Commentary on IBC Requirements for LANL[1]

Contents

Acronyms, Abbreviations, and Symbols

A_x = Torsional Amplification Factor	IEBC = International Existing Building Code
ACI = American Concrete Institute	lbs. = pounds
AISC = American Institute for Steel Construction	N/A = Not applicable
AISI = American Iron and Steel Institute	NFPA = National Fire Protection Association
ASCE = American Society of Civil Engineers	NSC = Nonstructural component
AWS = American Welding Society	NBS = Nonbuilding structure
CFS = Cold-formed steel	Ω_0 = Overstrength Factor
Ch. / Chs. = Chapter / Chapters	PC = Natural Phenomena Hazards Performance Category
CIP = Cast-In-Place	PI = Post-Installed
Δ = Design story drift	pp. = Page / pages
Δ_s = Allowable story drift	psf = pounds per square foot
EOR = Engineer of Record	psi = pounds per square inch
ESM = LANL Engineering Standards Manual	QA = Quality Assurance
f'c = specified concrete compressive strength	R = Response Modification Factor
ft. = Feet	S_{DS} = Design spectral response acceleration parameter at short periods
FPSS = Fire protection sprinkler system	ρ = Redundancy Factor
g = Acceleration due to gravity	r/c = Reinforced Concrete
HVAC = Heating, Ventilating and Air-Conditioning	SDC = Seismic Design Category
in. = Inch / inches	sf = square feet
I = Structural Importance Factor	SFRS = Seismic Force Resisting System
I_p = Nonstructural-Component Importance Factor	SSI = Statement of Special Inspections
IAW = In accordance with	$>, \geq, <, \leq$ = Greater than, greater than or equal to, less than, less than or equal to, respectively
IBC = International Building Code	
ICC = International Code Council (author of IBC and IEBC)	

1 As necessitated by being Seismic Design Category D (the category which LANL is in along with several other DOE sites).

Definitions

IBC: This document is based on the 2009 edition of the IBC.

The IBC 2009 requirements mentioned herein that are new (since the IBC 2006), and "significant (i.e., per ICC's *Significant Changes to the International Building Code, 2009 Edition*)," are highlighted using *italics*. Note that although a lot of the text in IBC 2009, Chapter 17 is 'barred (i.e., boldface, vertical, black bar in the margin),' thereby indicating technical changes to the IBC 2006, the reality is that the vast majority of the related requirements were in the IBC 2006 (albeit not nearly as clearly and organized as they are in the IBC 2009). Thus, barred Ch.17 text is not italicized herein.

Buildings: This commentary includes all buildings and non-building structures that are within the scope of the IBC[2].

Also, despite the fact that existing buildings are within the scope of the IBC, since the LANL code-of-record for work on existing buildings is the International Existing Building Code (IEBC 2009), only new buildings are considered herein.

Finally, by definition in the LANL Engineering Standards Manual (i.e., Chs. 5 and 16), only PC-0, PC-1, and PC-2 buildings are considered herein (i.e., PC-3-building requirements are 'above and beyond' the IBC).

SDC D: The IBC and ASCE 7 requirements for determination of seismic design category (i.e., Sect. 1613.5 and Ch. 11, respectively) are not addressed herein since LANL being SDC D is defined by ESM Ch. 5 Section II requirements.

On a related note, many IBC and ASCE 7 seismic design and detailing requirements are linked to a parameter known as the design spectral response acceleration parameter at short periods (S_{DS}). Per Section II requirements, the value of S_{DS} to be used at LANL is 0.75 g.

Format and Style

IBC requirements are listed first, followed by the requirements of the standards referred to in the IBC requirements: ASCE 7, AISC 341, and ACI 318. The commentary concludes with some context regarding the cost (i.e., time, effort, and money) of seismic design and construction in 'moderate-to-high' seismic areas.

All of the requirements herein are paraphrased and, in many cases, elaborated on so that this commentary is both efficient and effective (i.e., as short as possible, yet understandable by those lacking in-depth knowledge of the codes/standards).

Finally, since the SDCs range from A to F (with F being the most severe), there are no code/standard requirements that pertain only to SDC-D buildings (e.g., some code /standard requirements apply to SDCs B, C, D, E and F; others apply to SDCs D, E and F; etc.). Given this, in the interest of brevity, a shorthand is used herein in which only the lowest applicable SDC appears in the paraphrased requirement (e.g., SDC C is stated herein when the code/ standard requirement states SDCs C, D, E and F, etc.). Code/standard requirements applying only to SDCs E and/or F are not mentioned herein since they are N/A to LANL buildings.

References

The following are the primary codes and standards used in this commentary. Any other document that is referenced is cited at the location where it is mentioned.

ACI 318-08, Building Code Requirements for Structural Concrete (ACI 318)

ACI 530-08, Building Code Requirements for Masonry Structures; (ACI 530)

[2] Since the primary structural materials used in LANL buildings are CIP r/c and hot-rolled structural steel, only buildings consisting of those materials are considered herein. Thus, while the IBC contains requirements for SDC-D buildings consisting of structural masonry, structural wood, cold-formed steel light–frame construction, precast structural concrete, etc., these requirements are not mentioned.

AISC 341-05, Seismic Provisions for Structural Steel Buildings (AISC 341)
AISC 360-05, Specification for Structural Steel Buildings (AISC 360)
AISI S200-07, North American Standard for Cold-Formed Steel Framing—General Provisions (AISI S200)
AISI S213-07, North American Standard for Cold-Formed Steel Framing—Lateral Design (AISI S213)
ASCE 7-05, Minimum Design Loads for Buildings and Other Structures (ASCE 7)
IBC 2009, International Building Code (IBC)
LANL ESM Chapter 5, Section II rev. 6, XXX (ESM Ch. 5)
LANL ESM Chapter 16, rev. 5, 8/25/10 (ESM Ch. 16)
NFPA 13-2007, Installation of Sprinkler Systems (NFPA 13)

IBC Requirements

Chapter 9, Fire Protection Systems

903.3.5.2, Secondary water supply: A high-rise building[3] in SDC C must have a secondary on-site water supply.

Chapter 14, Exterior Walls

1405.6, Anchored masonry veneer

1405.6.2, Seismic requirements: Anchored masonry veneer located in SDC C must meet special requirements contained in ACI 530 [i.e., top and sides of veneer must be isolated from the building frame so that veneer won't experience seismic loads (SDC C); the weight of the veneer at each story must be supported solely by/at that story (SDC D); and the veneer must be specially reinforced and anchored (SDC D)].

Chapter 16, Structural Design

1604, General Design Requirements

1604.10, Wind and Seismic Detailing: Lateral-force-resisting systems shall meet seismic detailing requirements and limitations prescribed in this code and ASCE 7 even when wind-load effects are greater than seismic-load effects. Although this requirement is not directly related to any SDC, it merits inclusion (in this commentary) since the requirements for SDC D are so numerous and onerous (i.e., in other words, the effects of LANL being in SDC D are 'felt' even in those instances in which wind loads control the design of a building).

1613, Earthquake Loads

1613.1, Scope: Design and construction to resist seismic loads must comply with ASCE 7 (i.e., regardless of SDC), except for the chapters therein on material-specific seismic requirements (e.g., concrete, steel, etc.), and on QA requirements (e.g., QA plan, special inspection and testing, etc.). The reason for these exceptions is the IBC has 'superior' requirements on these topics.

1613.6.2, Additional SFRSs for seismically isolated structures: Use of seismically isolated structures at LANL is rare enough such that this requirement does not merit mention herein.

[3] Per IBC, high-rise = a building with an occupied floor located more than 75 feet (ft.) above the lowest level of access by fire department vehicles.

1613.6.3, Automatic Sprinkler Systems: This provision modifies the ASCE-7 requirement on the design and installation of automatic fire sprinkler systems. Specifically, regardless of SDC, when such systems comply with the 2007 edition of NFPA 13 they are recognized as being compliant with the ASCE 7 seismic bracing provisions (which do not recognize 'NFPA-13-only'-designs for SDC D).

1613.6.6, Steel plate shear wall height limits: This provision modifies the ASCE-7 requirement on height limits for steel braced frames, special steel plate shear walls, and special r/c shear walls. Specifically, for buildings with these types of SFRSs used in SDC D, the IBC provides requirements to take advantage of a 50% increase in height (i.e., over ASCE-7 height limit).

1613.6.8, HVAC Ductwork with $I_p = 1.5$: This provision expands the ASCE-7 exemption from seismic bracing requirements (for small ducts with $I_p = 1.0$) to include small ducts with $I_p = 1.5$. Since ASCE 7 exempts SDC-B mechanical components with $I_p = 1.5$ from seismic bracing requirements, this 'expansion' allows for more cost-effective HVAC duct installations in SDC C.

IBC Chapter 17, Structural Tests and Special Inspections

Section 1705, Statement of Special Inspections (SSI)

1705.3.1, Seismic-force-resisting systems: A previous paragraph states that where special inspection (SI) or testing is required (by other sects. in Ch. 17), the EOR must prepare an SSI in which required inspections and tests, to include their frequency, type, amount, etc. are documented. 1705.3.1 states that, if the building is in SDC C (unless it is not specifically detailed for seismic resistance; SDC D buildings must be specifically detailed for seismic resistance, so this exemption is N/A), the SFRS used must be identified in the SSI as requiring inspection (i.e., for verification that construction is IAW the construction documents).

- Paragraphs subsequent to 1705.3.1 (i.e., within 1705.3) include other items that must be identified in the SSI for SDC-C buildings as requiring inspection, as well as additional inspection and testing requirements (i.e., for more in-depth verification of compliance with construction documents):

- Designated Seismic Systems (in SDC D), which are defined (by IBC) as, Architectural, electrical and mechanical components that require design IAW ASCE 7 and for which I_p is greater than 1.0 (see ASCE-7 Requirements below);

- (In SDC C) HVAC ductwork containing hazardous materials and the anchorage of such ductwork; piping systems and mechanical units containing flammable, combustible or highly toxic materials; anchorage of electrical equipment used for emergency or standby power systems;

- (In SDC D) Exterior wall panels and their anchorage; suspended ceiling systems and their anchorage; access floors and their anchorage; steel storage racks and their anchorage, where their $I_p = 1.5$.

- Additional special inspections and testing to be provided as required by Sects. 1707 and 1708 and other applicable sects. of the IBC, including the applicable standards referenced by the IBC.

Section 1707, Special Inspections for Seismic Resistance

1707.1, Special Inspections for Seismic Resistance: Subsequent paragraphs of Sect. 1707 itemize the additional SIs referred to in Sect. 1705 (i.e., pertaining to SFRSs in non-exempt SDC-C buildings; designated seismic systems in SDC-D buildings; and 'hazardous' HVAC ductwork, exterior wall panels, etc., in SDC-C, and -D buildings).

1707.2, Structural steel (in non-exempt SDC C): Structural steel (in the SFRS) shall be 'specially inspected' IAW the quality assurance plan requirements of AISC 341 (i.e., Ch. 18).

1707.5, Storage racks and access floors (in SDC D): Periodic (vs. continuous) SI is required during the anchorage of access floors and storage racks eight ft. or greater in height.

1707.6, Architectural components (in SDC D): Periodic SI is required during the erection and fastening of exterior cladding, interior and exterior nonbearing walls and interior and exterior veneer structures unless these components are 30 ft. or less in height above grade or walking surface. Also, SI is not required for cladding and veneer weighing five psf or less. Finally, SI is not required for interior nonbearing walls weighing 15 psf or less.

1707.7, Mechanical and electrical components (in SDC C): Periodic SI is required during the anchorage of electrical equipment for emergency or standby power systems; the installation of piping systems intended to carry flammable, combustible or highly toxic contents and their associated mechanical units; the installation of HVAC ductwork that will contain hazardous materials; and during the installation of vibration isolation systems where the construction documents require a nominal clearance of ¼ inch (in.) or less between the equipment support frame and restraint.

1707.8, Designated seismic system verification (SDC C): The special inspector shall examine designated seismic systems requiring seismic qualification IAW Sect. 1708.4 and verify that the label, anchorage or mounting conforms to the certificate of compliance.

Section 1708, Structural Testing for Seismic Resistance

1708.1, Testing and qualification for seismic resistance: Subsequent paragraphs of Sect. 1708 itemize the testing referred to in Sect. 1705 (i.e., pertaining to SFRSs in non-exempt SDC-C buildings; and designated seismic systems in SDC-C buildings).

1708.2, Concrete reinforcement (SDC B): If ASTM A615 reinforcement (rebar) is used in r/c SFRSs, the rebar must comply with ACI 318, Sect. 21.1.5.2 (i.e., the amount by which the actual yield strength exceeds the specified-minimum yield strength, as determined by mill tests, is capped; and the ratio of the actual tensile strength to the actual yield strength must equal or exceed a specified value). Also, certified mill test reports must be provided for each shipment of such rebar. Finally, if such rebar is to be welded, chemical tests must be performed to determine weldability IAW ACI 318, Sect. 3.5.2 (i.e., welding of rebar must conform to AWS D1.4-98, Structural Welding Code—Reinforcing Steel).

1708.3, Structural steel (non-exempt SDC C): Testing for structural steel shall be IAW the QA plan requirements of AISC 341. There is an exception to certain types of weld testing in "ordinary moment frames;" however, ASCE 7 limits the use of such a SFRS in SDC-D buildings.

1708.4, Seismic certification of nonstructural components (in SDC C): Manufacturers of designated seismic systems must test or analyze the component and its mounting system or anchorage and submit a certificate of compliance for review and acceptance by the EOR, and for approval by the building official. This provision is also applicable to those 'normal (I_p = 1.0)' nonstructural components for which design complying with ASCE 7 is not performed by the EOR (i.e., although such components would have lesser testing/analysis performance goals, vs. designated seismic systems, specified by the EOR on the construction documents).

Section 1709, Contractor Responsibility

1709.1, Contractor Responsibility: Contractors responsible for the construction of SFRSs and designated safety systems listed in the SSI shall acknowledge, in writing, to the building official and owner awareness of the special requirements contained in the SSI.

Section 1710, Structural Observations

1710.2, Structural observations for seismic resistance: Required for SDC-D buildings which meet one or more of the following conditions: Occupancy Category III or IV (i.e., LANL PC-2), height exceeding 75 ft., when so designated by the EOR, and when required by the building official.

IBC Chapter 18, Soils and Foundations

Section 1803, Geotechnical Investigations

1803.5.11, SDCs C – F: A geotechnical investigation must be conducted, and must include an evaluation of all of the following potential geologic and seismic hazards: Slope instability, liquefaction, differential settlement, and surface displacement due to faulting or lateral spreading.

1803.5.12, SDCs D – F: The geotechnical investigation required by 1803.5.11 must also include: The determination of lateral pressures on foundation walls and retaining walls due to earthquake motions; the potential for liquefaction and soil strength loss evaluated for site peak ground accelerations, magnitudes and source characteristics consistent with the design earthquake ground motions; an assessment of potential consequences of liquefaction and soil strength loss; and discussion of mitigation measures.

Section 1807, Foundation Walls, Retaining Walls, and Embedded Posts and Poles

1807.1.3, Rubble stone foundation walls: Not allowed for SDC-C structures.

1807.1.6, Prescriptive design of concrete and masonry foundation walls: Per 1807.1.6.2.1, Seismic requirements (for concrete foundation walls), use of IBC's prescriptive-design tables is not allowed for SDC-C structures.

Section 1808, Foundations

1808.8.1, Concrete or grout strength and mix proportioning: Per Table 1808.8.1; foundations for Group R or U occupancies of light-frame construction, two stories or less in height, assigned to SDC D must have f'c not less than 2,500 psi; and foundations for other structures assigned to SDC D must have f'c not less than 3,000 psi.

1808.8.6, Seismic requirements (for concrete foundations): Sect. 1908, Modifications to ACI 318, contains additional requirements for concrete foundations (i.e., above and beyond those contained in Sect. 1808) for SDC-C structures.

Also, for SDC-D structures, provisions of ACI 318, Sect. 21.12.1 through 21.12.4 (i.e., design and detailing requirements for foundations of SDC-D structures) apply when they do not conflict with the provisions of IBC Sects. 1808 through 1810.

Section 1809, Shallow Foundations

1809.7, Prescriptive footings for light-frame construction: Concrete and masonry-unit footings supporting walls of light-framed construction can be designed 'traditionally' or prescriptively. The latter-type design must be IAW with IBC Table 1809.7. Footnote d to this table says that footings for SDC-C structures must comply with the additional requirements for concrete foundations in Sect. 1908.

1809.13, Footing seismic ties: Individual spread footings of SDC-D structures that are founded on soil classified as Site Class E or F (per Sect. 1613.5.2)[4] must be interconnected by ties (i.e., rebar), and the ties must be able to carry a prescribed (within 1809.13) force.

Section 1810, Deep Foundations (e.g., piles, micropiles, drilled shafts): Use of deep foundations at LANL is rare enough such that their numerous SDC-C and -D requirements do not merit mention herein.

IBC Chapter 19, Concrete

Section 1901, General

1901.4, Construction documents: *The construction documents for structural concrete construction shall include, for SDC-D structures, a statement if slab on grade is designed as a structural diaphragm (i.e., resists seismic forces from walls or columns that are part of the SFRS).*

Section 1908, Modifications to ACI 318 (with mods to ACI-318 requirements highlighted, and with mods that add rigor to ACI-318 requirements in **boldface**; thus, non-boldfaced mods to ACI-318 requirements decrease the rigor). It is worth noting that most of the modifications to ACI 318 pertain to its Ch. 21, Earthquake-Resistant Structures, which applies to SDC-B buildings.

1908.1.2, ACI 318, Sect. 21.1.1 (Scope for earthquake-resistant structures): Modify ACI 318 Sects. 21.1.1.3 and 21.1.1.7 to read as follows:

21.1.1.3 – All members (e.g., beams, columns, footing, etc.) of SDC-B structures, in addition to satisfying the requirements of ACI 318 Chs. 1 – 19 and 22 (all of which apply to all members regardless of a building's SDC), must satisfy the requirements of 21.1.1.4 – 21.1.1.8, as applicable. **Except for structural elements of plain concrete (i.e., unreinforced, or having less reinforcement than minimum required for r/c) complying with IBC Sect. 1908.1.8 (mods to ACI-318 requirements on the use of plain concrete in earthquake-resisting structures), structural elements of plain concrete are prohibited in SDC C.**

21.1.1.7 – Structural systems designated as part of the SFRS are restricted to those permitted by ASCE 7.

1908.1.4, ACI 318, Sect. 21.9 (Special Structural Walls and Coupling Beams): Modify ACI 318 Sect. 21.9, by adding new Sect. 21.9.10 to read as follows:

21.9.10 – Wall piers and wall segments

21.9.10.1 – Wall piers not designed as a part of a special moment frame shall have transverse reinforcement designed to satisfy the requirements in 21.9.10.2 (with the exception of wall piers that are not part of SFRS and satisfy the '318' requirement for deformation compatibility, and wall piers that are laterally supported by much stiffer shear walls along the same line within a story).

21.9.10.2 – Transverse reinforcement with seismic hooks at both ends shall be designed to resist shear force computed IAW '318' requirements for special moment frame members

[4] Although, per LANL ESM Ch. 5, rev. 1, 2/9/04"…LANL site conditions are typically considered to be Site Class D [i.e., better than E]…," as a conservatism, LANL ESM Ch. 5 has always required spread footings to be interconnected by ties (i.e., rev. 1 – rev. 6).

subjected to axial load and bending, spaced at no more than six in., and shall extend beyond the clear pier height by at least 12 in.

21.9.10.3 – Wall segments with a horizontal length-to-thickness ratio less than 2.5 shall be designed as columns.

IBC, 1908.1.6, ACI 318, Sect. 21.12.1.1 (Scope for foundations of earthquake-resistant structures): Modify ACI 318, Sect. 21.10.2, to read as follows:

21.10.2 – Foundations resisting earthquake-induced forces or transferring earthquake-induced forces between a structure and the ground shall comply with the requirements of Sect. 21.12 and other applicable provisions of ACI 318 **unless modified by IBC Ch. 18.**

1908.1.8, ACI 318, Sect. 22.10 (Plain concrete in earthquake-resisting structures): Delete ACI 318, Sect. 22.10, and replace with the following:

22.10 – Plain concrete in structures assigned to **SDC C.**

22.10.1 – Structures assigned to **SDC C** shall not have elements of structural plain concrete, except as follows:

(a) Isolated footings of plain concrete supporting pedestals or columns are permitted, provided the projection of the footing beyond the face of the supported member does not exceed the footing thickness.

(b) Plain concrete footings supporting walls are permitted, provided the footings have at least two continuous longitudinal reinforcing bars. Bars shall not be smaller than No. and shall have a total area of not less than 0.002 times the gross cross-sectional area of the footing. **For footings that exceed eight in. in thickness, a minimum of one bar shall be provided at the top and bottom of the footing.** Continuity of reinforcement shall be provided at corners and intersections.

Exceptions:

1. For foundation systems consisting of a plain concrete footing and a plain concrete stemwall, a minimum of one bar shall be provided at the top of the stemwall and at the bottom of the footing.
2. Where a slab on ground is cast monolithically with the footing, one No. 5 bar can be located at either the top of the slab or bottom of the footing.

1908.1.9, ACI 318, Sect. D.3.3 (General requirements, anchors resisting earthquake forces in SDC C structures): Modify ACI 318, Sects. D.3.3.4 and D.3.3.5 to read as follows:

D.3.3.4 – Anchors shall be designed to be governed by the steel strength of a ductile steel element as determined IAW D.5.1 (Steel strength of anchor in tension) and D.6.1 (Steel strength of anchor in shear), unless either D.3.3.5 or D.3.3.6 (‘brittle-anchor-design’ alternative to D.3.3.4 and D.3.3.5, which is superseded by ESM Ch. 5, Sect. II, App. A) is satisfied.

Exceptions:

- *Anchors in concrete designed to support nonstructural components IAW ASCE 7 Sect. 13.4.2 (Anchors in Concrete or Masonry, which includes* *several 'brittle-vs.-ductile' penalties / conservatisms) need not satisfy D.3.3.4.*

- *Anchors designed to resist wall out-of-plane forces with design strengths equal to or greater than the force determined IAW ASCE 7 Equation 12.11-1 (Structural Walls and Their Anchorage, Design for Out-of-Plane Forces; $F_p = 0.8S_{DS}IW_p$) or 12.14-10 (Simplified Alternative Structural Design Criteria for Simple Buildings with Bearing Wall or Building Frame Systems, Anchorage of Concrete or Masonry Walls; $F_p = 0.8S_{DS}IW_p$[5]) need not satisfy Sect. D.3.3.4.*

D.3.3.5 – Instead of D.3.3.4, the attachment that the anchor is connecting to the structure shall be designed so that the attachment will undergo ductile yielding at a force level corresponding to anchor forces no greater than the design strength of the anchors specified in D.3.3.3 (i.e., anchor design strength associated with concrete failure modes -- $0.75\varphi N_n$ and $0.75\varphi V_n$[6]-- which is an increase in rigor in ACI 318-08 (i.e., vs. ACI 318-05; "0.75" is applied to ALL failure modes).

Exceptions: Same as 1 and 2 above, except replace "need not satisfy D.3.3.4" with "need not satisfy D.3.3.5."

1908.1.10, ACI 318, Sect. D.4.2.2 (General requirements for strength of anchors; the applicability of the tensile and shear concrete breakout strength procedures -- D.5.2 and D.6.2, respectively – is limited to anchors not exceeding two-in. diameter and 25-in. embedment depth): Delete ACI 318, Sect. D.4.2.2 and replace with the following:

D.4.2.2 – The concrete breakout strength requirements for anchors in tension shall be considered satisfied by the design procedure of D.5.2 provided Equation D-8 (less conservative – vs. Equation D-7 – prediction of basic concrete breakout strength, N_b) is not used for anchor embedments exceeding 25 in[7]. *The concrete breakout strength requirements for anchors in shear shall be considered satisfied by the design procedure of D.6.2. For anchors in shear with diameters exceeding two in., shear anchor reinforcement shall be provided IAW the procedures of D.6.2.9 (anchor reinforcement requirements for shear such design strength of anchor reinforcement can be used in lieu of shear breakout strength in determination of φVn; anchor reinforcement – for both tension and shear – is new to ACI 318-08, and clearly distinguished from the 'old' supplementary reinforcement).*

<u>IBC Chapter 22, Steel</u>

Section 2205, Structural Steel

2205.2, Seismic requirements for steel structures

2205.2.2, SDCs D – F: Structural steel structures assigned to SDC D shall be designed and detailed IAW AISC 341, Part I (Seismic Provisions, Structural Steel Buildings).

2205.3, Seismic requirements for composite construction (i.e., concrete and structural steel combined in such a manner that they resist loads together / 'as one'): In SDC B, the design, construction and quality

[5] F_p and W_p are the ASCE-7 symbols for seismic force acting on a component and component weight, respectively.
[6] φN_n and φV_n are the ACI-318 symbols for 'unreduced (for seismic)' design strengths in tension and shear, respectively.
[7] While this is a significant change in IBC 2009, Sect. 1908, it is not italicized because the provision was contained in IBC 2006, Sect. 1912 (Anchorage to Concrete – Strength Design).

of composite components that resist seismic forces shall conform the requirements of AISC 341, Part II (Seismic Provisions, Composite Structural Steel and Reinforced Concrete Buildings).

2205.3.1, SDCs D – F: Composite structures are permitted in SDC D, subject to the limitations in ASCE 7 Sect. 12.2.1 (Selection and Limitation of SFRSs), where substantiating evidence is provided to demonstrate that the proposed system will perform as intended by AISC 341, Part II. The substantiating evidence will be subject to building official approval. Where composite elements or connections are required to sustain inelastic deformations (i.e., inelastic deformation means original length / shape not achieved when load is removed), the substantiating evidence shall be based on cyclic testing.

Section 2206, Steel Joists

2206.1, General: The design, manufacture and use of open web steel joists and joist girders shall be IAW four (listed in IBC) Steel Joist Institute specifications. In addition, the seismic design of buildings in SDC D shall be IAW 2205.2.2 (see above). Since joists are primarily used as ‘gravity-load-carrying’ members, more often than not, AISC 341 will apply to them only when they perform as a diaphragm (i.e., a floor / roof that transfers earthquake loads to SFRS, as well as carries gravity loads).

Section 2210, Cold-Formed Steel (CFS) Light-Frame Construction

2210.1, General: The design and installation of structural members and nonstructural members used CFS light-framed construction where the specified minimum base steel thickness is between 0.0179 in. and 0.1180 in.[8] shall be IAW AISI S200 and Sects. 2210.2 through 2210.7, as applicable.

2210.2.6, Lateral Design: Light-framed shear walls, diagonal strap bracing that is part of a structural wall, and diaphragms used to resist in-plane lateral loads (e.g., wind, seismic, etc.) shall be designed IAW AISI S213. The significance of this (in so far as this commentary is concerned) is that the portions of S213 that contain the requirements for walls and diaphragms have Special Seismic Requirements (i.e., applicable when the Seismic Response Modification Coefficient, R[9], is greater than 3). And ASCE 7, Sect. 12.2.1 includes some SFRSs for SDC B that consist of light-framed walls / wall systems in which the R-values exceed 3.

ASCE 7 Requirements

Chapter 12, Seismic Design Requirements for Building Structures

Section 12.2, Structural System Selection

12.2.1, Selection and Limitations: The lateral and vertical SFRS shall conform to one of the eight types indicated in Table 12.2-1, Design Coefficients and Factors for SFRSs (e.g., Bearing Wall Systems, Building Frame Systems, Moment-Resisting Frame Systems, etc.).

[8] AISI defines light-framed construction as construction where the vertical and horizontal structural elements are primarily formed by a system of repetitive CFS or wood framing members. Also, regarding the limits on base steel thickness, it is generally accepted that CFS consists of material that is, in most cases, less than 0.10-in. thick.

[9] R-values greater than 1.0 mean that the SFRS is expected to undergo inelastic deformation(s) in the Design Basis Earthquake; thus, special design, detailing, inspection, QA, etc. requirements must be applied to ensure that such can occur predictably and safely. R greater 3 is also used by AISC to distinguish between structural steel SFRSs that can be designed using AISC 360 vs. AISC 341. However, in the case of structural steel, the choice to design using an R-value less than, equal, or greater than 3 is ‘trumped’ by IBC paragraph 2205.2.2 (i.e., ‘341’ is required for SDC D; thus, R greater 3 MUST be used for the SFRS).

Six of these eight types are subdivided by the types of vertical elements used to resist seismic forces (e.g., Special and Ordinary r/c shear walls; Special, Intermediate and Ordinary reinforced masonry shear walls; Special and Ordinary steel concentrically braced frames; Special, Intermediate, and Ordinary steel moment frames, Light-framed walls sheathed with wood structural panels rated for shear resistance or steel sheets; etc.).

This subdivision results in a total of 83 types of tabulated vertical elements:

- For each type of vertical SFRS, the Table contains detailing requirements (superseded by IBC 1613.1, discussed above), design factors (e.g., Response Modification Coefficient, R, etc.), and SDC limitations and building height limits.

- 38 of the 83 SFRSs are "Not Permitted" for use SDC D.[10]

- Of the 45 SFRSs that can be used in SDC D, 32 have height restrictions (e.g., building must be ≤ 35-ft. tall, etc; some height restrictions are 'relaxed' by IBC 1613.6.6, discussed above).

ASCE 7 Section 12.3, Diaphragm Flexibility, Configuration Irregularities, and Redundancy

12.3.2, Irregular and Regular Classification: Structures shall be classified as regular or irregular based upon their horizontal and vertical configurations.

12.3.2.1, Horizontal Irregularity: Table 12.3-1, Horizontal Structural Irregularities, lists six types of irregularities -- 1a, 1b, and 2 – 5 (e.g., building roof / floor(s) twist too much when building responds to lateral load, deep reentrant corners, large openings in diaphragms / floors, etc.) -- each of which contain SDC-related design and analysis / modeling requirements:

- Design-type requirements (D) include increases in the amount of force a component can withstand and reducing the amount of building deflection under lateral load. Analysis-type requirements (A) include limitations on the types of analytical procedures that can be used and how they are to be performed, whether or not the structure can be modeled in 2-D vs. 3-D, and how the potential directions of seismic loading on the building are to be considered.

- Irregularity Type 1a has six D and A requirements: Two A pertain to SDC B, two D pertain to SDC C, and one each A and D pertain to SDC D.

- Irregularity Type 1b has seven D and A requirements: Two A pertain to SDC B, two D pertain to SDC C, and one each A and D pertain to SDC D (i.e., the 7th requirement pertains to SDC E).

- Irregularity Types 2 and 3 have one each D and A requirements, and they both pertain to SDC D.

- Irregularity Type 4 has five D and A requirements: Two A pertain to SDC B, one D pertains to SDC B, and one each A and D pertain to SDC D.

- Irregularity Type 5 has four A requirements: Two pertain to SDC B, one pertains to SDC C, and one pertains to SDC D.

[10] Two of the 38 are permitted provided that certain weight and height restrictions are met (ref. ASCE 7, paragraphs 12.2.5.6 and 12.2.5.7).

12.3.2.2, Vertical Irregularity: Table 12.3-2, Vertical Structural Irregularities, lists seven types of irregularities -- 1a, 1b, 2 – 4, and 5a and 5b (e.g., deflection of a story too large compared to that of next story above when building responds to lateral load, weight of a story too large compared to that of an adjacent story, strength of a story too small compared to that of next story above, etc.) -- each of which contain SDC-related D and A requirements:

- Irregularity Type 1a has one A requirement, and it pertains to SDC D.

- Irregularity Type 1b has two D and A requirements: The one A pertains to SDC D (and the one D pertains to SDC E).

- Irregularity Types 2 and 3 have one each A requirement, and they both pertain to SDC D.

- Irregularity Type 4 has three D and A requirements: One D pertains to SDC B, and one each A and D pertain to SDC D.

- Irregularity Type 5a has two D and A requirements: The one A pertains to SDC D (and the one D pertains to SDC E).

- Irregularity Type 5b has three D and A requirements: One D pertains to SDC B, and one each A and D pertain to SDC D.

- There are two exceptions to 12.3.2.2, the most important of which is that 1a, 1b and 2 are N/A to one-story buildings in any SDC, or for two-story buildings in SDC D.

12.3.4, Redundancy

12.3.4.2, Redundancy Factor, ρ, for SDC D: Unless one of two conditions is met, ρ = 1.3 (i.e., vs. 1.0 for SDCs A – C).

- The intent here is to ensure that a building's SFRS(s) will not be subject to a 'single-point failure.'

ASCE 7, Section 12.4, Seismic Load Effects and Combinations: All members of the structure, including those not part of the SFRS, shall be designed using the seismic load effects of Sect. 12. 4 unless otherwise exempted by this Standard. Seismic load effects are the axial, shear and flexural member forces resulting from application of horizontal and vertical seismic forces.

12.4.2, Seismic Load Effect: The horizontal seismic load effect shall be determined by multiplying the effects of horizontal seismic forces by ρ.

- The upshot is, when ρ = 1.3, SDC-D SFRSs have to be designed to withstand 30% more force (i.e., vs. that which the same SFRS in SDCs A – C would have to be designed for).

12.4.3, Seismic Load Effect Including Overstrength Factor: Where specifically required, the effects of horizontal seismic forces shall be modified to account for system overstrength.

- The applicable overstrength factor (Ω_0) comes from Table 12.2-1 (i.e., for a given vertical SFRS / R-value).
- Ω_0 ranges from 2 to 3, "modified" means multiplication, and ρ is not used when Ω_0 is.
- The intent here is to ensure that only those members that are designed and detailed to undergo inelastic behavior do so (i.e., other specific members would / could 'go inelastic,' and perhaps fail as a result, if they are not designed to an amplified force level / to remain elastic).

- "Where specifically required:"
    - SDC C collector elements, splices, and their connections to seismic-resisting elements (i.e., diaphragm-edge members, parallel to direction of load, in-between points of diaphragm support by vertical SFRS; ref. ASCE 7, 12.10.2.1), except for the case of light-framed shear walls.
    - Many structural steel items designed IAW AISC 341 (e.g., certain columns, welded column splices, column bases, moment-frame connections, braced-frame connections, etc.). Recall, from earlier herein, that structural steel SFRSs in SDC D must be designed IAW AISC 341.
- The upshot is specific SDC C / D structural members and connections have to be designed to withstand two-to-three times more force than 'their SDC A – B / C counterparts.'

12.4.4, Minimum Upward Force for Horizontal Cantilevers for SDC D: Horizontal cantilever structural components (e.g., a floor slab that extends beyond a building's exterior walls, etc.) shall be designed for a minimum net upward force of 0.2 times the dead load (i.e., primarily / largely self-weight) in addition to the applicable load combinations of Sect. 12.4. As mentioned under Sect. 12.4 (previous page), vertical seismic forces must be applied; however, the way in which these forces are both determined and applied (per ASCE-7 "Basic Combinations") could result in cantilevers being designed for only net downward forces (i.e., due to self-weight 'overcoming' uplift from vertical seismic force). Given this, the fact that the worst-case loading condition for most cantilevers is downward force, and the possibility that vertical seismic loads are underestimated, requiring design for a net upward force ensures that SDC-D cantilevers have some capacity to withstand upward-acting seismic forces.

ASCE 7 Section 12.5, Direction of Loading: Although earthquake forces act in both principal directions of a building (e.g., 'north-south' and 'east-west,' etc.) simultaneously, the earthquake effects in the two principal directions are unlikely to reach their maxima simultaneously. ASCE 7 provides reasonable and adequate methods, based on SDC and building configuration, to account for / take advantage of this.

12.5.4, SDC D – F: Barring two (2) exceptions, the design seismic forces can be applied independently in each of two orthogonal directions (i.e., at 90° angle) and orthogonal interaction effects can be neglected.

Exception 1: Vertical lateral-force-resisting elements are not parallel to or symmetric about the major orthogonal axes of the SFRS (e.g., buildings that are wedge-shaped, polygonal, or curved in plan, etc.). If this type of irregularity exists, then either the "orthogonal combination procedure (i.e., components and their foundations are designed to resist 100% of the forces for one direction of loading plus 30% of them in a perpendicular direction; and the combination requiring the maximum component strength is used)," or the "simultaneous application of orthogonal ground motion (i.e., orthogonal pairs of ground motion acceleration histories are applied simultaneously)" must be used.

Exception 2: Column or wall that is part of two or more intersecting SFRSs and is subject to axial load due to seismic forces acting along either principal axis that is ≥ 20% of its axial design strength. If this condition exists then the column or wall must be designed for the most critical load effect due to application of seismic forces in any direction, which can be satisfied by either of the procedures quoted under Exception 1.

Section 12.6, Analysis Procedure Selection: Structural analysis shall consist of one of three types (ref. Table 12.6-1), or an approved (by building official) alternative. The only restriction on the use of the three tabulated analysis types pertains to SDC D; however, it only applies to one of the three types (i.e., the simplest; Equivalent Lateral Force Analysis), this restriction is likely to be rarely applicable to LANL structures (i.e., the structure would have to possess most of the irregularities listed in paragraph 12.3.2 and/or be extremely flexible).

ASCE 7, Section 12.8, Equivalent Lateral Force Procedure

12.8.4, Horizontal Distribution of Forces

12.8.4.3, Amplification of Accidental Torsional Moment: Structures assigned to SDC C, where Type 1a or 1b torsional irregularity exists shall have the effects accounted for by multiplying the accidental torsional moments (ref. 12.8.4.2) at each story by a torsional amplification factor, A_x.

- Ax is N/A to structures of light-framed construction.[11]

- A_x is a function of the maximum displacement of a story relative to the average displacement of the extreme points of that story, and it does not have to exceed 3.0.

Section 12.10, Diaphragms, Chords and Collectors

12.10.2, Collector Elements.

12.10.2.1, Collector Elements Requiring Load Combos with Ω_0 for SDC C: Ref. 12.4.3

Section 12.11, Structural Walls and Their Anchorage

12.11.2, Anchorage of Concrete or Masonry Structural Walls (i.e., bearing or shear walls, ref. 11.2).

12.11.2.1, Anchorage of Concrete or Masonry Structural Walls to Flexible Diaphragms: In addition to the requirements set forth in Sect. 12.11.2, anchorage of such walls to flexible diaphragms (i.e., as defined in 12.3.1, and IBC 1613.6.1) in SDC-C structures shall have the strength to resist a prescribed amount of force perpendicular to the wall (i.e., which could be on the order of double that for lower SDCs).

12.11.2.2, Additional Requirements for Diaphragms in SDC-C Structures.

12.11.2.2.1, Transfer of Anchorage Forces into Diaphragm: A diaphragm resists lateral loads like a wide-flange beam does, in that the diaphragm chords act like the compression and tension flanges (in providing the majority of the flexural resistance), and the diaphragm itself acts like the web (in providing the majority of the shear resistance). In order to ensure that the diaphragm and its chords both participate, continuous ties or struts are required between the chords. Without these ties/struts, the anchorage forces at the chords (at the supporting / supported walls) might not 'make it' into the diaphragm (before the chords tear off at the edge of the diaphragm).

12.11.2.2.2, Steel Elements of Structural Wall Anchorage System: Steel elements of the structural wall anchorage system – other than anchor bolts and reinforcing steel – must be designed to withstand a 40% increase in the forces otherwise required by 12.11 (i.e., to ensure that such elements remain elastic, which is consistent with the Ch.-12 design basis).

12.11.2.2.3, Wood Diaphragms: The diaphragm sheathing shall not be considered effective as providing the ties / struts required by 12.11.2.2.1. Also, 'brittle-type' anchorage designs cannot be used (e.g., toe-nailing, cross-grain bending or tension of ledgers or framing, etc.).

[11] A_x is also N/A to the Model Response Spectrum Analysis if accidental torsional effects are included in the dynamic analysis model (ref. 12.9.5).

12.11.2.2.4, Metal Deck Diaphragms: The metal deck shall not be considered effective as providing the ties / struts required by 12.11.2.2.1.

12.11.2.2.5, Embedded Straps: If embedded straps are used to connect the diaphragm to structural walls, the straps must be attached to, or hooked around, the reinforcing steel or otherwise terminated so as to effectively transfer forces to the reinforcing steel.

12.11.2.2.6, Eccentrically Loaded Anchorage System: Where elements of the wall anchorage system are loaded eccentrically or are not perpendicular to the wall, the system shall be designed to resist all components of the forces induced by the eccentricity.

12.11.2.2.7, Walls with Pilasters: Where walls include pilasters, the anchorage forces at the pilasters shall be calculated considering the additional load transferred from the wall panels to the pilasters. However, the minimum anchorage force at a floor or roof shall not be reduced.

ASCE 7, Section 12.12, Drift and Deformation

12.12.1, Story Drift Limit: The design story drift (i.e., Δ, the amount of lateral movement in response to the design loads) must not exceed the allowable story drift (Δ_a, ref. Table 12.12-1). For SDC-C structures with horizontal irregularity types 1a or 1b, Δ shall be computed as the largest difference of the deflections along any of the edges of the structure at the top and bottom of the story under consideration (i.e., vs. SDCs A and B, in which Δ is based on the center of mass at the top and bottom of a story).

12.12.1.1, Moment Frames in SDC-D Structures: $\Delta < \Delta_a / \rho$ for any story (ref. 12.3.4.2 for ρ). The reason behind this limitation is to ensure that moment-frames have enough stiffness since they tend to be flexible (relative to other SFRSs) and, in some instances, they can be designed without much redundancy (i.e., using $\rho = 1.0$).

12.12.4, Deformation Compatibility for SDC D: The manner in which some SFRSs in SDC D are designed (per ASCE 7) could result in the associated buildings undergoing a lot of deformation. This could render structural components outside of the SFRS unable to perform their intended function following an earthquake (e.g., a gravity-load-only column 'attempting' to provide resistance to seismic deformation and becoming badly damaged in the process, etc.). To prevent such occurrences, ASCE 7 requires every structural component not included in the SFRS in the direction under consideration to be designed to be adequate for gravity load effects and the seismic forces resulting from displacement to Δ. There is an exception made for r/c frame members not designed as part of the SFRS; such members must be designed IAW ACI 318, 21.11 (Members not designated as part of the lateral-force-resisting system).

Section 12.13, Foundation Design

12.13.6, Requirements for SDC-D Structures.

12.13.6.2, Foundation Ties: Similar to IBC 1809.13 (discussed above).

Section 12.14, Simplified Alternative Structural Design Criteria for Simple Bearing Wall or Building Frame Systems: Rarely, if ever, used for LANL structures; therefore, further consideration herein is not warranted.

Chapter 13, Seismic Design Requirements for Nonstructural Components

Section 13.1, General

13.1.1, Scope: This Chapter establishes minimum design criteria for nonstructural components (NSCs) that are permanently attached to structures and for their supports and attachments.

13.1.2, SDC: For the purposes of this Chapter, NSCs shall be assigned to the same SDC as the structures that they occupy or to which they are attached.

13.1.3, Component Importance Factor (I_p): All components shall be assigned an I_p as indicated in this Sect. The value of I_p shall be taken as 1.5 if any of the following apply:

1. The component is required to function for life-safety purposes after an earthquake, including fire protection sprinkler systems.

2. The component contains hazardous materials (ref. Ch. 11, paragraph 11.2).

3. The component is in or attached to an Occupancy Category IV structure (i.e., LANL PC-2) and it is needed for continued operation of the facility or its failure could impair the continued operation of the facility.

All other components shall be assigned I_p = 1.0.

13.1.4, Exemptions: The following NSCs are exempt from the requirements of this Sect.:

1. Architectural components in SDC B, other than parapets supported by bearing walls or shear walls, provided that I_p = 1.0.

2. Mechanical and electrical components in SDC B.

3. Mech. and elec. components in SDC C provided that I_p = 1.0.

4. Mech. and elec. components in SDC D provided that I_p = 1.0 and both of the following apply:

- The components are flexibly connected to whatever runs to / from them, and

- The components are mounted $\leq$ 4 ft above a floor level and weigh $\leq$ 400 lbs.

5. Mech. and elec. components in SDC D provided that I_p = 1.0 and both of the following apply:

- The components are flexibly connected to whatever runs to / from them, and

- The components weigh $\leq$ 20 lbs or, for distribution systems, $\leq$ 5 pounds per foot.

ASCE 7 Section 13.2, General Design Requirements

13.2.2, Special Certification Requirements for Designated Seismic Systems: Certifications shall be provided for designated seismic systems in SDC C as follows:

- Active mech. and elec. equipment that must remain operable following the design earthquake shall be certified by the supplier as operable based on shake table testing IAW Sect. 13.2.5 or experience data IAW with Sect. 13.2.6. Evidence demonstrating compliance with this requirement shall be submitted to the building official after review and approval by the registered design professional.

- Components with hazardous contents shall be certified by the supplier as maintaining containment following the design earthquake by analysis, shake table testing (per 13.2.5), or experience data (per 13.2.6). Evidence demonstrating compliance with this requirement shall be submitted to the building official after review and approval by the registered design professional.

ASCE 7 Section 13.5, Architectural Components

ASCE 7, 13.5.6, Suspended Ceilings

13.5.6.2, Industry Standard Construction: Unless designed IAW Sect. 13.5.6.3 (Integral Construction; sprinkler system and ceiling grid designed – by a registered design professional – and tied together as an integral unit), suspended ceilings shall be designed and constructed IAW this Sect.

13.5.6.2.2, SDC D: Design and install IAW ASTM C635-2004 (Standard Specification for the Manufacture, Performance and Testing of Metal Suspension Systems for Acoustical Tile and Lay-in Panel Ceilings), ASTM C636-2004 (Standard Practice for Installation of Metal Ceiling Suspension Systems for Acoustical Tile and Lay-in Panels), and the CISCA-2004 for Seismic Zones 3-4 (Ceilings and Interior Systems Construction Association; Recommendations for Direct-Hung Acoustical Tile and Lay-in Panel Ceilings, Seismic Zones 3-4) as modified by the following:

a. A heavy-duty T-bar grid system shall be used.

b. The width of the perimeter supporting closure angle shall be ≥ 2 in. In each orthogonal horizontal direction, one end of the ceiling grid shall be attached to the closure angle. The other end in each horizontal direction shall have a 0.75-in. clearance from the wall and shall rest upon and be free to slide on the closure angle.

c. For ceiling areas > 1000 square feet (sf), horizontal restraint of the ceiling to the structural system shall be provided. The tributary area of the horizontal restraints shall be approximately equal.

   Exception: Rigid braces can be used instead of diagonal splay wires. Braces and attachments to the structural system above shall be adequate to limit relative lateral deflections at point of attachment of ceiling grid to < 0.25 in. for the loads prescribed in Sect. 13.3.1.

d. For ceiling areas > 2500 sf, a seismic separation joint or full height partition that breaks the ceiling up into areas ≤ 2500 sf shall be provided unless structural analyses are performed of the ceiling bracing system for the prescribed seismic forces that demonstrate ceiling system penetrations and closure angles provide sufficient clearance to accommodate the anticipated lateral displacement. Each area shall be provided with closure angles IAW item b and horizontal restraints or bracing IAW item c.

e. Except where rigid braces are used to limit lateral deflections, sprinkler heads and other penetrations shall have a two-in. oversize ring, sleeve, or adapter through the ceiling tile to allow for free movement of ≥ one in. in all horizontal directions. Alternatively, a swing joint that can accommodate one in. of ceiling movement in all horizontal directions can be provided at the top of the sprinkler head extension.

f. Changes in ceiling plan elevation shall be provided with positive bracing.

g. Cable trays and elec. conduits shall be supported independently of ceiling.

h. Suspended ceilings shall be subject to the special inspection requirements of IBC Sect. 1705.

ASCE 7 Section 13.6, Mechanical and Electrical Components

13.6.8, Piping Systems: Piping systems shall satisfy the requirements of this Sect. except that elevator system piping shall satisfy the requirements of Sect. 13.6.10. Except for piping designed and constructed IAW NFPA 13, seismic supports shall not be required for other piping systems where one of the following conditions is met:

1. Piping is supported by rod hangars; hangars in the pipe run are $\leq$ 12-in. long (from top of pipe to supporting structure); hangars are detailed to avoid bending of the hangars and their attachments; and provisions are made for piping to accommodate expected deflections.

2. High-deformability (ref. Ch. 11, Sect. 11.2) piping is used; provisions are made to avoid impact with larger piping or mech. Components or to protect the piping in the event of such impact; and the following size requirements are satisfied:

   - SDC D and $I_p > 1.0$: The nominal pipe size shall be $\leq$ one in.

   - SDC C and $I_p > 1.0$: The nominal pipe size shall be $\leq$ two in.

   - SDC D and $I_p = 1.0$: The nominal pipe size shall be $\leq$ three in.

13.6.8.3, Fire Protection Sprinkler Systems (FPSSs) in SDC D: Per IBC 1613.6.3, FPSSs designed and constructed IAW NFPA 13 shall be deemed to meet the requirements of Sect. 13.6.8.

Chapter 14, Material Specific Seismic Design and Detailing Requirements: Per IBC Sect. 1613.1, this Chapter is N/A (i.e., follow IBC Chs. 19, and 21 – 23).

Chapter 15, Seismic Design Requirements for Nonbuilding Structures: Nonbuilding structures (NBSs) include all self-supporting structures that carry gravity loads and that may be required to resist the effects of earthquake – steel storage racks (e.g., like those in a ‘big box’ store); cast-in-place concrete silos having walls continuous to the foundation; tanks / vessels supported on structural towers similar to buildings; shop-fabricated and field-erected towers; self-supported and field-erected cooling towers; etc.[12] – with the exception of building structures specifically excluded in Sect. 11.1.2 (e.g., vehicular bridges, electrical transmission towers, nuclear reactors, etc.), and other NSs where specific seismic provisions have yet to be developed.

Section 15.4, Structural Design Requirements

15.4.1, Design Basis: As was the case for buildings, the seismic design and detailing of NBSs requires selection of the SFRS, which, in turn, yields design factors (e.g., R, Ω_0, etc.), height limits (for some of the SDCs), and detailing requirements (for all SDCs). In order to make selection the SFRS, the NBS must first be classified as being either “Similar to Buildings (ref. Table 15.4-1)” or “Not Similar to Buildings (ref. Table 15.4-2).”

[12] As implied by this partial list, most NBSs are structures / items that are located outside of buildings; however, per ASCE 7 Chs. 13 and 15, there are structures / items located on / within buildings that, although they might appear to be NBSs, are to be designed and detailed as NSCs (e.g., certain chimneys, cooling towers, stacks, tanks, etc.).

- NBSs Similar to Buildings: Since the design and detailing of these parallels the Ch.-12 requirements for buildings very closely, not much of Ch. 15 is devoted to them, and even less so 'SDC-specific' requirements pertaining to them. Given this, these NBSs will not be addressed herein.

- NBSs Not Similar to Buildings: As one might expect, only some of the design of these parallels Ch. 12; the rest of the design requirements, and the vast majority of the detailing requirements, are contained in Ch. 15.

ASCE 7, Section 15.6, General Requirements for NBSs Not Similar to Buildings

15.6.1, Earth-Retaining Structures: This Sect. applies to all SDC-D earth-retaining structures. The lateral earth pressures due to earthquake ground motions shall be determined IAW IBC Sect. 1803.5.12 with a geotechnical investigation prepared by a registered design professional.

Section 15.7, Tanks and Vessels

15.7.5, Anchorage: Tanks and vessels at grade can be designed without anchorage where they meet the requirements for unanchored tanks in reference documents (ref. Ch. 23; American Petroleum Institute and American Water Works Association documents). The following special detailing requirements shall apply to steel tank anchor bolts where $S_{DS} > 0.5$ (recall, S_{DS} for LANL is 0.75), or where the structure is classified as Occupancy Category IV (i.e., LANL PC-2).

- Hooked CIP anchor bolts, or other anchorage systems based solely on bond or mechanical friction, shall not be used where $S_{DS} \geq 0.33$. PI anchors can be used provided that testing validates their ability to develop yield load in the anchor under cyclic loads in cracked concrete.

- Where anchorage is required, the anchor embedment into the foundation shall be designed to develop the minimum specified yield strength of the anchor.

Chapter 16, Seismic Response History Procedures: The requirements for the linear and nonlinear response history procedures are found here. These procedures are 'one' of the three types referred to above under Ch. 12, Sect. 12.6.

Chapter 17, Seismic Design Requirements for Seismically Isolated Structures: Not considered herein (ref. IBC 1613.6.2 discussion above).

Chapter 18, Seismic Design Requirements for Structures with Damping Systems: Use of structures with damping systems at LANL is rare enough such that the requirements in this Chapter do not merit mention herein.

Chapter 19, Soil Structure Interaction for Seismic Design: Includes requirements associated with an option for the manner in which design forces and displacements are determined. The Equivalent Lateral Force Procedure and the Modal Response Spectrum Procedure assume a fixed-base structural model without foundation springs; however, both procedures allow for a reduction (in forces and displacements) if soil-structure interaction (i.e., foundation flexibility), determined using Ch. 19, is accounted for (ref. Sects. 12.8.1.2 and 12.9.7). Since soil structure interaction is required to be considered for LANL PC-3 structures only, it is seldom, if ever, considered for PC-1 and PC-2 structures; therefore, no further consideration is warranted herein.

Chapter 20, Site Classification Procedure for Seismic Design: The requirements in this Chapter are N/A to LANL since the primary purpose of site classification is determination of SDC, and SDC for LANL has been declared to be D.

Chapter 21, Site-Specific Ground Motion Procedures for Seismic Design: The requirements in this Chapter are N/A to LANL since LANL conducts a much-more detailed / thorough site-specific seismic hazard assessment.

Chapter 22, Seismic Ground Motion and Long-Period Transition Maps: The requirements in this Chapter are N/A to LANL given the LANL site-specific seismic hazard assessment.

Chapter 23, Seismic Design Reference Documents: Listing of documents referenced in Chs. 11 – 22.

Appendix 11A, Quality Assurance Provisions: Per IBC Sect. 1613.1, this Chapter is N/A (i.e., follow IBC Chs. 17 – 23).

Appendix 11B, Existing Building Provisions: Per LANL ESM Ch. 16, this Chapter is N/A (i.e., follow LANL version of IEBC).

AISC 341 Requirements

Since AISC 341 requirements are not SDC-based, given the purpose of this commentary, there is no point in listing those requirements. Instead, the following statements summarize AISC 341 with regard to the purpose and content of this commentary. The page number(s) provided after each statement is where some basis for the statement can be found herein (i.e., for complete information / detail, see AISC 341).

- What?
  - AISC 341 is to AISC 360 as ACI 318, Ch. 21 is to ACI 318, Chs. 1 – 19 and 22 (discussed above)
- When / Where?
  - AISC 341 is required for use with SDC-D SFRSs (discussed above)
- How?
  - Design and construction to AISC 341 takes more time, effort and money than to AISC 360 (discussed above)

ACI 318 Requirements

As is indicated previously in this commentary, the portion of ACI 318 that contains the seismic requirements for design and construction is Ch. 21. Although Ch. 21 contains SDC-based requirements, SDC-D structures are not exempt from any of them (ref. Table R21.1.1). Given this, and the fact that ACI 318 is written in a format that provides the commentary adjacent to the requirements, it is much more effective and efficient for those who are 'interested / affected' to read Ch. 21 than it is to include a listing of those requirements herein. Instead, the following statements summarize ACI 318, Ch. 21 with regard to the purpose and content of this commentary. The page number(s) provided after each statement is where some basis for the statement can be found herein (i.e., for complete information / detail, see ACI 318, Ch. 21).

- What?
  - ACI 318, Ch. 21 is the 'seismic bible' for r/c structures (like AISC 341 is for structural steel ones)
- When / Where?
  - ACI 318, Ch. 21 is required for use with SDC-B SFRSs
- How?
  - Design and construction to Ch. 21 takes more time, effort and money than to Chs. 1-19 and 22 and this effect is amplified as the SDC increases.
    - For example,
      - Unlike in SDC B, anchors resisting earthquake-induced forces in SDC-C structures must conform to the requirements of ACI 318, App. D, para. D.3.3 (i.e., several additional requirements including 'ductile design' and special qualification of post-installed anchors).
      - Unlike in SDC C, SDC-D structures must conform to the Ch.21 requirements on diaphragms, foundations, and members-not-designated-as-part-of-the-SFRS.

Some Context on Design and Construction of Buildings in "Moderate-to-High[13]" Seismic Areas

Given the negative connotation associated with design and construction of SDC-D buildings throughout this commentary (i.e., extra time, effort and expense), it is important to provide some context for this. In that regard, the following quotes are provided for consideration:

"The additional cost of providing seismic resistance is hard to establish because buildings tend to be unique projects and it is difficult to compare sufficiently similar buildings which differ only in their need for seismic resistance. Indicative figures for areas of high seismicity are 20% on structural design costs, 10% on structural construction costs, and significantly less on overall project costs, once building contents, services, land cost, etc. are taken into account."

Earthquake Design Practice for Buildings, 2nd Ed., 2006, pp. 115, Cost of Providing Seismic Resistance

"While building to newer codes may result in slight increases in construction costs, studies show that every dollar spent on building safer and stronger prevents four to seven dollars in future losses."

Richard P. Weiland, Chief Executive Officer of the International Code Council, 1/13/10

[13] Per IBC, SDCs A and B = low seismic risk, SDC C = moderate, and SDCs D – F = high (ref. IBC 2003 Commentary, pp. 19-36 and 19-37)