Design Example 1
Design Spectral Response Acceleration Parameters §11.4

OVERVIEW

For a given building site, the risk-targeted maximum considered earthquake spectral response accelerations \( S_S \), at short periods, and \( S_1 \), at a 1-second period, are given by the acceleration contour maps in Chapter 22 in Figures 22-1 through 22-8. This example illustrates the general procedure for determining the design spectral response acceleration parameters \( S_{DS} \) and \( S_{D1} \) from the mapped values of \( S_S \) and \( S_1 \). The parameters \( S_{DS} \) and \( S_{D1} \) are used to calculate the design response spectrum in Section 11.4.6 and the design base shear in Section 12.8.

The easiest and most accurate way to obtain the spectral values is to use the “SEAOC/OSHPD Seismic Design Maps” website (seismicmaps.org). Values of \( S_S \) and \( S_1 \) are provided based on the address or the longitude and latitude of the site being entered.

Note that per Section 11.4.8 of Supplement 3 to ASCE 7-16, a site-specific ground motion hazard analysis shall be performed for structures located on Site Class F sites and for the following cases:

1. Structures on Site Class D sites with \( S_1 \) greater than or equal to 0.2 except where the value of the parameter \( S_{M1} \) determined by Equation 11.4-2 is increased by 50 percent for all applications of \( S_{M1} \) and the resulting value of the parameter \( S_{D1} \) determined by Equation 11.4-4 is used for all applications of \( S_{D1} \).

2. Structures on Site Class E sites with \( S_S \) greater than or equal to 1.0 and with \( S_1 \) greater than or equal to 0.2 except where (1) the equivalent lateral force procedure is used for the design and the value of \( C_y \) is determined by Equation 12.8-2 for all values of \( T \) OR (2) where the value of \( S_{a0} \) is determined by Equation 15.7-7 for all values of \( T_i \) AND the value of the parameter \( S_{D1} \) is replaced with \( 1.5 \times S_{D1} \) in Equations 15.7-10 and 15.7-11.

PROBLEM STATEMENT

A building site in California is located at 38.123° North (Latitude 38.123°) and 121.123° West (Longitude -121.123°). The soil profile is Site Class D.

The value of \( S_{D1} \) will be increased by 50 percent to determine the base shear in order to avoid the requirement for a site-specific ground motion hazard analysis.
DETERMINE THE FOLLOWING:

1. Mapped risk-targeted maximum considered earthquake (MCE\textsubscript{R}) spectral response acceleration parameters \( S\textsubscript{s} \) and \( S\textsubscript{1} \).

2. Site coefficients \( F\textsubscript{a} \) and \( F\textsubscript{v} \) and MCE\textsubscript{R} spectral response acceleration parameters \( S\textsubscript{MS} \) and \( S\textsubscript{M1} \) adjusted for Site Class effects.

3. Design spectral response acceleration parameters \( S\textsubscript{DS} \) and \( S\textsubscript{D1} \).

### 1. Mapped MCE\textsubscript{R} Spectral Response Acceleration Parameters \( S\textsubscript{s} \) and \( S\textsubscript{1} \) §11.4.2

For the given site at 38.123° North (Latitude 38.123°) and 121.123° West (Longitude -121.123°), the “SEAOC/OSHPD Design Maps” website provides the values of

\[
S\textsubscript{s} = 0.52g \\
S\textsubscript{1} = 0.232g
\]

### 2. Site Coefficients \( F\textsubscript{a} \) and \( F\textsubscript{v} \) and MCE\textsubscript{R} Spectral Response Acceleration Parameters \( S\textsubscript{MS} \) and \( S\textsubscript{M1} \) Adjusted for Site Class Effects §11.4.3

For the given Site Class D and the values of \( S\textsubscript{s} \) and \( S\textsubscript{1} \) determined above, the site coefficients are

\[
F\textsubscript{a} = 1.384 \\
F\textsubscript{v} = 2.136
\]

Note that the value of \( F\textsubscript{v} \) from Table 11.4-2 can only be used to determine \( T\textsubscript{s} \), to determine the seismic design category, for linear interpolation for intermediate values of \( S\textsubscript{1} \), and when taking the exceptions to Items 1 and 2 of Section 11.4.8 for the calculation of \( S\textsubscript{DS} \) per Footnote a of this table. For a site-specific analysis, \( F\textsubscript{v} \) shall be determined in accordance with Section 21.3.

The MCE\textsubscript{R} spectral response acceleration parameters adjusted for Site Class effects are

\[
S\textsubscript{MS} = F\textsubscript{a} S\textsubscript{s} = 1.384(0.52g) = 0.720g \\
S\textsubscript{M1} = F\textsubscript{v} S\textsubscript{1} = 1.5 \times 2.136(0.232g) = 0.743g
\]

### 3. Design Spectral Response Acceleration Parameters \( S\textsubscript{DS} \) and \( S\textsubscript{D1} \) §11.4.4

\[
S\textsubscript{DS} = (2/3) S\textsubscript{MS} = (2/3)(0.720g) = 0.480g \\
S\textsubscript{D1} = (2/3) S\textsubscript{M1} = (2/3)(0.743g) = 0.496g
\]

### Commentary

The “SEAOC/OSHPD Design Maps” website requires the risk category to be specified, even though that category is not necessary for determining \( S\textsubscript{DS} \) and \( S\textsubscript{D1} \).
Design Example 2  
Design Response Spectrum  §11.4.6

PROBLEM STATEMENT

A building site in California has the following design spectral response acceleration parameters determined in accordance with Section 11.4.5 and mapped long-period transition period evaluated from Figure 22-14:

\[ S_{DS} = 0.55g \]
\[ S_{D1} = 0.34g \]
\[ T_L = 8 \text{ sec} \]

Note that for the purposes of determining \( T_s \), \( S_{DS} \) can be calculated using the value of \( F_v \) determined from Table 11.4-2.

DETERMINE THE FOLLOWING:

1. Design response spectrum.

1. Design Response Spectrum  §11.4.6

Section 11.4.6 provides the equations for the 5 percent damped spectral response acceleration, \( S_a \), relative to period, \( T \), in the following ranges:

\[ 0 \leq T < T_0, \quad T_0 \leq T \leq T_s, \quad T_s < T \leq T_L, \quad \text{and} \quad T_L < T \]

where:

\[ T_0 = 0.2 \frac{S_{D1}}{S_{DS}} \]
\[ T_s = \frac{S_{D1}}{S_{DS}} \]
\[ T_L = \text{long-period transition period from Figures 22-14 through 22-17} \]

Given the values for this example,

\[ T_0 = 0.2 \frac{0.34g}{0.55g} = 0.12 \text{ sec} \]
\[ T_s = \frac{0.34g}{0.55g} = 0.62 \text{ sec} \]
\[ T_L = 8 \text{ sec} \]
The spectral response acceleration, $S_a$, is calculated as follows:

1. For the interval $0 \leq T < T_0$ ($0 \leq T < 0.12$ sec),

   \[ S_a = S_{DS}(0.4 + 0.6T/T_0) \quad \text{Eq 11.4-5} \]
   \[ S_a = 0.55g(0.4 + 0.67/0.12) = (0.22 + 2.75T)g \]

2. For the interval $T_0 \leq T \leq T_S$ ($0.12$ sec $\leq T \leq 0.62$ sec),

   \[ S_a = S_{DS} = 0.55g \]

3. For the interval $T_S < T \leq T_L$ ($0.62$ sec $< T \leq 8$ sec),

   \[ S_a = S_{DL}/T \quad \text{Eq 11.4-6} \]
   \[ S_a = (0.34/T)g \]

4. For the interval $T_L < T$ ($8$ sec $< T$),

   \[ S_a = S_{DL}T_L/T^2 \quad \text{Eq 11.4-7} \]
   \[ S_a = 0.34g(8)/T^2 = (2.72/T^2)g \]

From this information, the elastic design response spectrum for this site can be drawn, as shown in Figure 2-1, in accordance with Figure 11.4-1:

<table>
<thead>
<tr>
<th>$T$ (sec)</th>
<th>$S_a$ (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>0.22</td>
</tr>
<tr>
<td>0.12</td>
<td>0.55</td>
</tr>
<tr>
<td>0.62</td>
<td>0.55</td>
</tr>
<tr>
<td>0.75</td>
<td>0.45</td>
</tr>
<tr>
<td>1.00</td>
<td>0.34</td>
</tr>
<tr>
<td>1.50</td>
<td>0.23</td>
</tr>
<tr>
<td>2.00</td>
<td>0.17</td>
</tr>
<tr>
<td>4.00</td>
<td>0.09</td>
</tr>
<tr>
<td>8.00</td>
<td>0.04</td>
</tr>
<tr>
<td>10.00</td>
<td>0.03</td>
</tr>
</tbody>
</table>
Figure 2-1.
Design response spectrum per Section 11.4.6
Design Example 3
Site-specific Ground Motion Procedures §11.4.8

Per Section 11.4.8 of Supplement 3 to ASCE 7-16, 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.
- Structures on Site Class E sites with $S_1$ greater than or equal to 0.2 or with $S_s$ greater than or equal to 1.0.
- Structures on Site Class D sites with $S_1$ greater than or equal to 0.2.

A ground motion hazard analysis is not required for:

- Structures on Site Class E sites with $S_s$ greater than or equal to 1.0, provided that (1) the equivalent lateral force procedure is used for the design and the value of $C_s$ is determined by Equation 12.8-2 for all values of $T$ OR (2) where the value of $S_{ai}$ is determined by Equation 15.7-7 for all values of $T_i$ AND the value of the parameter $S_{DI}$ is replaced with $1.5*S_{DI}$ in Equations 15.7-10 and 15.7-11.
- Structures on Site Class D sites with $S_1$ greater than or equal to 0.2, provided that the value of the parameter $S_{DI}$ determined by Equation 11.4-2 is increased by 50 percent for all applications of $S_{DI}$ and the resulting value of the parameter $S_{DI}$ determined by Equation 11.4-4 is used for all applications of $S_{DI}$.

This example illustrates the general procedure for deriving the site-specific design response spectrum based on a given site-specific response spectrum 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 be derived using either Figures 22-1 through 22-8 or the “SEAOC/OSHPD Seismic Design Maps” website (seismicmaps.org).

Site Class = D, $T_L = 12$ sec

$S_s = 1.500g$, $S_1 = 0.623g$

$F_o = 1.0$, $F_v = 2.5$ §21.3

$S_{MS} = F_oS_s = 1.500g(1.0) = 1.500g$ §11.4.3, Eq 11.4-1

$S_{MT} = F_vS_1 = 0.623g(2.5) = 1.558g$ §11.4.3, Eq 11.4-2

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

$S_{DI} = (2/3)S_{MT} = (2/3)1.558g = 1.039g$ §11.4.4, Eq 11.4-4