

ASCE STANDARD

ASCE/SEI

**41-23**

# Seismic Evaluation and Retrofit of Existing Buildings

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## ASCE STANDARDS

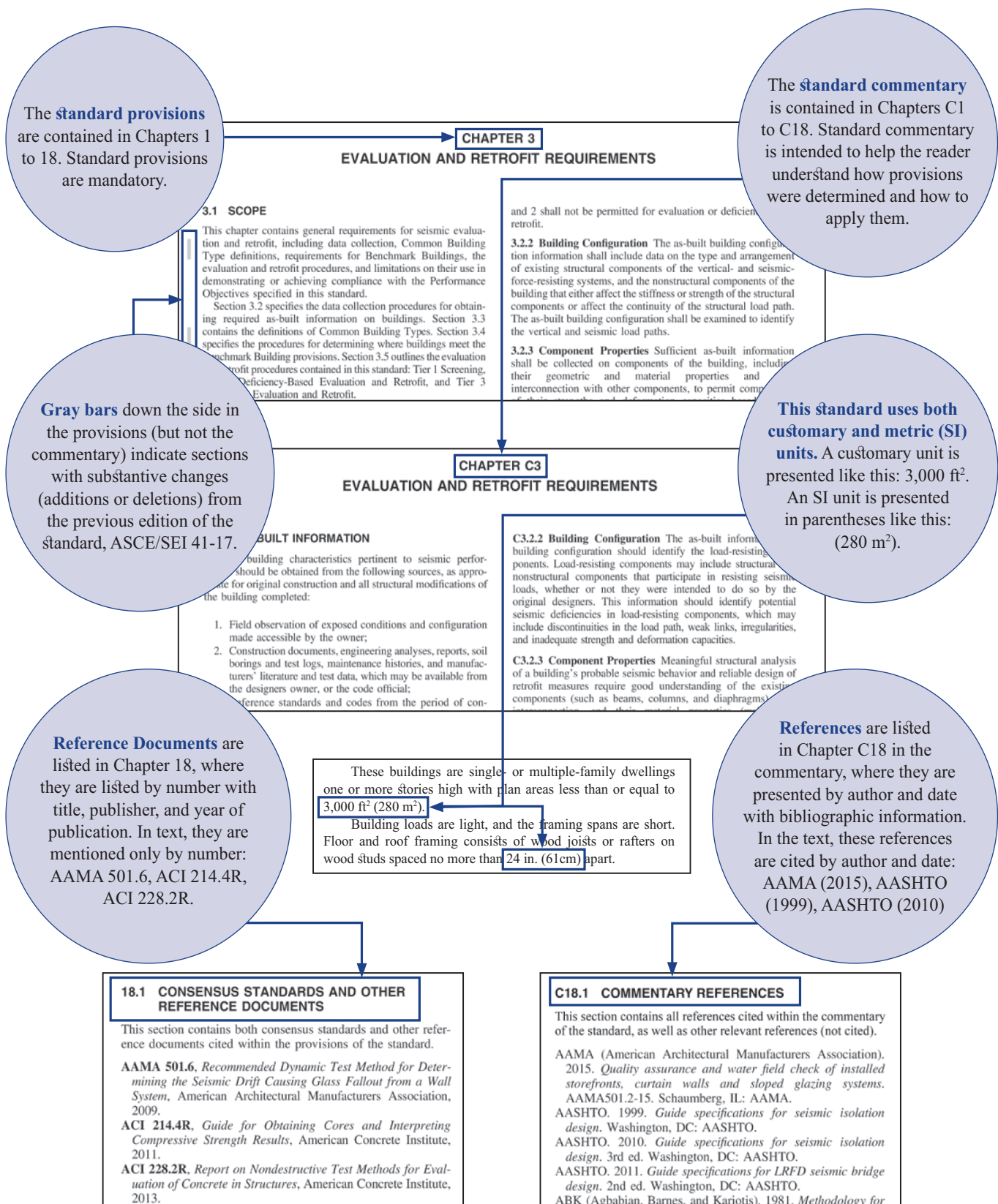
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# Tips for Using This Standard



Supplements, errata, and interpretations may become available in the future.  
Please check for important new materials at <https://doi.org/10.16/9780784416112>.

# Tips for Using the ASCE Hazard Tool

## asce7hazardtool.online

The ASCE Hazard Tool provides access to the digital data defined in the hazard Geodatabases required by ASCE standards. The digital data required for flood, ice, rain, seismic, snow, tornado, and wind are available at <https://asce7hazardtool.online/>. Digital data required for tsunami is available at <https://asce7tsunami.online/>.

The screenshot shows the ASCE Hazard Tool interface. On the left, there are input fields for 'Location' (San Francisco, California), 'Elevation' (60 ft), 'Lat' (37.77712), 'Long' (-122.41964), 'Standard' (ASCE/SEI 7:22), 'Risk Category' (I), and 'Soil Class' (Default). A 'Seismic Details' window is open, showing a table of seismic coefficients and two graphs: 'Multi-Period Design Spectrum' and 'Multi-Period MCE<sub>R</sub> Spectrum'. The table includes values for S<sub>S</sub>, S<sub>1</sub>, S<sub>MS</sub>, S<sub>MI</sub>, S<sub>DS</sub>, S<sub>DI</sub>, T<sub>L</sub>, PGA<sub>M</sub>, and V<sub>S30</sub>. The 'FULL REPORT' button is highlighted with a red circle and an arrow pointing to it from a text box below the screenshot.

**Digital Data:** The ASCE Hazard Tool provides digital data required by ASCE Standards:

- **NEW!** Seismic hazard data from ASCE/SEI 41-23 and 41-17, including coefficients and response spectra grouped by different hazard level responses (BSE-2N, BSE-1N, etc...)
- Flood: Flood zone and static base flood elevation, plus direct links to additional information
- Tsunami: Whether the site is in a mapped tsunami design zone per the ASCE Tsunami Design Geodatabase, and link to ASCE Tsunami Design Geodatabase if required for design
- Snow: Ground snow load and winter wind parameter
- Rain: Median 15-minute and 60-minute duration rainfall intensities for 100-year mean recurrence interval
- Ice: Radial ice thickness with concurrent 3-second gust speeds and temperature concurrent with ice thickness due to freezing rain
- Seismic: Seismic coefficients  $S_S$ ,  $S_1$ ,  $S_{MS}$ ,  $S_{MI}$ ,  $S_{DS}$ ,  $S_{DI}$ ,  $T_L$ ,  $PGA_M$ , and  $V_{S30}$ , plus the seismic design category, as well as the multi-period spectrum, the multi-period MCE<sub>R</sub> spectrum, the two-period design spectrum, and the two-period MCE<sub>R</sub> spectrum
- Wind: Three-second gust wind speeds at 33 feet (10 meters) above ground for Exposure Category C, including identification of hurricane-prone and wind-borne debris regions
- Tornado: Tornado wind speeds for 1,700-, 3,000-, 10,000-, 100,000-, 1,000,000-, and 10,000,000-year MRI, and for 1-, 2,000-, 10,000-, 40,000-, 100,000-, 250,000-, 1,000,000-, and 4,000,000-ft<sub>2</sub> target areas



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## Introducing ASCE Amplify: A faster, easier way to work with ASCE Standards

This new digital, interactive, secure platform launches with ASCE/SEI 7-22, 7-16, 7-10, and ASCE/SEI 41-23 and Tier 1 Checklists (*coming soon: ASCE/SEI 41-17*). The complete Provisions and Commentary of ASCE 7 and ASCE 41 are available within a suite of interactive tools and feature-rich functionality. **Additional standards and materials will be added on a rolling basis.**

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- One-click syncing between Provisions and Commentary;
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#### Includes:

*Minimum Design Loads and Associated Criteria for Buildings and Other Structures*

7-22, 7-16, 7-10

*Seismic Evaluation and Retrofit of Existing Buildings*

41-23 and Tier 1 Checklists

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or demo, contact:

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# CONTENTS

<b>ASCE STANDARDS.</b>		iii
<b>TIPS FOR USING THIS STANDARD</b>		iv
<b>TIPS FOR USING THE ASCE HAZARD TOOL</b>		v
<b>PREFACE</b>		xxxvii
<b>ACKNOWLEDGMENTS</b>		xl
<b>DEDICATION</b>		xliv
<b>UNIT CONVERSIONS</b>		xlv
<b>1</b>	<b>GENERAL REQUIREMENTS</b>	<b>1</b>
1.1	Scope	1
1.2	Definitions and Notation	1
1.2.1	Definitions	1
1.2.2	Notation	7
1.2.2.1	Uppercase Notation	7
1.2.2.2	Lowercase Notation	14
1.2.2.3	Greek Notation	16
1.3	Seismic Evaluation Process	18
1.3.1	Assignment of Performance Objective	18
1.3.2	Level of Seismicity	19
1.3.3	As-Built Information	19
1.3.4	Evaluation Procedures	19
1.4	Seismic Retrofit Process	19
1.4.1	Assignment of Performance Objective	19
1.4.2	Level of Seismicity	19
1.4.3	As-Built Information	19
1.4.4	Verification of Retrofit Design	19
1.4.5	Quality Assurance and Structural Observation	19
1.4.5.1	Special Inspections and Testing	19
1.4.5.2	Structural Observation	19
<b>2</b>	<b>PERFORMANCE OBJECTIVES AND SEISMIC HAZARDS.</b>	<b>21</b>
2.1	Scope	21
2.2	Performance Levels	21
2.2.1	Structural Performance Levels and Ranges	21
2.2.2	Nonstructural Performance Levels	21
2.3	Seismic Hazard	21
2.3.1	Seismic Hazard Levels	21
2.3.1.1	BSE-2N Seismic Hazard Level	22
2.3.1.2	BSE-1N Seismic Hazard Level	22
2.3.1.3	BSE-2E Seismic Hazard Level	22
2.3.1.4	BSE-1E Seismic Hazard Level	22
2.3.1.5	Seismic Hazard Levels for Other Probabilities of Exceedance, Risk Targets, or Deterministic Hazards	22
2.3.2	General Response Spectrum	22
2.3.2.1	Multi-Period General Horizontal Response Spectrum	22

	2.3.2.2	Two-Period General Horizontal Response Spectrum . . . . .	23
	2.3.2.3	General Vertical Response Spectrum . . . . .	23
	2.3.3	Site-Specific Procedure for Hazards Caused by Ground Shaking . . . . .	23
	2.3.4	Ground Motion Acceleration Histories . . . . .	23
2.4		Performance Objectives . . . . .	23
	2.4.1	Basic Performance Objective for Existing Buildings (BPOE) . . . . .	23
	2.4.2	Enhanced Performance Objectives. . . . .	23
	2.4.3	Limited Performance Objectives. . . . .	24
	2.4.4	Basic Performance Objective Equivalent to New Building Standards (BPON) . . . . .	24
	2.4.5	Partial Retrofit . . . . .	24
	2.4.6	System-Specific Performance Procedures . . . . .	25
2.5		Level of Seismicity. . . . .	25
3		EVALUATION AND RETROFIT REQUIREMENTS . . . . .	27
	3.1	Scope . . . . .	27
	3.2	As-Built Information . . . . .	27
	3.2.1	Building Type . . . . .	27
	3.2.2	Building Configuration. . . . .	27
	3.2.3	Component Properties . . . . .	27
	3.2.4	Site and Foundation Information . . . . .	27
	3.2.5	Adjacent Buildings. . . . .	27
	3.2.5.1	Building Pounding . . . . .	27
	3.2.5.2	Shared Element Condition . . . . .	28
	3.2.5.3	Hazards from Adjacent Buildings . . . . .	28
	3.3	Common Building Types . . . . .	28
	3.4	Benchmark Buildings . . . . .	30
	3.4.1	Benchmark Procedure Checklist. . . . .	32
	3.4.2	Parameters for Benchmark Procedure . . . . .	32
	3.4.2.1	Level of Seismicity . . . . .	32
	3.4.2.2	Seismic Force Provisions . . . . .	32
	3.5	Evaluation and Retrofit Procedures . . . . .	33
	3.5.1	Limitations on the Use of Tier 1 and Tier 2 Evaluation and Retrofit Procedures.. . . .	33
	3.5.1.1	Buildings Conforming to One of the Common Building Types . . . . .	34
	3.5.1.2	Buildings Composed of More than One of the Common Building Types. . . . .	34
	3.5.2	Tier 1 Screening Procedure . . . . .	36
	3.5.3	Tier 2 Deficiency-Based Evaluation and Retrofit Procedures. . . . .	36
	3.5.3.1	Evaluation Requirements. . . . .	37
	3.5.3.2	Retrofit Requirements . . . . .	37
	3.5.4	Tier 3 Systematic Evaluation and Retrofit Procedures . . . . .	37
	3.5.4.1	Evaluation Requirements. . . . .	37
	3.5.4.2	Retrofit Requirements . . . . .	37
4		TIER 1 SCREENING . . . . .	39
	4.1	Scope . . . . .	39
	4.1.1	Performance Level . . . . .	40
	4.1.2	Seismic Hazard Level . . . . .	40
	4.1.3	Level of Seismicity . . . . .	40
	4.2	Scope of Investigation Required. . . . .	40
	4.2.1	On-Site Investigation and Condition Assessment . . . . .	40
	4.2.2	Building Type . . . . .	41
	4.2.3	Default Material Values . . . . .	41
	4.3	Selection and Use of Checklists . . . . .	41
	4.4	Tier 1 Analysis. . . . .	42
	4.4.1	Overview . . . . .	42
	4.4.2	Seismic Forces . . . . .	42
	4.4.2.1	Pseudo Seismic Force . . . . .	42
	4.4.2.2	Story Shear Forces . . . . .	43
	4.4.2.3	Spectral Acceleration. . . . .	43
	4.4.2.4	Period. . . . .	44
	4.4.3	Quick Checks for Strength and Stiffness . . . . .	44
	4.4.3.1	Story Drift for Moment Frames . . . . .	44
	4.4.3.2	Shear Stress in Concrete Frame Columns . . . . .	44
	4.4.3.3	Shear Stress in Shear Walls . . . . .	44

	4.4.3.4	Diagonal Bracing. . . . .	44
	4.4.3.5	Precast Connections . . . . .	45
	4.4.3.6	Column Axial Stress Caused by Overturning. . . . .	45
	4.4.3.7	Flexible Diaphragm Connection Forces . . . . .	45
	4.4.3.8	Prestressed Elements . . . . .	45
	4.4.3.9	Flexural Stress in Columns and Beams of Steel Moment Frames. . . . .	45
5		TIER 2 DEFICIENCY-BASED EVALUATION AND RETROFIT . . . . .	47
	5.1	Scope . . . . .	47
	5.2	General Requirements . . . . .	47
	5.2.1	Performance Level and Seismic Hazard Level . . . . .	47
	5.2.2	As-Built Information . . . . .	47
	5.2.3	Condition Assessment . . . . .	47
	5.2.4	Tier 2 Analysis Methods. . . . .	47
	5.2.5	Tier 2 Acceptance Criteria. . . . .	50
	5.2.6	Knowledge Factor . . . . .	50
	5.3	Tier 2 Deficiency-Based Evaluation Requirements . . . . .	50
	5.4	Procedures for Basic Configuration of Building Systems. . . . .	50
	5.4.1	General . . . . .	50
	5.4.1.1	Load Path. . . . .	50
	5.4.1.2	Adjacent Buildings. . . . .	50
	5.4.1.3	Mezzanines . . . . .	50
	5.4.2	Building Configuration. . . . .	50
	5.4.2.1	Weak Story Irregularity . . . . .	50
	5.4.2.2	Soft Story Irregularity . . . . .	50
	5.4.2.3	Vertical Irregularities. . . . .	50
	5.4.2.4	Geometric Irregularity . . . . .	50
	5.4.2.5	Mass Irregularity . . . . .	50
	5.4.2.6	Torsion Irregularity. . . . .	50
	5.4.3	Geologic Site Hazards and Foundation Components . . . . .	50
	5.4.3.1	Geologic Site Hazards . . . . .	50
	5.4.3.2	Foundation Performance . . . . .	51
	5.4.3.3	Overturning. . . . .	51
	5.4.3.4	Ties between Foundation Elements . . . . .	51
	5.5	Procedures for Seismic-Force-Resisting Systems . . . . .	51
	5.5.1	General . . . . .	51
	5.5.1.1	Redundancy . . . . .	51
	5.5.2	Procedures for Moment Frames . . . . .	51
	5.5.2.1	General Procedures for Moment Frames . . . . .	51
	5.5.2.2	Procedures for Steel Moment Frames . . . . .	51
	5.5.2.3	Procedures for Concrete Moment Frames . . . . .	51
	5.5.2.4	Procedures for Precast Concrete Moment Frames. . . . .	52
	5.5.2.5	Procedures for Frames Not Part of the Seismic-Force-Resisting System. . . . .	52
	5.5.3	Procedures for Shear Walls . . . . .	52
	5.5.3.1	General Procedures for Shear Walls. . . . .	52
	5.5.3.2	Procedures for Concrete Shear Walls . . . . .	52
	5.5.3.3	Procedures for Precast Concrete Shear Walls . . . . .	52
	5.5.3.4	Procedures for Unreinforced Masonry Shear Walls. . . . .	53
	5.5.3.5	Procedures for Infill Walls in Frames . . . . .	53
	5.5.3.6	Procedures for Walls in Wood Frame Buildings . . . . .	53
	5.5.3.7	Procedures for Cold-Formed Steel Light-Frame Construction, Shear Wall Systems . . . . .	53
	5.5.4	Procedures for Braced Frames. . . . .	53
	5.5.4.1	Axial Stress Check. . . . .	53
	5.5.4.2	Column Splices. . . . .	53
	5.5.4.3	Slenderness of Diagonals . . . . .	53
	5.5.4.4	Connection Strength . . . . .	53
	5.5.4.5	Out-of-Plane Restraint for Braced Frames. . . . .	54
	5.5.4.6	K-Bracing and Chevron-Bracing Configurations . . . . .	54
	5.5.4.7	Tension-Only Braces . . . . .	54
	5.5.4.8	Centrally Braced Frame Joints . . . . .	54
	5.5.4.9	Procedures for Cold-Formed Steel Light-Frame Construction, Strap-Braced Wall Systems. . . . .	54
	5.6	Procedures for Diaphragms . . . . .	54
	5.6.1	General Procedures for Diaphragms. . . . .	54

	5.6.1.1	Diaphragm and Roof Chord Continuity . . . . .	54
	5.6.1.2	Diaphragm Cross Ties . . . . .	54
	5.6.1.3	Openings in Diaphragms at Shear Walls, Braced Frames, and Moment Frames . . . . .	54
	5.6.1.4	Plan Irregularities in Diaphragms . . . . .	54
	5.6.1.5	Diaphragm Reinforcement at Openings . . . . .	54
	5.6.2	Procedures for Wood Diaphragms . . . . .	54
	5.6.3	Procedures for Steel Deck Diaphragms . . . . .	54
	5.6.4	Procedures for Precast Concrete Diaphragms . . . . .	55
	5.6.5	Diaphragms Other Than Wood, Steel Deck, Concrete, or Horizontal Bracing . . . . .	55
5.7		Procedures for Connections . . . . .	55
	5.7.1	Anchorage for Normal Forces . . . . .	55
	5.7.1.1	Wall Anchorage . . . . .	55
	5.7.1.2	Stiffness of Wall Anchors . . . . .	55
	5.7.1.3	Wood Ledgers with Cross-Grain Bending . . . . .	55
	5.7.1.4	Precast Concrete Panel Connections . . . . .	55
	5.7.2	Connections for Shear Transfer . . . . .	55
	5.7.3	Connections for Vertical Elements . . . . .	55
	5.7.3.1	Steel and Concrete Columns . . . . .	55
	5.7.3.2	Shear Wall Boundary Columns . . . . .	55
	5.7.3.3	Wood or Cold-Formed Steel Posts and Wood Sills and Cold-Formed Steel Base Tracks . . . . .	55
	5.7.3.4	Concrete Walls, Precast Wall Panels, and Other Wall Panels . . . . .	55
	5.7.3.5	Uplift at Pile Caps . . . . .	55
	5.7.4	Interconnection of Elements . . . . .	55
	5.7.4.1	Girder–Column Connection . . . . .	55
	5.7.4.2	Girders Supported by Walls or Pilasters . . . . .	55
	5.7.4.3	Corbel Bearing and Connections . . . . .	55
	5.7.4.4	Beam, Girder, and Truss Supported on Unreinforced Masonry (URM) Walls or URM Pilasters . . . . .	55
	5.7.5	Roof and Wall Panel Connections . . . . .	55
5.8		Tier 2 Deficiency-Based Retrofit Requirements . . . . .	55
	5.8.1	Compliance with Deficiency-Based Evaluation . . . . .	55
	5.8.2	Additional Evaluation of the Resulting Building . . . . .	56
	5.8.2.1	Building Configuration . . . . .	56
	5.8.2.2	Increased Gravity Demands to Existing Elements . . . . .	56
	5.8.2.3	Increased Seismic Demands to Existing Elements . . . . .	56
	5.8.3	Evaluation of New and Modified Structural Elements and Connections . . . . .	56
	5.8.4	Retrofit-Specific Requirements . . . . .	56
	5.8.4.1	General . . . . .	56
	5.8.4.2	Design and Detailing Requirements . . . . .	56
	5.8.4.3	Scope of Evaluation Requirements for Existing Components . . . . .	56
6		TIER 3 SYSTEMATIC EVALUATION AND RETROFIT . . . . .	57
	6.1	Scope . . . . .	57
	6.2	Data Collection Requirements . . . . .	57
	6.2.1	Construction Documentation . . . . .	57
	6.2.2	Condition Assessment . . . . .	57
	6.2.3	Material Properties . . . . .	57
	6.2.3.1	Knowledge Factor for Linear Procedures . . . . .	58
	6.2.3.2	Property Bounding for Nonlinear Procedures . . . . .	58
	6.3	Tier 3 Evaluation Requirements . . . . .	59
	6.4	Tier 3 Retrofit Requirements . . . . .	59
7		ANALYSIS PROCEDURES AND ACCEPTANCE CRITERIA . . . . .	61
	7.1	Scope . . . . .	61
	7.2	General Analysis Requirements . . . . .	61
	7.2.1	Analysis Procedures . . . . .	61
	7.2.2	Effective Seismic Weight . . . . .	61
	7.2.3	Component Gravity Loads and Load Combinations . . . . .	61
	7.2.3.1	Dead Load . . . . .	61
	7.2.3.2	Live Load . . . . .	61
	7.2.3.3	Snow Load . . . . .	61

7.2.4	Mathematical Modeling . . . . .	62
7.2.4.1	Basic Assumptions . . . . .	62
7.2.4.2	Torsion . . . . .	62
7.2.4.3	Primary and Secondary Components . . . . .	63
7.2.4.4	Stiffness and Strength Assumptions . . . . .	64
7.2.4.5	Foundation Modeling . . . . .	64
7.2.4.6	Damping . . . . .	64
7.2.5	Configuration . . . . .	64
7.2.6	Multidirectional Seismic Effects . . . . .	64
7.2.6.1	Concurrent Seismic Effects . . . . .	64
7.2.6.2	Vertical Seismic Effects . . . . .	65
7.2.7	P-delta Effects . . . . .	65
7.2.8	Soil–Structure Interaction . . . . .	65
7.2.9	Overturning . . . . .	65
7.2.9.1	Overturning Effects for Linear Procedures . . . . .	65
7.2.9.2	Overturning Effects for Nonlinear Procedures . . . . .	66
7.2.10	Sliding at the Soil–Structure Interface . . . . .	66
7.2.10.1	Foundation Interconnection . . . . .	66
7.2.11	Diaphragms, Chords, Collectors, and Ties . . . . .	66
7.2.11.1	Classification of Diaphragms . . . . .	66
7.2.11.2	Mathematical Modeling . . . . .	67
7.2.11.3	Diaphragm Chords . . . . .	67
7.2.11.4	Diaphragm Collectors . . . . .	67
7.2.11.5	Diaphragm Ties . . . . .	67
7.2.12	Continuity . . . . .	67
7.2.13	Structural Walls and Their Anchorage . . . . .	67
7.2.13.1	Out-of-Plane Wall Anchorage to Diaphragms . . . . .	67
7.2.13.2	Out-of-Plane Strength of Walls . . . . .	68
7.2.14	Structures Sharing Common Elements . . . . .	68
7.2.14.1	Interconnection . . . . .	68
7.2.14.2	Separation . . . . .	68
7.2.15	Building Separation . . . . .	68
7.2.15.1	Minimum Separation . . . . .	68
7.2.15.2	Separation Exceptions . . . . .	69
7.2.16	Verification of Analysis Assumptions . . . . .	69
7.3	Analysis Procedure Selection . . . . .	69
7.3.1	Linear Procedures . . . . .	69
7.3.1.1	Method to Determine Limitations on Use of Linear Procedures . . . . .	69
7.3.1.2	Limitations on Use of the Linear Static Procedure . . . . .	70
7.3.2	Nonlinear Procedures . . . . .	70
7.3.2.1	Nonlinear Static Procedure . . . . .	70
7.3.2.2	Nonlinear Dynamic Procedure . . . . .	71
7.3.3	Alternative Rational Analysis . . . . .	71
7.4	Analysis Procedures . . . . .	71
7.4.1	Linear Static Procedure . . . . .	71
7.4.1.1	Basis of the Procedure . . . . .	71
7.4.1.2	Period Determination for Linear Static Procedure . . . . .	71
7.4.1.3	Determination of Forces and Deformations for Linear Static Procedure . . . . .	71
7.4.1.4	Damping for Linear Static Procedure . . . . .	73
7.4.2	Linear Dynamic Procedure . . . . .	73
7.4.2.1	Basis of the Procedure . . . . .	73
7.4.2.2	Modeling and Analysis Considerations for Linear Dynamic Procedure . . . . .	73
7.4.2.3	Determination of Forces and Deformations for Linear Dynamic Procedure . . . . .	74
7.4.2.4	Damping for Linear Dynamic Procedure . . . . .	74
7.4.3	Nonlinear Static Procedure . . . . .	74
7.4.3.1	Basis of the Procedure . . . . .	74
7.4.3.2	Modeling and Analysis Considerations for Nonlinear Static Procedure . . . . .	74
7.4.3.3	Determination of Forces, Displacements, and Deformations for Nonlinear Static Procedure . . . . .	75
7.4.3.4	Damping for Nonlinear Static Procedure . . . . .	77
7.4.4	Nonlinear Dynamic Procedure . . . . .	77
7.4.4.1	Basis of the Procedure . . . . .	77
7.4.4.2	Modeling and Analysis Considerations for Nonlinear Dynamic Procedure . . . . .	77
7.4.4.3	Determination of Forces and Deformations for Nonlinear Dynamic Procedure . . . . .	78
7.4.4.4	Damping for Nonlinear Dynamic Procedure . . . . .	78

7.5	Acceptance Criteria . . . . .	79
7.5.1	General Requirements . . . . .	79
7.5.1.1	Deformation-Controlled and Force-Controlled Actions . . . . .	79
7.5.1.2	Critical and Noncritical Actions . . . . .	80
7.5.1.3	Expected and Lower-Bound Strengths . . . . .	80
7.5.1.4	Material Properties . . . . .	80
7.5.1.5	Component Capacities . . . . .	80
7.5.2	Linear Procedures . . . . .	80
7.5.2.1	Forces and Deformations . . . . .	80
7.5.2.2	Acceptance Criteria for Linear Procedures . . . . .	81
7.5.3	Nonlinear Procedures . . . . .	81
7.5.3.1	Forces and Deformations . . . . .	81
7.5.3.2	Acceptance Criteria for Nonlinear Procedures . . . . .	81
7.6	Experimentally Derived Modeling Parameters and Acceptance Criteria . . . . .	83
7.6.1	Criteria for General Use Parameters . . . . .	83
7.6.1.1	Experimental Test Data . . . . .	83
7.6.1.2	Analytical Model Data . . . . .	83
7.6.2	Criteria for Individual Project Testing . . . . .	83
7.6.2.1	Experimental Setup . . . . .	83
7.6.2.2	Data Reduction and Reporting . . . . .	83
7.6.2.3	Peer Review . . . . .	84
7.6.3	Modeling Parameters and Acceptance Criteria for Nonadaptive Force–Deformation Curves . . . . .	84
7.6.4	Modeling Parameters and Acceptance Criteria for Component Actions Based on Experimental Data for Fiber Models . . . . .	87
7.6.5	Modeling Parameters and Acceptance Criteria for Component Actions Based on Experimental Data for Adaptive Force–Deformation Models in the Mathematical Model . . . . .	87
8	FOUNDATIONS, SUBSURFACE SOIL, AND GEOLOGIC SITE HAZARDS . . . . .	89
8.1	Scope . . . . .	89
8.2	Site Characterization . . . . .	89
8.2.1	Subsurface Soil Foundation Information . . . . .	89
8.2.1.1	Subsurface Soil Conditions . . . . .	89
8.2.1.2	Foundation Conditions . . . . .	89
8.2.1.3	Load–Deformation Characteristics of Subsurface Soil under Seismic Loading . . . . .	89
8.2.1.4	Soil Shear Modulus and Poisson’s Ratio Parameters . . . . .	89
8.2.2	Seismic–Geologic Site Hazards . . . . .	90
8.2.2.1	Fault Rupture . . . . .	90
8.2.2.2	Liquefaction . . . . .	90
8.2.2.3	Settlement of Nonliquefiable Soils . . . . .	92
8.2.2.4	Landsliding . . . . .	92
8.2.2.5	Flooding or Inundation . . . . .	92
8.3	Mitigation of Seismic–Geologic Site Hazards . . . . .	92
8.4	Shallow Foundations . . . . .	92
8.4.1	Selection of Evaluation Procedures . . . . .	92
8.4.2	Expected Soil Bearing Capacities . . . . .	93
8.4.2.1	Prescriptive Expected Soil Bearing Capacities . . . . .	93
8.4.2.2	Site-Specific Capacities . . . . .	93
8.4.3	Simplified Procedure . . . . .	93
8.4.4	Fixed-Base Procedure . . . . .	93
8.4.4.1	Linear Procedures . . . . .	93
8.4.4.2	Nonlinear Procedures . . . . .	97
8.4.5	Flexible-Base Procedure . . . . .	97
8.4.5.1	Soil Stiffness . . . . .	98
8.4.5.2	Linear Procedures . . . . .	98
8.4.5.3	Nonlinear Procedures . . . . .	99
8.4.6	Shallow Foundation Lateral Load . . . . .	101
8.5	Deep Foundations . . . . .	101
8.5.1	Pile Foundations . . . . .	101
8.5.1.1	Stiffness Parameters . . . . .	102
8.5.1.2	Capacity Parameters . . . . .	102
8.5.2	Drilled Shafts . . . . .	102
8.5.3	Deep Foundation Acceptance Criteria . . . . .	102
8.5.3.1	Linear Procedures . . . . .	103
8.5.3.2	Nonlinear Procedures . . . . .	103

8.6	Soil–Structure Interaction Effects . . . . .	103
8.6.1	Kinematic Interaction . . . . .	103
8.6.1.1	Base Slab Averaging . . . . .	103
8.6.1.2	Embedment . . . . .	104
8.6.2	Foundation Damping Soil–Structure Interaction Effects . . . . .	104
8.6.2.1	Radiation Damping for Rectangular Foundations . . . . .	104
8.6.2.2	Soil Hysteretic Damping . . . . .	105
8.7	Seismic Earth Pressure . . . . .	105
8.8	Foundation Retrofit . . . . .	106
9	STEEL AND IRON . . . . .	107
9.1	Scope . . . . .	107
9.2	Reference Standard for Structural Steel, Composite Steel–Concrete, and Cast and Wrought Iron . . . . .	107
9.3	Modification to the Reference Standard for Structural Steel, Composite Steel–Concrete, and Cast and Wrought Iron . . . . .	107
9.4	Material Properties and Condition Assessment for Cold-Formed Steel . . . . .	107
9.4.1	General . . . . .	107
9.4.2	Properties of In-Place Materials and Components . . . . .	107
9.4.2.1	Material Properties . . . . .	107
9.4.2.2	Component Properties . . . . .	108
9.4.2.3	Test Methods to Quantify Mechanical Properties . . . . .	108
9.4.2.4	Minimum Number of Tests . . . . .	108
9.4.2.5	Default Mechanical Properties . . . . .	108
9.4.3	Condition Assessment . . . . .	109
9.4.3.1	General . . . . .	109
9.4.3.2	Scope and Procedures . . . . .	109
9.4.3.3	Basis for the Mathematical Building Model . . . . .	109
9.4.4	Knowledge Factor . . . . .	109
9.5	General Assumptions and Requirements for Cold-Formed Steel . . . . .	109
9.5.1	Stiffness . . . . .	109
9.5.1.1	Use of Linear Procedures for Cold-Formed Steel Light-Frame Construction . . . . .	109
9.5.1.2	Use of Nonlinear Procedures for Cold-Formed Steel Light-Frame Construction . . . . .	109
9.5.2	Strength and Acceptance Criteria . . . . .	110
9.5.2.1	General . . . . .	110
9.5.2.2	Deformation-Controlled Actions . . . . .	110
9.5.2.3	Force-Controlled Actions . . . . .	110
9.5.2.4	Anchorage to Concrete . . . . .	110
9.5.3	Connection Requirements in Cold-Formed Steel Light-Frame Construction . . . . .	110
9.5.4	Components Supporting Discontinuous Shear Walls in Cold-Formed Steel Light-Frame Construction . . . . .	110
9.5.5	Retrofit Measures . . . . .	110
9.6	Cold-Formed Steel Light-Frame Construction, Shear Wall Systems . . . . .	111
9.6.1	General . . . . .	111
9.6.2	Types of Cold-Formed Steel Light-Frame Construction, Shear Wall Systems . . . . .	111
9.6.2.1	Existing Cold-Formed Steel Light-Frame Shear Walls . . . . .	111
9.6.2.2	Enhanced Cold-Formed Steel Light-Frame Shear Walls . . . . .	111
9.6.2.3	New Cold-Formed Steel Light-Frame Shear Walls . . . . .	111
9.6.3	Stiffness, Strength, Acceptance Criteria, and Connection Design for Cold-Formed Steel Light-Frame Construction Shear Wall Systems . . . . .	111
9.6.3.1	Wood Structural Panels . . . . .	111
9.6.3.2	Steel Sheet Sheathing . . . . .	111
9.6.3.3	Gypsum Board Panel . . . . .	112
9.6.3.4	Fiberboard Panels . . . . .	114
9.6.3.5	Plaster on Metal Lath Shear Walls . . . . .	114
9.7	Cold-Formed Steel Moment-Frame Systems . . . . .	114
9.7.1	General . . . . .	114
9.7.2	Types of Cold-Formed Steel Moment-Frame Systems . . . . .	114
9.7.2.1	Existing Cold-Formed Steel Moment-Frame Systems . . . . .	114
9.7.2.2	Enhanced Cold-Formed Steel Moment-Frame Systems . . . . .	114
9.7.2.3	New Cold-Formed Steel Moment-Frame Systems . . . . .	114
9.7.3	Stiffness, Strength, Acceptance Criteria, and Connection Design for Cold-Formed Steel Moment-Frame Systems . . . . .	114
9.7.3.1	Generic Cold-Formed Steel Moment Connection . . . . .	114

	9.7.3.2	Cold-Formed Steel Special Bolted Moment Frame . . . . .	116
9.8		Cold-Formed Steel Light-Frame Construction, Strap-Braced Wall Systems . . . . .	116
	9.8.1	General . . . . .	116
	9.8.2	Types of Cold-Formed Steel Light-Frame Construction with Strap-Braced Walls . . . . .	116
	9.8.2.1	Existing Cold-Formed Steel Light-Frame Construction with Strap-Braced Walls . . . . .	116
	9.8.2.2	Cold-Formed Steel Light-Frame Construction with Enhanced Strap-Braced Walls . . . . .	116
	9.8.2.3	Cold-Formed Steel Light-Frame Construction with New Strap-Braced Walls . . . . .	116
	9.8.3	Stiffness, Strength, Acceptance Criteria, and Connection Design for Cold-Formed Steel Light-Frame Construction with Strap-Braced Walls . . . . .	117
	9.8.3.1	Stiffness . . . . .	117
	9.8.3.2	Strength. . . . .	117
	9.8.3.3	Acceptance Criteria . . . . .	117
	9.8.3.4	Connections . . . . .	117
9.9		Cold-Formed Steel Diaphragms . . . . .	117
10		CONCRETE . . . . .	119
	10.1	Scope . . . . .	119
	10.2	Reference Standard. . . . .	119
	10.3	Modifications to the Reference Standard . . . . .	119
	10.3.1	General Assumptions and Requirements . . . . .	119
	10.3.2	Concrete Structural Walls . . . . .	122
	10.3.3	Concrete Foundations . . . . .	132
	10.3.4	Notation . . . . .	134
11		MASONRY. . . . .	137
	11.1	Scope . . . . .	137
	11.2	Condition Assessment and Material Properties . . . . .	137
	11.2.1	General . . . . .	137
	11.2.2	Condition Assessment . . . . .	137
	11.2.2.1	Visual Condition Assessment . . . . .	137
	11.2.2.2	Comprehensive Condition Assessment . . . . .	138
	11.2.2.3	Supplemental Tests. . . . .	138
	11.2.2.4	Condition Enhancement . . . . .	138
	11.2.2.5	Pointing or Repointing of Unreinforced Masonry Walls . . . . .	138
	11.2.3	Properties of In-Place Materials and Components . . . . .	138
	11.2.3.1	General . . . . .	138
	11.2.3.2	Nominal or Specified Properties . . . . .	138
	11.2.3.3	Masonry Compressive Strength . . . . .	138
	11.2.3.4	Masonry Elastic Modulus in Compression . . . . .	138
	11.2.3.5	Masonry Flexural Tensile Strength . . . . .	139
	11.2.3.6	Unreinforced Masonry Shear Strength. . . . .	139
	11.2.3.7	Masonry Shear Modulus. . . . .	140
	11.2.3.8	Steel Reinforcement Yield Strength Properties . . . . .	140
	11.2.3.9	Minimum Number of Tests . . . . .	140
	11.2.3.10	Default Properties . . . . .	141
	11.2.4	Knowledge Factor . . . . .	141
11.3		Masonry Walls . . . . .	141
	11.3.1	Types of Masonry Walls. . . . .	141
	11.3.1.1	Existing Masonry Walls . . . . .	141
	11.3.1.2	New Masonry Walls . . . . .	142
	11.3.1.3	Retrofitted Masonry Walls. . . . .	142
	11.3.2	Unreinforced Masonry Walls and Wall Piers Subject to In-Plane Actions. . . . .	142
	11.3.2.1	Stiffness of URM Walls and Wall Piers Subject to In-Plane Actions . . . . .	142
	11.3.2.2	Strength of URM Walls Subject to In-Plane Actions. . . . .	142
	11.3.2.3	Acceptance Criteria for URM In-Plane Actions. . . . .	145
	11.3.3	Unreinforced Masonry Walls Subject to Out-of-Plane Actions. . . . .	145
	11.3.3.1	Stiffness of URM Walls Subject to Out-of-Plane Actions . . . . .	145
	11.3.3.2	Strength of URM Walls Subject to Out-of-Plane Actions . . . . .	146
	11.3.3.3	Acceptance Criteria for URM Walls Subject to Out-of-Plane Actions . . . . .	146
	11.3.4	Reinforced Masonry Walls and Wall Piers In-Plane Actions. . . . .	148

	11.3.4.1	Reinforced Masonry Walls and Wall Piers with Flanged Sections . . . . .	148
	11.3.4.2	In-Plane Lateral Stiffness of Reinforced Masonry Walls and Wall Piers . . . . .	148
	11.3.4.3	Flexure-Governed In-Plane Actions of Reinforced Masonry Walls and Wall Piers . . . . .	149
	11.3.4.4	Shear-Governed In-Plane Actions of Reinforced Masonry Walls and Wall Piers . . . . .	151
	11.3.4.5	Vertical Compressive Strength of Walls and Wall Piers . . . . .	151
	11.3.4.6	Acceptance Criteria for In-Plane Actions of Reinforced Masonry Walls and Wall Piers . . . . .	151
	11.3.5	Reinforced Masonry Wall Out-of-Plane Actions . . . . .	152
	11.3.5.1	Stiffness: Reinforced Masonry Wall Out-of-Plane Actions . . . . .	152
	11.3.5.2	Strength: Reinforced Masonry Wall Out-of-Plane Actions . . . . .	152
	11.3.5.3	Acceptance Criteria for Reinforced Masonry Wall Out-of-Plane Actions . . . . .	152
11.4		Masonry Infills . . . . .	152
	11.4.1	Types of Masonry Infills . . . . .	153
	11.4.1.1	Existing Masonry Infills . . . . .	153
	11.4.1.2	New Masonry Infills . . . . .	153
	11.4.1.3	Retrofitted Masonry Infills . . . . .	153
	11.4.2	Masonry Infill In-Plane Actions . . . . .	153
	11.4.2.1	Stiffness: Masonry Infill In-Plane Actions . . . . .	153
	11.4.2.2	Stiffness: Masonry Infill with Openings In-Plane Actions . . . . .	153
	11.4.2.3	Strength: Infilled Reinforced Concrete Frames In-Plane Actions . . . . .	154
	11.4.2.4	Strength: Infilled Steel Frames In-Plane Actions . . . . .	155
	11.4.2.5	Drift: Infill Wall In-Plane Actions . . . . .	155
	11.4.2.6	Strut Model for Infill In-Plane Actions . . . . .	155
	11.4.2.7	Acceptance Criteria for Infill Wall In-Plane Actions . . . . .	156
	11.4.3	Masonry Infill Wall Out-of-Plane Actions . . . . .	157
	11.4.3.1	Stiffness: Infill Wall Out-of-Plane Actions . . . . .	157
	11.4.3.2	Strength: Infill Wall Out-of-Plane Actions . . . . .	157
	11.4.3.3	Strength: Infill Wall In-Plane and Out-of-Plane Interaction . . . . .	158
	11.4.3.4	Acceptance Criteria: Infill Wall Out-of-Plane Actions . . . . .	158
11.5		Anchorage to Masonry Walls . . . . .	158
	11.5.1	Types of Anchors . . . . .	158
	11.5.2	Analysis of Anchors . . . . .	158
	11.5.3	Quality Assurance for Anchors in Masonry Walls . . . . .	158
11.6		Masonry Foundation Elements . . . . .	159
	11.6.1	Types of Masonry Foundations . . . . .	159
	11.6.2	Seismic Evaluation of Existing Masonry Foundations . . . . .	159
	11.6.3	Foundation Retrofit Measures . . . . .	159
11.7		Masonry Diaphragms . . . . .	159
	11.7.1	General . . . . .	159
	11.7.2	Seismic Evaluation of Masonry Diaphragms . . . . .	159
	11.7.3	Retrofit Measures for Masonry Diaphragms . . . . .	159
12		WOOD . . . . .	161
	12.1	Scope . . . . .	161
	12.2	Material Properties and Condition Assessment . . . . .	161
	12.2.1	General . . . . .	161
	12.2.2	Properties of In-Place Materials and Components . . . . .	161
	12.2.2.1	Material Properties . . . . .	161
	12.2.2.2	Component Properties . . . . .	161
	12.2.2.3	Test Methods to Quantify Material Properties . . . . .	162
	12.2.2.4	Minimum Number of Tests . . . . .	162
	12.2.2.5	Default Properties . . . . .	162
	12.2.3	Condition Assessment . . . . .	162
	12.2.3.1	General . . . . .	162
	12.2.3.2	Scope and Procedures for Condition Assessment . . . . .	164
	12.2.3.3	Basis for the Mathematical Building Model . . . . .	164
	12.2.4	Knowledge Factor . . . . .	164
	12.2.4.1	Wood Components and Assemblies . . . . .	164
12.3		General Assumptions and Requirements . . . . .	164
	12.3.1	Stiffness . . . . .	164
	12.3.1.1	Use of Linear Procedures . . . . .	164
	12.3.1.2	Use of Nonlinear Procedures for Wood Construction . . . . .	164
	12.3.2	Strength and Acceptance Criteria . . . . .	164
	12.3.2.1	General . . . . .	164

	12.3.2.2	Deformation-Controlled Actions . . . . .	164
	12.3.2.3	Force-Controlled Actions . . . . .	164
	12.3.3	Connection Requirements . . . . .	165
	12.3.3.1	Wood Construction. . . . .	165
	12.3.4	Components Supporting Discontinuous Shear Walls . . . . .	165
	12.3.4.1	Wood Construction. . . . .	165
	12.3.5	Retrofit Measures . . . . .	165
	12.3.5.1	Wood Construction. . . . .	165
12.4		Wood Shear Walls . . . . .	165
	12.4.1	General . . . . .	165
	12.4.2	Types of Wood Shear Walls. . . . .	165
	12.4.2.1	Existing Wood Shear Walls . . . . .	165
	12.4.2.2	Enhanced Wood Shear Walls . . . . .	166
	12.4.2.3	New Wood Shear Walls . . . . .	166
	12.4.3	Stiffness, Strength, Acceptance Criteria, and Connection Design for Wood Shear Walls . . . . .	166
	12.4.3.1	Single-Layer Horizontal Lumber Sheathing or Siding Shear Walls . . . . .	166
	12.4.3.2	Diagonal Lumber Sheathing Shear Walls . . . . .	166
	12.4.3.3	Vertical Wood Siding Shear Walls . . . . .	166
	12.4.3.4	Wood Siding Over Horizontal Lumber Sheathing Shear Walls . . . . .	170
	12.4.3.5	Wood Siding Over Diagonal Lumber Sheathing Shear Walls. . . . .	170
	12.4.3.6	Wood Structural Panel Sheathing or Siding Shear Walls. . . . .	170
	12.4.3.7	Stucco on Studs, Sheathing, or Fiberboard Shear Walls . . . . .	170
	12.4.3.8	Gypsum Plaster on Wood Lath Shear Walls . . . . .	171
	12.4.3.9	Gypsum Plaster on Gypsum Lath Shear Walls . . . . .	171
	12.4.3.10	Gypsum Wallboard Shear Walls. . . . .	171
	12.4.3.11	Gypsum Sheathing Shear Walls . . . . .	171
	12.4.3.12	Plaster on Metal Lath Shear Walls . . . . .	171
	12.4.3.13	Horizontal Lumber Sheathing with Cut-In Braces or Diagonal Blocking Shear Walls . . . . .	172
	12.4.3.14	Fiberboard or Particleboard Sheathing Shear Walls. . . . .	172
12.5		Wood Diaphragms . . . . .	172
	12.5.1	General . . . . .	172
	12.5.2	Types of Wood Diaphragms. . . . .	172
	12.5.2.1	Existing Wood Diaphragms . . . . .	172
	12.5.2.2	Enhanced Wood Diaphragms . . . . .	173
	12.5.2.3	New Wood Diaphragms . . . . .	173
	12.5.3	Stiffness, Strength, Acceptance Criteria, and Connection Design for Wood Diaphragms . . . . .	173
	12.5.3.1	Single-Layer Straight Lumber Sheathing Diaphragms . . . . .	173
	12.5.3.2	Double-Layer Straight Lumber Sheathing Diaphragms . . . . .	173
	12.5.3.3	Single-Layer Diagonal Lumber Sheathing Diaphragms. . . . .	173
	12.5.3.4	Diagonal Lumber Sheathing with Straight Lumber Sheathing or Flooring above Diaphragms. . . . .	174
	12.5.3.5	Double-Layer Diagonal Lumber Sheathing Diaphragms . . . . .	174
	12.5.3.6	Wood Structural Panel Sheathing Diaphragm. . . . .	174
	12.5.3.7	Wood Structural Panel Overlays on Straight or Diagonal Lumber Sheathing Diaphragms. . . . .	175
	12.5.3.8	Wood Structural Panel Overlays on Existing Wood Structural Panel Sheathing Diaphragms. . . . .	175
	12.5.3.9	Braced Horizontal Diaphragms . . . . .	175
12.6		Wood Foundations . . . . .	175
	12.6.1	Types of Wood Foundations. . . . .	175
	12.6.2	Analysis, Strength, and Acceptance Criteria for Wood Foundations. . . . .	175
	12.6.3	Retrofit Measures for Wood Foundations . . . . .	175
12.7		Other Wood Elements and Components. . . . .	175
	12.7.1	General . . . . .	175
	12.7.1.1	Stiffness of Other Wood Elements and Components . . . . .	176
	12.7.1.2	Strength of Other Wood Elements and Components . . . . .	176
	12.7.1.3	Acceptance Criteria for Other Wood Elements and Components. . . . .	176
13		ARCHITECTURAL, MECHANICAL, AND ELECTRICAL COMPONENTS . . . . .	177
	13.1	Scope . . . . .	177
	13.2	Evaluation and Retrofit Procedure for Nonstructural Components . . . . .	177
	13.2.1	Classification of Components . . . . .	177
	13.3	Component Condition Assessment and Anchorage Testing . . . . .	179

13.3.1	Condition Assessment . . . . .	179
13.3.2	Testing Requirements for Evaluating the Performance of Existing Anchorage for Nonstructural Components . . . . .	180
13.3.2.1	Components Evaluated to the Operational Performance Level . . . . .	180
13.3.2.2	Components Evaluated to the Position Retention or Life Safety Performance Level . . . . .	180
13.3.2.3	Tension Testing Procedure . . . . .	181
13.3.2.4	Torque Testing Procedure . . . . .	181
13.3.2.5	Alternate Test Criteria . . . . .	181
13.3.2.6	Shear Capacity of Existing Anchors . . . . .	181
13.4	Evaluation Procedures . . . . .	181
13.4.1	Acceptance Criteria . . . . .	181
13.4.2	Analytical Procedure . . . . .	181
13.4.3	Prescriptive Procedure . . . . .	182
13.4.4	Force Analysis: General Equations . . . . .	182
13.4.4.1	Horizontal Seismic Forces . . . . .	182
13.4.4.2	Vertical Seismic Forces . . . . .	182
13.4.4.3	Load Combinations . . . . .	182
13.4.4.4	Nonstructural Support Capacity . . . . .	182
13.4.5	Deformation Analysis . . . . .	185
13.4.6	Component Testing . . . . .	185
13.4.7	Overturning Evaluation . . . . .	185
13.5	Retrofit Approaches . . . . .	185
13.6	Architectural Components: Definition, Behavior, and Acceptance Criteria. . . . .	185
13.6.1	Exterior Wall Components. . . . .	185
13.6.1.1	Adhered Veneer . . . . .	185
13.6.1.2	Anchored Veneer. . . . .	186
13.6.1.3	Glass Block Units and Other Nonstructural Masonry. . . . .	186
13.6.1.4	Prefabricated Panels . . . . .	187
13.6.1.5	Glazed Exterior Wall Systems. . . . .	187
13.6.2	Partitions . . . . .	188
13.6.2.1	Definition and Scope. . . . .	188
13.6.2.2	Component Behavior and Retrofit Methods. . . . .	188
13.6.2.3	Acceptance Criteria . . . . .	188
13.6.2.4	Evaluation Requirements. . . . .	189
13.6.3	Interior Veneers . . . . .	189
13.6.3.1	Definition and Scope. . . . .	189
13.6.3.2	Component Behavior and Retrofit Methods. . . . .	189
13.6.3.3	Acceptance Criteria . . . . .	189
13.6.3.4	Evaluation Requirements. . . . .	189
13.6.4	Ceilings. . . . .	189
13.6.4.1	Definition and Scope. . . . .	189
13.6.4.2	Component Behavior and Retrofit Methods. . . . .	189
13.6.4.3	Acceptance Criteria . . . . .	189
13.6.4.4	Evaluation Requirements. . . . .	189
13.6.5	Parapets and Cornices . . . . .	189
13.6.5.1	Definition and Scope. . . . .	189
13.6.5.2	Component Behavior and Retrofit Methods. . . . .	190
13.6.5.3	Acceptance Criteria . . . . .	190
13.6.5.4	Evaluation Requirements. . . . .	190
13.6.6	Architectural Appendages and Marquees . . . . .	190
13.6.6.1	Definition and Scope. . . . .	190
13.6.6.2	Component Behavior and Retrofit Methods. . . . .	190
13.6.6.3	Acceptance Criteria . . . . .	190
13.6.6.4	Evaluation Requirements. . . . .	190
13.6.7	Penthouses . . . . .	190
13.6.7.1	Definition and Scope. . . . .	190
13.6.7.2	Component Behavior and Retrofit Methods. . . . .	190
13.6.7.3	Acceptance Criteria . . . . .	190
13.6.8	Tile Roofs . . . . .	190
13.6.8.1	Definition and Scope. . . . .	190
13.6.8.2	Component Behavior and Retrofit Methods. . . . .	191
13.6.8.3	Acceptance Criteria . . . . .	191
13.6.9	Chimneys and Stacks . . . . .	191
13.6.9.1	Definition and Scope. . . . .	191

	13.6.9.2	Component Behavior and Retrofit Methods. . . . .	191
	13.6.9.3	Acceptance Criteria . . . . .	191
	13.6.9.4	Evaluation Requirements. . . . .	191
13.6.10		Stairs and Ramps. . . . .	191
	13.6.10.1	Definition and Scope. . . . .	191
	13.6.10.2	Component Behavior and Retrofit Methods. . . . .	191
	13.6.10.3	Acceptance Criteria . . . . .	191
	13.6.10.4	Evaluation Requirements. . . . .	192
13.6.11		Doors Required for Emergency Services Egress in Essential Facilities . . . . .	192
	13.6.11.1	Definition and Scope. . . . .	192
	13.6.11.2	Component Behavior and Retrofit Methods. . . . .	192
	13.6.11.3	Acceptance Criteria . . . . .	192
	13.6.11.4	Evaluation Requirements. . . . .	192
13.6.12		Computer Access Floors . . . . .	192
	13.6.12.1	Definition and Scope. . . . .	192
	13.6.12.2	Component Behavior and Retrofit Methods. . . . .	192
	13.6.12.3	Acceptance Criteria . . . . .	192
	13.6.12.4	Evaluation Requirements. . . . .	192
13.7		Mechanical, Electrical, and Plumbing Components: Definition, Behavior, and Acceptance Criteria . . . . .	192
	13.7.1	Mechanical Equipment. . . . .	192
	13.7.1.1	Definition and Scope. . . . .	192
	13.7.1.2	Component Behavior and Retrofit Methods. . . . .	193
	13.7.1.3	Acceptance Criteria . . . . .	193
	13.7.1.4	Evaluation Requirements. . . . .	193
13.7.2		Storage Vessels and Water Heaters . . . . .	193
	13.7.2.1	Definition and Scope. . . . .	193
	13.7.2.2	Component Behavior and Retrofit Methods. . . . .	193
	13.7.2.3	Acceptance Criteria . . . . .	193
	13.7.2.4	Evaluation Requirements. . . . .	194
13.7.3		Pressure Piping. . . . .	194
	13.7.3.1	Definition and Scope. . . . .	194
	13.7.3.2	Component Behavior and Retrofit Methods. . . . .	194
	13.7.3.3	Acceptance Criteria . . . . .	194
	13.7.3.4	Evaluation Requirements. . . . .	194
13.7.4		Fire Suppression Piping . . . . .	194
	13.7.4.1	Definition and Scope. . . . .	194
	13.7.4.2	Component Behavior and Retrofit Methods. . . . .	194
	13.7.4.3	Acceptance Criteria . . . . .	194
	13.7.4.4	Evaluation Requirements. . . . .	194
13.7.5		Fluid Piping Other than Fire Suppression. . . . .	194
	13.7.5.1	Definition and Scope. . . . .	194
	13.7.5.2	Component Behavior and Retrofit Methods. . . . .	195
	13.7.5.3	Acceptance Criteria . . . . .	195
	13.7.5.4	Evaluation Requirements. . . . .	195
13.7.6		Ductwork. . . . .	195
	13.7.6.1	Definition and Scope. . . . .	195
	13.7.6.2	Component Behavior and Retrofit Methods. . . . .	195
	13.7.6.3	Acceptance Criteria . . . . .	195
	13.7.6.4	Evaluation Requirements. . . . .	195
13.7.7		Electrical and Communications Equipment . . . . .	196
	13.7.7.1	Definition and Scope. . . . .	196
	13.7.7.2	Component Behavior and Retrofit Methods. . . . .	196
	13.7.7.3	Acceptance Criteria . . . . .	196
	13.7.7.4	Evaluation Requirements. . . . .	196
13.7.8		Electrical and Communications Distribution Components . . . . .	196
	13.7.8.1	Definition and Scope. . . . .	196
	13.7.8.2	Component Behavior and Retrofit Methods. . . . .	196
	13.7.8.3	Acceptance Criteria . . . . .	196
	13.7.8.4	Evaluation Requirements. . . . .	197
13.7.9		Light Fixtures . . . . .	197
	13.7.9.1	Definition and Scope. . . . .	197
	13.7.9.2	Component Behavior and Retrofit Methods. . . . .	197
	13.7.9.3	Acceptance Criteria . . . . .	197
	13.7.9.4	Evaluation Requirements. . . . .	197
13.7.10		Rooftop Solar Photovoltaic Arrays . . . . .	197

	13.7.10.1	Definition and Scope . . . . .	197
	13.7.10.2	Component Behavior and Retrofit Methods . . . . .	197
	13.7.10.3	Acceptance Criteria . . . . .	197
	13.7.10.4	Evaluation Requirements . . . . .	197
13.7.11	Elevators . . . . .		198
	13.7.11.1	Definition and Scope . . . . .	198
	13.7.11.2	Component Behavior and Retrofit Methods . . . . .	198
	13.7.11.3	Acceptance Criteria . . . . .	198
	13.7.11.4	Evaluation Requirements . . . . .	198
13.7.12	Conveyors . . . . .		198
	13.7.12.1	Definition and Scope . . . . .	198
	13.7.12.2	Component Behavior and Retrofit Methods . . . . .	198
	13.7.12.3	Acceptance Criteria . . . . .	198
	13.7.12.4	Evaluation Requirements . . . . .	198
13.8	Furnishings and Contents: Definition, Behavior, and Acceptance Criteria . . . . .		198
13.8.1	Steel Storage Racks . . . . .		198
	13.8.1.1	Definition and Scope . . . . .	198
	13.8.1.2	Component Behavior and Retrofit Methods . . . . .	198
	13.8.1.3	Acceptance Criteria . . . . .	198
	13.8.1.4	Evaluation Requirements . . . . .	199
13.8.2	Contents . . . . .		199
	13.8.2.1	Definition and Scope . . . . .	199
	13.8.2.2	Component Behavior and Retrofit Methods . . . . .	199
	13.8.2.3	Acceptance Criteria . . . . .	199
	13.8.2.4	Evaluation Requirements . . . . .	199
13.8.3	Hazardous Material Storage . . . . .		199
	13.8.3.1	Definition and Scope . . . . .	199
	13.8.3.2	Component Behavior and Retrofit Methods . . . . .	199
	13.8.3.3	Acceptance Criteria . . . . .	199
	13.8.3.4	Evaluation Requirements . . . . .	199
13.8.4	Computer and Communication Racks . . . . .		199
	13.8.4.1	Definition and Scope . . . . .	199
	13.8.4.2	Component Behavior and Retrofit Methods . . . . .	199
	13.8.4.3	Acceptance Criteria . . . . .	199
	13.8.4.4	Evaluation Requirements . . . . .	200
14	SEISMIC ISOLATION . . . . .		201
14.1	Scope . . . . .		201
14.2	General Requirements . . . . .		201
14.2.1	General . . . . .		201
14.2.2	Seismic Hazard . . . . .		201
	14.2.2.1	Ground Motion Acceleration Histories . . . . .	201
14.2.3	Isolation System . . . . .		201
	14.2.3.1	Environmental Conditions . . . . .	201
	14.2.3.2	Wind Displacement . . . . .	201
	14.2.3.3	Fire Resistance . . . . .	201
	14.2.3.4	Lateral Restoring Force . . . . .	201
	14.2.3.5	Displacement Restraint . . . . .	201
	14.2.3.6	Vertical Load Stability . . . . .	202
	14.2.3.7	Overturning . . . . .	202
	14.2.3.8	Inspection and Replacement . . . . .	202
14.2.4	Structural System . . . . .		202
	14.2.4.1	Horizontal Distribution of Force . . . . .	202
	14.2.4.2	Minimum Separations . . . . .	202
14.2.5	Elements of Structures and Nonstructural Components . . . . .		202
	14.2.5.1	General . . . . .	202
	14.2.5.2	Components at or above the Isolation Interface . . . . .	202
	14.2.5.3	Components Crossing the Isolation Interface . . . . .	202
	14.2.5.4	Components below the Isolation Interface . . . . .	202
14.2.6	Seismic Load Effects and Load Combinations . . . . .		202
	14.2.6.1	General . . . . .	202
	14.2.6.2	Isolation System Device Vertical Load Combinations . . . . .	203
14.3	Seismic Isolation System Device Properties . . . . .		203
14.3.1	Isolation System Device Types . . . . .		203

14.3.2	Nominal Design Properties of Isolation System Devices . . . . .	203
14.3.3	Bounding Properties of Isolation System Devices . . . . .	203
14.3.3.1	Specification Tolerance on Design Properties . . . . .	203
14.3.3.2	Testing Variations on Design Properties . . . . .	203
14.3.3.3	Aging and Environmental Effects on Design Properties . . . . .	203
14.3.4	Property Modification Factors . . . . .	203
14.3.5	Upper- and Lower-Bound Properties . . . . .	203
14.4	Modeling . . . . .	204
14.4.1	Isolation System Device Modeling . . . . .	204
14.4.1.1	Upper-Bound and Lower-Bound Force–Deflection Behavior of Isolation System Devices . . . . .	204
14.4.1.2	Isolation System Properties . . . . .	204
14.4.1.3	Isolation System Models for Linear Procedures . . . . .	204
14.4.1.4	Isolation System Device Models for Nonlinear Procedures . . . . .	204
14.4.2	Isolation System and Superstructure Modeling . . . . .	204
14.4.2.1	General . . . . .	204
14.4.2.2	Isolation System Model . . . . .	204
14.4.2.3	Superstructure Model . . . . .	204
14.5	Analysis Procedures . . . . .	204
14.5.1	Selection of Analysis Procedure . . . . .	204
14.5.1.1	Linear Static Procedure . . . . .	205
14.5.1.2	Linear Dynamic Procedure . . . . .	205
14.5.1.3	Nonlinear Static Procedure . . . . .	205
14.5.1.4	Nonlinear Dynamic Procedure . . . . .	205
14.5.1.5	Design Forces and Deformations . . . . .	205
14.5.2	Linear Static Procedure . . . . .	205
14.5.2.1	General . . . . .	205
14.5.2.2	Minimum Lateral Displacements . . . . .	205
14.5.2.3	Minimum Lateral Forces . . . . .	206
14.5.2.4	Vertical Distribution of Force . . . . .	206
14.5.2.5	Design Forces and Deformations . . . . .	207
14.5.3	Linear Dynamic Procedure . . . . .	207
14.5.3.1	General . . . . .	207
14.5.3.2	Response Spectrum Method . . . . .	207
14.5.3.3	Isolation System and Structural Elements at or below the Base Level . . . . .	207
14.5.3.4	Structural Elements above the Base Level . . . . .	207
14.5.3.5	Scaling of Results . . . . .	207
14.5.3.6	Design Forces and Deformations . . . . .	207
14.5.4	Nonlinear Static Procedure . . . . .	207
14.5.4.1	General . . . . .	207
14.5.4.2	Target Displacement . . . . .	207
14.5.4.3	Seismic Force Pattern . . . . .	208
14.5.4.4	Design Forces and Deformations . . . . .	208
14.5.5	Nonlinear Dynamic Procedure . . . . .	208
14.5.5.1	General . . . . .	208
14.5.5.2	Accidental Mass Eccentricity . . . . .	208
14.5.5.3	Isolation System and Structural Elements at or below the Base Level . . . . .	208
14.5.5.4	Structural Elements above the Base Level . . . . .	208
14.5.5.5	Scaling of Results . . . . .	208
14.5.5.6	Design Forces and Deformations . . . . .	208
14.6	Isolation System Testing and Design Properties . . . . .	208
14.6.1	General . . . . .	208
14.6.2	Qualification Tests . . . . .	208
14.6.3	Prototype Tests . . . . .	208
14.6.3.1	General . . . . .	208
14.6.3.2	Record . . . . .	208
14.6.3.3	Sequence and Cycles . . . . .	208
14.6.3.4	Vertical-Load-Carrying Isolation System Devices . . . . .	209
14.6.3.5	Dynamic Testing . . . . .	209
14.6.3.6	Isolation System Devices Dependent on Bilateral Load . . . . .	209
14.6.3.7	Maximum and Minimum Vertical Load . . . . .	209
14.6.3.8	Sacrificial Wind-Restraint Systems . . . . .	209
14.6.3.9	Testing Similar Isolation System Devices . . . . .	209
14.6.4	Production Testing . . . . .	210
14.6.5	Determination of Force–Deflection Characteristics . . . . .	210

14.6.6	Test Specimen Adequacy . . . . .	210
14.7	Design Review . . . . .	211
15	DESIGN REQUIREMENTS FOR STRUCTURES WITH SUPPLEMENTAL ENERGY DISSIPATION . . . . .	213
15.1	Scope . . . . .	213
15.2	General Design Requirements . . . . .	213
15.2.1	General Requirements . . . . .	213
15.2.2	Seismic Hazard. . . . .	213
15.2.2.1	Ground Motion Acceleration Histories . . . . .	213
15.2.3	Damping Device Requirements . . . . .	213
15.2.3.1	Device Classification . . . . .	213
15.2.3.2	Multiaxis Movement . . . . .	213
15.2.3.3	Inspection and Periodic Testing . . . . .	213
15.2.3.4	Performance Objectives and System Redundancy. . . . .	214
15.3	Properties of Energy Dissipation Devices . . . . .	214
15.3.1	Nominal Design Properties . . . . .	214
15.3.2	Maximum and Minimum Damper Properties . . . . .	214
15.4	Analysis Procedure Selection . . . . .	214
15.4.1	General Limitations for the Linear Analysis Procedures . . . . .	214
15.5	Nonlinear Dynamic Procedures . . . . .	215
15.5.1	General Requirements . . . . .	215
15.5.2	Modeling of Energy Dissipation Devices . . . . .	215
15.5.2.1	Displacement-Dependent Devices . . . . .	215
15.5.2.2	Velocity-Dependent Devices. . . . .	215
15.5.2.3	Other Types of Devices . . . . .	216
15.5.3	Accidental Eccentricity. . . . .	216
15.6	Detailed System Requirements. . . . .	216
15.6.1	General . . . . .	216
15.6.2	Wind Forces . . . . .	216
15.6.3	Inspection and Replacement . . . . .	216
15.6.4	Maintenance . . . . .	216
15.7	Design Review . . . . .	216
15.8	Required Tests of Energy Dissipation Devices . . . . .	216
15.8.1	Prototype Tests. . . . .	216
15.8.1.1	General . . . . .	216
15.8.1.2	Sequence and Cycles of Testing. . . . .	216
15.8.1.3	Testing Similar Devices . . . . .	217
15.8.1.4	Determination of Force–Velocity–Displacement Characteristics . . . . .	217
15.8.1.5	Device Adequacy . . . . .	218
15.8.2	Production Tests . . . . .	218
15.9	Linear Analysis Procedures . . . . .	218
15.9.1	Modeling of Energy Dissipation Devices . . . . .	218
15.9.1.1	Displacement-Dependent Devices . . . . .	218
15.9.1.2	Velocity-Dependent Devices. . . . .	218
15.9.2	Linear Static Procedure . . . . .	219
15.9.2.1	Displacement-Dependent Devices . . . . .	219
15.9.2.2	Velocity-Dependent Devices. . . . .	219
15.9.2.3	Design Actions . . . . .	220
15.9.2.4	Linear Dynamic Procedure. . . . .	220
15.9.2.5	Displacement-Dependent Devices . . . . .	220
15.9.2.6	Velocity-Dependent Devices. . . . .	220
15.10	Nonlinear Static Procedure. . . . .	221
15.10.1	Displacement-Dependent Devices . . . . .	221
15.10.2	Velocity-Dependent Devices. . . . .	221
16	SYSTEM-SPECIFIC PERFORMANCE PROCEDURES. . . . .	223
16.1	Scope . . . . .	223
16.2	Special Procedure for Unreinforced Masonry . . . . .	223
16.2.1	Scope . . . . .	223
16.2.2	Condition of Existing Materials . . . . .	223
16.2.2.1	Layup of Walls. . . . .	223
16.2.2.2	Testing . . . . .	224
16.2.2.3	Masonry Strength . . . . .	225

16.2.3	Analysis . . . . .	225
	16.2.3.1 Cross Walls. . . . .	225
	16.2.3.2 Diaphragms. . . . .	226
	16.2.3.3 Shear Walls. . . . .	228
	16.2.3.4 Buildings with Open Fronts . . . . .	228
	16.2.3.5 New Vertical Elements. . . . .	228
16.2.4	Other Components and Systems of Unreinforced Masonry Buildings . . . . .	229
	16.2.4.1 References to Applicable Sections. . . . .	229
	16.2.4.2 Out-of-Plane Demands . . . . .	229
	16.2.4.3 Wall Anchorage . . . . .	230
	16.2.4.4 Truss and Beam Supports . . . . .	230
16.2.5	Detailing for New Elements . . . . .	230
17	TIER 1 CHECKLISTS . . . . .	231
17.1	Basic Checklists . . . . .	231
	17.1.1 Very Low Seismicity Checklist . . . . .	231
	17.1.2 Basic Configuration Checklist . . . . .	231
17.2	Structural Checklists for Building Types W1: Wood Light Frames, Small Residential . . . . .	231
17.3	Structural Checklists for Building Type W2: Wood Frames, Large Residential, Commercial, Industrial, and Institutional. . . . .	231
17.4	Structural Checklists for Building Types S1: Steel Moment Frames with Stiff Diaphragms, and S1A: Steel Moment Frames with Flexible Diaphragms . . . . .	239
17.5	Structural Checklist for Building Types S2: Steel Braced Frames with Stiff Diaphragms, and S2A: Steel Braced Frames with Flexible Diaphragms. . . . .	242
17.6	Structural Checklists for Building Type S3: Metal Building Frames. . . . .	245
17.7	Structural Checklists for Building Type S4: Dual Systems with Backup Steel Moment Frames and Stiff Diaphragms. . . . .	247
17.8	Structural Checklists for Building Types S5: Steel Frames with Infill Masonry Shear Walls and Stiff Diaphragms, and S5A: Steel Frames with Infill Masonry Shear Walls and Flexible Diaphragms . . . . .	247
17.9	Structural Checklists for Building Type CFS1: Cold-Formed Steel Light-Frame Bearing Wall Construction, Shear Wall Lateral System. . . . .	255
17.10	Structural Checklists for Building Type CFS2: Cold-Formed Steel Light-Frame Bearing Wall Construction, Strap-Braced Lateral Wall System. . . . .	255
17.11	Structural Checklists for Building Type C1: Concrete Moment Frames . . . . .	260
17.12	Structural Checklist for Building Types C2: Concrete Shear Walls with Stiff Diaphragms, and C2A: Concrete Shear Walls with Flexible Diaphragms . . . . .	260
17.13	Structural Checklists for Building Types C3: Concrete Frames with Infill Masonry Shear Walls, and C3A: Concrete Frames with Infill Masonry Shear Walls and Flexible Diaphragms . . . . .	260
17.14	Structural Checklists for Building Types PC1: Precast or Tilt-up Concrete Shear Walls with Flexible Diaphragms, and PC1a: Precast or Tilt-up Concrete Shear Walls with Stiff Diaphragms . . . . .	270
17.15	Structural Checklists for Building Type PC2: Precast Concrete Frames with Shear Walls . . . . .	274
17.16	Structural Checklists for Building Type PC2a: Precast Concrete Frames without Shear Walls . . . . .	277
17.17	Structural Checklists for Building Types RM1: Reinforced Masonry Bearing Walls with Flexible Diaphragms, and RM2: Reinforced Masonry Bearing Walls with Stiff Diaphragms . . . . .	277
17.18	Structural Checklists for Building Types URM: Unreinforced Masonry Bearing Walls with Flexible Diaphragms, and URMA: Unreinforced Masonry Bearing Walls with Stiff Diaphragms . . . . .	283
17.19	Nonstructural Checklist . . . . .	287
18	REFERENCE DOCUMENTS . . . . .	295
18.1	Consensus Standards and other Reference Documents . . . . .	295
APPENDIX A GUIDELINES FOR DEFICIENCY-BASED PROCEDURES . . . . .		299
A.1	General . . . . .	299
A.2	Procedures for Building Systems . . . . .	300
	A.2.1 General . . . . .	300
	A.2.1.1 Load Path. . . . .	300
	A.2.1.2 Adjacent Buildings. . . . .	300
	A.2.1.3 Mezzanines . . . . .	301
	A.2.2 Configuration. . . . .	301
	A.2.2.1 General . . . . .	301
	A.2.2.2 Weak Story. . . . .	301
	A.2.2.3 Soft Story. . . . .	302
	A.2.2.4 Vertical Irregularities. . . . .	302

	A.2.2.5	Geometry . . . . .	303
	A.2.2.6	Mass . . . . .	303
	A.2.2.7	Torsion . . . . .	303
A.3		Procedures for Seismic-Force-Resisting Systems . . . . .	304
	A.3.1	Moment Frames . . . . .	304
	A.3.1.1	General . . . . .	305
	A.3.1.2	Moment Frames with Infill Walls . . . . .	305
	A.3.1.3	Steel Moment Frames . . . . .	305
	A.3.1.4	Concrete Moment Frames . . . . .	307
	A.3.1.5	Precast Concrete Moment Frames . . . . .	309
	A.3.1.6	Frames Not Part of the Seismic-Force-Resisting System . . . . .	310
	A.3.2	Shear Walls . . . . .	310
	A.3.2.1	General . . . . .	310
	A.3.2.2	Concrete Shear Walls . . . . .	311
	A.3.2.3	Precast Concrete Shear Walls . . . . .	313
	A.3.2.4	Reinforced Masonry Shear Walls . . . . .	313
	A.3.2.5	Unreinforced Masonry Shear Walls . . . . .	314
	A.3.2.6	Infill Walls in Frames . . . . .	314
	A.3.2.7	Walls in Wood-Frame Buildings . . . . .	315
	A.3.2.8	Cold-Formed Steel Light-Frame Construction, Shear Wall Systems . . . . .	316
	A.3.3	Braced Frames . . . . .	318
	A.3.3.1	General . . . . .	318
	A.3.3.2	Centrally Braced Frames . . . . .	319
	A.3.3.3	Eccentrically Braced Frames . . . . .	321
A.4		Procedures for Diaphragms . . . . .	321
	A.4.1	General . . . . .	321
	A.4.1.1	Diaphragm Continuity . . . . .	323
	A.4.1.2	Crossties . . . . .	323
	A.4.1.3	Roof Chord Continuity . . . . .	323
	A.4.1.4	Openings at Shear Walls . . . . .	324
	A.4.1.5	Openings at Frames . . . . .	324
	A.4.1.6	Openings at Exterior Masonry Shear Walls . . . . .	324
	A.4.1.7	Plan Irregularities . . . . .	324
	A.4.1.8	Diaphragm Reinforcement at Openings . . . . .	324
	A.4.2	Wood Diaphragms . . . . .	325
	A.4.2.1	Straight Sheathing . . . . .	325
	A.4.2.2	Diagonally Sheathed and Unblocked Diaphragms . . . . .	325
	A.4.2.3	Blocked Diaphragms . . . . .	325
	A.4.2.4	Cantilevered Wood Diaphragms . . . . .	326
	A.4.3	Metal Deck Diaphragms . . . . .	326
	A.4.3.1	Non-Concrete-Filled Diaphragms . . . . .	326
	A.4.4	Concrete Diaphragms . . . . .	326
	A.4.5	Precast Concrete Diaphragms . . . . .	326
	A.4.5.1	Topping Slab . . . . .	326
	A.4.6	Horizontal Bracing . . . . .	327
	A.4.7	Other Diaphragms . . . . .	327
	A.4.7.1	Other Diaphragms . . . . .	327
A.5		Procedures for Connections . . . . .	327
	A.5.1	Anchorage for Normal Forces . . . . .	327
	A.5.1.1	Wall Anchorage . . . . .	327
	A.5.1.2	Wood Ledgers . . . . .	327
	A.5.1.3	Minimum Number of Wall Anchors Per Panel . . . . .	328
	A.5.1.4	Stiffness of Wall Anchors . . . . .	328
	A.5.2	Shear Transfer . . . . .	328
	A.5.2.1	Transfer to Shear Walls or Concrete and Infill Walls . . . . .	328
	A.5.2.2	Transfer to Steel Frames . . . . .	328
	A.5.2.3	Topping Slab to Walls or Frames . . . . .	328
	A.5.3	Vertical Components . . . . .	328
	A.5.3.1	Steel Columns . . . . .	329
	A.5.3.2	Concrete Columns . . . . .	329
	A.5.3.3	Wood or Cold-Formed Steel Posts . . . . .	329
	A.5.3.4	Wood Sills and Cold-Formed Steel Base Tracks . . . . .	329
	A.5.3.5	Foundation Dowels . . . . .	330
	A.5.3.6	Precast Wall Panels . . . . .	330
	A.5.3.7	Wood Sill and Cold-Formed Steel Base Track Bolts . . . . .	330

	A.5.3.8	Uplift at Pile Caps . . . . .	330
A.5.4		Interconnection of Elements . . . . .	330
	A.5.4.1	Girder–Column Connection . . . . .	330
	A.5.4.2	Girders . . . . .	330
	A.5.4.3	Corbel Bearing . . . . .	331
	A.5.4.4	Corbel Connections . . . . .	331
	A.5.4.5	Beam, Girder, and Truss Supports. . . . .	331
A.5.5		Panel Connections . . . . .	331
	A.5.5.1	Roof Panels . . . . .	331
	A.5.5.2	Wall Panels. . . . .	331
A.6		Procedures for Geologic Site Hazards and Foundations . . . . .	331
	A.6.1	Geologic Site Hazards . . . . .	331
		A.6.1.1 Liquefaction . . . . .	331
		A.6.1.2 Slope Failure . . . . .	331
		A.6.1.3 Surface Fault Rupture . . . . .	332
		A.6.1.4 Tsunami . . . . .	332
	A.6.2	Foundation Configuration . . . . .	332
		A.6.2.1 Overturning. . . . .	332
		A.6.2.2 Ties between Foundation Elements . . . . .	332
		A.6.2.3 Deep Foundations . . . . .	332
		A.6.2.4 Sloping Sites . . . . .	333
A.7		Procedures for Nonstructural Components . . . . .	334
	A.7.1	Partitions . . . . .	334
		A.7.1.1 Unreinforced Masonry . . . . .	334
		A.7.1.2 Drift . . . . .	334
		A.7.1.3 Structural Separations . . . . .	334
		A.7.1.4 Tops . . . . .	334
	A.7.2	Ceiling Systems . . . . .	334
		A.7.2.1 Heavy or Light Partitions Supported by Ceilings. . . . .	334
		A.7.2.2 Integrated Ceilings . . . . .	334
		A.7.2.3 Suspended Lath and Plaster or Gypsum Board . . . . .	335
		A.7.2.4 Edge Clearance. . . . .	335
		A.7.2.5 Continuity across Structure . . . . .	335
		A.7.2.6 Edge Support. . . . .	335
		A.7.2.7 Seismic Joints . . . . .	335
	A.7.3	Light Fixtures . . . . .	335
		A.7.3.1 Emergency Lighting . . . . .	335
		A.7.3.2 Independent Support . . . . .	335
		A.7.3.3 Pendant Supports. . . . .	335
		A.7.3.4 Lens Covers . . . . .	335
	A.7.4	Cladding and Glazing . . . . .	336
		A.7.4.1 Cladding Anchors . . . . .	336
		A.7.4.2 Cladding Isolation . . . . .	336
		A.7.4.3 Multistory Panels. . . . .	336
		A.7.4.4 Panel Connections . . . . .	336
		A.7.4.5 Bearing Connections . . . . .	336
		A.7.4.6 Inserts. . . . .	336
		A.7.4.7 Overhead Glazing . . . . .	336
		A.7.4.8 Threaded Rods . . . . .	336
	A.7.5	Masonry Veneer . . . . .	336
		A.7.5.1 Ties . . . . .	336
		A.7.5.2 Shelf Angles . . . . .	336
		A.7.5.3 Weakened Planes. . . . .	337
		A.7.5.4 Weep Holes . . . . .	337
	A.7.6	Metal Stud Backup Systems. . . . .	337
		A.7.6.1 Stud Tracks. . . . .	337
		A.7.6.2 Openings . . . . .	337
	A.7.7	Concrete Block and Masonry Backup Systems . . . . .	337
		A.7.7.1 Anchorage . . . . .	337
		A.7.7.2 Unreinforced Masonry Backup . . . . .	337
	A.7.8	Parapets, Cornices, Ornamentation, and Appendages . . . . .	337
		A.7.8.1 Unreinforced Masonry Parapets or Cornices . . . . .	337
		A.7.8.2 Canopies . . . . .	337
		A.7.8.3 Concrete Parapets . . . . .	337
		A.7.8.4 Appendages . . . . .	337

	A.7.8.5	Penthouses . . . . .	337
	A.7.8.6	Tile Roofs . . . . .	338
A.7.9	Masonry Chimneys . . . . .	338	
	A.7.9.1	Unreinforced Masonry Chimneys . . . . .	338
	A.7.9.2	Anchorage . . . . .	338
A.7.10	Stairs . . . . .	338	
	A.7.10.1	Stair Enclosures . . . . .	338
	A.7.10.2	Stair Details . . . . .	338
A.7.11	Building Contents and Furnishing . . . . .	338	
	A.7.11.1	Industrial Storage Racks . . . . .	338
	A.7.11.2	Tall Narrow Contents . . . . .	338
	A.7.11.3	Fall-Prone Contents . . . . .	338
	A.7.11.4	Access Floors . . . . .	338
	A.7.11.5	Equipment on Access Floors . . . . .	339
	A.7.11.6	Suspended Contents . . . . .	339
A.7.12	Mechanical and Electrical Equipment . . . . .	339	
	A.7.12.1	Emergency Power . . . . .	339
	A.7.12.2	Hazardous Material Equipment . . . . .	339
	A.7.12.3	Equipment Support Deterioration . . . . .	339
	A.7.12.4	Fall-Prone Equipment . . . . .	339
	A.7.12.5	In-Line Equipment . . . . .	339
	A.7.12.6	Tall Narrow Equipment . . . . .	339
	A.7.12.7	Mechanical Doors . . . . .	339
	A.7.12.8	Suspended Equipment . . . . .	339
	A.7.12.9	Vibration Isolators . . . . .	339
	A.7.12.10	Heavy Equipment . . . . .	339
	A.7.12.11	Electrical Equipment . . . . .	340
	A.7.12.12	Conduit Couplings . . . . .	340
A.7.13	Piping . . . . .	340	
	A.7.13.1	Fire Suppression Piping . . . . .	340
	A.7.13.2	Flexible Couplings . . . . .	340
	A.7.13.3	Sprinkler Ceiling Clearance . . . . .	340
	A.7.13.4	Fluid and Gas Piping . . . . .	340
	A.7.13.5	C-Clamps . . . . .	340
	A.7.13.6	Piping Crossing Seismic Joints . . . . .	340
A.7.14	Ducts . . . . .	340	
	A.7.14.1	Stair and Smoke Ducts . . . . .	340
	A.7.14.2	Duct Bracing . . . . .	340
	A.7.14.3	Duct Support . . . . .	341
	A.7.14.4	Ducts Crossing Seismic Joints . . . . .	341
A.7.15	Hazardous Materials . . . . .	341	
	A.7.15.1	Hazardous Material Storage . . . . .	341
	A.7.15.2	Shutoff Valves . . . . .	341
	A.7.15.3	Shutoff Valves . . . . .	341
	A.7.15.4	Flexible Couplings . . . . .	341
A.7.16	Elevators . . . . .	341	
	A.7.16.1	Retainer Guards . . . . .	341
	A.7.16.2	Retainer Plate . . . . .	341
	A.7.16.3	Elevator Equipment . . . . .	341
	A.7.16.4	Seismic Switch . . . . .	341
	A.7.16.5	Shaft Walls . . . . .	342
	A.7.16.6	Counterweight Rails . . . . .	342
	A.7.16.7	Brackets . . . . .	342
	A.7.16.8	Spreader Bracket . . . . .	342
	A.7.16.9	Go-Slow Elevators . . . . .	342

APPENDIX B APPLYING ASCE 41 IN BUILDING CODES, REGULATORY POLICIES, AND MITIGATION PROGRAMS . . . . .		343
B.1	Introduction . . . . .	343
B.2	Mandatory Mitigation . . . . .	343
	B.2.1 Performance Objectives . . . . .	344
	B.2.2 Implementation Issues . . . . .	345
	B.2.3 Historic Buildings . . . . .	345
	B.2.4 Example Programs . . . . .	345

B.3	Voluntary Mitigation . . . . .	346
B.3.1	Performance Objectives . . . . .	346
B.3.2	Implementation Issues . . . . .	346
B.3.3	Historic Buildings . . . . .	347
B.3.4	Example Programs . . . . .	347
B.4	Triggered Mitigation . . . . .	347
B.4.1	Performance Objectives . . . . .	347
B.4.2	Implementation Issues . . . . .	347
B.4.3	Historic Buildings . . . . .	348
B.4.4	Example Programs . . . . .	348
Reference . . . . .		349

APPENDIX C SUMMARY DATA SHEET . . . . .	351
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Commentary to Standard ASCE/SEI 41-23

C1	GENERAL REQUIREMENTS . . . . .	353
C1.1	Scope . . . . .	353
C1.3	Seismic Evaluation Process . . . . .	355
C1.3.1	Assignment of Performance Objective . . . . .	355
C1.3.3	As-Built Information . . . . .	356
C1.3.4	Evaluation Procedures . . . . .	356
C1.4	Seismic Retrofit Process . . . . .	357
C1.4.1	Assignment of Performance Objective . . . . .	359
C1.4.4	Verification of Retrofit Design. . . . .	359
C1.4.5	Quality Assurance and Structural Observation . . . . .	360
C1.4.5.1	Special Inspections and Testing . . . . .	360
C1.4.5.2	Structural Observation . . . . .	360
C2	PERFORMANCE OBJECTIVES AND SEISMIC HAZARDS. . . . .	361
C2.2	Performance Levels . . . . .	361
C2.2.1	Structural Performance Levels and Ranges . . . . .	361
C2.2.2	Nonstructural Performance Levels . . . . .	367
C2.3	Seismic Hazard. . . . .	372
C2.3.1	Seismic Hazard. . . . .	372
C2.3.1.1	BSE-2N Seismic Hazard Level . . . . .	372
C2.3.1.2	BSE-1N Seismic Hazard Level . . . . .	372
C2.3.1.3	BSE-2E Seismic Hazard Level . . . . .	372
C2.3.1.4	BSE-1E Seismic Hazard Level . . . . .	373
C2.3.1.5	Seismic Hazard Levels for Other Probabilities of Exceedance, Risk Targets, or Deterministic Hazards. . . . .	373
C2.3.2	General Response Spectrum . . . . .	373
C2.3.2.1	Multiperiod General Horizontal Response Spectrum . . . . .	373
C2.3.2.2	Two-Period General Horizontal Response Spectrum . . . . .	373
C2.3.2.3	General Vertical Response Spectrum . . . . .	373
C2.3.3	Site-Specific Procedure for Hazards Caused by Ground Shaking . . . . .	373
C2.3.4	Ground Motion Acceleration Histories . . . . .	374
C2.4	Performance Objectives . . . . .	374
C2.4.1	Basic Performance Objective for Existing Buildings (BPOE) . . . . .	375
C2.4.2	Enhanced Performance Objectives. . . . .	377
C2.4.3	Limited Performance Objectives. . . . .	377
C2.4.4	Basic Performance Objective Equivalent to New Building Standards (BPON) . . . . .	377
C2.4.5	Partial Retrofit . . . . .	377
C2.4.6	System-Specific Performance Procedures . . . . .	377
C2.5	Level of Seismicity. . . . .	378
C3	EVALUATION AND RETROFIT REQUIREMENTS . . . . .	379
C3.2	As-Built Information . . . . .	379
C3.2.1	Building Type . . . . .	379
C3.2.2	Building Configuration. . . . .	379
C3.2.3	Component Properties . . . . .	379
C3.2.4	Site and Foundation Information . . . . .	379

	C3.2.5	Adjacent Buildings . . . . .	379
		C3.2.5.1 Building Pounding . . . . .	379
		C3.2.5.2 Shared Element Condition . . . . .	379
		C3.2.5.3 Hazards from Adjacent Buildings . . . . .	380
C3.3		Common Building Types . . . . .	380
C3.4		Benchmark Buildings . . . . .	380
	C3.4.1	Benchmark Procedure Checklist . . . . .	385
		C3.4.2.1 Level of Seismicity . . . . .	386
		C3.4.2.2 Seismic Force Provisions . . . . .	386
C3.5		Evaluation and Retrofit Procedures . . . . .	387
	C3.5.1	Limitations on the Use of Tier 1 and Tier 2 Evaluation and Retrofit Procedures . . . . .	387
		C3.5.1.2 Buildings Composed of More than One of the Common Building Types . . . . .	387
	C3.5.2	Tier 1 Screening Procedure . . . . .	388
	C3.5.3	Tier 2 Deficiency-Based Evaluation and Retrofit Procedures . . . . .	388
		C3.5.3.1 Evaluation Requirements . . . . .	388
		C3.5.3.2 Retrofit Requirements . . . . .	388
	C3.5.4	Tier 3 Systematic Evaluation and Retrofit Procedures . . . . .	388
		C3.5.4.1 Evaluation Requirements . . . . .	388
		C3.5.4.2 Retrofit Requirements . . . . .	388
C4		TIER 1 SCREENING . . . . .	389
	C4.1	Scope . . . . .	389
		C4.1.1 Performance Level . . . . .	389
	C4.2	Scope of Investigation Required . . . . .	389
		C4.2.1 On-Site Investigation and Condition Assessment . . . . .	389
		C4.2.3 Default Material Values . . . . .	389
	C4.3	Selection and Use of Checklists . . . . .	389
	C4.4	Tier 1 Analysis . . . . .	389
		C4.4.2.1 Pseudo Seismic Force . . . . .	389
		C4.4.2.4 Period . . . . .	393
		C4.4.3.1 Story Drift for Moment Frames . . . . .	393
		C4.4.3.2 Shear Stress in Concrete Frame Columns . . . . .	393
		C4.4.3.5 Precast Connections . . . . .	393
		C4.4.3.6 Column Axial Stress Caused by Overturning . . . . .	393
		C4.4.3.7 Flexible Diaphragm Connection Forces . . . . .	393
		C4.4.3.8 Prestressed Elements . . . . .	393
		C4.4.3.9 Flexural Stress in Columns and Beams of Steel Moment Frames . . . . .	393
C5		TIER 2 DEFICIENCY-BASED EVALUATION AND RETROFIT . . . . .	395
	C5.1	Scope . . . . .	395
	C5.2	General Requirements . . . . .	395
		C5.2.1 Performance Level and Seismic Hazard Level . . . . .	395
		C5.2.2 As-Built Information . . . . .	395
		C5.2.3 Condition Assessment . . . . .	395
		C5.2.4 Tier 2 Analysis Methods . . . . .	395
		C5.2.5 Tier 2 Acceptance Criteria . . . . .	396
		C5.2.6 Knowledge Factor . . . . .	396
	C5.3	Tier 2 Deficiency-Based Evaluation Requirements . . . . .	396
	C5.4	Procedures for Basic Configuration of Building Systems . . . . .	396
		C5.4.1 General . . . . .	396
		C5.4.1.1 Load Path . . . . .	396
		C5.4.1.2 Adjacent Buildings . . . . .	396
		C5.4.1.3 Mezzanines . . . . .	396
	C5.4.2	Building Configuration . . . . .	396
		C5.4.2.1 Weak Story Irregularity . . . . .	396
		C5.4.2.2 Soft Story Irregularity . . . . .	396
		C5.4.2.3 Vertical Irregularities . . . . .	397
		C5.4.2.4 Geometric Irregularity . . . . .	397
		C5.4.2.5 Mass Irregularity . . . . .	397
		C5.4.2.6 Torsion Irregularity . . . . .	397
	C5.4.3	Geologic Site Hazards and Foundation Components . . . . .	397
		C5.4.3.1 Geologic Site Hazards . . . . .	397
		C5.4.3.3 Overturning . . . . .	397

C5.5	Procedures for Seismic-Force-Resisting Systems . . . . .	397
C5.5.1	General . . . . .	397
	C5.5.1.1 Redundancy . . . . .	397
C5.5.2	Procedures for Moment Frames . . . . .	397
	C5.5.2.1 General Procedures for Moment Frames . . . . .	397
	C5.5.2.2 Procedures for Steel Moment Frames . . . . .	397
	C5.5.2.3 Procedures for Concrete Moment Frames . . . . .	397
C5.5.3	Procedures for Shear Walls . . . . .	397
	C5.5.3.1 General Procedures for Shear Walls. . . . .	397
	C5.5.3.3 Procedures for Precast Concrete Shear Walls . . . . .	398
C5.5.4	Procedures for Braced Frames. . . . .	398
	C5.5.4.1 Axial Stress Check. . . . .	398
C5.7	Procedures for Connections . . . . .	398
C5.7.4	Interconnection of Elements . . . . .	398
	C5.7.4.4 Beam, Girder, and Truss Supported on Unreinforced Masonry (URM) Walls or URM Pilasters. . . . .	398
C5.8	Tier 2 Deficiency-Based Retrofit Requirements. . . . .	398
C5.8.1	Compliance with Deficiency-Based Evaluation . . . . .	398
C5.8.2	Additional Evaluation of the Resulting Building . . . . .	398
	C5.8.2.1 Building Configuration. . . . .	398
	C5.8.2.2 Increased Gravity Demands to Existing Elements . . . . .	398
	C5.8.2.3 Increased Seismic Demands to Existing Elements . . . . .	398
C5.8.3	Evaluation of New and Modified Structural Elements and Connections. . . . .	398
	C5.8.4.2 Design and Detailing Requirements . . . . .	398
	C5.8.4.3 Scope of Evaluation Requirements for Existing Components . . . . .	399
C6	TIER 3 SYSTEMATIC EVALUATION AND RETROFIT . . . . .	401
C6.2	Data Collection Requirements . . . . .	401
	C6.2.2 Condition Assessment . . . . .	401
	C6.2.3 Material Properties . . . . .	401
	C6.2.3.1 Knowledge Factor for Linear Procedures . . . . .	401
	C6.2.3.2 Property Bounding for Nonlinear Procedures . . . . .	402
C6.3	Tier 3 Evaluation Requirements . . . . .	403
C6.4	Tier 3 Retrofit Requirements. . . . .	403
C7	ANALYSIS PROCEDURES AND ACCEPTANCE CRITERIA. . . . .	405
C7.1	Scope . . . . .	405
C7.2	General Analysis Requirements . . . . .	405
	C7.2.2 Effective Seismic Weight . . . . .	405
	C7.2.3 Component Gravity Loads and Load Combinations . . . . .	405
	C7.2.3.1 Dead Load . . . . .	405
	C7.2.3.2 Live Load . . . . .	405
	C7.2.3.3 Snow Load . . . . .	405
	C7.2.4 Mathematical Modeling . . . . .	405
	C7.2.4.1 Basic Assumptions. . . . .	405
	C7.2.4.2 Torsion . . . . .	406
	C7.2.4.3 Primary and Secondary Components . . . . .	407
	C7.2.4.5 Foundation Modeling . . . . .	408
	C7.2.4.6 Damping . . . . .	408
	C7.2.5 Configuration. . . . .	408
	C7.2.6 Multidirectional Seismic Effects. . . . .	408
	C7.2.6.1 Concurrent Seismic Effects . . . . .	408
	C7.2.7 P-Delta Effects . . . . .	409
	C7.2.8 Soil–Structure Interaction . . . . .	409
	C7.2.9 Overturning. . . . .	409
	C7.2.9.1 Overturning Effects for Linear Procedures . . . . .	409
	C7.2.10 Sliding at the Soil–Structure Interface. . . . .	410
	C7.2.10.1 Foundation Interconnection . . . . .	410
	C7.2.11 Diaphragms, Chords, Collectors, and Ties . . . . .	410
	C7.2.12 Continuity . . . . .	411
	C7.2.13 Structural Walls and Their Anchorage . . . . .	411
	C7.2.13.2 Out-of-Plane Strength of Walls . . . . .	411
	C7.2.15 Building Separation . . . . .	411

	C7.2.15.2	Separation Exceptions . . . . .	411
	C7.2.16	Verification of Analysis Assumptions . . . . .	411
C7.3		Analysis Procedure Selection . . . . .	411
	C7.3.1	Linear Procedures . . . . .	412
	C7.3.1.1	Method to Determine Limitations on Use of Linear Procedures . . . . .	412
	C7.3.1.2	Limitations on Use of the Linear Static Procedure . . . . .	413
	C7.3.2	Nonlinear Procedures . . . . .	413
	C7.3.2.1	Nonlinear Static Procedure. . . . .	413
	C7.3.2.2	Nonlinear Dynamic Procedure. . . . .	413
C7.4		Analysis Procedures . . . . .	413
	C7.4.1	Linear Static Procedure . . . . .	413
	C7.4.1.1	Basis of the Procedure. . . . .	413
	C7.4.1.2	Period Determination for Linear Static Procedure . . . . .	413
	C7.4.1.3	Determination of Forces and Deformations for Linear Static Procedure . . . . .	414
	C7.4.2	Linear Dynamic Procedure. . . . .	415
	C7.4.2.1	Basis of the Procedure. . . . .	415
	C7.4.2.2	Modeling and Analysis Considerations for Linear Dynamic Procedure . . . . .	415
	C7.4.2.3	Determination of Forces and Deformations for Linear Dynamic Procedure . . . . .	416
	C7.4.3	Nonlinear Static Procedure. . . . .	416
	C7.4.3.1	Basis of the Procedure. . . . .	416
	C7.4.3.2	Modeling and Analysis Considerations for Nonlinear static Procedure . . . . .	416
	C7.4.3.3	Determination of Forces, Displacements, and Deformations for Nonlinear Static Procedure. . . . .	417
	C7.4.4	Nonlinear Dynamic Procedure. . . . .	419
	C7.4.4.1	Basis of the Procedure. . . . .	419
	C7.4.4.3	Determination of Forces and Deformations for Nonlinear Dynamic Procedure . . . . .	419
	C7.4.4.4	Damping for Nonlinear Dynamic Procedure . . . . .	421
C7.5		Acceptance Criteria . . . . .	421
	C7.5.1	General Requirements . . . . .	421
	C7.5.1.1	Deformation-Controlled and Force-Controlled Actions . . . . .	422
	C7.5.1.2	Critical and Noncritical Actions . . . . .	423
	C7.5.1.3	Expected and Lower-Bound Strengths . . . . .	423
	C7.5.1.4	Material Properties . . . . .	423
	C7.5.2	Linear Procedures . . . . .	423
	C7.5.2.1	Forces and Deformations . . . . .	423
	C7.5.2.2	Acceptance Criteria for Linear Procedures . . . . .	424
	C7.5.3	Nonlinear Procedures . . . . .	424
	C7.5.3.2	Acceptance Criteria for Nonlinear Procedures . . . . .	424
C7.6		Experimentally Derived Modeling Parameters and Acceptance Criteria . . . . .	426
	C7.6.1	Criteria for General Use Parameters. . . . .	426
	C7.6.2	Criteria for Individual Project Testing. . . . .	429
	C7.6.2.1	Experimental Setup. . . . .	429
	C7.6.2.2	Data Reduction and Reporting. . . . .	430
	C7.6.3	Modeling Parameters and Acceptance Criteria for Nonadaptive Force–Deformation Curves . . . . .	430
	C7.6.4	Modeling Parameters and Acceptance Criteria for Component Actions based on Experimental Data for Fiber Models . . . . .	432
	C7.6.5	Modeling Parameters and Acceptance Criteria for Component Actions based on Experimental Data for Adaptive Force–Deformation Models in the Mathematical Model . . . . .	432
C8		FOUNDATIONS, SUBSURFACE SOIL, AND GEOLOGIC SITE HAZARDS . . . . .	433
	C8.1	Scope . . . . .	433
	C8.2	Site Characterization . . . . .	433
	C8.2.1	Subsurface Soil and Foundation Information . . . . .	433
	C8.2.1.1	Subsurface Soil Conditions . . . . .	433
	C8.2.1.2	Foundation Conditions . . . . .	433
	C8.2.1.3	Load–Deformation Characteristics of Subsurface Soil Under Seismic Loading . . . . .	433
	C8.2.1.4	Soil Shear Modulus and Poisson’s Ratio Parameters . . . . .	433
	C8.2.2	Seismic–Geologic Site Hazards . . . . .	434
	C8.2.2.1	Fault Rupture. . . . .	434
	C8.2.2.2	Liquefaction . . . . .	434
	C8.2.2.3	Settlement of Nonliquefiable Soils. . . . .	436
	C8.2.2.4	Landsliding . . . . .	436
	C8.3	Mitigation of Seismic–Geologic Site Hazards. . . . .	436
	C8.4	Shallow Foundations . . . . .	437

	C8.4.1	Selection of Evaluation Procedures . . . . .	437
	C8.4.2	Expected Soil Bearing Capacities . . . . .	440
		C8.4.2.1 Prescriptive Expected Soil Bearing Capacities . . . . .	440
		C8.4.2.2 Site-Specific Capacities . . . . .	441
	C8.4.3	Simplified Procedure . . . . .	441
	C8.4.4	Fixed-Base Procedure . . . . .	442
		C8.4.4.1 Linear Procedures . . . . .	443
		C8.4.4.2 Nonlinear Procedures . . . . .	452
	C8.4.5	Flexible-Base Procedure . . . . .	452
		C8.4.5.1 Soil Stiffness . . . . .	452
		C8.4.5.2 Linear Procedures . . . . .	452
		C8.4.5.3 Nonlinear Procedures . . . . .	454
	C8.4.6	Shallow Foundation Lateral Load . . . . .	456
C8.5		Deep Foundations . . . . .	456
	C8.5.1	Pile Foundations . . . . .	456
		C8.5.1.1 Stiffness Parameters . . . . .	456
		C8.5.1.2 Capacity Parameters . . . . .	456
	C8.5.2	Drilled Shafts . . . . .	456
C8.6		Soil–Structure Interaction Effects . . . . .	456
	C8.6.1	Kinematic Interaction . . . . .	457
		C8.6.1.1 Base Slab Averaging . . . . .	457
		C8.6.1.2 Embedment . . . . .	457
	C8.6.2	Foundation Damping Soil–Structure Interaction Effects . . . . .	457
		C8.6.2.1 Radiation Damping for Rectangular Foundations . . . . .	457
C8.7		Seismic Earth Pressure . . . . .	458
C8.8		Foundation Retrofit . . . . .	459
C9		STEEL AND IRON . . . . .	461
	C9.1	Scope . . . . .	461
	C9.2	Reference Standard for Structural Steel, Composite Steel–Concrete, and Cast and Wrought Iron . . . . .	461
	C9.3	Modification to the Reference Standard for Structural Steel, Composite Steel–Concrete, and Cast and Wrought Iron . . . . .	461
	C9.4	Material Properties and Condition Assessment for Cold-Formed Steel . . . . .	461
		C9.4.1 General . . . . .	461
		C9.4.2.1 Material Properties . . . . .	462
		C9.4.2.2 Component Properties . . . . .	462
		C9.4.2.3 Test Methods to Quantify Mechanical Properties . . . . .	462
		C9.4.2.4 Minimum Number of Tests . . . . .	462
		C9.4.2.5 Default Mechanical Properties . . . . .	462
		C9.4.3 Condition Assessment . . . . .	462
		C9.4.3.1 General . . . . .	462
		C9.4.3.2 Scope and Procedures . . . . .	463
		C9.4.3.3 Basis for the Mathematical Building Model . . . . .	463
	C9.5	General Assumptions and Requirements for Cold-Formed Steel . . . . .	463
		C9.5.1 Stiffness . . . . .	463
		C9.5.1.2 Use of Nonlinear Procedures for Cold-Formed Steel Light-Frame Construction . . . . .	463
		C9.5.2 Strength and Acceptance Criteria . . . . .	463
		C9.5.2.2 Deformation-Controlled Actions . . . . .	463
		C9.5.2.3 Force-Controlled Actions . . . . .	463
		C9.5.3 Connection Requirements in Cold-Formed Steel Light-Frame Construction . . . . .	464
		C9.5.5 Retrofit Measures . . . . .	464
	C9.6	Cold-Formed Steel Light-Frame Construction, Shear Wall Systems . . . . .	464
		C9.6.1 General . . . . .	464
		C9.6.2 Types of Cold-Formed Steel Light-Frame Construction, Shear Wall Systems . . . . .	464
		C9.6.2.1 Existing Cold-Formed Steel Light-Frame Shear Walls . . . . .	464
		C9.6.2.2 Enhanced Cold-Formed Steel Light-Frame Shear Walls . . . . .	464
		C9.6.3 Stiffness, Strength, Acceptance Criteria, and Connection Design for Cold-Formed Steel Light-Frame Construction Shear Wall Systems . . . . .	465
	C9.7	Cold-Formed Steel Moment-Frame Systems . . . . .	465
		C9.7.3.1 Generic Cold-Formed Steel Moment Connection . . . . .	465
		C9.7.3.2 Cold-Formed Steel Special Bolted Moment Frame . . . . .	465
	C9.8	Cold-Formed Steel Light-Frame Construction, Strap-Braced Wall Systems . . . . .	465
		C9.8.1 General . . . . .	465
		C9.8.2 Types of Cold-Formed Steel Light-Framed Construction with Strap-Braced Walls . . . . .	465

	C9.8.2.1	Existing Cold-Formed Steel Light-Frame Construction with Strap-Braced Walls	465	
	C9.8.2.2	Cold-Formed Steel Light-Frame Construction with Enhanced Strap-Braced Walls	465	
C9.9	CFS Diaphragms		465	
C10	CONCRETE		467	
	C10.3	Modifications to the Reference Standard	467	
		C10.3.1 General Assumptions and Requirements	467	
		C10.3.2 Concrete Structural Walls	471	
		C10.3.3 Concrete Foundations	480	
C11	MASONRY		483	
	C11.1	Scope	483	
	C11.2	Condition Assessment and Material Properties	483	
		C11.2.1 General	483	
		C11.2.2 Condition Assessment	483	
			C11.2.2.2 Comprehensive Condition Assessment	484
			C11.2.2.3 Supplemental Tests	485
			C11.2.2.4 Condition Enhancement	485
			C11.2.2.5 Pointing or Repointing of Unreinforced Masonry Walls	485
		C11.2.3 Properties of In-Place Materials and Components	485	
			C11.2.3.3 Masonry Compressive Strength	485
			C11.2.3.4 Masonry Elastic Modulus in Compression	486
			C11.2.3.5 Masonry Flexural Tensile Strength	486
			C11.2.3.6 Unreinforced Masonry Shear Strength	486
			C11.2.3.7 Masonry Shear Modulus	486
			C11.2.3.8 Steel Reinforcement Yield Strength Properties	486
			C11.2.3.9 Minimum Number of Tests	487
			C11.2.3.10 Default Properties	487
	C11.3	Masonry Walls	487	
		C11.3.1 Types of Masonry Walls	487	
			C11.3.1.2 New Masonry Walls	487
			C11.3.1.3 Retrofitted Masonry Walls	487
		C11.3.2 Unreinforced Masonry Walls and Wall Piers Subject to In-Plane Actions	488	
			C11.3.2.1 Stiffness of URM Walls and Wall Piers Subject to In-Plane Actions	488
			C11.3.2.2 Strength of URM Walls Subject to In-Plane Actions	490
			C11.3.2.3 Acceptance Criteria for URM In-Plane Actions	495
			C11.3.3.2 Strength of URM Walls Subject to Out-of-Plane Actions	497
			C11.3.3.3 Acceptance Criteria for URM Walls Subject to out-of-Plane Actions	497
		C11.3.4 Reinforced Masonry Walls and Wall Piers In-Plane Actions	498	
			C11.3.4.3 Flexure-Governed In-Plane Actions of Reinforced Masonry Walls and Wall Piers	499
			C11.3.4.4 Shear-Governed In-Plane Actions of Reinforced Masonry Walls and Wall Piers	499
			C11.3.4.6 Acceptance Criteria for In-Plane Actions of Reinforced Masonry Walls and Wall Piers	500
		C11.3.5 Reinforced Masonry Wall Out-of-Plane Actions	500	
			C11.3.5.3 Acceptance Criteria for Reinforced Masonry Wall Out-of-Plane Actions	500
	C11.4	Masonry Infills	500	
		C11.4.1 Types of Masonry Infills	500	
			C11.4.1.1 Existing Masonry Infills	500
			C11.4.1.3 Retrofitted Masonry Infills	500
		C11.4.2 Masonry Infill In-Plane Actions	500	
			C11.4.2.1 Stiffness: Masonry Infill In-Plane Actions	500
			C11.4.2.2 Stiffness: Masonry Infill with Openings In-Plane Actions	500
			C11.4.2.3 Strength: Infilled Reinforced Concrete Frames in-Plane Actions	501
			C11.4.2.4 Strength: Infilled Steel Frames In-Plane Actions	502
			C11.4.2.5 Drift: Infill Wall In-Plane Actions	502
			C11.4.2.6 Strut Model for Infill In-Plane Actions	502
			C11.4.2.7 Acceptance Criteria for Infill Wall In-Plane Actions	502
		C11.4.3 Masonry Infill Wall Out-of-Plane Actions	502	
			C11.4.3.1 Stiffness: Infill Wall Out-of-Plane Actions	502
			C11.4.3.2 Strength: Infill Wall Out-of-Plane Actions	502
			C11.4.3.3 Strength: Infill Wall In-Plane and Out-of-Plane Interaction	502

C11.5	Anchorage to Masonry Walls . . . . .	503
	C11.5.2 Analysis of Anchors . . . . .	503
	C11.5.3 Quality Assurance for Anchors in Masonry Walls . . . . .	503
C11.6	Masonry Foundation Elements. . . . .	503
	C11.6.1 Types of Masonry Foundations . . . . .	503
	C11.6.3 Foundation Retrofit Measures . . . . .	503
C11.7	Masonry Diaphragms . . . . .	503
	C11.7.1 General . . . . .	503
	C11.7.2 Seismic Evaluation of Masonry Diaphragms . . . . .	503
	C11.7.3 Retrofit Measures for Masonry Diaphragms . . . . .	504
C12	WOOD . . . . .	505
C12.1	Scope . . . . .	505
C12.2	Material Properties and Condition Assessment . . . . .	505
	C12.2.1 General . . . . .	505
	C12.2.2.2 Component Properties . . . . .	506
	C12.2.2.3 Test Methods to Quantify Material Properties . . . . .	506
	C12.2.2.4 Minimum Number of Tests . . . . .	506
	C12.2.2.5 Default Properties . . . . .	507
	C12.2.3 Condition Assessment . . . . .	507
	C12.2.3.1 General . . . . .	507
	C12.2.3.2 Scope and Procedures for Condition Assessment . . . . .	507
	C12.2.3.3 Basis for the Mathematical Building Model . . . . .	507
C12.3	General Assumptions and Requirements . . . . .	508
	C12.3.2.2 Deformation-Controlled Actions . . . . .	508
	C12.3.2.3 Force-Controlled Actions . . . . .	508
	C12.3.3 Connection Requirements . . . . .	508
	C12.3.5 Retrofit Measures . . . . .	508
C12.4	Wood Shear Walls . . . . .	508
	C12.4.1 General . . . . .	508
	C12.4.2 Types of Wood Shear Walls. . . . .	509
	C12.4.2.1 Existing Wood Shear Walls . . . . .	509
	C12.4.2.2 Enhanced Wood Shear Walls . . . . .	509
	C12.4.2.3 New Wood Shear Walls . . . . .	510
	C12.4.3 Stiffness, Strength, Acceptance Criteria, and Connection Design for Wood Shear Walls . . . . .	510
	C12.4.3.1 Single-Layer Horizontal Lumber Sheathing or Siding Shear Walls . . . . .	510
	C12.4.3.2 Diagonal Lumber Sheathing Shear Walls . . . . .	510
	C12.4.3.3 Vertical Wood Siding Shear Walls . . . . .	510
	C12.4.3.4 Wood Siding Over Horizontal Lumber Sheathing Shear Walls . . . . .	510
	C12.4.3.5 Wood Siding Over Diagonal Lumber Sheathing Shear Walls . . . . .	511
	C12.4.3.6 Wood Structural Panel Sheathing or Siding Shear Walls. . . . .	511
	C12.4.3.7 Stucco on Studs, Sheathing, or Fiberboard Shear Walls . . . . .	511
	C12.4.3.8 Gypsum Plaster on Wood Lath Shear Walls . . . . .	511
	C12.4.3.9 Gypsum Plaster on Gypsum Lath Shear Walls . . . . .	511
	C12.4.3.10 Gypsum Wallboard Shear Walls. . . . .	511
	C12.4.3.11 Gypsum Sheathing Shear Walls . . . . .	511
	C12.4.3.12 Plaster on Metal Lath Shear Walls . . . . .	512
	C12.4.3.13 Horizontal Lumber Sheathing with Cut-In Braces or Diagonal Blocking Shear Walls . . . . .	512
	C12.4.3.14 Fiberboard or Particleboard Sheathing Shear Walls. . . . .	512
C12.5	Wood Diaphragms . . . . .	512
	C12.5.1 General . . . . .	512
	C12.5.2 Types of Wood Diaphragms. . . . .	512
	C12.5.2.1 Existing Wood Diaphragms . . . . .	512
	C12.5.2.2 Enhanced Wood Diaphragms . . . . .	513
	C12.5.2.3 New Wood Diaphragms . . . . .	513
	C12.5.3 Stiffness, Strength, Acceptance Criteria, and Connection Design for Wood Diaphragms . . . . .	514
	C12.5.3.1 Single-Layer Straight Lumber Sheathing Diaphragms . . . . .	514
	C12.5.3.2 Double-Layer Straight Lumber Sheathing Diaphragms . . . . .	514
	C12.5.3.3 Single-Layer Diagonal Lumber Sheathing Diaphragms. . . . .	514
	C12.5.3.4 Diagonal Lumber Sheathing with Straight Lumber Sheathing or Flooring above Diaphragms. . . . .	514
	C12.5.3.5 Double-Layer Diagonal Lumber Sheathing Diaphragms . . . . .	514
	C12.5.3.6 Wood Structural Panel Sheathing Diaphragm. . . . .	515

	C12.5.3.7	Wood Structural Panel Overlays on Straight or Diagonal Lumber Sheathing Diaphragms . . . . .	515
	C12.5.3.8	Wood Structural Panel Overlays on Existing Wood Structural Panel Sheathing Diaphragms . . . . .	515
C12.6		Wood Foundations . . . . .	515
	C12.6.1	Types of Wood Foundations . . . . .	515
	C12.6.2	Analysis, Strength, and Acceptance Criteria for Wood Foundations . . . . .	516
	C12.6.3	Retrofit Measures for Wood Foundations . . . . .	516
C12.7		Other Wood Elements and Components . . . . .	516
	C12.7.1	General . . . . .	516
	C12.7.1.2	Strength of Other Wood Elements and Components . . . . .	516
	C12.7.1.3	Acceptance Criteria for Other Wood Elements and Components . . . . .	516
C13		ARCHITECTURAL, MECHANICAL, AND ELECTRICAL COMPONENTS . . . . .	517
	C13.1	Scope . . . . .	517
	C13.2	Evaluation and Retrofit Procedure for Nonstructural Components . . . . .	517
	C13.2.1	Classification of Components . . . . .	517
C13.3		Component Assessment and Anchorage Testing . . . . .	517
	C13.3.1	Condition Assessment . . . . .	518
	C13.3.2	Testing Requirements for Evaluating the Performance of Existing Attachments for Nonstructural Components . . . . .	518
	C13.3.2.1	Components Evaluated to the Operational Performance Level . . . . .	518
	C13.3.2.2	Components Evaluated to the Position Retention or Life Safety Performance Level . . . . .	518
	C13.3.2.3	Tension Testing Procedure . . . . .	518
	C13.3.2.5	Alternate Test Criteria . . . . .	518
C13.4		Evaluation Procedures . . . . .	518
	C13.4.2	Analytical Procedure . . . . .	518
	C13.4.3	Prescriptive Procedure . . . . .	518
	C13.4.4.1	Horizontal Seismic Forces . . . . .	519
	C13.4.4.3	Load Combination . . . . .	519
	C13.4.4.4	Nonstructural Support Capacity . . . . .	519
	C13.4.5	Deformation Analysis . . . . .	519
C13.5		Retrofit Approaches . . . . .	519
C13.6		Architectural Components: Definition, Behavior, and Acceptance Criteria . . . . .	520
	C13.6.1	Exterior Wall Components . . . . .	520
	C13.6.1.1	Adhered Veneer . . . . .	520
	C13.6.1.2	Anchored Veneer . . . . .	520
	C13.6.1.3	Glass Block Units and Other Nonstructural Masonry . . . . .	521
	C13.6.1.4	Prefabricated Panels . . . . .	521
	C13.6.1.5	Glazed Exterior Wall Systems . . . . .	521
	C13.6.2	Partitions . . . . .	522
	C13.6.2.1	Definition and Scope . . . . .	522
	C13.6.2.2	Component Behavior and Retrofit Methods . . . . .	522
	C13.6.2.4	Evaluation Requirements . . . . .	522
	C13.6.3	Interior Veneers . . . . .	522
	C13.6.3.2	Component Behavior and Retrofit Methods . . . . .	522
	C13.6.4	Ceilings . . . . .	522
	C13.6.4.1	Definition and Scope . . . . .	522
	C13.6.4.2	Component Behavior and Retrofit Methods . . . . .	522
	C13.6.5	Parapets and Cornices . . . . .	522
	C13.6.5.1	Definition and Scope . . . . .	522
	C13.6.5.2	Component Behavior and Retrofit Methods . . . . .	522
	C13.6.6	Architectural Appendages and Marquees . . . . .	522
	C13.6.6.1	Definition and Scope . . . . .	522
	C13.6.6.2	Component Behavior and Retrofit Methods . . . . .	522
	C13.6.9	Chimneys and Stacks . . . . .	523
	C13.6.9.2	Component Behavior and Retrofit Methods . . . . .	523
	C13.6.10	Stairs and Ramps . . . . .	523
	C13.6.10.1	Definition and Scope . . . . .	523
	C13.6.10.2	Component Behavior and Retrofit Methods . . . . .	523
	C13.6.11	Doors Required for Emergency Services Egress in Essential Facilities . . . . .	523
	C13.6.11.1	Definition and Scope . . . . .	523
	C13.6.12	Computer Access Floors . . . . .	523

	C13.6.12.1	Definition and Scope . . . . .	523
	C13.6.12.2	Component Behavior and Retrofit Methods . . . . .	523
	C13.6.12.4	Evaluation Requirements . . . . .	523
C13.7		Mechanical, Electrical, and Plumbing Components: Definition, Behavior, and Acceptance Criteria . . . . .	523
	C13.7.1	Mechanical Equipment . . . . .	523
	C13.7.1.1	Definition and Scope . . . . .	523
	C13.7.1.2	Component Behavior and Retrofit Methods . . . . .	523
	C13.7.1.4	Evaluation Requirements . . . . .	524
	C13.7.2	Storage Vessels and Water Heaters . . . . .	524
	C13.7.2.1	Definition and Scope . . . . .	524
	C13.7.2.2	Component Behavior and Retrofit Methods . . . . .	524
	C13.7.2.4	Evaluation Requirements . . . . .	524
	C13.7.3	Pressure Piping . . . . .	524
	C13.7.3.2	Component Behavior and Retrofit Methods . . . . .	524
	C13.7.3.4	Evaluation Requirements . . . . .	524
	C13.7.4	Fire Suppression Piping . . . . .	524
	C13.7.4.2	Component Behavior and Retrofit Methods . . . . .	524
	C13.7.4.3	Acceptance Criteria . . . . .	524
	C13.7.4.4	Evaluation Requirements . . . . .	524
	C13.7.5	Fluid Piping Other than Fire Suppression . . . . .	524
	C13.7.5.1	Definition and Scope . . . . .	524
	C13.7.5.2	Component Behavior and Retrofit Methods . . . . .	524
	C13.7.5.4	Evaluation Requirements . . . . .	524
	C13.7.6	Ductwork . . . . .	525
	C13.7.6.2	Component Behavior and Retrofit Methods . . . . .	525
	C13.7.7	Electrical and Communications Equipment . . . . .	525
	C13.7.7.2	Component Behavior and Retrofit Methods . . . . .	525
	C13.7.7.4	Evaluation Requirements . . . . .	525
	C13.7.8	Electrical and Communications Distribution Components . . . . .	525
	C13.7.8.2	Component Behavior and Retrofit Methods . . . . .	525
	C13.7.9	Light Fixtures . . . . .	525
	C13.7.9.2	Component Behavior and Retrofit Methods . . . . .	525
	C13.7.10	Rooftop Solar Photovoltaic Arrays . . . . .	525
	C13.7.10.1	Definition and Scope . . . . .	525
	C13.7.10.2	Component Behavior and Retrofit Methods . . . . .	525
	C13.7.10.4	Evaluation Requirements . . . . .	525
	C13.7.11	Elevators . . . . .	525
	C13.7.11.2	Component Behavior and Retrofit Methods . . . . .	525
	C13.7.11.4	Evaluation Requirements . . . . .	525
	C13.7.12	Conveyors . . . . .	525
	C13.7.12.2	Component Behavior and Retrofit Methods . . . . .	525
C13.8		Furnishings and Contents: Definition, Behavior, and Acceptance Criteria . . . . .	525
	C13.8.1	Steel Storage Racks . . . . .	525
	C13.8.1.1	Definition and Scope . . . . .	525
	C13.8.1.2	Component Behavior and Retrofit Methods . . . . .	526
	C13.8.2	Contents . . . . .	526
	C13.8.2.1	Definition and Scope . . . . .	526
	C13.8.2.2	Component Behavior and Retrofit Methods . . . . .	526
	C13.8.3	Hazardous Material Storage . . . . .	526
	C13.8.3.2	Component Behavior and Retrofit Methods . . . . .	526
	C13.8.4	Computer and Communication Racks . . . . .	526
	C13.8.4.1	Definition and Scope . . . . .	526
	C13.8.4.2	Component Behavior and Retrofit Methods . . . . .	526
C14		SEISMIC ISOLATION . . . . .	527
	C14.1	Scope . . . . .	527
	C14.2	General Requirements . . . . .	527
	C14.2.2	Seismic Hazard . . . . .	527
	C14.2.2.1	Ground Motion Acceleration Histories . . . . .	527
	C14.2.3	Isolation System . . . . .	527
	C14.2.3.1	Environmental Conditions . . . . .	527
	C14.2.3.2	Wind Displacement . . . . .	527
	C14.2.3.3	Fire Resistance . . . . .	527
	C14.2.3.4	Lateral Restoring Force . . . . .	527

	C14.2.3.5	Displacement Restraint. . . . .	527
	C14.2.3.6	Vertical Load Stability. . . . .	527
	C14.2.3.7	Overtuning. . . . .	527
	C14.2.3.8	Inspection and Replacement. . . . .	528
C14.2.4		Structural System. . . . .	528
	C14.2.4.2	Minimum Separations. . . . .	528
C14.2.5		Elements of Structures and Nonstructural Components. . . . .	528
	C14.2.5.2	Components at or above the Isolation Interface. . . . .	528
	C14.2.5.3	Components Crossing the Isolation Interface. . . . .	528
C14.2.6		Seismic Load Effects and Load Combinations. . . . .	528
C14.3		Seismic Isolation System Device Properties. . . . .	529
	C14.3.1	Isolation System Device Types. . . . .	529
	C14.3.2	Nominal Design Properties of Isolation System Devices. . . . .	529
	C14.3.3	Bounding Properties of Isolation System Devices. . . . .	529
	C14.3.3.1	Specification Tolerance on Design Properties. . . . .	529
	C14.3.3.2	Testing Variations on Design Properties. . . . .	529
	C14.3.3.3	Aging and Environmental Effects on Design Properties. . . . .	530
	C14.3.4	Property Modification Factors. . . . .	530
	C14.3.5	Upper- and Lower-Bound Properties. . . . .	530
C14.4		Modeling. . . . .	530
	C14.4.1	Isolation System Device Modeling. . . . .	530
	C14.4.2	Isolation System and Superstructure Modeling. . . . .	531
	C14.4.2.3	Superstructure Model. . . . .	531
C14.5		Analysis Procedures. . . . .	531
	C14.5.1	Selection of Analysis Procedure. . . . .	531
	C14.5.1.1	Linear Static Procedure. . . . .	531
	C14.5.2	Linear Static Procedure. . . . .	531
	C14.5.2.2	Minimum Lateral Displacements. . . . .	531
	C14.5.2.3	Minimum Lateral Forces. . . . .	532
	C14.5.2.4	Vertical Distribution of Force. . . . .	532
	C14.5.5	Nonlinear Dynamic Procedure. . . . .	533
	C14.5.5.2	Accidental Mass Eccentricity. . . . .	533
C14.6		Isolation System Testing and Design Properties. . . . .	533
	C14.6.3	Prototype Tests. . . . .	533
	C14.6.3.5	Dynamic Testing. . . . .	533
	C14.6.3.9	Testing Similar Isolation System Devices. . . . .	533
	C14.6.4	Production Testing. . . . .	533
	C14.6.5	Determination of Force–Deflection Characteristics. . . . .	534
	C14.6.6	Test Specimen Adequacy. . . . .	534
C14.7		Design Review. . . . .	534
C15		DESIGN REQUIREMENTS FOR STRUCTURES WITH SUPPLEMENTAL ENERGY DISSIPATION. . . . .	535
	C15.1	Scope. . . . .	535
	C15.2	General Design Requirements. . . . .	535
	C15.2.2.1	Ground Motion Acceleration Histories. . . . .	535
	C15.2.3	Damping Device Requirements. . . . .	535
	C15.2.3.1	Device Classification. . . . .	535
	C15.2.3.4	Performance Objectives and System Redundancy. . . . .	536
C15.3		Properties of Energy Dissipation Devices. . . . .	537
	C15.3.1	Nominal Design Properties. . . . .	537
	C15.3.2	Maximum and Minimum Damper Properties. . . . .	537
C15.4		Analysis Procedure Selection. . . . .	537
	C15.4.1	General Limitations for the Linear Analysis Procedures. . . . .	537
C15.5		Nonlinear Dynamic Procedures. . . . .	537
	C15.5.1	General Requirements. . . . .	537
	C15.5.2.2	Velocity-Dependent Devices. . . . .	537
	C15.5.2.3	Other Types of Devices. . . . .	537
	C15.5.3	Accidental Eccentricity. . . . .	537
C15.7		Design Review. . . . .	538
C15.8		Required Tests of Energy Dissipation Devices. . . . .	538
	C15.8.2	Production Tests. . . . .	538
C15.10		Nonlinear Static Procedure. . . . .	538
	C15.10.2	Velocity-Dependent Devices. . . . .	538

C16	SYSTEM-SPECIFIC PERFORMANCE PROCEDURES . . . . .	539
C16.1	Scope . . . . .	539
C16.2	Special Procedure for Unreinforced Masonry . . . . .	539
C16.2.1	Scope . . . . .	539
C16.2.2	Condition of Existing Materials . . . . .	540
C16.2.2.2	Testing . . . . .	540
C16.2.2.3	Masonry Strength . . . . .	540
C16.2.3	Analysis . . . . .	541
C16.2.3.2	Diaphragms . . . . .	541
C16.2.3.5	New Vertical Elements . . . . .	541
C16.2.4	Other Components and Systems of URM Buildings . . . . .	542
C16.2.4.2	Out-of-Plane Demands . . . . .	542
C16.2.4.3	Wall Anchorage . . . . .	542
C16.2.5	Detailing for New Elements . . . . .	542
C17	TIER 1 CHECKLISTS . . . . .	545
C17.1	Basic Checklists . . . . .	545
C17.1.1	Very Low Seismicity Checklist . . . . .	545
C17.1.2	Basic Configuration Checklist . . . . .	545
C17.2	Structural Checklists for Building Types W1: Wood Light Frames, Small Residential . . . . .	545
C17.3	Structural Checklists for Building Type W2: Wood Frames, Large Residential, Commercial, Industrial, and Institutional . . . . .	545
C17.4	Structural Checklists for Building Types S1: Steel Moment Frames with Stiff Diaphragms, and S1A: Steel Moment Frames with Flexible Diaphragms . . . . .	545
C17.5	Structural Checklists for Building Types S2: Steel Braced Frames with Stiff Diaphragms, and S2A: Steel Braced Frames with Flexible Diaphragms . . . . .	545
C17.6	Structural Checklists for Building Type S3: Metal Building Frames . . . . .	545
C17.7	Structural Checklists for Building Type S4: Dual Systems with Backup Steel Moment Frames and Stiff Diaphragms . . . . .	545
C17.8	Structural Checklists for Building Types S5: Steel Frames with Infill Masonry Shear Walls and Stiff Diaphragms, and S5A: Steel Frames with Infill Masonry Shear Walls and Flexible Diaphragms . . . . .	545
C17.9	Structural Checklists for Building Type CFS1: Cold-Formed Steel Light-Frame Bearing Wall Construction, Shear Wall Lateral System . . . . .	545
C17.10	Structural Checklists for Building Type CFS2: Cold-Formed Steel Light-Frame Bearing Wall Construction, Strap-Braced Lateral Wall System . . . . .	546
C17.11	Structural Checklists for Building Type C1: Concrete Moment Frames . . . . .	546
C17.12	Structural Checklists for Building Types C2: Concrete Shear Walls with Stiff Diaphragms, and C2A: Concrete Shear Walls with Flexible Diaphragms . . . . .	546
C17.13	Structural Checklists for Building Types C3: Concrete Frames with Infill Masonry Shear Walls, and C3A: Concrete Frames with Infill Masonry Shear Walls and Flexible Diaphragms . . . . .	546
C17.14	Structural Checklists for Building Types PC1: Precast or Tilt-up Concrete Shear Walls with Flexible Diaphragms, and PC1A: Precast or Tilt-up Concrete Shear Walls with Stiff Diaphragms . . . . .	546
C17.15	Structural Checklists for Building Type PC2: Precast Concrete Frames with Shear Walls . . . . .	546
C17.16	Structural Checklists for Building Type PC2A: Precast Concrete Frames without Shear Walls . . . . .	546
C17.17	Structural Checklists for Building Types RM1: Reinforced Masonry Bearing Walls with Flexible Diaphragms, and RM2: Reinforced Masonry Bearing Walls with Stiff Diaphragms . . . . .	546
C17.18	Structural Checklists for Building Types URM: Unreinforced Masonry Bearing Walls with Flexible Diaphragms, and URMA: Unreinforced Masonry Bearing Walls with Stiff Diaphragms . . . . .	546
C17.19	Nonstructural Checklist . . . . .	546
C18	REFERENCES . . . . .	547
	INDEX . . . . .	561

## PREFACE

This 2023 edition of ASCE/SEI 41 *Seismic Evaluation and Retrofit of Existing Buildings* is a revision to the 2017 edition. A summary of the most significant changes that are in the ASCE/SEI 41-23 standard includes the following:

### Chapter 1

- Revised the chapter to move significant material to commentary
- Changed the quality assurance, testing, and structural observation provisions to align with the *International Building Code*

### Chapter 2

- Reorganized the chapter sections to place performance levels and Seismic Hazard Levels before Performance Objectives
- Adopted the 2018 USGS seismic hazard model and multi-period spectra
- Pointed to ASCE 7-22 for seismic hazard information, including new site class designations

### Chapter 3

- Revised the Common Building Type definitions for wood-framed buildings
- Added criteria related to changes in Seismic Hazard Level for Benchmark Buildings
- Revised the Benchmark Building code editions
- Added Benchmark Building criteria for Risk Category III structures

### Chapter 4

- Changed several of the Tier 1 Quick Check procedures

### Chapter 5

- Aligned the Tier 2 Knowledge Factor with the Tier 3 requirements
- Updated the Tier 2 evaluation requirements for Steel Deck diaphragms
- Updated the Tier 2 Deficiency-Based Retrofit requirements to include retrofit-specific requirements on the resulting structure, design and detailing requirements, and definition of the scope of evaluation requirements for existing components

### Chapter 6

- Revised the condition assessment and data collection requirements
- Eliminated the dependence of performance level for data collection and material testing
- Granted permission to use material property bounding in a nonlinear analysis in lieu of material testing

### Chapter 7

- Aligned the dead and live load specifications with those of ASCE 7
- Aligned the snow load specifications with the new risk-targeted snow loads of ASCE 7
- Updated the viscous damping specifications
- Clarified that diaphragm ties, interconnection, wall out-of-plane anchorage, and wall out-of-plane demands are force-controlled actions

- Updated diaphragm specifications to better account for force transfer between offset vertical elements, to eliminate the linear static floor on linear dynamic forces, to allow diaphragm forces to be taken directly from a linear dynamic model or nonlinear static model, and to allow limited deformation-controlled acceptance for components modeled as linear elements in nonlinear static or dynamic analysis
- Revised the limitations for linear analysis to categorically allow linear analysis for certain simple model building types and to allow linear analysis for in-plane and out-of-plane discontinuities if the elements are treated as force-controlled
- Revised the linear lateral force specifications to be based on the new multi-period response spectra of ASCE 7
- Eliminated the J factor and added a minimum demand/capacity-based alternate for force-controlled actions
- Created specifications for modeling and acceptance of fiber elements
- Clarified the definitions of critical and noncritical elements
- Defined the valid range of modeling for unacceptable response
- Added a transient response limitation for unacceptable response
- Separated project-specific testing from general testing specifications
- Created specifications for the development of modeling parameters and acceptance criteria based on large data sets for general use
- Eliminated the use of monotonic testing except in the case of calibration of adaptive hinges
- Revised the specifications to explicitly set the Damage Control point on the generalized force-displacement curve
- Expanded the force-displacement curve beyond the Collapse Prevention point to the point of loss of vertical load-carrying capacity
- Revised the specifications to eliminate local acceptance criteria for Collapse Prevention of noncritical elements
- Added new requirements to check sliding at the soil-structure interface

### Chapter 8

- Restructured the chapter to have a more logical flow when navigating the chapter based on the building foundation type, shallow or deep
- For buildings on shallow foundations, added a new section to select the appropriate analysis procedure for foundation evaluation based on foundation and superstructure characteristics prior to performing the analysis
- Added a simplified procedure for rapid evaluation of the foundation when certain conditions are met by idealizing the foundation into individual foundation segments
- Eliminated analysis procedures for shallow foundations using Methods 1-2 and 3, and foundation can be modeled as fixed base or a flexible base using linear or nonlinear analysis procedures
- Added a new section for selection of the analysis procedure
- Removed the requirement for building analysis using upper and lower bound soil properties
- Defined a new term to represent the soil short-term soil bearing capacity which is equivalent to the upper bound

soil bearing capacity value permitted to be used for foundations modeled as a fixed base or flexible base

- Determined foundation acceptance based on foundation action, either overturning axial load action, or overturning moment and axial load actions on the foundation
- Added different criteria when evaluating the foundation depending if the building is on isolated spread footings, combined footings, or mat foundations
- Added alternate provisions to determine the minimum foundation width to be used to calculate the soil stiffness for buildings on Mat foundations
- Expanded the foundation overturning moment capacity acceptance to include bidirectional moments on the footing
- For linear analysis where soil springs resist both tension and compression, spring stiffness values are half the expected stiffness of the soil which is the previous lower bound soil stiffness value
- Updated the requirements for seismic increment of earth pressure on retaining walls, which need to be considered only for performance objects higher than life safety

#### Chapter 9

- Chapter 9 now references AISC 342 for the modeling parameters and acceptance criteria for structural steel, composite steel-concrete, and cast and wrought iron components
- AISC 342 revises the default material strengths for various steels
- AISC 342 revises the material testing requirements for welded components
- AISC 342 revises the modeling parameters and acceptance criteria for steel columns
- AISC 342 revises the modeling parameters and acceptance criteria for beam-column connection panel zones
- AISC 342 revises the modeling parameters and acceptance criteria for pre-Northridge WUF-B beam-column connections
- AISC 342 revises the modeling parameters and acceptance criteria for welded bottom haunch with slab to include minimum requirements for the composite slab
- AISC 342 revises the modeling parameters and acceptance criteria for AISC 341 conforming beam-column connections
- AISC 342 revises the modeling parameters and acceptance criteria for steel braces in both tension and compression, with a particular impact on braces with thin walls
- AISC 342 adds explicit requirements to evaluate partial penetration welded column splices
- AISC 342 changes the designation of untopped steel deck diaphragms from force-controlled to deformation controlled and provides modeling parameters and acceptance criteria for them
- AISC 342 provides modeling parameters and acceptance criteria for concrete-filled steel deck diaphragms
- AISC 342 updates requirements for cast and wrought iron columns

#### Chapter 10

- 9 now references ACI 369.1 for the modeling parameters and acceptance criteria for structural steel, composite steel-concrete, and cast and wrought iron components
- ACI 369.1 revises the means to classify structural walls as shear or flexure controlled
- ACI 369.1 revises the modeling parameters and acceptance criteria for flexure controlled structural walls

- The standard modifies ACI 369.1 to revise the modeling parameters and acceptance criteria for structural walls governed by shear or shear friction at the base of the wall
- The standard modified ACI 369.1 to permit deformation-controlled actions in foundation components using modeling parameters and acceptance criteria for similar superstructure components

#### Chapter 11

- Revised the diagonal tension strength calculation for URM spandrels
- Clarified requirements for Comprehensive Testing of masonry
- Revised and expanded the provisions for anchorage to masonry walls
- Permitted the use of force redistribution in URM deformation-controlled lines of resistance
- Revised the linear  $m$ -factors for URM walls to permit evaluation of axial load ratios between 4% and 8%
- Revised the Collapse Prevention, Damage Control, and Limited Safety acceptance criteria for URM walls subject to out-of-plane actions to be consistent with the Life Safety procedure; a similar revision was also made to the Chapter 16 provisions for out-of-plane evaluation
- Completely rewritten provisions for Reinforced Masonry Walls and Wall Piers subject to in-plane actions
- Added provisions to allow the evaluation of nonconforming lap splices in Reinforced Masonry
- Added provisions for evaluation of masonry diaphragms

#### Chapter 12

- Revised Table 12.2-2 for single straight sheathed lumber diaphragms to clarify applicability of default properties whether the diaphragm is chorded or unchorded and accompanied by addition of a simplified diaphragm deflection equation
- Updated reference standards, including ASTM D245, ASTM D5457, US DOC PS 1, US DOC PS2, AWC National Design Specification (NDS) for Wood Construction, and AWC Special Design Provisions for Wind and Seismic (SDPWS)
- Updated criteria for determination of expected strength from SDPWS tabulated nominal strengths for shear walls and diaphragms to coordinate with reference to the 2021 Special Design Provisions for Wind and Seismic (SDPWS)
- Retitled Chapter 12 to “Wood” to reflect broad applicability of requirements beyond wood Light-frame construction; implemented consistent terminology for lumber sheathed systems throughout Chapter 12
- Revised Section 12.3.3.1 to clarify that demands on wood elements as well as bodies of metal connections are considered force-controlled actions

#### Chapter 13

- Reorganized the chapter to provide a more logical description of the process
- Revised Table 13-1 to eliminate the column for evaluation procedure and added section references
- Moved evaluation criteria from footnotes to Table 13-1 into the scope and acceptance criteria for the components
- Added tables of coefficients for calculation of seismic forces from ASCE 7-16
- Added a new section to clarify the requirements for determining capacity of new and existing nonstructural components
- Added a new procedure for evaluating overturning resistance for unanchored equipment

- Added criteria for evaluation of penthouses and clay tile roofs
- Clarified the requirements for evaluation of mechanical and electrical distribution systems
- Added a procedure for evaluation of multilevel steel storage racks

#### Chapter 14

- Revised the number of ground motions required and period range of interest for seismically isolated buildings that use the nonlinear dynamic procedure
- Editorially rewrote much of Chapter 14 for seismically isolated buildings for alignment with ASCE 7 Chapter 17
- Revised prototype test specimen adequacy/acceptance criteria for seismically isolated buildings

#### Chapter 15

- Revised the number of ground motions required and period range of interest for buildings with supplemental energy dissipation that use the nonlinear dynamic procedure

- Revised the criteria for deformation-controlled actions for buildings with supplemental energy dissipation which use the linear analysis procedures

#### Chapter 16

- Clarified and revised the requirements for New Vertical Elements in URM buildings using Chapter 16
- Added minimum requirements for the transfer of URM wall anchorage forces into diaphragms using Chapter 16

#### Chapter 17

- Revised and added to the Tier 1 structural checklist statements related to diaphragms
- Revised the Tier 1 structural checklist statements related to foundations and overturning
- Added Tier 1 nonstructural checklist statements for penthouses and tile roofs

## ACKNOWLEDGMENTS

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## DEDICATION



Michael Mahoney

ASCE 41-23 is dedicated to Mike Mahoney, who recently retired from the Federal Emergency Management Agency (FEMA) after nearly 40 years of service, mostly as a project officer for earthquake engineering programs. Mike's tireless work at FEMA led to many significant updates to this standard and its predecessor FEMA publications. He passionately advocated for FEMA to fund projects that addressed issues related to the seismic safety of new and existing buildings. Many of the FEMA-funded projects he championed and led resulted in material that greatly impacted this standard. In addition to his advocacy for the seismic safety of existing buildings, Mike was involved in or led many FEMA-funded projects that contributed to improvements in ASCE 7-22 *Minimum Design Loads and*

*Associated Criteria for Buildings and Other Structures*. Following the Northridge earthquake, Mike served as FEMA's project officer for the SAC Steel project, resulting in the formation of much of the criteria embedded in ASCE 41 and its referenced standards for steel structures. Of all of Mike's contributions, the most significant to this standard may be his leadership in the formation of a FEMA-funded project, Update Seismic Retrofit Design Guidance, focused solely on technical development, advancement, and improvement of performance-based evaluation and retrofit provisions in ASCE 41. This project has already contributed significantly to ASCE 41-23, and ongoing work will help ensure that future editions remain a cutting-edge resource for performance-based treatment of existing buildings.





## CHAPTER 1 GENERAL REQUIREMENTS

### 1.1 SCOPE

This standard, *Seismic Evaluation and Retrofit of Existing Buildings*, referred to herein as “this standard,” specifies provisions for the seismic evaluation and retrofit of buildings. Seismic evaluation and retrofit of existing buildings shall comply with requirements of this standard to demonstrate compliance or non-compliance with, or achievement of Performance Objectives. Definitions and notation used throughout this standard are contained in Section 1.2. References used throughout this standard are cited separately in Chapter 18. Where standards are referenced and no edition or date is appended, then the edition or dated document listed in Chapter 18 is to be used. The processes for using this standard for seismic evaluation and retrofit and the associated procedures are defined in Sections 1.3 and 1.4, respectively.

### 1.2 DEFINITIONS AND NOTATION

#### 1.2.1 Definitions

**Acceleration-Sensitive Component:** A component that is sensitive to, and subject to, damage from inertial loading.

**Acceptance Criteria:** Limiting values of properties, such as drift, strength demand, and inelastic deformation, used to determine the acceptability of a component at a given Performance Level.

**Action:** An internal moment, shear, torque, axial force, deformation, displacement, or rotation corresponding to a displacement caused by a structural degree of freedom; designated as force or deformation controlled.

**Active Fault:** A fault for which there is an average historic slip rate of 0.04 in. (1 mm) per year or more and evidence of seismic activity within Holocene times (the last 11,000 years).

**Adaptive Model:** An element model where component non-linear action is represented by a force–deformation curve whose points change in the mathematical model based on the previous loading undergone in the mathematical model. Adaptive models should be capable of acceptable representing monotonic and cyclic response, and cyclic response to different loading protocols, as demonstrated by laboratory test data.

**Aspect Ratio:** Ratio of full height to length for concrete and masonry shear walls; ratio of story height to length for wood shear walls; ratio of span to depth for horizontal diaphragms.

**Assembly:** Two or more interconnected components.

**Authority Having Jurisdiction:** The organization, political subdivision, office, or individual legally charged with responsibility for administering and enforcing the provisions of this standard.

**Balloon Framing:** Continuous stud framing from sill to roof, with intervening floor joists nailed to studs and supported by a let-in ribbon.

**Base:** The level at which the horizontal seismic ground motions are considered to be imparted to the structure.

**Basic Performance Objective for Existing Buildings (BPOE):** A series of defined Performance Objectives based on a building’s risk category meant for evaluation and retrofit of existing buildings. See Section 2.2.1.

**Basic Performance Objective Equivalent to New Building Standards (BPON):** A series of defined Performance Objectives based on a building’s risk category meant for evaluation and retrofit of existing buildings to achieve a level of performance commensurate with the intended performance of buildings designed to a standard for new construction. See Chapter 2.

**Beam:** A structural member whose primary function is to carry loads transverse to its longitudinal axis.

**Bearing Wall:** A wall that supports gravity loads of at least 200 lb/ft (2,919 N/m) from floors or roofs.

**Bed Joint:** The horizontal layer of mortar on which a masonry unit is laid.

**Benchmark Building:** A building designed and constructed or evaluated to a specific performance level using an acceptable code or standard listed in Table 4-6.

**Boundary Component:** A structural component at the boundary of a shear wall or a diaphragm or at an edge of an opening in a shear wall or a diaphragm that possesses tensile or compressive strength to transfer lateral forces to the seismic-force-resisting system.

**Braced Frame:** A structural system consisting of vertical, horizontal, and diagonal structural components joined by concentric or eccentric connections. See **Concentrically Braced Frame** or **Eccentrically Braced Frame**.

**BSE-1E:** Basic Safety Earthquake-1 for use with the Basic Performance Objective for Existing Buildings, taken as a seismic hazard with a 20% probability of exceedance in 50 years, but not greater than the BSE-1N, at a site.

**BSE-1N:** Basic Safety Earthquake-1 for use with the Basic Performance Objective Equivalent to New Building Standards, taken as two-thirds of the BSE-2N at a site.

**BSE-1X:** Basic Safety Earthquake-1, either the BSE-1E or BSE-1N.

**BSE-2E:** Basic Safety Earthquake-2 for use with the Basic Performance Objective for Existing Buildings, taken as a seismic hazard with a 5% probability of exceedance in 50 years, but not greater than the BSE-2N, at a site.

**BSE-2N:** Basic Safety Earthquake-2 for use with the Basic Performance Objective Equivalent to New Building Standards, taken as the ground shaking based on the Risk-Targeted Maximum Considered Earthquake ( $MCE_R$ ) per ASCE 7 at a site.

**BSE-2X:** Basic Safety Earthquake-2, either the BSE-2E or BSE-2N.