Southern California Seismic Site Response: Effects of Basin Geometry and Shallow Geology

Jonathan P. Stewart

University of California, Los Angeles
Overview

• Parameterization of site factors – categories versus continuous variables (CV)
• Special considerations for basins
• Opportunities for improving AASHTO provisions
Parameterization of Site Factors

- NEHRP: \( V_{s30} \)-based categories, 
  \( f_S = f(A...E, S_a, \text{rock}) \)

<table>
<thead>
<tr>
<th>NEHRP Category</th>
<th>Description</th>
<th>Mean Shear Wave Velocity to 30 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Hard rock</td>
<td>&gt;1500 m/s</td>
</tr>
<tr>
<td>B</td>
<td>Firm to hard rock</td>
<td>760–1500 m/s</td>
</tr>
<tr>
<td>C</td>
<td>Dense soil, soft rock</td>
<td>360–760 m/s</td>
</tr>
<tr>
<td>D</td>
<td>Stiff soil</td>
<td>180–360 m/s</td>
</tr>
<tr>
<td>E</td>
<td>Soft clays</td>
<td>&lt;180 m/s</td>
</tr>
<tr>
<td>F</td>
<td>Special study soils, e.g., liquefiable soils, sensitive clays, organic soils, soft clays &gt;36 m thick</td>
<td></td>
</tr>
</tbody>
</table>
Parameterization of Site Factors

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  $f_S = f(A \ldots E, S_a, \text{rock})$

Borcherdt (1994)
Parameterization of Site Factors

- NEHRP: $V_{s30}$-based categories, $f_S=f(A\ldots E, S_{a,\text{ref}})$
- $V_{s30}$ as a continuous variable, $f_S=f(V_{s30}, S_{a,\text{ref}})$
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  - Linear
  - $\sigma$ independent of $V_{s30}$
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  - $\sigma$ independent of $V_{s30}$
- **CS (2005)**
  - Nonlinear
  - $\sigma = f(V_{s30})$
Velocity-dependence of linear site response

\[ \ln(F_{ij}) = c \ln \left( \frac{V_{s-30ij}}{V_{ref}} \right) + b \ln \left( \frac{PHA_{rij}}{0.1} \right) + \eta_i + \varepsilon_{ij} \]
Velocity-dependence of slope representing non-linearity

\[ \ln(F_{ij}) = c \ln\left(\frac{V_{s-30_{ij}}}{V_{ref}}\right) + b \ln\left(\frac{PHA_{r_{ij}}}{0.1}\right) + \eta_i + \varepsilon_{ij} \]
Velocity-dependence of standard deviation

\[
\ln(F_{ij}) = c \ln \left( \frac{V_{s-30,ij}}{V_{ref}} \right) + b \ln \left( \frac{PHA_{r,ij}}{0.1} \right) + \eta_i + \varepsilon_{ij}
\]
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  - Linear
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  - $\sigma = f(V_{s30})$
- NGA (2008)
  - Empirical: BA, CY
  - Hybrid: AS, CB
NGA: $V_{s30}$-scaling of weak ground motion (M7, SS, r100km)

Abrahamson et al., 2008
NGA: $V_{s30}$-scaling of strong ground motion (M7, SS, r10km)

Abrahamson et al., 2008
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Physics of Basin Response

Source beneath basin
- Nearly vertical wave propagation
- Ruptured fault

Source outside basin
- Surface wave generated (travels across basin)

CBL = Coincident source and site Basin Locations

DBL = Distinct source and site Basin Locations
Results of linear regression against depth within CBL and DBL categories...

Depth dependence

- CBL: slope > 0
- DBL: slope ≈ 0

**F-test:** Distinct

- Basin effect important for $T > \sim 0.7 \text{ s}$
- CBL similar to 1D ground response (long recognized as depth dependent)
- DBL expected to be unaffected by depth
- Similar results from simulations
Basin Models

- Source/site specific, e.g. Shakeout (Graves et al., 2008)
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- Empirical:
  - SCEC (2000): linear trend with $z^{2.5}$
  - CSG (2005): trend for CBL, not for DBL
  - NGA:
    - No basin: BA, I
    - Empirical, linear: CY, CB
    - Hybrid: AS

Abrahamson and Silva, 2008
Improving AASHTO Provisions

- Ideal: web site for site-specific analysis
- Move away from category-based site classifications
- Traditional vs PSHA-based factors?
- Basin effect – work needed before ready for national provisions