Site-Specific $\text{MCE}_R$ Response Spectra for Los Angeles Region based on 3-D Numerical Simulations and the NGA West2 Equations

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Tuesday, June 26 – Friday, June 29
Site-Specific MCE_R Response Spectra for Design of Structures in L.A. Region from 3-D Numerical Simulations & NGA West2 GMPEs

C.B. Crouse, AECOM

11 NCEE Conference: June, 2018
Presentation

- Brief background
- Details of simulation & GMPE approaches
  - $\text{MCE}_R$ response spectra from each approach
  - Procedure to combine $\text{MCE}_R$ & final site-specific $\text{MCE}_R$ response spectra for L.A. area sites
- Illustrate SCEC UGMS look-up tool
Project to Develop MCER Response Spectra
Undertaken by
Utilization of Ground-Motion Simulations Committee (UGMS) of Southern California Earthquake Center (SCEC)
Formed in 2013
UGMS Committee Members

- C. Crouse – Chair
- T Jordan – SCEC
- N. Luco – USGS
- R. Bachman
- J. Hooper – MKA
- J. Bielak – CMU
- C. Kircher
- M. Hudson – Wood plc
- M. Lew – Wood plc
- R. Hamburger - SGH
- A. Frankel – USGS
- N. Abrahamson – PG&E
- R. Graves – USGS
- F. Naeim
- A. Sumer – OSHPD
- P. Somerville – AECOM
- Jack Baker – Stanford
- J. Anderson – UNR
- S. Rezaeian – USGS
- C. Goulet – SCEC
3-D Numerical Simulation Approach

1. Use UCERF2 fault recurrence models
2. Do simulations
   - H1 & H2 accel. $a(t)$
   - response spectra, $S_a(T)$
   - median $S_a(T)$ & $\sigma_{ln}$
3. Proceed with PSHA/DSHA (C. 21, ASCE 7-16)
4. $M C E_R$ Response Spectra
CyberShake Computational Platform used for Simulations

- 3-D physics-based model of fault rupture and wave propagation for S. CA EQs
- 40,000 regional earthquakes (M ≥ 6) were simulated
  - Multiple hypocenter and slip models for each given M on given fault
  - e.g., 140 models for M6.7 on Northridge fault
- 440,000 simulations for each of 336 sites
Simulated Motions computed at 336 CyberShake Sites
Advantages of 3D Simulations for L.A. Region

Basin Structure, $V_p$, $V_s$, & $Q$ – Well known for modeling propagation of longer period waves.
Validation of Simulations

Validated against recordings from moderate M events. Validations also done for 1994 M6.7 Northridge EQ.
M 7.8 San Andreas Earthquake Simulations

Graves et al. (2008)
M 7.8 San Andreas Earthquake Simulations

$Sa \ (T = 3 \text{ sec}, \zeta = 5\%)$

Graves et al. (2008)
# Velocity Records for M 7.8 San Andreas Event

Graves et al. (2008)

<table>
<thead>
<tr>
<th>Location</th>
<th>000</th>
<th>090</th>
<th>Ver</th>
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</thead>
<tbody>
<tr>
<td>TAB</td>
<td>193.0</td>
<td>127.1</td>
<td>40.7</td>
</tr>
<tr>
<td>PAS</td>
<td>32.6</td>
<td>28.9</td>
<td>17.0</td>
</tr>
<tr>
<td>LADT</td>
<td>33.5</td>
<td>64.8</td>
<td>25.0</td>
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<tr>
<td>DOWN</td>
<td>107.3</td>
<td>157.7</td>
<td>88.3</td>
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<tr>
<td>LBCH</td>
<td>40.5</td>
<td>57.9</td>
<td>28.1</td>
</tr>
</tbody>
</table>

Distance: 0.9 km

South Hypocenter Vel (cm/s)
1. Use UCERF3 recurrence models

2. Select ground-motion eqns.
   - Four NGA West 2 eqns.
     - basin depth ($Z_{1.0}$ or $Z_{2.5}$)
     - shear-wave vel. ($V_{S30}$)
   - Substitute $Z_{1.0}$, $Z_{2.5}$, $V_{S30}$ values into eqns.

3. Proceed with PSHA/DSHA (C. 21, ASCE 7-16)

4. MCE$_R$ Response Spectra
2013 NGA West2 Equations with Basin Depth Terms

- Abrahamson et al – $Z_{1.0}$
- Boore et al – $Z_{1.0}$
- Campbell & Bozorgnia – $Z_{2.5}$
- Chiou & Youngs – $Z_{1.0}$

<table>
<thead>
<tr>
<th>$V_{S30}$ (m/s)</th>
<th>Site Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
<td>A/B</td>
</tr>
<tr>
<td>880</td>
<td></td>
</tr>
<tr>
<td>760</td>
<td>B/C</td>
</tr>
<tr>
<td>662</td>
<td></td>
</tr>
<tr>
<td>564</td>
<td>C</td>
</tr>
<tr>
<td>465</td>
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</tr>
<tr>
<td>366</td>
<td>C/D</td>
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<tr>
<td>320</td>
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<td>274</td>
<td>D</td>
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<tr>
<td>229</td>
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<tr>
<td>183</td>
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<tr>
<td>166</td>
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</tr>
<tr>
<td>150</td>
<td>E</td>
</tr>
</tbody>
</table>

2-D Basin Profile

$V_s = 1$ km/s

$V_s = 2.5$ km/s

$Z_{1.0}$

$Z_{2.5}$
MCE\textsubscript{R} Response Spectra

- CyberShake (T = 2 – 10 sec)
- NGA West2 GMPEs (0 – 10 sec)
Determination of $MCE_R$ Response Spectra, $T = 2 - 10$ sec

- Computed $MCE_R$ from both approaches at selected sites in L.A. area
- Developed procedure for combining two $MCE_R$
- Checked final $MCE_R$ for many L.A. area sites
Transform $S_a$ to PSV

$$PSV = \left(\frac{T}{2\pi}\right)S_a$$
MCE_R PSV for 7 Sites to Illustrate Trends
**Weighted Averaging of MCE$_R$ Response Spectra**

<table>
<thead>
<tr>
<th>Source Model</th>
<th>G-M Models</th>
<th>Weights</th>
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<tr>
<td></td>
<td>GMPE</td>
<td>Collective Weights for Periods, T - sec</td>
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<tr>
<td></td>
<td>NGA West2</td>
<td>&lt; 2</td>
</tr>
<tr>
<td></td>
<td>AKS</td>
<td>0.25</td>
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<tr>
<td></td>
<td>BASS</td>
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<tr>
<td></td>
<td>CB</td>
<td>0.25</td>
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<tr>
<td></td>
<td>CY</td>
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<td>UCERF3</td>
<td>CyberShake</td>
<td>1</td>
</tr>
<tr>
<td>UCERF2</td>
<td></td>
<td>0</td>
</tr>
</tbody>
</table>
MCE$_R$: COO (Compton) - Deep Basin

![Graph showing the relationship between PSV and T (seconds). The PSV (cm/sec) values range from 100 to 1000, and the T values range from 1 to 10 seconds. The graph shows a steady trend.]
MCE<sub>R</sub>: COO (Compton) - Deep Basin

![Graph showing seismic response]

- Sa : Acceleration response
- T : Time in seconds
End Products of UGMS Project

- Site-Specific MCE$_R$ for L. A. area
  - Alternative to ASCE 7-16 “maps” (Ch 22) for Southern California and F$_a$ & F$_v$ (Ch 11)
  - Resource to bldg. officials & engineers

- SCEC/UGMS look-up tool
  - ~ USGS web app tool
Official Release

Look-Up Tool at:

https://data2.scecc.org/ugms-mcerGM-tool_v18.4
Site-Specific MCE_R & Design Response Spectra per Sect. 21.2, 21.3, 21.4 of ASCE 7-16

Input Parameters

Report Title
My Report

Latitude and longitude in decimal degrees (or click on map to select site):
Latitude (e.g. 34.45)
Longitude (e.g. -118.35)

Site Geotechnical Classification:

- OR -
   - Site Class
     Site Class NOT automatically determined based on site location.
   - OR -
     V_{30} (m/s) Value
   - OR -
     Unknown (V_{30} estimated from Wills et al., 2015)

Compute Response Spectra

The UGMS MCE_R tool was developed by the SCEC Committee for Utilization of Ground Motion Simulations (or "UGMS Committee") from research supported by the Southern California Earthquake Center (SCEC). SCEC is funded by NSF Cooperative Agreement EAR-1033452 & USGS Cooperative Agreement G12AG20038. For more information on the UGMS Committee, visit https://www.scec.org/research/ugms.
Site-Specific MCE<sub>R</sub> & Design Response Spectra per Sect. 21.2, 21.3, 21.4 of ASCE 7-16

Input Parameters

Report Title
LADT

Latitude and longitude in decimal degrees (or click on map to select site):
34.0548
-118.2487

Site Geotechnical Classification:

- Site Class
  - Select -
  Site Class NOT automatically determined based on site location.

- OR -
  - V<sub>s30</sub> (m/s) 446

- OR -
  Unknown (Vs30 estimated from Wills et al., 2015)

Compute Response Spectra

The UGMS MCE<sub>R</sub> tool was developed by the SCEC Committee for Utilization of Ground Motion Simulations (or "UGMS Committee") from research supported by the Southern California Earthquake Center (SCEC). SCEC is funded by NSF Cooperative Agreement EAR-1033462 & USGS Cooperative Agreement G12AC20038. For more information on the UGMS Committee, visit https://www.scec.org/research/ugms.
LADT Site-Specific $MCE_R$ Response Spectrum

\[ Sa \cdot g \]

\[ T \cdot \text{sec} \]

\(0\) \(0.5\) \(1\) \(1.5\) \(2\) \(2.5\) \(3\)

\(0\) \(2\) \(4\) \(6\) \(8\) \(10\)
LADT Site-Specific MCE$_R$ Response Spectra
LADT MCE\textsubscript{R} Response Spectra

![Graph showing response spectra for NGA West2 and CyberShake against time (T - sec) and peak ground velocity (PSV - cm/sec).]
LADT Final Site-Specific MCE$_R$ from Averaging

![Graph showing the comparison of NGA West2, CyberShake, and Recom MCER over time.](image)
% Difference between Site-Specific & NGA West2 MCE$_R$

Diagram showing the percentage difference between Site-Specific and NGA West2 MCE$_R$ over time (T - sec) with specific values at certain time points:

- At T = 2 sec: +2%
- At T = 3 sec: 5%
- At T = 4 sec: 9%
- At T = 5 sec: 12%
- At T = 7 sec: 5%
- At T = 10 sec: 6%
LADT Site-Specific vs ASCE 7-16 (Ch. 11) MCE_R
LADT Site-Specific vs ASCE 7-16 (Ch. 11) $MCE_R$

![Graph comparing Site-Specific MCER and ASCE 7-16 (Ch. 11, S. Class C) with T in seconds on the x-axis and PSV in cm/sec on the y-axis.](image)
Why New $MCE_R$ are Improvement to $MCE_R$ from Ch. 11 in ASCE 7-16 or from Ch. 21 using NGA West2 Eqns only

- Site-Specific for Los Angeles Region

- Better job in accounting for:
  - local & regional geology
  - fault directivity & fling (CyberShake)
  - 3-D effects of fault rupture & basin structure on ground motion (CyberShake)