



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

FEMA P-50 / May 2012



FEMA



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



FEMA



Notice

Any opinions, findings, conclusions, or recommendations expressed in this publication do not necessarily reflect the views of the Applied Technology Council (ATC), the Department of Homeland Security (DHS), or the Federal Emergency Management Agency (FEMA). Additionally, neither ATC, DHS, FEMA, nor any of their employees, makes any warranty, expressed or implied, nor assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, product, or process included in this publication. Users of information from this publication assume all liability arising from such use.

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. Cobeon, 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		
	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		
	Background.....	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