Seismic Attenuation in the Korean Peninsula

Seismic Parameters for Prediction of Strong Ground Motions in Korea

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1. Basic Definition on Earthquake

Ground Motions
“By Any Other Name”

- Attenuation laws (Europe)
- Attenuation relations (U.S. Engineers)
- Attenuation relationships (U.S. Engineers)
- Attenuation equations
- Ground motion relations (U.S. Seismologists)
- Ground motion prediction relations
- Ground motion prediction equations
- Ground motion estimation equations
Definition

“An attenuation law is a mathematical equation or engineering model that relates a strong-motion parameter to one or more parameters of the earthquake source, wave propagation path, and local site conditions”
Methods of Development

- **Empirical methods**
  - Derived from strong-motion recordings

- **Hybrid empirical methods**
  - Derived by modifying empirical attenuation laws in one region to use in another region based on seismological transfer functions usually derived using stochastic methods (see below)

- **Stochastic methods**
  - Derived from stochastic ground-motion simulations and simple seismological models

- **Theoretical methods**
  - Derived from kinematic and dynamic ground-motion simulations and rigorous seismological models
Basic Functional Form

\[ \log Y = c_1 + c_2 M - c_3 \log R - c_4 R + \varepsilon_a + \varepsilon_e \]

where,
- \( \log Y \) = log of strong-motion parameter
- \( M \) = earthquake magnitude or \( f(M) \)
- \( R \) = source-to-site distance or \( f(R, M) \)
- \( \varepsilon_a \) = aleatory uncertainty
- \( \varepsilon_e \) = epistemic uncertainty
- \( c_i \) = model coefficients
Common Parameters

- Ground-motion measure
- Earthquake magnitude
- Source-to-site distance
- Finite faulting effects
- Local site conditions
- Stress drop
- Hanging-wall effects
- Tectonic environment
2. Efficient Procedure for Estimation of Seismic Parameters for Ground Motions
Seismic parameters for computation of ground motions

- **Source parameters**
  - Seismic moment ($M_0$), Corner frequency ($f_c$), Stress drop ($\Delta \sigma$)

- **Propagation constants**
  - Quality factor $Q (\kappa_q)$, site-dependent $\kappa_s$, Geometrical spreading $R^{-\gamma}$

\[
A(f, R) \propto e^{-\pi \kappa f} \cdot R^{-\gamma}
\]

\[
\kappa = \kappa_q R + \kappa_s
\]

$\kappa$ is a site-specific parameter, $\kappa_q$ is a regional parameter ($\sim Q$)
$\kappa$-values from acceleration spectrum

Fourier Amplitude Spectrum of Acceleration
1999/06/02  \textbf{KRA station}  $R = 58.0$ km

\begin{align*}
\log(\text{FAS}) &= -0.126045 f - 0.132014 \\
\kappa^{\text{KRA}}_{R=58\,\text{km}} &= 0.0401
\end{align*}
Linear curve fitting for $\kappa = \kappa_s + \kappa_q R$

$\kappa$-value; May be seriously influenced by the site effect

→ Need to propose a new procedure for $\kappa_s$ and $\kappa_q$
Computation of site-dependent $\kappa$

1\textsuperscript{st} STEP: computation of site independent value $\kappa_q$ (or $Q$)

Using coda normalization method (Frankel, 1990) or others

$t_c = 85.7$ sec ($2T_s^{120}$ for $R=120$ km)

$T_s^{58}$

Origin time

$S$ window

Coda window

1999/06/02  \textbf{KRA station}  $R = 58$ km
Result of inversion for $Q$ and $\gamma$

$\gamma = 0.7649$

$Q = 2022.58$

$\leftrightarrow \kappa_q = 0.0001413$

; slope in $\kappa-R$ relation is obtained
2\textsuperscript{nd} STEP: computation of $\kappa_s$ for each site using given $\kappa_q$ value

<table>
<thead>
<tr>
<th>Station</th>
<th>WSA</th>
<th>WSB</th>
<th>WSC</th>
<th>WSN</th>
<th>KRA</th>
<th>KRB</th>
<th>KOR</th>
<th>UJA</th>
<th>TAG</th>
<th>GKP</th>
<th>PUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\kappa_s$</td>
<td>0.02647</td>
<td>0.01337</td>
<td>0.01732</td>
<td>0.02885</td>
<td>0.03300</td>
<td>0.01513</td>
<td>0.02577</td>
<td>0.03588</td>
<td>0.002665</td>
<td>-0.01087</td>
<td>0.01302</td>
</tr>
</tbody>
</table>
Site-dependent $\kappa_5$ values

LATITUDE

LONGITUDE

37.5N
37N
36.5N
36N
35.5N
35N
127.5E
128E
128.5E
129E
129.5E
130E

GKP
TAG
0.002665
-0.01087

WSC
WSA
KRA
KRB
PUS
UJA
KOR
WSN

0.03588
0.01732
-0.01087
0.002665
0.02647
0.01338
0.02885
0.01513
0.01302
0.02577
Brune’s stress drop

Stress drop ($\Delta\sigma$) is obtained from
- Low frequency spectral value ($\Omega_0$)
- Corner frequency ($f_c$)
1999 Gyeongju Earthquakes, Korea

Three small-to-medium-sized earthquakes at almost the same location
Computed source spectrum (smoothed)
Computed source parameters

**Low-frequency spectral level**

- $\Omega_0$ (cm · sec)
- $f_c$ (Hz)

**Stress drop**

- Weighted average
  - 78-bar

**Stress drop values**

- $M_w=3.1$
  - Apr. 24
- $M_w=3.4$
  - Sep. 12
- $M_w=3.8$
  - Jun. 2
Conclusion

Proposed methods and procedures for estimation of site-dependent ground motions can be efficiently used in the low and moderate seismicity regions.