Site-Specific $MCE_R$ Response Spectra for Design of Structures in L.A. Region from 3-D Numerical Simulations & NGA West2 GMPEs

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Meeting with LATBSDC: October 22, 2018
Brief background & 2018 UGMS Recap

3-D Simulation & GMPE approaches
- $MCE_R$ response spectra from each approach
- Procedure to average $MCE_R$ to get final site-specific $MCE_R$ response spectra for L.A. tall building sites

Illustrate SCEC UGMS look-up tool

Suggested L.A. City requirement for tall buildings
2018 UGMS Summary

- SCEC UGMS MCER look-up tool launched in spring

- UGMS Presentations at three venues
  - American Association of Advancement of Science, Feb., Austin, TX
  - LATBSDC seminar, May, Los Angeles
  - 11 NCEE (Workshop, Theme & Simulation Sessions), June, Los Angeles

- Began tool implementation discussions for tall builds with LATBSDC
Project to Develop MCE\textsubscript{R} 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. MCE$_R$ 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
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
MCE$_R$ Response Spectra

- CyberShake ($T = 2 - 10$ sec)
- NGA West2 GMPEs ($0 - 10$ sec)
## Weighted Averaging of MCE<sub>R</sub> Response Spectra

<table>
<thead>
<tr>
<th>Source Model</th>
<th>G-M Models</th>
<th>Weights (Collective Weights for Periods, T - sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>UCERF3</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>GMPE</td>
<td></td>
</tr>
<tr>
<td>NGA West2</td>
<td>Individual Weight</td>
<td></td>
</tr>
<tr>
<td>AKS</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td>BASS</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td>CB</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td>CY</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td><strong>UCERF2</strong></td>
<td>CyberShake</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>0.2 0.3 0.4 0.5</td>
</tr>
</tbody>
</table>

Collective Weights for Periods, T - sec:

- < 2
- 2
- 3
- 4
- ≥ 5

Weights for Periods, T - sec:

- UCERF3: 1 0.8 0.7 0.6 0.5
- UCERF2: 0 0.2 0.3 0.4 0.5
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
Look-Up Tool at:

https://data2.sceec.org/ugms-mcerGM-tool_v18.4
SCEC UGMS MCE_R Look-Up Tool

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:

- Site Class
  - Select -

- OR -
  - V_s30 (m/s)
    - Value

- OR -
  Unknown (V_s30 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-1033462 & USGS Cooperative Agreement G12AC20038. For more information on the UGMS Committee, visit https://www.scec.org/research/ugms.
Downtown Los Angeles (LADT) Example

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
  Site Class NOT automatically determined based on site location.

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

- OR -
  Unknown (V<sub>s30</sub> estimated from Wills et al., 2015)

Compute Response Spectra

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LADT Site-Specific MCE\textsubscript{R} Response Spectrum

\begin{figure}
\centering
\includegraphics[width=\textwidth]{LADT_Site-Specific_MCE_R_Response_Spectrum}
\end{figure}
LADT Site-Specific MCE$\text{R}$ Response Spectra

The graph illustrates the response spectra for different scenarios:
- **NGA West2**
- **CyberShake**
- **Site-Specific MCER**

The x-axis represents time (T - sec), while the y-axis represents the acceleration (Sa - g). The graph shows the comparison of these spectra.
LADT MCE_R Response Spectra
LADT Final Site-Specific $MCE_R$ from Averaging
% Difference between Site-Specific & NGA West2 MCE$_R$
LADT Site-Specific vs ASCE 7-16 (Ch. 11) MCE₀
LADT Site-Specific vs ASCE 7-16 (Ch. 11) MCE_R

Graph showing the comparison between Site-Specific MCER and ASCE 7-16 (Ch. 11, S. Class C) for variables PSV (cm/sec) and T (sec).
Century City Plaza (CCP) Example

Site-Specific $MCE_R$ & Design Response Spectra per Sect. 21.2, 21.3, 21.4 of ASCE 7-16

Input Parameters

Report Title
CCP

Latitude and longitude in decimal degrees (or click on map to select site):
34.0549
-118.413

Site Geotechnical Classification:

- Select -

- OR -

- $V_{s30}$ (m/s) - Value

- OR -

Unknown ($V_{s30}$ estimated from Wills et al., 2015)

Compute Response Spectra

The UGMS $MCE_a$ 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.
CCP Site-Specific MCE$_R$ Response Spectrum
CCP Site-Specific $\text{MCE}_R$ Response Spectra

![Graph showing response spectra comparison]
CCP MCE_R Response Spectra

PSV - cm/sec

T - sec

NGA West2
CyberShake
CCP Final Site-Specific MCE\textsubscript{R} from Averaging
% Difference between Site-Specific & NGA West2 MCE

- NGA West2
- Final MCER

PSV - cm/sec

T - sec

7%

11%

8%

7%
CCP Site-Specific vs ASCE 7-16 (Ch. 11) $MCE_R$
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)
Suggestion for Implementation by L.A. City

- Requirement for tall buildings using LATBSDC Guidelines in conjunction with ASCE 7-16 & IBC 2018

- Similar requirement adopted by City of Seattle:
  - Director’s Rule 20-2018 (eff. 12/01/18)
  - 3-D simulations from M9 Cascadia earthquake including Seattle basin effects
  - Recorded ground-motion data in Seattle area
Future Additions to Look-Up Tool

- **Deaggregation Data**
  - M-Distance
  - Fault

- **Acceleration Time Histories**
  - San Andreas M~8 events
  - Local M~7 events

- **BSE-1 & BSE-2 (ASCE 41-17)**

- **SLE (LATBSDC & TBI-2)**