Seismic Design Updates for the California Building Code

Dave Baska PhD, PE, GE, CEG
August 2019
Effective January 1, 2020

All applications for a building permit submitted on or after January 1, 2020 are subject to compliance to the 2019 CBC.
Outline

- Ground motions
- Ground displacements
- Future issues
Outline

- Ground motions
- Ground displacements
- Future issues
UBC End Result

![Graph showing spectral acceleration versus period for design response spectra.]

**CONTROL PERIODS**
- $T_0 = C_s/2.5C_a$
- $T_0 = 0.2T_a$

**Figure 16-3—Design Response Spectra**
Computing Response Spectra

![Diagram showing acceleration response spectrum and ground accelerogram.](image)

Figure 1  Acceleration Response spectrum
New Site-Specific Ground Motion Requirements of ASCE 7-16

Charles A. Kircher, Ph.D., P.E.
Kircher & Associates
Palo Alto, California

2017 Structural Engineering Summit – Washington, D.C.
New Site-Specific Ground Motion Requirements of ASCE 7-16

Charles A. Kircher, Ph.D, P.E.
Kircher & Associates
Palo Alto, California
Seismic Code Development Process

- 2015 NEHRP Recommended Provisions
  - Building Seismic Safety Council (BSSC) for the Federal Emergency Management Agency (FEMA)
  - Provisions Update Committee (PUC)

- ASCE 7-16 - Minimum Design Loads on Buildings and Other Structures
  - Structural Engineering Institute (SEI) of the American Society of Civil Engineers (ASCE)
    - ASCE 7 Seismic Subcommittee (SSC)

- 2018 International Building Code (IBC)
  - International Code Council, Codes and Standards
    - IBC Structural Committee
IEHRP Recommended Provisions for Seismic Safety Council (BSSC) for the Federal Agency Management Agency (FEMA)

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- 2018 International Building Code (IBC)
  - International Code Council, Codes and Standards Council Structural Committee
Summary of New ASCE 7-16 Ground Motions

What’s New (or Changed)?
- **Site Class Coefficients**
  - Tables 11.4-1 and 11.4-2

What’s Not New?
- **Site Classification**
  - Section 11.4.3 (Table 20.3-1)
New Values of the Site Coefficient, $F_a$ (Table 11.4-1 of ASCE7-16) (shown as proposed changes to ASCE 7-10)

**Table 11.4-1 Site Coefficient, $F_a$**

<table>
<thead>
<tr>
<th>Site Class</th>
<th>$S_S \leq 0.25$</th>
<th>$S_S = 0.5$</th>
<th>$S_S = 0.7$</th>
<th>$S_S = 1.0$</th>
<th>$S_S = 1.25$</th>
<th>$S_S \geq 1.5$</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.8</td>
<td>0.8</td>
<td>0.8</td>
<td>0.8</td>
<td>0.8</td>
<td>0.8</td>
</tr>
<tr>
<td>B</td>
<td>1.9 0.9</td>
<td>1.9 0.9</td>
<td>1.9 0.9</td>
<td>1.9 0.9</td>
<td>1.9 0.9</td>
<td>0.9</td>
</tr>
<tr>
<td>C</td>
<td>4.2 1.3</td>
<td>4.2 1.3</td>
<td>4.4 1.2</td>
<td>4.9 1.2</td>
<td>4.9 1.2</td>
<td>1.2</td>
</tr>
<tr>
<td>D</td>
<td>1.6</td>
<td>1.4</td>
<td>1.2</td>
<td>1.1</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>E</td>
<td>2.5 2.4</td>
<td>1.7</td>
<td>4.2 1.3</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: Use straight-line interpolation for intermediate values of $S_S$. **At the Site Class B-C boundary, $F_a = 1.0$ for all $S_S$ levels. If site classes A or B is established without the use of on-site geophysical measurements of shear wave velocity, use $F_a = 1.0$.**

Note – Site Class B is no longer the “reference” site class of MCE$_R$ ground motion parameters $S_S$ and $S_1$ (i.e., new coefficients reflect Site Class BC boundary of 2,500 f/s) and Site Class D is no longer the “default” site class (when Site Class C amplification is greater, i.e., $S_S \geq 1.0$).

**Note – Site-Specific analysis required for Site Class E sites where $S_S \geq 1.0$ w/exception**
New Values of the Site Coefficient, $F_v$ (Table 11.4-2 of ASCE7-16) (shown as proposed changes to ASCE 7-10)

Table 11.4-2 Site Coefficient, $F_v$

<table>
<thead>
<tr>
<th>Site Class</th>
<th>$S_f \leq 0.1$</th>
<th>$S_f = 0.2$</th>
<th>$S_f = 0.3$</th>
<th>$S_f = 0.4$</th>
<th>$S_f = 0.5$</th>
<th>$S_f \geq 0.6$</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.8</td>
<td>0.8</td>
<td>0.8</td>
<td>0.8</td>
<td>0.8</td>
<td>0.8</td>
</tr>
<tr>
<td>B</td>
<td>4.9 0.8</td>
<td>4.9 0.8</td>
<td>4.9 0.8</td>
<td>4.9 0.8</td>
<td>4.9 0.8</td>
<td>0.8</td>
</tr>
<tr>
<td>C</td>
<td>4.7 1.5</td>
<td>4.6 1.5</td>
<td>1.5</td>
<td>4.4 1.5</td>
<td>4.3 1.5</td>
<td>1.4</td>
</tr>
<tr>
<td>D</td>
<td>2.4</td>
<td>2.0 2.2</td>
<td>4.8 2.0</td>
<td>4.6 1.9</td>
<td>4.5 1.8</td>
<td>1.7</td>
</tr>
<tr>
<td>E</td>
<td>3.5 4.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>See Section 11.4.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: Use straight-line interpolation for intermediate values of $S_f$. At the Site Class B-C boundary, $F_v = 1.0$ for all $S_f$ levels. If site classes A or B are established without the use of on-site geophysical measurements of shear wave velocity, use $F_v = 1.0$.

Note – Site Class B is no longer the “reference” site class of $MCE_R$ ground motion parameters $S_s$ and $S_f$ (i.e., new coefficients reflect Site Class BC boundary of 2,500 f/s).

Note - Site-Specific analysis required for Site Class D sites where $S_f \geq 0.2$ w/exceptions

Site-Specific analysis required for Site Class E sites where $S_f \geq 0.2$ w/o exception
Summary of New ASCE 7-16 Ground Motions

What’s New (or Changed)?

• Site Class Coefficients
  – Tables 11.4-1 and 11.4-2

• Ground Motion Parameter Values
  – $MCE_R$ Ground Motion Maps, Section 11.4.2 (Chapter 22)

What’s Not New?

• Site Classification
  – Section 11.4.3 (Table 20.3-1)

• Ground Motion Parameter Definitions and Formulas
  – Sections 11.4.4 and 11.4.5

• Design Response Spectrum
  – Figure 11.4-1 (Section 11.4.6)
Update worldwide database

NGA-West2 database includes over 21,000 three-component recordings...
(over 63,000 records)

From NGA-West1 to NGA-West2 the size of database was increased by a factor of 6
Summary of New ASCE 7-16 Ground Motions

What’s New (or Changed)?

- **Site Class Coefficients**
  - Tables 11.4-1 and 11.4-2
- **Ground Motion Parameter Values**
  - $MCE_R$ Ground Motion Maps, Section 11.4.2 (Chapter 22)
- **Site-Specific Procedures**
  - Section 11.4.8
  - Sections 21.4, 21.2.3, 21.3

What’s Not New?

- **Site Classification**
  - Section 11.4.3 (Table 20.3-1)
- **Ground Motion Parameter Definitions and Formulas**
  - Sections 11.4.4 and 11.4.5
- **Design Response Spectrum**
  - Figure 11.4-1 (Section 11.4.6)
- **Probabilistic and Deterministic $MCE_R$ Definitions and Methods**
  - Section 21.2 (except 21.2.3)
Standard 7-16

Minimum Design Loads and Associated Criteria
for Buildings and Other Structures

SUPPLEMENT 1

Effective: December 12, 2018

This document contains CHANGES to the above title, which is posted on the ASCE Library at
https://doi.org/10.1061/9780784414248

THREE AND SIZE FONT INDICATES DIRECTIVE TEXT THAT IS NOT PART OF THE TITLE. CHANGES ARE
INDICATED USING HIGHLIGHTED, STRIKE-OUT, AND UNDERLINED TEXT. A HORIZONTAL RULE INDICATES
A BREAK BETWEEN CHAPTERS.

Chapter 6

SECTION 6.6.1 AS FOLLOWS:

6.6.1 Maximum Inundation Depth and Flow Velocities Based on Runup.

The maximum inundation depths and flow velocities associated with the stages of tsunami
flooding shall be determined in accordance with Section 6.6.2. Calculated flow velocity shall not
be taken as less than 10 ft/s (3.0 m/s) and need not be taken as greater than the lesser of
1.5(gh_w) 1/2 and 50 ft/s (15.2 m/s).

Where the maximum topographic elevation along the topographic transect between the shoreline
and the inundation limit is greater than the runup elevation, one of the following methods shall be used:

1. The site-specific procedure of Section 6.7.6 shall be used to determine inundation depth
and flow velocities at the site, subject to the above range of calculated velocities.
Summary of New ASCE 7-16 Ground Motions

What’s New (or Changed)?

- **Site Class Coefficients**
  - Tables 11.4-1 and 11.4-2
- **Ground Motion Parameter Values**
  - $MCE_R$ Ground Motion Maps, Section 11.4.2 (Chapter 22)
- **Site-Specific Procedures**
  - Section 11.4.8
  - Sections 21.4, 21.2.3, 21.3
- **Vertical Ground Motions**
  - Section 11.9

What’s Not New?

- **Site Classification**
  - Section 11.4.3 (Table 20.3-1)
- **Ground Motion Parameter Definitions and Formulas**
  - Sections 11.4.4 and 11.4.5
- **Design Response Spectrum**
  - Figure 11.4-1 (Section 11.4.6)
- **Probabilistic and Deterministic $MCE_R$ Definitions and Methods**
  - Section 21.2 (except 21.2.3)
Summary of New ASCE 7-16 Ground Motions

What’s New (or Changed)?

- **Site Class Coefficients**
  - Tables 11.4-1 and 11.4-2
- **Ground Motion Parameter Values**
  - $MCE_R$ Ground Motion Maps, Section 11.4.2 (Chapter 22)
- **Site-Specific Procedures**
  - Section 11.4.8
  - Sections 21.4, 21.2.3, 21.3
- **Vertical Ground Motions**
  - Section 11.9
- **Nonlinear RHA Ground Motions**
  - Section 16.2
  - Section 11.4.1 (Near-Fault)

What’s Not New?

- **Site Classification**
  - Section 11.4.3 (Table 20.3-1)
- **Ground Motion Parameter Definitions and Formulas**
  - Sections 11.4.4 and 11.4.5
- **Design Response Spectrum**
  - Figure 11.4-1 (Section 11.4.6)
- **Probabilistic and Deterministic $MCE_R$ Definitions and Methods**
  - Section 21.2 (except 21.2.3)
- **Nonlinear RHA Ground Motions (Isolation/Damping Systems)**
  - Section 17.3 and Section 18.2.2
The “Problem”
The “Problem” with ELF (MRSA) Methods

- Use of only two response periods (0.2s and 1.0s) to define ELF (and MRSA) design forces is not sufficient, in general, to accurately represent response spectral acceleration for all design periods of interest

  - **Reasonably Accurate (or Conservative)** – When peak $MCE_R$ response spectral acceleration occurs at or near 0.2s and peak $MCE_R$ response spectral velocity occurs at or near 1.0s for the site of interest

  - **Potentially Non-conservative** – When peak $MCE_R$ response spectral velocity occurs at periods greater than 1.0s for the site of interest
The “Problem” with ELF (MRSA) Methods

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  - **Reasonably Accurate (or Conservative)** – When peak $\text{MCE}_R$ response spectral acceleration occurs at or near 0.2s and peak $\text{MCE}_R$ response spectral velocity occurs at or near 1.0s for the site of interest

  - **Potentially Non-conservative** – When peak $\text{MCE}_R$ response spectral velocity occurs at periods greater than 1.0s for the site of interest

- Softer soil sites whose seismic hazard is dominated by large magnitude events
FIGURE C11.4-3 Comparison of ELF and Multiperiod Design Spectra—Site Class C Ground Motions ($V_s/V_{s30} = 1,600$ ft/s)
FIGURE C11.4-4 Comparison of ELF and Multiperiod Design Spectra—Site Class D Ground Motions ($V_{s30} = 870$ ft/s)
FIGURE C11.4-5 Comparison of ELF and Multiperiod Design Spectra—Site Class E Ground Motions ($V_s \sqrt{V_{s30}} = 510$ ft/s)
Figure 8.12  Average normalized response spectra (5% damping) for different local site conditions. (After Seed et al., 1976.)
Long-Term Solution (*Project 17/ASCE 7-22*)

- Develop and adopt multi-period design spectrum approach
  - Not feasible in the code cycle of ASCE 7-16
- Multi-period spectrum approach will require:
  - Reworking of seismic design requirements and criteria now based on two response periods
  - Development of new ground motion design parameters (by the USGS) for each new response period of interest
  - Development of new site factors for each new response period of interest (or embed site effects directly in ground motion design values)
Interim Solution (ASCE 7-16)

- Require site-specific analysis when site factors (alone) are not sufficiently conservative
- Provide exceptions to site-specific requirements that allow designers the option to design for conservative forces in lieu of performing a site-specific analysis
Conterminous United States Regions with $S_1 \geq 0.2g$
Outline

- Ground motions
- **Ground displacements**
- Future codes
## Table 12.13-2 Upper Limit on Lateral Spreading Horizontal Ground Displacement for Shallow Foundations Beyond Which Deep Foundations Are Required

<table>
<thead>
<tr>
<th>Risk Category</th>
<th>I or II</th>
<th>III</th>
<th>IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limit (in. (mm))</td>
<td>18 (455)</td>
<td>12 (305)</td>
<td>4 (100)</td>
</tr>
</tbody>
</table>
Lateral Spread Threshold

- LA County (Youd 1989): 12 inches
- ASCE 7-16: 4, 12 and 18 inches (RC IV, III, and II)
<table>
<thead>
<tr>
<th>Structure Type</th>
<th>I or II</th>
<th>III</th>
<th>IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single-story structures with concrete or masonry wall systems</td>
<td>0.0075$L$</td>
<td>0.005$L$</td>
<td>0.002$L$</td>
</tr>
<tr>
<td>Other single-story structures</td>
<td>0.015$L$</td>
<td>0.010$L$</td>
<td>0.002$L$</td>
</tr>
<tr>
<td>Multistory structures with concrete or masonry wall systems</td>
<td>0.005$L$</td>
<td>0.003$L$</td>
<td>0.002$L$</td>
</tr>
<tr>
<td>Other multistory structures</td>
<td>0.010$L$</td>
<td>0.006$L$</td>
<td>0.002$L$</td>
</tr>
</tbody>
</table>
Differential Settlement Threshold

- **LA County (Youd 1989):** 1 inch over 30 feet (4 inches of total settlement)
- **OSHPD/DSA:** L/600
- **ASCE 7-16:** 2-1/2 to 3 inches over 30 to 50 feet (RC II and III)
ASCE 7-16 Summary

- Requires site-specific ground motion study for more projects (Chapter 11)
- Site-specific procedures are enhanced (Chapter 21)
- Provides threshold values of post-liquefaction displacement for shallow foundations (Chapter 12)
Outline

- Ground motions
- Ground displacements
- Future issues
Future Issues

- Multi-period design spectrum (ASCE 7-22)
- Performance of existing, vulnerable buildings
- Performance-based design
- Not life safety, but continued function for new buildings
Existing Vulnerable Buildings

- **Before 1976 UBC:**
  - Unreinforced masonry
  - Nonductile concrete buildings
  - Soft or weak ground floor level

- **Before 1998 CBC (1997 UBC):**
  - Steel moment frame connections
  - Precast, prestressed or post-tensioned concrete
Performance-Based Design
Continued Function

- Resilient communities
  - Occupiable buildings, including limited non-structural damage
  - Lifeline infrastructure
- As much a social and economic matter as it is a technical one
site response. The survey respondents provided a wide range of answers on a number of key issues in site response analysis, including input motion, material properties, analysis procedures, and use of results. The responses illustrate the lack of consensus and the need to develop guidance on these important issues.

A Synthesis of Highway Practice
TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES