



Seismic Evaluation and Retrofit of Multi-Unit Wood-Frame Buildings With Weak First Stories

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Notice

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Cover Photo: Near-collapse of typical weak-story wood-frame buildings in the 1989 Loma Prieta earthquake.

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, FEMA has observed that multi-unit wood-frame buildings with a weak first story represent a significant risk in highly seismic regions of the United States because of their high potential for collapse. This risk is magnified by the sheer numbers of these buildings that still exist and the numbers of people who occupy them. This collapse potential is due primarily to their soft or weak first-story walls, which have often been weakened by large numbers of openings such as garages or store front windows.

FEMA worked with ATC to develop these guidelines to address seismic retrofit requirements for weak-story wood-frame buildings in seismically active regions of the United States, with a particular focus on Northern and Southern California and the Pacific Northwest. The guidelines focus on multi-family, multi-story buildings with weak first stories, such as those damaged in the Marina District of San Francisco in the 1989 Loma Prieta earthquake, and apartment buildings with tuck-under parking, such as those damaged in Southern California in the 1994 Northridge earthquake.

These seismic retrofitting guidelines are the first to focus solely on the weak first story and to provide just enough additional strength to protect the first floor from collapse but not so much as to drive earthquake forces into the upper stories, placing them at risk of collapse. They are also the first to take into account the strength provided by existing non-structural walls. Both of

these steps will make seismic retrofitting more affordable. This methodology does presume, however, that the upper stories are basically regular and do provide enough strength to match the retrofitted first story.

FEMA is indebted to the Project Management Committee of David Mar (Project Technical Director), David Bonowitz, Kelly Cobeen, Dan Dolan, Andre Filiatrault, and John Price, for preparing this report, and to Mike Korolyk, who as the Analysis Consultant conducted the computer analyses to validate the guidelines. We also wish to thank the Project Review Panel of Chris Poland (Chair), Tony DeMascole, Laurence Kornfield, Bret Lizundia (ATC Board Representative), Joan MacQuarrie, Andrew Merovich, and Tom Tobin, who provided expert review and guidance throughout the developmental effort. Without their dedication and hard work, this project would not have been possible.

– Federal Emergency Management Agency

Preface

In May 2009 the Applied Technology Council (ATC), with funding from the Federal Emergency Management Agency (FEMA) under Task Order Contract HSFEHQ-08-D-0726, commenced development of simplified guidelines for the seismic retrofit of weak-story wood-frame buildings—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.

Multi-unit wood-frame buildings with a weak first story represent a significant risk in highly seismic regions of the United States, not only because of their damage and collapse potential, but also because of their size, prevalence and the high numbers of people who occupy them. In San Francisco, for example, approximately 4,400 older, pre-seismic-code, wood-frame residential buildings have been inventoried that contain five or more living units and are 3 or more stories in height (ATC, 2009a). Most of these buildings have potentially soft or weak ground floor (first story) walls, as do an expectedly high but unknown number of pre-seismic-code 3-to-5 story wood-frame commercial buildings, and similar buildings constructed after 1974 not included in the San Francisco inventory.

FEMA and ATC agreed that the retrofit guidelines development project should address seismic retrofit requirements for weak-story wood-frame buildings in seismically active regions of the United States, focusing primarily on Northern and Southern California and the Pacific Northwest. Configurations to be addressed included multi-family, multi-story buildings with weak first stories, such as those prevalent in San Francisco, and apartment buildings with tuck-under parking, such as those significantly damaged by the 1994 Northridge earthquake in Southern California. The project team was also charged with developing practical, model code provisions for seismic retrofit of weak-story wood-frame buildings that can be adopted by cities such as San Francisco and that are written to ensure that application and enforcement is uniform and enforceable.

This *Guidelines* document sets forth the framework for procedures for seismic evaluation and retrofit of weak-story wood-frame buildings. Throughout this document the term weak-story is used to describe a building's vulnerability, rather than soft-story. The reason is that while both

flexibility and strength contribute to the structure’s response, strength is the more dominant characteristic.

ATC is indebted to the ATC Project Management Committee, which consisted of David Mar (Project Technical Director), David Bonowitz, Kelly Cobeen, Dan Dolan, Andre Filiatrault, and John Price, for their efforts in researching and preparing this report; to Mike Korolyk, who served as the Analysis Consultant and conducted thousands of computer analyses to support and validate the guidelines; to Maikol Del Carpio, who assisted in the data analysis; and to the Project Review Panel, which consisted of Chris Poland (Chair), Tony DeMascole, Laurence Kornfield, Bret Lizundia (ATC Board Representative), Joan MacQuarrie, Andrew Merovich, and Tom Tobin, who provided expert review and guidance throughout the developmental effort. Thomas R. McLane served as Project Manager, William Holmes served as the Project Technical Monitor, and Peter Mork provided report production services. The affiliations of these individuals are provided in the list of Project Participants.

ATC also gratefully acknowledges the input, support, and guidance provided by Michael Mahoney (FEMA Project Officer), Cathleen Carlisle (FEMA Project Monitor), Robert Hanson (FEMA Subject Matter Expert), and Daniel Shapiro (FEMA Technical Monitor).

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Table of Contents

Foreword.....	iii
Preface.....	v
List of Figures.....	xiii
List of Tables	xxiii
Glossary	xxv
1. Introduction.....	1
1.1 Earthquake Risks of Multi-Unit Weak-Story Wood-Frame Buildings	1
1.2 Weak-Story Building Characteristics	2
1.2.1 The Critical Deficiency: A First Story Lacking Adequate Strength or Stiffness.....	3
1.3 Engineering Codes and Standards.....	4
1.3.1 The Guidelines as an Alternative	5
1.4 Purpose and Intended Use of the <i>Guidelines</i>	6
1.4.1 Policy Options	7
1.4.2 Selecting Performance Objectives.....	8
1.5 Validation	10
1.6 The Weak-Story Tool.....	10
1.7 <i>Guidelines</i> Organization and Content	10
2. Technical Overview.....	13
2.1 Statistical Basis.....	15
2.2 Modeling Actual and Surrogate Structures	15
2.2.1 The Surrogate Models	15
2.2.2 Characterizing an Existing Building	17
2.3 Acceptability Criteria	18
2.3.1 Performance Measure.....	18
2.3.2 Performance Objective.....	18
2.3.3 Relationship to Other Codes and Standards	19
2.4 Critical Deficiencies	21
2.5 Retrofit Design Philosophy	22
2.5.1 Cost-Effective, First-Story Retrofit.....	22
2.5.2 Bounded Design and Relative Strength.....	24
2.6 Limitations and Eligibility Requirements	25
2.6.1 General Eligibility Requirements.....	26
2.6.2 Upper-Story Eligibility Requirements.....	26
2.6.3 First-Story, Basement, and Foundation Eligibility Requirements.....	27
2.6.4 Floor and Roof Diaphragms Eligibility Requirements.....	28

3.	Simplified Evaluation.....	33
3.1	Purpose	33
3.1.1	Limitations.....	33
3.2	Simplified Evaluation Procedure	33
3.3	Building Survey	34
3.3.1	First-Story Survey.....	34
3.3.2	Upper-Story Survey	35
3.4	Building Characterization	35
3.4.1	Total Building Weight, W	36
3.4.2	Shear Strengths of First-Story Walls	36
3.4.3	Shear Strength of First Story	37
3.4.4	Center of Strength (COS_1) of First Story.....	37
3.4.5	Center of Strength (COS_2) of Upper Stories.....	38
3.4.6	Eccentricity	38
3.4.7	Simplified Torsion Coefficient, C_{Ts}	38
3.5	Simplified Evaluation of Seismic Performance.....	39
3.5.1	Site-Specific Spectral Acceleration Demand.....	39
3.5.2	Story-Height Factor, Q_s	40
3.5.3	Simplified Spectral Acceleration Capacity, S_{cs}	40
3.5.4	Comparison of Demand Versus Capacity.....	40
4.	Structure Characterization for Detailed Evaluation.....	41
4.1	Introduction.....	41
4.2	Wall Materials	42
4.3	Detailed Building Survey	42
4.4	Load-Drift Curves for Common Sheathing Materials	43
4.5	Wall Line Load-Drift Curves.....	47
4.5.1	Load-Drift Curves for Combinations of Sheathing Materials	49
4.5.2	Adjustment Factor for Openings in the Wall Line	50
4.5.3	Adjustment Factor for Overturning	53
4.5.4	Drift Ratio Adjustment for First-Story Wall Line Height	56
4.6	Determine Strength of Each Story	57
4.6.1	Translational Load-Drift Curve	57
4.6.2	Peak Strength.....	58
4.6.3	Drift Ratio at Peak Strength.....	59
4.6.4	Center of Strength.....	60
4.6.5	Torsional Eccentricity at the First Story	61
4.6.6	Load-Rotation Curve	61
4.6.7	Torsional Strength	63
4.6.8	Torsional Demand	64
4.7	Characteristic Coefficients.....	64
4.7.1	Normalized First-Story Strength.....	64
4.7.2	Normalized Upper-Story Strength.....	65
4.7.3	Weak-Story Ratio, A_W	66
4.7.4	Strength-Degradation Ratio, C_D	66
4.7.5	Torsion Coefficient, C_T	66
4.7.6	Story Height Factor, Q_s	67
5.	Detailed Evaluation	69
5.1	Evaluation Steps	69
5.2	Calculate the Median Spectral Acceleration Capacity.....	71

5.3	Calculate the Spectral Acceleration Capacity	72
5.4	Evaluate the Existing Structure	74
5.4.1	Compare the Spectral Acceleration Capacity with Site-Specific Demand.....	74
5.4.2	Calculating the Probability of Exceedance.....	75
6.	Retrofit	77
6.1	Retrofit Scope.....	77
6.2	Retrofit Strength.....	79
6.2.1	Estimated Minimum Required Strength of the Retrofitted First Story.....	80
6.2.2	Estimated Maximum Acceptable Strength of the Retrofitted First Story.....	81
6.2.3	Estimated Ranges of Acceptable Retrofit Strength	83
6.3	Locating Retrofit Elements	85
6.3.1	Retrofit Element Location to Minimize Torsion	86
6.3.2	Retrofit Element Location to Ensure Eligibility.....	87
6.4	Confirmed Performance of the Retrofitted Structure	88
6.4.1	Retrofits Intended to Satisfy the Performance Objective	90
6.4.2	Optimized Retrofits that Do Not Satisfy the Performance Objective	90
6.5	Retrofit Element Selection and Design	91
6.5.1	Load Path Components	93
6.5.2	Second Floor Diaphragm.....	93
6.5.3	Wood Structural Panel Shear Walls	93
6.5.4	Steel Moment Frames.....	94
6.5.5	Steel Braced Frames.....	94
6.5.6	Concrete or Reinforced Masonry Shear Walls.....	95
7.	Alternative Performance Assessment.....	97
7.1	Purpose	97
7.2	Assessment Background.....	97
7.3	Interstory Drift Limits	97
7.4	Spectral Acceleration Capacity	98
7.5	Estimating the Drift Limit Probability of Exceedance	99
	Appendix A: Guide to Weak-Story Tool.....	A-1
A.1	Introduction	A-1
A.2	Obtaining the Weak-Story Tool	A-1
A.3	System Requirements	A-1
A.4	Weak-Story Tool Installation	A-1
A.5	Basic Controls	A-2
A.6	General Building Properties and Geometry	A-2
A.7	CAD Interface	A-4
A.7.1	Analytical Entities	A-4
A.7.2	Non-Analytical Entities.....	A-4
A.7.3	Other CAD Tools	A-6
A.8	Defining Sheathing Assemblies	A-7
A.9	Assigning Level Properties and Laying Out Walls	A-11
A.9.1	The Shearwall Layout Tab	A-12
A.9.2	Shearwall Table.....	A-15

A.10	Evaluation and Retrofit Summary	A-15
A.10.1	Evaluation Data Tab	A-15
A.10.2	Backbone Curves Tab.....	A-17
A.10.3	Performance Data Tab	A-17
Appendix B:	Model Provisions for Mitigation Programs.....	B-1
B.1	Targeted Mitigation Programs	B-1
B.1.1	Planning and Program Development	B-2
B.1.2	Screening	B-3
B.1.3	Evaluation.....	B-3
B.1.4	Retrofit Prioritization.....	B-4
B.1.5	Retrofit.....	B-5
B.2	Program Performance Objectives	B-5
B.3	Model Provisions and Commentary	B-7
Appendix C:	Example Calculations.....	C-1
C.1	Simplified Evaluation (Chapter 3).....	C-3
C.2	Structure Characterization and Evaluation (Chapters 4 and 5)	C-7
C.3	Retrofit (Chapter 6).....	C-9
C.4	Torsion Calculations (Chapters 3 and 4)	C-17
Appendix D:	Characterization of Existing Materials	D-1
D.1	Introduction.....	D-1
D.2	Research Addressing Wall Bracing Materials	D-1
D.3	Load-Deflection Backbone	D-5
D.3.1	Plaster on Wood Lath	D-6
D.3.2	Horizontal Lumber Sheathing.....	D-8
D.3.3	Diagonal Lumber Sheathing	D-9
D.3.4	Stucco	D-11
D.3.5	Gypsum Wallboard.....	D-13
D.3.6	Plaster on Gypsum Lath.....	D-15
D.3.7	Wood Structural Panel Siding	D-17
D.3.8	Wood Structural Panel Sheathing	D-18
D.4	Recommended Descriptions of Wall Bracing Materials	D-29
D.5	Adjustment Factor for Combinations of Bracing Materials ..	D-30
D.6	Adjustment Factor for Openings in the Wall Line.....	D-32
D.7	Adjustment Factor for Overturning	D-33
D.8	Drift Adjustment for First-Story Wall-Line Height.....	D-34
D.9	Descriptions of Damage versus Drift.....	D-35
D.10	Recommended Future Research	D-54
Appendix E:	Detailed Analytical Background	E-1
E.1	Purpose	E-1
E.2	General.....	E-1
E.2.1	Overview and Limitations	E-1
E.2.2	Building Characterization.....	E-1
E.2.3	IDA Approach	E-2
E.2.4	Material Characterization	E-3
E.2.5	Performance Criteria.....	E-5
E.3	Modeling Details	E-7
E.3.1	Software.....	E-7

E.3.2	Typical Building Model	E-7
E.3.3	Hysteretic Damping.....	E-9
E.3.4	Viscous Damping	E-11
E.3.5	P-Delta.....	E-11
E.3.6	Accounting for Overturning Effects.....	E-11
E.4	Ground Acceleration Records	E-14
E.5	Translational Analyses	E-14
E.5.1	Analysis Flow.....	E-14
E.5.2	Median Performance	E-15
E.5.3	Interpolation for Intermediate Values of C_D	E-18
E.5.4	Adjustment for Uncertainty	E-20
E.5.5	Assessment and Probability of Exceedance	E-26
E.5.6	Retrofit Analyses.....	E-29
E.5.7	Effect of First-Story Retrofit	E-31
E.5.8	Estimating the Minimum Retrofit for Achieving Desired Performance	E-33
E.5.9	Wood-Sheathed Walls versus Moment Frame Retrofit	E-34
E.5.10	First-Story Height.....	E-36
E.6	Torsional Analyses	E-38
E.6.1	Discussion on Torsional Behavior	E-38
E.6.2	Torsion Coefficient, C_T	E-38
E.6.3	Modeling	E-39
E.6.4	Response-History Input.....	E-39
E.6.5	Assessing the Effect of Torsion.....	E-41
E.6.6	Simplified Torsion Coefficient, C_{Ts}	E-42

Appendix F: Validation of Analysis Methods.....F-1

F.1	Purpose	F-1
F.2	The Building Under Consideration	F-1
F.3	Differences in Scope of Analysis	F-2
F.3.1	Number of Stories	F-3
F.3.2	Sheathing Assemblies	F-3
F.4	Differences in Analytical Methods.....	F-3
F.4.1	Software	F-3
F.4.2	Viscous Damping	F-6
F.4.3	Backbone of Increasing Retrofit.....	F-7
F.5	Comparison of Results	F-8
F.5.1	Existing Building.....	F-9
F.5.2	Retrofitted Building.....	F-10
F.6	The Optimal Retrofit for Relative Strength.....	F-11
F.7	Conclusions	F-12

References..... G-1

Project Participants H-1