# Incorporating commercial practice and standards for design and construction of nuclear civil structures


Brian McDonald, Ph.D., P.E., S.E.
Principal Engineer and Vice President, Exponent
~~Chair, ASCE DANS Committee~~
Co-chair, ASCE 92 Committee
mcdonald@exponent.com

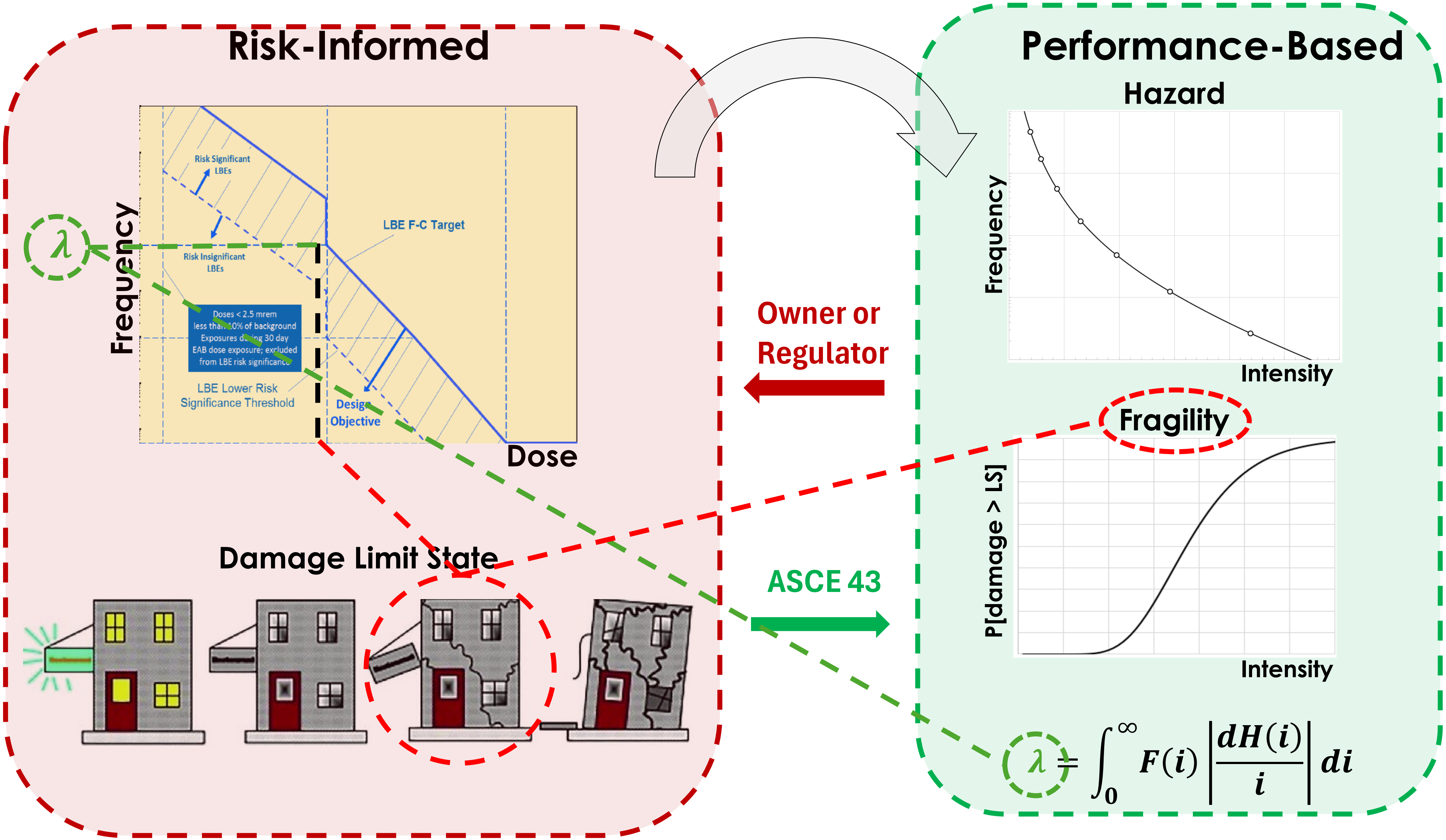



Andrew Whittaker, Ph.D., P.E., S.E.
SUNY Distinguished Professor, University at Buffalo
~~Chair, ASCE Nuclear Standards Committee~~
Co-chair, ASCE 92 Committee
awhittak@buffalo.edu


**NRC Standards Forum Part II - Codes and Standards for Nuclear Energy Applications, January 28, 2026**

# If you take away nothing else

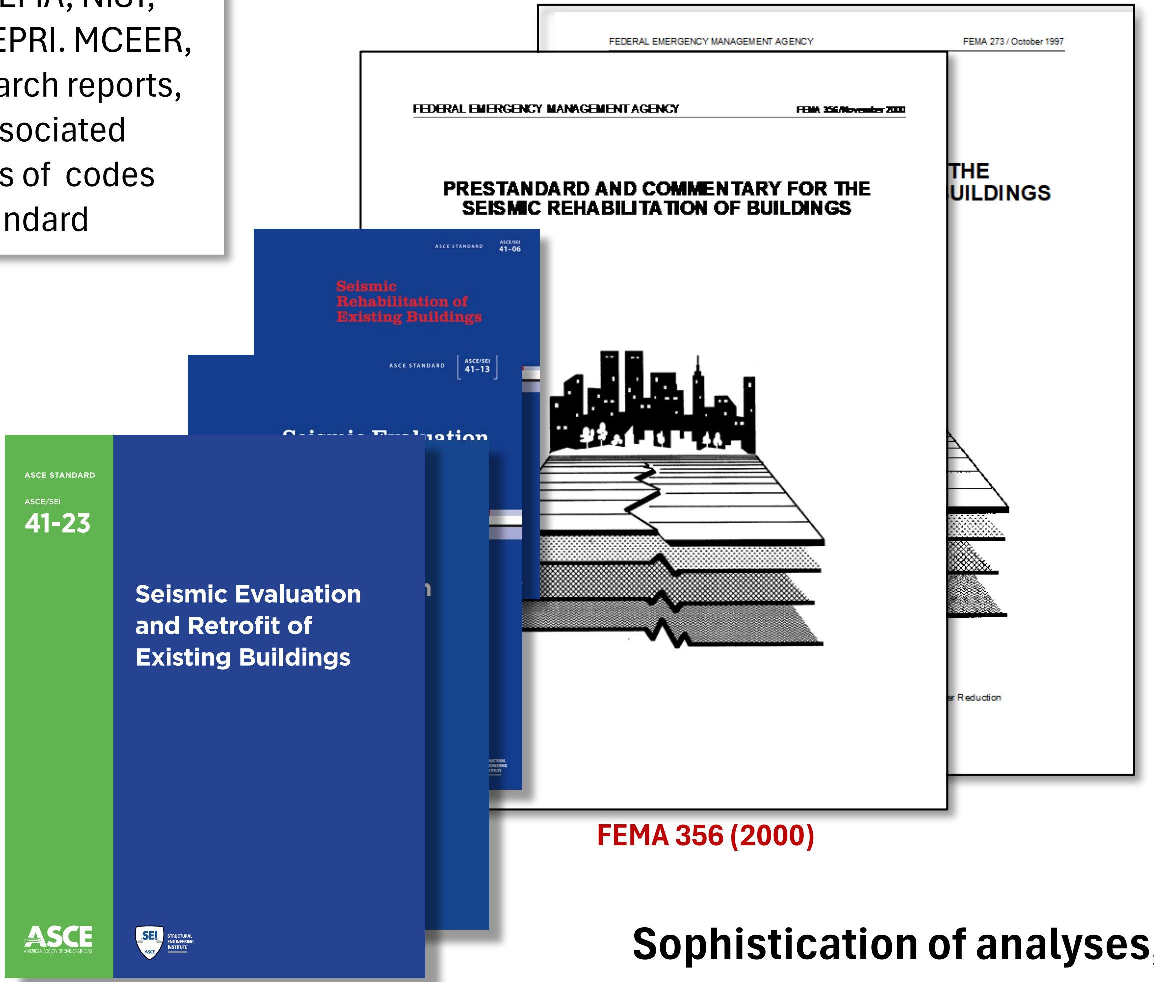
- Risk-Informed Performance-Based (RIPB) seismic design for nuclear civil structures has its roots in the early 1990s
- PB seismic design for commercial structures also started in the early 1990s and is now routine
- Number of commercial, mission-critical structures successfully designed and constructed using PB seismic standards is **orders of magnitude greater** than RIPB nuclear structures
- Commercial PB seismic design, construction and safety provisions were developed by prominent engineers in conjunction with academia, and **have surpassed nuclear standards** in many ways, particularly analyses methods, acceptance criteria, and QA/QC
  - Compatible with ASCE 7, which addresses loadings and hazards other than seismic
- Foolish to ignore PB improvements in the commercial world


Risk-Informed
Risk Significant LBEs
LBE F-C Target
Risk Insignificant LBEs
Doses < 2.5 mrem
EAB dose exposure; excluded
LBE Lower Risk Significance Threshold
Design Objective
Frequency
Dose
λ
Damage Limit State
Owner or Regulator
ASCE 43
Performance-Based
Hazard
Frequency
Intensity
Fragility
P[damage > LS]
Intensity
$\lambda = \int_0^\infty F(i) \left| \frac{dH(i)}{i} \right| di$

# RIPB standards for commercial and nuclear civil structures

Many FEMA, NIST, PEER, EPRI. MCEER, … research reports, with associated updates of codes and standard

FEMA 273/274 (1992-1997)

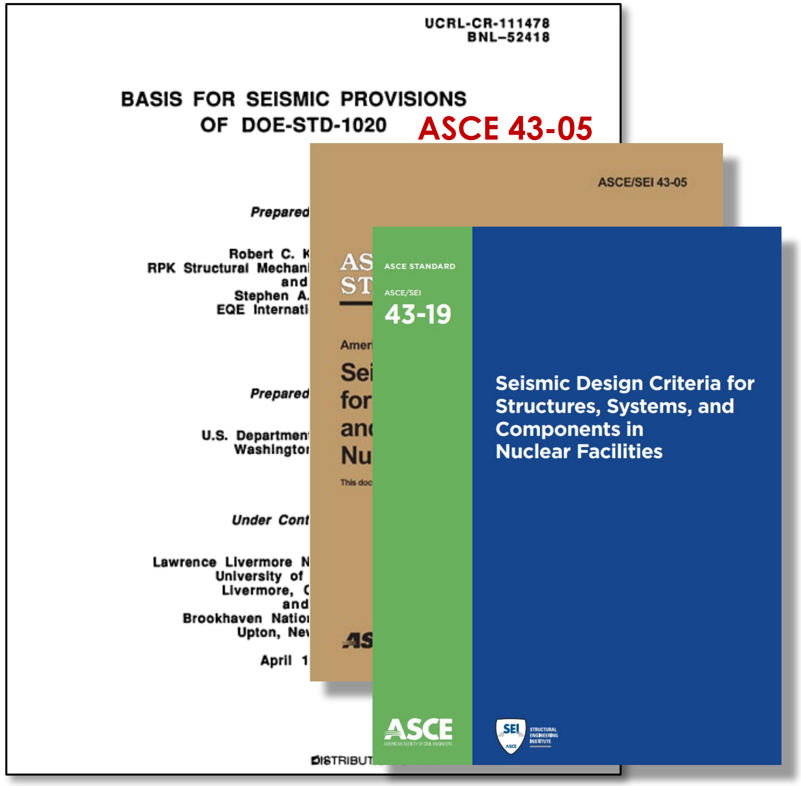



FEMA 356 (2000)

ASCE 41-23

Kennedy & Short 1994

ASCE 43-05




ASCE 43-19

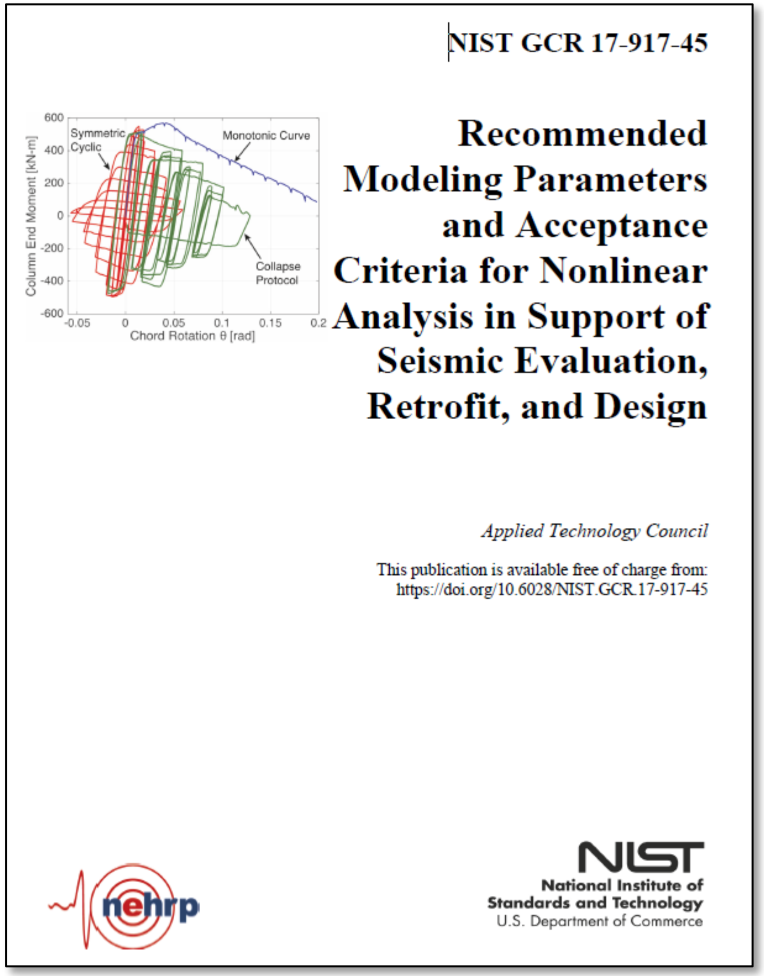
Relatively few updates of nuclear standards

Sophistication of analyses, acceptance criteria, and quality provisions have diverged

**Commercial**

**Nuclear**

# Nonlinear analysis routine for assessment of commercial structures


NIST GCR 17-917-45



**Recommended Modeling Parameters and Acceptance Criteria for Nonlinear Analysis in Support of Seismic Evaluation, Retrofit, and Design**

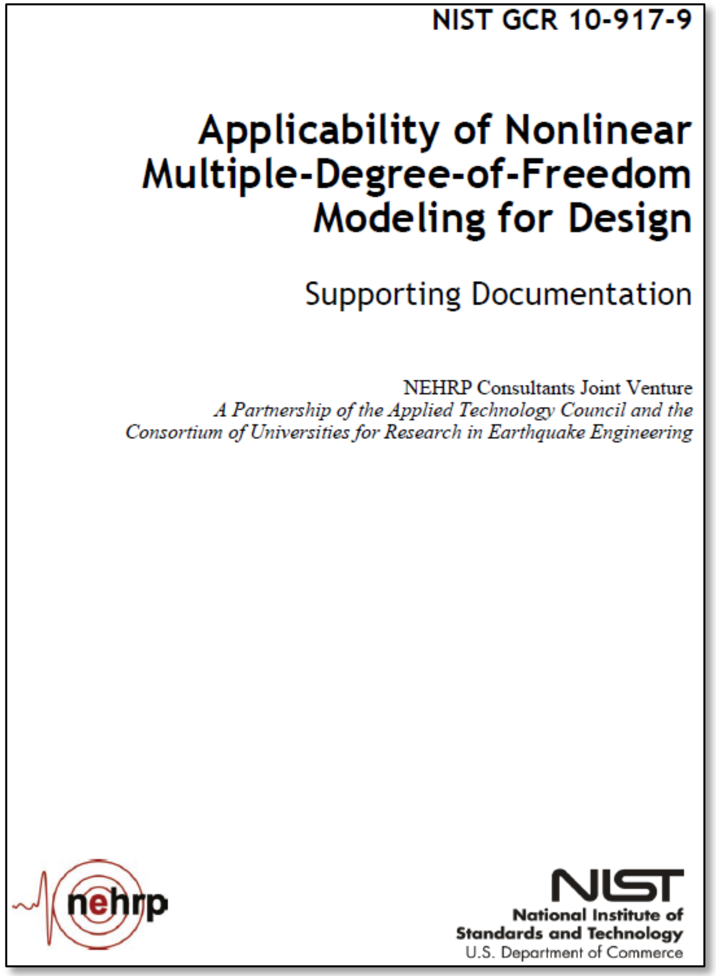
*Applied Technology Council*

This publication is available free of charge from:
https://doi.org/10.6028/NIST.GCR.17-917-45

nehrp

NIST
National Institute of Standards and Technology
U.S. Department of Commerce

+


NIST GCR 10-917-9

**Applicability of Nonlinear Multiple-Degree-of-Freedom Modeling for Design**

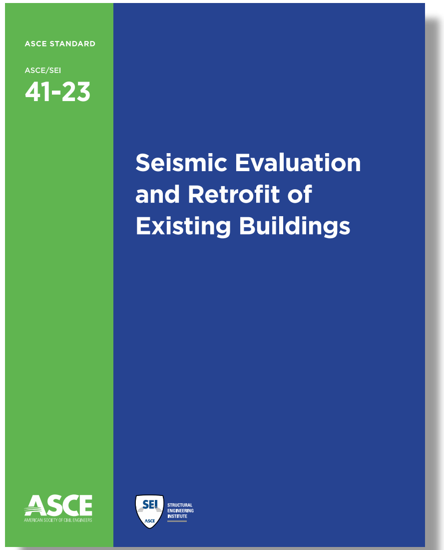
Supporting Documentation

NEHRP Consultants Joint Venture
*A Partnership of the Applied Technology Council and the Consortium of Universities for Research in Earthquake Engineering*

nehrp

NIST
National Institute of Standards and Technology
U.S. Department of Commerce

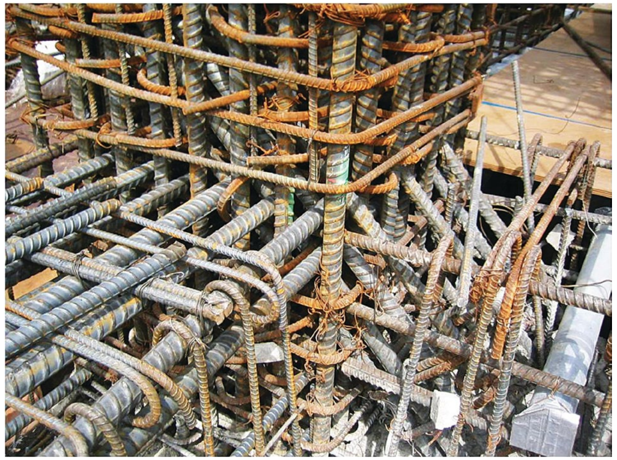
→


ASCE STANDARD
ASCE/SEI
41-23

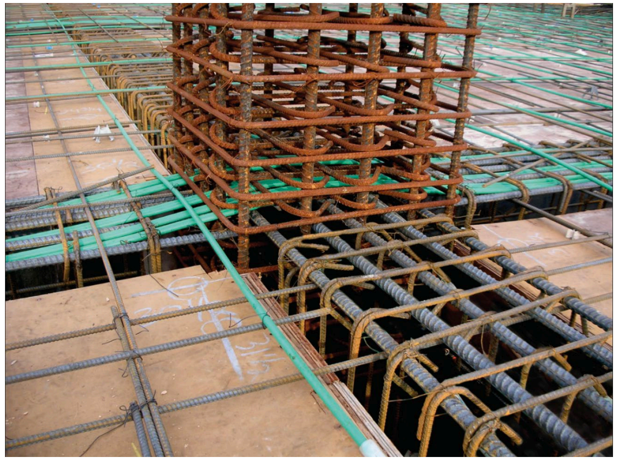
**Seismic Evaluation and Retrofit of Existing Buildings**

ASCE
SEI

# Achieving high quality: engineering



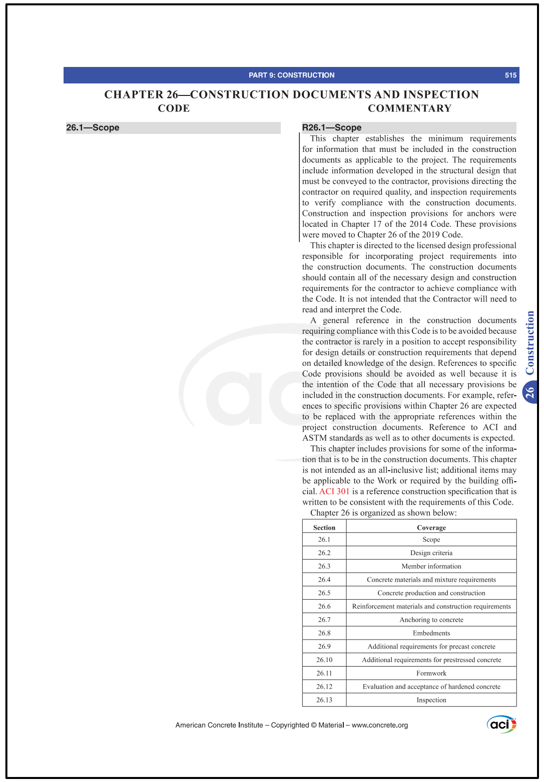
F. Grant, SGH, 2024



- Per commercial RIPB practice
    - Mandate design peer review
    - Continue on-site testing of materials
    - On-site special inspections of key construction
    - Mandate on-site structural observations by EoR
    - Incorporate best material and construction quality standards from commercial ACI / AISC / ASCE standards
- Plan
    - Demonstrate compliance of above with the intent of Appendix B to Part 50—Quality Assurance Criteria (all 18 pieces)

# Achieving high quality: materials and concrete for example

- Concrete
  - Cylinder test is primarily for **quality control**
  - On-site testing
  - 28-day compressive strength, $f_c$, including Section 26.12.3.1,
    - ACI 214R-11, 1% probability less than $f_c$
  - Long-term, in-service strength between 130% and 150% of $f_c$
  - **Conclusion**: in-service strength will always exceed $f_c$
- But is concrete strength important? Impact of a 25% cut?
  - Shear strength of beams, columns, walls: insignificant
  - Axial strength: insignificant. Richart addressed at UIUC (1930)
  - Deformation capacity (Limit States A, B, and C): insignificant



PART 9: CONSTRUCTION 515

CHAPTER 26—CONSTRUCTION DOCUMENTS AND INSPECTION

CODE

26.1—Scope

COMMENTARY

R26.1—Scope

This chapter establishes the minimum requirements for information that must be included in the construction documents as applicable to the project. The requirements include information developed in the structural design that must be conveyed to the contractor, provisions directing the contractor on required quality, and inspection requirements to verify compliance with the construction documents. Construction and inspection provisions for anchors were located in Chapter 17 of the 2014 Code. These provisions were moved to Chapter 26 of the 2019 Code.

This chapter is directed to the licensed design professional responsible for incorporating project requirements into the construction documents. The construction documents should contain all of the necessary design and construction requirements for the contractor to achieve compliance with the Code. It is not intended that the Contractor will need to read and interpret the Code.

A general reference in the construction documents requiring compliance with this Code is to be avoided because the contractor is rarely in a position to accept responsibility for design details or construction requirements that depend on detailed knowledge of the design. References to specific Code provisions should be avoided as well because it is the intention of the Code that all necessary provisions be included in the construction documents. For example, references to specific provisions within Chapter 26 are expected to be replaced with the appropriate references within the project construction documents. Reference to ACI and ASTM standards as well as to other documents is expected.

This chapter includes provisions for some of the information that is to be in the construction documents. This chapter is not intended as an all-inclusive list; additional items may be applicable to the Work or required by the building official. ACI 301 is a reference construction specification that is written to be consistent with the requirements of this Code.

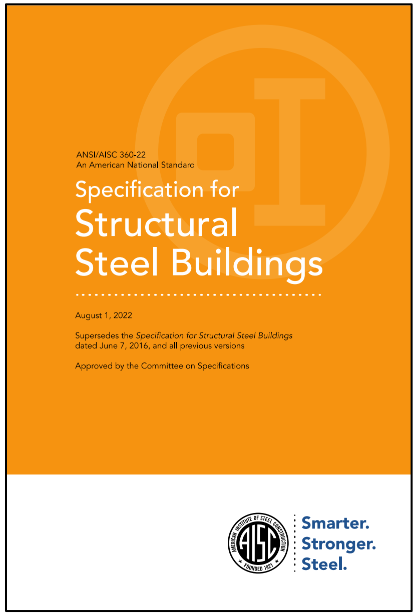
Chapter 26 is organized as shown below:

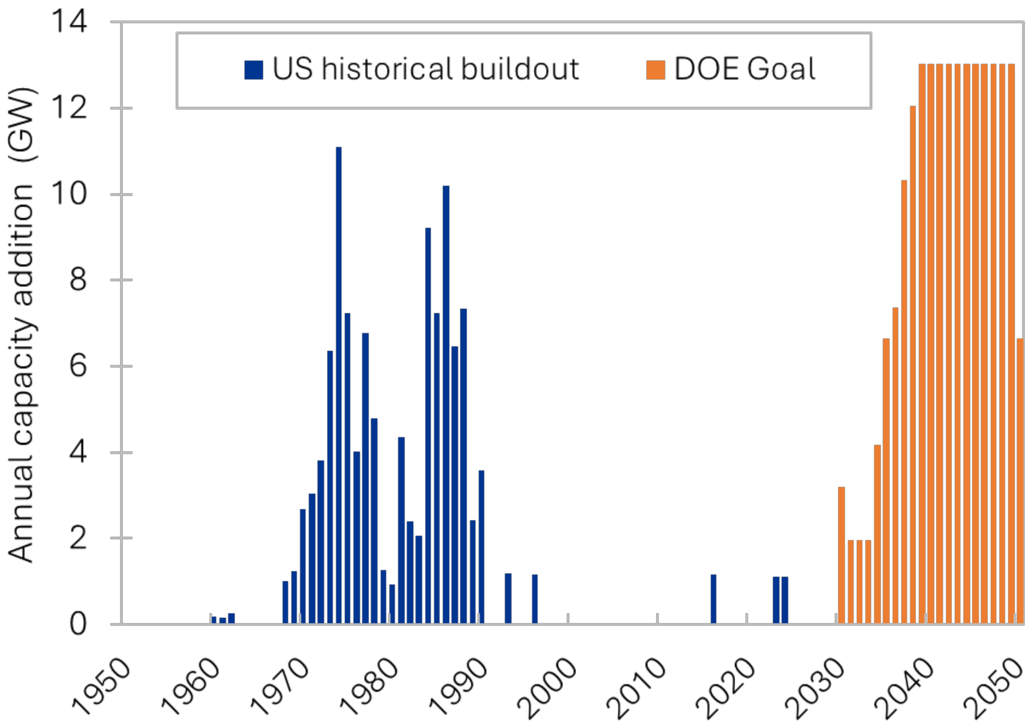
| Section | Coverage |
|---|---|
| 26.1 | Scope |
| 26.2 | Design criteria |
| 26.3 | Member information |
| 26.4 | Concrete materials and mixture requirements |
| 26.5 | Concrete production and construction |
| 26.6 | Reinforcement materials and construction requirements |
| 26.7 | Anchoring to concrete |
| 26.8 | Embedments |
| 26.9 | Additional requirements for precast concrete |
| 26.10 | Additional requirements for prestressed concrete |
| 26.11 | Formwork |
| 26.12 | Evaluation and acceptance of hardened concrete |
| 26.13 | Inspection |

26 Construction

# Achieving high quality: standards

- Non-nuclear civil standards?
  - ASCE/SEI 7 and 41
  - ACI 318, AISC 360 and 341
    - Standards referenced therein, including ASTM
  - Updated on 5- to 6-year cycles
- Non-nuclear standards deliver what?
  - Limit State A through Limit State D
  - Performance-based seismic design, since mid 1990s
- Nuclear standards ACI 349 and AISC N690 deliver what?
  - Limit State D






W. Robb Stewart (Alva) and DOE LPO, 2024

**Right-size**

**Modernize**

**Achieve risk targets**

**Achieve cost targets**

**Achieve build times**

**Standardize**

**Achieve build target in GWe**