Changes in Seismic Design Requirements from ASCE 7-16 to ASCE 7-22

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ABSTRACT

There are highly significant changes in the seismic design provisions from ASCE 7-16 to ASCE 7-22. The most important changes are six in number. These are enumerated and discussed in this report. The consequences of the changes are also discussed. In the case of two of the changes, some modifications to ASCE 7-22 appear to be necessary. The modifications have been proposed as code changes intended for inclusion in the 2027 IBC. The substance of the proposed code changes is included here.

1. SEISMIC DESIGN OF ASCE 7-16

To understand the differences in seismic design from ASCE 7-16 to ASCE 7-22, it is necessary to start with the seismic design of ASCE 7-16.

The first step in that design is to determine the mapped MCE_R, 5%- damped, spectral response acceleration parameter at short periods (more specifically, at a period of 0.2 s), S_S, and the mapped MCE_R, 5%- damped spectral response acceleration parameter at a period of 1.0 s [referred to as intermediate period in this paper], S_1, at the Site Class B-C interface, at the site of the structure. S_S and S_1 are obtainable from the ASCE Hazard Tool (https://ascehazardtool.org/).

The second step is to determine the site class at the site of the structure. There are six site classes: A, B, C, D, E, and F. The distinctions among the site classes are based on the measured properties of the soils at the site over the top 100 ft of the site (Table 1). While shear wave velocity is the preferred property to be measured, site class can also be based on blow count or standard penetration resistance for cohesionless soils or undrained shear strength for cohesive soils. It is understood that there is no equivalency. If, based on shear wave velocity, the site class is D for a particular site, based on blow count, the site class for the same site may very well be C. In the absence of measured properties over the top 100 ft of the site, the default site class is D (with short-period site coefficient, $F_a \geq 1.2$), "unless the authority having jurisdiction or geotechnical data determine that Site Class E or F soils are present at the site."

Table 1. Site Classification of ASCE 7-16

Site Class	$\bar{v}_s$	$\bar{N}$ or $\bar{N}_{ch}$	$\bar{s}_u$
A. Hard rock	> 5,000 ft/s	NA	NA
B. Rock	2,500 to 5,000 ft/s	NA	NA
C. Very dense soil and soft rock	1,200 to 2,500 ft/s	> 50 blows/ft	> 2,000 lb/ft^2
D. Stiff soil	600 to 1,200 ft/s	15 to 50 blows/ft	1,000 to 2,000 lb/ft^2
E. Soft clay soil	< 600 ft/s	< 15 blows/ft	< 1,000 lb/ft^2
	Any profile with more than 10 ft of soil that has the following characteristics: — Plasticity index PI > 20, — Moisture content $w \geq 40\%$, — Undrained shear strength $\bar{s}_u < 500$ lb/ft^2		
F. Soils requiring site response analysis in accordance with Section 21.1	See Section 20.3.1		

The short- and intermediate-period mapped quantities, S_S and S_1, respectively, have to be amplified by a short-period site coefficient F_a and an intermediate-period site coefficient F_v, respectively, to obtain S_{MS} and S_{M1}:

$$S_{MS} = F_a S_S \quad (1)$$

$$S_{M1} = F_v S_1 \quad (2)$$

S_{MS} = MCE$_R$, 5%- damped, spectral response acceleration parameter at a period of 0.2 s, adjusted for site class effects, and

S_{M1} = MCE$_R$, 5%- damped, spectral response acceleration parameter at a period of 1.0 s, adjusted for site class effects.

F_a and F_v are given in ASCE 7-16 Tables 11.4-1 and 11.4-2, respectively. These tables are modified in Supplement No. 3 to ASCE 7-16. Design is based on:

$$S_{DS} = (2/3)S_{MS} \quad (3)$$

$$S_{D1} = (2/3)S_{M1} \quad (4)$$

S_{DS} = design, 5%- damped, spectral response acceleration parameter at a period of 0.2 s, adjusted for site class effects and

S_{D1} = design, 5%- damped, spectral response acceleration parameter at a period of 1.0 s, adjusted for site class effects.

In Eqs. (3) and (4), (2/3) =1/1.5. Based on a number of surveys 1.5 is accepted as the lower-bound margin of safety built into structures designed by the modern seismic code, which, by common acknowledgment, dates back to the 1973 *Uniform Building Code* (UBC). If all structures are designed for (2/3) of MCE$_R$ ground motion, then the built-in margin of safety of

1.5 would ensure that such structures will, at the very least, barely avoid collapse when subjected to MCE_R shaking. Thus, the performance objective underlying the seismic design of ASCE 7 is prevention of collapse under MCE_R-level ground motions.

S_{DS}, S_{D1}, and T_L define the design response spectrum in ASCE 7 Fig. 11.4-1, reproduced here as Figure 1. The long-period transition period T_L is given in ASCE 7 Fig. 22-14 for the conterminous United States.

The design response spectrum of Figure 1 is typically referred to as the two-period spectrum, because it is defined by spectral ordinates at two different periods: 0.2 s and 1.0 s. The design base shear of the Equivalent Lateral Force procedure is obtained from this spectrum, as modified by ASCE 7 (Figure 2).

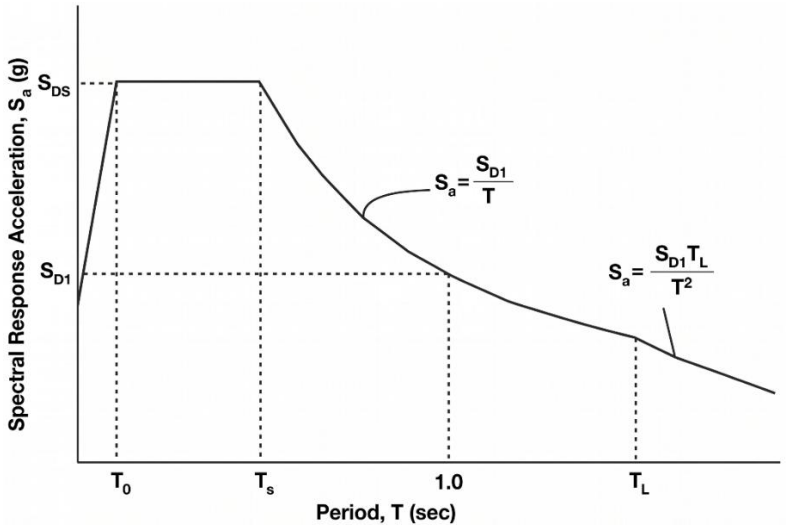


Figure 1. ASCE 7 Figure 11.4-1 – Design Response Spectrum

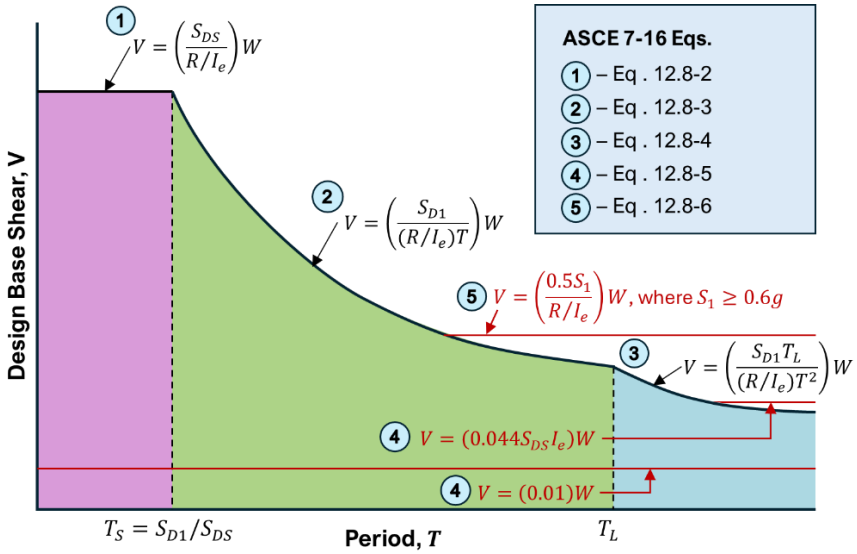


Figure 2. ASCE 7 Design Response Spectrum Modified for the Equivalent Lateral Force Procedure

2. SEISMIC DESIGN OF ASCE 7-22

The major changes in seismic design from ASCE 7-16 to ASCE 7-22 are enumerated here.

2.1. Change No. 1

S_S and S_1 are not the starting point of seismic design anymore. S_S and S_1 are still obtainable from the ASCE Hazard Tool because a number of requirements of ASCE 7 are triggered when S_S or S_1 equals and/or exceeds certain threshold values. For instance, Seismic Design Categories E and F are triggered when $S_1 \geq 0.75$.

2.2. Change No. 2

There are now three additional site classes: BC, CD, and DE, for a total of nine. Site classes in ASCE 7-22 are defined in terms of the average shear wave velocity of the 100-ft long soil profile. Where measured shear wave velocity data are not available, Section 20.3 of ASCE 7-22 permits shear wave velocity to be estimated using correlations with other site-specific geotechnical parameters, including SPT (standard penetration test) blow counts, undrained shear strength, overburden pressure, void ratio, or CPT (cone penetration test) tip resistance. The use of such correlations is subject to the additional requirements of Section 20.3.

Table 2. Site Classification of ASCE 7-22

Site Class	$\bar{v}_s$ Calculated Using Measured or Estimated Shear Wave Velocity Profile
A. Hard rock	> 5,000 ft/s
B. Rock	3,000 to 5,000 ft/s
BC. Soft Rock	2,100 to 3,000 ft/s
C. Very dense sand or Hard clay	1,450 to 2,100 ft/s
CD. Dense sand or Very stiff clay	1,000 to 1,450 ft/s
D. Medium dense sand or Stiff clay	700 to 1,000 ft/s
DE. Loose sand or Medium stiff clay	500 to 700 ft/s
E. Very loose sand or Soft clay	< 500 ft/s
F. Soils requiring site response analysis in accordance with Section 21.1	See Section 20.3.1

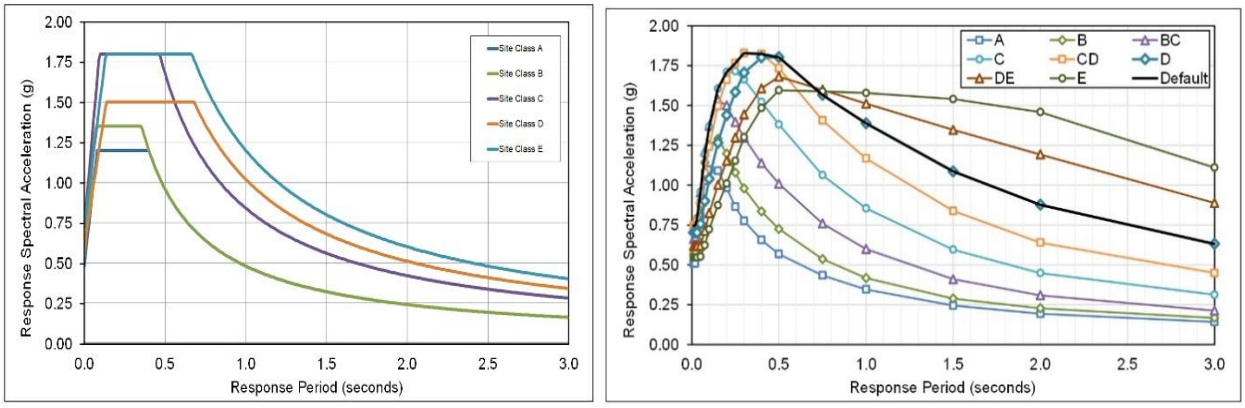
ASCE 7-22 Section 11.4.2.1 states the following concerning default site conditions: **"**Where the soil properties are not known in sufficient detail to determine the site class, risk-targeted maximum considered earthquake (MCE_R) spectral response accelerations shall be based on the most critical spectral response acceleration at each period of Site Class C, Site Class CD, and Site Class D, unless the Authority Having Jurisdiction determines, based on geotechnical data, that Site Class DE, E, or F soils are present at the site."

2.3. Change No. 3

ASCE 7-22 has introduced multi-period design response spectra defined at 22, rather than just two, different periods for its eight site classes (Site Class F requires a site-specific spectrum and is, therefore, not included). Two-period spectra can be derived from these multi-period spectra, if desired.

Equations (3) and (4) are still valid. Multi-period design as well as MCE_R response spectra are directly obtainable from the ASCE Hazard Tool.

Representative two-period design response spectra of ASCE 7-16 for different site classes are shown in Figure 3a. Representative multi-period design response spectra of ASCE 7-22 for different site classes are shown in Figure 3b. The criss-crossing of the spectra in Figure 3b is significant and should be noted. The site class that results in the largest spectral response accelerations at long periods may very well result in the smallest spectral response accelerations at short periods.



(a) (b)

Figure 3. (a) Representative two-period design response spectra of ASCE 7-16 for different site classes; (b) Representative multi-period design response spectra of ASCE 7-22 for different site classes.

2.4. Change No. 4

There are no site coefficients F_a and F_v anymore. The multi-period spectra of ASCE 7-22 are already soil-modified. There are built-in or implicit site coefficients that vary with period. It is possible to back-calculate these implicit site coefficients for different building periods. At a particular period, the implicit F_a for a particular site class is the S_{MS} for that site class, divided by S_{MS} for Site Class BC. Similarly, at a particular period, the implicit F_v for a particular site class is the S_{M1} for that site class, divided by S_{M1} for Site Class BC. Note that these implicit coefficients are not code-defined quantities but are introduced here solely to aid comparison with ASCE 7-16.

Short-Period Site Coefficients

Implicit F_a-values of ASCE 7-22 and F_a-values of ASCE 7-16 for multiple cities in the Western United States (WUS) are plotted in Figures 4a and 4b, respectively. Similar plots for multiple Central and Eastern United States (CEUS) cities are presented in Figs. 5a and 5b, respectively. Site Classes CD and DE are not included, to avoid clutter. F_{a22} (implicit F_a of ASE 7-22) for Site Class BC is 1; there is very little point in showing it.

Site Classes A, B, and C show increasing amplification of ground motion, as is to be expected. Site Classes D and E show big spikes in amplification in various cities. Quite often, the plot for Site Class E dips below the plot for Site Class D.

The ASCE 7-16 plots are as expected, in the sense that softer soils result in higher amplifications of ground motion. The only anomaly, if it can be called that, is that for locations in Western United States, Site Class D produces lower amplification than Site Class C. The plots are consistent with the values of F_a in ASCE 7-16 Table 11.4-1.

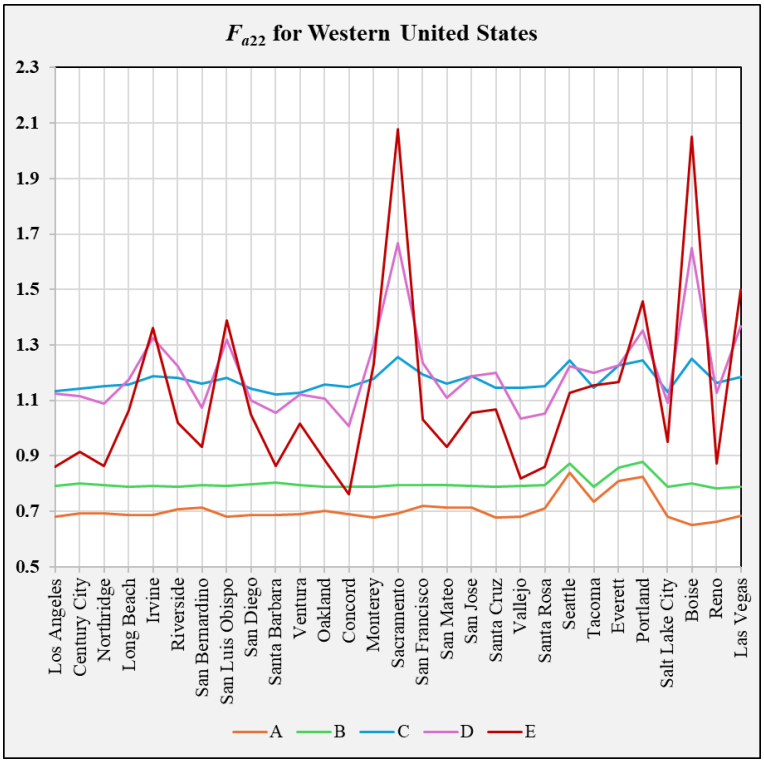


Figure 4a. Implicit F_a-values of ASCE 7-22 for multiple WUS cities