NATIONAL ACCELERATOR LABORATORY

ENVIRONMENT, SAFETY & HEALTH DIVISION

Seismic Design Specification for Buildings, Structures, Equipment, and Systems: 2020

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Executive Summary

This document is intended to provide an overview of the requirements for seismic analysis and design of buildings, structures, equipment, and systems that will be constructed and installed at SLAC National Accelerator Laboratory.

SLAC will use the 2019 *California Building Code (CBC)* for structural design criteria.

Contents

1 General Design Requirements

SLAC will use the 2019 *California Building Code (CBC)* for structural design criteria.[1]

The 2019 CBC adjusts the level of design based on risk categories from I to IV. Most projects at SLAC will be Risk Category II, which provides life safety seismic performance. There are a few exceptions to this risk category, which are clearly identified in the building code. These exceptions include assembly occupancies where more than 300 people congregate (Risk Category III). Refer to 2019 CBC Table 1604.5 for more information.

For more information, refer to SLAC ES&H Public Safety Department's Building Inspection Office (BIO) webpage at below weblink:

https://www-group.slac.stanford.edu/esh/groups/psd/bio.htm

1.1 Design Guidance

In order to facilitate the process of designing structures and equipment anchorage, the following issues should be considered when designing for resistance to seismic loads:

- Site-specific seismic criteria may be based on values determined in accordance with ASCE 7-16[2] as amended by the 2019 CBC, Chapter 16. As an alternative, the seismic criteria may be based on the worst case values shown in Section 5 of this document for the location of the proposed work.
- For all anchors embedded into concrete that resist seismic loading, the cracked concrete provisions of ACI 318-14 [3], Chapter 17, as amended by 2019 CBC, Section 1905.1.8, must be considered.
  - Post-installed anchors installed into hardened concrete (such as epoxy or expansion anchors) must be designed and installed in accordance with the same cracked concrete provisions using the procedures summarized by the manufacturer's approved ICC-ES/ESR report.[4] Additional information on post-installed anchors can be found in Section 4 of this document.

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1 The *California Building Code (CBC)* is codified as Title 24, *California Code of Regulations*, "California Building Standards Code", Part 2, "California Building Code" (24 CCR Part 2)

2 American Society of Civil Engineers (ASCE) 7-16, "Minimum Design Loads for Buildings and Other Structures, including Supplement No. 1 as well as any new supplement at the time of design.

For a list of ASCE standards and errata, see the ASCE Structural Engineering Institute, http://www.asce.org/structural-engineering/sei-supplements-and-errata/

3 American Concrete Institute (ACI) 318-14 , "Building Code Requirements for Structural Concrete and Commentary" (ACI 318-14)
For a list of ACI standards, see the ACI Bookstore:
https://www.concrete.org/store.aspx

4 International Code Council (ICC) Evaluation Report (ER)

For a list of ICC ERs, see "ICC-ES: Evaluation Reports"
https://icc-es.org/evaluation-report-program/reports-directory/

- Anchor design must be governed by ductile yielding of a steel element (anchor or attachment), unless the exceptions of ACI 318-14, Section 17.3 are met. Any questions about correct implementation of code requirements for seismic design should be directed to the Building Inspection Office (BIO) and structural authority having jurisdiction (SAHJ).

1.2 Modular / Portable Buildings

Modular/portable buildings that are permanently installed must be designed to meet the same criteria as those installed at California public schools K-12 and anchored to meet the criteria for Risk Category II.

Regarding non-permanent modular/portable structures that are for short term usage only, minimum strapping to ground anchors are necessary. For more details, refer to latest SLAC document titled ‘Guidelines for Temporary Construction Trailers’ on weblink below; and, the latest edition of ‘Building Inspection Office Review Triggers’ document (Doc ID: SLAC-I-720-0A24J-001-R007).

https://www-group.slac.stanford.edu/esh/groups/psd/bio.htm

1.3 Nonstructural Components

In compliance with the 2019 CBC, nonstructural components (including architectural, mechanical, electrical, and plumbing equipment) and their supports and attachments that are permanently attached to a structure must be designed and constructed to resist the effects of the earthquake motions in accordance with governing Building Codes. Refer to ASCE 7-16, Chapter 13, for more information.

ASCE 7-16 section 13.1.4 exemptions that apply at SLAC are the following. Note that these exemptions do not require a designed anchorage or bracing to be reviewed by Building Inspection Office, but all equipment still must be secured in place &/or positively connected to supporting structural element(s) as directed by other applicable ASCE7-16 code sections (such as section 13.2.3 and 13.4), the manufacturer requirements, and Building Code Official (or SLAC’s Structural Authority Having Jurisdiction):

- section 13.1.4 exemptions: Discrete mechanical and electrical components in Seismic Design Categories D, E, or F that are positively attached to the structure, are exempted, provided that:
  - The component weighs 400 lbs. (1,779 N) or less, and the center of mass is located 4 ft (1.22 m) or less above the adjacent floor level, and flexible connections are provided between the component and associated ductwork, piping, and conduit, and the component Importance Factor, Ip, is equal to 1.0.
  - The component weighs 20 pounds or less, in case of a distribution systems, weighing five pounds per foot or less; and.
  - Distribution systems in Seismic Design Categories D, E, or F included in the exceptions for conduit, cable tray, and raceways in Section 13.6.5, duct systems in 13.6.6 and piping and tubing systems in 13.6.7.3. Where in-line components, such as valves, in-line suspended pumps, and mixing boxes require independent support, they shall be addressed as discrete components and shall be braced considering the tributary contribution of the attached distribution system.

2 Programmatic / Experimental Equipment Design Requirements

The following programmatic/experimental equipment and structures must be designed and constructed to resist the effects of earthquake motions in a manner that ensures life safety:

- For any structure that personnel can enter, such as radiation hutches, shielding structures, modular clean room, etc.:

  The seismic design criteria will be met by using the 2019 CBC for seismic design (risk category as appropriate per the 2019 CBC).

- For any experimental equipment that weighs more than 400 pounds:

  The seismic design criteria will be met by using the 2019 CBC for seismic design. For ground-mounted experimental equipment, use the following strength design load combinations of ASCE 7-16 section 2.3.6 Basic Combinations with Seismic Load Effects (Note: this alternate method is allowed to be used only for equipment assigned to Risk Category II of ASCE 7-16):

  – (1.2) x Dead Load + Ev + Emh + L +(0.2) x Snow Load   Equation 6

  – (0.9) x Dead Load - Ev + Emh   Equation 7

  – Ev = 0.2 x S_{DS} x Dead Load   Equation 12.4-4a (Ch. 12)

  Where “dead load” includes operating live load (where applicable) and “E” = effects of horizontal seismic forces. The seismic loading is analyzed as an inertial force, so the effects of the horizontal acceleration may include overturning effects. Refer to Table 1, below. Overstrength factor Ωo for seismic load shall be used for anchor bolt calculations.

Table 1 Horizontal Earthquake Acceleration Values for Experimental Equipment

Horizontal Earthquake Acceleration		
280 and West, incl. Sector 25	East of 280	Experimental Equipment Structure Type Similar to the Following
0.82 g	0.75 g	▪ Elevated tanks, vessels, bins, or hoppers on symmetrically braced legs ▪ Horizontal, saddle supported welded steel vessels ▪ Flat-bottom ground-supported tanks (steel or fiber reinforced plastic) ▪ Steel and reinforced concrete distributed mass cantilever structures ▪ Components and systems isolated using neoprene elements
1.03 g	0.92 g	▪ Elevated tanks, vessels, bins, or hoppers on unbraced or asymmetrically braced legs ▪ Inverted pendulum type structure (except elevated tanks, vessels, bins or hoppers) ▪ Spring isolated components and systems ▪ Internally isolated component and systems

Note: consideration should be given for equipment that may be relocated or installed in multiple locations to use the higher acceleration from the table above. Contact the Building Inspection Office if you have any questions about what acceleration to use.

In all cases, the anchors and the adequacy of the anchorage to support the design loads must be design-reviewed by a California-licensed civil engineer, assigned by BIO or SAHJ.

3 Approved Concrete Anchors

Post-installed anchors (anchors installed into existing hardened concrete) must be approved to resist seismic loads and have a current ICC-ES/ESR report. Where anchorage conditions require an engineered design, it must be performed in accordance with the ICC-ES/ESR report and the cracked concrete provisions of ACI 318-14, Chapter 17.

The overstrength factor (Ωo omega) shall be applicable for the design of post-installed anchorage of nonstructural components in accordance with ASCE 7-16, Chapter 13. (See ACI 318-14, Section 17.3).

Some commonly used anchors are listed below (intended as examples, not an inclusive list):

- Epoxy Materials
  - Hilti HIT-RE 500 V3 (ICC ESR No. 3814, Latest Edition)
  - Hilti-HY 200 (ICC ESR No. 3187, Latest Edition)
  - Hilti HVU2 (ICC ESR No. 4372, Latest Edition)
  - Simpson SET-XP (ICC ESR No. 2508, Latest Edition)
- Adhesive Anchors
  - Hilti HAS (all threaded), HIS (internally threaded), HIT-Z (Cone-shaped)
  - Simpson RFB
- Expansion anchors
  - Hilti Kwik-Bolt TZ (ICC ESR No. 1917, Latest Edition)
  - Simpson Strong-Bolt 2 Wedge Anchor (ICC ERS No. 3037, Latest Edition)

4 Special Design Requirements

There is the possibility that a project at SLAC will require exceptional seismic performance (higher than would be required per the building code), due to special importance to mission or extreme safety hazard. SLAC is subject to Department of Energy Standard DOE-STD-1020-2016[5] as a non-nuclear facility under Section 2.2 of that standard. Projects that contain significant chemical or toxicological hazards must be designed in accordance with DOE-STD-1020-2016, Section 3.0, “Criteria and Guidelines for Seismic Design”.

For these projects, the structural design must use the importance factors for Risk Categories III and IV. Only the importance factor is changed; the building code chapters used for structural design would be those that are normally used for the particular structure. Note that for some limit states, DOE-STD-1020-2016

5 Department of Energy Standard 1020-2016, “Natural Phenomena Hazards Analysis and Design Criteria for DOE Facilities” (DOE-STD-1020-2016)

Table 3-1 requires substituting a Response Modification Coefficient “R” that is reduced from the ASCE 7-16 value.

The imposition of Risk Category IV has a significant design and cost impact, requiring seismic testing for the internal parts of equipment such as electrical panel boards, HVAC units, and racks, in addition to stringent building structural requirements. This category is intended to apply only to those structures and systems that must be fully operable during and immediately after a design-level earthquake.

4.1 Determination and Approval

The decision to identify a project as being critical to safety or mission and assign it to Risk Category IV requires the written approval of the laboratory director. This determination must be made and properly documented, during the initiation and conceptual phase of the project, using the policy and guidelines from DOE-STD-1020-2016, CBC 2019, and ASCE7-16.

5 Seismic Design Map

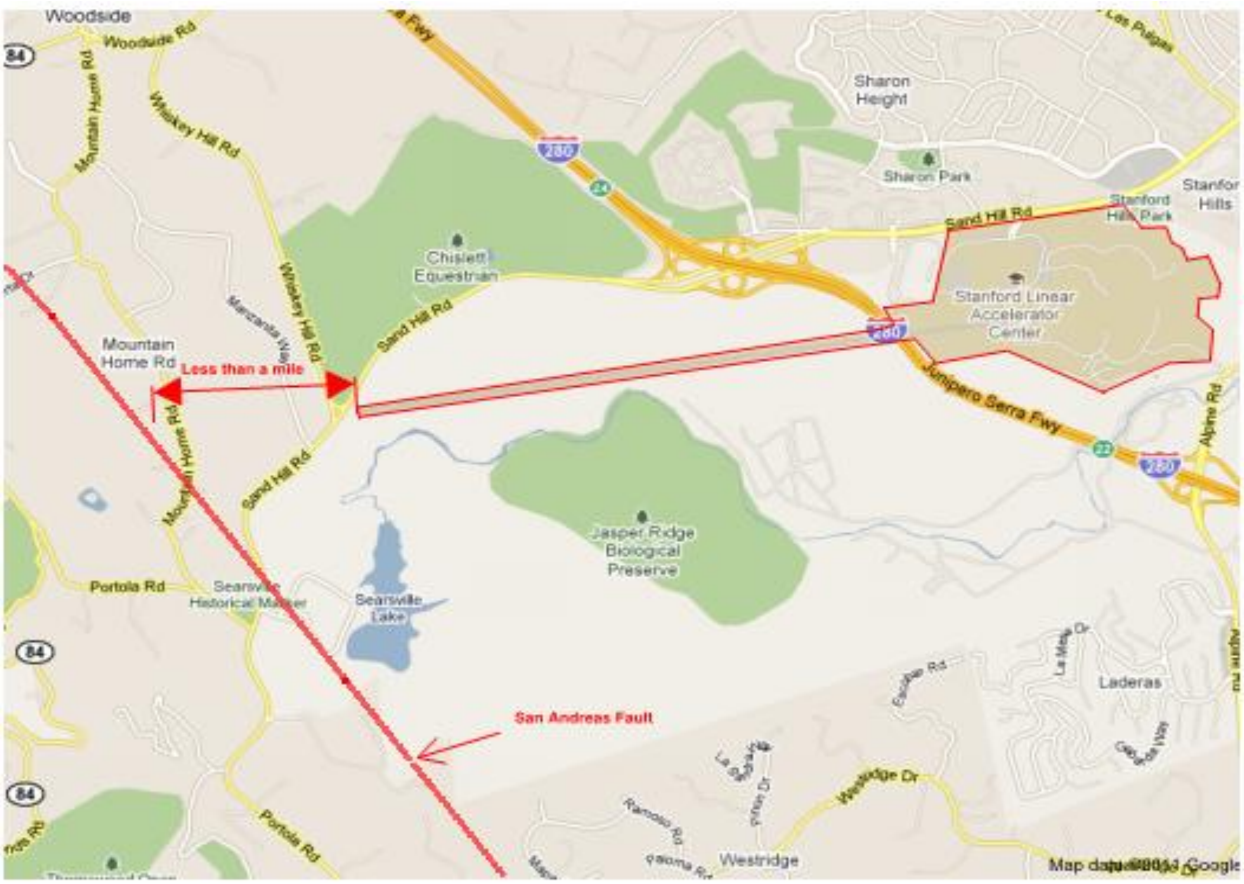

Figure 1 Proximity to San Andreas Fault

Figure 2 SLAC Map

Table 2 Seismic Ground Motion Values

ASCE7-16				SITE CLASS C (VERY DENSE SOIL & SOFT ROCK)					SITE CLASS D - STIFF SOIL (FROM SOIL REPORT BY GEOR)			SITE CLASS D - DEFAULT (FOR CASES OF NO SOIL REPORT)		
NEW LOCATION	PREVIOUS LOCATION	LAT	LONG	S_S (g)	S_1 (g)	S_{DS} (g)	S_{D1} (g)	SDC	S_{DS} (g)	S_{D1} (g)	SDC	S_{DS} (g)	S_{D1} (g)	SDC
1	1 2	37.419	-122.194	2.25	0.82	1.80	0.77	E	1.50	NULL	NULL	1.80	NULL	NULL
2	6 14 3 7	37.418	-122.203	2.30	0.86	1.84	0.80	E	1.53	NULL	NULL	1.84	NULL	NULL
3	4 5 8	37.416	-122.210	2.33	0.88	1.86	0.82	E	1.55	NULL	NULL	1.86	NULL	NULL
4	9 10 11	37.414	-122.229	2.49	0.96	1.99	0.89	E	1.66	NULL	NULL	1.99	NULL	NULL
5	12 13	37.412	-122.239	2.57	1.00	2.05	0.94	E	1.71	NULL	NULL	2.05	NULL	NULL
S_{D1} & S_{DS}	FOR NULL, SEE ASCE 7-16 SECTION 11.4.8			Note: Spectral acceleration values for "Default Site Class D" are more conservative than Site Class D values (approximately equal to values for Site Class C in many cases).										

* Use site specific ground motion data from geotechnical report if available. The S_{DS} and S_{D1} values for various soil site classes.