

ASCE STANDARD

ASCE/SEI

41-23

Seismic Evaluation and Retrofit of Existing Buildings

Currently in preview, click to buy full version

ASCE STANDARD

ASCE/SEI

41-23

Seismic Evaluation and Retrofit of Existing Buildings



PUBLISHED BY THE AMERICAN SOCIETY OF CIVIL ENGINEERS

Library of Congress Cataloging-in-Publication Data

Names: Structural Engineering Institute, author. | American Society of Civil Engineers, issuing body.

Title: Seismic evaluation and retrofit of existing buildings.

Other titles: ASCE/SEI 41-23

Description: Reston, Virginia : American Society of Civil Engineers, [2023] | Series: ASCE standard | "ASCE, American Society of Civil Engineers, SEI, ASCE, Structural Engineering Institute." | Includes bibliographical references and index. | Summary: "ASCE/SEI 41-23 describes deficiency-based and systematic procedures that use performance-based principles to evaluate and retrofit existing buildings to withstand the effects of earthquakes"— Provided by publisher.

Identifiers: LCCN 2023014494 | ISBN 9780784416112 (soft cover) | ISBN 9780784484760 (PDF)

Subjects: LCSH: Buildings—Earthquake effects. | Earthquake resistant design—Standards—United States. | Earthquake hazard analysis.

Classification: LCC TH1095 .S76 2023 | DDC 693.8/52—dc23/eng/20230809

LC record available at <https://lccn.loc.gov/2023014494>

Published by American Society of Civil Engineers

1801 Alexander Bell Drive

Reston, Virginia, 20191-4382

www.asce.org/bookstore | ascelibrary.org

This standard was developed by a consensus standards development process that has been accredited by the American National Standards Institute (ANSI). Accreditation by ANSI, a voluntary accreditation body representing public and private sector standards development organizations in the United States and abroad, signifies that the standards development process used by ASCE has met the ANSI requirements for openness, balance, consensus, and due process.

While ASCE's process is designed to promote standards that reflect a fair and reasoned consensus among all interested participants, while preserving the public health, safety, and welfare that is paramount to its mission, it has not made an independent assessment of and does not warrant the accuracy, completeness, suitability, or utility of any information, apparatus, product, or process discussed herein. ASCE does not intend, nor should anyone interpret, ASCE's standards, to replace the sound judgment of a competent professional, having knowledge and experience in the appropriate field(s) of practice, nor to substitute for the standard of care required of such professionals in interpreting and applying the contents of this standard.

ASCE has no authority to enforce compliance with its standards and does not undertake to certify products for compliance or to render any professional services to any person or entity.

ASCE disclaims any and all liability for any personal injury, property damage, financial loss, or other damages of any nature whatsoever, including without limitation any direct, indirect, special, exemplary, or consequential damages, resulting from any person's use of, or reliance on, this standard. Any individual who relies on this standard assumes full responsibility for such use.

ASCE and American Society of Civil Engineers—Registered in US Patent and Trademark Office.

Photocopies and permissions. Permission to photocopy or reproduce material from ASCE publications can be requested by sending an e-mail to permissions@asce.org or by locating a title in ASCE's Civil Engineering Database (<https://cedb.asce.org>) or ASCE Library (<https://ascelibrary.org>) and using the "Permissions" link.

Errata: Errata, if any, can be found at <https://doi.org/10.1061/9780784416112>.

Copyright © 2023 by the American Society of Civil Engineers.

All Rights Reserved.

ISBN 978-0-7844-1611-2 (soft cover)

ISBN 978-0-7844-8476-0 (PDF)

Manufactured in the United States of America.

27 26 25 24 23 1 2 3 4 5

ASCE STANDARDS

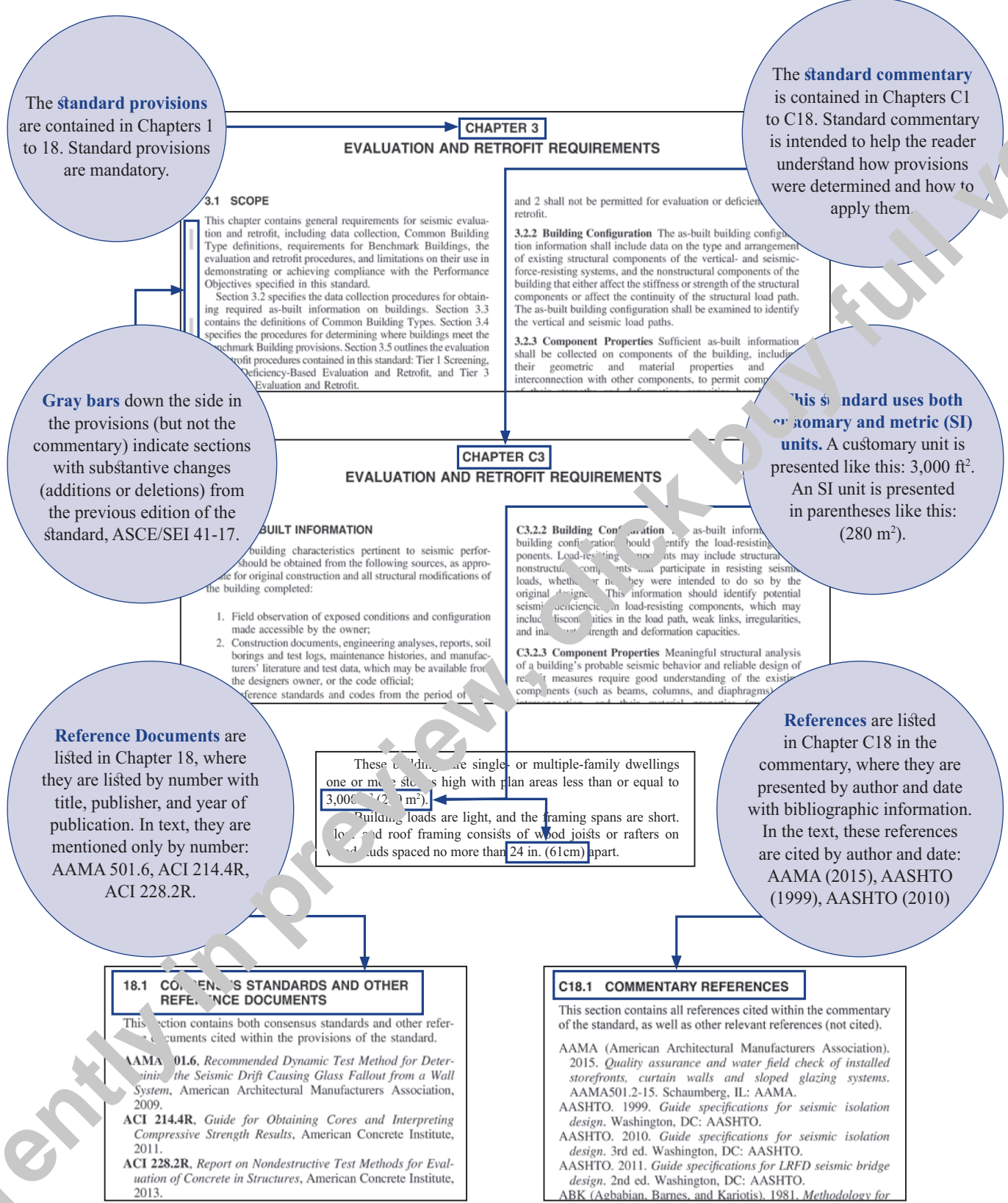
In 2016, the Board of Direction approved revisions to the ASCE Rules for Standards Committees to govern the writing and maintenance of standards developed by ASCE. All such standards are developed by a consensus standards process managed by the ASCE Codes and Standards Committee. The consensus process includes balloting by a balanced standards committee and reviewing during a public comment period. All standards are revised or reaffirmed every five years, unless approved for an extension. Requests for formal interpretations shall be processed in accordance with Section 7 of ASCE Rules for Standards Committees, which are available at www.asce.org. Errata, addenda, supplements, and interpretations, if any, for this standard can also be found at www.asce.org.

The provisions of this document are written in permissive language and, as such, offer the user a series of options or instructions but do not prescribe a specific course of action. Significant judgment is left to the user of this document.

This standard has been prepared in accordance with recognized engineering principles and should not be used without the user's competent knowledge for a given application. The publication of this standard by ASCE is not intended to warrant that the information contained therein is suitable for any general or specific use, and ASCE takes no position respecting the validity of patent rights. The user is advised that the determination of patent rights or risk of infringement is entirely their own responsibility.

A complete list of currently available standards is available in the ASCE Library (<https://ascelibrary.org/page/books/s-standards>).

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). Below these are buttons for 'FULL REPORT' and 'SUMMARY'. A 'Seismic Details' panel is open, showing a table of seismic coefficients and a 'Multi-Period Design Spectrum' graph. The table includes values for S_S (1.56), S_1 (0.6), S_{MS} (1.8), S_{M1} (1.75), S_{DS} (1.2), S_{D1} (1.17), T_L (12), and PGA_M (0.63). The graph shows a red shaded area representing the seismic hazard spectrum. A map of the San Francisco Bay Area is visible on the right side of the interface.

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_{M1} , S_{DS} , S_{D1} , T_L , PGA_M , and V_{S30} , plus the seismic design category, as well as the multi-period spectrum, the multi-period MCE_R spectrum, the two-period design spectrum, and the two-period MCE_R 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-ft². target areas



amplify.asce.org



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.**

Amplify offers enhancements that are exclusive to the platform version of these standards, including

- One-click syncing between Provisions and Commentary;
- Redlining feature to quickly spot changes between editions;
- Two-level search functionality
 - Site-wide search returns results across standards at the chapter and section levels;
 - Product level search returns specific results within the standard you are searching;
- Critical real-time incorporation of supplements and errata with date stamps;
- Fully integrated third-party tool to manage personal notes, annotations, and bookmarking;
- Bonus customary and SI unit measurements included. Customize your display in the user account settings;
- Individual and corporate subscriptions available.

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

For information
or demo, contact:

amplifytools@asce.org

CONTENTS

ASCE STANDARDS		iii
TIPS FOR USING THIS STANDARD		iv
TIPS FOR USING THE ASCE HAZARD TOOL		
PREFACE		xxxvii
ACKNOWLEDGMENTS		xi
DEDICATION		xliv
UNIT CONVERSIONS		xlv
1 GENERAL REQUIREMENTS		1
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
2 PERFORMANCE OBJECTIVES AND SEISMIC HAZARDS		21
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.	5
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	Concentrically 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

14.7	14.6.6	Test Specimen Adequacy	210
		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
---	-----

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

ASCE/SEI 41-23 Seismic Evaluation and Retrofit of Existing Buildings

Voting Members

Robert George Pekelnicky, P.E., S.E., F.SEI, M.ASCE, *Chair*
Peter W. Somers, P.E., S.E., M.ASCE, *Vice Chair*
Russell A. Berkowitz, P.E., S.E., M.ASCE
David Bonowitz, S.E.
Michael Thomas Braund Jr., P.E., S.E., M.ASCE
Scott Campbell, Ph.D., P.E., M.ASCE
Jeff J. Dragovich, Ph.D., P.E., M.ASCE
Wassim M. Ghannoum, Ph.D., P.E., F.SEI, M.ASCE
Satyendra K. Ghosh, Ph.D., F.SEI, F.ASCE
Nathaniel P. Gonner, S.E., M.ASCE
Ronald O. Hamburger, P.E., S.E., F.SEI
John L. Harris, Ph.D., P.E., S.E., F.SEI, M.ASCE
Brian Edward Kehoe, P.E., S.E., F.SEI, F.ASCE
Philip Line, P.E., M.ASCE
Roy F. Lobo, Ph.D., S.E., M.ASCE
Terry R. Lundeen, P.E., S.E., M.ASCE
Bonnie E. Manley, P.E., F.SEI, M.ASCE
Matthew C. McBride, S.E., M.ASCE
James McDonald, P.E., S.E., Aff.M.ASCE
Mark A. Moore, S.E., M.ASCE
James C. Parker, P.E., S.E., M.ASCE
Owen Arthur Rosenboom, Ph.D., P.E., S.E., M.ASCE
Brandt W. Saxey, P.E., S.E., M.ASCE
Marko Ilke Schotanus, Ph.D., P.E., S.E., M.ASCE
John F. Silva, P.E., S.E., F.SEI, M.ASCE
John M. Tehaney, P.E., S.E., M.ASCE
Eugene L. Trahern, P.E., S.E., M.ASCE
William Tremayne, P.E., S.E.
Frederick Michael Turner, P.E., S.E., M.ASCE
Ryan Turner, P.E., S.E.
Reid B. Zimmerman, P.E., S.E., M.ASCE

Associate Members

David Mark Martin, S.E., A.M.ASCE, *Secretary*
Ian Aiken, Ph.D., P.E., M.ASCE
Shahen Akelyan, P.E., S.E.
Juan Aleman, Ph.D., P.E.
Abdalsattar Alfarra, M.ASCE
Mohammad AlHamaydeh, Ph.D., P.E., F.SEI, M.ASCE
Mohammad Aliaari, Ph.D., P.E., S.E.
Christina Aronson, P.E., S.E., M.ASCE
Alireza Asgari, Ph.D., S.E.
Ari Peter Baranian, P.E., M.ASCE
Daniel Terence Tasman Bech, P.E., S.E., M.ASCE
Randall P. Bernhardt, P.E., F.SEI, F.ASCE
David T. Biggs, P.E., S.E., F.SEI, Dist.M.ASCE
William B. Black, P.E., M.ASCE
Katie Boisseree,
Matthew E. Bowers, P.E., M.ASCE
Michael Brekken, P.E.
Sergio Francisco Breña, Ph.D., M.ASCE
Wayne Brown, P.E., S.E.
Francisco Chitty, Ph.D.
Carlo Citto, P.E., M.ASCE
Richard Patrick Clarke, Ph.D., M.ASCE
Rebecca Hix Collins, P.E., S.E., M.ASCE

Paul P. Cordova, Ph.D., P.E., S.E.
William Sandy Cumming, P.E.
Maikol Del Carpio Ramos, Ph.D., P.E., Aff.M.ASCE
Hossein Derakhshan,
Nancy H. Devine, P.E., S.E.
William R. Earl, P.E., S.E., M.ASCE
Kenneth John Elwood, Ph.D.
Konrad Brian Eriksen,
Farrokh Fazileh, Ph.D., P.Eng, M.ASCE
Omar Leonel Garza, P.E., S.E., M.ASCE
Daniel Gaspar Rodriguez, P.E.
Babak Gerami, P.E., S.E., M.ASCE
Amir S. J. Gilani, Ph.D., S.E., M.ASCE
Ivan Giongo, Ph.D., P.E., S.E.
Max A. Gregersen, P.E., S.E., M.ASCE
Selim Gunay, Ph.D.
Mahmoud Mhd Hachem, Ph.D., P.E., M.ASCE
Garrett Richard Hagen, P.E., M.ASCE
Arne Halterman, P.E., S.E.
Andrew Herseth, P.E., S.E., M.ASCE
John Hinchcliffe, P.E., M.ASCE
Darrick B. Hom, P.E., S.E., M.ASCE
Jonas Houston, S.E., A.M.ASCE
Jen-Kan Hsiao, Ph.D., P.E.
Timothy Eugene Huff, Ph.D., P.E., M.ASCE
Brian W. Hulsey, P.E.
Saif Mohammed Hussain, P.E., S.E., F.SEI, LM.ASCE
Jason Maxwell Ingham, M.ASCE
Robert C. Jackson, P.E., F.SEI, F.ASCE
Adam Jongeward, P.E., S.E., M.ASCE
Kamalpreet Singh Kalsi, S.E.
M. R. Karim, Ph.D., P.E., S.E., M.ASCE
Mehrshad Ketabdar, P.E., S.E., M.ASCE
Hayne Kim, Ph.D., S.E., M.ASCE
Insung Kim, Ph.D., P.E., M.ASCE
Allison Konwinski, P.E., S.E.
Lawrence Francis Kruth, P.E., M.ASCE
Amit Kumar, P.E., S.E.
Sashi K. Kunnath, Ph.D., P.E., F.SEI, F.ASCE
Bruce Lloyd Kutter, Ph.D., M.ASCE
Lynsey Willadsen LaScola, P.E., M.ASCE
Ron C. Larsen, P.E.
Dimitrios Lignos, Ph.D., M.ASCE
Bret J. Lizundia,
Richard Jay Love, P.E., S.E., M.ASCE
Bruce Maison, P.E., S.E.
Aaron Charles Malatesta, P.E.
Dion Marriott, Ph.D., S.E.
Mustafa Mashal, Ph.D., P.E., CP.Eng, IntPE(NZ), M.ASCE
Mohammed Masmoum, R.Eng, M.ASCE
Anthony Thomas Massari, Ph.D., P.E., M.ASCE
Adolfo B. Matamoros, Ph.D., P.E., F.SEI, M.ASCE
Ronald L. Mayes, Ph. D., M.ASCE
John S. McDonald, P.E., S.E., M.ASCE
Russell McLellan, P.E., S.E.
Matthew J. Michnewich, P.E., S.E., M.ASCE
Gary Lee Mochizuki, P.E., S.E., M.ASCE

Ammar Khalil Mohammed, M.ASCE
 Douglas Michael Moon, P.E., S.E., M.ASCE
 Kevin S. Moore, P.E., S.E., M.ASCE
 Guillermo Morado, P.E., M.ASCE
 Justin Cole Moresco, P.E., M.ASCE
 Hossein Mostafaei, Ph.D., M.ASCE
 Konstantinos Oikonomou, Ph.D., P.E., M.ASCE
 Milad Oliae, Ph.D., P.E.
 Stuart J. Oliver, S.E., M.ASCE
 Brian Olson,
 Baki Ozturk, Ph.D., M.ASCE
 Conrad Paulson, P.E., M.ASCE
 Jennifer Anna Pazdon, P.E.
 Daniel E. Pradel, Ph.D., P.E., G.E., D.GE, F.ASCE
 Nikhil Raut, Ph.D., P.E., PMP, M.ASCE
 Ricardo Roldan, Ph.D., PE
 Shubin Ruan, Ph.D., P.E., M.ASCE
 Keri L. Ryan, A.M.ASCE
 Mehrdad Sasani, Ph.D., P.E., F.SEI, F.ASCE
 Siamak Sattar, Ph.D., A.M.ASCE
 Benjamin W. Schafer, Ph.D., P.E., F.SEI, M.ASCE
 Arturo Ernest Schultz, Ph.D., A.M.ASCE
 Halil Sezen, Ph.D., P.E., F.SEI, F.ASCE
 Raju Sharma
 Pui-Shum Benson Shing, Ph.D., M.ASCE
 Constantine Shuhaibar, Ph.D., P.E.
 Dan Sloat
 Rob Smith, C.Eng, P.E., S.E., M.ASCE
 David Sommer, P.E., S.E., M.ASCE
 Matthew Speicher, Ph.D., A.M.ASCE
 Andreas Stavridis, Ph.D., A.M.ASCE
 Spencer Straub, P.E., S.E., M.ASCE
 Ali Sumer, Ph.D., S.E.
 Kenneth Tam, P.E., S.E.
 Bryce G. Tanner, S.E.
 Charles Conrad Thiel, Ph.D.
 Seth Thomas, P.E., S.E., M.ASCE
 Christos V. Tokas
 Kevin Quinn Walsh, Ph.D., P.E., S.E.
 Zachary J. Whitman, P.E., S.E., A.M.ASCE
 Andrew S Whittaker, Ph.D., P.E., S.E., F.SEI, F.ASCE
 Gergis W. William, Ph.D., P.E., F.SEI, F.ASCE
 Kevin Wong, M.ASCE
 Ben Yousefi, P.E., S.E.
 Victor A. Zayas, P.E., M.ASCE
 Daniel Zepeda, P.E., S.E.

Subcommittee for General Requirements

Robert George Pekelnicky, P.E., S.E., F.SEI, M.ASCE, *Chair*
 Shahen Akelyan, P.E., S.E.
 William B. Black, P.E., M.ASCE
 Katie Boisseree, P.E.
 David Bonowitz, S.E.
 Matthew E. Bowers, P.E., M.ASCE
 Michael Thomas Braund Jr., P.E., S.E., M.ASCE
 Rebecca Hix Collins, P.E., S.E., M.ASCE
 Roy F. Lobo, Ph.D., S.E., M.ASCE
 Nico Luco, Ph.D.
 David Mark Martin, S.E., A.M.ASCE
 Baki Ozturk, Ph.D., M.ASCE
 Sanaz Rezaeian, Ph.D.
 Bryce G. Tanner, S.E.
 Zia Zafir, Ph.D., P.E., G.E.
 Daniel Zepeda, P.E., S.E.

Subcommittee for Analysis

Terry R. Lundeen, P.E., S.E., M.ASCE, *Chair*
 Mohammad AlHamaydeh, Ph.D., P.E., F.SEI, M.ASCE
 Mohammad Aliaari, Ph.D., P.E., S.E.
 Alireza Asgari, Ph.D., S.E.,
 Ari Baranian, P.E.
 Daniel Terence Tasman Bech, P.E., S.E., M.ASCE
 William B. Black, P.E., M.ASCE
 Maikol Del Carpio Ramos, Ph.D., P.E., Aff.M.ASCE
 Rebecca Hix Collins, P.E., S.E., M.ASCE
 Daniel Gaspar Rodriguez, P.E.
 Nikhil Raut, Ph.D., P.E., PMP, M.ASCE
 Babak Gerami, P.E., S.E., M.ASCE
 Adam Jongeward, P.E., S.E., M.ASCE
 Kamalpreet Singh Kalsi, S.E.
 Sashi K. Kunnath, Ph.D., P.E., F.SEI, F.ASCE
 Bruce Maison,
 Dion Marriott, Ph.D., S.E.
 Mohammed Masmoum, R.Eng, M.ASCE
 Matthew J. Michnewich, P.E., S.E., M.ASCE
 Kevin S. Moore, P.E., S.E., M.ASCE
 Baki Ozturk, Ph.D., M.ASCE
 Robert George Pekelnicky, P.E., S.E., F.SEI, M.ASCE
 Ricardo Roldan, Ph.D., P.E.
 Owen Arthur Rosenboom, Ph.D., P.E., S.E., M.ASCE
 Ali Roufegarinejad, Ph.D., P.E.
 Constantine Shuhaibar, Ph.D., P.E.
 Matthew Speicher, Ph.D., A.M.ASCE
 Zachary J. Whitman, P.E., S.E., A.M.ASCE
 Reid B. Zimmerman, P.E., S.E., M.ASCE

Subcommittee for Foundations

Abdalsattar Alfarra, M.ASCE
 Mohammad AlHamaydeh, Ph.D., P.E., F.SEI, M.ASCE
 Alireza Asgari, Ph.D., S.E.,
 William B. Black, P.E., M.ASCE
 Matthew E. Bowers, P.E., M.ASCE
 Maikol Del Carpio Ramos, Ph.D., P.E., Aff.M.ASCE
 Babak Gerami, P.E., S.E., M.ASCE
 Hayne Kim, Ph.D., S.E., M.ASCE
 Bruce Lloyd Kutter, Ph.D., M.ASCE
 Roy F. Lobo, Ph.D., S.E., M.ASCE
 Richard J. Love, P.E., M.ASCE
 David Mark Martin, A.M.ASCE
 Douglas Michael Moon, P.E., S.E., M.ASCE
 Kevin S. Moore, P.E., S.E., M.ASCE
 Mark A. Moore, S.E., M.ASCE
 Robert George Pekelnicky, P.E., S.E., F.SEI, M.ASCE
 Daniel Pradel, Ph.D., P.E., G.E., D.GE, F.ASCE
 Bryce G. Tanner, S.E.
 John M. Tehaney, P.E., S.E., M.ASCE
 Seth Thomas, P.E., S.E., M.ASCE
 Ryan Turner, P.E., S.E.

Subcommittee for Masonry

William Tremayne, P.E., S.E., *Subcommittee Chair*
 Juan Aleman, Ph.D., P.E.
 David T. Biggs, P.E., S.E., F.SEI, Dist.M.ASCE
 Carlo Citto, P.E., M.ASCE
 Nancy H. Devine, P.E., S.E.
 Dmytro Dizhur, Ph.D., A.M.ASCE
 Jennifer Eggers, P.E., S.E.
 Ivan Giongo, Ph.D., P.E., S.E.

Selim Gunay, Ph.D.
Amit Kumar, P.E., S.E.
Matthew C. McBride, S.E., M.ASCE
Milad Oliae, Ph.D., P.E.
Stuart J. Oliver, S.E., M.ASCE
Robert George Pekelnicky, P.E., S.E., F.SEI, M.ASCE
Pui-Shum Benson Shing, Ph.D., M.ASCE
Can Simsir, Ph.D., P.E., M.ASCE
David Sommer, P.E., S.E., M.ASCE
Andreas Stavridis, Ph.D., A.M.ASCE
Kenneth T. Tam, P.E., S.E.
John M. Tehaney, P.E., S.E., M.ASCE
Frederick Michael Turner, P.E., S.E., M.ASCE
Kevin Quinn Walsh, Ph.D.

Subcommittee for Steel

John L. Harris, Ph.D., P.E., S.E., F.SEI, M.ASCE, *Chair*
Bonnie E. Manley, P.E., F.SEI, M.ASCE, *Vice Chair*
Daniel Terence Tasman Bech, P.E., S.E., M.ASCE
Michael Thomas Braund Jr., P.E., S.E., M.ASCE
Paul P. Cordova
Kamalpreet Singh Kalsi, S.E.
Hayne Kim, Ph.D., S.E., M.ASCE
Seung Jai Ko, P.E., S.E., M.ASCE
Dimitrios Lignos, Ph.D., M.ASCE
Anthony Thomas Massari, Ph.D., P.E., M.ASCE
Baki Ozturk, Ph.D., M.ASCE
Jennifer Anna Pazdon, P.E.
Robert George Pekelnicky, P.E., S.E., F.SEI, M.ASCE
Brandt W. Saxey, P.E., S.E., M.ASCE
Benjamin W. Schafer, Ph.D., P.E., F.SEI, M.ASCE
Dan Sloat
Matthew Speicher, Ph.D., A.M.ASCE
Ali Sumer, Ph.D., S.E.

Subcommittee for Seismic Isolation and Energy Dissipation

Reid B. Zimmerman, P.E., S.E., M.ASCE, *Chair*
Ian Aiken, Ph.D., P.E., M.ASCE
Mohammad AlHamaydeh, Ph.D., P.E., F.SEI, M.ASCE
Cameron Black, Ph.D., P.E., M.ASCE
Nathan Canney, Ph.D., P.E., M.ASCE
Scott Darling, P.E.
Konrad Eriksen
Amir S. J. Gilani, Ph.D., S.E., M.ASCE
Saif Mohammed Hussain, P.E., S.E., F.SEI, M.ASCE
Kamalpreet Singh Kalsi, S.E.
M. Karim, Ph.D., P.E., S.E.
Roy Lobo, Ph.D., P.E., S.E., M.ASCE
Aaron Charles Malatesta, P.E.
Dion Marriott, Ph.D., S.E.
Ronald L. Mayes, P.E., M.ASCE
Mohammed Mohammed, Ph.D., P.E.
Baki Ozturk, Ph.D., M.ASCE
Robert George Pekelnicky, P.E., S.E., F.SEI, M.ASCE
Ricardo Roldan, Ph.D., P.E.
Ali Roufegarinejad, Ph.D., P.E.
Shubin Ruan, Ph.D., P.E., M.ASCE
Keri L. Ryan, A.M.ASCE
Constantine Shuhaibar, Ph.D., P.E.
William Tremayne, P.E., S.E.
Andrew S. Whittaker, Ph.D., P.E., S.E., F.SEI, F.ASCE
Victor A. Zayas, P.E., M.ASCE

Subcommittee for Tier 2

Russell Berkowitz, P.E., S.E., M.ASCE, *Chair*
Baki Ozturk, Ph.D., M.ASCE
Daniel Zepeda, P.E., S.E.
James Parker, P.E., S.E.
Kevin S. Moore, P.E., S.E., M.ASCE
Matthew J. Michnewich, P.E., S.E., M.ASCE
Michael Brekken, P.E.
Mark A. Moore, S.E., M.ASCE
Nik Blanchette, P.E.
Peter W. Somers, P.E., S.E., M.ASCE
Russell McLellan, P.E., S.E.
John M. Tehaney, P.E., S.E., M.ASCE

Subcommittee for Tier 1

Peter W. Somers, P.E., S.E., M.ASCE, *Chair*
David Bonowitz, S.E.
Michael Brekken, P.E.
William Sandy Cumming, P.E.
John Hinchcliffe, P.E., M.ASCE
Darrick B. Hom, P.E., S.E., M.ASCE
Brian Edward Kehoe, P.E., S.E., F.SEI, F.ASCE
Lynsey Willadsen LaScola, P.E., M.ASCE
Baki Ozturk, Ph.D., M.ASCE
James Parker, P.E., S.E.
Marko IJke Schotanus, Ph.D., P.E., S.E., M.ASCE
Eugene L. Trahern, P.E., S.E., M.ASCE
Daniel Zepeda, P.E., S.E.

Subcommittee for Wood

Philip Line, P.E., M.ASCE, *Chair*
Sandy Cumming, P.E.
Ivan Giongo, Ph.D., P.E., S.E.
Brian Edward Kehoe, P.E., S.E., F.SEI, F.ASCE
Bruce Maison, P.E., S.E.
Matthew C. McBride, S.E., M.ASCE
Gary Lee Mochizuki, P.E., S.E., M.ASCE
Robert George Pekelnicky, P.E., S.E., F.SEI, M.ASCE
Kenneth T. Tam, P.E., S.E.

Subcommittee for Concrete

Wassim M. Ghannoum, Ph.D., P.E., F.SEI, M.ASCE, *Chair*
Satyendra K. Ghosh, Ph.D., F.SEI, F.ASCE
Jeff J. Dragovich, Ph.D., P.E., M.ASCE
Brian Edward Kehoe, P.E., S.E., F.SEI, F.ASCE
Mark A. Moore, S.E., M.ASCE
Mohammad AlHamaydeh, Ph.D., P.E., F.SEI, M.ASCE
Ari Peter Baranian, P.E., M.ASCE
Sergio Francisco Breña, Ph.D., M.ASCE
Paul P. Cordova, Ph.D., P.E., S.E.
Garrett Richard Hagen, P.E., M.ASCE
Jonas Houston, S.E., A.M.ASCE
Mehrshad Ketabdar, P.E., S.E., M.ASCE
Hayne Kim, Ph.D., S.E., M.ASCE
Insung Kim, Ph.D., P.E., M.ASCE
Sashi K. Kunnath, Ph.D., P.E., F.SEI, F.ASCE
Adolfo B. Matamoros, Ph.D., P.E., F.SEI, M.ASCE
Matthew J. Michnewich, P.E., S.E., M.ASCE
Siamak Sattar, Ph.D., A.M.ASCE
Halil Sezen, Ph.D., P.E., F.SEI, F.ASCE
Ali Sumer, Ph.D., S.E.

Subcommittee for Material Testing

Robert George Pekelnicky, P.E., S.E., F.SEI, M.ASCE, *Chair*
Michael Thomas Braund Jr., P.E., S.E., M.ASCE
Carlo Citto, P.E., M.ASCE
John L. Harris, Ph.D., P.E., S.E., F.SEI, M.ASCE
Hayne Kim, Ph.D., S.E., M.ASCE
Insung Kim, Ph.D., P.E., M.ASCE
Philip Line, P.E., M.ASCE
Roy F. Lobo, Ph.D., S.E., M.ASCE
Conrad Paulson, P.E., M.ASCE

Subcommittee for Nonstructural

Brian Edward Kehoe, P.E., S.E., F.SEI, F.ASCE, *Chair*
David Bonowitz, S.E.
Michael Brekken, P.E.
Scott Campbell, Ph.D., P.E., M.ASCE
Maikol Del Carpio Ramos, Ph.D., P.E., Aff.M.ASCE
Babak Gerami, P.E., S.E., M.ASCE
Darrick B. Hom, P.E., S.E., M.ASCE
Mehrshad Ketabdar, P.E., M.ASCE
Guillermo Morado, P.E., M.ASCE
Konstantinos Oikonomou, Ph.D., P.E., M.ASCE
John M. Tehaney, P.E., S.E., M.ASCE

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.