Chapter 3

GROUND MOTION

3.1 GENERAL

3.1.1 Scope. All structures shall be designed for the earthquake ground motions prescribed in this chapter. If the alternate design procedure of Alternative Simplified Chapter 4 is used, the values of F_a, S_{MS}, and S_{DS} shall be as determined in that Alternate Chapter, and values for F_v, S_{M1}, and S_{D1} need not be determined.

3.1.2 References. The following documents shall be used as specified in this chapter.

ASTM D 1586 *Standard Test Method for Penetration Test and Split-barrel Sampling of Soils* (D 1586-99), American Society for Testing and Materials, 2003.

ASTM D 2166 *Standard Test Method for Unconfined Compressive Strength of Cohesive Soil* (D 2166-00), American Society for Testing and Materials, 2003.

ASTM D 2216 *Standard Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass* (D 2216-98), American Society for Testing and Materials, 2003.

ASTM D 2850 *Standard Test Method for Unconsolidated-Undrained Triaxial Compression Test on Cohesive Soils in* (D 2850-03), American Society for Testing and Materials, 2003.

ASTM D 4318 *Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils* (D 4318-00), American Society for Testing and Materials, 2003.

3.1.3 Definitions

Active fault: A fault for which there is an average historic slip rate of 1 mm per year or more and geographic evidence of seismic activity within Holocene times (past 11,000 years).

Characteristic earthquake: An earthquake assessed for an active fault having a magnitude equal to the best-estimate of the maximum magnitude capable of occurring on the fault, but not less than the largest magnitude that has occurred historically on the fault.

Design earthquake ground motion: See Sec. 1.1.4.

Maximum considered earthquake ground motion: The most severe earthquake effects considered by these *Provisions* as defined in this chapter.

Seismic Design Category: See Sec. 1.1.4.

Site Class: A classification assigned to a site based on the types of soils present and their properties as defined in Sec. 3.5.1.

Site coefficients: The values of F_a and F_v indicated in Tables 3.3-1 and 3.3-2, respectively.

Structure: See Sec. 1.1.4.

3.1.4 Notation

d_c The total thickness of cohesive soil layers in the top 100 ft (30 m); see Sec. 3.5.1.

d_i The thickness of any soil or rock layer i (between 0 and 100 ft [30 m]); see Sec. 3.5.1.

d_s The total thickness of cohesionless soil layers in the top 100 ft (30 m); see Sec. 3.5.1.

F_a Short-period site coefficient (at 0.2 sec period); see Sec. 3.3.2.

F_v Long-period site coefficient (at 1.0 second period); see Sec. 3.3.2.

H Thickness of soil.

N Standard penetration resistance, ASTM D1586-99.

N_i Standard penetration resistance of any soil or rock layer *i* (between 0 and 100 ft (30m); see Sec.3.5.1.

$\overline{N}$ Average standard penetration resistance for the top 100 ft (30 m); see Sec. 3.5.1.

$\overline{N}_{ch}$ Average standard penetration resistance of cohesionless soil layers for the top 100 ft (30 m); see Sec. 3.5.1.

PI Plasticity index, ASTM D4318.

S_1 The mapped, maximum considered earthquake, 5-percent-damped, spectral response acceleration parameter at a period of one second as determined in Sec. 3.3.1.

S_a The design spectral response acceleration at any period as defined in this chapter.

S_{aM} The maximum considered earthquake spectral response acceleration at any period as defined in this chapter.

S_{D1} The design, 5-percent-damped, spectral response acceleration parameter at a period of one second as defined in Sec. 3.3.3.

S_{DS} The design, 5-percent-damped, spectral response acceleration parameter at short periods as defined in Sec. 3.3.3.

S_{M1} The maximum considered earthquake, 5-percent-damped, spectral response acceleration parameter at a period of one second adjusted for site class effects as defined in Sec. 3.3.2.

S_{MS} The maximum considered earthquake, 5-percent-damped, spectral response acceleration parameter at short periods adjusted for site class effects as defined in Sec. 3.3.2.

S_S The mapped, maximum considered earthquake, 5-percent-damped, spectral response acceleration parameter at short periods as determined in Sec. 3.3.1.

s_u Undrained shear strength, ASTM D2166 or ASTM D2850.

s_{ui} Undrained shear strength of any cohesive soil layer *i* (between 0 and 100 ft (30 m); see Sec. 3.5.1.

$\overline{s}_u$ Average undrained shear strength in top 100 ft. (30 m); see Sec. 3.5.1.

T See Sec. 4.1.4.

T_0 $0.2S_{D1}/S_{DS}$

T_L Long-period transition period as defined in Sec. 3.3.4.

T_S S_{DI}/S_{DS}.

v_s The shear wave velocity at small shear strains (equal to 10-3 percent strain or less).

v_{si} The shear wave velocity of any soil or rock layer *i* (between 0 and 100 ft (30m); see Sec. 3.5.1.

$\overline{v}_s$ The average shear wave velocity at small shear strains in the top 100 ft (30 m); see Sec. 3.5.1.

w Moisture content (in percent), ASTM D2216.

3.2 GENERAL REQUIREMENTS

As used in these *Provisions*, spectral acceleration parameters are coefficients corresponding to spectral accelerations in terms of *g*, the acceleration due to gravity.

3.2.1 Site Class. For all structures, the site shall be classified in accordance with Sec. 3.5.

3.2.2 Procedure selection

Ground motions, represented by response spectra and parameters associated with those spectra, shall be determined in accordance with the general procedure of Sec. 3.3 or the site-specific procedure of Sec. 3.4. Ground motions for structures on class F sites and for seismically isolated structures on sites with S_1 greater than 0.6 shall be determined using the site-specific procedure of Sec. 3.4.

3.3 GENERAL PROCEDURE

3.3.1 Mapped acceleration parameters. The parameters S_S and S_1 shall be determined from the respective 0.2 sec and 1.0 sec spectral response accelerations shown on Figures 3.3-1 through Figures 3.3-14.

3.3.2 Site coefficients and adjusted acceleration parameters. The maximum considered earthquake (MCE) spectral response acceleration parameters S_{MS} and S_{M1}, adjusted for site class effects, shall be determined using Eq. 3.3-1 and 3.3-2, respectively:

$$S_{MS} = F_a S_S \tag{3.3-1}$$

and

$$S_{M1} = F_v S_1 \tag{3.3-2}$$

where *Fa* and *Fv* are defined in Tables 3.3-1 and 3.3-2, respectively.

Table 3.3-1 Values of Site Coefficient F_a

Site Class	Mapped MCE Spectral Response Acceleration Parameter at 0.2 Second Period [a]				
	$S_S \leq$ 0.25	S_S = 0.50	S_S = 0.75	S_S = 1.00	$S_S \geq$ 1.25
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.2	1.2	1.1	1.0	1.0
D	1.6	1.4	1.2	1.1	1.0
E	2.5	1.7	1.2	0.9	0.9
F	[b]	[b]	[b]	[b]	[b]

[a] Use straight line interpolation for intermediate values of S_S.
[b] Site-specific geotechnical investigation and dynamic site response analyses shall be performed.