Seismic Hazards and Response Spectrum Fundamentals

Derrell Manceaux
Senior Structural Engineer
FHWA Resource Center
Learning Outcomes

- Identify Upper & Lower Level EQ hazards
- Explain how seismic hazard maps are used
- Determine Seismic Design Category (Zone)
- Define a response spectrum and factors that effect the spectrum shape
- Describe how a “three point” response spectrum is constructed
Upper & Lower Seismic Hazards

- Lower Seismic Hazard - 100 year recurrence
  - Retrofit
- Upper Seismic Hazard - 1000 year recurrence
  - Retrofit
  - Guide Specification
  - LRFD 2008 Interims
- Upper Seismic Hazard - 500 year recurrence
  - Old AASHTO
# Upper & Lower Seismic Hazards

<table>
<thead>
<tr>
<th>Recurrence Period (years)</th>
<th>Time (years)</th>
<th>Probability of Exceedence</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>75</td>
<td>75%</td>
</tr>
<tr>
<td>500</td>
<td>50</td>
<td>10%</td>
</tr>
<tr>
<td>500</td>
<td>75</td>
<td>15%</td>
</tr>
<tr>
<td>1000</td>
<td>75</td>
<td>7%</td>
</tr>
</tbody>
</table>

Probability of Exceedence $\approx \frac{\text{Time}}{\text{Return Period}}$
Upper & Lower Seismic Hazards

- Retrofit
- AASHTO
- USGS

Return Period:
- 100
- 500
- 1000
- 1500
- 2000
- 2500

Ground Acceleration (g)

Topic Applicability
- Force
- Displ.
- Retro

Sixth National Seismic Conference on Bridges and Highways
Seismic Technologies for Extreme Loads
Seismic Hazard Maps

- Seismic Hazard Maps display earthquake ground accelerations for various probability levels
  - 100 year return period (Retrofit)
  - 1000 year return period (LRFD & GS)
- Used to Determine:
  - Acc of structure (3 Points) on Rock
  - Seismic Design Category (Zones)
Seismic Hazard Maps (PGA, 1 sec & 0.2 sec - 1000 year)

AASHTO Guide Specifications for LRFD Seismic Bridge Design

This program allows the user to obtain seismic design parameters for sites in the 50 states of the United States, Puerto Rico and the U.S. Virgin Islands. Ground motion maps are also included in PDF format.

Click on Okay to begin calculation.

Correct application of the data obtained from the use of this program and/or maps is the responsibility of the design and/or owner.

2007 AASHTO Ground Motion Maps for 7% Probability of Exceedance in 75 Years
5% of Critical Damping, Site Class B

Continuous United States - Peak Ground Acceleration
Continuous United States - 0.2 sec Spectral Response Acceleration
Continuous United States - 1.0 sec Spectral Response Acceleration

Region 1 (California/Western Nevada) - Peak Ground Acceleration
Region 1 (California/Western Nevada) - 0.2 sec period Spectral Response Acceleration
Region 1 (California/Western Nevada) - 1.0 sec period Spectral Response Acceleration

Region 2 (Salt Lake City Area) - Peak Ground Acceleration
Region 2 (Salt Lake City Area) - 0.2 sec period Spectral Response Acceleration
Region 2 (Salt Lake City Area) - 1.0 sec period Spectral Response Acceleration

Region 3 (New Madrid Area) - Peak Ground Acceleration
Region 3 (New Madrid Area) - 0.2 sec period Spectral Response Acceleration
Region 3 (New Madrid Area) - 1.0 sec period Spectral Response Acceleration
2002 USGS National Seismic Hazard Maps, Conterminous United States, Revised April 2003

This page contains probabilistic seismic hazard maps for the conterminous 48 States. Six maps are presented: peak ground acceleration (pga), 5-Hz spectral acceleration, and 1-Hz spectral acceleration (5% damping), each for 15% and 2%-in-fifty-years probability of exceedance.

Explanation of April 2003 Revision

To view and print the postscript (ps) files from your browser, download, (free), the GSview utility. To view and print the PDF files from your browser, download, (free), the Adobe Acrobat Reader.

<table>
<thead>
<tr>
<th>Hazard Maps</th>
<th>Probability of Exceedance in 50 Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spectral Acceleration</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2%</td>
</tr>
<tr>
<td></td>
<td>10%</td>
</tr>
<tr>
<td>Peak Ground Acceleration</td>
<td></td>
</tr>
<tr>
<td>0.2 Second</td>
<td></td>
</tr>
<tr>
<td>1.0 Second</td>
<td></td>
</tr>
</tbody>
</table>

Although these maps have been used by the U.S. Geological Survey, no warranty, expressed or implied is made by the USGS as to the accuracy of the maps and related material nor shall the fact of distribution constitute any such warranty, and no responsibility is assumed by the USGS in connection therewith.

2500 year recurrence
500 year recurrence
Seismic Hazard Maps

Linear Interpolation (ASCE 41-06)

\[
\ln(S_i) = \frac{\ln(S_{20/50}) - \ln(S_{10/50})}{\ln(2475) - \ln(475)} \times (\ln(P) - \ln(475))
\]
Seismic Hazard Maps

<table>
<thead>
<tr>
<th>Site</th>
<th>Fpga</th>
<th>Fa</th>
<th>Fv</th>
<th>PGA</th>
<th>Ss</th>
<th>S1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.0050</td>
<td>0.0107</td>
<td>0.0051</td>
</tr>
</tbody>
</table>

Period, T | Sa
---|---
0.01 | 0.0050
0.20 | 0.0107
0.40 | 0.0107
0.60 | 0.0064
0.80 | 0.0051
1.00 | 0.0043
1.20 | 0.0037
1.40 | 0.0032
1.60 | 0.0033
1.80 | 0.0020
2.00 | 0.0020
2.20 | 0.0023
2.40 | 0.0021
2.60 | 0.0020
2.80 | 0.0018
3.00 | 0.0017
3.20 | 0.0016
3.40 | 0.0015
3.60 | 0.0014
3.80 | 0.0014
4.00 | 0.0012

Spectrum Sa vs T

Sixth National Seismic Conference on Bridges and Highways
Seismic Technologies for Extreme Loads
Seismic Hazard Maps (PGA-500 year)

<table>
<thead>
<tr>
<th>Acc Coefficient (PGA)</th>
<th>Seismic Zone</th>
</tr>
</thead>
<tbody>
<tr>
<td>A ≤ 0.09</td>
<td>1</td>
</tr>
<tr>
<td>0.09 &lt; A ≤ 0.19</td>
<td>2</td>
</tr>
<tr>
<td>0.19 &lt; A ≤ 0.29</td>
<td>3</td>
</tr>
<tr>
<td>0.29 &lt; A</td>
<td>4</td>
</tr>
</tbody>
</table>

Seismic Zone:
- Zone 1: Rock
- Zone 2: Soils with low to moderate shear modulus
- Zone 3: Soils with moderate to high shear modulus
- Zone 4: Soils with high shear modulus

 PGA Map

K=∞ rock

Seismic Technologies for Extreme Loads
Seismic Hazard Maps

PGA, 0.2 sec & 1.0 sec (1000 year)

T=1-second

PGA

T=0.2 second

rock

T=1-second

rock
Seismic Hazard Maps

PGA, 1 sec & 0.2 sec (1000 year)

Structure Acceleration on Rock

Period, T (seconds)

PGA

0.2 second

1-second

Seismic Technologies for Extreme Loads
Seismic Hazard Maps
PGA, 0.2 sec & 1.0 sec (1000 year)
Seismic Hazard Maps

Structure

Soil

Rock

Structure Acc on Rock

Period, T (seconds)

Seismic Technologies for Extreme Loads

Sixth National Seismic Conference on Bridges and Highways

Charleston 2008
Seismic Hazard Maps

Seismic Hazard

Structure

Soil

Rock

Structure acc on Soil

Period, T (seconds)

Seismic technologies for extreme loads
Seismic Hazard Maps

\[ S_{D1} = S_1 \times F_v \]

POF
Seismic Hazard Maps

- How are Seismic Hazard Maps used?
  - To get 3 points to build the “rock” response spectrum (“Struct. acc on rock”)
  - To determine Seismic Design Category (Zone), \( S_{D1} \), using \( acc, S_1 \), modified with Site (soil) factor, \( F_v \)
Seismic Design Category (Zone)

- Calculate associated soil factors
  - Long Period, $F_v$

<table>
<thead>
<tr>
<th>Site Class</th>
<th>$S_1 \leq 0.1$</th>
<th>$S_1 = 0.2$</th>
<th>$S_1 = 0.3$</th>
<th>$S_1 = 0.4$</th>
<th>$S_1 \geq 0.5$</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>C</td>
<td>1.7</td>
<td>1.6</td>
<td>1.5</td>
<td>1.4</td>
<td>1.3</td>
</tr>
<tr>
<td>D</td>
<td>2.4</td>
<td>2.0</td>
<td>1.8</td>
<td>1.6</td>
<td>1.5</td>
</tr>
<tr>
<td>E</td>
<td>3.5</td>
<td>3.2</td>
<td>2.8</td>
<td>2.4</td>
<td>2.4</td>
</tr>
</tbody>
</table>

Sixth National Seismic Conference on Bridges and Highways
Seismic Technologies for Extreme Loads
# Seismic Design Category (zone)

- New Seismic Zones (SDC)
- 500 year

### 2007 4th Edition LRFD

<table>
<thead>
<tr>
<th>Acceleration Coefficient</th>
<th>Seismic Zone</th>
</tr>
</thead>
<tbody>
<tr>
<td>( A \leq 0.09 )</td>
<td>1</td>
</tr>
<tr>
<td>0.09 &lt; ( A ) \leq 0.19</td>
<td>2</td>
</tr>
<tr>
<td>0.19 &lt; ( A ) \leq 0.29</td>
<td>3</td>
</tr>
<tr>
<td>0.29 &lt; ( A )</td>
<td>4</td>
</tr>
</tbody>
</table>

\( A = \text{PGA} \)

### 2008 Interims & Guide Specs

<table>
<thead>
<tr>
<th>Acceleration Coefficient</th>
<th>Seismic Zone (SDC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( S_{D1} \leq 0.15 )</td>
<td>1</td>
</tr>
<tr>
<td>0.15 &lt; ( S_{D1} ) \leq 0.30</td>
<td>2</td>
</tr>
<tr>
<td>0.30 &lt; ( S_{D1} ) \leq 0.50</td>
<td>3</td>
</tr>
<tr>
<td>0.50 &lt; ( S_{D1} )</td>
<td>4</td>
</tr>
</tbody>
</table>

\( S_{D1} = \text{Structure acceleration}=S_1 \times F_v \)

---

**Sixth National Seismic Conference on Bridges and Highways**

Seismic Technologies for Extreme Loads
### Seismic Design Category (Zone)

<table>
<thead>
<tr>
<th>Soil Site B</th>
<th>Soil Site C</th>
<th>Soil Site D</th>
<th>Soil Site E</th>
<th>Seismic Zone</th>
<th>PGA 2007 4th Edition (500 year)</th>
<th>Acceleration Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>( S_1 &lt; 0.15 )</td>
<td>( S_1 &lt; 0.09 )</td>
<td>( S_1 &lt; 0.07 )</td>
<td>( S_1 &lt; 0.04 )</td>
<td>1</td>
<td>( A_{PGA} &lt; 0.09 )</td>
<td></td>
</tr>
<tr>
<td>( 0.15 &lt; S_1 \leq 0.30 )</td>
<td>( 0.09 &lt; 0.20 )</td>
<td>( 0.07 &lt; .15 )</td>
<td>( 0.04 &lt; .09 )</td>
<td>2</td>
<td>( 0.09 &lt; A_{PGA} \leq 0.19 )</td>
<td></td>
</tr>
<tr>
<td>( 0.30 &lt; 0.50 )</td>
<td>( 0.20 &lt; 0.35 )</td>
<td>( 0.15 &lt; .27 )</td>
<td>( 0.09 &lt; .15 )</td>
<td>3</td>
<td>( 0.19 &lt; A_{PGA} \leq 0.29 )</td>
<td></td>
</tr>
<tr>
<td>( 0.50 &lt; S_1 )</td>
<td>( 0.35 &lt; S_1 )</td>
<td>( 0.27 &lt; S_1 )</td>
<td>( 0.15 &lt; S_1 )</td>
<td>4</td>
<td>( 0.30 &lt; A_{PGA} )</td>
<td></td>
</tr>
</tbody>
</table>
Seismic Design Category

Seismic Zones vs Acceleration, $S_1$

$S_1$ (g)

Soil Type

Zone 4
Zone 3
Zone 2
Zone 1

Seismic Zones vs Acceleration, $S_1$
Seismic Design Category

- SDC-Zones
  - Zone 1-SDC “A”
  - Zone 2-SDC “B”
  - Zone 3-SDC “C”
  - Zone 4-SDC “D”

- Soil (Site) Class
  - “B” (Rock)
  - “C” (N> 50 blows/ft)
  - “D” (15<N<50 blows/ft)
  - “E” (N<15 blows/ft)
# Seismic Design Category

<table>
<thead>
<tr>
<th>SITE CLASS</th>
<th>SOIL TYPE and PROFILE</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Hard rock with measured shear wave velocity, $\bar{v}_s &gt; 1500$ m/sec (5,000 ft/sec).</td>
</tr>
<tr>
<td>B</td>
<td>Rock with $760$ m/sec $&lt; \bar{v}_s \leq 1500$ m/sec (2,500 ft/sec $&lt; \bar{v}_s \leq 5,000$ ft/sec).</td>
</tr>
<tr>
<td>C</td>
<td>Very dense soil and soil rock with $360$ m/sec $&lt; \bar{v}_s \leq 760$ m/sec (1,200 ft/sec $&lt; \bar{v}_s \leq 2,500$ ft/sec) or with either $\bar{N} &gt; 50$ blows/0.30m (50 blows/ft) or $\bar{s}_u &gt; 100$ kPa (2,000 psf).</td>
</tr>
<tr>
<td>D</td>
<td>Stiff soil with $180$ m/sec $&lt; \bar{v}_s \leq 360$ m/sec (600 ft/sec $&lt; \bar{v}_s \leq 1,200$ ft/sec) or with either $15 \leq \bar{N} \leq 50$ blows/0.30m (15 $\leq \bar{N} \leq 50$ blows/ft) or $50$ kPa $\leq \bar{s}_u \leq 100$ kPa (1,000 $\leq \bar{s}_u \leq 2,000$ psf).</td>
</tr>
<tr>
<td>E</td>
<td>Soil profile with $\bar{v}_s &lt; 180$ m/sec (600 ft/sec) or with either $\bar{N} &lt; 15$ blows/0.30m ($\bar{N} &lt; 15$ blows/ft) or $\bar{s}_u &lt; 50$ kPa (1,000 psf), or any profile with more than 3 m (10 ft) of soft clay defined as soil with PI $&gt; 20$, $w \geq 40$ percent and $\bar{s}_u &lt; 25$ kPa (500 psf).</td>
</tr>
</tbody>
</table>
| F          | Soils requiring site-specific evaluations, such as:  
1. Peats or highly organic clays ($H > 3$ m [10 ft] of peat or highly organic clay where $H =$ thickness of soil).  
2. Very high plasticity clays ($H > 8$ m [25 ft] with $\text{PI} > 75$).  
3. Very thick soft/medium stiff clays ($H > 36$ m [120 ft]). |

---

**Sixth National Seismic Conference on Bridges and Highways**  
Seismic Technologies for Extreme Loads
Seismic Design Category (zone) 
(500 year Return Period)

Zone 1-SDC “A”
Zone 2-SDC “B”
Zone 3-SDC “C”
Zone 4-SDC “D”
Seismic Design Category (zone)
(1000 Year Return Period)

- Zone 1-SDC “A”
- Zone 2-SDC “B”
- Zone 3-SDC “C”
- Zone 4-SDC “D”

SITE CLASS “B”

Seismic Technologies for Extreme Loads
Seismic Design Category (zone)
(1000 Year Return Period)

Zone 1-SDC “A”
Zone 2-SDC “B”
Zone 3-SDC “C”
Zone 4-SDC “D”

SITE CLASS “C”

Sixth National Seismic Conference on Bridges and Highways
Seismic Technologies for Extreme Loads
Seismic Design Category (zone)
(1000 Year Return Period)

Zone 1-SDC “A”
Zone 2-SDC “B”
Zone 3-SDC “C”
Zone 4-SDC “D”
Seismic Design Category (zone) (1000 Year Return Period)

Zone 1 - SDC “A”
Zone 2 - SDC “B”
Zone 3 - SDC “C”
Zone 4 - SDC “D”

SITE CLASS “E”
**Seismic Design Category (zone)**
*(1000 Year Return Period)*

- How to Calculate Seismic Design Category (zone)?
  - Multiply Rock Spectrum \((S_1)\) x Site Class \((F_v)\) Amplification Factor @ 1.0 sec
  - \(S_{D1} = \text{Structure acceleration} = S_1 \times F_v\)
- SDC is variable at any single location
  - No single seismic map can determine SDC
Response Spectrum

- What is the Response Spectrum?
  - The response spectrum provides the maximum acceleration a single degree of freedom structure will experience when it is subjected to a ground motion.

\[
\text{Total Acceleration or "Spectral Acceleration"}
\]

\[
a_{\text{total}} = C_s \cdot g_s
\]

\(C_s\) = Acceleration Due to Gravity
Response Spectrum

How is it created?

- Determine Maximum Response for a Group of Structures, All with Different Periods; then Plot

All Structures Subject to the Same Ground Motion
Response Spectrum

- Actual Spectra vs. Smoothed Spectra

- Range one structure may experience for a variety of ground motions.

- Smoothed Spectrum

- Actual Spectra, Each for a Different Earthquake

Amplification zone

Acceleration Response max(\text{total})

Period T
Response Spectrum
Response Spectrum

- 2007 Design Response Spectrum

Total Acceleration or ‘Spectral Acceleration’
\[ a_{\text{total}} = C_s \cdot g \]

Acceleration Due to Gravity

A — Design Acceleration
S — Soil Coefficient
5% Damping of Structure

\[ 1.2AS \frac{T^{2/3}}{} \]

Neglect

2.5A

Topic Applicability

- Force
- Displ.
- Retro

Sixth National Seismic Conference on Bridges and Highways
Seismic Technologies for Extreme Loads
Three Point Response Spectrum

- Determine Rock Accelerations
  - \( S_s \) = Rock Acceleration @ 0.2 s
  - \( S_1 \) = Rock Acceleration @ 1.0 s
  - \( S_{PGA} \) = Rock Acceleration @ 0.0 s
Three Point Response Spectrum

- Determine Soil (Site) Coefficients
  - \( F_a = \text{Site Coefficient @ 0.2 s} \)
  - \( F_{\text{PGA}} = \text{Site Coefficient @ 0.0 s} \)

<table>
<thead>
<tr>
<th>Site Class</th>
<th>Mapped PGA and Spectral Acc at 0.2 s ((F_a, F_{\text{PGA}}))</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( \text{PGA} \leq 0.1 )</td>
</tr>
<tr>
<td></td>
<td>( S_s \leq 0.25 )</td>
</tr>
<tr>
<td>B</td>
<td>1.0</td>
</tr>
<tr>
<td>C</td>
<td>1.2</td>
</tr>
<tr>
<td>D</td>
<td>1.6</td>
</tr>
<tr>
<td>E</td>
<td>2.5</td>
</tr>
</tbody>
</table>
## Three Point Response Spectrum

- Determine Soil (Site) Coefficients
  - $F_v = \text{Site Coefficient @ 1.0 s}$

<table>
<thead>
<tr>
<th>Site Class</th>
<th>Mapped Spectral Acc at 1.0 s</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$S_1 \leq 0.1$</td>
</tr>
<tr>
<td>B</td>
<td>1.0</td>
</tr>
<tr>
<td>C</td>
<td>1.7</td>
</tr>
<tr>
<td>D</td>
<td>2.4</td>
</tr>
<tr>
<td>E</td>
<td>3.5</td>
</tr>
</tbody>
</table>

### Topic Applicability
- **Force**: ✓ ✓ ✓
Three Point Response Spectrum

Response Spectral Acceleration, $S_a$

Period, $T$ (seconds)

$T_o = 0.2T_s$

$T_s = \frac{S_{DI}}{S_{DS}}$

Sixth National Seismic Conference on Bridges and Highways
Seismic Technologies for Extreme Loads
Three Point Response Spectrum

South West Indiana

- $S_s = \text{Acceleration @ 0.2 s} = 0.5 \text{ g}$
- $S_1 = \text{Acceleration @ 1.0 s} = 0.13 \text{ g}$

0.2 second spectral response (5% damp)

1 second spectral response (5% damp)

Sixth National Seismic Conference on Bridges and Highways
Seismic Technologies for Extreme Loads
Three Point Response Spectrum

<table>
<thead>
<tr>
<th>Site</th>
<th>Spectral Acc at $S_s$ (0.2 sec)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$S_s \leq$</td>
<td>$.25g$</td>
</tr>
<tr>
<td>A</td>
<td>0.8</td>
<td>0.8</td>
</tr>
<tr>
<td>B</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>C</td>
<td>1.2</td>
<td>1.2</td>
</tr>
<tr>
<td>D</td>
<td>1.6</td>
<td>1.4</td>
</tr>
<tr>
<td>E</td>
<td>2.5</td>
<td>1.7</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Site</th>
<th>Spectral $S_1$ (1.0 sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$S_1 \leq$</td>
</tr>
<tr>
<td>A</td>
<td>0.8</td>
</tr>
<tr>
<td>B</td>
<td>1.0</td>
</tr>
<tr>
<td>C</td>
<td>1.7</td>
</tr>
<tr>
<td>D</td>
<td>2.4</td>
</tr>
<tr>
<td>E</td>
<td>3.5</td>
</tr>
</tbody>
</table>

$S_{D1} = 0.13 \times 3.3 = 0.43 > 0.3$ Zone “3” Bridges and Highways

Seismic Technologies for Extreme Loads
Three Point Response Spectrum

South Indiana (1000 vs 500 year return period)

Acc\textsubscript{1000 year} / Φ (.9)
Soil “C”

Acc\textsubscript{500 year} / Φ (.9)

Acc\textsubscript{500 year} / Φ (.75)

Soil type “E” – Zone “3”
Three Point Response Spectrum

West Tennessee (1000 vs 500 year return period)

Acc\(_{1000\text{ year}} / \Phi\) (0.9)

Acc\(_{500\text{ year}} / \Phi\) (0.5)

Acc\(_{500\text{ year}} / \Phi\) (0.9)

Soil=“B”

Soil=“E”

Sixth National Seismic Conference on Bridges and Highways
Seismic Technologies for Extreme Loads
Three Point Response Spectrum
East Idaho (1000 vs 500 year return period)

Soil="B"

Soil="E"

Sixth National Seismic Conference on Bridges and Highways
Seismic Technologies for Extreme Loads
Three Point Response Spectrum

North New Jersey (1000 vs 500 year return period)

1000 EQ vs 500 EQ

Acc_{500 \text{ year}} / \Phi (0.75)

Acc_{500 \text{ year}} / \Phi (0.9)

Acc_{1000 \text{ year}} / \Phi (0.9)

Period (Sec)

Spec Acc (Fraction of g)

Soil=“B”

Soil=“E”

Sixth National Seismic Conference on
Bridges and Highways
Seismic Technologies for Extreme Loads
Three Point Response Spectrum

- Determine Rock Accelerations
  - \( S_s \) = Rock Acceleration @ 0.2 s
  - \( S_1 \) = Rock Acceleration @ 1.0 s
  - \( S_{PGA} \) = Rock Acceleration @ 0.0 s
- Determine Soil (Site) Coefficients
- Calculate Ratios \( S_{D1}/S_{DS} \)
- Plot Response Spectrum
Conclusion

- New recurrence period from 500 to 1000 year does not:
  - double the demand
  - necessarily increase population of seismic bridges
- Seismic Design Categories (Zones) are:
  - Impacted by Soil (Site) Coefficients
  - Determined by structural acceleration on soil
**Conclusion**

- New Response Spectrum is:
  - Less conservative in long period range

![Graph showing the comparison between 1/T and 1/T^{2/3}](image)
What questions do you have?