CHANGING SEISMIC REQUIREMENTS FOR BATTERY RACKS & CABINETS

Jeff Donato
Chief Technology Officer
EnviroGuard
Montclair, California

Josh Michel
VP of Product Management
EnviroGuard
Montclair, California

Abstract

Seismic requirements for battery racks and cabinets have existed for decades and have largely been based on the Uniform Building Code (UBC). The International Building Code (IBC) was created in 1997 and adopted thereafter by many State and local jurisdictions. Currently, the IBC is adopted by every State either at the state code level or by local jurisdiction and municipalities, thus replacing the UBC. The IBC describes any kind of battery rack or cabinet as an "Other Structure". These structures must meet occupancy requirements and corresponding importance factors to be in compliance with the building code. Other industry standards also exist to provide seismic protections based on the specific application. Examples are IEEE 693, IEEE 344, Telcordia GR-63-Core (NEBS), and OSHPOD. This paper discusses the various seismic requirements for battery racks and cabinets based on industry standards and legislative code requirements. Also discussed are the differences between legacy codes which are still found in many specs today versus new codes that are required by the authorities having jurisdiction (AHJ).

Introduction of Building Codes

Building Codes have been recorded as early in history as the Code of Hammurabi before 2,000 BC in the Babylonian empire. The first formal building codes in the US were created in 1778 and larger cities in the 1800's to control extensive fires. By the 1900's three building codes were established: The National Building Code, The Standard Building Code, and The Uniform Building Code. At that time, codes were very much regionalized:

Southern Building Code Congress (SBCCI)	Standard Building Code	Southeast US	Hurricane & wind design provision
International Conference of Building Officials (ICBO)	Uniform Building Code	Western US	Earthquake design provision
Building Officials and Code Administrators International (BOCA)	National Building Code	Northeast and Central US	Fire resistance & urban construction design provision

Figure 1

Later in the 1900's, these three organizations merged to create the International Code Council (ICC) to create model codes, otherwise known as "I-Codes". I-Codes were created that dealt with all types of buildings including existing structures. I-Codes are updated and published every three years based on technical criteria made from consensus standards groups such as the American Society of Civil Engineers (ASCE). The document *ASCE 7-10 Minimum Design Loads for Buildings and Other Structures ASCE/SEI 7-10, 2013, [2]),* was created to address minimum load requirements and appropriate load combinations that address strength and stress design requirements.

Today, the International Building Code (International Code Council, Inc., 2018 [12]) has been adopted by 49 states, many cities, and local governments with a few exceptions of some government facilities and two cities that have adopted the NFPA 5000 model code. Colorado is the only state that does not adopt a statewide code with the exception of state buildings.

Nonstructural Components

Battery racks and cabinets are included in the long list of nonstructural components such as air conditioning, generators, transformers, and switchgear to name a few. Compliance is required for these components to meet the International Building Code Provisions that superseded the Uniform Building Code. These components are required to meet ASCE 7 (ASCE/SEI 7-10, 2013 [2]) testing standards to comply with current building code.

What Drove the Seismic Code Evolution?

Earthquake events in US history drove progression in codes that address seismic construction. Before 1971, several events led up to advances in seismic detection and prevention of structural damage. In 1935, the Richter Scale was introduced by Charles Richter of the California Institute of Technology to compare the size of earthquakes.

Notable earthquakes in US history helped shape the building code prior to 1970:

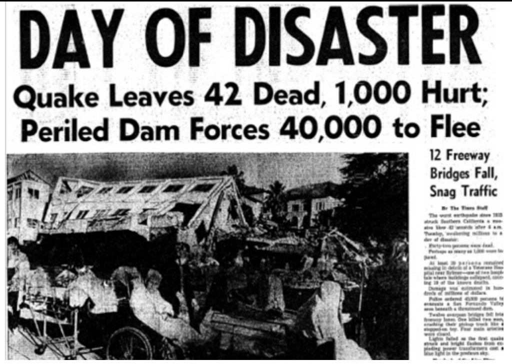
1933	Long Beach California
1949	Olympia, Washington
1952	Kern County, California
1964	Prince William Sound, Alaska

Figure 2

In 1959, the Structural Engineers Association of California (SEAOC) released the “Recommended Lateral Force Requirements and Commentary” (aka “The Blue Book). This was later adopted into the Uniform Building Code 1961 edition.

The San Fernando [Sylmar] Earthquake of 1971

Near the San Fernando Valley, a 6.6 magnitude earthquake occurred in Sylmar, California that caused much damage to buildings that already conformed to the current building code at that time.

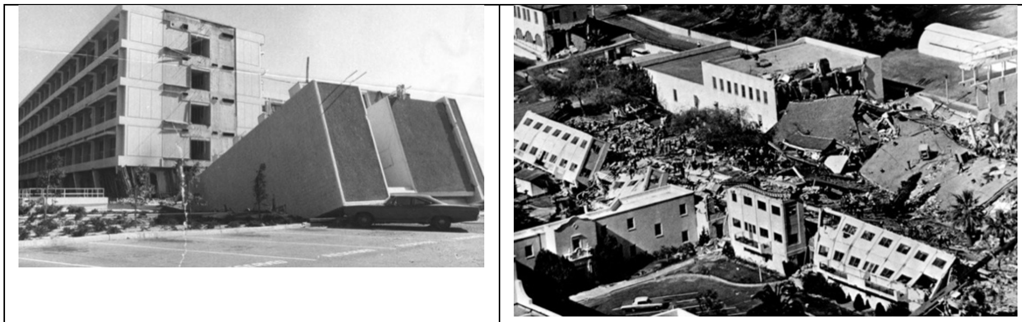


DAY OF DISASTER

Quake Leaves 42 Dead, 1,000 Hurt; Periled Dam Forces 40,000 to Flee

12 Freeway Bridges Fall, Snag Traffic

https://www.latimes.com/california/newsletter/2021-02-09/sylmar-earthquake-1971-essential-california



https://www.kcrw.com/news/shows/greater-la/construction-housing-waste-quake/sylmar-earthquake-lessons

https://www.latimes.com/local/earthquakes/la-me-building11-2005oct11-story.html

Figure 3

The San Fernando earthquake proved that the current building code, at that time, was not sufficient. The Structural Engineers Association of California, a non-profit group, formed the Applied Technology Council (ATC). Congress passed the Earthquake Hazards Reduction Act of 1977 (Public Law 95-124), which resulted in the creation of the National Earthquake Hazards Reduction Program (NEHRP).

Groups under the NEHRP:

The Federal Emergency Management Agency	FEMA	Public & Individual assistance after a disaster occurs.
National Institute of Standards and Technology	NIST	Research & development, Improved technology competitiveness of the US.
National Science Foundation	NSF	Technology leadership & research centers.
United States Geological Survey	USGS	Identification of level of earthquake hazard. Developed national seismic hazard maps.

Figure 4

Since the 1980's, FEMA has funded the creation of the NEHRP Recommended Provisions. In 1994, The Northridge earthquake occurred in northern Los Angeles with a 6.7 magnitude. This earthquake sparked improvement in the weld quality required to withstand this level of earthquake.

These events led to major change to the codes and standards:

1991 NEHRP Recommended Provisions	• Adopted by BOCA & SBCCI
1997 NEHRP Recommended Provisions	• Adopted into the ASCE/SEI 7 (ASCE/SEI 7-10, 2013 [2]) standard. • Adopted by the International Building Code
2020 NEHRP Recommended Provisions	

Figure 5

Seismic Codes vs. Standards

Seismic Codes

Codes are designed to meet the minimum requirements to protect life safety components including egress. Model codes (I-Codes) are adopted by state, city and local governments with their changes based on local requirements. Once adoption is final, the code becomes law.

Seismic Standards

Standards describe “best practices” for selecting, sizing, installing, and maintaining equipment to achieve a desired performance and expected life. For this reason, seismic standards for batteries describe how to best keep equipment functioning through a seismic event. Standby power industry seismic standards are also often called Mission critical applications where equipment must remain functioning after an event for reasons other than life safety. Many of these reasons have great functional and/or financial impacts to an organization.

Testing and Requirement Overview

The following section will provide an overview of the most widely adopted seismic codes and standards in the stationary power industry. OSHPD (California Administrative Code, 2019 [1]) (for healthcare facilities in California) will not be addressed in this paper due to how rarely the standard is used.

Type	Code/Standard	Market Segment	Testing and Certification Criteria
Standards	IEEE 693 (PE/SUB-Substations, 2018 [9])	Utility	Triaxial testing. Uses Seismic Levels Low, Moderate and High
	NEBS (GR-63, Issue #5, 2017 [21])	Telecommunications	Single axis at a time. Uses NEBS Zones 1-4
Codes	UBC (Paul Armstrong & Interwest Consulting Group, 2000 [4])	General	Single axis at a time. Uses UBC Zones 1, 2a, 2b, 3 and 4 (Fig 9)
	IBC (International Code Council, Inc., 2018 [12])	General	Triaxial testing. Uses site specific data for proper seismic design specification.

Figure 6

IEEE 693

The Triaxial based seismic testing standard specified by IEEE 693 (PE/SUB-Substations, 2018 [9]) for Substation Design follows the seismic testing standards specified in ICC-ES AC156 (ICC-ES AC156, 2010 [8]) and ASCE-7 (ASCE/SEI 7-10, 2013 [2]). Seismic shake table testing will follow the ICC-ESAC156 (ICC-ES AC156, 2010 [8]) standard while qualification through computer simulation otherwise known as Finite Element Analysis (FEA) follows ASCE-7-10 (ASCE/SEI 7-10, 2013 [2]) specifications and requirements. The IEEE 693 HIGH seismic certification requires testing or FEA to a Horizontal Acceleration of 0.5g in the two horizontal directions and 0.4g in the vertical direction. This may correspond to a Horizontal Spectral Response Acceleration of 1.6g and a Vertical Spectral Response Acceleration of 1.3 g. depending on the natural frequency of vibration of the non-structural component (i.e., rack). The IEEE 693 standard does allow for certification through FEA if shake table testing is not specifically required by the end user. It is important to note that IEEE 693 is not a code therefore not law. It is a standard adopted largely by the utility industry and rarely if at all adopted outside that industry. The code adopted by the AHJ will still need to be met.

However, the IEEE (PE/SUB-Substations, 2018 [9]) guidelines still uses the specific peak ground acceleration (PGA) developed in a study of the site seismic hazard, selected at a 2% probability of exceedance in 50 years and modified for site conditions. This represents the probability of a worst-case seismic event for any given location. The following table summarizes how to correspond the mapped acceleration at the site to the IEEE 693 (PE/SUB-Substations, 2018 [9]) seismic qualification level.

IEEE 693 Qualification Levels

Mapped Peak Ground Acceleration (PGA)	**Level**
Less than 0.1g	Low
Greater than 0.1g but less than or equal to 0.5g	Moderate
Greater than 0.5g	High

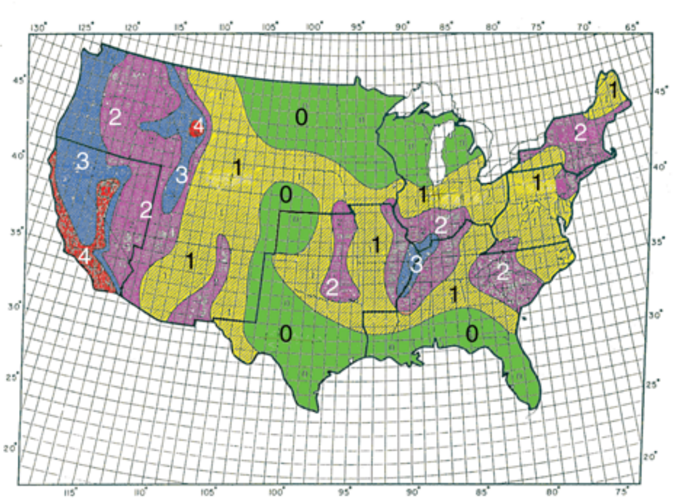
Figure 7

NEBS

NEBS GR-63-CORE (GR-63, Issue #5, 2017 [21]), the “Network Equipment Building Standard”, is used exclusively in the telecommunications industry. This standard was originally created by Bell Labs to bring harmonization to the telecom industry’s best practices and standards. Ericsson (Telcordia) now owns and maintains the NEBS standards. Like IEEE 693 it is important to note NEBS is not a Building Code. Companies that have adopted NEBS may still be required to meet local and state building codes depending on the AHJ. There have been cases in the field where NEBS seismic rated equipment has been installed and the inspectors have asked for the IBC anchor and or seismic calculations. In each of the cases the authors were involved with the end user was forced to delay the start up until a PE certification to IBC was completed on the installed designs. In one case the end user had to drill extra holes in the base plate to add more anchors to satisfy the IBC anchor requirement for the area they were installing the system.

The major carriers that have standardized on NEBS for their seismic specification should be aware of a growing movement of AHJs not being satisfied with a standard replacing a building code when it comes to seismic certification of equipment being installed. This trend seems to be most prevalent in the Western US although there have been cases in other parts of the country.

The NEBS seismic standard is still adopted by the major telecoms because it typically takes a more robust design to pass, especially for the NEBS Class 1 Zone 4 rating. Even though the NEBS seismic test is done one single axis at a time, it is performed at a 2.5 g. The relatively high acceleration along with the built-up inertia from shaking on the same axis for 35 seconds creates a substantial amount of energy causing a strong tendency for displacement at the top of the equipment. However, NEBS only allows for 3 inches of displacement at the top requiring ancillary equipment such as racking and cabinets to use very rigid designs, materials and anchoring that drive up the cost of the equipment. The often-sizable increased cost of NEBS seismically rated equipment is one of the main reason smaller independent telecoms have been switching to specifying building codes for their seismic standards such as the International Building Code (IBC).



Telcordia Earthquake Zone Map
(Dave Lorusso, 2011)
Figure 8

IBC

The Occupancy Category will determine the type of test required for certification according to the code (Note: Occupancy Category is not the same as Use and Occupancy Classification as described in Chapter 3 of the IBC).

US Occupancy Category	Canadian Occupancy Category	Importance Factor Earthquake, I_E*	Required Seismic Test (per ASCE 7)	Nature of Occupancy (For Buildings and Other Structures)
I	Low	1	FEA	LOW hazard to human life in event of failure Examples: Agricultural, Temporary & Minor Storage Facilities.
II	Normal	1	FEA	Those NOT listed in Occupancy Categories I, III or IV Examples: Office, Retail & Commercial Buildings.
III	High	1.25	FEA	SUBSTANTIAL hazard to human life in event of failure Examples: Schools, Jails, Buildings with Public Assembly Areas containing greater than 300 occupants.
IV	Post-Disaster	1.5	Triaxial Shake Table	Designated as an ESSENTIAL facility. Examples: Hospitals, Police, Fire & Rescue Stations, Designated Emergency Shelters, Critical National Defense Facilities Equipment to remain functioning after an event.

Importance Factors (I_P) include the following: Wind (I_W), Snow (I_S), and Earthquake (I_E). For this figure, we are only discussing Earthquake (I_E).

Figure 9

Occupancy Category

The occupancy category interpretation is described in the “Nature of Occupancy” column as it pertains to the building occupancy rating to protect the life and safety of the public. The second column illustrates the same occupancy categories as described in the National Building Code of Canada (National Research Council Canada, 2015). Notice that building category IV directly describes facilities that must remain operating after an earthquake. International Building Code requires shake testing on Occupancy Category IV facilities and nonstructural components that have a direct impact to protecting human life.

Importance Factor

The Importance Factor I_P (sometimes called a safety factor) is a multiplier that increases or decreases the base design loads (Figure 9). Importance Factor Earthquake I_E is determined from Design Loads for Buildings and Other Structures (ASCE 7) based on the Occupancy Category (risk inherent in the type of facility under consideration). Typically, the base design loads are outlined by the code as a 2% annual probability of exceedance (2% in 50 years for seismic loads). A higher importance factor is intended to improve the reliability and resiliency of the structure, but not necessarily the aesthetics of the structure.

Exceptions to the Rule

There may be instances where code minimums should be expanded to provide additional protections for systems that need to operate after an event such as a mission critical facility for data centers, telecom, and utility facilities. These facilities may need to operate in a post-disaster situation regardless of the Occupancy Category. This is the primary reason for design adoption of the seismic standards such as IEEE and NEBS.

Calculating SDS

SDS (Siemens, n.d. [23]) is the *Design Spectral Response Acceleration* parameter at short periods (g). This parameter is based on Ss (geographic location of the structure), adjusted for soil properties at the installation site as well as location in the building (elevation = z/h*). Calculated values range from 0.0 g to 2.13g. ASCE 7 and the International Building Code require the nonstructural component be tested to an SDS level (Advanced Spectral Response) which is based on the factors below:

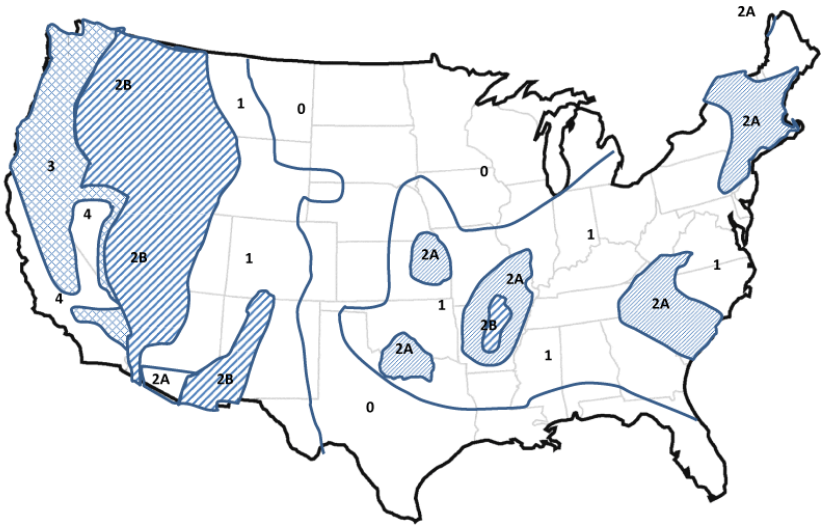
- **Site class – Soil Density**
    - Hard Rock
    - Rock
    - Very Dense Soil & Soft Rock
    - Stiff Soil
    - Soft Clay Soil
- **Risk Category/Occupancy Category (relates to Importance Factor Earthquake I_E level) ***
    - 1-4 as described in Figure 9
- **Location in the Building – z/h** Elevation**
    - At grade
    - Below grade
    - Above Grade
- **Short term Acceleration or Short Period Shaking Factor S_S (0.2 sec)**
    - From the U.S.G.S. Short Term (0.2 second) Spectral Response Acceleration (Based on site address/coordinates)

** As the occupancy category increases, so does the Importance Factor*

***z/h Ratio (0.0 - 1.0) representing the component mounting height in relation to the total building height. z is the component mounting height (above ground level), and h is the total building height (above ground level).*

UBC (Legacy model code)

The last update to the Uniform Building Code was 1997. The UBC has since been superseded by the International Building Code making the UBC more of a "Legacy Code". UBC seismic zones are still found in many specifications and need to be updated to meet the current code requirements. The reasons for the continued use of this legacy code may vary from old seismic designs, comfort level and ease of using the color coded UBC zone maps.

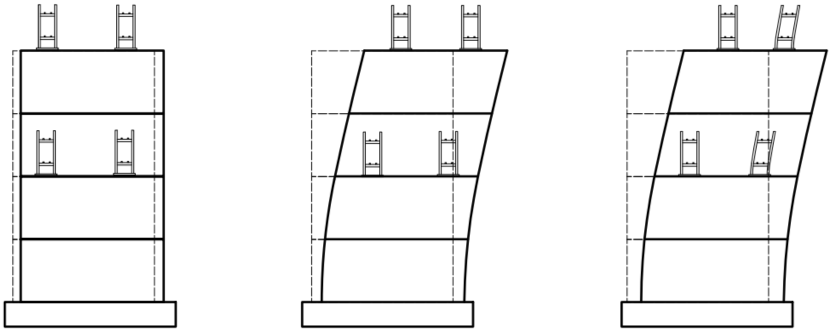


UBC Zone Map
Figure 10

Major Differences

Why does triaxial shake testing matter. Triaxial shake testing is the method of seismic shake testing specified by ASCE-7 which IEEE 693 and IBC reference for their seismic testing and certification standards. This makes certification via triaxial shake testing and or experience data the most adopted form of seismic certification in the engineering world. UBC and NEBS seismic testing only require one axis to be tested at a time and the last update to UBC in 1997 still did not consider the vertical axis. Single axial testing can be an effective test method, but it is not the most state-of-the-art form of shake testing, and it really does not simulate a real-world seismic event as triaxial shake testing does.

Location in the building (z/h factor) is one of the main characteristics IBC accounts for that IEEE 693 and NEBS GR-63 do not. ASCE-7 (Section 13.3.1.1) introduced the use of a “Floor Response Spectrum” also known as “Relative Floor Acceleration”, which accounts for the increased seismic forces on Nonstructural components such as Battery racks, cabinets, and other equipment the further up from ground level in the building the equipment is installed.



(1) Ground Acceleration

(2) Ground & Relative Floor Acceleration

(3) Ground, Relative Floor & Relative Component Acceleration

Figure 11

What figure 11 above illustrates is the top of building displacement is more severe than that of the base in a seismic event. More importantly, it also illustrates what happens to the individual Non-structural components and how they have their own displacement that gets more severe the higher up in the building they are installed. This insinuates two identical battery racks installed in the same building will perform differently during the same seismic event. The rack installed at ground level will experience less acceleration than the same rack installed on the fourth floor. This is because the top floor rack is affected by the G*round Acceleration + the Relative Floor Acceleration + the Relative Component Acceleration (*i.e. “whiplash” effect). Like NEBS, the IEEE 693 Seismic standard also does not make considerations for above grade installs and the whiplash effect. Getting an IEEE 693 seismic rating for an above ground install requires analysis of the building and the component which can be very costly.

Figure 12 below illustrates the increased forces on a frame that would be calculated on the same components relative to their elevation in the building.

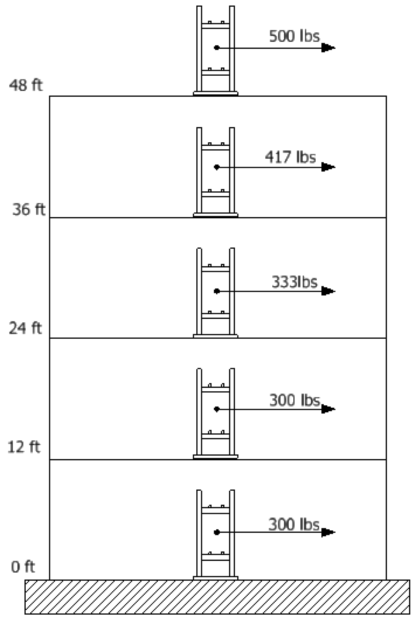


Figure 12

Soil Class is the other "site condition" that only IBC considers. Scientific research has proven that the type of ground the site is located on will affect the seismic performance of the building and or equipment during a seismic event. This along with factoring in location in the building are two critical factors considered in an IBC seismic certification that are not addressed in the NEBS and IEEE 693 seismic standards.

The year of the code matters

It is clear looking at the table in figure 13 that nearly the entire United States has adopted some form of IBC as their adopted state building code. In the rare cases the state has not adopted IBC it is found at the local county and city levels of adoption. Some states like California have published their own codes. In the case of California, it is the CBC (California Building Code [1]). However, in the case of the CBC it is essentially a copy of the most current version of IBC. California just puts the CBC out the year after IBC publishes the latest version.

State	Version
Alabama	2015
Alaska	2012
Arizona	X
Arkansas	2012
California	2018
Colorado	X
Connecticut	2015
Delaware	X
District of Columbia	2015
Florida	2015
Georgia	2018
Hawaii	2018
Idaho	2018
Illinois	X
Indiana	2012
Iowa	2015
Kansas	X
Kentucky	2015
Louisiana	2015
Maine	2015
Maryland	2018
Massachusetts	2015
Michigan	2015
Minnesota	2018
Mississippi	2018
Missouri	X
Montana	2018
Nebraska	2018
Nevada	X
New Hampshire	2015
New Jersey	2018
New Mexico	2015
New York	2018
North Carolina	2015
North Dakota	2018
Ohio	2015
Oklahoma	2015
Oregon	2018
Pennsylvania	2015
Rhode Island	2015
South Carolina	2018
South Dakota	2018
Tennessee	2012
Texas	2003
Utah	2018
Vermont	2015
Virginia	2015
Washington	2015
West Virginia	2015
Wisconsin	2015
Wyoming	2018
U.S. Territories	IBC
American Samoa	
Guam	2009
Puerto Rico	2018
Northern Mariana Islands	2009
U.S. Virgin Islands	2018

X = One or more state or local agencies/jurisdictions have adopted an edition of the specific code. However, the particular code is not used as a standard for all buildings.

Blank = The specific code has not been adopted by any state or local jurisdiction in the state.

https://www.iccsafe.org/wp-content/uploads/Master-I-Code-Adoption-Chart-jan-2021.pdf

Figure 13

Essential or Non-Essential?
(Mission Critical or Not? - Post Disaster Operation)

The NEBS standard focuses on operation after a seismic event and remaining operational, which is the reason the NEBS Zone 4 seismic testing is so severe. Similarly, the IEEE 693 seismic standard requires the equipment remain operational after a seismic event. IBC for Essential Facilities (Building Class IV) requires the equipment to be operational after a seismic event as well. To get the Essential Facility rating, the certification must be based on actual Triaxial shake test data rather than FEA analysis. Further the Essential Facility rating under IBC is a model code and concerned with Life Safety more than just equipment continuing to operate.

Seismic Properties					
Standard/ Model Code	**Site Specific Rating**	**Site Class (Soil Class)**	**Location in Building (Elevation)**	**Post Disaster Operation**	**Rating/Certification (Shake Testing Requirement)** **Triaxial**
IEEE 693				✓	✓
NEBS				✓	
UBC			✓		
IBC	✓	✓	✓	✓	✓

Figure 14

Conclusion

It is the opinion of the authors that while all the seismic codes and standards discussed have their strengths and weaknesses relative to each other, there is only one that captures the most modern testing and engineering methods while also considering varying site-specific conditions based on scientific research. The International Building Code (IBC) is the only seismic code or standard that considers soil classification and exact location. It is also the only current building code or standard that provides methodology to calculate seismic certification for installations above ground up to top of building.

NEBS considers only location of equipment at ground level making it a more limiting standard and less practical for adoption outside of the major telecom carriers. IEEE 693 also falls short of providing methodology to calculate above ground level installations of non-structural components.

The use of Zoned maps in general makes calculating the correct seismic level required for any given city or area quick and easy but depending on the site-specific conditions, the rack may not be adequate, or it may be potentially over designed for what is required. Studies have found the zone methodology is inadequate especially if the site is located near an active fault. There are also inactive faults that scientist do not know much about due to lack of data (e.g., near New York City).

Along with meeting local and state building codes, specifying IBC Occupancy Category IV for Essential Facilities along with an SDS level that factors in the site conditions will ensure the equipment installed has been triaxial shake tested and designed with the most modern scientific data and best practices. Codes constantly evolve and improve for a reason, and we learn from past events and through scientific research and testing! With that in mind, we will leave you with one final question: What kind of seismic codes or standards are you specifying for your own company or for the customers you serve? There are only two answers. Either you are specifying products with the most modern seismic certifications...or you are not.

Acknowledgement

A sincere thank you to Brett McElhaney, MBA, MS, PE, SE at McElhaney Structural Engineers for his diligent contribution of this paper.

Resources

1. 2019 California Administrative Code, Title 24, Part 1, Chapter 6, Seismic Evaluation Procedures for Hospital Buildings, July 2019
2. American Society of Civil Engineers (ASCE) Minimum Design Loads for Buildings and Other Structures ASCE 7-10
3. AN OVERVIEW OF IEEE 693- – IEEE RECOMMENDED PRACTICE FOR THE SEISMIC DESIGN OF SUBSTATIONS
4. Armstrong, P. & Interwest Consulting Group (2000) 1997 Uniform Building Code to 2006 International Building Code Cross Reference Table. Retrieved from https://www.iccsafe.org/wp-content/uploads/Free%20Codes/Legacy/UBC_IBC_crossref_06.pdf
5. CHAPTER 16 STRUCTURAL DESIGN SECTION 1604.5 2009, Edition IBC Interpretation 11-11
6. Earthquake-Resistant Design Concepts, FEMA P-749 / December 2010
7. Hamburger, R.O. SE, SECB (2016) *Seismic Design Value Maps*. Retrieved from https://www.structuremag.org/?p=9687
8. ICC-ES AC156 Seismic Certification by Shake-Table Testing of Nonstructural Components - Approved October 2010, editorially revised December 2020
9. IEEE 693-05
10. International Building Code 2012
11. International Building Code 2015
12. International Building Code 2018
13. International Codes-Adoption by State (Jan. 2021)
14. Kelly, E. PE. (2020) *A Chronology of Improvements in the Building Code for Seismic Design.* Retrieved from https://www.schoolofpe.com/blog/2020/05/a-chronology-of-improvements-in-building-code-for-seismic-design.html
15. Lorusso, D. (2011) The “Core” of Designing for NEBS Compliance. Retrieved from https://incompliancemag.com/article/the-core-of-designing-for-nebs-compliance/
16. Modern Seismic Codes Make Buildings Safer, Outdoor Safety, 2012
17. National Research Council Canada (2015) National Building Code of Canada 2015. Retrieved from https://nrc.canada.ca

18. NEHRP (n.d.) *National Earthquake Hazards Reduction Program*. Retrieved from https://www.nehrp.gov/library/guidance_new.htm
19. NEHRP (n.d.) *Design & Construction* https://www.nehrp.gov/library/guidance_new.htm
20. NEHRP (n.d.) *New Buildings* https://www.nehrp.gov/library/guidance_new.htm
21. NEBS GR-63-CORE Issue 4
22. USGS (n.d.) *Earthquake Glossary*. Retrieved from https://earthquake.usgs.gov/learn/glossary/?term=richter%20scale1.
23. Siemens (n.d.) Seismic Compliance Review: Low Voltage Power Distribution. Retrieved from https://s3.amazonaws.com/dcc-data-extract/new-delta/asset/Compas/daily/Compas/2019-10-30/Selection%20Application%20Guide/ANSI_LV_MCC_LVTM-LVSEI-0416_V2.pdf
24. Seismic Building Code Provisions for New Buildings to Create Safer Communities, October, 2020
25. Speight, M. & Speight, F. P.C. (n.d.) *Occupancy Category and Importance Factor*. Virginia Beach, VA, Bulletin No XXXIV. Retrieved from https://www.smandf.com/application/files/1914/9978/5746/34.pdf
26. The Relationship of Seismic Hazard and Building Codes in Supercities, Chu, Long, Bercovici, 2019