ASCE STANDARD

ASCE/SEI

41-23

Seismic Evaluation and Retrofit of Existing Buildings

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AMERICAN SOCIETY OF CIVIL ENGINEERS

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STRUCTURAL ENGINEERING INSTITUTE

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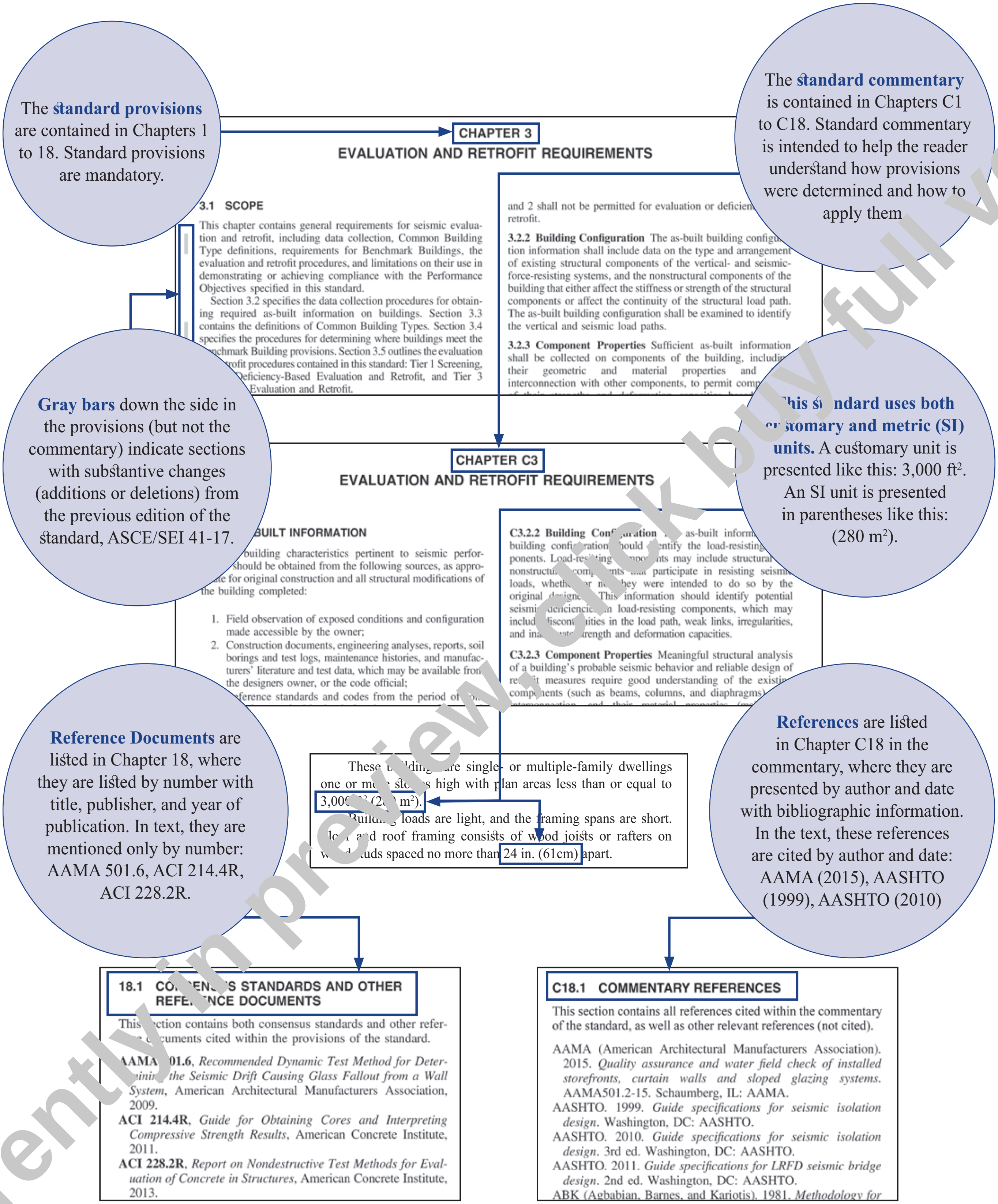

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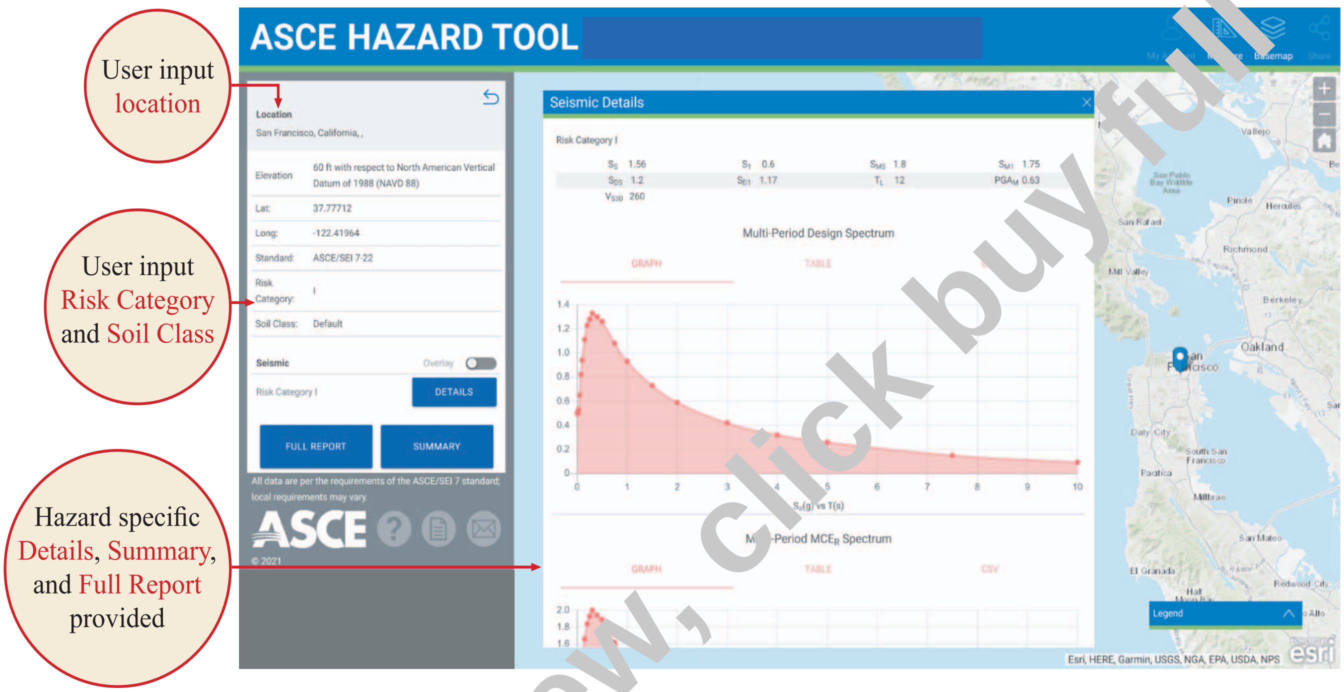

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CONTENTS

Commentary to Standard ASCE/SEI 41-23

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

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DEDICATION

Michael Mahoney

ASCE 41-23 is dedicated to Mike Mahoney, who recently retired from the Federal Emergency Management Agency (FEMA) after nearly 40 years of service, mostly as a project officer for earthquake engineering programs. Mike's tireless work at FEMA led to many significant updates to this standard and its predecessor FEMA publications. He passionately advocated for FEMA to fund projects that addressed issues related to the seismic safety of new and existing buildings. Many of the FEMA-funded projects he championed and led resulted in material that greatly impacted this standard. In addition to his advocacy for the seismic safety of existing buildings, Mike was involved in or led many FEMA-funded projects that contributed to improvements in ASCE 7-22 *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*. Following the Northridge earthquake, Mike served as FEMA's project officer for the SAC Steel project, resulting in the formation of much of the criteria embedded in ASCE 41 and its referenced standards for steel structures. Of all of Mike's contributions, the most significant to this standard may be his leadership in the formation of a FEMA-funded project, Update Seismic Retrofit Design Guidance, focused solely on technical development, advancement, and improvement of performance-based evaluation and retrofit provisions in ASCE 41. This project has already contributed significantly to ASCE 41-23, and ongoing work will help ensure that future editions remain a cutting-edge resource for performance-based treatment of existing buildings.

UNIT CONVERSIONS

SI Units	*Customary Units*
Measurement	
m = meter (SI base unit of length)	yd = yard
cm = centimeter	in. = inch
km = kilometer	mi = mile
ha = hectare	acre
L = liter (S.I. base unit of volume)	gal. = gallon
mL = milliliters	qt = quart
kg = kilogram (SI base unit of mass)	lb = pound
g = gram	oz = ounce
N = Newton ($m{\cdot}kg{\cdot}s^2$)	lbf = pound-force (lb/ft)
Pa = Pascals (N/m^2)	psi = pounds per square inch
kPa = kilopascals	atm = atmosphere
J = Joule ft	lbf = feet per pound-force
W = watt	Btu = British thermal unit
kW = kilowatt	hp = horsepower
s = second (S.I. base unit of time)	s = second
min = minute	min = minute
h = hour	h = hour
day	day
°C = degrees Celsius	°F = degrees Fahrenheit
ppm = parts per million	ppm = parts per million
Length	
1 m = 3.2808 ft = 1.0936 yd	1 ft = 3 yd = 0.3048 m
1 cm = 0.3937 in.	1 in. = 2.54 cm
1 km = 0.6214 mile	1 mile = 0.869 nautical mile = 1.6093 km
Area	
1 m^2 = 10.7643 ft^2	1 ft^2 = 0.0929 m^2
1 km^2 = 0.3861 mi^2	1 mi^2 = 2.59 km^2
1 ha = 2.4710 acre	1 acre = 43,560 ft^2 = 0.4047 ha
Volume 1 L = 0.2642 gal.	1 gal. = 4 qt = 3.7854 L
1 ml = 1 cm^3	1 ft^3 = 7.481 gal. = 28.32 L
Mass	
1 g = 0.0353 oz	1 oz = 28.3495 g
1 kg = 2.2046 lb	1 lb = 0.4536 kg
Force	
1 N = 0.2248 lb/ft	1 lbf = 4.4482 N
Density	
1 kg/m^2 = 0.2048 lb/ft^2	1 lb/ft^2 = 4.882 kg/m^2
1 kg/m^3 = 6.2427 lb/ft^3	1 lb/ft^3 = 16.018 kg/m^3
Pressure	
1 kPa = 0.145 psi	1 psi = 6.8948 kPa
1 atm = 14.7	1 psi = 101.35 kPa
Energy and Power	
1 J = 1.00 W·s = 0.7376 ft·lbf	1 ft·lbf = 1.3558 J
1 kJ = 0.2778 W·h = 0.948 Btu	1 Btu = 1.0551 kJ
1 W = 0.7376 ft·lbf/s = 3.4122 Btu/h	1 ft·lbf/s = 1.3558 W
1 kW = 1,3410 hp	1 hp = 550 ft·lb/s = 0.7457 kW
Flow Concentration Temperature	1 L/s = 15.85 gal./min = 2.119 ft^3/min 1 gal./min = 0.1337 ft^3/min = 0.0631 L/s mg/L = ppm_m (in dilute solutions) °C = (°F − 32) × 5/9 °F = (°C × 9/5) + 32 Acceleration of gravity 32.2 ft/s^2 = 9.81 m/s^2
Fundamental Constants and Relationships	Density of water (at 4 °C) = 1,000 kg/m^3 = 1 g/cm^3 Specific weight of water (15 °C) = 62.4 lb/ft^3 = 9,810 N/m^3 Weight of water 1 gal. = 8.345 lb = 3.7854 kg

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 noncompliance 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 nonlinear 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.