ASCE STANDARD

ASCE/SEI

# 41-23

# Seismic Evaluation and Retrofit of Existing Buildings

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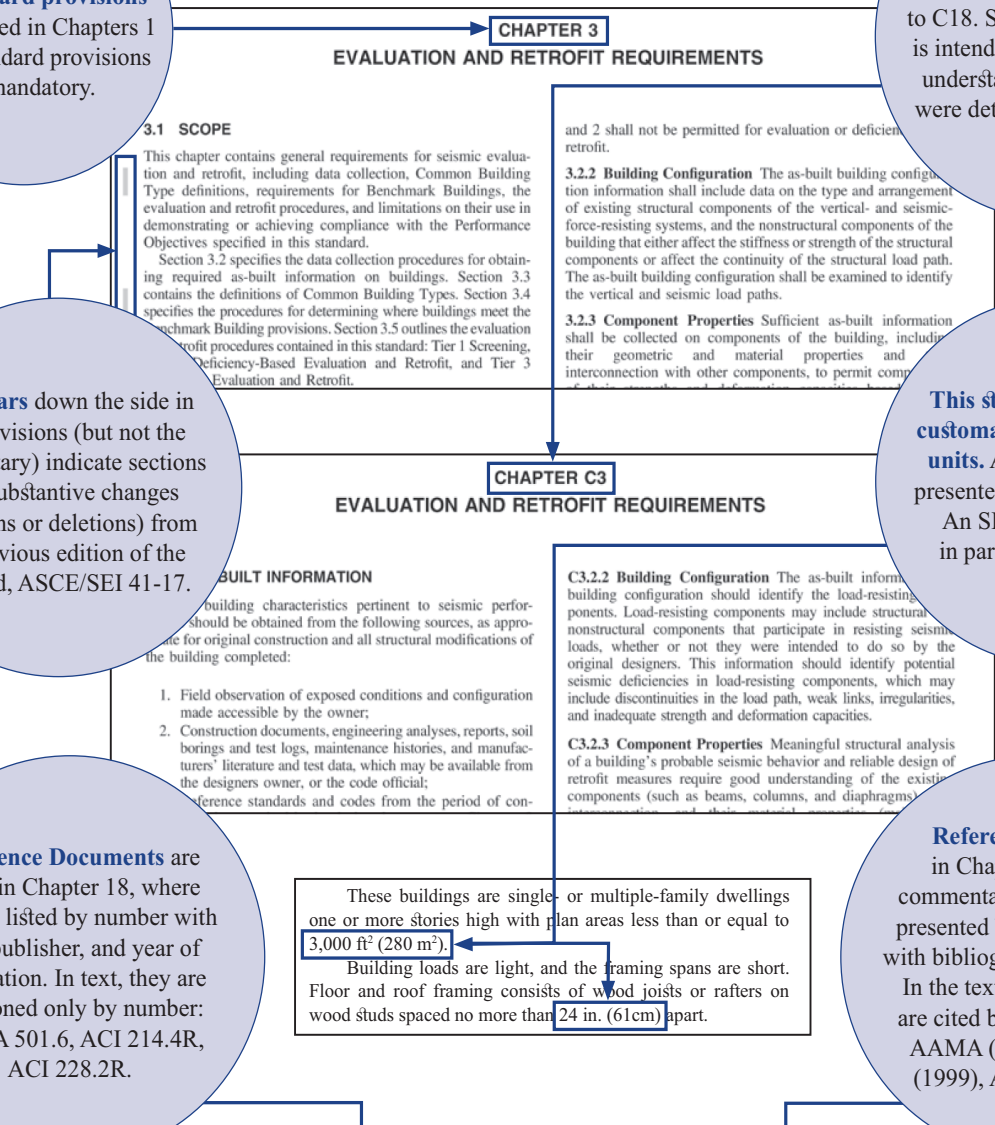
# Tips for Using This Standard

The **standard provisions** are contained in Chapters 1 to 18. Standard provisions are mandatory.

The **standard commentary** is contained in Chapters C1 to C18. Standard commentary is intended to help the reader understand how provisions were determined and how to apply them.



CHAPTER 3
EVALUATION AND RETROFIT REQUIREMENTS

3.1 SCOPE

This chapter contains general requirements for seismic evaluation and retrofit, including data collection, Common Building Type definitions, requirements for Benchmark Buildings, the evaluation and retrofit procedures, and limitations on their use in demonstrating or achieving compliance with the Performance Objectives specified in this standard.

Section 3.2 specifies the data collection procedures for obtaining required as-built information on buildings. Section 3.3 contains the definitions of Common Building Types. Section 3.4 specifies the procedures for determining where buildings meet the Benchmark Building provisions. Section 3.5 outlines the evaluation and retrofit procedures contained in this standard: Tier 1 Screening, Deficiency-Based Evaluation and Retrofit, and Tier 3 Evaluation and Retrofit.

and 2 shall not be permitted for evaluation or deficien
retrofit.

**3.2.2 Building Configuration** The as-built building configu
tion information shall include data on the type and arrangement
of existing structural components of the vertical- and seismic-
force-resisting systems, and the nonstructural components of the
building that either affect the stiffness or strength of the structural
components or affect the continuity of the structural load path.
The as-built building configuration shall be examined to identify
the vertical and seismic load paths.

**3.2.3 Component Properties** Sufficient as-built information
shall be collected on components of the building, includi
their geometric and material properties and
interconnection with other components, to permit comp

CHAPTER C3
EVALUATION AND RETROFIT REQUIREMENTS

BUILT INFORMATION

building characteristics pertinent to seismic perfor-
should be obtained from the following sources, as appro-
ate for original construction and all structural modifications of
the building completed:

1. Field observation of exposed conditions and configuration made accessible by the owner;
2. Construction documents, engineering analyses, reports, soil borings and test logs, maintenance histories, and manufacturers' literature and test data, which may be available from the designers owner, or the code official;
ference standards and codes from the period of con-

**C3.2.2 Building Configuration** The as-built inform
building configuration should identify the load-resisting
ponents. Load-resisting components may include structura
nonstructural components that participate in resisting seismi
loads, whether or not they were intended to do so by the
original designers. This information should identify potential
seismic deficiencies in load-resisting components, which may
include discontinuities in the load path, weak links, irregularities,
and inadequate strength and deformation capacities.

**C3.2.3 Component Properties** Meaningful structural analysis
of a building's probable seismic behavior and reliable design of
retrofit measures require good understanding of the existi
components (such as beams, columns, and diaphragms)

These buildings are single- or multiple-family dwellings one or more stories high with plan areas less than or equal to 3,000 ft$^2$ (280 m$^2$).

Building loads are light, and the framing spans are short. Floor and roof framing consists of wood joists or rafters on wood studs spaced no more than 24 in. (61cm) apart.

**Gray bars** down the side in the provisions (but not the commentary) indicate sections with substantive changes (additions or deletions) from the previous edition of the standard, ASCE/SEI 41-17.

**This standard uses both customary and metric (SI) units.** A customary unit is presented like this: 3,000 ft$^2$. An SI unit is presented in parentheses like this: (280 m$^2$).

**Reference Documents** are listed in Chapter 18, where they are listed by number with title, publisher, and year of publication. In text, they are mentioned only by number: AAMA 501.6, ACI 214.4R, ACI 228.2R.

**References** are listed in Chapter C18 in the commentary, where they are presented by author and date with bibliographic information. In the text, these references are cited by author and date: AAMA (2015), AASHTO (1999), AASHTO (2010)

**18.1 CONSENSUS STANDARDS AND OTHER REFERENCE DOCUMENTS**

This section contains both consensus standards and other reference documents cited within the provisions of the standard.

**AAMA 501.6**, *Recommended Dynamic Test Method for Determining the Seismic Drift Causing Glass Fallout from a Wall System*, American Architectural Manufacturers Association, 2009.

**ACI 214.4R**, *Guide for Obtaining Cores and Interpreting Compressive Strength Results*, American Concrete Institute, 2011.

**ACI 228.2R**, *Report on Nondestructive Test Methods for Evaluation of Concrete in Structures*, American Concrete Institute, 2013.

**C18.1 COMMENTARY REFERENCES**

This section contains all references cited within the commentary of the standard, as well as other relevant references (not cited).

AAMA (American Architectural Manufacturers Association). 2015. *Quality assurance and water field check of installed storefronts, curtain walls and sloped glazing systems*. AAMA501.2-15. Schaumberg, IL: AAMA.

AASHTO. 1999. *Guide specifications for seismic isolation design*. Washington, DC: AASHTO.

AASHTO. 2010. *Guide specifications for seismic isolation design*. 3rd ed. Washington, DC: AASHTO.

AASHTO. 2011. *Guide specifications for LRFD seismic bridge design*. 2nd ed. Washington, DC: AASHTO.

ABK (Agbabian, Barnes, and Kariotis). 1981. *Methodology for*

**Supplements, errata, and interpretations may become available in the future. Please check for important new materials at https://doi.org.10/16/9780784416112.**



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# 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/.


**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-$ft_2$. target areas



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# 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





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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



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- 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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## ACKNOWLEDGMENTS

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## DEDICATION

Michael Mahoney

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

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# 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<br>mg/L = $ppm_m$ (in dilute solutions)<br>°C = (°F − 32) × 5/9  °F = (°C × 9/5) + 32<br>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 $g/cm^3$<br>Specific weight of water (15 °C) = 62.4 $lb/ft^3$ = 9,810 $N/m^3$<br>Weight of water 1 gal. = 8.345 lb = 3.7854 kg |

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