | | 5 | 3 | | 42 | 23 | 9 | 11 | 10 | 4 | 107 |
| N/A | 65 | 43 | 7 | 283 | 135 | 31 | 1,331 | 599 | 38 | 116 | 87 | 13 | 2,748 |
| Total | 123 | 95 | 21 | 844 | 410 | 61 | 7,444 | 4,201 | 469 | 1,281 | 1,058 | 158 | 16,165 |

*Includes those for which design and construction date not specified.

**Table C-3** Number of Buildings in Damage Ranges: Single-Family Wood Frame Dwellings by Intensity, Vintage, and Square Foot Range (from ABS Consulting et al., 1995) (continued)

| | MMI = VI | | | MMI = VII | | | MMI = VIII | | | MMI = IX | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Square footage: | | | Square footage: | | | Square footage: | | | Square footage: | | | |
| Damage Range | <1600 | 1600-2500 | >2500 | <1600 | 1600-2500 | >2500 | <1600 | 1600-2500 | >2500 | <1600 | 1600-2500 | >2500 | Total |
| *Year Built: 1961-1976* | | | | | | | | | | | | | |
| 0.05-0.3 | | 2 | | 16 | 28 | 10 | 33 | 145 | 66 | | 4 | 2 | 306 |
| 0.3-1.25 | 3 | 7 | | 55 | 134 | 17 | 182 | 810 | 276 | 7 | 54 | 43 | 1,588 |
| 1.25-3.5 | | 4 | 2 | 81 | 140 | 18 | 211 | 1,085 | 356 | 13 | 120 | 40 | 2,070 |
| 3.5-7.5 | 7 | | | 44 | 96 | 19 | 162 | 1,040 | 351 | 20 | 129 | 44 | 1,912 |
| 7.5-20 | | 1 | | 37 | 70 | 11 | 173 | 1,032 | 322 | 45 | 158 | 75 | 1,924 |
| 20-65 | | | | 19 | 17 | 1 | 44 | 298 | 129 | 3 | 37 | 33 | 581 |
| 65-100 | | | | 4 | 2 | 2 | 15 | 82 | 20 | | 6 | 6 | 137 |
| N/A | 9 | 13 | 1 | 69 | 206 | 49 | 206 | 565 | 173 | 17 | 45 | 24 | 1,377 |
| Total | 19 | 27 | 3 | 325 | 693 | 127 | 1,026 | 5,057 | 1,693 | 105 | 553 | 267 | 9,895 |
| *Year Built: Post-1976* | | | | | | | | | | | | | |
| 0.05-0.3 | | 4 | 12 | 14 | 32 | 12 | 26 | 68 | 87 | | 2 | 5 | 262 |
| 0.3-1.25 | 2 | 4 | 4 | 23 | 53 | 39 | 54 | 311 | 347 | 2 | 21 | 28 | 888 |
| 1.25-3.5 | 2 | 1 | 10 | 11 | 35 | 24 | 65 | 447 | 370 | 4 | 25 | 50 | 1,044 |
| 3.5-7.5 | 1 | 1 | 9 | 12 | 19 | 7 | 27 | 260 | 297 | 8 | 31 | 37 | 709 |
| 7.5-20 | | 1 | 1 | 8 | 4 | 4 | 33 | 292 | 277 | 3 | 29 | 33 | 685 |
| 20-65 | | | 2 | 5 | | 4 | 7 | 113 | 100 | 2 | 6 | 14 | 253 |
| 65-100 | 1 | | 1 | | | 2 | 1 | 28 | 30 | 2 | 2 | 1 | 68 |
| N/A | 5 | 9 | 26 | 20 | 66 | 30 | 128 | 297 | 202 | 4 | 10 | 26 | 823 |
| Total | 11 | 20 | 65 | 93 | 209 | 122 | 341 | 1,816 | 1,710 | 25 | 126 | 194 | 4,732 |
| *Total* | | | | | | | | | | | | | |
| | 1,861 | 514 | 139 | 5,832 | 3,577 | 1,325 | 15,802 | 13,070 | 4,390 | 1,734 | 1,832 | 643 | 50,719 |

N/A: Not applicable: damage range not available, or not recorded.

An evaluation of the OES 1994 Northridge earthquake data by Wiggins and Taylor indicates that, for a given MMI level, dwellings that were more likely to be one-story (those with less than 1600 square feet) performed worse in the Northridge earthquake than did dwellings that may have additional full or partial stories (those with between 1600 and 2500 square feet).

Collectively the dwelling performance data from the 1971 San Fernando earthquake and the 1994 Northridge earthquake suggest that damageability is not consistently correlated with number of stories.

### C.4.2 Effects of Age of Construction

The Steinbrugge (1982) data (see Table C-2) suggest that pre-1940 dwellings perform worse than dwellings built in 1940 and thereafter. An analysis of the OES 1994 Northridge data (ABS Consulting et al., 1995) to evaluate the effects of dwelling age indicate that dwellings built in 1940 and before perform worse than dwellings built after 1940[1] (see Table C-4). At intensity VI, 1960-76 dwellings are the best performers. At intensity VII, post-1976 dwellings are the best performers. At intensity VIII, 1950-60 dwellings are the best performers. At intensity IX, 1950-1960 and post-1976 dwellings are the best performers. Collectively, these data indicate that pre-1941 dwellings perform worse than post-1940 dwellings. However, among the post-1940 dwellings, there is not a consistent relationship between age and performance.

**Table C-4 Mean Loss Ratio for Dwellings in 1994 Northridge Earthquake as Function of MMI and Year Built (from ATC, 2002a)**

| Year Built | Modified Mercalli Intensity | | | |
|---|---|---|---|---|
| | VI | VII | VIII | IX |
| Pre-1941 | 0.074 | 0.079 | 0.110 | 0.139 |
| 1941-1950 | 0.038 | 0.054 | 0.079 | 0.100 |
| 1950-1960 | 0.035 | 0.058 | 0.073 | 0.085 |
| 1960-1976 | 0.024 | 0.061 | 0.088 | 0.100 |
| Post-1976 | 0.047 | 0.037 | 0.078 | 0.085 |

### C.4.3 Loss Ratio as a Function of MMI, Year Built and Building Square Footage

The data evaluations described in Sections C.4.1 and C.4.2 yields mixed results with respect to the role of building square footage (as a proxy for number of stories) on damageability. The results also indicate that pre-1940/41 dwellings perform worse than dwellings designed and built after that time frame. In order to examine these results further, loss ratios were evaluated considering MMI, year built, and building square footage.

The use of loss ratios to analyze Northridge data (ABS Consulting et al., 1995) is illustrated in Table C-5, which is limited to dwellings under 1600 square feet. At MMI VI, the worst performers are post-1976 dwellings.

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[1] Note: The ABS Consulting et al. study (1995) designates older dwellings as pre-1941; Steinbrugge (1982) designates older dwellings as pre-1940.

However, at intensities VII and VIII, as expected, the worst performers are pre-1941 dwellings. At intensity IX, the worst performers are again the post-1976 dwellings. The best performers are 1941-1950 dwellings at intensity VI, 1960-76 dwellings at intensities VII and VIII, and 1950-60 dwellings at intensity IX.

**Table C-5 Mean Loss Ratio for Dwellings in 1994 Northridge Earthquake as Function of MMI and Year Built (Dwellings under 1600 sq ft) (from ATC, 2002a)**

| Year Built | Modified Mercalli Intensity | | | |
|---|---|---|---|---|
| | VI | VII | VIII | IX |
| Pre-1941 | 0.077 | 0.100 | 0.122 | 0.149 |
| 1941-1950 | 0.041 | 0.061 | 0.079 | 0.093 |
| 1950-1960 | 0.047 | 0.061 | 0.077 | 0.088 |
| 1960-1976 | 0.043 | 0.088 | 0.084 | 0.090 |
| Post-1976 | 0.108 | 0.047 | 0.049 | 0.153 |

Table C-6 presents a slightly different picture with respect to dwellings between 1600 and 2500 square feet. Pre-1941 dwellings are the worst performers at intensities VI and IX. 1960-76 dwellings are the worst performers at intensities VII and VIII. Post-1976 dwellings are the best performers at intensity VIII, and 1950-60 dwellings are the best performers at intensities VIII and IX.

**Table C-6 Mean Loss Ratio of Dwellings in 1994 Northridge Earthquake as Function of MMI and Year Built (Dwellings between 1600 and 2500 sq ft) (from ATC, 2002a)**

| Year Built | Modified Mercalli Intensity | | | |
|---|---|---|---|---|
| | VI | VII | VIII | IX |
| Pre-1941 | 0.066 | 0.056 | 0.078 | 0.121 |
| 1941-1950 | 0.032 | 0.043 | 0.072 | 0.110 |
| 1950-1960 | 0.024 | 0.058 | 0.068 | 0.078 |
| 1960-1976 | 0.014 | 0.059 | 0.086 | 0.092 |
| Post-1976 | 0.013 | 0.028 | 0.081 | 0.082 |

Table C-7 summarizes findings for dwellings of over 2500 square feet. Post-1976 dwellings are the worst performers at intensity VI, 1960-76 dwellings are the worst performers at intensity VII, pre-1941 and 1941-1950 dwellings are the worst performers at intensity VIII, and 1941-1950 dwellings are the worst performers at intensity IX. In contrast, 1941-50 dwellings are the best performers at intensities VI and VII, 1950-60 dwellings are the best

**Table C-7** **Mean Loss Ratio of Dwellings in 1994 Northridge Earthquake as Function of MMI and Year Built (Dwellings over 2500 sq ft) (from ATC, 2002a)**

| Year Built | Modified Mercalli Intensity | | | |
|---|---|---|---|---|
| | VI | VII | VIII | IX |
| Pre-1941 | 0.035 | 0.039 | 0.094 | 0.076 |
| 1941-1950 | 0.010 | 0.026 | 0.094 | 0.124 |
| 1950-1960 | 0.016 | 0.043 | 0.074 | 0.110 |
| 1960-1976 | 0.017 | 0.049 | 0.093 | 0.120 |
| Post-1976 | 0.048 | 0.041 | 0.080 | 0.077 |

performers at intensity VIII, and pre-1941 dwellings are the best performers at intensity IX.

### C.4.4 Summary of Findings: Factors that Significantly Affect Damageability

These evaluations of the 1994 Northridge earthquake building inspection data and the analysis of the 1971 San Fernando data suggest that age (pre-1941) is a significant factor, especially at lower earthquake intensities.

Building square footage, a proxy for number of stories, does not appear to have the same impact in the Northridge data as was suggested by data from the 1971 San Fernando earthquake. There are several possible explanations for this divergence.

- The number of split-level dwellings affected by the 1971 San Fernando earthquake was very small (only 0.5% of all dwellings in the Steinbrugge database), which can yield statistically misleading results.
- There may have been removal or seismic rehabilitation of some of the poorly constructed dwellings following the 1971 San Fernando earthquake.
- Modifications were made in the seismic requirements for split-level and two-story dwellings following the 1971 earthquake.

These mixed results suggest that it is not the number of stories that is the critical factor. Instead, the seismic design of split-level and two- or more story buildings may be the critical factor.

In general, all analyses performed on these data sets exhibit only small correlations between the damageability of single-family dwellings and specific building characteristics.

### *C.4.5 Recommendations for Improved Collection of Dwelling Earthquake Performance Data*

The difficulty in developing meaningful correlations between the damageability of single-family dwellings and specific building characteristics is due to the lack of available detailed data sets. Sufficient detail in the data allows multiple regression analysis, a superior technique for modeling the effects of various building characteristics.

The collection of detailed wood frame dwelling damage data sets following earthquakes requires planning for the selection of buildings to survey, the information to be collected, the personnel to conduct the surveys, and funding of the survey effort. These issues are covered in detail in the ATC-38 Report, *Database on the Performance of Structures near Strong Motion Recordings: 1994 Northridge, California, Earthquake* (ATC, 2000). This report provides guidance on post-earthquake surveys of buildings, including a detailed survey form for documenting damage data and building characteristics. An additional source of guidance on post-earthquake survey of buildings is provided in USGS Circular 1242, *The Plan to Coordinate NEHRP Post-Earthquake Investigations* (Holzer et al., 2001).

# Appendix D

# Development of Damage Ranges for Seismic Performance Grades

This appendix describes the technical approach and results of the independent study to develop damage ranges for Seismic Performance Grades. The analysis was performed by EQECAT, using the WORLDCATenterprise$^{TM}$ Version 3.16 model. Funding for EQECAT's analysis was provided by the California Earthquake Authority, which makes no warranty, express or implied, regarding the accuracy of completeness of the analysis and assumes no liability or responsibility for the analysis or its use.

The results are presented in a matrix of damage ratios (repair cost/replacement cost) associated with each cell in Table 5 of the Simplified Seismic Assessment Form (Structural Performance Grades Based on Structural Score and Regional Seismic Hazard Score). Earthquake damage ratios reported in this appendix represent the damage with a 1/500 annual probability of being exceeded. The damage ratios associated with this probability can also be understood as having a 10% chance of exceedance in 50-years.

While best available tools for earthquake damage estimation were used, the resulting estimated damage ranges should be viewed as approximate. This is due to a variety of uncertainties inherent in the analysis, including uncertainty in earthquake ground motion, in knowledge of the condition of the dwelling, and in linkage between assessed conditions, ground motion levels and dwelling performance. The limitations and disclaimers provided in Section 2.5 of this FEMA document are also applicable to the damage ratios discussed in this chapter.

The following sections describe the prototype structure selection (Section D-1), the sites (Section D-2), the EQECAT earthquake model methodology (Section D-3), the analysis and results (Section D-4), and the sensitivity analyses (Section D-5). Supplemental information is provided in Appendix D.1, Structure Definitions in the Analyzed Portfolio, which also provides maps of California showing the locations of sites used.

## D.1 Prototype Structures

Seventy-six prototype structures were identified and used in this analysis. Details on the 76 prototype structures with their secondary modifier features as available in the EQECAT model, and definitions of each modifier value, are provided in Appendix D.1, Structure Definitions in Analyzed Portfolio. The basis for selecting which structural configurations to include in the portfolio is a combination of:

- Structural engineering experience – to select combinations that are both sensible / realistic and are also representative.
- Familiarity with exposure characteristics – so that selected combinations represent structural configurations present in the built environment.
- Full representation of possible scores – so that structures are included for all scoring categories.

Table D-1 shows the number of prototype structures in each Structural Scoring Category, along with the average Structural Score associated with the structures in each of these categories.

**Table D-1 Summary of Prototype Structures**

| Structural Scoring Category | Structural Score Range | No. of Prototype Structures | Average Structural Score |
|---|---|---|---|
| 1 | 1.0 – 45.9 | 12 | 39.1 |
| 2 | 46.0 – 64.9 | 16 | 58.6 |
| 3 | 65.0 – 74.9 | 16 | 70.7 |
| 4 | 75.0 – 84.9 | 16 | 78.8 |
| 5 | 85.0 - 100 | 16 | 93.0 |

## D.2 Site Selection

One hundred different sites were identified in such a way that each of the five FEMA P-50 Hazard Zones is represented by twenty different sites. Table D-2 lists the geographic location of these 100 sites along with their corresponding Hazard Zone. Maps showing the geographic location of these sites are presented in Appendix D.1.

## D.3 Model Methodology

The EQECAT earthquake model estimates losses by simulating thousands of hypothetical events. Damage from each hypothetical earthquake is calculated as the statistical convolution of hazard and vulnerability

**Table D-2 Site Locations and Details**

| Site No. | Latitude | Longitude | Hazard Zone | $S_{DS}$ |
|---|---|---|---|---|
| 1 | 39.125 | -121.525 | C&D$_0$ | 49.9 |
| 2 | 41.700 | -120.900 | C&D$_0$ | 50.0 |
| 3 | 37.250 | -119.900 | C&D$_0$ | 48.0 |
| 4 | 41.500 | -121.100 | C&D$_0$ | 56.4 |
| 5 | 35.900 | -116.200 | C&D$_0$ | 54.3 |
| 6 | 40.225 | -122.300 | C&D$_0$ | 56.5 |
| 7 | 37.100 | -119.900 | C&D$_0$ | 50.1 |
| 8 | 33.625 | -114.600 | C&D$_0$ | 37.3 |
| 9 | 38.625 | -121.325 | C&D$_0$ | 49.9 |
| 10 | 38.625 | -121.450 | C&D$_0$ | 54.2 |
| 11 | 37.625 | -120.350 | C&D$_0$ | 44.5 |
| 12 | 39.200 | -121.200 | C&D$_0$ | 49.4 |
| 13 | 38.725 | -120.925 | C&D$_0$ | 43.6 |
| 14 | 36.375 | -119.300 | C&D$_0$ | 48.8 |
| 15 | 36.975 | -119.525 | C&D$_0$ | 49.8 |
| 16 | 37.550 | -120.850 | C&D$_0$ | 64.5 |
| 17 | 37.300 | -119.525 | C&D$_0$ | 55.6 |
| 18 | 40.850 | -120.450 | C&D$_0$ | 58.0 |
| 19 | 38.650 | -120.300 | C&D$_0$ | 56.6 |
| 20 | 39.100 | -121.625 | C&D$_0$ | 52.2 |
| 21 | 34.600 | -120.450 | D$_1$ | 81.0 |
| 22 | 35.300 | -117.700 | D$_1$ | 81.4 |
| 23 | 41.075 | -121.550 | D$_1$ | 79.7 |
| 24 | 39.425 | -122.525 | D$_1$ | 72.0 |
| 25 | 37.825 | -121.300 | D$_1$ | 76.0 |
| 26 | 33.200 | -117.375 | D$_1$ | 80.2 |
| 27 | 36.975 | -120.650 | D$_1$ | 77.5 |
| 28 | 37.775 | -121.100 | D$_1$ | 67.3 |
| 29 | 35.700 | -118.450 | D$_1$ | 75.9 |
| 30 | 37.900 | -119.300 | D$_1$ | 76.9 |
| 31 | 32.975 | -116.900 | D$_1$ | 73.0 |
| 32 | 34.950 | -120.575 | D$_1$ | 75.0 |
| 33 | 36.150 | -117.000 | D$_1$ | 72.3 |
| 34 | 38.250 | -121.600 | D$_1$ | 71.1 |
| 35 | 32.750 | -117.250 | D$_1$ | 78.8 |
| 36 | 32.875 | -116.950 | D$_1$ | 68.5 |
| 37 | 36.100 | -117.700 | D$_1$ | 74.2 |
| 38 | 40.300 | -121.100 | D$_1$ | 67.8 |
| 39 | 34.725 | -120.475 | D$_1$ | 75.5 |
| 40 | 40.125 | -120.900 | D$_1$ | 72.2 |
| 41 | 39.675 | -123.650 | D$_2$ | 100.0 |
| 42 | 38.250 | -122.850 | D$_2$ | 100.7 |
| 43 | 37.075 | -122.075 | D$_2$ | 100.0 |
| 44 | 33.775 | -117.750 | D$_2$ | 100.0 |
| 45 | 37.400 | -121.500 | D$_2$ | 100.0 |
| 46 | 34.600 | -117.350 | D$_2$ | 86.6 |
| 47 | 37.775 | -121.550 | D$_2$ | 111.9 |
| 48 | 35.500 | -117.750 | D$_2$ | 90.5 |
| 49 | 34.650 | -120.125 | D$_2$ | 110.2 |
| 50 | 36.600 | -121.800 | D$_2$ | 96.6 |
| 51 | 33.725 | -117.850 | D$_2$ | 99.5 |

**Table D-2 Site Locations and Details (continued)**

| Site No. | Latitude | Longitude | Hazard Zone | $S_{DS}$ |
|---|---|---|---|---|
| 52 | 35.150 | -120.525 | $D_2$ | 85.5 |
| 53 | 36.600 | -121.625 | $D_2$ | 104.4 |
| 54 | 36.625 | -121.800 | $D_2$ | 97.8 |
| 55 | 36.100 | -120.750 | $D_2$ | 100.0 |
| 56 | 36.850 | -121.725 | $D_2$ | 110.6 |
| 57 | 39.700 | -123.800 | $D_2$ | 100.0 |
| 58 | 36.750 | -120.650 | $D_2$ | 102.8 |
| 59 | 39.250 | -122.850 | $D_2$ | 115.4 |
| 60 | 37.475 | -121.125 | $D_2$ | 115.5 |
| 61 | 34.250 | -118.850 | $E_0$ | 148.4 |
| 62 | 39.450 | -122.900 | $E_0$ | 128.4 |
| 63 | 36.875 | -121.725 | $E_0$ | 128.5 |
| 64 | 37.375 | -122.400 | $E_0$ | 143.4 |
| 65 | 38.800 | -122.400 | $E_0$ | 153.2 |
| 66 | 37.600 | -122.425 | $E_0$ | 172.3 |
| 67 | 37.075 | -122.000 | $E_0$ | 134.3 |
| 68 | 37.600 | -122.000 | $E_0$ | 166.0 |
| 69 | 33.150 | -116.550 | $E_0$ | 146.4 |
| 70 | 33.600 | -117.250 | $E_0$ | 157.1 |
| 71 | 34.150 | -117.500 | $E_0$ | 148.8 |
| 72 | 37.425 | -122.325 | $E_0$ | 137.9 |
| 73 | 40.125 | -123.875 | $E_0$ | 158.5 |
| 74 | 33.500 | -116.600 | $E_0$ | 134.1 |
| 75 | 34.125 | -117.700 | $E_0$ | 179.2 |
| 76 | 33.700 | -116.225 | $E_0$ | 125.0 |
| 77 | 37.900 | -122.700 | $E_0$ | 155.4 |
| 78 | 40.250 | -123.500 | $E_0$ | 135.7 |
| 79 | 37.275 | -122.100 | $E_0$ | 182.6 |
| 80 | 34.500 | -118.125 | $E_0$ | 125.1 |
| 81 | 34.150 | -117.725 | $E_1$ | 224.9 |
| 82 | 33.925 | -116.550 | $E_1$ | 198.2 |
| 83 | 34.175 | -117.475 | $E_1$ | 208.2 |
| 84 | 34.900 | -119.250 | $E_1$ | 232.4 |
| 85 | 33.850 | -116.400 | $E_1$ | 198.4 |
| 86 | 33.400 | -115.750 | $E_1$ | 189.4 |
| 87 | 34.825 | -118.900 | $E_1$ | 188.9 |
| 88 | 33.750 | -116.200 | $E_1$ | 192.9 |
| 89 | 34.875 | -118.900 | $E_1$ | 203.0 |
| 90 | 34.900 | -119.300 | $E_1$ | 226.9 |
| 91 | 34.400 | -118.750 | $E_1$ | 222.3 |
| 92 | 33.825 | -116.250 | $E_1$ | 202.4 |
| 93 | 33.525 | -115.925 | $E_1$ | 187.6 |
| 94 | 33.925 | -116.600 | $E_1$ | 195.7 |
| 95 | 33.875 | -116.375 | $E_1$ | 196.8 |
| 96 | 34.150 | -117.225 | $E_1$ | 188.6 |
| 97 | 34.175 | -117.500 | $E_1$ | 208.8 |
| 98 | 34.850 | -118.900 | $E_1$ | 207.7 |
| 99 | 33.900 | -116.500 | $E_1$ | 202.4 |
| 100 | 34.225 | -117.500 | $E_1$ | 216.4 |

distributions, and then weighted by the probability of that earthquake's occurrence and summed to produce probabilistic damage results.

The hazard module calculates shaking intensity, as expressed by spectral acceleration, at any given site, given the occurrence of the hypothetical earthquake. Hazard module methodologies, assumptions, and parameters, including the probability of occurrence of any given earthquake, are based on the USGS 2008 hazard model used to generate the National Seismic Hazard Maps (NSHMP) and the Uniform California Earthquake Rupture Forecast (UCERF-2).

Vulnerability is the relationship between hazard intensity and damage ratio, and vulnerability varies by occupancy type, structural system, age, construction material, number of stories, quality of construction and other secondary modifiers that account for structural conditions or features affecting earthquake performance. For wood-framed residential construction, these features include but are not limited to unbraced cripple walls, foundation bolting, house over garage, tile roof, etc.

For any given hypothetical earthquake and any given structure, damage to a particular building is calculated using statistical sampling techniques over the distributions of hazard and vulnerability.

Since it is used primarily by insurance industry clients, EQECAT's model is best-suited for calculating losses to an aggregate portfolio of buildings. Furthermore, model results have a large inherent uncertainty. Therefore damage ratios from a catastrophe model, whether expected annual damage or damage associated with a given return period, represent middle values within a broad range of possibilities rather than extreme or conservative outcomes.

The earthquake loss estimation model steps can be summarized as follows:

a. Define the portfolio of properties to be analyzed.

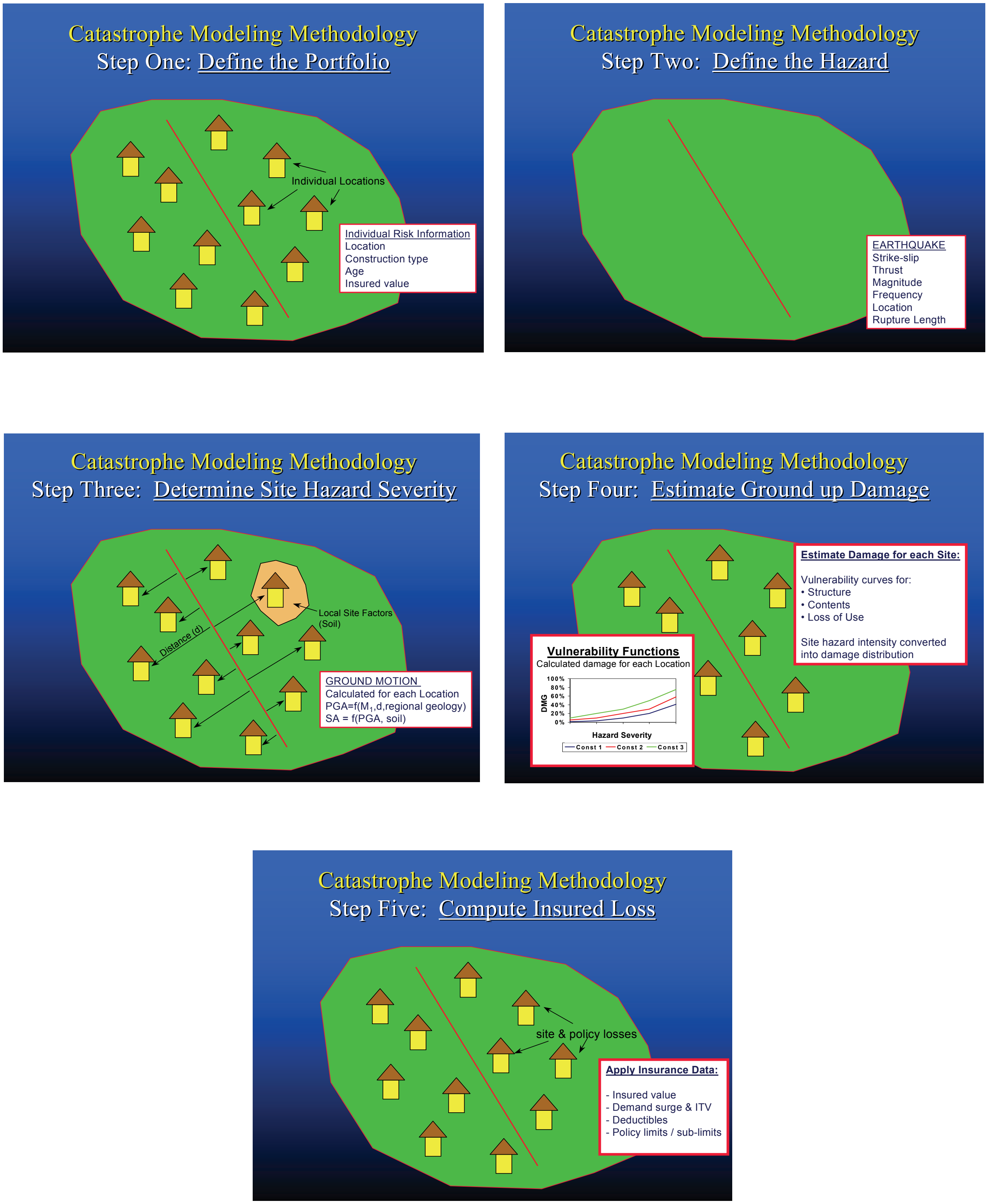
b. Specify the seismic hazard and estimate the earthquake ground shaking at the properties from all earthquakes affecting each site.

c. Define damage and loss vulnerability functions based on construction type, age, height, foundation type, and insurance coverage.

d. Estimate damage and loss to individual properties.

e. Probabilistically combine the damage and loss estimates for individual properties to estimate overall portfolio damage and loss.

The overall loss-estimation methodology is displayed in Figure D-1.



Catastrophe Modeling Methodology
Step One: Define the Portfolio

Individual Locations

Individual Risk Information
Location
Construction type
Age
Insured value

Catastrophe Modeling Methodology
Step Two: Define the Hazard

EARTHQUAKE
Strike-slip
Thrust
Magnitude
Frequency
Location
Rupture Length

Catastrophe Modeling Methodology
Step Three: Determine Site Hazard Severity

Local Site Factors (Soil)

Distance (d)

GROUND MOTION
Calculated for each Location
PGA=f($M_1$,d,regional geology)
SA = f(PGA, soil)

Catastrophe Modeling Methodology
Step Four: Estimate Ground up Damage

**Estimate Damage for each Site:**

Vulnerability curves for:
- Structure
- Contents
- Loss of Use

Site hazard intensity converted into damage distribution

**Vulnerability Functions**
Calculated damage for each Location

Catastrophe Modeling Methodology
Step Five: Compute Insured Loss

site & policy losses

**Apply Insurance Data:**

- Insured value
- Demand surge & ITV
- Deductibles
- Policy limits / sub-limits

Figure D-1 Generalized portfolio loss estimation analysis methodology.

## D.4 Analysis and Results

Using the 76 prototype structures summarized in Table D-1 (refer to Table D.1-3 in Appendix D.1 for structure details) and the 100 sites listed in Table D-2, a portfolio was created with 7600 site-structure combinations. The number of site-structure combinations within each Structural Scoring and regional Seismic Hazard Scoring Categories is listed in Table D-3. A uniform total insured value (TIV) is assigned to all sites in the portfolio. The portfolio is then imported and analyzed in WORLDCATenterprise (WCe) Version 3.16. From the WCe-generated damage report, a damage ratio for each of the 7600 site-structure combinations is calculated by dividing the damage by the TIV. Table D-4 provides the summary statistics [Average Damage Ratio, (Minimum Damage Ratio – Maximum Damage Ratio) range] for the 500-year return period damage ratio, as it varies across Structural Scoring and Seismic Hazard Scoring Categories. In each cell of Table D-4, the values in bold format represent the average damage ratio, and the values within the parentheses represent the range in terms of minimum and maximum damage ratios for the group of structures represented in that cell.

**Table D-3 Number of Site-Structure Combinations Within Each Structural Score and Regional Hazard Score**

| Seismic Hazard Score | | 0-1 | 2-3 | 4-5 | 6-7 | 8-10 | 11-12 |
|---|---|---|---|---|---|---|---|
| **Structural Score** | 1.0-45.9 | 240 | 240 | 240 | 240 | 240 | N/A |
| | 46.0-64.9 | 320 | 320 | 320 | 320 | 320 | N/A |
| | 65.0-74.9 | 320 | 320 | 320 | 320 | 320 | N/A |
| | 75.0-84.9 | 320 | 320 | 320 | 320 | 320 | N/A |
| | 85.0-100 | 320 | 320 | 320 | 320 | 320 | N/A |

**Table D-4 500-year Return Period Damage Ratio Variation Within Each Structural Score and Regional Hazard Score***

| Seismic Hazard Score | | 0-1 | 2-3 | 4-5 | 6-7 | 8-10 | 11-12 |
|---|---|---|---|---|---|---|---|
| **Structural Score** | **1.0-45.9** | **4.1%**<br>(0.6% - 11%) | **7.8%**<br>(1.8% - 15.1%) | **20.7%**<br>(8.7% - 31.5%) | **37.5%**<br>(16.4% - 62.8%) | **58.2%**<br>(33.6% - 79.8%) | N/A |
| | **46.0-64.9** | **3.3%**<br>(0.3% - 11%) | **7.1%**<br>(1.3% - 15.1%) | **19.2%**<br>(7.3% - 31.5%) | **35.2%**<br>(14.2% - 62.8%) | **54.8%**<br>(29.4% - 79.8%) | N/A |
| | **65.0-74.9** | **2.2%**<br>(0.2% - 7.4%) | **5.1%**<br>(1.1% - 10.8%) | **14.9%**<br>(6.3% - 23.7%) | **28.2%**<br>(12.4% - 48.8%) | **44.4%**<br>(26.2% - 61.6%) | N/A |
| | **75.0-84.9** | **1.8%**<br>(0.1% - 6.7%) | **4.7%**<br>(0.8% - 10.4%) | **13.8%**<br>(5.0% - 22.8%) | **26.5%**<br>(10.1% - 48.2%) | **42.2%**<br>(21.8% - 61.6%) | N/A |
| | **85.0-100** | **1.1%**<br>(0.1% - 5.4%) | **3.1%**<br>(0.5% - 8.2%) | **9.7%**<br>(3.4% - 19.0%) | **19.7%**<br>(7.5% - 40.1%) | **32.2%**<br>(16.4% - 51.6%) | N/A |

*Average Damage Ratio (Minimum Damage Ratio – Maximum Damage Ratio)

The trends observed in the results are aligned with expectations for average damage of large portfolios. Structures with higher Structural Scores tend to show less damage, and structures in lower Seismic Hazard Scoring Categories likewise tend to experience less damage. Additionally, there is a nonlinear relationship between hazard and damage. Finally, Seismic Hazard Scoring Category influences damage ratio more significantly than Structural Scoring Category. In other words, the difference (both absolute and relative) between damage ratios in the highest vs. lowest Seismic Hazard Scoring Category, for structures in a given Structural Scoring Category, is greater than the difference between damage ratios in the highest vs. lowest Structural Scoring Category, for structures in a given Seismic Hazard Scoring Category.

In many of the Seismic Hazard Scoring Categories, the maximum and minimum damage ratios are identical across adjacent Structural Scoring Categories. This can be understood by recognizing the imprecise nature of mapping between FEMA P-50 scoring penalties and secondary modifiers available in the EQECAT model. Two different structural configurations resulting in different FEMA P-50 scores may produce identical model results. The converse may also be true, but this cannot be easily ascertained in Table D-4.

The large difference between maximum and minimum damage ratios in any given cell of Table D-4 can be understood to reflect a difference in approach between FEMA P-50 scoring and catastrophe modeling. A limited subset of structural characteristics (for example year built, structural condition, and number of stories) significantly affects the modeled damage, but have little effect on the associated FEMA P-50 Structural Score. Therefore there is wide variability of damage ratios associated with the set of structures residing within any given Structural Scoring Category. Conversely, if ranges of damage ratios were to be predefined, a significant scatter would be expected among the Structural Scores in any one damage range.

In addition, mean damage ratio values are sensitive to the thresholds defining the boundary between one Seismic Hazard Scoring Category and the next.

A pictorial representation of the variation of average damage ratio for each Structural Scoring Category across different hazard zones is presented in Figure D-2. Similarly, Figure D-3 shows the variation in damage ratio by Structural Scoring Category, for each hazard zone.

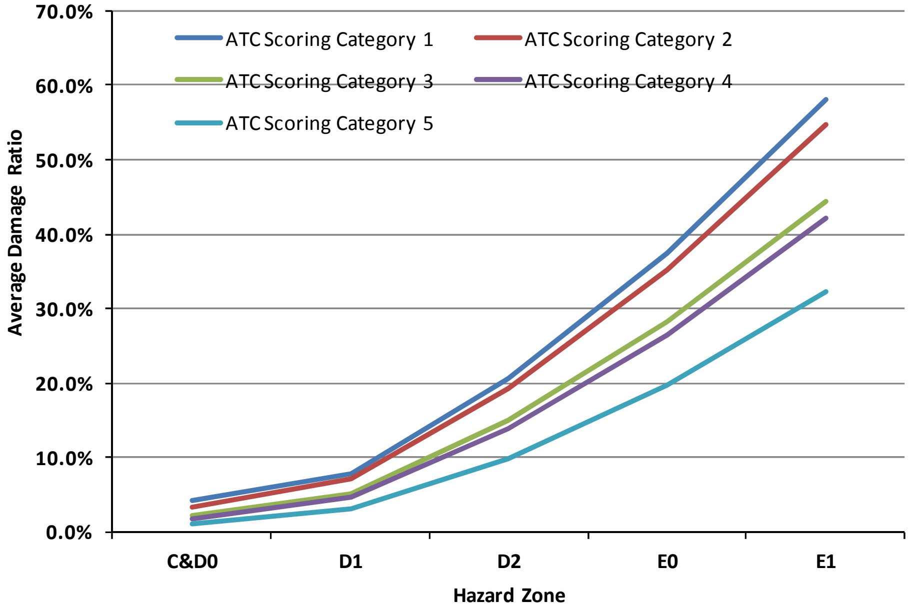


Figure D-2 Average 500-year return period damage ratio across different hazard zones. ATC Scoring Category = Structural Scoring Category. Hazard Zones are defined in terms of Seismic Design Category, as shown in Figures 2-1 through 2-4. Notation here is not subscripted as it is in those figures.

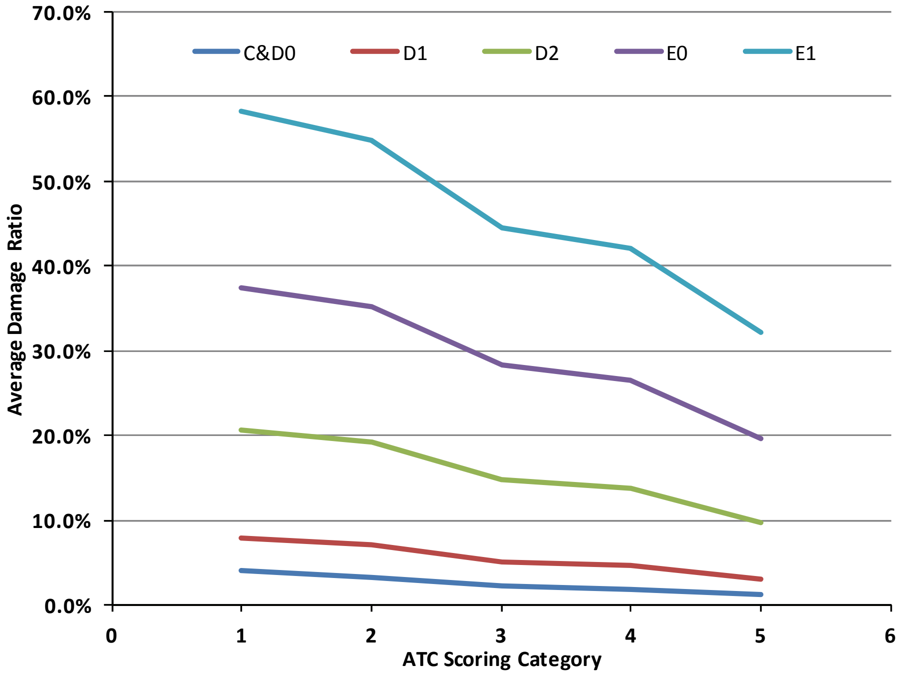


Figure D-3 Average 500-year return period damage ratio across different scoring category. ATC Scoring Category = Structural Scoring Category. Hazard Zones are defined in terms of Seismic Design Category, as shown in Figures 2-1 through 2-4. Notation here is not subscripted as it is in those figures.

Figure D-2 indicates that damage increases disproportionately to increased hazard, particularly notable beginning in Hazard Zone D2. This reflects the fundamental nonlinearity in structural fragility curves.

In Figure D-2, there is notable proximity of the two curves for Scoring Categories 3 and 4, across the full range of Hazard Zones. This can be understood by observing that Structural Scoring Categories 3 and 4 each have a range of 10 points whereas the "width" of Structural Scoring Categories 1, 2, and 5 are 46, 19, and 15 points, respectively. Likewise, structures in Structural Scoring Categories 1 and 2 show similar scores. This can be understood by recognizing that the two most-penalizing characteristic subtract 14 and 15 scoring points. Most other penalties subtract 1 to 4 points. Therefore, it requires a large number of penalties – and associated structural deficiencies – for a structure to be classified in Structural Scoring Category 1. Only a limited number of structural configurations would be placed in the lowest-scoring category.

As expected, Figure D-3 shows a downward trend in damage with higher Scoring Category, across all Hazard Zones. Figure D-3 also shows that the difference in damage between a good-performing structure and a poor-performing structure are more dramatic in the higher Hazard Zones than the lower Hazard Zones. Finally, the trends observed in Figure D-2 are also apparent in Figure 3: similarity in relative damage ratios between Structural Scoring Categories 3 and 4, and between Structural Scoring Categories 1 and 2. A plot similar to Figure D-3, but with a horizontal axis scaled by numerical score, would show smoother curves for any given Hazard Zone.

## D.5 Sensitivity Analyses

### *D.5.1 Sensitivity of Damage Ratios to Soil Conditions*

Embedded in the model is high-resolution soil classification. Thus, damage results as reported in Table D-4, Figure D-2, and Figure D-3 account for variation in soil amplification at any given site. This differs from the approach used in the FEMA P-50 document to establish the Seismic Hazard Score, where site class D is assumed for all locations. In order to assess the sensitivity of damage ratios to soil conditions, two additional analyses were performed. The first set of analyses used firm soil conditions (site class D, $V_{S30}$ = 270 m/s) for all 100 sites. The second set of analyses used site class B as the reference soil condition ($V_{S30}$ = 760 m/s) for all 100 sites. As expected, the damage ratios from the analysis using site class D were significantly higher than the corresponding damage ratios obtained by using site class B as the reference soil condition. Overall, for each of the structural and hazard score bins, damage ratios obtained using site-specific soil conditions (Table D-4) are between the values obtained from the upper and lower bounds of the sensitivity analysis.

### *D.5.2 Sensitivity of Damage Ratios to Structure Definition*

As a coarse means to evaluate the sensitivity of results to the earlier-noted subjectivity in assigning Structural Score penalties to modeled secondary modifiers, we removed the four structure types in each Structural Scoring Category that consistently produced the two highest and two lowest damage ratios across Seismic Hazard Scoring Categories. With the reduced number of structures, we recalculated damage ratios in each cell of Table D-4.

Removal of outlying structure types results in less than 1% change to mean damage ratios, and the ranges of damage ratios contracted slightly. Perhaps the most relevant outcome of this exercise was that maximum and minimum values of damage ratio ranges were no longer identical between adjacent cells.

# Appendix D.1 Structure Definitions in Analyzed Portfolio

This appendix outlines selection criteria for structures populating the portfolio used to generate damage ratios. Structures were defined by varying EQECAT secondary modifiers, which were mapped to the Structural Scoring penalties. Selection criteria was as follows:

> At least four prototype structures should reside in each range of scores ("scoring bin"): one structure each with a score on the high and low ends of the range, and each of those in both 1- and 2-story configurations.

Proposed prototype structures can be characterized thus (on flat sites unless noted otherwise):

- Historic 2-story circa 1900 in original condition.
- Historic 2-story circa 1900 with seismic upgrades throughout and on a sloped site.
- Pre-war (1920s) 2-story in original condition.
- Pre-war 2-story with retrofitted cripple wall (only).
- 1950s 1-story bungalow in original condition with unbraced cripple wall.
- 1950s 1-story bungalow with seismic upgrades throughout.
- 1950s 2-story bungalow with retrofitted cripple wall but heavy cladding and roof.
- 1960s 1-story ranch-style on slab.
- 1960s 2-story ranch-style on slab with heavy cladding and roof.
- 1970s 2-story split-level on sloping site with large wall openings.
- 1990s 2-story on slab with large wall openings.

Detailed characteristics of proposed prototype structures, relative to the available EQECAT modifiers, are listed in Table D.1-1. Table D.1-2 lists the FEMA P-50 form penalty assessment items for each of the proposed prototype structures, and Table D.1-3 provides the final portfolio of structural configurations used in the analysis. Definitions of each value for secondary structural modifiers used in the EQECAT model are provided in Table D.1-3. Geographic locations of sites used in the analysis are provided in Figures D.1-1 through D.1-5.

Table D.1-1 Variations of Structural Configurations Proposed as Prototype Structures for FEMA P-50 Benchmarking

| Brief Description | Historic original | Historic retrofitted | Pre-war original | Pre-war retrofitted | Bungalow original | Bungalow retrofitted | 2-story bungalow | Ranch | 2-story Ranch | Split-Level | Modern |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Year Built | 1900 | 1900 | 1926 | 1926 | 1950 | 1950 | 1950 | 1965 | 1965 | 1975 | 2000 |
| Number Stories | 2 | 2 | 2 | 2 | 1 | 1 | 2 | 1 | 2 | 2 | 2 |
| Structural Condition | poor | fair | fair | fair | good | good | good | excel. | excel. | excel. | excel. |
| Unbraced Cripple Wall? | yes | no | no | yes | yes | no | no | no | no | no | no |
| Foundation Anchored? | no | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes |
| House over Garage? | no | no | no | no | no | no | yes | no | yes | yes | no |
| Masonry Chimney? | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes |
| Masonry Veneer? | yes | yes | no | no | no | no | yes | no | no | no | no |
| Heavy Roof? | no | no | no | no | no | no | yes | no | yes | no | no |
| Siding Material | brick | brick | wood | wood | stucco | stucco | stucco | stucco | stucco | stucco | stucco |
| Foundation Material | stone | stone | unreinf. concrete | unreinf. concrete | reinf. conc. | reinf. conc. | reinf. conc. | reinf. conc. | reinf. conc. | reinf. conc. | reinf. conc. |
| FEMA P-50 Score | 32.3 | 52.3 | 68 | 59.3 | 71.8 | 89.4 | 75.9 | 93.8 | 83.8 | 74 | 87.1 |

Table D.1-2 Assignment of FEMA P-50 Penalty Assessment Items to Prototype Structures

| FEMA P-50 Assessment Item | Historic original | Historic retrofitted | Pre-war original | Pre-war retrofitted | Bungalow original | Bungalow retrofitted | 2-story bungalow | Ranch | 2-story Ranch | Split-Level | Modern |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A-1 | 4.2 | 4.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| A-2 | 2.9 | 2.9 | 2.9 | 2.9 | 2.9 | 2.9 | 2.9 | 0 | 0 | 0 | 0 |
| A-3 | 2.2 | 0.8 | 0.8 | 0.8 | 0.8 | 0 | 0 | 0 | 0 | 0 | 0 |
| A-4 | 0 | 3.7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.8 | 1.6 |
| A-5 | 15 | 0 | 0 | 1.7 | 1.7 | 0 | 0 | 0 | 0 | 0 | 0 |
| B-1 | 2.3 | 2.3 | 2.3 | 2.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 2 | 0 |
| B-2 | 3.2 | 3.2 | 3.2 | 3.2 | 0 | 0 | 0 | 0 | 0 | 3.2 | 3.2 |
| B-3 | 0 | 0 | 0 | 0 | 0 | 0 | 3.5 | 0 | 3.5 | 0 | 0 |
| B-4 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 3 | 3 | 0 |
| B-5 | 3.5 | 3.5 | 0 | 0 | 0 | 0 | 3.5 | 0 | 0 | 0 | 0 |
| B-6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| B-7 | 1.8 | 1.8 | 1.8 | 1.8 | 0 | 0 | 1.8 | 0 | 1.8 | 1.8 | 1.8 |
| B-8 | 14 | 2 | 7 | 14 | 14 | 1 | 1 | 0 | 0 | 4 | 0 |
| C-1 | 2.1 | 2.1 | 2.1 | 2.1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| C-2 | 1.5 | 1.5 | 1.5 | 1.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C-3 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C-4 | 1.3 | 1.3 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0 | 0 | 0 | 0 |
| C-5 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0 |
| D-1 | 2.1 | 1 | 2.1 | 2.1 | 2.1 | 1 | 1 | 2.1 | 2.1 | 1 | 1 |
| D-2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| D-3 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 |
| D-4 | 1.7 | 1.7 | 0 | 0 | 0 | 0 | 1.7 | 0 | 1.7 | 0 | 0 |

## Table D.1-2 Assignment of FEMA P-50 Penalty Assessment Items to Prototype Structures (continued)

| FEMA P-50 Assessment Item | Historic original | Historic retrofitted | Pre-war original | Pre-war retrofitted | Bungalow original | Bungalow retrofitted | 2-story bungalow | Ranch | 2-story Ranch | Split-Level | Modern |
|---|---|---|---|---|---|---|---|---|---|---|---|
| D-5 | 2.6 | 2.6 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 0 |
| D-6 | 0.6 | 0.6 | 0.6 | 0.6 | 0 | 0 | 0 | 0 | 0 | 0.6 | 1.3 |
| E-1 | 0 | 3.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3.2 | 3 |
| E-2 | 0 | 2.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2.6 | 0 |
| E-3 | 2.6 | 2.6 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| E-4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| E-5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| E-6 | 1.3 | 1.3 | 1.3 | 1.3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| sum of penalties | 67.7 | 47.7 | 32 | 40.7 | 28.2 | 10.6 | 24.1 | 6.2 | 16.2 | 26 | 12.9 |
| structural score | 32.3 | 52.3 | 68 | 59.3 | 71.8 | 89.4 | 75.9 | 93.8 | 83.8 | 74 | 87.1 |
| Scoring "bin" | 1 | 2 | 3 | 2 | 3 | 5 | 4 | 5 | 4 | 3 | 5 |

### Table D.1-3 Final Portfolio of Structural Configurations Used in the FEMA P-50 Analysis

| | | | EQECAT Modifier Values | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Structure Number: | Structural Scoring Category: | Structural Score: | Year Built | Number Stories | Struct. Condition | Cripple Wall | Foundation Anchor | House over Garage | Masonry Chimney | Masonry Veneer | Heavy Roof | Siding Mat'l | Fdn Reinfmt. |
| 1 | 1 | 38.0 | 1900 | 2 | 4 | 1 | 3 | 2 | 2 | 3 | 2 | 4 | 3 |
| 2 | 2 | 56.2 | 1900 | 2 | 3 | 3 | 3 | 2 | 1 | 3 | 2 | 4 | 3 |
| 3 | 3 | 68.8 | 1926 | 2 | 4 | 3 | 2 | 3 | 2 | 4 | 2 | 2 | 2 |
| 4 | 2 | 57.3 | 1926 | 2 | 4 | 1 | 2 | 2 | 2 | 4 | 2 | 2 | 2 |
| 5 | 3 | 74.1 | 1950 | 1 | 2 | 1 | 2 | 2 | 1 | 4 | 2 | 1 | 1 |
| 6 | 5 | 90.7 | 1950 | 1 | 2 | 3 | 1 | 2 | 1 | 4 | 2 | 1 | 1 |
| 7 | 4 | 77.2 | 1950 | 2 | 2 | 3 | 1 | 1 | 1 | 2 | 1 | 4 | 1 |
| 8 | 5 | 97.0 | 1965 | 1 | 1 | 2 | 1 | 2 | 1 | 4 | 2 | 1 | 1 |
| 9 | 4 | 84.5 | 1965 | 2 | 2 | 2 | 1 | 1 | 2 | 2 | 1 | 1 | 1 |
| 10 | 5 | 90.3 | 2000 | 2 | 3 | 2 | 1 | 2 | 1 | 4 | 2 | 1 | 1 |
| 11 | 1 | 39.8 | 1900 | 1 | 4 | 1 | 3 | 2 | 2 | 3 | 2 | 4 | 3 |
| 12 | 2 | 58.0 | 1900 | 1 | 3 | 3 | 3 | 2 | 1 | 3 | 2 | 4 | 3 |
| 13 | 3 | 70.6 | 1926 | 1 | 4 | 3 | 2 | 3 | 2 | 4 | 2 | 2 | 2 |
| 14 | 2 | 59.1 | 1926 | 1 | 4 | 1 | 2 | 2 | 2 | 4 | 2 | 2 | 2 |
| 15 | 3 | 72.3 | 1950 | 2 | 2 | 1 | 2 | 2 | 1 | 4 | 2 | 1 | 1 |
| 16 | 5 | 88.9 | 1950 | 2 | 2 | 3 | 1 | 2 | 1 | 4 | 2 | 1 | 1 |
| 17 | 4 | 80.9 | 1950 | 1 | 2 | 3 | 1 | 1 | 1 | 2 | 1 | 4 | 1 |
| 18 | 5 | 95.2 | 1965 | 2 | 1 | 2 | 1 | 2 | 1 | 4 | 2 | 1 | 1 |
| 19 | 5 | 88.2 | 1965 | 1 | 2 | 2 | 1 | 1 | 2 | 2 | 1 | 1 | 1 |

Table D.1-3 Final Portfolio of Structural Configurations Used in the FEMA P-50 Analysis (continued)

| | | | EQECAT Modifier Values | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Structure Number: | Structural Scoring Category: | Structural Score: | Year Built | Number Stories | Struct. Condition | Cripple Wall | Foundation Anchor | House over Garage | Masonry Chimney | Masonry Veneer | Heavy Roof | Siding Mat'l | Fdn Reinfmt. |
| 20 | 4 | 75.7 | 1975 | 1 | 2 | 1 | 1 | 1 | 1 | 4 | 2 | 1 | 1 |
| 21 | 5 | 92.1 | 2000 | 1 | 3 | 2 | 1 | 2 | 1 | 4 | 2 | 1 | 1 |
| 22 | 1 | 38.0 | 1900 | 1 | 4 | 1 | 3 | 2 | 2 | 3 | 2 | 4 | 3 |
| 23 | 3 | 71.2 | 1900 | 2 | 3 | 3 | 1 | 2 | 1 | 3 | 2 | 4 | 3 |
| 24 | 3 | 73.9 | 1926 | 2 | 4 | 3 | 1 | 2 | 2 | 4 | 2 | 2 | 2 |
| 25 | 2 | 62.4 | 1926 | 2 | 3 | 1 | 2 | 2 | 2 | 4 | 2 | 2 | 2 |
| 26 | 4 | 77.2 | 1942 | 2 | 2 | 3 | 1 | 1 | 1 | 2 | 1 | 4 | 1 |
| 27 | 5 | 97.2 | 2000 | 2 | 1 | 2 | 1 | 2 | 1 | 4 | 2 | 1 | 1 |
| 28 | 1 | 35.8 | 1920 | 1 | 4 | 1 | 3 | 1 | 2 | 3 | 1 | 4 | 3 |
| 29 | 1 | 32.1 | 1920 | 2 | 4 | 1 | 3 | 1 | 2 | 3 | 1 | 4 | 3 |
| 30 | 2 | 58.1 | 1975 | 1 | 4 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 2 |
| 31 | 2 | 54.4 | 1975 | 2 | 4 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 2 |
| 32 | 4 | 76.6 | 1960 | 1 | 3 | 3 | 2 | 3 | 1 | 1 | 2 | 2 | 1 |
| 33 | 3 | 74.8 | 1960 | 2 | 3 | 3 | 2 | 3 | 1 | 1 | 2 | 2 | 1 |
| 34 | 5 | 96.1 | 1985 | 1 | 2 | 2 | 1 | 3 | 1 | 4 | 2 | 1 | 1 |
| 35 | 5 | 94.3 | 1985 | 2 | 2 | 2 | 1 | 3 | 1 | 4 | 2 | 1 | 1 |
| 36 | 5 | 98.2 | 2000 | 2 | 1 | 2 | 1 | 2 | 3 | 4 | 2 | 1 | 1 |
| 37 | 3 | 68.1 | 1960 | 1 | 3 | 1 | 2 | 3 | 1 | 4 | 2 | 1 | 1 |
| 38 | 3 | 66.3 | 1960 | 2 | 3 | 1 | 2 | 3 | 1 | 4 | 2 | 1 | 1 |

## Table D.1-3 Final Portfolio of Structural Configurations Used in the FEMA P-50 Analysis (continued)

| | | | EQECAT Modifier Values | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Structure Number: | Structural Scoring Category: | Structural Score: | Year Built | Number Stories | Struct. Condition | Cripple Wall | Foundation Anchor | House over Garage | Masonry Chimney | Masonry Veneer | Heavy Roof | Siding Mat'l | Fdn Reinfmt. |
| 39 | 3 | 67.3 | 1978 | 2 | 3 | 1 | 2 | 3 | 1 | 4 | 2 | 1 | 1 |
| 40 | 4 | 75.4 | 1950 | 1 | 3 | 3 | 1 | 1 | 1 | 3 | 1 | 4 | 1 |
| 41 | 3 | 71.7 | 1950 | 2 | 3 | 3 | 1 | 1 | 1 | 3 | 1 | 4 | 1 |
| 42 | 4 | 76.4 | 1980 | 1 | 3 | 3 | 1 | 1 | 1 | 3 | 1 | 4 | 1 |
| 43 | 3 | 72.7 | 1980 | 2 | 3 | 3 | 1 | 1 | 1 | 3 | 1 | 4 | 1 |
| 44 | 4 | 76.9 | 1920 | 1 | 2 | 3 | 2 | 3 | 2 | 3 | 1 | 4 | 2 |
| 45 | 3 | 73.2 | 1920 | 2 | 2 | 3 | 2 | 3 | 2 | 3 | 1 | 4 | 2 |
| 46 | 4 | 76.9 | 1970 | 1 | 2 | 3 | 2 | 3 | 2 | 3 | 1 | 4 | 2 |
| 47 | 3 | 73.2 | 1970 | 2 | 2 | 3 | 2 | 3 | 2 | 3 | 1 | 4 | 2 |
| 48 | 3 | 67.3 | 1940 | 1 | 4 | 1 | 1 | 2 | 1 | 4 | 2 | 1 | 2 |
| 49 | 3 | 65.5 | 1940 | 2 | 4 | 1 | 1 | 2 | 1 | 4 | 2 | 1 | 2 |
| 50 | 1 | 45.6 | 1900 | 1 | 4 | 1 | 2 | 1 | 2 | 3 | 1 | 4 | 3 |
| 51 | 1 | 41.9 | 1900 | 2 | 4 | 1 | 2 | 1 | 2 | 3 | 1 | 4 | 3 |
| 52 | 2 | 46.2 | 1930 | 1 | 4 | 1 | 2 | 1 | 2 | 3 | 1 | 4 | 3 |
| 53 | 1 | 42.5 | 1930 | 2 | 4 | 1 | 2 | 1 | 2 | 3 | 1 | 4 | 3 |
| 54 | 1 | 40.3 | 1900 | 1 | 3 | 1 | 3 | 1 | 2 | 3 | 1 | 4 | 3 |
| 55 | 1 | 36.6 | 1900 | 2 | 3 | 1 | 3 | 1 | 2 | 3 | 1 | 4 | 3 |
| 56 | 1 | 40.9 | 1930 | 1 | 3 | 1 | 3 | 1 | 2 | 3 | 1 | 4 | 3 |
| 57 | 1 | 37.2 | 1930 | 2 | 3 | 1 | 3 | 1 | 2 | 3 | 1 | 4 | 3 |

Table D.1-3 Final Portfolio of Structural Configurations Used in the FEMA P-50 Analysis (continued)

| | | | EQECAT Modifier Values | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Structure Number: | Structural Scoring Category: | Structural Score: | Year Built | Number Stories | Struct. Condition | Cripple Wall | Foundation Anchor | House over Garage | Masonry Chimney | Masonry Veneer | Heavy Roof | Siding Mat'l | Fdn Reinfmt. |
| 58 | 2 | 58.9 | 1900 | 1 | 3 | 1 | 2 | 1 | 2 | 3 | 2 | 2 | 2 |
| 59 | 2 | 57.1 | 1900 | 2 | 3 | 1 | 2 | 1 | 2 | 3 | 2 | 2 | 2 |
| 60 | 2 | 59.5 | 1930 | 1 | 3 | 1 | 2 | 1 | 2 | 3 | 2 | 2 | 2 |
| 61 | 2 | 57.7 | 1930 | 2 | 3 | 1 | 2 | 1 | 2 | 3 | 2 | 2 | 2 |
| 62 | 2 | 64.2 | 1950 | 1 | 3 | 1 | 1 | 1 | 1 | 2 | 2 | 4 | 2 |
| 63 | 2 | 62.4 | 1950 | 2 | 3 | 1 | 1 | 1 | 1 | 2 | 2 | 4 | 2 |
| 64 | 2 | 64.2 | 1975 | 1 | 3 | 1 | 1 | 1 | 1 | 2 | 2 | 4 | 2 |
| 65 | 2 | 62.4 | 1975 | 2 | 3 | 1 | 1 | 1 | 1 | 2 | 2 | 4 | 2 |
| 66 | 4 | 79.7 | 1975 | 1 | 3 | 3 | 1 | 1 | 1 | 4 | 2 | 2 | 1 |
| 67 | 4 | 77.9 | 1975 | 2 | 3 | 3 | 1 | 1 | 1 | 4 | 2 | 2 | 1 |
| 68 | 4 | 80.7 | 1985 | 1 | 3 | 3 | 1 | 1 | 1 | 4 | 2 | 2 | 1 |
| 69 | 4 | 78.9 | 1985 | 2 | 3 | 3 | 1 | 1 | 1 | 4 | 2 | 2 | 1 |
| 70 | 4 | 82.1 | 1975 | 2 | 2 | 2 | 1 | 1 | 1 | 3 | 1 | 4 | 1 |
| 71 | 5 | 86.8 | 1985 | 1 | 2 | 2 | 1 | 1 | 1 | 3 | 1 | 4 | 1 |
| 72 | 4 | 83.1 | 1985 | 2 | 2 | 2 | 1 | 1 | 1 | 3 | 1 | 4 | 1 |
| 73 | 5 | 93.6 | 1985 | 1 | 2 | 2 | 1 | 3 | 1 | 4 | 2 | 2 | 1 |
| 74 | 5 | 91.8 | 1985 | 2 | 2 | 2 | 1 | 3 | 1 | 4 | 2 | 2 | 1 |
| 75 | 5 | 94.6 | 1995 | 1 | 2 | 2 | 1 | 3 | 1 | 4 | 2 | 2 | 1 |
| 76 | 5 | 92.8 | 1995 | 2 | 2 | 2 | 1 | 3 | 1 | 4 | 2 | 2 | 1 |

**Table D.1-4 Definitions of each Value for Secondary Structural Modifiers Used in the EQECAT Model**

| FIELD_NAME | OPTION_ID | SHORT_DESC | FULL_DESC |
|---|---|---|---|
| STR_CONDN | 0 | Unknown | Unknown. |
| STR_CONDN | 1 | Excellent | Condition of structural elements is excellent (no cracking, corrosion, spalling, wood rot, water damage, foundation settlement, etc.). |
| STR_CONDN | 2 | Good | Condition of structural elements is good (cracks up to 1/16" wide, some localized deterioration). |
| STR_CONDN | 3 | Fair | Condition of structural elements is fair. |
| STR_CONDN | 4 | Poor | Condition of structural elements is poor (cracks over1/8" wide). |
| CRIP_WALL | 0 | Unknown | Unknown. |
| CRIP_WALL | 1 | Yes | Building has cripple walls. |
| CRIP_WALL | 2 | No, stem wall or slab on grade | Building is supported on a stem-wall foundation or a slab-on-grade foundation. |
| CRIP_WALL | 3 | No, other | Building is supported on post-and-beam or other foundation system. |
| FND_ANCHOR | 0 | Unknown | Unknown. |
| FND_ANCHOR | 1 | Yes | Building is attached to its foundation with anchor bolts. |
| FND_ANCHOR | 2 | Yes, weak anchorage | Building is attached to foundation by means other than anchor bolts (e.g., cut nails, shot pins, etc.). |
| FND_ANCHOR | 3 | No | Building is not attached to its foundation with anchor bolts. |
| HOG | 0 | Unknown | Unknown. |
| HOG | 1 | Yes | Building has a house-over-garage type configuration with large opening(s) along one wall. |
| HOG | 2 | No, single story | Building does not have a house-over-garage type configuration and is a single story structure. |
| HOG | 3 | No, mulitple stories | Building does not have a house-over-garage type configuration and has two or three stories. |
| MAS_CHMNY | 0 | Unknown | Unknown. |
| MAS_CHMNY | 1 | Yes, one | Building has one masonry chimney. |
| MAS_CHMNY | 2 | Yes, more than one | Building has more than one masonry chimney |
| MAS_CHMNY | 3 | No | Building does not have a masonry chimney. |
| MAS_VENR | 0 | Unknown | Unknown. |
| MAS_VENR | 1 | Yes, partial height | Masonry veneer is less than 4 feet in height. |
| MAS_VENR | 2 | Yes, full height, one elevation | Building has full-height masonry veneer on the front elevation. |
| MAS_VENR | 3 | Yes, full height, more than one elevation | Building has full-height masonry veneer on more than one elevation |
| MAS_VENR | 4 | No | Building does not have masonry veneer. |
| CLYTIL_RF | 0 | Unknown | Unknown. |

**Table D.1-4 Definitions of each Value for Secondary Structural Modifiers Used in the EQECAT Model (continued)**

| FIELD_NAME | OPTION_ID | SHORT_DESC | FULL_DESC |
|---|---|---|---|
| CLYTIL_RF | 1 | Yes | Building has a heavy clay tile roof. |
| CLYTIL_RF | 2 | No | Building does not have a heavy clay tile roof. |
| SIDING_MTL | 0 | Unknown | Unknown. |
| SIDING_MTL | 1 | Stucco | Exterior surface of structure is covered by stucco. |
| SIDING_MTL | 2 | Wood siding | Exterior surface of structure is covered by wood siding or plywood. |
| SIDING_MTL | 3 | Vinyl or metal | Exterior surface of structure is covered with vinyl or metal. |
| SIDING_MTL | 4 | Brick veneer | Exterior surface of structure is covered with brick veneer. |
| SIDING_MTL | 5 | Other | Exterior surface is covered by another material. |
| FND_REINF | 0 | Unknown | Unknown. |
| FND_REINF | 1 | Reinforced concrete | The perimeter foundation consists of reinforced concrete footings. |
| FND_REINF | 2 | Unreinforced concrete or reinforced concrete block | The perimeter foundation consists of unreinforced concrete or concrete block with grout and reinforcing. |
| FND_REINF | 3 | Unreinforced concrete block, brick or stone | The perimeter foundation includes unreinforced concrete block, stone, or brick. |
| NUM_STORY | 0 | Unknown | Unknown. |
| NUM_STORY | 1 | One story | The structure has one story. |
| NUM_STORY | 2 | Two stories | The structure has two stories. |
| NUM_STORY | 3 | Three stories | The structure has three stories. |

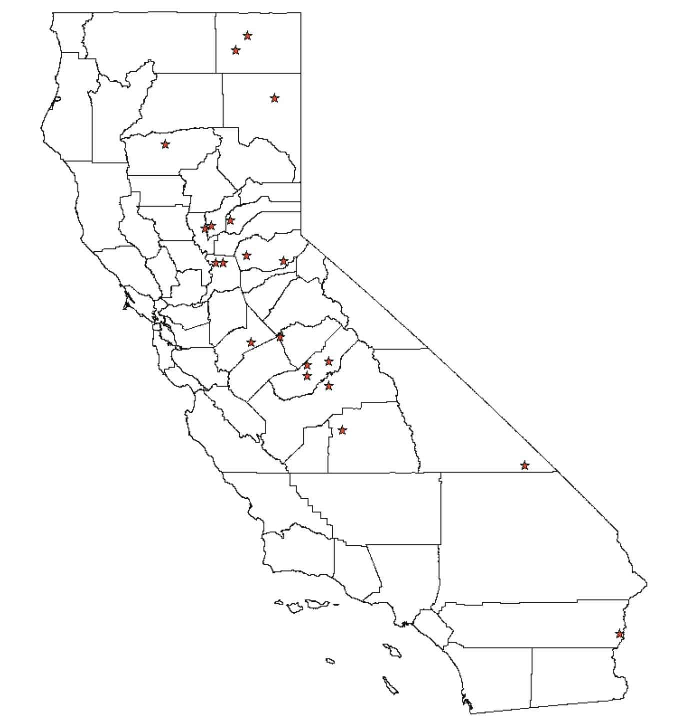


Figure D.1-1 Site locations for hazard zone C & D0.

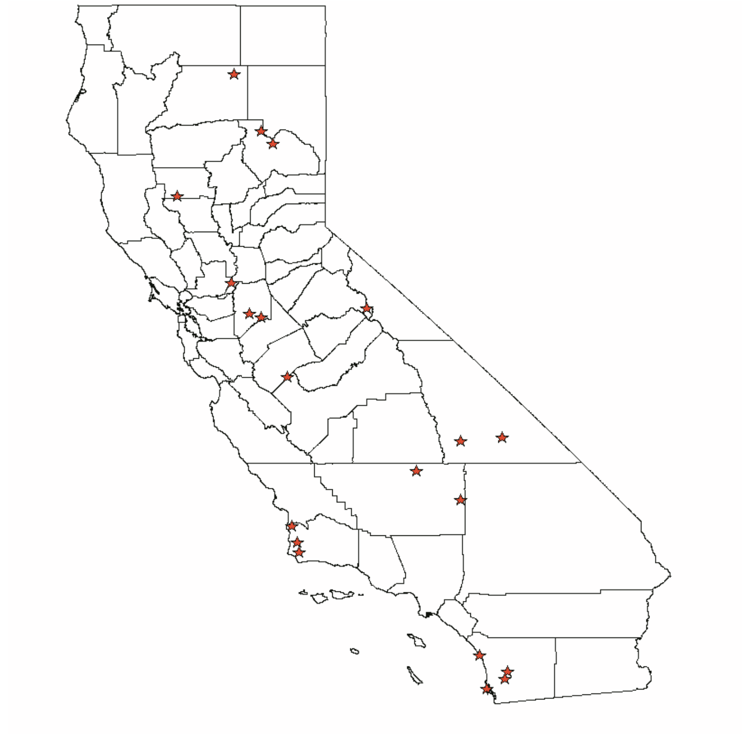


Figure D.1-2 Site locations for hazard zone D1.

Figure D.1-3 Site locations for hazard zone D2.

Figure D.1-4 Site locations for hazard zone E0.

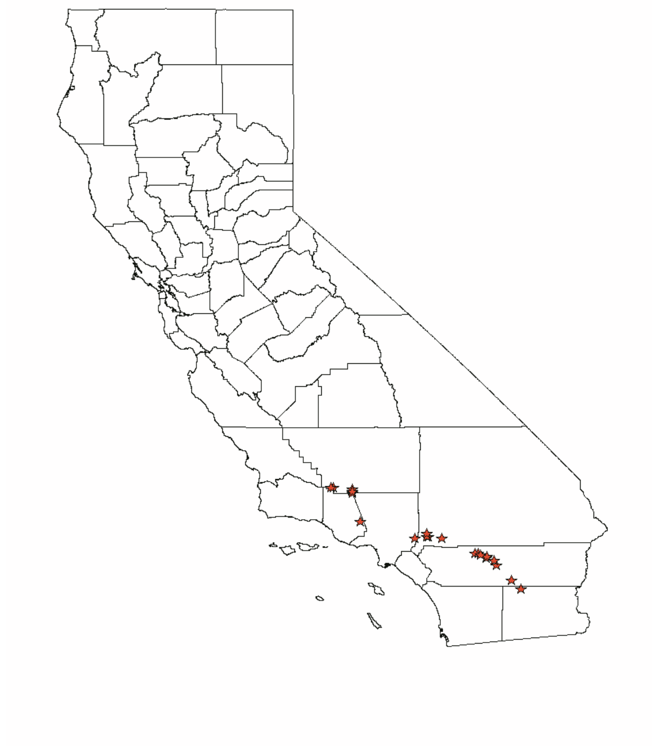


Figure D.1-5 Site locations for hazard zone E1.

# Appendix E

# Basis of Structural Score Methodology

## E.1 Background

The Simplified Seismic Assessment Form was first developed as part of the ATC-50 report developmental effort, and subsequently revised for nation-wide use as part of the project to develop this FEMA P-50 report. As a result the Structural Score methodology was revisited and revised as part of the FEMA P-50 developmental effort. This appendix describes the initial development of the methodology for ATC-50, followed by the revisions to the methodology incorporated into the FEMA P-50 assessment form.

## E.2 ATC-50 Development

Sections E.2.1 though E.2.4 describe the methodology developed in the ATC-50 form.

### *E.2.1 Categorization*

Six categories were selected for addressing vulnerabilities:

1. Foundation,
2. Superstructure framing and configuration,
3. Non-structural and miscellaneous elements,
4. Local site conditions,
5. Condition of structural elements, and
6. Seismic hazard.

Categories 1 through 5 were considered structural categories (the house and its building site) and category 6, seismic hazard, was considered independent of the Structural Score.

Definitions were developed to help place elements or conditions in specific categories. For example, foundation anchor bolts were determined to be part of the foundation, not part of the wood-frame superstructure. This breakdown into categories allowed relative weights to be assigned to each condition listed on the form.

### *E.2.2 Application of Past Earthquake Data*

Because the ATC-50 project was originally developed for the City of Los Angeles, the most relevant earthquake loss data were provided by two significant, relatively recent Los Angeles area events—the 1971 San Fernando earthquake and the 1994 Northridge earthquake. Reports and data from these two events were thought to be directly applicable, even though the housing stock obviously changed in the 23 years between them.

The analysis of data from these two earthquakes is discussed in Appendix C. The data were used to evaluate building characteristics that contribute to damageability. The ability to reach detailed conclusions, though, was limited in spite of the large quantity of data. One major limitation was that the data gathered in these studies did not readily fit the categories agreed upon by the project team.

The task, using primarily data on insurance losses in the Northridge earthquake, was to redefine the data to better fit the categories selected. Loss data related to regional site location came from research described in Appendix C.

### *E.2.3 Initial Weighting Assessments*

Using the earthquake loss data and the selected categories, the project team members voted on relative weights for the five structural categories (listed as 1 through 5 in Section E.1). The Balloting Committee of David Breiholz, Shafat Qazi, Nels Roselund and John Wiggins, with equal votes, submitted a recommendation on the percent damageability contribution of each of the five categories. The percent damageability translates into the maximum penalty that can be assessed on a specific section of the form. These weighting percentages were averaged, with results shown in Table E-1.

**Table E-1 Initial Weights Assigned to Assessment Categories**

| Category | Maximum Penalty |
|---|---|
| Foundation | 19.0 |
| Superstructure framing and configuration | 34.0 |
| Nonstructural and miscellaneous elements | 10.0 |
| Local site conditions | 16.7 |
| Condition of structural elements | 20.3 |
| Total: | 100 |

### *E.2.4 Final Weighting Assignments*

Final weighting of each category took place after all the questions were assigned to their appropriate categories. For each question there were two separate ballots. One ballot was cast to place the question in a specific category and the other for considerations to place a question in more than one category.

The relative weighting of specific features came from a list of hypothetical questions regarding the relative damage that may occur to two different dwellings that differ in only one respect. One example is: "During the next earthquake, the most damage would occur to: (a) a dwelling at the base of a 1950s 1½ : 1 slope or (b) the same dwelling on a transition cut-fill pad."

The original category weights changed very little throughout this process. The weighting assigned to nonstructural and miscellaneous elements increased, and the weighting assigned to the condition of structural elements decreased.

Once the categories were assigned appropriate weights, the final step was to distribute the assigned penalties appropriately among the questions within each category. After several team meetings, the distribution was finalized by ballot.

The final weights represent a consensus opinion of the project team on the impact of various features and conditions on the seismic performance of wood-frame dwellings. The opinion is based in part on statistical analysis of data from previous earthquakes and in part on the professional judgment of team members.

## E.3 FEMA P-50 Development

Sections E.3.1 though E.3.3 describe the methodology used in the FEMA P-50 assessment form.

### *E.3.1 General*

The FEMA P-50 Project Management Committee chose to keep changes to the assessment form to a minimum. This was done both in deference to the effort put into the development of the ATC-50 assessment form, and based on the observation that the form in general gave low grades to buildings believed likely to be poor performers and high grades to dwellings believed to be good performers, and so appeared to achieve the intended goal. Several portions of the form were identified as needing to be revised, as discussed below.

### *E.3.2 Vulnerabilities Causing Extensive Damage*

It was recognized that two of the assessment items have been repeatedly associated with extensive damage in past earthquakes. These are Items A-5, lack of adequate bolting to the foundation, and Item B-8, involving lack of adequate bracing between the lowest floor and foundation. In the assessment form, these items were not assigned enough penalty points to clearly identify them as causing significant damage, or to identify them as priorities for retrofit. In order to clearly communicate these messages, the number of penalty points assigned to these items was increased. The assessment item A-5 penalty for not having anchor bolts was therefore increased from 4.6 to 15 points, and the assessment item B-8 penalty for cripple walls without plywood or OSB sheathing was increased from 8.8 to 14 points. Because the total number of points was intended to add to 100, this required that penalty points be reduced elsewhere; most of the needed penalty points were taken from Section C of the assessment form, where most awarded points for building condition were reduced by half.

In addition, one new assessment item was added. New item D-4 addresses exterior stairs, decks and porch roofs that are not positively anchored to the dwelling that provided earthquake bracing. Damage to these elements has shown up repeatedly in past earthquakes and is discussed in seismic retrofit guidelines.

### *E.3.3 Other Revisions*

Additional minor revisions were made to the form. These included deleting items that were penalized more than once (i.e. brick veneer), and wording changes to clarify intent.

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# Project Participants

## ATC Management and Oversight

Christopher Rojahn (Project Executive)
Applied Technology Council
201 Redwood Shores Parkway, Suite 240
Redwood City, California 94065

Jon A. Heintz (Project Quality Control Monitor)
Applied Technology Council
201 Redwood Shores Parkway, Suite 240
Redwood City, California 94065

Thomas R. McLane (Project Manager)
Applied Technology Council
2111 Wilson Blvd., Suite 700
Arlington, Virginia 22201

William T. Holmes (Project Technical Monitor)
Rutherford & Chekene
55 Second Street, Suite 600
San Francisco, California 94105

## Federal Emergency Management Agency

Michael Mahoney (FEMA Project Officer)
Federal Emergency Management Agency
500 C Street, SW
Washington, DC 20472

Jennifer Lynette (FEMA Region IX)
Federal Emergency Management Agency
1111 Broadway, Suite 1200
Oakland, California 94607

John Gillengerten (FEMA Subject Matter Expert)
Office of Statewide Health Planning and
Development (OSHPD)
400 R Street
Sacramento, California 95811-6213

## Project Management Committee

Ronald T. Eguchi (Project Technical Director)
ImageCat, Inc.
Union Bank of California Building
400 Oceangate, Suite 1050
Long Beach, California 90802

Kelly E. Cobeen
Wiss, Janney, Elstner Associates
2000 Powell Street, Suite 1650
Emeryville, California 94608

Doug Hohbach
Hohbach-Lewin, Inc.
260 Sheridan Ave. Suite 150
Palo Alto, California 94306

Nicolas Luco
USGS
PO Box 25046, MS 966
Denver, Colorado 80225

Charles R. Real
California Geological Survey
801 K Street MS 12-31
Sacramento, California 94814-3531

Jonathan P. Stewart
5731 Boelter Hall
University of California
Los Angeles, California 90095-1593

## Stochastic Analysis Team

Surya Gunturi
EQECAT
475 14th Street, Suite 500
Oakland, California 94618

Kate Stillwell
EQECAT
475 14th Street, Suite 500
Oakland, California 94618

Kamban Parasuraman
EQECAT
475 14th Street, Suite 500
Oakland, California 94618

## Project Review Panel

Barry Welliver (Chair)
BHW Engineers L.L.C.
13065 South 132 East
Suite 210
Draper, Utah 84020

Susan Dowty
S.K. Ghosh Associates Inc.
43 Vantis Drive
Aliso Viejo, California 92656

Gary J. Ehrlich
National Association of Home Builders
1201 15th Street, NW
Washington, DC 20005

Mark Legg
Legg Geophysical, Inc.
16541 Gothard Street, Suite 107
Huntington Beach, California 92647

Philip Line
American Wood Council
803 Sycolin Road, Suite 201
Leesburg, Virginia 20175

James Russell
Building Codes Consultant
3654 Sun View Way
Concord, California 94520

## Other Contributors

Janiele Maffei
California Earthquake Authority
801 K Street, Suite 1000
Sacramento, California 95814

Shawna Ackerman
California Earthquake Authority
801 K Street, Suite 1000
Sacramento, California 95814

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