Improving Long Period Ground-Motions in Seismic Codes

SCEC UGMS Progress Report

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AECOM
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Improving Seismic Provisions in US Codes through Ground-Motion Simulations: The Role SCEC Can Play

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URS Corporation

September 2012
New Approach for Computing Long Period \( S_a \)

Use 3-D Numerical Models

Application: Urban Areas

Primary End Product

Long Period \( S_a \) Maps

Next Generation Seismic Codes

2022 (ASCE 7-22)
Utilization of Ground-Motion Simulations to Develop Long Period Spectral Acceleration Maps for Los Angeles Region

SCEC UGMS Committee

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 – AMEC
- M. Lew – AMEC
- R. Hamburger - SGH
- A. Frankel – USGS
- N. Abrahamson – PG&E
- R. Graves – USGS
- F. Naeim
- C. Hazelton – CSC
- P. Somerville – AECOM
- Jack Baker – Stanford
- J. Anderson – UNR
- S. Rezaeian – USGS
- C. Goulet – SCEC
3-D Simulation Approach

1. Characterize fault Mw recurrence (SCEC UCERF2)

2. Perform simulations
   - H1 & H2 accel. a(t)
   - response spectra, $S_a(T)$
   - median $S_a(T)$ & $\sigma_{ln}$

3. Proceed with PSHA/DSHA (Ch 21, ASCE 7)

4. $MCE_R$ Response Spectra (ASCE 7 Standard)
CyberShake Computational Platform

- 3D waveform simulations using full kinematic rupture description
- 40,000 earthquakes ($M_W \geq 6$) in Southern California from UCERF2.0 (2008)
  - Multiple hypocenters and slip models for each given $M_W$ on given fault
- 440,000 ground motion simulations for each of ~300 sites
Advantages of 3D Simulations for L.A. Region

Basin Structure, Vp, Vs, & Q – Fairly well known for modeling propagation of longer period waves.
Validation of Simulations

Validated against recordings from moderate M events.

UGMS is beginning validations for 1994 Northridge earthquake.
~300 CyberShake Sites
$MCE_R$ Response Spectra Computed at 14 Sites Initially
MCE_R Response Spectra

- CyberShake
- NGA West2 GMPEs
2013 NGA Equations with Basin Depth Terms

- Abrahamson et al – Z1.0
- Boore et al – Z1.0
- Campbell & Bozorgnia – Z2.5
- Chiou & Youngs – Z1.0

V_s = 1 km/s
V_s = 2.5 km/s

Site

Z_{1.0}
Z_{2.5}

Depth

Basin Profile
MCE_R Response Spectrum

ASCE 7-10

Spectral Response Acceleration, $S_a$ (g)

$S_{MS}$
$S_{M1}$

Period, $T$ (sec)

$T_O$ $T_S$ 1.0 $T_L$

$S_a = \frac{S_{M1}}{T}$

$S_a = \frac{S_{M1} \cdot T_L}{T^2}$
Transform $S_a$ to PSV

$$PSV = \left(\frac{T}{2\pi}\right)S_a$$
MCE_R PSV for 7 Sites to Illustrate Trends

- LAPD (Palmdale) - rock site
- PAS (old CIT seismoc lab) - rock site
- P22 (Ventura Freeway) - basin edge
- LADT (Downtown L.A.) - basin edge
- CPP (Century City Plaza) - basin edge
- COO (Compton) - deep basin
- s429 (Carson) - deep basin

Graphs showing PSV cm/sec and Depth km for different sites.
Logic Tree for PSHA/DSHA for MCE<sub>R</sub>

**Source Model**

- UCERF3
  - UCERF2
    - CyberShake

**G-M Models**

- GMPE
  - Individual Weight
    - NGA West2
      - AKS: 0.25
      - BASS: 0.25
      - CB: 0.25
      - CY: 0.25
    - NGA West2
      - G-M:

**Weights**

<table>
<thead>
<tr>
<th>Collective Weights for Periods, T - sec</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 1.0</td>
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<td>1</td>
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</table>
MCE$_R$: COO (Compton) - Deep Basin

![Graph showing PSV (cm/sec) vs. T (sec) for MCE$_R$: COO (Compton) - Deep Basin.](image-url)
$MCE_R$: COO (Compton) - Deep Basin
MCE_R: s383 (Palos Verdes) - rock site

- Depth (km)
- PSV (cm/sec)
- T (sec)
- MCE_R:
  - s383 (Palos Verdes)
  - (San Gabriel Mnts) - rock site
  - (E. Pasadena) - basin edge
  - (L.A.) - basin edge
  - (Central L.A.) - deep basin
  - (Torrance) - basin
  - (Palos Verdes) - rock site
Line 2

MCE_\text{R}: s510 (Seal Beach) - deep basin

**Depth - km**

- Z1.0
- Z2.5

**PSV - cm/sec**

**T - sec**

1. MCE_\text{R}: s520 (La Verne) - shallow basin
2. MCE_\text{R}: s518 (Walnut) - shallow basin
3. MCE_\text{R}: s516 (Brea) - basin
4. MCE_\text{R}: s514 (Fullerton) - deep basin
5. MCE_\text{R}: s512 (Garden Grove) - deep basin
6. MCE_\text{R}: s510 (Seal Beach) - deep basin
Intermediate Goal of UGMS

- $MCE_R$ “maps” for L. A. region
  - Amendment to ASCE 7-16 maps for L. A. City
  - Resource to City and consultants

- Look-up tool ~ USGS web app tool
MCER Look-up Tool for L. A. City

- Enter Site lat./long.
  - Lat. 34.05204
  - Long. -118.25713

- Site Geology Parameter
  - $V_{S30}$
  - Site Class (A, B, C, D, E)
  - Unknown

- Compute

Source: Google Earth Pro
Output

Site Class = C

- $V_{S30} = 390 \text{ km/sec}$
- $Z_{1.0} = 0.31 \text{ km}$
- $Z_{2.5} = 2.08 \text{ km}$

Table: $MCE_R$ $S_a$ vs $T$

<table>
<thead>
<tr>
<th>$T$-sec</th>
<th>$S_a$ - g</th>
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<tbody>
<tr>
<td>0.01</td>
<td>1.017</td>
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<tr>
<td>0.02</td>
<td>1.026</td>
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<tr>
<td>0.03</td>
<td>1.078</td>
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<tr>
<td>0.05</td>
<td>1.275</td>
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<tr>
<td>0.075</td>
<td>1.600</td>
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<tr>
<td>0.1</td>
<td>1.870</td>
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<tr>
<td>0.15</td>
<td>2.256</td>
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<tr>
<td>0.2</td>
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<tr>
<td>0.25</td>
<td>2.612</td>
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<tr>
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<td>7.5</td>
<td>0.106</td>
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<tr>
<td>10</td>
<td>0.069</td>
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</table>

$S_{DS} = 1.65$

$S_{D1} = 0.89$
ASCE 7; Ch.21 Site-Specific Ground Motion
Vs Profiles. Carson Site, s429

Depth - m

Vs - m/sec

CyberShake
Actual
What’s next for UGMS
Validations: CyberShake vs 1994 Northridge EQ Records

Stations
- 1994 Northridge EQ
- CyberShake

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, gettyimages.com
Distribution of $S_a$ (3.0 sec) Values at LADT from 140 CyberShake Simulations of M 6.7 on Northridge Fault

1994 Northridge EQ
Sta. 1000: 0.031g
Sta 1005: 0.029g

CyberShake ($\overline{S}_a = 0.034g$)
NGA West2 ($\overline{S}_a = 0.029g$)
Parallel Efforts Affecting Future Direction of UGMS

- Project 17 ➔ ASCE 7-22
  \(MCE_R\) may be replaced

- Tall Building Initiative Guidelines ➔ TBI (2017)
  Some guidelines may differ from ASCE 7-22
Los Angeles Region Hazard Map, 2% in 50-yr $S_a (3 \text{ sec})$

Graves et al. (2010) CyberShake Simulations

Graves et al. (2010) – Fig. 9