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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; incorporated concepts from DOE O 420.1A; FEM became ESM, an OST.	Mike Salmon, *FWO-DECS*	Gurinder Grewal, *FWO-DO*
2	5/17/06	Revised load combos since ACI 349 is specified for PC-3 R/C structures and the load factors in the current version of ASCE 7 (used for load combos) are inconsistent with the strength reduction factors in the current version of ACI 349, including new section 1.1.13 on crane and pipe restraint loads, companion table to go with former Table III-6 (i.e., Table III-6 became Tables III-6 and -7. Minor editing changes; 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 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 DBE Response Spectra. Added Appendices A & B for concrete anchor design.	Mike Salmon, *D-5*	Kirk Christensen, *CENG*
5	6/20/11	Major revision. Added 1189 requirements; removed PC-4 requirements; new response spectra.	Mike Salmon, *D-5*	Larry Goen, *CENG*

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

Ch. 5 Section III	**Structural POC/Committee**

III NUCLEAR DESIGN AND ANALYSIS REQUIREMENTS

A. This Section provides requirements for the design and analysis of nuclear facility structures, nonstructural components, equipment, distribution systems, and non-building structures. General Requirements of the LANL Engineering Standards Manual, Chapter 5, Subsection I also apply.[1]

B. *Per ESM Chapter 1 Section Z10 (Codes and Standards subsection), significant nuclear facility projects require compliance with DOE-STD-1189, Integration of Safety into the Design Process.* DOE-STD-1189, Appendix A provides criteria for specification of the seismic design basis of structures, systems, and components (SSC) for new nuclear facilities and major modifications to them; within these, the criteria relate to radiological and chemical hazards.

C. DOE-STD-1189 is compliant with DOE G 420.1-2 and invokes the use of ANSI/ANS 2.26-2004, "Categorization of Nuclear Facility Structures, Systems and Components for Seismic Design," and ASCE/SEI 43-05, "Seismic Design Criteria for Structures, Systems and Components in Nuclear Facilities." [2]

D. For safety SSCs in these types of facilities, Seismic Design Bases (SDBs) are used instead of Performance Categories. SDBs include the designation of both Seismic Design Categories (1-5) [not the same as IBC SDCs] and Limit States (A-D) for a total of 20 SDBs. For other NPH design matters, the PCs from DOE-STD-1020 are used.

E. For DOE purposes, the criteria for selecting an SDC shall be based on the dose associated with an unmitigated seismic accident determined by the accident or hazard analysis performed by the safety analyst. The SDC for LANL nuclear[3] facilities shall per Table III-1.

Table III-1. SDC Determination

	Unmitigated Consequence of SSC Failure from a Seismic Event	
Category[4]	**Collocated Worker**	**Public**
SDC-1	Dose < 5 rem	Not applicable

[1] These criteria implement the requirements of the applicable DOE Orders and Standards for PC-3 facilities. Voluntary Consensus Standards are followed wherever possible in accordance with Public Law (PL) 104-113 and DOE O 252.1. Footnotes to LANL specific requirements are added where possible to provide further clarification.
[2] ANS Standard 2.26 was adopted by DOE for purposes of seismic design basis specification. The seismic design classifications of ANS 2.26 are to be used in association with DOE radiological criteria provided in DOE-STD-1189 Appendix A. It is intended that the requirements of Section 5 of ANS 2.26 and Appendix A of ANS 2.26 be used for the selection of the appropriate Limit States for SSCs performing the safety functions specified. The resulting combination of Seismic Design Category (SDC) and Limit State (LS) selection provides the seismic design basis for SSCs to be implemented in design through ASCE 43.
[3] Should LANL missions change such that a large chemical hazard (per DOE-STD-1189 App. C) became possible, follow NNSA's "Guidance and Expectations for DOE STD 1189-2008, *Integration of Safety into the Design Process,* Natural Phenomena Hazard Design Basis Criteria for Chemical Hazard Safety Structures, Systems and Components," 7/9/09, posted on Chapter 5 webpage as a reference.
[4] In accordance with DOE-STD-1189 Appendix A, Table III-1 includes only SDC-1, 2 and 3. ANS 2.26 includes SDC-4 and 5 but it is not expected that DOE facilities will approach the criteria in ANS 2.26 for these seismic design categories

SDC-2	5 rem < dose < 100 rem	5 rem < Dose < 25 rem
SDC-3	100 rem < dose	25 rem < dose

The following supplemental guidance to ANS 2.26 shall be used when selecting SDCs and Limit States:

1. To ensure that SSC Limit State selected for determining the permissible maximum stress, strain, deformation, or displacement is consistent with the safety function(s) of the SSC as determined from hazard and accident analyses, the safety analyst (responsible for hazard and accident analysis), the Seismic Design Engineer (responsible for seismic design, and for coordinating the selection of SSC Limit State and SSC Seismic Design Category), and the Equipment Expert (responsible for the mechanical or electrical design of the equipment) must work together and evaluate the functional requirements of the SSC and its subcomponents in relation to their modes of failure.

   There are four limit states to be considered:

   Limit State A: An SSC designed to this Limit State may sustain large permanent distortion short of collapse and instability (i.e., uncontrolled deformation under minimal incremental load) but shall still perform its safety function and not impact the safety performance of other SSCs.

   Limit State B: An SSC designed to this Limit State may sustain moderate permanent distortion but shall still perform its safety function. The acceptability of moderate distortion may include consideration of both structural integrity and leak-tightness.

   Limit State C: An SSC designed to this Limit State may sustain minor permanent distortion but shall still perform its safety function. An SSC that is expected to undergo minimal damage during and following an earthquake such that no post earthquake repair is necessary may be assigned this Limit State. An SSC in this Limit State may perform its confinement function during and following an earthquake.

   Limit State D: An SSC designed to this Limit State shall maintain its elastic behavior. An SSC in this Limit State shall perform its safety function during and following an earthquake. Gaseous, particulate, and liquid confinement by SSCs is maintained. The component sustains no damage that would reduce its capability to perform its safety function.

   <u>In conceptual design</u>, if there are no bases for defining seismic-related DBAs, Hazard Category 2 facility structural designs must default to ANSI/ANS 2.26 SDC-3, Limit State D.

2. If the safety functions of an SSC include confinement and leak tightness, irrespective of the Seismic Design Category (SDC) of the SSC[5], a Limit State C or D must be selected, unless the SSC functional requirements can be described as given in Limit State B column for SSC Type “confinement barriers and…” in ANS 2.26, Appendix B.
   a. SDC-1 and SDC-2 SSCs having safety functions requiring Limit States are to be designed per Table III-2:

[5] following the intent of Section 5 of ANS 2.26

Table III-2. Effect of Limit State on SDC-1/SDC-2 Design

SDC	Limit State			
	A[Note 1]	B	C	D
1	ASCE 7 Occupancy Category I or II (I=1.0) $R_a = R$[Note 3]	ASCE 7 Occupancy Category I or II (I=1.0) $R_a = 0.8\ R$[Note 3] But $R_a \geq 1.0$	ASCE 7 Occupancy Category I or II (I=1.0) $R_a = 0.67\ R$[Note 3] But $R_a \geq 1.0$	ASCE 7 Occupancy Category I or II (I=1.0) $R_a = 1.0$
2	ASCE 7 Occupancy Category III or IV (I= Note 2) $R_a = R$[Note 3]	ASCE 7 Occupancy Category III or IV (I= Note 2) $R_a = 0.8\ R$[Note 3] But $R_a \geq 1.0$	ASCE 7 Occupancy Category III or IV (I= Note 2) $R_a = 0.67\ R$[Note 3] But $R_a \geq 1.0$	ASCE 7 Occupancy Category III or IV (I= Note 2) $R_a = 1.0$

Note 1: SSCs with Limit State A are not required to function following the earthquake
Note 2: I=Importance Factor from Table 11.5-1 of ASCE 7.
Note 3: R=Response Modification Coefficient given in ASCE 7; R_a is to be used in the design.

With the exception of the criteria specified in Table III-2, the requirements for PC-0, 1, and 2 (and SDC-1 and SDC-2 as well as the requirements for all other NPH criteria) are provided in Section II of this Chapter. Requirements for SDC-3 are provided in this document (Section III).

1.0 PC-3 STRUCTURES

1.1 Acceptance Criteria

1.1.1 General

A. The structural demands (member forces, displacements, etc) shall be calculated using the loads of Section 1.2, the load combinations of Section 1.3, and the analysis procedures of Section 1.4.

B. Linear analyses shall meet the strength acceptance criteria in Section 1.1.2(A) and the displacement criteria in 1.1.3.

C. Nonlinear analyses shall meet the displacement acceptance criteria in Section 1.1.3. The capacity of yielding elements in nonlinear analyses shall meet the strength design criteria in Section 1.1.2(B).

D. The following materials may be used for the design of PC-3 structures provided that they are designed in accordance with the material design code/standard, as amended by these criteria.

Material	Material Design Code/Standard[6]
Reinforced Concrete	ACI 349
Structural Steel	ANSI/AISC N690
Stainless Steel	ANSI/ASCE 8
Cold Formed Steel	AISI/COS/NASPEC
Reinforced Masonry	ACI 530

E. Adoption of a material design code/standard in Section 1.1.1(D) includes all provisions in that code/standard, including seismic detailing provisions, as amended by this criteria.

F. Seismic design category, SDC, as defined in ASCE 43, shall be SDC-3 for PC-3 structures.

G. The ASCE 43 limit state for confinement safety function shall be limit state C. The ASCE 43 limit state for collapse prevention safety function of new SSC shall be limit state B. The evaluation of existing structures may use ASCE 43 limit state A for collapse prevention safety function.

1.1.2 Strength Acceptance Criteria

A. For linear analyses, the total demand acting on an element shall be less than or equal to the element's code capacity:

$$\text{Demand} \leq \text{Capacity} \qquad \text{(Eq. 1-1)}$$

where the code capacity is developed in accordance with Section 1.5.

B. For nonlinear analyses, the capacity of all elements, including yielding elements, shall be limited to code capacities:

$$\begin{array}{c} \phi M_n \text{ for bending,} \\ \phi V_n \text{ for shear, and} \\ \phi P_n \text{ for axial loads.} \end{array} \qquad \text{(Eq. 1-2)}$$

where ϕM_n ϕV_n and ϕP_n are the code capacities in flexure, shear, and axial force, respectively which are developed in accordance with Section 1.5.

1.1.3 Deformation Acceptance Criteria

A. The deformation limits, serviceability requirements and deformation acceptance criteria for impulsive and impact loads of the material codes/standards identified in 1.1.1(D) shall apply.

B. The deformation acceptance criteria for seismic loads shall be in accordance with Section 5.2.3 of ASCE 43.

[6] Use the most recent version of the applicable material codes in force in agreement with the established code of record. Project design documents shall contain the dates for the code of records. Where no code of record is established for the modification of existing facilities, the engineer in responsible charge shall document the revision of the code used for design.

1.2 Loads

The load criteria given below are consistent with minimum load requirements in ASCE 7-05, “Minimum Design Loads for Buildings and other Structures.” However, LANL has specific climatologic data and natural phenomena hazard data to supplement the minimum load requirements in ASCE 7. In general, the site specific data are used whenever possible. Footnoting is added to assist the user in interpreting LANL-specific loads.

1.2.1 Dead Load (D)

A. Dead loads consist of the weight of all materials of construction incorporated into the building including, but not limited to, walls, floors, roofs, ceilings, stairways, built-in partitions, finishes, cladding and other similarly incorporated architectural and structural items, and fixed service equipment, piping including the weight of cranes.

B. Dead loads shall be determined using unit weights of 150 pcf for reinforced concrete and 490 pcf for steel.

C. Ten (10) psf shall be added to the best estimate dead load for all floors (not roofs) for use in design of new structures to accommodate future dead load.[7]

D. Evaluation of existing facilities shall use best estimate of existing loads and shall give consideration for future use.

1.2.2 Live Load, (L), Roof Live Load, (L_r) and Experiment Blast Load (L_{EB})

A. Live load to be used in design shall be based on project specific requirements and shall not be less than the minimum live load requirements in Section 4.0 of ASCE 7. Floor live loads shall not be reduced.

B. All roofs at LANL shall be designed for a minimum roof live load of 30 psf. Roof live loads shall not be reduced.[8]

C. Loads from experimental explosions, and reactions from experimental explosion containment structures, due to explosions, shall be considered live loads.

1.2.3 Crane Loads (C or C_{cr})

A. Rated capacity of crane including the maximum wheel loads of the crane and the vertical, lateral, and longitudinal forces induced by the moving crane, including impact factor.

1.2.4 Fluid Loads (F)

A. Fluid load (F) is the load resulting from the pressure of the fluid. These loads are from fluids with well-defined pressures and maximum height (such as fluids in tanks).

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[7] Based on historical use of LANL structures. Also see LA-UR-14165, “Design Load Basis for LANL Structures, Systems and Components, Sept. 2004.

[8] 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.).

1.2.5 Lateral Soil Pressure Loads (H)

A. Subterranean structural walls shall be designed to resist at-rest lateral soil pressure loads (H). The magnitude of at-rest lateral soil pressure shall be specified by a soil investigation report approved by LANL. A default at-rest lateral soil pressure coefficient of K_o=0.5 may be used.

B. In computing the lateral soil pressures, the density of the backfill or native soil, whichever is greater, shall be used.

C. Design lateral pressure shall be increased if soils with expansion potential are present at the site based on criteria provided by a geotechnical expert for the project.

1.2.6 Snow Loads (S)

A. Snow loads shall be calculated using the procedure prescribed in Section 7.0 of ASCE 7 as amended by the following:

1. ASCE 7 Section 7.2 *Ground snow loads, p_g*, Substitute the following text: The ground snow load, p_g, shall be taken as 29 psf for PC-3 structures.[9]

2. ASCE 7 Section 7.3.3 *Importance Factor, I*, Substitute the following text: The importance factor (I) for PC-3 structures shall be taken as 1.2.

1.2.7 Rain Loads (R)

A. Rain loads shall be calculated using the procedure prescribed in Section 8.0 of ASCE 7 as amended by the following:

1. ASCE 7 Section 8.2 *Roof drainage*, Replace with the following text: Roof drainage shall be performed with the hydrological analyses in accordance with LANL ESM Chapter 3 – Civil Section G20. The roof shall have positive drainage. The analysis of the roof drainage system shall assume that the primary roof drains are blocked and shall provide over-flow scuppers capable of draining the roof.

1.2.8 Ice Loads – Atmospheric Icing (D_i)

A. Ice loads (D_i) shall be considered for “ice sensitive” structures, i.e., structures with small weight and larger exterior surface areas, such as lattice towers and cable structures. Ice loads are not required for buildings and building-like structures.

B. Ice loads shall be calculated using the procedure prescribed in Section 10.0 of ASCE 7 as amended by the following[10]:

1. The nominal ice thickness due to freezing rain, t, shall be taken as 1.0 inches.
2. The importance factor or multiplier on ice thickness, I_i, shall be taken as 1.0.
3. The wind load concurrent with ice loading, W_i, shall be based on a 52 mph 3-second gust wind speed.

[9] This load comes from LA-14165.
[10] The IBC does not address ice loads; however, ASCE 7 does, and LA-14165 indicates that these loads could occur on certain LANL SSCs.

1.2.9 Thermal Effects (T_o)

A. Thermal effects and loads during normal operating, start-up, or shutdown conditions, based on the most critical transient or steady-state condition.

B. The consideration of thermal effects in concrete structures shall be consistent with the guidance of ACI 349.1R (*2007, Section 1.3*).

1.2.10 Pipe Reactions (R_o)

A. Pipe and equipment reactions, or related internal moments and forces, that occur during normal operating, start-up, or shutdown conditions, based on the most critical transient or steady-state condition shall be considered.

1.2.11 Operating Basis Earthquake (E_o)

A. The operating basis earthquake is not defined for PC-3 facilities and shall be taken as zero.

1.2.12 Wind Loading (W)

A. Wind loading (W) shall be calculated using the procedure prescribed in Section 6.0 of ASCE 7 as amended by the following:

1. ASCE 7 Section 6.5.4 *Basic wind speed*, Substitute the following text: The basic wind speed, V, shall be taken as 117 mph for PC3 SSCs.[11]

2. ASCE 7 Section 6.5.5 *Importance Factor,* Substitute the following text: The importance factor (I) for PC-3 structures for wind loading is 1.0.[12]

3. ASCE 7 Section 6.5.6.3 *Exposure Categories*, Substitute the following text: The wind exposure category shall be taken as Exposure C.

4. Add Section 6.8 *Wind Driven Missiles:* A 2×4 timber plank weighing 15 pounds with a 50 mph horizontal velocity shall be considered for heights less than or equal to 30 ft above grade is the specified missile.

1.2.13 Design Basis Earthquake (E, E_s, or E_{ss})

A. The LANL design basis earthquake response spectra are defined in the free-field at the ground surface.

B. The design basis earthquake response spectra in Figures III-1 through III-4 and Tables III-3 through III-6 are the Design Response Spectra (DRS) defined in ASCE 43 Equation 2-1 and includes the effects of the Design Factor (DF).

C. The LANL design basis earthquake response spectra for site-wide use, excluding TA-55 site, is specified in Figures III-1, III-2 and Tables III-3, III-4[13]. Response spectra at intermediate frequencies shall be obtained by log-log interpolation. Response spectra at intermediate damping shall be obtained using the interpolation procedure in ASCE 4.

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[11] This load comes from LA-14165
[12] Ibid
[13] And TA-50, with approved variance addressing geotechnical consistency.

D. The LANL design basis earthquake response spectra for TA-55 site are specified in Figures III-3, III-4 and Tables III-5, III-6.[14] Response spectra at intermediate frequencies shall be obtained by log-log interpolation. Response spectra at intermediate damping shall be obtained using the interpolation procedure in ASCE 4.

E. Lateral soil pressure on embedded structures resulting from earthquake ground shaking shall be calculated using ASCE 4 and shall be included in the earthquake load (E). In computing the lateral soil pressures, the density of the backfill or native soil, whichever is greater, shall be used.

F. The potential for seismic-induced displacement hazards (i.e., fault rupture) must be assessed on a project specific basis. The project specific plan for addressing fault displacement hazards associated with new construction shall be submitted to the LANL Site Chief Engineer or designee for review and approval prior to the start of construction.

G. A minimum fault displacement of 2 cm (0.8 in.) at the surface shall be used for design.

1.2.14 Tornado Loading (W_t)

A. There is not a PC-3 tornado load at LANL and the design basis tornado loading, W_t, shall be taken as zero.

1.2.15 Abnormal Loads (P_a, T_a, R_a, Y_r, Y_j, Y_m)

A. Abnormal loads may be generated by a postulated high-energy pipe break accident and include:

P_a = maximum differential pressure load generated by the postulated accident
T_a = thermal loads generated by the postulated accident, including T_o
R_a = pipe and equipment reactions generated by the postulated accident, including R_o
Y_r = loads on the structure generated by the reaction of the broken high-energy pipe during the postulated accident
Y_j = jet impingement load generated by the postulated accident
Y_m= missile impact load, such as pipe whipping generated by or during the postulated accident

B. Abnormal loads may be generated by an accidental blast, P_a.

1.2.16 Self-Straining Forces

A. In the design for normal loads, consideration shall be given to the forces due to such effects as prestressing, vibration, impact, shrinkage, creep, unequal settlement of supports, construction, and testing.

B. Where the structural effects of differential settlement, creep, shrinkage, or expansion of shrinkage-compensating concrete are significant, they shall be included with the dead load in

[14] Except for TA-55, PC-3 (SDC-3) ground motion were derived following DOE-STD-1023 and the results of URS Corp, “Update of the Probabilistic Seismic Hazard Analysis and Development of Seismic Design Ground Motions at the Los Alamos National Laboratory,” May, 2007. The derivation of this ground motion for the site can be found in LANL Calculation SB-DO: CALC 08-038, 10/8/08. For TA-55, the SDC-3 ground motion was derived from the results of URS Corp, “Update of the Probabilistic Seismic Hazard Analysis and Development of CMRR Design Ground Motions Los Alamos National Laboratory, New Mexico”, October, 2009. See calc SB-DO: CALC-09-024, Rev. 0 for derivation.

the load combinations in Section 1.3. Estimation of these effects shall be based on a realistic assessment of such effects occurring in service.

1.2.17 Flood Loads

A. New PC-3 SSCs shall be located on mesa tops which are not susceptible to stream flooding.

B. DOE-STD-1020 shall be used to determine susceptibility to flooding for local site drainage.

1.3 Load Combinations

1.3.1 Reinforced Concrete Members and Reinforced Masonry Members

A. The load combinations of ACI 349 shall be used to combine demands for reinforced concrete and masonry members as amended by the following:

   1. The term E_{ss} in ACI 349 Equations 9-6 and 9-9 shall be replaced by $E_{ss}/F_{\mu S}$, where $F_{\mu S}$ is the inelastic force reduction factor in Section 1.3.3.

B. The load combinations in ACI 530 are omitted.

1.3.2 Structural Steel Members, Cold Formed Steel Members and Stainless Steel Members

A. The load combinations of ANSI/AISC N690 shall be used to combine demands for structural steel, cold formed steel and stainless steel members as amended by the following:

   1. The term E_s in ANSI/AISC N690 Equations NB2-6, NB2-9, NB2-15 and NB2-18 shall be replaced by $E_s/F_{\mu S}$, where $F_{\mu S}$ is the inelastic force reduction factor in Section 1.3.3.
   2. Load combinations for atmospheric ice are ANSI/AISC N690 Equations NB2-4 and NB2-13 with the ice weight Di added to the dead load, D, and the concurrent wind load, W_i, instead of the PC-3 wind load, W.

B. The load combinations in ASCE 8 are omitted.

C. The load combinations in AISI/COS/NASPEC are omitted.

1.3.3 Inelastic Force Reduction Factor ($F_{\mu S}$)

A. The inelastic force reduction factor, $F_{\mu S}$, is defined in ASCE 43 for bending moment, shear and axial loads in diagonal braces, except as amended below:

   1. $F_{\mu S}$ shall be taken as one (1.0) for torsion, and axial loads in members that are not diagonal braces.
   2. $F_{\mu S}$ shall be taken as one (1.0) for non-compact members or members subject to local buckling.

B. The inelastic force reduction factor, $F_{\mu S}$, for masonry and cold formed steel members shall be 1.0.

C. The inelastic force reduction factor, $F_{\mu S}$, for stainless steel members shall be the same as structural steel members in ASCE 43 provide that the ductility provisions of DOE-STD-1020 are met.

1.4 Analysis Procedures

A. The structural analysis shall be consistent with the requirements in the material codes identified in Section 1.1.1(D).

B. Seismic analyses shall be consistent with the requirements of ASCE 43 and ASCE 4.

C. Time histories shall meet the requirements of ASCE 43 and shall be consistent with a magnitude 6 to 6.5 earthquake at a distance less than 2.5 km.

1.5 Capacities

A. ASCE 43 Section 4.2 *Structural Capacities* is replaced by the following criteria.

B. ACI 349 shall be used for the capacities of reinforced concrete members as amended by the following:

1. ACI 349-06 Appendix C *Alternate Load and Strength Reduction Factors,* shall not be used for new construction.
2. Delete ACI 349-06 Section 9.2.10.

C. Design of anchors in concrete shall be in accordance with Appendix A of this Section.

D. ANSI/AISC N690 shall be used for the capacities of structural steel members.

E. ASCE 8 shall be used for the capacities of stainless steel members.

F. AISI/COS/NASPEC (S100) shall be used for the capacities of cold formed steel members.

G. ACI 530 shall be used for the capacities of reinforced masonry as amended by the following (*sections listed based on 2008 edition*):

1. Delete ACI 530 Chapter 2 on Allowable Stress Design of Masonry
2. ACI 530 Section 3.1.6: Add the following sentence: It is not permissible to support PC-3 components using post installed (PI) anchor bolts in reinforced masonry.
3. Delete ACI 530 Chapter 5 Empirical Design of Masonry.

1.6 Detailing Requirements

A. The detailing requirements of ASCE 43 Chapter 6 shall be implemented.

1.7 Additional Structural Design Considerations

1.7.1 Foundation Design

A. Detailing of PC-3 building foundations shall meet the following requirements:

1. Minimum embedment depth of foundations is 36 inches unless the foundation sets directly on welded tuff. [15]
2. Interconnect all spread footing type foundations using tie beams[16]. 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 and to eccentric positioning of columns and corresponding column loads on spread footings, simultaneously with the horizontal force.
3. Foundations shall not be designed in locations that are within 50 feet of mapped active faults.

1.7.2 Seismic Interaction

A. Potential seismic interactions between adjacent SSCs, as appropriate, shall be evaluated. This evaluation may entail estimating or calculating displacements and providing sufficient clearance between the potentially interacting components or may be designed using the guidance contained in Chapter 7 of DOE/EH-0545.

1.7.3 Progressive Collapse

A. Structural design measures on progressive collapse avoidance and on window protection presented in the DOD UFC 4-010-01 "Minimum Antiterrorism Standards for Buildings" shall be considered for those buildings where there is a credible terrorist threat at the building. The determination of credible terrorist threat shall be made on a project by project basis.

1.7.4 Permanent Explosive Facilities

A. The design of all new facilities, or those with major modifications, shall conform to the DOE Explosives Safety Manual, DOE M 440.1-1A. Permanent explosives facilities shall comply fully with UFC 3-340-02, "Structures to Resist the Effects of Accidental Explosions, Unified Facilities Criteria (UFC), December 2008 and, as applicable, DOD UFC 3-340-01, Design and Analysis of Hardened Structures for Conventional Weapons Effects."

1.7.5 Seismic Design Considerations

A. The special consideration of ASCE 43 Chapter 7 shall be implemented.

B. The provisions of DOE-STD-1020 Section 1.3 *Evaluation of Existing Facilities*; Section 2.4.2 *Evaluation of Existing Facilities*; and Section 2.4.3 *Basic Intention of Dynamic Analysis Based Deterministic Seismic Evaluation and Acceptance Criteria*, shall apply as applicable.

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[15] Los Alamos County Municipal Building Code for new construction.
[16] The tie-beam provision was added to address the uncertainties associated with distributed faulting on the Pajarito Plateau.

2.0 PC-3 SYSTEMS AND COMPONENTS

A. The structural design of PC-3 systems and components shall conform to Section 1.0 of this Chapter of the LANL ESM in addition to the requirements contained herein.

B. The design and documentation requirements for nonstructural components and systems vary, depending upon the functional requirements For PC-3 projects, the functionality requirements of components (safety class, safety significant or important to safety) are normally specified in preliminary hazards assessment documents, or documented safety analysis

C. The seismic design/qualification of systems and components shall be in accordance with the requirements of ASCE 43 and Sections 1.1.1(F) and 1.1.1(G).

1. Seismic input to internal systems and components shall be in-structure response spectra that are consistent with ASCE 4.

2. Seismic input to external systems and components shall be the DBE in Section 1.2.13, modified to account for the response of adjacent structures per ASCE 4.

3. Seismic loads on buried systems and components shall be in accordance with ASCE 4.

D. The design/qualification of systems and components for non-seismic NPH loadings shall:

1. Utilize the NPH loads in Section 1.2.

2. Utilize the load combinations in Section 1.3.2 for NPH loads.

3.0 EXISTING FACILITY AND SYSTEM MODIFICATIONS

A. Major Modifications

For building additions and whenever the proposed modification meets the criteria of a “major modification” or DOE-STD-1189 applicability (as defined in ESM Chapter 1 Section Z10 or Chapter 5 Section I), DOE-STD-1189 methodology shall be followed along with this Section.

B. Minor Modifications

For modifications not meeting the “major” thresholds above, the decision to follow code of record criteria, this Section’s criteria, or something in between shall be based on the graded approach for Repairs and Alterations defined in the International Existing Building Code (IEBC) as amended by ESM Chapter 16 Section IBC-GEN App B, LEBC to the extent possible, except that:

1. In the IEBC/LEBC, references to the IBC structural provisions shall be taken to mean ESM Chapter 5 Section III, and
2. IEBC/LEBC provisions for following code of record for minor work are only allowed with approval of the LANL Site Chief Engineer in consultation with the POC for ESM Chapter 5 (LEBC automatic approval list is N/A to PC-3).

Table III-3 Site-Wide Free-Field Surface PC-3 Horizontal Design Response Spectra

	Spectral Acceleration (g)		
Frequency (Hz)	**2% Damping**	**5% Damping**	**10% Damping**
0.2	0.107	0.094	0.073
0.498	0.662	0.583	0.456
0.925	1.374	1.083	0.862
9	1.374	1.083	0.862
33	0.482	0.482	0.482
100	0.482	0.482	0.482

Table III-4 Site-Wide Free-Field Surface PC-3 Vertical Design Response Spectra

	Spectral Acceleration (g)		
Frequency (Hz)	**2% Damping**	**5% Damping**	**10% Damping**
0.2	0.048	0.039	0.032
0.469	0.262	0.213	0.175
1	0.585	0.455	0.354
8	2.499	1.885	1.454
12	2.499	1.885	1.454
50	0.564	0.564	0.564
100	0.564	0.564	0.564

Table III-5 TA-55 Free-Field Surface PC-3 Horizontal Design Response Spectra

Spectral Acceleration (g)

Period (s)	Frequency (Hz)	2% Damping	5% Damping	10% Damping
10	0.100	**0.025**	**0.021**	**0.018**
5	0.200	**0.125**	**0.106**	**0.090**
1.5	0.667	**0.690**	**0.552**	**0.444**
1	1.000	**0.915**	**0.724**	**0.578**
0.5	2.000	**1.022**	**0.806**	**0.640**
0.15	6.667	**1.115**	**0.888**	**0.712**
0.1	10.000	**0.933**	**0.770**	**0.640**
0.85	11.765	**0.826**	**0.695**	**0.589**
0.075	13.333	**0.752**	**0.643**	**0.552**
0.06	16.667	**0.644**	**0.566**	**0.498**
0.05	20.000	**0.578**	**0.519**	**0.466**
0.03	33.333	**0.439**	**0.419**	**0.419**
0.02	50.000	**0.419**	**0.419**	**0.419**
0.01	100.000	**0.419**	**0.419**	**0.419**

Table III-6 TA-55 Free-Field Surface PC-3 Vertical Design Response Spectra

Spectral Acceleration (g)

Period (s)	Frequency (Hz)	2% Damping	5% Damping	10% Damping
10	0.100	**0.015**	**0.012**	**0.010**
5	0.200	**0.074**	**0.062**	**0.052**
1.5	0.667	**0.403**	**0.312**	**0.246**
1	1.000	**0.538**	**0.412**	**0.322**
0.5	2.000	**0.682**	**0.563**	**0.404**
0.15	6.667	**1.302**	**0.971**	**0.741**
0.1	10.000	**1.524**	**1.173**	**0.922**
0.85	11.765	**1.623**	**1.266**	**1.006**
0.075	13.333	**1.623**	**1.266**	**1.006**
0.06	16.667	**1.431**	**1.141**	**0.925**
0.05	20.000	**1.216**	**0.989**	**0.816**
0.03	33.333	**0.741**	**0.655**	**0.585**
0.02	50.000	**0.474**	**0.474**	**0.474**
0.01	100.000	**0.474**	**0.474**	**0.474**

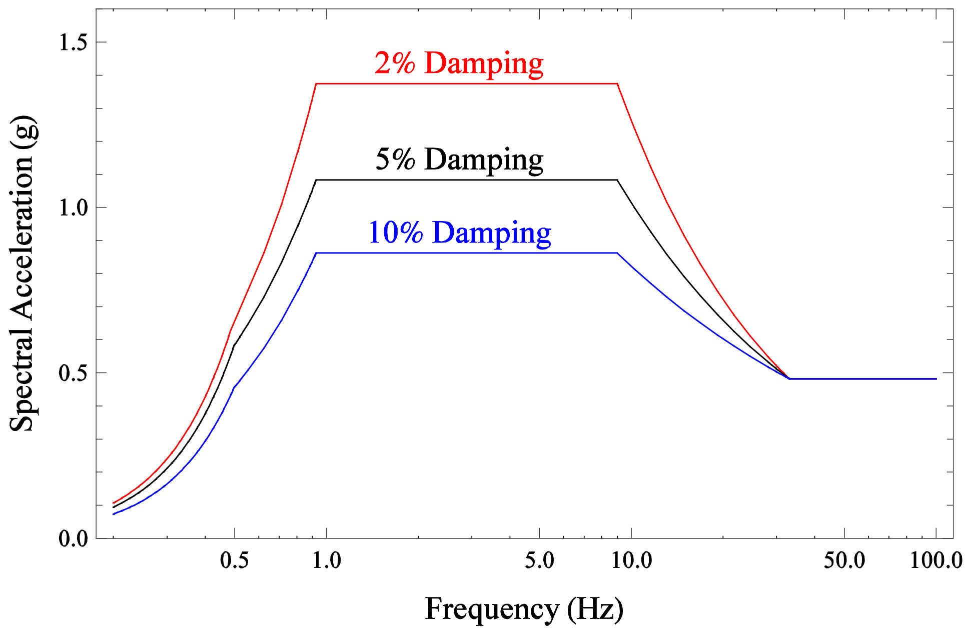


Figure III-1 Site Wide Free Field Surface PC-3 DBE Horizontal Design Response Spectra

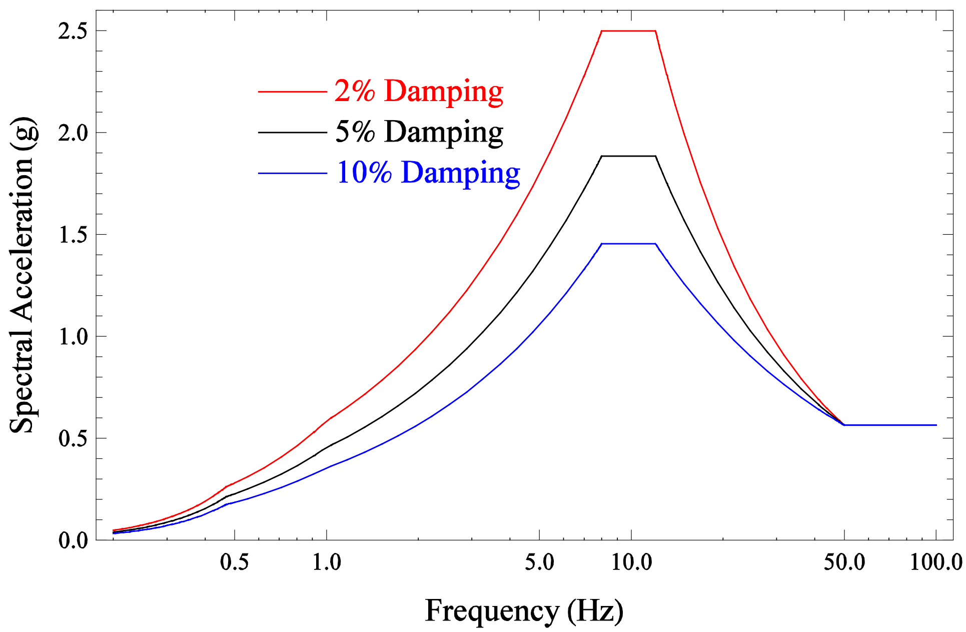


Figure III-2 Site Wide Free Field Surface PC-3 DBE Vertical Design Response Spectra

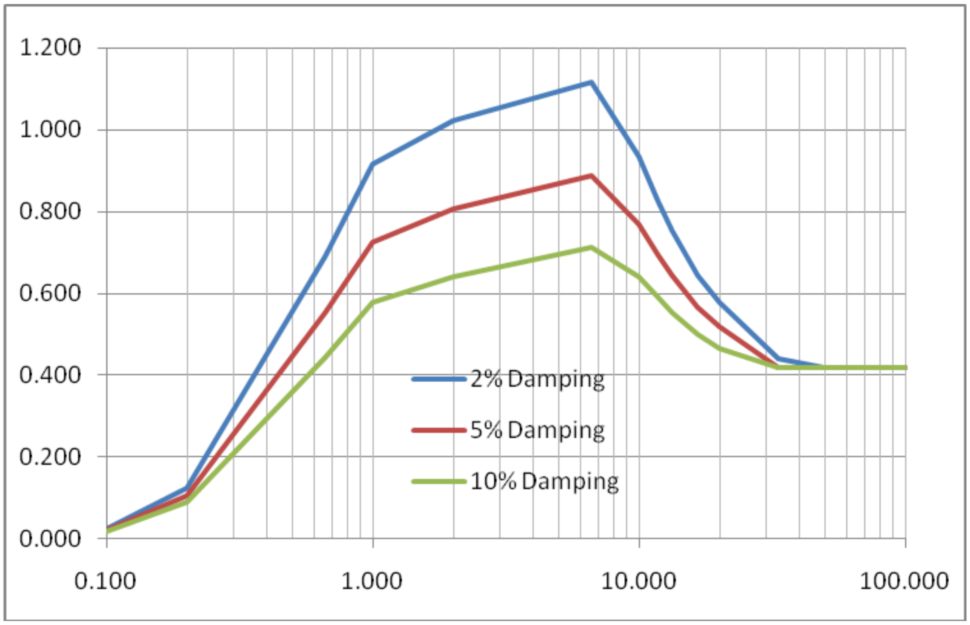


Figure III-3 TA-55 Free Field Surface PC-3 Horizontal Design Response Spectra with acceleration (g) on vertical versus frequency (Hz) on horizontal

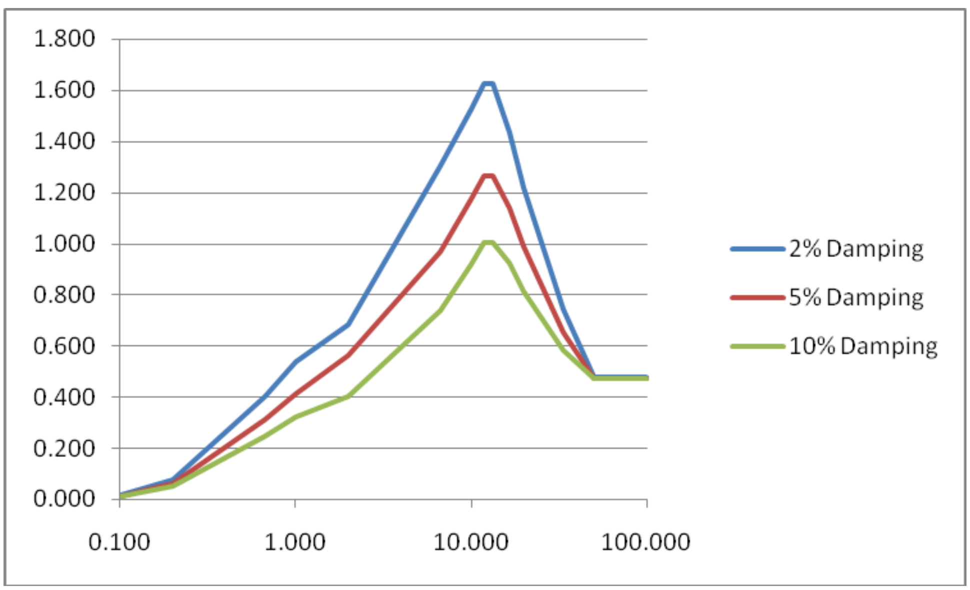


Figure III-4 TA-55 Free Field Surface PC-3 Vertical Design Response Spectra

APPENDIX A, DESIGN OF ANCHORS IN CONCRETE

A. 1 DESCRIPTION

A. This Appendix specification establishes the technical requirements for designing post-installed (PI) concrete anchors for PC-3 and SDC-3 SSCs at LANL.(Note: PC-3 is used throughout this appendix and should be interpreted as inclusive of the SDC-3 designation).

B. Appendix A covers the design of the following anchor types:
- 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. Welding and mechanical properties of headed studs shall comply with AWS D1.1.
- Post-installed anchors: The following PI anchors are referred in this appendix: Drillco Maxi-Bolt Undercut anchors, herein referred as Maxi-Bolts. Maxi-Bolts are available in standard lengths and are available in 1-inch increments shorter or longer than the standard length. **NOTE: At time of Rev. 5 issuance, the flush-mount- / coupling-type variation of the Maxi-Bolts were NOT approved for LANL; verify approval status before use.**

C. Not Included: Design of PI concrete anchors for PC-1 and PC-2 applications is covered in Section II of Chapter 5. Purchase, installation and testing requirements are given in the LANL Master Specification sections listed below. Anchors not listed as PC-3 in LANL Master Spec Section 03 1512 are excluded from use in PC-3 applications.

A.2 DEFINITIONS

A. Definitions of anchors per ACI 355.2 apply.

B. Unless noted otherwise, all variable notation and definition in this appendix follows ACI 349-06, Appendix D.

C. Ductile Design: Ductile design occurs when the strength of all concrete failure modes is higher than the strength of steel failure (e.g. failure is in the steel). See ACI 349-06, D.3.6.1 for more information.

D. Non-Ductile Design: Non-ductile design occurs when the strength of steel failure modes is higher than the strength of concrete failure (e.g. failure is in the concrete). See ACI 349-06, D.3.6.3 for more information.

A.3 APPLICABLE CODES AND STANDARDS

ACI 355.2	Qualification of Post-Installed Mechanical Anchors in Concrete and Commentary
ACI 349, App. D	Code Requirements for Nuclear Safety Related Concrete Structures

A.4 APPLICABLE INDUSTRY STANDARDS

ASTM A 36-05	Standard Specification for Carbon Steel
ASTM A 193-10	Standard Specification for Alloy-Steel and Stainless Steel Bolting for High Temperature or High Pressure Service and Other Special Purpose Applications
ASME NQA-1	Quality Assurance Requirements for Nuclear Facility Applications, American Society of Mechanical Engineers

A.5 LANL AND OTHER DOCUMENTS

Master Spec Section 03 1512	Post-Installed Concrete Anchors Purchase – High Confidence
Master Spec Section 03 1534	Post-Installed Concrete Anchors– Purchase – Normal Confidence

Master Spec Section 03 1550	Post-Installed Concrete Anchors – Installation and Testing
24590-QL-BPO-FA02-00002-07-00001	Report of Maxi-Bolt Anchor Testing for the Hanford River Protection Project Waste Treatment Plant

A.6 PERFORMANCE CATEGORY CLASSIFICATION

A. The Engineer of Record shall coordinate with appropriate safety basis and design authority representative to determine and document the Performance Category of the anchorage. The safety class of the item or system being attached determines the performance category for the anchorage. A higher safety class design (PC-3) can be used in a lower safety class applications (PC-1 or PC-2)

A.7 ENVIRONMENTAL CONDITIONS

A. Anchors for indoor use in non-aggressive chemical environments may be carbon steel with a zinc coating. Anchors for use outdoors or in aggressive environments should be galvanized, made of stainless steel, or otherwise coated for corrosion protection.

A.8 GENERAL DESIGN REQUIREMENTS

A. PI anchors are used to attach structures, systems, and components (SSCs) to hardened concrete where cast-in-place embeds do not exist or where it is determined to be proper and more economical to use post-installed anchorage. Cases exist where post-installed anchors will be specified prior to concrete placement to allow for release of construction documents (such as where baseplate details or locations are not known at the time of drawing issue). The decision to specify post-installed anchors prior to concrete placement should be weighed carefully, considering the amount of construction effort required to drill holes, field modify plates, and avoid cutting rebar.
B. PI anchors and surface-mounted plates are recommended for applications where support requirements are added or modified after concrete placement. PI anchors may be specified on design drawings prior to concrete placement 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.
C. Rotating, reciprocating, or vibrating equipment such as fans, pumps, and motors should use cast-in-place embeds. In the event that concrete is already placed due to construction sequencing, contact the ESM Structural POC for guidance. Use of Drillco Maxi-bolts is acceptable for all equipment with motors less than 20 horsepower.
D. Preloading anchors: anchors used for equipment supports should be torqued or preloaded to the specified equipment manufacturer's recommendations whenever it is specified. This is particularly true for anchors at rotating or vibrating equipment.
E. Tightening of anchors
    - Anchors manufactured out of A307 or A36 material should be installed with only a nominal preload. It is recommended that they be tightened to a snug tight condition. Snug tight is defined as tightness attained by a few impacts of an impact wrench or the full effort of a man using an ordinary spud wrench.
    - When the anchors are for equipment or are subject to possible loosening during operation, a locking device should be provided. Acceptable locking devices include: double nuts or jam nuts, interrupted threads, and tack welds (for A36 anchors and weldable A307 anchors; i.e., if the carbon equivalent (CE) does not exceed 0.55 as calculated per Section s1.5.2 of ASTM A307.

F. Supplementary reinforcement: if the minimum edge distance is not met, or if side-face blowout governs (as in many cases of anchors in piers, or in walls), supplementary reinforcement shall be provided. This reinforcement is proportioned to tie a potential concrete failure prism to the structural member. Useful guidance may be obtained from the ACI 349 commentary RD.4.2.1.

G. Use of PI anchors shall comply with the following:
   - PI anchors should not be installed through liner plate. Contact the Engineering Standards Manual (ESM) Structural Point of Contact (POC) for guidance.
   - 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. This will require over-sized baseplates to allow for field drilling of holes.
   - Welding to post-installed anchors is not permitted.
   - PI anchors should not be used in masonry walls. If construction sequence requires use in masonry walls, contact the ESM Structural POC for guidance. Through-bolting may be an acceptable alternative.
   - A minimum of two (2) and a maximum of eight (8) PI anchors shall be used at each connection. One (1) anchor may be use used for connecting conduit clamps of for similar installations. Only 2/3 of the design strength shall be used for single anchor installations. *Note: equipment, glove boxes, etc mounted on four-legged type of frames may have one anchor bolt per leg.*
   - PI anchors shall not be located in the bottom of precast and pre/post-tensioned T-beams stems. Post-installed anchors onto the sides of the T-beam stems shall be designed and approved by the Engineer of Record.

A.9 DESIGN REQUIREMENTS

A. Anchor design strength shall be determined in accordance with ACI 349, Appendix D. ACI 349, Appendix D, design strength is based on Ultimate Strength Design, which is to be used with factored loads.

B. All new PI anchor design shall be based on 'cracked' concrete.

C. Engineers may use higher strength for 'uncracked concrete' provided they demonstrate and document that the concrete remains uncracked (tensile stresses in concrete do not exceed $7.5\sqrt{f_c'}$) under service loads, including wind and seismic forces.

D. Due consideration should be given to the location tolerances of the anchors to avoid interferences with reinforcement. These locations tolerances may affect the ductile behavior of the anchors and the design of the baseplate.

E. The following clarifications shall apply to each section of ACI 349-06, Appendix D:
   1. D.3.3 Post-installed anchors shall be qualified to the procedures of ACI 355.2.
   2. D.4.2.1 The effect of supplementary reinforcement should not be considered in the design of post-installed anchors.
   3. D.4.2.2 For anchors with diameters exceeding 2" and longer than 25", contact the ESM Structural POC for guidance for determining concrete breakout strength.
   4. D.5.2.2 Use the following k value for Drillco Maxi-bolts: k = 24
   5. D.5.2.6 $\psi_{CN} = 1.0$
   6. D.5.2.9 k and ψ_3 factors are based on the 5% fractile of product-specific testing.
   7. D.5.3.1 Based on testing of Drillco Maxi-Bolt, pullout (N_p) is not an observed failure mode and does not need to be considered.

8. D.5.3.5 & D.6.2.7 All concrete shall be considered cracked unless a substantial analysis is performed to determine that no cracking occurs under expected service loads with load factors taken as unity.
9. D.7 In lieu of Sections D.7.1, D.7.2, and D.7.3, the shear-tension interaction expression given in the commentary, Section RD.7 may be used with $\alpha = 5/3$.
10. Add ACI 349-06 Section D.8.8: D.8.8 Post-installed anchors shall not be located closer than 6 inches to pre-tensioning, post-tensioning, or prestressing or steel.
11. D.9.1 Many anchor performance characteristics depend on proper installation of the anchor. Anchor strength and deformations shall be assessed by acceptance testing under ACI 355.2.

APPENDIX B:DESIGN TABLES: DRILLCO MAXI-BOLT UNDERCUT ANCHORS

Table III B-1 Drillco Maxi-Bolt – Naming System

Drillco Maxi-Bolts shall be specified on engineering drawings using the following naming system:

Material – Diameter – Overall Length – Sleeve Length

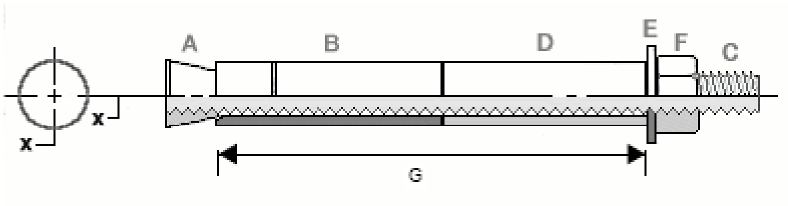
Example: MBA36-500-10-6 ½

Material:
MBA36 = ASTM A36 (Carbon Steel)
MB = ASTM A 193 B7 (High Strength Steel)
SAMB = ASTM A 193 B8

Maxi-Bolt Part Specification

A	Conical Nut
B	Expansion Sleeve
C	Threaded Stud Bolt
D	Distance Tube
E	Washer
F	Heavy Hex Nut
G	Embedment Length

Diameter:
375 = 3/8”
500 = 1/2”
625 = 5/8”
750 = 3/4”
1000 = 1”
1250 = 1-1/4”



Overall Length:
Anchor overall lengths are available in 1” increments longer or shorter than the standard lengths. Standard overall lengths are given in Tables 2, 3, 4, and 5 for Drillco Maxi-Bolts.

Sleeve Length:
Sleeve length is equal to the embedment depth for Type I installations (i.e. top of sleeve is flush with the top of concrete). Type II installations is where the sleeve projects through the baseplate hole and the top of sleeve is flush with the top of plate.

Standard sleeve/embedment lengths are given in Tables 2, 3, 4, and 5 for Drillco Maxi-Bolts.
Design data are given in Table 6 for Drillco Maxi-Bolts.

Table III B-2 Drillco Maxi-Bolt – Standard Sizes (Carbon Steel A36)

ANCHOR PART NO.	ANCHOR STUD DIAMTER (IN)	MAXIMUM ATTACHMENT THICKNESS (IN)	STANDARD TOTAL LENGTH[1] (IN)	EMBEDMENT (IN)
MBA36-375-6-3 1/4	3/8	2	6	3 1/4
MBA36-375-6-4 1/2	3/8	1	6	4 1/2
MBA36-500-7-4 1/2	1/2	1 3/4	7	4 1/2
MBA36-500-9-6	1/2	2 1/4	9	6
MBA36-500-10-7	1/2	2 1/4	10	7
MBA36-625-8-5 1/2	5/8	1 3/4	8	5 1/2
MBA36-625-10-7 1/2	5/8	1 3/4	10	7 1/2
MBA36-625-11-8	5/8	2 1/4	11	8
MBA36-750-10-7	3/4	2	10	7
MBA36-750-13-9	3/4	3	13	9
MBA36-750-14-10 1/2	3/4	3 1/2	14	10 1/2
MBA36-1000-13-9	1	2 3/4	13	9
MBA36-1000-16-12	1	2 3/4	16	12
MBA36-1000-18-14	1	2 3/4	18	14
MBA36-1250-16-12	1 1/4	2 3/4	16	12
MBA36-1250-18-14	1 1/4	2 3/4	18	14
MBA36-1250-23-19	1 1/4	2 3/4	23	19

[1]Engineer may specify a longer total length to accommodate more projection (grout, attachment thickness, etc.).

Table III B-3 Drillco Maxi-Bolt – Standard Sizes (ASTM A193 B7)

ANCHOR PART NO.	ANCHOR STUD DIAMTER (IN)	MAXIMUM ATTACHMENT THICKNESS (IN)	STANDARD TOTAL LENGTH[1] (IN)	EMBEDMENT (IN)
MB-375-6-3 1/2	3/8	2 1/2	6	3 1/2
MB-375-6-4 1/2	3/8	1 1/2	6	4 1/2
MB-500-8 1/4-6	1/2	1	8	6
MB-500-11 1/4-8	1/2	2	11	8
MB-500-13 1/4-10	1/2	2	13	10
MB-625-10-7 1/2	5/8	1 1/4	10	7 1/2
MB-625-13-9 1/2	5/8	2 1/4	13	9 1/2
MB-625-16-12	5/8	2 3/4	16	12
MB-750-13 1/2-9 1/4	3/4	2 3/4	13	9 1/4
MB-750-16 1/2-11 1/2	3/4	3 1/2	16	11 1/2
MB-750-18 1/2-13	3/4	4	18	13
MB-1000-16 1/2-12 1/2	1	2	16	12 1/2
MB-1000-22 1/2-16 1/2	1	3 1/2	22	16 1/2
MB-1000-26 1/2-20 1/2	1	3 1/2	26	20 1/2
MB-1250-20-16	1 1/4	1 3/4	20	16
MB-1250-30-23	1 1/4	5	30	23
MB-1250-37-29 1/2	1 1/4	5 1/2	37	29 1/2

[1]Engineer may specify a longer total length to accommodate more projection (grout, attachment thickness, etc.).

Table III B-4 Drillco Maxi-Bolt – Standard Sizes (ASTM A193 B8 Class 1)

ANCHOR PART NO.	ANCHOR STUD DIAMTER (IN)	MAXIMUM ATTACHMENT THICKNESS (IN)	STANDARD TOTAL LENGTH[1] (IN)	EMBEDMENT (IN)
SAMB-375-6-3 1/2	3/8	2 1/2	6	3 1/2
SAMB-375-6-4 1/2	3/8	1 1/2	6	4 1/2
SAMB-500-8-5	1/2	2	8	5
SAMB-500-10-6 1/2	1/2	2 1/2	10	6 1/2
SAMB-625-10-6	5/8	2 3/4	10	6
SAMB-625-12-8	5/8	2 3/4	12	8
SAMB-750-11-7	3/4	2 1/2	11	7
SAMB-750-13-9 1/2	3/4	2	13	9 1/2
SAMB-1000-14-9 1/2	1	2 1/2	14	9 1/2
SAMB-1000-16-12	1	2	16	12
SAMB-1250-16-12	1 1/4	1 3/4	16	12
SAMB-1250-22-16	1 1/4	3 3/4	22	16

[1]Engineer may specify a longer total length to accommodate more projection (grout, attachment thickness, etc.).

Table III B-5 Drillco Maxi-Bolt – Standard Sizes (ASTM A193 B8 Class 2)

ANCHOR PART NO.	ANCHOR STUD DIAMTER (IN)	MAXIMUM ATTACHMENT THICKNESS (IN)	STANDARD TOTAL LENGTH[1] (IN)	EMBEDMENT (IN)
SAMB-375-6-4 1/2	3/8	1 1/2	6	4 1/2
SAMB-500-8-6	1/2	1	8	6
SAMB-500-11-8	1/2	2	11	8
SAMB-500-13-10	1/2	2	13	10
SAMB-625-10-7 1/2	5/8	1 1/4	10	7 1/2
SAMB-625-13-9 1/2	5/8	2 1/4	13	9 1/2
SAMB-625-16-12	5/8	2 3/4	16	12
SAMB-750-13-9 1/4	3/4	2 3/4	13	9 1/4
SAMB-750-16-11 1/2	3/4	3 1/2	16	11 1/2
SAMB-750-18-13	3/4	4	18	13
SAMB-1000-16-12	1	2	16	12
SAMB-1000-22-16	1	4	22	16
SAMB-1000-26-20	1	4	26	20
SAMB-1250-20-15	1 1/4	3	20	15
SAMB-1250-25-20	1 1/4	3	25	20
SAMB-1250-30-25	1 1/4	3	30	25

[1]Engineer may specify a longer total length to accommodate more projection (grout, attachment thickness, etc.).

Table III B-6 Drillco Maxi-Bolt Design Data

	Symbol	Units	Carbon Steel A36	High Strength Steel A 193 B7	Stainless Steel A 193 B8 Class 1	Stainless Steel A 193 B8 Class 2
Yield Stress of Anchor Steel	f_y	PSI	36,000	105,000	30,000	100,000
Ultimate Stress of Anchor Steel	f_{ut}	PSI	58,000	125,000	75,000	125,000
Ultimate Stress of Anchor Sleeve	f_{utsi}	PSI	75,000	75,000	75,000	75,000
Effectiveness Factor, Cracked Concrete	k	-	24	24	24	24
Increase Factor for Uncracked Concrete	ψ_3	-	1.0	1.0	1.0	1.0
Ductile Design Minimum Edge Distance	Cd_{min}	IN	$6d_o$	$6d_o$	$6d_o$	$6d_o$
Ductile Design Min. spacing to achieve ductile design	Sd_{min}	IN	(Note 1)	(Note 1)	(Note 1)	(Note 1)
Non-ductile Design (Note 2) Minimum Edge Distance	Cn_{min}	IN	$1.5h_{ef}$	$1.5h_{ef}$	$1.5h_{ef}$	$1.5h_{ef}$
Non-ductile Design Minimum Spacing	Sn_{min}	IN	$8d_o$	$8d_o$	$8d_o$	$8d_o$

ANCHOR DIAMETER	Symbol	Units	3/8	1/2	5/8	3/4	1	1-1/4
Stud Diameter	d_s	IN	0.375	0.500	0.625	0.750	1.000	1.250
Stud Tensile Area	A_{se}	IN^2	0.078	0.142	0.226	0.334	0.606	1.000
Sleeve Cross-Sectional Area	A_{sl}	IN^2	0.190	0.290	0.317	0.486	1.257	1.875
Undercut Bearing Area	A_{brg}	IN^2	0.196	0.306	0.395	0.583	1.289	1.914
Sleeve outer Diameter	d_o	IN	0.625	0.800	0.905	1.101	1.625	2.000
Sleeve inner Diameter	d_i	IN	0.385	0.520	0.645	0.770	1.020	1.270
Anchor Axial Stiffness, Uncracked[7]	β_{un}	Kip/in	173	478	376	915	N/A	N/A
Anchor Axial Stiffness, Cracked[7]	β_{cr}	Kip/in	78	119	196	500	411	863

Notes:

1) For **ductile** anchors located greater than $6d_o$ from a free edge, the minimum spacing shall be based on ductile design.
2) For **non-ductile** anchors with edge distances closer than $1.5h_{ef}$, contact the ESM Structural POC for guidance.
3) Maximum embedment, h_{ef}, is 2/3 the thickness of the concrete member.
4) Minimum member thickness for the above spacings and edge distances is 12”.
5) Minimum concrete strength to achieve the above spacings and edge distances is f'_c = 4,000 psi.
6) Tensile area for 1-1/4” diam. Maxi-Bolt is based on 8 threads per inch.
7) Anchor stiffness values are from test report. N/A = the uncracked test was not performed for this diameter.