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American Society of Civil Engineers

Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities

This document uses both the International System of Units (SI) and customary units.

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STANDARDS

In April 1980, the Board of Direction approved ASCE Rules for Standards Committees to govern the writing and maintenance of standards developed by the Society. All such standards are developed by a consensus standards process managed by the Codes and Standards Activities Committee. The consensus process includes balloting by the Balanced Standards Committee, which is composed of Society members and nonmembers, balloting by the membership of ASCE as a whole, and balloting by the public. All standards are updated or reaffirmed by the same process at intervals not exceeding 5 years.

The following Standards have been issued:

ANSI/ASCE 1-82 N-725 Guideline for Design and Analysis of Nuclear Safety Related Earth Structures
ANSI/ASCE 2-91 Measurement of Oxygen Transfer in Clean Water
ANSI/ASCE 3-91 Standard for the Structural Design of Composite Slabs and ANSI/ASCE 9-91 Standard Practice for the Construction and Inspection of Composite Slabs
ASCE 4-98 Seismic Analysis of Safety-Related Nuclear Structures
Building Code Requirements for Masonry Structures (ACI 530-02/ASCE 5-02/TMS 402-02) and Specifications for Masonry Structures (ACI 530.1-02/ASCE 6-02/TMS 602-02)
SEI/ASCE 7-02 Minimum Design Loads for Buildings and Other Structures
ANSI/ASCE 8-90 Standard Specification for the Design of Cold-Formed Stainless Steel Structural Members
ANSI/ASCE 9-91 listed with ASCE 3-91
ASCE 10-97 Design of Latticed Steel Transmission Structures
SEI/ASCE 11-99 Guideline for Structural Condition Assessment of Existing Buildings
ANSI/ASCE 12-91 Guideline for the Design of Urban Subsurface Drainage
ASCE 13-93 Standard Guidelines for Installation of Urban Subsurface Drainage
ASCE 14-93 Standard Guidelines for Operation and Maintenance of Urban Subsurface Drainage
ASCE 15-98 Standard Practice for Direct Design of Buried Precast Concrete Pipe Using Standard Installations (SIDD)
ASCE 16-95 Standard for Load and Resistance Factor Design (LRFD) of Engineered Wood Construction
ASCE 17-96 Air-Supported Structures
ASCE 18-96 Standard Guidelines for In-Process Oxygen Transfer Testing
ASCE 19-96 Structural Applications of Steel Cables for Buildings
ASCE 20-96 Standard Guidelines for the Design and Installation of Pile Foundations
ASCE 21-96 Automated People Mover Standards—Part 1
ASCE 21-98 Automated People Mover Standards—Part 2
ASCE 21-00 Automated People Mover Standards—Part 3
SEI/ASCE 23-97 Specification for Structural Steel Beams with Web Openings
SEI/ASCE 24-98 Flood Resistant Design and Construction
ASCE 25-97 Earthquake-Actuated Automatic Gas Shut-Off Devices
ASCE 26-97 Standard Practice for Design of Buried Precast Concrete Box Sections
ASCE 27-00 Standard Practice for Direct Design of Precast Concrete Pipe for Jacking in Trenchless Construction
ASCE 28-00 Standard Practice for Direct Design of Precast Concrete Box Sections for Jacking in Trenchless Construction
SEI/ASCE/SFPE 29-99 Standard Calculation Methods for Structural Fire Protection
SEI/ASCE 30-00 Guideline for Condition Assessment of the Building Envelope
SEI/ASCE 31-03 Seismic Evaluation of Existing Buildings
SEI/ASCE 32-01 Design and Construction of Frost-Protected Shallow Foundations
EWRI/ASCE 33-01 Comprehensive Transboundary International Water Quality Management Agreement
EWRI/ASCE 34-01 Standard Guidelines for Artificial Recharge of Ground Water
EWRI/ASCE 35-01 Guidelines for Quality Assurance of Installed Fine-Pore Aeration Equipment
CI/ASCE 36-01 Standard Construction Guidelines for Microtunneling
SEI/ASCE 37-02 Design Loads on Structures During Construction
CI/ASCE 38-02 Standard Guideline for the Collection and Depiction of Existing Subsurface Utility Data
EWRI/ASCE 39-03 Standard Practice for the Design and Operation of Hail Suppression Projects
ASCE/EWRI 40-03 Regulated Riparian Model Water Code
ASCE/EWRI 42-04 Standard Practice for the Design and Operation of Precipitation Enhancement Projects
ASCE/SEI 43-05 Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities
ASCE/EWRI 44-05 Standard Practice for the Design and Operation of Supercooled Fog Dispersal Projects

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Commentary

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FOREWORD

Nuclear facilities are defined as facilities that process, store, or handle radioactive materials in a form and quantity that pose potential nuclear hazard to the workers, the public, or the environment. Due to the risk associated with such hazards, it is desirable that nuclear facilities have a lower probability that structural damage will be caused by earthquakes than do conventional facilities. This Standard provides seismic design criteria that are more stringent than normal building codes. The goal of this Standard is to ensure that nuclear facilities can withstand the effects of earthquake ground shaking with desired performance, expressed as probabilistic Target Performance Goals. Design for other earthquake effects (such as differential fault displacement and seismic slope instability) are not covered by this Standard. This Standard is intended for use in the design of new facilities and is to be used in conjunction with other national consensus standards specified herein.

This Standard can also be used for facilities handling explosives, toxic materials, or chemicals; for facilities where safety, mission, or investment protection are concerns; and where more stringent seismic criteria than provided by building codes are desired.

This Standard is intended to be used with ASCE 4, which provides criteria for seismic analysis of safety related nuclear facilities Structures, Systems and Components (SSCs); ACI 349 for concrete structures; AISC standards for steel structures; ASME standards for mechanical systems and components; IEEE standards for electrical systems and components; and ASCE 7 for minimum non-seismic design loads for buildings and other structures. This ASCE Standard specifies seismic load combinations.

This Standard uses the Target Performance Goal–based seismic design approach documented in U.S. Department of Energy Natural Phenomena Hazards (NPH) standards. This Standard is also consistent with the philosophy used in the National Earthquake Hazard Reduction Program (NEHRP) for seismic mitigation of new and existing facilities. The Standard uses input from ANSI/ANS Standard 2.26 to assign Seismic Design Categories (SDCs)* to SSCs. It provides requirements for determining design basis seismic loading using input from ANSI/ANS Standards 2.27 and 2.29, and it prescribes design criteria that are tied to structural Limit States.

ANS 2.26 employs a graded approach to ensure that the level of conservatism and rigor in design is appropriate for facility characteristics, such as hazards to workers, the public, and the environment. ANS 2.26 specifies five SDCs for classifying SSCs based on their importance and failure consequences. Each SSC has a specified numerical Target Performance Goal. ANS 2.26 also provides descriptive criteria to assist the designer in selecting an appropriate Limit State for use in the design of SSCs. Four Limit States are defined—A, B, C, and D—where A is short of collapse and D is essentially elastic behavior. This Standard specifies design criteria for load combinations, including earthquake ground shaking (i.e., stress, displacement, and ductility limits), such that these Limit States are not exceeded.

The combination of SDC and Limit State defines the Seismic Design Basis (SDB) for each SSC. Thus, an SSC with SDB-3C would use criteria for SDC-3 and Limit State C. A total of 20 SDBs are defined in ANS 2.26 that can match seismic design criteria to SSC safety function and importance, implementing a graded approach.

SDBs defined by SDC 1 and 2 are covered by the approach presented in ASCE 7. This Standard presents design and analysis requirements for SDBs defined by SDC 3, 4, and 5 and all Limit States. The approach presented for SDC 3, 4, and 5 has been adapted from that used in the U.S. Department of Energy Standard 1020, ASCE 4, and the U.S. Nuclear Regulatory Commission Standard Review Plan (NUREG-0800).

The intended user of this Standard is the designer or analyst involved in the design of a new nuclear structure, system, or component. The Standard is intended to provide a rational basis for the performance-based, risk-consistent seismic design of SSCs in nuclear facilities. Designers once were initiated into the field of probabilistic design by being taught that seismic performance categories for SSCs were established by DOE-STD-1020-94 and subsequent revisions. Each performance category was tied to a probabilistic performance goal that represented a target annual frequency of seismic-induced failure. However, these earlier design codes did not allow designers the freedom to select a Limit State (the permissible deformation limit for the SSC established from functional considerations). There has been a movement within the structural engineering community to give designers freedom to select the desired state of the facility following the Design Basis Earthquake (DBE, defined in ATC-40, FEMA 273 and FEMA 356, SEAOC-Vision 2000, and ASCE 31). The traditional design Limit State of providing life safety can now be expanded to include nuclear confinement, remain fully functional, or minimize operational loss.

* In this Standard, the term "Seismic Design Category" has a different meaning than in the International Building Code and ASCE 7.

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ACRONYMS/NOTATION

A_I — Arias intensity
A_R — Ground motion ratio
ACI — American Concrete Institute
AISC — American Institute of Steel Construction
AISI — American Iron and Steel Institute
ANS — American Nuclear Society
ANSI — American National Standards Institute
APE — Annual probability of exceedance
ASD — Allowable Stress Design
ASME — American Society of Mechanical Engineers
ATC — Applied Technology Council
AWWA — American Water Works Association
B&PVC — Boiler and Pressure Vessel Code
C — Capacity determined in accordance with building codes
CMAA — Crane Manufacturer Association of America
COV — Coefficient of variation
D — Total demand; also, distance to controlling earthquake; also, peak ground displacement
D_{NS} — Non-seismic demand
D_S — Elastic seismic demand
DBE — Design Basis Earthquake
DF — Design Factor
DOE — U.S. Department of Energy
DRS — Design Earthquake Response Spectrum: $DRS = DF \times UHRS$
EBF — Eccentrically Braced Frame
EES — Earthquake Experience Spectrum
ENA — Eastern North America
EUS — Eastern United States
EPRI — Electric Power Research Institute
LRFD — Load and Resistance Factor Design
F_μ — Inelastic energy absorption factor
$F_{\mu S}$ — System inelastic energy absorption factor
FEMA — Federal Emergency Management Agency
FS — Factor of Safety
GIP — Generic Implementation Procedure
H_D — Mean annual hazard exceedance frequency: $H_D = R_P \times P_F$
IBC — International Building Code
IEEE — The Institute of Electrical and Electronics Engineers, Inc.
K — Capacity increase factor
LS — Limit State (A, B, C, or D)
M — Magnitude of controlling earthquake
N_y — Nyquist frequency
NEHRP — National Earthquake Hazard Reduction Program
NEMA — National Electrical Manufacturer Association
NEP — Non-Exceedance Probability
NFPA — National Fire Protection Association
NPH — Natural Phenomena Hazards
NPP — Nuclear Power Plant
NRC — U.S. Nuclear Regulatory Commission
PC — Performance Category
P_F — Mean annual frequency of unacceptable performance (Target Performance Goal)
PGA — Peak Ground Acceleration; A is also used for Peak Ground Acceleration
PSD — Power Spectral Density
PSHA — Probabilistic Seismic Hazard Assessment
QA — Quality Assurance
R_P — Probability Ratio: H_D / P_F
RBS — Reduced Beam Sections
RRS — Required Response Spectra
SA_f — Spectral Acceleration at natural frequency, f
SA_{PEAK} — Peak Spectral Acceleration
SAM — Seismic Anchor Motion
SDB — Seismic Design Basis
SDC — Seismic Design Category* (SDC-1, SDC-2, SDC-3, SDC-4, or SDC-5)
SF — Seismic Scale Factor
SMACNA — Sheet Metal and Air-Conditioning Contractors National Association
SMRF — Special Moment-Resisting Frame
SQUG — Seismic Qualification Utility Group
SRSS — Square root sum of squares
SSC — Structure, System, or Component
SSE — Safe Shutdown Earthquake
SSI — Soil-Structure Interaction
T_{sm} — Strong motion duration
TES — Test Experience Spectrum
TRS — Test Response Spectrum
UHRS — Uniform Hazard Response Spectra
USGS — U.S. Geological Survey
V — Peak Ground Velocity
ZPA — Zero Period Acceleration
α — Parameter used to determine Design Factor
ϕ — Capacity reduction factor

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