Design Example 3
Site-specific Ground Motion Procedures §11.4.7

Per Section 11.4.7, a site-specific response spectrum may be derived for any structure based on the procedures set forth in Chapter 21. The site-specific ground motion procedures of Chapter 21 are required for the following cases:

- Structures on Site Class F sites, unless the exception to Section 20.3.1 is applicable;
- Seismically isolated structures and for structures with damping systems on sites with S_1 greater than or equal to 0.6.

This example illustrates the general procedure for deriving the site-specific design response spectrum based on a given site-specific response spectrum determined based on analysis per Sections 21.1 and 21.2.

PROBLEM STATEMENT

The following site-specific response spectra have been provided by an official report in accordance with Section 21.1 or Section 21.2, and the mapped response acceleration parameters S_S and S_1 have been provided according to USGS. The response acceleration parameters S_S and S_1 may either be derived using Figures 22-1 through 22-6 or the USGS website (earthquake.usgs.gov/designmaps/us/application.php):

Site Class = D, T_L = 12 sec

S_S = 1.500g (USGS), S_1 = 0.623g (USGS)

F_a = 1.0 (per Table 11.4-1), F_v = 1.5 (per Table 11.4-2)

$S_{MS} = S_S F_a$ = 1.500g(1.0) = 1.500g (per Section 11.4.3, Eq 11.4-1)

$S_{M1} = S_1 F_v$ = 0.623g(1.5) = 0.935g (per Section 11.4.3, Eq 11.4-2)

$S_{DS} = (2/3)S_{MS}$ = (2/3)1.500g = 1.00g (per Section 11.4.4, Eq 11.4-3)

$S_{D1} = (2/3)S_{M1}$ = (2/3)0.935g = 0.623g (per Section 11.4.4, Eq 11.4-4)

Site-specific response spectra from official report:

Period (Seconds)	Site-specific MCE_R Response Spectrum, S_{aM} (g)	DBE Response Spectrum, $S_a = 2/3S_{aM}$ (g)
0.00	0.452	0.301
0.03	0.711	0.474
0.07	1.083	0.722
0.10	1.301	0.867
0.20	1.402	0.935
0.30	1.390	0.927
0.50	1.210	0.807
1.00	0.554	0.369
1.50	0.322	0.215
2.00	0.212	0.141
3.00	0.113	0.075
4.00	0.085	0.057

DETERMINE THE FOLLOWING:

1. Design response spectrum per Section 11.4.5 (using map-based acceleration parameters).
2. Scaled site-specific design response spectrum per Section 21.3.
3. Design spectral response acceleration parameters S_{DS}, $S_{D1,}$ S_{MS}, and S_{M1} per Section 21.4.

1. Design Response Spectrum Per Section 11.4.5 (Using Map-Based Acceleration Parameters)

$S_{DS} = 1.00g$
$S_{D1} = 0.623g$

$T_0 = 0.2\ S_{D1}/S_{DS}$
$T_0 = 0.2(0.623g)/(1.00g) = 0.125$ sec

$T_S = S_{D1}/S_{DS}$
$T_S = (0.623g)/(1.00g) = 0.623$ sec

$T_L = 12$ sec (given above)

For $T < T_0$:

$$S_a = S_{DS}\,(0.4 + 0.6T/T_0)$$

For periods $T_0 \le T \le T_S$:

$$S_a = S_{DS}$$

For periods $T_S < T \le T_L$:

$$S_a = S_{D1}/T$$

For periods $T_L < T$:

$$S_a = S_{D1}T_L/T^2$$

Design response spectrum per Section 11.4.5 (using map-based acceleration parameters):

Period (Seconds)	S_a (g)
0.00	0.400
0.03	0.544
0.07	0.737
0.10	0.882
0.20	1.000
0.30	1.000
0.50	1.000
1.00	0.623
1.50	0.415
2.00	0.312
3.00	0.208
4.00	0.156

2. Scaled Site-specific Design Response Spectrum Per Section 21.3

In accordance with Section 21.3, the design site-specific spectral response acceleration at any period shall not be taken less than 80 percent of the S_a determined in accordance with Section 11.4.5, as done in Part 1. Governing S_a values are shown in bold. Not all periods are shown in the table. Therefore, the governing period(s) for the structure being designed shall be evaluated in the same way.

Period (Seconds)	Site-specific MCE_R Response Spectrum, S_{aM} (g)	Site-specific DBE Response Spectrum, $S_a = 2/3S_{aM}$ (g)	S_a per §11.4.5	80% of S_a per §11.4.5	Governing Site-specific Design Response Spectrum, S_a (g)
0.00	0.452	0.301	0.400	**0.320**	0.320
0.03	0.711	**0.474**	0.544	0.436	0.474
0.07	1.083	**0.722**	0.737	0.590	0.722
0.10	1.301	**0.867**	0.882	0.705	0.867
0.20	1.402	**0.935**	1.000	0.800	0.935
0.30	1.390	**0.927**	1.000	0.800	0.927
0.50	1.210	**0.807**	1.000	0.800	0.807
1.00	0.554	0.369	0.623	**0.498**	0.498
1.50	0.322	0.215	0.415	**0.332**	0.332
2.00	0.212	0.141	0.312	**0.249**	0.249
3.00	0.113	0.075	0.208	**0.166**	0.166
4.00	0.085	0.057	0.156	**0.125**	0.125

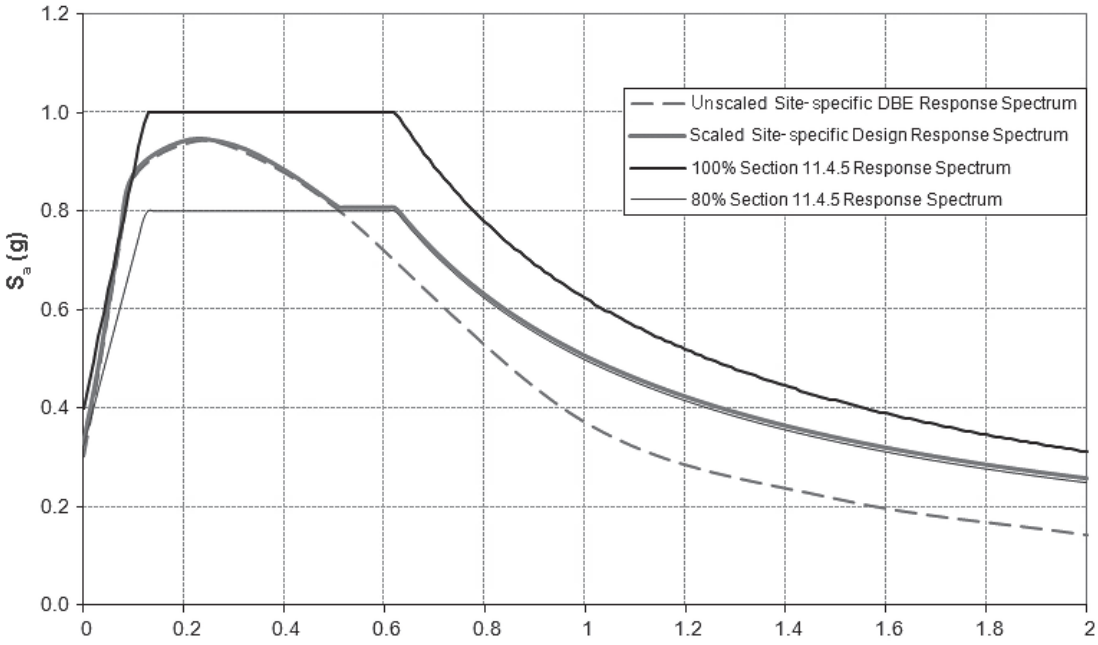

Figure 3-1.
Scaling of design site-specific response spectrum

3. Design Spectral Response Acceleration Parameters S_{DS}, S_{D1}, S_{MS}, and S_{M1} per Section 21.4

S_{DS} = greatest of site-specific DBE S_a at 0.2 seconds, 90 percent of largest site-specific DBE S_a at any period greater than 0.2 seconds, and 80 percent of S_{DS} (per Section 11.4.4)

S_{DS} = greatest of {0.935g, (0.90)0.935g, (0.80)1.0}

S_{DS} = 0.935g

S_{D1} = greatest of site-specific DBE S_a at 1 second, two times DBE S_a at 2 seconds, and 80 percent of S_{D1} (per Section 11.4.4)

S_{D1} = greatest of {0.369g, (2)0.141g = 0.282g, (0.80)0.623g = 0.498g}

S_{D1} = 0.498g

S_{MS} = greater of $1.5S_{DS}$ (per Section 21.4) and 80 percent of S_{MS} (per Section 11.4.3)

S_{MS} = greater of {(1.5)0.935g = 1.402g, (0.80)1.50g = 1.20g}

S_{MS} = 1.402g

S_{M1} = greater of $1.5S_{D1}$ (per § 21.4) and 80 percent of S_{M1} (per Section 11.4.3)

S_{M1} = greater of {(1.5)0.498g = 0.747g, (0.80)0.935g = 0.748g}

S_{M1} = 0.748g

Commentary

According to Section 21.4, for use with the Equivalent Lateral Force Procedure, the site-specific acceleration, S_a, at T shall be permitted to replace S_{D1}/T in Equation 12.8-3, and $S_{D1}T_L/T^2$ in Equation 12.8-4. Similarly, the parameter S_{DS} calculated in accordance with Section 21.4 (governing S_a at $T = 0.20$ seconds from Part 3), may be used in Equations 12.8-2, 12.8-5, 15.4-1, and 15.4-3. However, the mapped value of S_1 shall be used in Equations 12.8-6, 15.4-2, and 15.4-4.

Design Example 4
Importance Factor and Risk Category §11.5
Seismic Design Category §11.6

PROBLEM STATEMENT

Two private high school buildings each have an occupant load greater than 250 and the following design spectral acceleration parameters:

$S_{DS} = 1.17$
$S_{D1} = 0.75$
$S_1 = 0.75.$

One building is a traditional classroom wing. The other building is a gymnasium designated as an emergency shelter.

DETERMINE THE FOLLOWING:

1. Risk Category and Seismic Importance Factor for each building.

2. Seismic Design Category (SDC) for each building.

1. Risk Category and Seismic Importance Factor §11.5

From IBC Table 1604.5, "Risk Category of Buildings and Other Structures," the Risk Category for a private high school classroom building with an occupant load greater than 250 is Risk Category III. The Risk Category is used to determine the "Seismic Design Category," in accordance with Section 11.6. For a gymnasium that is designated as an emergency shelter, the Risk Category is IV.

The importance factors for seismic loads are from Table 1.5-2.

Occupancy	Risk Category	Seismic Factor I_e
Classroom	III	1.25
Gymnasium/Emergency Shelter	IV	1.5

2. Seismic Design Category §11.6

All structures are assigned to a Seismic Design Category (SDC) based on their Risk Category and the spectral response acceleration coefficients S_{DS} and S_{D1}, irrespective of the fundamental period of vibration of the structure T. Each building and structure shall be assigned to the most severe SDC in accordance with Table 11.6-1 or 11.6-2 as follows.

Occupancy	Risk Category	Table 11.6-1		Table 11.6-2		SDC Use*
		S_{DS}	SDC	S_{D1}	SDC	
Classroom	III	1.17	D*	0.75	D*	E
Gymnasium/ Emergency Shelter	IV	1.17	D*	0.75	D*	F

*Note that for Risk Categories I, II, and III having $S_1 \geq 0.75$ (recall $S_1 = 0.75$), the building shall be assigned to SDC E. Also for Risk Category IV having $S_1 \geq 0.75$, the building shall be assigned to SDC F.