Characteristics of Long-Period (3 to 10 s) Ground Motions Observed in and around the Los Angeles Basin during the Mw7.2 El Mayor-Cucapah Earthquake

Ken Hatayama
(National Research Institute of Fire and Disaster, Japan)
[Now at U.S. Geological Survey, Menlo Park, CA]

Erol Kalkan
(U.S. Geological Survey, Menlo Park, CA)

Acknowledgment
This study was supported by Excellent Young Researchers Overseas Visit Program of Japan Society for the Promotion of Science.
Significance of Studying This Earthquake ~ Number of Records!

- 2010 El Mayor-Cucapah Eq. (Mw7.2)
- 1994 Northridge Eq. (Ml6.4)
- 1992 Landers Eq. (Ml7.3)
- 1999 Hector Mine Eq. (Ml7.1)
Outline

- PGV of Observed Long-Period Ground Motion
- Spectral Amplification Factors Derived from the Observations
- FDM Simulation by Using SCEC CVM-H 6.2
PGV of Observed Ground Motion
Observed PGV (Period Range: 3 to 16 s)
Observed PGV (Period Range: 3 to 16 s)

Western Part of LA Basin

San Gabriel Valley

Central Part of LA Basin
Observed PGV (Period Range: 3 to 16 s)
Sediment Thickness (Colors) vs Observed PGV (Contours)

Vs < 3.2 km/s [SCEC CVM-H 6.2]
Sediment Thickness (Colors) vs. Observed PGV (Contours)

Vs < 2.8 km/s [SCEC CVM-H 6.2]
Sediment Thickness (Colors) v’s Observed PGV (Contours)

Vs < 1.5 km/s [SCEC CVM-H 6.2]
Spectral Amplification Factor
Fourier Acceleration Spectra (RMS of Two Horizontal Comps.)

Fourier Amplitude

Stations from which Fourier Spectra are Computed

In order to Evaluate Amplification Factors
1. Select Appropriate Reference Stations
2. Compute Spectral Ratio
How to Select Reference Stations

<<Criteria>>

1. Record has Long Duration (> 300 s).
   Basin Model Suggests that the Station is NOT on Sediment.
2. Observed Spectral Amplitudes are Relatively Small.

Phase Velocity of Love Wave at T= 4 s
[Computed from SCEC CVM-H 6.2]
Obs. Fourier Acceleration Spectra (RMS of Horizontal Comp.)

Fourier Amplitude

Fourier Spectral Ratio

Period (s)

Fourier Acceleration (m/s)
Observed Fourier Spectral Ratio: $T=10\,s$
Observed Fourier Spectral Ratio

Period: 10 s

Period: 8 s

Period: 6 s

Period: 4 s
FDM Simulation by Using SCEC CVM-H 6.2
Outline of Simulation

- Velocity-Stress Staggered Grid
- FD Approximation
  - Temporal 2\textsuperscript{nd}-order
  - Spatial 4\textsuperscript{th}-order
- $D_x = D_y = 0.5$ km; $D_z = 0.2$ km
- $V_s$: 0.5 to 3.8 km/s
- Attenuation: No Q

Source Box
(Alterman & Karal, 1968)

Application to Input Motion to Irregular Media
(Zahradnik & Moczo, 1996)

Depth = 10 km
$M_w = 7.2$ ($M_o = 8.5 \times 10^{19}$ Nm)
Moment Rate Function: Delta Function
Simulated vs. Observed Fourier Acceleration Spectra

Simulated Fourier Acceleration (m/s) vs. Period (s)

Spectral Ratio vs. Period(s)
Simulated v’s Observed Fourier Spectral Ratio

Simulated

Period: 6 s

Observed

Period: 6 s

Period: 8 s

Period: 8 s
Summary

■ Over 200 stations recorded this earthquake in and around the LA Basins.

■ Higher PGV values were observed at the Western and Central Part of the LA, and San Gabriel Valley Basins as compared to non-basin sites.

■ For the Central Part of the LA basin, spatial variation to depth of Vs 3.2 km/s and Vs 2.8 km/s are in good agreement with the observed high PGV values. For San Gabriel Valley, however, spatial variation to depth of Vs 1.5 km/s better agrees with the observed high PGV values.

■ Spectral amplification factors were evaluated with respect to reference stations on hard rock.

  ➢ At 8 and 10 s, the maximum amplification factor of 5 is observed at the Central Part of the LA Basin. The maximum amplification factor reached to 10 at 6 s at the Western Part of the LA Basin (Manhattan Beach).

■ We compared spectral amplification factors computed from observations with those from simulations using a simple point source model and the SCEC CVM-H 6.2.

  ➢ Simulation results generally agreed with observations for spatial variation of amplification factors at long periods over 8 s, however, intensity of amplification factors were overestimated.

  ➢ Including Q-value and/or using detailed source model might improve the agreement between simulations and observations.
Records around Manhattan Beach (Vel. ; BPF 3 to 16 s)

<table>
<thead>
<tr>
<th>EW</th>
<th>Time (s)</th>
<th>PGV</th>
</tr>
</thead>
<tbody>
<tr>
<td>14221</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14822</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14767</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14036</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PDR</td>
<td></td>
<td>7.2 cm/s</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>NS</th>
<th>Time (s)</th>
<th>PGV</th>
</tr>
</thead>
<tbody>
<tr>
<td>14221</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14822</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14767</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14036</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PDR</td>
<td></td>
<td>5.9 cm/s</td>
</tr>
</tbody>
</table>
Sediment Thickness (Colors) vs. Observed PGV (Contours)

Vs < 3.6 km/s [SCEC CVM-H 6.2]
Sediment Thickness (Colors) vs. Observed PGV (Contours)

Vs < 2.5 km/s [SCEC CVM-H 6.2]
Sediment Thickness (Colors) vs. Observed PGV (Contours)

Vs < 2.0 km/s [SCEC CVM-H 6.2]
Sediment Thickness (Colors) vs. Observed PGV (Contours)

Vs < 1.0 km/s [SCEC CVM-H 6.2]
Sediment Thickness (Colors) vs. Observed PGV (Contours)

Vs < 0.7 km/s [SCEC CVM-H 6.2]
Why Spectra?

- Long-period structures (e.g., high-rise buildings and large oil tanks) have low damping.
- Their seismic responses are sensitive to spectral ordinates of input ground motions.

### Velocity Response Spectra

- **h = 0.5%**
- **h = 5%**

### Liquid Sloshing of Large Tanks

- Liquid Height 16 m
- Tank Diameter (m): 20, 30, 40, 50, 60, 70, 80, 90, 100
- Liquid Levels: 11,300 kl, 45,200 kl, 101,700 kl
FDM used in this Study

<<FDM>>
+ Velocity-Stress Staggered Grid
+ FD Approximation
  – Temporal 2\textsuperscript{nd}-order
  – Spatial 4\textsuperscript{th}-order

<<How to Give Input Motion>>
+ Source Box (Alterman & Karal, 1968)
+ Application to Input Motion to Irregular Media (Zahradnik & Moczo, 1996)

Original Source Box
Outside of Irregular Media: Horizontally Layered Media
Irregular Media (Sedimentary Basin)
Source Box
Absorbing Boundary

This Study
Outside of Irregular Media: Horizontally Layered Media
Irregular Media (Sedimentary Basin)
Source Box
Absorbing Boundary
Incoming Wave
Incident Waves (Fourier Acc. Spectra)

Simulation

Observed

[Graphs showing Fourier acceleration spectra versus period with labeled axes: Fourier Acceleration (m/s) on the y-axis and Period (s) on the x-axis.]
Simulated vs. Observed PGV (Period Range: 5 to 16 s)

Simulated:
Max. of PGV = 0.22 m/s

Observed:
Max. of PGV = 0.12 m/s
Simulated vs. Observed Velocity Waveform  
(Period Range: 5 to 16 s)