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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	Incorporated IBC & ASCE 7 in place of UBC 97; incorporated DOE-STD-1020-2002 versus 1994 and concepts from DOE O 420.1A; FEM became ESM, an OST.	Mike Salmon, *FWO-DECS*	Gurinder Grewal, *FWO-DO*
2	5/17/06	Major revision: Reduced commentary in favor of IBC 2003 amendments only; clarification of PC-0 applicability; OST became ISD.	Mike Salmon, *D-5*	Mitch Harris, *ENG-DO*
3	10/27/06	Administrative changes only. Organization and contract reference updates from LANS transition; 420.1A became 420.1B. IMP and ISD number changes based on new Conduct of Engineering IMP 341. Master Spec number/title updates. Other administrative changes.	Mike Salmon, *D-5*	Kirk Christensen, *CENG*
4	6/19/07	Incorporated new seismic hazard analysis results into the seismic design parameters (1.7.1); supersedes 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	Incorporated IBC 2006 & ASCE 7-05 in place of 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. Admin 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. Updated references.	Mike Salmon, *AET-2*	Larry Goen, *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 for certain lightweight equipment items, furniture, etc, and for other special circumstances where there is little or no potential impact on safety, mission, or cost. Assignment of PC-0 to an SSC is intended to be consistent with, and not take exception to, model building code NPH provisions.

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 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.

1.0 IBC CHAPTER 16 STRUCTURAL DESIGN

1.1 SECTION 1604 GENERAL DESIGN REQUIREMENTS

A. **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[3].

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.**[4] 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**[5] 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.[6] However, this allowance shall not be used with equations 16-6, -7, -14, -15, and -21.[7]

[3] 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.
[4] The IBC does not address ice loads; however, ASCE 7 does, and LA-14165 indicates that these loads could occur on certain LANL SSCs.
[5] Ibid
[6] 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.
[7] 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.

1.4 SECTION 1607 LIVE LOADS

1.4.1 1607.8 Impact loads

A. Add **1607.8.3 Experimental explosion loads.**[8]

1. Reactions from experimental explosion containment structures, due to explosions, shall be considered live loads.
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:[9] 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.[10] 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.[11]

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).[12]

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

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

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[8] 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).

[9] 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."

[10] See footnote 6: same background/basis, and similar logic behind the exception.

[11] This load comes from LA-14165.

[12] 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.

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.[13]

1.7.2 1613.5 Seismic ground motion values

A. **1613.5.4 Design spectral response acceleration parameters.**[14] Substitute the following text:

Five-percent damped design spectral response acceleration

	Labwide	TA-50/55 may use these if desired[15]
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 text:

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 in Holocene time (the most recent time of Quaternary period, 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).

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[13] LANL has adopted the IEBC for work on existing structures, and ESM Ch. 16 provides direction on implementation, exceptions taken, deletions, etc.

[14] 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.

[15] 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.

1.7.4 Add **1613.9 Additional requirements for architectural, mechanical, and electrical components, and their supports and attachments**[16]

A. Replace the following text in ASCE 7, Section 13.4.2, "The anchor is designed in accordance with Section 14.2.2.14," with the following text:

The design strength of anchors in concrete shall be determined in accordance with the provisions of IBC Section 1912 as amended below in this Section.

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.

1.9 ADD SECTION 1616 ACCIDENTAL BLAST LOADS[18]

A. Permanent explosive facilities shall comply with DOD TM 5-1300 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 DOD TM 5-1300 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.

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[16] Without this addition, IBC 1613 results in seismic design of all anchorage systems for nonstructural components that is compliant with ASCE 7. The problem with compliance with ASCE 7 for all anchorage systems is that ASCE 7 14.2.2.14 (which was corrected in one of the errata to 14.2.2.17) contains a modification to ACI 318, App. D allowing for non-ductile-designed, post-installed (PI), anchorage systems that is less conservative than the "Brittle PI anchors" provisions of IBC Sect. 1912 (i.e., as amended by App. A herein).

[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.

[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. The addition of the material in 1.10 addresses this shortcoming.

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, 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[21]. *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.[22]

4.0 IBC CHAPTER 19 CONCRETE

4.1 SECTION 1904 DURABILITY REQUIREMENTS[23]

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

[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] 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.
[22] LANL-specific requirement for conservatism.
[23] 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.

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.

4.2 SECTION 1912 ANCHORAGE TO CONCRETE STRENGTH DESIGN

Substitute the following text: Anchorage to concrete shall follow Section II, Appendix A.[24]

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:

Post-installed anchors shall not be used in masonry walls unless they meet the definition of "Non-Structural Anchors" in Section II, Appendix A.[25]

6.2 SECTION 2108 STRENGTH DESIGN OF MASONRY

[24] The treatment of Anchorage to Concrete by IBC, as well as its various applicable reference standards, has evolved significantly during the past several years, and there is 'no end in sight.' Given this, and many other factors (e.g., the importance of anchorage, the myriad applications, the fact that anchorage systems are 'shared turf' between AISC, ASCE, ACI, etc. and 'differences of opinion' exist between them, footnote 14, etc.), it is not uncommon for organizations with responsibility for many buildings (like LANL) to have their own anchorage requirements.
[25] Sect. II, App. A prohibits the use of 'structural' PI anchors in masonry walls, while IBC and the applicable referenced standard (i.e., TMS 402/ACI 530/ASCE 5) are silent on the use of any PI anchors in masonry. The reason for the LANL prohibition is that the 'state-of-the-art' in PI anchorage in masonry has not evolved to that which exists for PI anchors in concrete. More specifically, there is currently no way to ensure that the design of PI anchorage system involving masonry will fail in a ductile manner,

6.2.1 2108.1 General. Add the following text:
Post-installed anchors shall not be used in masonry walls unless they meet the definition of "Non-Structural Anchors" in Section II, Appendix A.[26]

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.*[27]

8.0 IBC CHAPTER 23 WOOD

No change.

[26] Ibid.
[27] 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

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. An anchor acceptable for a higher safety classification (PC-3) may be used for a lower PC application.

B. Cast-in anchors: This appendix covers the design of the following cast-in anchors: Headed bolts, bolts with embedded nuts, or headed studs. Cast-in 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, and powder actuated fasteners. Grouted rebar is also covered. 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[28]

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 Reports	ICC Evaluation Services Reports (http ://www.icc-es.org/)

A.4 LANL DOCUMENTS

Master Spec Section 03 1512	Post-installed Concrete Anchors – High Confidence
Master Spec Section 03 1534	Post-installed Concrete Anchors – Normal Confidence
Master Spec Section 03 6000	Grout
ESM Chapter 13	Welding, Joining, and NDE
ESM Chapter 16	IBC Program, Section IBC-GEN

A.5 PERFORMANCE CATEGORY CLASSIFICATION

A. The Engineer of Record shall determine if an attachment is PC-1, PC-2, PC-3, or PC-4. *For example, anchorage for a PC-1 or -2 pump being installed on a PC-3 or -4 concrete slab is considered PC-1 or -2. Documentation of whether a system is PC-1, -2, -3 or -4 may be obtained from the LANL FIMS database or contact the facility or project Design Authority Representative for guidance.*

B. Anchors for PC-1 and PC-2 systems for which failure could compromise a PC-3 or PC-4 system shall be designated as PC-3 or PC-4 to account for seismic ‘II over I’ or ‘III over I’ design basis

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

issues. Engineering drawings shall indicate the designated Performance Category. A higher safety class design (PC-3 or PC-4) 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 NON-STRUCTURAL ANCHORS

A. Non-structural anchors support very light loads and subsequently are exempt from being "seismically designed anchors." PI anchors for use in non-structural applications shall be chosen from qualified anchors in compliance with the IBC and ESM Chapter 16, IBC Program.

B. A non-structural application must meet the following criteria:[29]
   1. PC-1 mechanical and electrical components with flexible connections between the components and associated ductwork, piping, and conduit; and
   2. One of the following conditions applies:
      a. Components are mounted at 4 ft or less above a floor level and weigh 400 lb or less, or
      b. Components weighing 20 lb or less, or
      c. Distribution systems weighing 5 lb/ft or less.

A.8 POWDER-ACTUATED FASTENERS

A. Powder-actuated fasteners may be used for attachment to concrete. Structural applications must be designed to resist applied forces and displacements. Powder-actuated fasteners shall not be used for seismic 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 REBAR

A. Rebar 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. PI anchors and surface mounted plates are limited to applications where support requirements are added or modified after concrete placement, except for lightly loaded items where an embedded plate is not economical. *For heavy loads, cast-in-place embeds should be used in lieu of PI anchors where possible.*

B. Anchors for vibrating and rotating machineries: only cast-in place (CIP) or PI undercut anchors shall be used.

C. Use of PI anchors shall comply with the following:
   1. PI anchors shall not be installed through liner plate.

[29] This comes from ASCE 7, Ch. 13, Exemptions.

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. PI anchors shall not be used in masonry walls. Through-bolting may be an acceptable alternative PI anchors shall not be located in the bottom of precast and pre/post-tensioned T-beams stems. PI anchors in the sides of the T-beam stems shall be designed and approved by the Engineer of Record.
5. Adhesive anchors shall not be used where they are subjected to sustained tension load (e.g., overhead applications)[30].
6. Adhesive anchors shall not be used in high temperature service or in high radiation environments. 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 (sections based on IBC 2009).

B. **Section 1704.15 Special Cases.** Add the following text: Special case components such as anchors are subject to LANL Building Official approval per ESM Chapter 16, IBC Program (Section IBC-GEN Subsection 6.2).

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

Edit IBC modification D.3.3.4 as follows:[31]

Change "…, unless either D.3.3.5 or D.3.3.6 is satisfied" to read, unless D.3.3.5 is satisfied.

Also, delete ACI 318, Section D.3.3.6.

D. **Section 1912.1 Scope.** Add the following text after first paragraph:

PI anchors may be used in lieu of CIP anchors provided either 1912.2 or 1912.3 are met.

E. Add **Section 1912.2 Ductile PI anchors.** The strength of ductile PI anchors is governed by ductile yielding of a steel element.

- **1912.2.1 Ductile PI anchor applicability.** Either ductile PI anchors or CIP anchors shall be used for the following circumstances:
  1. Column anchorage for vertical bracing with a height greater than 12 feet.
  2. Fixed-base column anchorage for moment-resisting frames which are part of the seismic-force-resisting system.

[30] Adhesive creep issue; ref. Bechtel Corporation Engineering Data Letter, Post Installed Adhesive Anchors, 3DL-C13-00001 Rev. 000 March 17, 2008

[31] These edits ensure that A) The LANL "Brittle PI anchors" provisions (contained herein under A.11.F) are used in lieu of ACI's provision for such, and B) Anchorage systems that include cast-in-place anchors are designed such that ductile yielding (i.e., of the anchors or the attachment) will occur prior to a brittle failure.

3. Any component, greater than 12-feet high, which transfers lateral seismic loads to the foundation.

Ductile anchors may be used for any structure, system or component.

- **1912.2.2 Ductile PI anchor criteria.** Ductile PI anchors shall be designed and evaluated in accordance with Appendix D of ACI 318 as modified by Sections 1908.1.9 and 1908.1.10.

F. Add **1912.3 Brittle PI anchors.**[32] The strength of brittle PI anchors is governed by brittle behavior (i.e., tension or shear on a brittle steel element; concrete breakout, side-face blowout, pullout, or pryout). All anchors shall be assumed to have brittle behavior unless ductile behavior has been demonstrated by meeting Appendix D, paragraphs D.3.3.1 through D.3.3.5, of ACI 318 as modified by Section 1908.1.9.

- **1912.3.1 Brittle PI anchor applicability.** Brittle PI anchors shall not be used where ductile PI anchors are required.

- **1912.3.2 Brittle PI anchor criteria.** The capacity of brittle PI anchors shall be developed from either 1 (strength design) or 2 (ASD):

1. $\text{Capacity} = \begin{cases} \dfrac{0.6}{R_p} \times \phi N_n \\ \dfrac{0.6}{R_p} \times \phi V_n \end{cases}$ 2. $\text{Capacity} = \begin{cases} \dfrac{0.6\lambda}{R_p} \times N_{allowable} \\ \dfrac{0.6\lambda}{R_p} \times V_{allowable} \end{cases}$

in which:

ϕN_n and ϕV_n are calculated in accordance with Appendix D of ACI 318, excluding paragraph D.3.3; and $0.6/R_p \leq 0.4$.

$N_{allowable}$ and $V_{allowable}$ are manufacturer's allowable working capacities, per an International Code Council Evaluation Service Report (ICC-ES ESR), based on the manufacturer's recommended factor of safety (FS). If FS < 4, then multiply allowable capacity by the ratio FS/4.

[32] Ductile anchors are currently required by ACI 318 for structural members because seismic loads are assumed to be reduced for inelastic energy absorption. The requirement for ductile anchors is retained in these criteria for structural elements that are part of the seismic lateral load resisting system. While it is conservative to design equipment anchorage, component anchorage, etc. using ductile anchors, it is not always cost effective. The brittle anchor criteria are developed to provide a safe, conservative, alternative design approach. The brittle anchor criteria are not applicable to components that are part of the structure's lateral seismic load path. The brittle anchor modifications to ACI 318 code capacities, 0.6/Rp, is intended to (1) remove the effects of the inelastic response modification factor, Rp; and (2) provide a capacity similar to the brittle anchor criteria in ACI 349. The net effects of these criteria are that the brittle anchor will not fail below 167% of the design seismic load. Brittle anchor criteria are also provided for anchors using vendor catalog allowable capacities. Vendor catalog allowable capacities are usually based on the average (mean) ultimate capacity, determined by testing, divided by a factor-of-safety (FS). Use of 60% of the allowable capacity results in less than a 1% probability of failure for an FS = 3 and coefficients-of-variation (COV) less than 0.67. It is judged that anchors with a COV greater than 0.67 will have a larger FS. Thus, it is judged that the brittle anchor criteria are sufficiently conservative. ACI 318 considers cracked concrete in anchor design, while previous codes were often silent on the effects of cracked concrete on anchor strength. Vendor allowable capacities which do not consider cracking are multiplied by the factor $\lambda = 0.75$, which is based on the guidance of DOE-EH-0545 for expansion anchors.

λ = 0.75, unless (1) the manufacturer's allowable capacity includes the effects of cracked concrete, or (2) it can be demonstrated by calculation that the concrete will not crack for all applied loading combinations. If (1) or (2) apply, λ may be taken as 1.0.

R_p is the Response Modification Coefficient used to develop the seismic loads, given as R in ASCE 7 Tables 12.2–1 and 12.4–1, or as R_p in ASCE 7 Tables 13.5–1 and 13.6–1.

- Allowable loads, minimum embedment, spacing, edge distance, increase factors for short term loading, etc., for PC-1 and PC-2 anchors shall be determined per the most current ICC Evaluation Service Report (www.icc-es.org).
- Use allowable load tables for "with special inspection." Capacity of the anchor bolts shall be determined in accordance with this Appendix.
- Combined shear and tension interaction shall be determined per the ICC ES Report.
- Allowable loads may not be increased for short term (wind or seismic) loading unless specifically allowed by the ICC ES Report.
- Threaded rod used for epoxy and acrylic anchors shall be of the steel grades listed in the ICC ES Report unless otherwise approved by the ESM Structural POC.

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.[33] In the event that none of these properties change from one anchorage location to another, the Engineer of Record need only indicate them once.

[33] 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