TABLE OF CONTENTS

RECORD OF REVISIONS

Rev	Date	Description	POC	OIC
0	6/28/99	Initial issue in Facility Eng Manual.	Doug Volkman, *PM-2*	Dennis McLain, *FWO-FE*
1	2/09/04	IBC-2003 & ASCE 7 replaced UBC 97; DOE-STD-1020-2002 replaced 1994; incorporated DOE O 420.1A; FEM became ESM, an OST.	Mike Salmon, *FWO-DECS*	Gurinder Grewal, *FWO-DO*
2	5/17/06	Major revision to IBC 2003 amendment style and less commentary; clarification of PC-0 applicability; OST became ISD.	Mike Salmon, *D-5*	Mitch Harris, *ENG-DO*
3	10/27/06	Administrative changes including organization and contract reference updates from LANS transition; 420.1A became 420.1B. IMP and ISD number changes based on new CoE IMP 341. Master Spec number/title updates.	Mike Salmon, *D-5*	Kirk Christensen, *CENG*
4	6/19/07	New seismic design parameters from PSHA superseding Salmon interim guidance of 1/22/07 (D5:07-021). Added Appendix A on concrete anchor design.	Mike Salmon, *D-5*	Kirk Christensen, *CENG*
5	6/16/08	IBC 2006 & ASCE 7-05 replaced IBC 2003/ASCE 7-02; minor App A changes.	Mike Salmon, *D-5*	Kirk Christensen, *CENG*
6	6/20/11	Update for IBC 2009. New Commentary on design and inspection. Administrative changes including document number.	Mike Salmon, *D-5*	Larry Goen, *CENG*
7	10/30/12	Added TA-50/55 ground motion values at 1613.5, mass concrete at 1904, erection planning at 2205.1, drawing requirements in App A.	Mike Salmon, *AET-2*	Larry Goen, *ES-DO*
8	11/06/14	Consolidated anchorage in App. A; added adhesive anchors and limited use of anchorage to masonry; also, eliminated former brittle PI anchor procedure in deference to similar provision in IBC 2009/ ACI 318-08. Other minor changes in section proper.	Mike Salmon, *AET-2*	Mel Burnett, *ES-DO*

Contact the Structural Standards POC
for upkeep, interpretation, and variance issues

Ch. 5, Section II	**Structural POC/Committee**

This Chapter is online at http://engstandards.lanl.gov

II COMMERCIAL DESIGN & ANALYSIS REQUIREMENTS

A. This Section provides the minimum requirements for the structural design and analysis of PC-0, PC-1, and PC-2 building structures, nonstructural components, and non-building structures at LANL, including programmatic equipment. These are designed using commercial codes [(i.e., the International Building Code (IBC)].

B. Nuclear facility SSCs that are designated SDC-1 or SDC-2 to comply with DOE-STD-1189 must also follow this document (as modified by Section III[1]).

C. *Guidance: Structural design procedure generally consists of the following:*

- *Establish structural arrangement/geometry*
- *Establish loads and load combinations*
- *Establish a complete load path for vertical and horizontal loads*
- *Evaluate the structural response to the loads*
- *Specification of structural capacity and drift limits (acceptance criteria)*
- *Special design considerations, such as ductile detailing requirements*
- *Development of inspections (e.g., special inspections) and tests*

D. PC-1 and PC-2 structures, systems, and components (SSC) design, tests, inspections, observations, quality, and construction shall follow the provisions of the IBC; edition and amendments per ESM Chapter 16, IBC Program and IBC Chapters 16 through 23, as further amended below (citations based on IBC 2009).[2]

1. PC-0 recognizes that design or evaluation for natural phenomena hazards may not be needed where failure of that SSC has little or no potential impact on safety, mission, or cost.

E. Loads listed in this Section shall be used in the design of PC-0, PC-1, and PC-2 SSC. Criteria for assessment and mitigation for other natural phenomena loads listed in Appendix C of DOE G 420.1-2[3] are documented in "Design-Load Basis for LANL Structures, Systems, and Components," LANL Report No. LA-14165 [6]. This report [6] provides the basis for the non-seismic loads, analysis procedures, and codes to be used in this Chapter.

F. *Guidance: Refer to Section II document "Commercial Design and Analysis - Commentary" for guidance on implementation of the IBC and its major, referenced structural standards.*

G. *Guidance: Note that Chapter 6 – Mechanical, Chapter 7 – Electrical, and others of this ESM also contain design requirements for many nonstructural components, and non-building structures.*

[1] For clarity, the phrase "and SDC-1 and SDC-2" was not added to every instance of "PC-1 and PC-2" for the benefit of those nuclear facilities using this Section, but this Section must be followed as if it was. Likewise, "and SDC-3 and SDC-4" was not added where "PC-3" is stated, but this Section must be read as if it was.
[2] Follows the graded approach philosophy outlined in DOE Order 420.1B, "Facility Safety" and implemented in guidance document DOE G 420.1-2 and design/evaluation standard DOE-STD-1020.
[3] Soon to be replaced at LANL by DOE-STD-1020-2012

1.0 IBC CHAPTER 16 STRUCTURAL DESIGN

1.1 SECTION 1604 GENERAL DESIGN REQUIREMENTS

1.1.1 1604.5 Occupancy category. Add the following text:

PC-0 SSC shall be Occupancy Category I. PC-1 SSC shall be Occupancy Category II. PC-2 SSC shall be Occupancy Category IV[4].

1.2 SECTION 1605 LOAD COMBINATIONS

1.2.1 1605.2 Load combinations using strength design or load and resistance factor design

Add **1605.2.3 Ice loads.**[5] Ice loads shall be considered in accordance with Section 2.3.4 of ASCE 7.

1.2.2 1605.3 Load combinations using allowable stress design

A. **1605.3.1 Basic load combinations**

- Add **1605.3.1.3 Ice loads**[6] Ice loads shall be considered in accordance with Section 2.4.3 of ASCE 7.

B. **1605.3.2 Alternative basic load combinations.** Add the following text:

The alternative basic load combinations shall not be used for anchorage design of SSCs.

1.3 SECTION 1606 DEAD LOADS

1.3.1 Add **1606.3 Future floor dead load**

An allowance for a 10-psf future dead load in addition to project dead loads shall be included for the floors (not roofs) of new PC-1 and PC-2 buildings.[7] However, this allowance shall not be used with equations 16-6, -7, -14, -15, and -21.[8]

1.4 SECTION 1607 LIVE LOADS

1.4.1 1607.8 Impact loads

A. Add **1607.8.3 Experimental explosion loads.**[9]

1. Reactions from experimental explosion containment structures, due to explosions, shall be considered live loads.

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[4] These 'conversions/translations' are necessary in order to design DOE SSCs using the IBC, and each one of them results in the intent of both DOE-STD-1020 and the IBC being met.
[5] The IBC does not address ice loads; however, ASCE 7 does, and LA-14165 indicates that these loads could occur on certain LANL SSCs.
[6] Ibid
[7] The future-dead-load allowance is a long-standing LANL conservatism that history has proven to be prudent given several unique factors (e.g., multiple changes in mission, building occupancy, types of nonstructural components, etc.); however, it is not required for PC-0 buildings since these tend to be pre-engineered, so inclusion of this allowance would be cost prohibitive.
[8] Including the future-dead-load allowance in these equations would be contrary to their intent, which is to minimize the effect of dead load in counteracting the effects of lateral loads.
[9] LANL conducts experiments involving explosions; however, the IBC does not address the loads that result from such (i.e., either in the form of reaction forces on a building as a result of an explosion that occurs inside of an internal containment structure, or loads on a building as a result of an exterior explosion).

2. External loads from experimental explosions shall be calculated in accordance with DOD TM 5-1300 and shall be considered live loads.

1.4.2 1607.11 Roof loads

A. **1607.11.2 Reduction in roof live loads**

- **1607.11.2.1 Flat, pitched and curved roofs.** In the first sentence, replace "Ordinary flat, pitched and curved roofs, and" with the following two sentences:[10]
  With the exception of awnings and canopies, the minimum roof live load shall be taken as 30 psf for PC-1 and PC-2 buildings.[11] This 30 psf shall not be reduced.

1.5 SECTION 1608 SNOW LOADS

A. **1608.2 Ground snow loads.** Substitute the following text:

The ground snow load shall be taken as 16 psf.[12]

1.6 SECTION 1609 WIND LOADS

A. **1609.1.1 Determination of Wind Loads.** Revise the second sentence to read as follows:

The type of opening protection required for a site is permitted to be determined in accordance with Section 1609 or ASCE 7; however, the basic wind speed and exposure category must be determined solely in accordance with Section 1609.

B. **1609.3 Basic wind speed.** Substitute the following text:

The basic wind speed shall be taken as 90 mph (i.e., 3-second gust).[13]

C. **1609.4 Exposure category.** Substitute the following text:

The exposure category shall be taken as Exposure C for each wind direction considered.

1.7 SECTION 1613 EARTHQUAKE LOADS

1.7.1 1613.3 Existing Buildings

Replace "Chapter 34" with ESM Chapter 16 Section IBC-GEN App B, LANL Existing Building/System Code.[14]

[10] After making this change, the 3rd sentence of IBC 1607.11.2.1 will read "Awnings and canopies other than of fabric construction…whichever produces the greater load."
[11] See footnote 6: same background/basis, and similar logic behind the exception.
[12] This load comes from LA-14165.
[13] The wind speed and exposure category comes from LA-14165. Note that DOE-STD-1020 states that the basic wind load, V, for PC-2 SSCs at LANL is 96 mph, and the importance factor, I is 1.0. Nevertheless, the velocity pressure due to wind loads in ASCE 7 Eq. 6-15 is the same if V = 90 mph and I = 1.15 (ASCE 7 Table 6-1 for Category IV) are used instead.
[14] LANL has adopted the IEBC for work on existing structures, and ESM Ch. 16 provides direction on implementation, exceptions taken, deletions, etc.

1.7.2 1613.5 Seismic ground motion values

A. **1613.5.4 Design spectral response acceleration parameters.**[15] Substitute the following text:

Five-percent damped design spectral response acceleration

	Labwide	TA-50/55 may use these if desired[16]
At short periods, S_{DS}	0.75 g	0.60 g
At 1-second period, S_{D1}	0.64 g	0.52 g

B. Replace in Sections 11.3 and 11.4.5 of ASCE 7, the definition for T_o from $T_o = 0.2\ S_{D1}/S_{DS}$ to $T_o = 0.1$ sec.

C. **1613.5.6 Determination of seismic design category.** Substitute the following:

The seismic design category shall be taken as Seismic Design Category D.

1.7.3 Add **1613.8 Foundations**

A. Foundations shall not be designed in locations that are within 50 feet of known active faults. Hazardous waste treatment, storage and disposal facilities must not be located within 200 feet of a fault that has had displacement within the last 11,000 years regardless of their performance category per 40 CFR 264.

B. To mitigate potential differential movements associated with surface faulting during the design-level earthquake, the design shall provide for a minimum horizontal and vertical differential movement between footings of ½ inch for PC-2 structures unless greater movement is indicated by geotechnical investigation.

C. The perimeter basement walls, and other subterranean structural walls, shall be designed for soil pressures, including potential seismic loads, as recommended by a licensed geotechnical engineer knowledgeable of LANL soil conditions. An alternative for obtaining potential seismic loads is use of the Elastic Solution in ASCE 4 (para. 3.5.3.2).

1.7.4 Add **1613.9 Additional requirements for architectural, mechanical, and electrical components, and their supports and attachments**

Refer to Appendix A, Anchorage to Concrete and Masonry.

1.8 ADD SECTION 1615 ICE LOADS[17]

Ice-sensitive structures, such as trussed towers, cable-supported structures, etc., shall consider the additional effects of ice loads in accordance with ASCE 7 Chapter 10.

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[15] The values given for the 3 parameters (i.e., S_{DS}, S_{D1}, and T_o) come from the 2007 UPSHA, and Memo D5:07-021.
[16] Memorandum, "Design Basis Ground Motion for Use in the Design of PC1 and PC2 Facilities at Los Alamos National Laboratory (SAFER-012-001)", Michael Salmon, January 18, 2012 (EMRef-66). Incorporates VAR-2012-053, same topic. For evaluation of existing SSCs at TA-50/55, other response spectrum may be more appropriate (e.g., Site Spec Alt Function of Memo's calc Fig. 6 (pg. 9) per L. Goen.
[17] The IBC does not address ice loads; however, ASCE 7 does, and LA-14165 indicates that these loads could occur on certain LANL SSCs.

1.9 ADD SECTION 1616 ACCIDENTAL BLAST LOADS[18]

A. Permanent explosive facilities shall comply with UFC 3-340-02 and, as applicable, DOD UFC 3-340-01.

B. The design of all new facilities, or those with major modifications, shall conform to DOE-STD-1212 *Explosives Safety* requirements for either accidental explosions of explosives or vapor cloud explosions. Protective construction design features are provided in UFC 3-340-02 and DOD UFC 3-340-01. When evaluating for accidental blast load, A_B, the loading A_B shall replace E (earthquake) loads in the load combination equations. All potential blast effects shall be considered including blast overpressure, gas pressure, fragments, and ground shock.

1.10 ADD SECTION 1617 MINIMUM ANTITERRORISM STRUCTURAL DESIGN MEASURES[19]

Structural design measures on progressive-collapse avoidance and window protection and presented in DOD UFC 4-010-01 shall be considered for those buildings where there is a credible terrorist threat. LANL shall specify whether these minimum antiterrorism measures are to be implemented; see also ESM Chapter 9, Facility Protection and Security.

2.0 IBC CHAPTER 17 STRUCTURAL TESTS AND SPECIAL INSPECTIONS

Refer to LANL ESM Chapter 16, IBC Program for LANL amendments to this and other IBC chapters.

3.0 IBC CHAPTER 18 SOILS AND FOUNDATIONS

3.1 SECTION 1808 FOUNDATIONS

3.1.1 1808.1 General. Add the following text:

Permanent buildings and similar structures shall have a permanent foundation (e.g., full perimeter support, rodent-excluding, no trailer skirting, etc.). Permanent is defined in ESM Chapter 16, Section IBC-GEN[20].

A. Exception: For transportables[21], a permanent foundation may be achieved by placing gravity bearing pads on 24 inches of non-frost susceptible ground or fill (95% compacted granular material with less than 6% material passing the 200 sieve)*, and providing insulated skirting around the perimeter of the buildings[22].

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[18] LANL has buildings that contain explosives: however, the IBC does not address the loads that result from such, nor does it address how such buildings are to be designed. The addition of the material in 1.9.A and 1.9.B addresses both loads and design (and more). Treating A_B like E (i.e., with regard to load combination equations and use of a load factor = 1.0) is consistent with documents that address the 'design of structures to resist blast loads.'

[19] LANL has buildings where there is a credible terrorist threat; however, the IBC does not address how such buildings should be designed so this material was added.

[20] LANL experience is that permanent foundations reduce O&M costs by minimizing settling that causes roof and structure cracks, excluding rodents and other pests, and improving energy efficiency by virtue of their superior insulation.

[21] A transportable is an easily moved prefabricated building (e.g., a trailer or manufactured office) generally intended for less than 20 year life. See ESM Ch 1 Section Z10 on design goals and Ch 16 IBC-GEN on temporary.

[22] Cost effective given limited service life and meets ASCE 32 (Sect 4.2). The 24-inch depth is in keeping with LA-14165 re frost (page 3-53). Wind anchors provide motion control.

See also LANL Standard Details ST-Z1052-1 and -2 regarding foundation support for temporary trailers.

* If fill is used, it must replace the existing material to depth of at least 24 inches.

3.2 SECTION 1809 SHALLOW FOUNDATIONS

3.2.1 1805.13 Footing seismic ties. Substitute the following text:

Interconnect all spread-footing-type foundations using tie beams. The tie beam shall be capable of resisting, in tension or compression, a minimum horizontal force equal to 10% of the larger column vertical load. The tie beams shall also be capable of resisting bending due to prescribed differential settlements of the interconnected footings, as stipulated by the project geotechnical engineer.[23]

4.0 IBC CHAPTER 19 CONCRETE

4.1 SECTION 1904 DURABILITY REQUIREMENTS[24]

Add Section 1904.6 Mass Concrete:

A. Mass concrete is defined as "any volume of structural concrete in which a combination of dimensions of the member being cast, the boundary conditions, the characteristics of the concrete mixture, and the ambient conditions can lead to undesirable thermal stresses, cracking, deleterious chemical reactions, or reduction in the long-term strength as a result of elevated concrete temperature due to heat from hydration. *In general, a placement of structural concrete with a minimum dimension equal to or greater than 4 ft should be considered mass concrete. Similar considerations should be given to other concrete placement that do not meet this minimum dimension but contain Type III cement, accelerating admixtures, or cementitious materials in excess of 660 lb/yd^3 of concrete. Consideration should also be given to placements that trap heat.*

B. The Construction Documents shall designate those portions of the structure, or concrete placement that are to be treated as mass concrete. The Project Specification (e.g., Section 03 3001, Reinforced Concrete) shall adopt the ACI 301, Section 8 requirements. The Engineer of Record shall review the Project Specification against both the Mandatory and Optional Requirements Checklists presented in ACI 301 to ensure that the Project Specification adequately addresses mass concrete.

1. In lieu of mass concrete designation and specification requirements, the engineer-of-record can opt to demonstrate (analytically, using ACI 207.2R) that these requirements are not required/applicable.

[23] LANL-specific requirement for conservatism

[24] Highlights need for such measures when required by ACI 301, since neither the IBC nor ACI 318 explicitly address mass concrete. ACI 318 Introduction states (on pp. 7), "…the contract documents should contain all of the necessary requirements to ensure compliance with the code…ACI publications, such as *Specification for Structural Concrete* (ACI 301) are written specifically for use as contract documents for construction." ACI 301 is used in this manner in the LANL Master Spec Section 03 3001 and contains provisions pertaining to mass concrete, and since some of these provisions are 'beyond the capability' of the constructor, the EOR must ensure compliance with ACI 301. Added under durability since that is the primary concern with mass concrete (i.e., cracks resulting from temperature differential between the exposed surface and the interior can be detrimental to serviceability, service life, or appearance). See ACI 201.2R, para. 3.6; ACI 207.1R, para. 1.1; and ACI 207.2R, para. 1.2.

4.2 SECTIONS 1908 MODIFICATIONS TO ACI 318 AND 1912 ANCHORAGE TO CONCRETE -- STRENGTH DESIGN

Refer to Appendix A, Anchorage to Concrete and Masonry [25]

5.0 IBC CHAPTER 20 ALUMINUM

No change.

6.0 IBC CHAPTER 21 MASONRY

6.1 SECTION 2107 ALLOWABLE STRESS DESIGN

6.1.1 2107.1 General. Add the following text:

Refer to Appendix A, Anchorage to Concrete and Masonry..

6.2 SECTION 2108 STRENGTH DESIGN OF MASONRY

6.2.1 2108.1 General. Add the following text:

Refer to Appendix A, Anchorage to Concrete and Masonry.

7.0 IBC CHAPTER 22 STEEL

7.1 SECTION 2205 STRUCTURAL STEEL

7.1.1 2205.1 General. Add the following text:

Design shall comply with OSHA provisions 29 CFR 1926, Subpart R (Steel Erection), Section 755(a), General Requirements for Erection Stability. All columns shall be securely anchored with a minimum of four (4) anchor rods or anchor bolts to address construction safety. Furthermore, each column base plate assembly, including the column-to-base plate weld and the column foundation, shall be designed to resist a minimum eccentric gravity load of 300 pounds located 18 inches from the extreme outer face of the column in each direction at the top of the column shaft to address construction safety. *See also LANL Master Specification Section 05 1000, Structural Metal Framing, for additional discussion.*[26]

8.0 IBC CHAPTER 23 WOOD

No change.

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[25] Criteria provided in Appendix A for anchorage to concrete have been adapted through ACI 318 and ACI 349 and were developed to avoid differences in anchorage provisions presented in ACI 318, ACI 349, ASCE 7, and other material standards.

[26] Lessons Learned, 2011 TA-16-200 stairs incident (ORPS-2011-1963). Subpart R definitions: *Column* means a load-carrying vertical member that is part of the primary skeletal framing system. Columns do not include posts. *Post* means a structural member with a longitudinal axis that is essentially vertical, that: (1) weighs 300 pounds or less and is axially loaded (a load presses down on the top end), or (2) is not axially loaded, but is laterally restrained by the above member. Posts typically support stair landings, wall framing, mezzanines and other substructures.

APPENDIX A – DESIGN OF ANCHORS IN CONCRETE AND MASONRY

A.1 DESCRIPTION

A. This appendix establishes the technical design requirements for designing concrete anchors for PC-0, PC-1, and PC-2 Structures Systems, and Components (SSCs) at Los Alamos National Laboratory (LANL). There are different design criteria for PC-3 concrete anchors (see Chapter 5 Section III). An anchor acceptable for a higher safety classification (PC-3) may be used for a lower PC application.

B. Cast-in place (CIP) anchors: This appendix covers the design of the following CIP anchors: Headed bolts, bolts with embedded nuts, or headed studs. CIP anchors are generally ASTM A36, A307, A354, A449, A193, or F1554 material. ASTM F1554 is the preferred material due to its excellent ductile properties, as well as its being manufactured in longer lengths (i.e., relative to other material types) that could be required by some anchorage designs. Welding and mechanical properties of headed studs shall comply with AWS D1.1 and ESM Chapter 13 - Welding, Joining, and NDE.

C. Post-installed (PI) concrete anchors: This appendix covers the design of the following types of PI anchors: expansion, adhesive, undercut, screw, and power-actuated. Anchorage to grouted masonry is also covered, as is grouted rebar. Purchase, installation, and testing requirements for PI anchors are given in the LANL Master Specification Sections listed below.

D. Not Included: Design of concrete anchors for PC-3 SSC.

E. Definitions: Definitions of anchors per ACI 355.1R and ACI 355.2 apply.

A.2 APPLICABLE CODES

IBC International Building Code by International Code Council (ICC), edition per ESM Ch 16

A.3 APPLICABLE INDUSTRY STANDARDS AND REPORTS[27]

ACI 355.2	Qualification of Post-Installed Mechanical Anchors in Concrete and Commentary
ACI 355.1R	State-of-the-Art Report on Anchorage to Concrete
ACI 318	Building Code Requirements for Structural Concrete and Commentary
ICC-ES AC	ICC Evaluation Service Acceptance Criteria (http ://www.icc-es.org/)
ICC ES Reports	ICC Evaluation Services Reports (http ://www.icc-es.org/)

A.4 LANL DOCUMENTS

Master Spec Section 05 0520	Post-installed Concrete and Grouted Masonry Anchors – Normal Confidence
Master Spec Section 05 0521	Post-installed Concrete Anchors – High Confidence
Master Spec Section 03 6000	Grout
ESM Chapter 13	Welding, Joining, and NDE
ESM Chapter 16	IBC Program, Section IBC-GEN

LANL Standard Details for anchorage (facility/IBC, may be adaptable for R&D/programmatic)
Motor Control Center Anchorage, ST-D5020-3
Low Voltage Dry Type Three Phase Transformer Anchorage Requirements, ST-G4010-40 Sheet 2
Wall Mounted Enclosures, ST-F1033-1

[27] As a minimum, use standard edition referenced by required IBC edition; more recent also acceptable

A.5 PERFORMANCE CATEGORY CLASSIFICATION

A. Anchorage shall be designed to the highest performance category or NPH design category assigned to the component or bracing. The performance category shall be assigned by team of professionals working together that include the safety analyst, the NPH Design Engineer and the Cognizant System Engineer who is responsible for the mechanical and electrical design of the equipment.

B. Anchorage for PC-1 and PC-2 systems whose failure could compromise a PC-3 system shall be designated as PC-3 to account for seismic 'II over I' or 'III over I' design basis issues. Engineering drawings shall indicate the designated Performance Category. A higher safety class design (PC-3) can be used in lower safety class applications (PC-1 or PC-2).

A.6 ENVIRONMENTAL CONDITIONS

A. Anchors for indoor use in non-aggressive chemical environments may be carbon steel with zinc electroplating. Anchors for use outdoors or in aggressive environments shall be galvanized or made of stainless steel.

A.7 SEISMICALLY EXEMPT ANCHORS[28]

A. Anchorage for nonstructural components that are exempt per ASCE 7 paragraph 13.1.4.4 and 13.1.4.5 are not required to be designed for seismic forces; therefore, such anchors do not need to comply with the requirements in A.11.B (herein), ACI 318 paragraph D.3.3., or the provisions of ASCE 7, 13.4.2 (as amended by Appendix A).

B. PI anchors that are seismically exempt are still proprietary products; thus, they are required to comply with the IBC and ESM Chapter 16, IBC Program[29].

A.8 POWER-ACTUATED FASTENERS

A. Power-actuated fasteners may be used for attachment to concrete. Power-actuated fasteners shall not be used to resist permanent tension loading unless approved for such loading in their ICC ES Report and in compliance with the IBC. Design shall comply with all requirements of the ICC ES Report (including minimum spacing, edge distance, allowable loads, etc.).

A.9 GROUTED REINFORCING STEEL

A. Reinforcing steel bar may be post-installed into hardened concrete by using an epoxy, acrylic, or cementitious grout. The allowable load and embedment depth for epoxy and acrylic grouted rebar shall be determined per the ICC ES Report. In cases where the ICC report does not give an embedment depth sufficient to develop the full design strength of the bar, use an embedment depth equal to the development length of the bar being post-installed.

B. Embedment length of grouted rebar or threaded rod shall be determined per manufacturer design guides, subject to the ESM Structural POC approval.

A.10 GENERAL DESIGN REQUIREMENTS

A. Cast in place (CIP) anchors such as headed bolts, headed studs and hooked (J- or L-) bolts should be used over PI anchors whenever possible.

B. CIP or PI undercut anchors shall be used to anchor vibrating and rotating equipment that is not vibration-isolated. Use of PI anchors shall comply with the following:

1. PI anchors shall not be installed through liner plate.

[28] The term "non-structural anchors" was used in this document prior to 2014 revision.

2. To minimize rebar damage during anchor installation, the PI anchor design shall provide for limited anchor relocation (at least ± 1 inch) to facilitate anchor installation. Due consideration shall be given to the location tolerances of the anchors to avoid interferences with reinforcement.
3. Welding base plates to high-strength or non-weldable PI anchors is not permitted.
4. Except as indicated below (in A.11.B), PI anchors shall not be used in masonry walls. [29] Through-bolting may be an acceptable alternative.
5. PI anchors shall not be located in the bottom of precast and pre/post-tensioned T-beam stems. PI anchors in the sides of the T-beam stems shall be designed and approved by the Engineer of Record.
6. Adhesive anchors shall not be used in in environments with temperature extremes in excess of that allowed by a given ICC-ES Report. See manufacturer's data and ICC ES reports for reduced allowable strength at elevated temperatures and limitations on aggressive exposure conditions including fire. *At elevated temperatures where strength reduction is significant for epoxy and adhesive anchors, consider the use of cementitious grout.*

A.11 DESIGN REQUIREMENTS

A. Anchors approved for use at LANL for PC-0, PC-1, and PC-2 SSCs must be in compliance with the IBC as amended below (based on IBC-2009, unless noted otherwise, and ASCE 7-05).

B. Additional requirements for architectural, mechanical, and electrical components and their supports and attachments (ref. 1613.9 added to IBC in Section II text)

1. Add the following sentence to the end of ASCE 7, 13.4.1:

   The value of Rp used in Section 13.3.1 shall not exceed 6.

2. Replace ASCE 7, Section 13.4.2 with the following:

   13.4.2 Anchors in concrete or masonry

   13.4.2.1 Anchors in concrete. Anchors in concrete used for component anchorage shall be designed in accordance with LANL ESM, Chapter 5, Section II.

   13.4.2.2 Anchors in masonry. Anchors in masonry used for component anchorage shall be designed in accordance with LANL ESM, Chapter 5, Section II.. Anchors shall be designed to be governed by the tensile or shear strength of a ductile steel element. Exception: Anchors shall be permitted to be designed so that the support that the anchor is connecting to the structure undergoes ductile yielding at a load level corresponding to anchor forces not greater than their design strength, or the minimum design strength of the anchors shall be at least 2.5 times the factored forces transmitted by the component.

   13.4.2.3 Post-installed anchors in concrete and masonry. Post-installed anchors shall fulfill the requirements of 13.4.2.1 or 13.4.2.2. Post-installed anchors in concrete used for component anchorage shall be prequalified for seismic applications in accordance with ACI 355.2 or other approved qualification procedures. Post-installed anchors in masonry used for component anchorage shall be prequalified for seismic applications in accordance with ICC-ES AC01, AC58 or AC106.

[29] The reason for the LANL prohibition (i.e., subject to the exception noted) is two-fold: 1) Concern for the structural integrity of the wall (following introduction of the anchor and the new load). 2) Unpredictability associated with the behavior / response of the anchorage system,

Exceptions:

- Adhesive anchors shall not be permitted in applications where normal gravity loads induce tension in the anchor or other applications that produce sustained tension load.
- Anchors prequalified for seismic applications need not be governed by the steel strength of a ductile steel element.

C. **Section 1704.15 Special Cases.** Add the following text: Special-case components, such as post-installed anchors, are subject to LANL Building Official approval per ESM Chapter 16, IBC Program (Section IBC-GEN Subsection 8.2).

D. **Section 1908.1.9 ACI 318, Section D.3.3.**

Edit IBC modifications D.3.3.4 and D.3.3.5 as follows:[30]

Delete Exception 1.

E. **Section 1908.1.9 ACI 318, Section D.3.3.**

Add IBC modification D.3.3.6[31]:

D.3.3.6 – ACI 318, Appendix D, D.3.3.6 shall not be used in the following instances:

1. Column base plate anchorage in braced-frame bays that exceed 12 feet in height.
2. Column base plate anchorage in moment-resisting-frame bays in which the column base is “fixed” (i.e., versus “pinned”).
3. Base plate anchorage of any component that transfers lateral seismic loads to the foundation and that exceeds 12 feet in height.

F. **Section 1912.1 Scope.** Add the following text at the end of 1912.1:

The strength design of adhesive anchors shall be in accordance with ACI 318-11, Appendix D as modified by Sections 1908.1.9 and 1908.1.10[32]. All portions, and only those portions, of ACI 318-11 that pertain specifically to adhesive anchors shall be complied with.

G. **Sections 2107.1 and 2108.1 General.** Add the following text at the end of 2107.1 and 2108.1:

PI anchors can be used in masonry provided that ESM Chapter 5, Section II, Appendix A (including paragraph A.11.B) is followed.[33]

[30] IBC 2009 includes these exceptions due to the conservatism of ASCE 7-05 Section 13.4. The removal of that conservatism herein (ref. A.11.B) negates the need for the exceptions.

[31] This edit to ACI 318 App. D ‘brittle-anchorage design’ ensures that ductile yielding will occur prior to a brittle failure in specific instances that LANL believes warrant such behavior.

[32] Prior to IBC-2012 / ACI 318-11, adhesive-anchor design was ‘outside of the IBC (hence regulated solely by ICC-ES Reports and similar).’ Since the 2012 inclusion involved significant changes associated with the design, installation and inspection, all pre-IBC-2012 ESRs will be rescinded by Jan 2015. Thus, in order for LANL to ensure uninterrupted use of these anchors, it was necessary to ‘leap ahead’ one version of the IBC for anchorage only (via this amendment to IBC-2009).

[33] Since the industry standard (ASCE 7-10, Ch. 13) has evolved to where use of PI anchors in masonry is permitted (for nonstructural components only, and subject to limitations placed on the anchor products), it makes sense for LANL to allow the same. It should be noted that IBC-2009 and its referenced standard editions of TMS 402/ACI 530/ASCE 5 are silent on the use of PI anchors in masonry while IBC-2012-referenced editions are not.

A.12 DRAWING REQUIREMENTS

A. The Engineer of Record shall specify each PI anchor to be installed. This specification shall include the manufacturer's name, product name, anchor diameter, minimum embedment depth, minimum edge distance, minimum spacing, and the ESR number.

B. The Engineer of Record shall specify, for each location in which a PI anchor is to be installed, the concrete type (i.e., normal- vs. light-weight), compressive strength (i.e., f'c) and thickness.[34] In the event that none of these properties change from one anchorage location to another, the Engineer of Record need only indicate them once.

A.13 METHODOLOGY FOR SEISMIC DESIGN OF ANCHORAGE TO CONCRETE OR MASONRY FOR NONSTRUCTURAL COMPONENTS

NOTE: For use with adhesive anchors, what follows must be modified. Refer to A.11.F.

A. Determine force on component

2009 IBC (1613) – ASCE 7-05 (Chapter 13, 13.3) – ESM Rp less than or equal to 6

B. Compute force in anchorage

For concrete, compute anchor capacities for various failure modes use ACI 318-08.

For masonry, use TMS 402/ACI 530/ASCE 5 for CIP anchors; for PI anchors use ICC-ES reports based on ICC-ES AC01, AC58, or AC106.

C. Determine controlling capacity for brittle failure modes.

Per D.3.3.3 concrete failure modes shall be factored by 0.75 for earthquake forces for SSC in Seismic Design Category C, D, E, or F. If earthquake forces are not included then the 0.75 can be omitted.

$\phi N_{n.brit} = 0.75 \bullet \min(\phi N_{cb}, \phi N_{pn}, \phi N_{sb})$ $\phi V_{n.brit} = 0.75 \bullet \min(\phi V_{cb}, \phi V_{cp})$

D. Determine reduction factor for situation where a brittle failure mode is controlling

ESM Chapter 5, Section II, Appendix A

$\phi_{brit} = 0.4$

E. Determine anchor capacity considering whether a ductile or brittle failure mode controls

$\phi N_n =$

$|\phi N_{sa}$ if $\phi N_{n.brit} > \phi N_{sa}$ ^$\phi V_{n.brit} > \phi V_{sa}$ $\phi_{brit} \phi N_{n.brit}$ otherwise

$\phi V_n = \begin{cases} \phi V_{sa} \text{ if } \phi N_{n.brit} > \phi N_{sa} \text{ ^} \phi V_{n.brit} > \phi V_{sa} \\ \phi_{brit} \phi V_{n.brit} \text{ otherwise} \end{cases}$

[34] Since the design and performance of PI anchors are dependent upon these properties (i.e., in addition to those listed in A.12.A), they are included in the Special Inspections section of each ESR, as well as the inspection table in each of the PI-anchor specification sections. Given this, the fact these properties can't be found in an ESR, and the possibility that the installer and the inspector don't know them (particularly for projects on / in existing structures), they must appear on the construction drawings.

F. Check interaction in anchor. Use either the provisions of D.7 or equation in RD.7

$$IC = \left(\frac{N_{ua}}{\phi N_n}\right)^{\frac{5}{3}} + \left(\frac{V_{ua}}{\phi V_n}\right)^{\frac{5}{3}} \quad \begin{cases} \text{OK if IC} \leq 1.0 \\ \text{"NOT OK" } otherwise \end{cases}$$

Where:

ϕ	ϕ values are according to ACI 318-08, App. D, D.4.4 or D.4.5
N_{sa}	Steel strength of anchor in tension per ACI 318-08, App. D, D.5.1
N_{cb}	Concrete breakout strength of anchor in tension per ACI 318-08, App. D, D.5.2
N_{pn}	Pullout strength of anchor in tension per ACI 318-08, App. D, D.5.3. Per D.3.3.2, for earthquake forces for SSC in Seismic Design Category C, D, E, or F, N_p shall be based on the results of the ACI 355.2 Simulated Seismic Tests.
N_{sb}	Concrete side-face blowout strength of a headed anchor in tension per ACI 318-08, App. D, D.5.4
V_{sa}	Steel strength of anchor in shear per ACI 318-08, App. D, D.6.1. Per D.3.3.2, for earthquake forces for SSC in Seismic Design Category C, D, E, or F, V_{sa} shall be based on the results of the ACI 355.2 Simulated Seismic Tests.
V_{cb}	Concrete breakout strength in anchor in shear per ACI 318-08, App. D, D.6.2.
V_{cp}	Concrete pryout strength of anchor in shear per ACI 318-08, App. D, D.6.3