Discussion on Seismic Site Response Characteristics in Korea

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Contents

Site Effects and Site Classification

Seismic Site Response in Korea

Summary
Site Effects and Site Classification
Complexity of Earthquake Ground Motion

- **Main Influence Effects**
  - Source effects / Path effects / Site effects

- **Geological Issue**
  - *Source* represented by occurred earthquake characteristics
  - *Path* represented by attenuation relationship in rock

- **Geotechnical Issue:** *Site effects* (sometimes included source & path)

- **Site effects**
  - The effects of near surface geologic and soil conditions
  - The effects of subsurface geometry and surface topography
Observational Evidence of Site Effects

- 1994 Northridge Earthquake (Santa Monica; Gao et al., 1996)
  - The amplitudes at soil site are about 4 and 7 times stronger than those at rock site located apart from 650 m
Determination of Site Coefficients, $F_a$ and $F_v$ Based on 1989 Loma Prieta and Other Earthquakes

Short-period
Site (amplification) coefficient ($F_a$)

$$F_a = \frac{R_{\text{soil}}}{R_{\text{rock}}} \frac{1}{0.4} \int_{0.1}^{0.5} \frac{R S_{\text{soil}}(T)}{R S_{\text{rock}}(T)} dT$$

Mid-period
Site (amplification) coefficient ($F_v$)

$$F_v = \frac{R_{\text{soil}}}{R_{\text{rock}}} \frac{1}{1.6} \int_{0.4}^{2.0} \frac{R S_{\text{soil}}(T)}{R S_{\text{rock}}(T)} dT$$

Intermediate-period
Site (amplification) coefficient ($F_i$)

$$F_i = \frac{R_{\text{soil}}}{R_{\text{rock}}} \frac{1}{1.5} \int_{0.5}^{1.5} \frac{R S_{\text{soil}}(T)}{R S_{\text{rock}}(T)} dT$$

Long-period
Site (amplification) coefficient ($F_d$)

$$F_d = \frac{R_{\text{soil}}}{R_{\text{rock}}} \frac{1}{3.5} \int_{1.5}^{5.0} \frac{R S_{\text{surface}}(T)}{R S_{\text{bedrock}}(T)} dT$$

Sites were classified based on the mean shear wave velocity of the upper 30m ($V_{s30}$; 100ft or 30.48m) depth.

$V_{s30} = \frac{30}{\sum_{i=1}^{n} \frac{d_i}{V_{St}}}$

Basis of the Current Site Classification System
## Current Site Classification System for Seismic Design
*(UBC 1997; NEHRP 1997; 2000)*

<table>
<thead>
<tr>
<th>Soil Profile Type</th>
<th>Generic Description</th>
<th>Average Soil Prop (Vs30) (m/s)</th>
<th>Short-Period</th>
<th>Mid-Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>( S_A ) (Site Class A)</td>
<td>Hard Rock</td>
<td>&gt; 1,500</td>
<td>0.09 0.82</td>
<td>0.09 0.82</td>
</tr>
<tr>
<td>( S_B ) (Site Class B)</td>
<td>Rock</td>
<td>760 - 1,500</td>
<td>0.11 1.00</td>
<td>0.11 1.00</td>
</tr>
<tr>
<td>( S_C ) (Site Class C)</td>
<td>Very Dense and Soft Rock</td>
<td>360 - 760</td>
<td>0.13 1.18</td>
<td>0.18 1.64</td>
</tr>
<tr>
<td>( S_D ) (Site Class D)</td>
<td>Stiff Soil</td>
<td>180 - 360</td>
<td>0.16 1.45</td>
<td>0.23 2.09</td>
</tr>
<tr>
<td>( S_E ) (Site Class E)</td>
<td>Soft Soil</td>
<td>&lt; 180</td>
<td>0.22 2.00</td>
<td>0.37 3.36</td>
</tr>
<tr>
<td>( S_F ) (Site Class F)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

![Diagram showing site classification system](image)

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*Notes:*
- \( \text{Vs} \) is the shear wave velocity.
- \( \text{Z} = 0.11 \) for Short-Period and \( \text{Z} = 0.07 \) for Mid-Period.
- \( \text{Ca} \) and \( \text{Cv} \) are site-specific acceleration factors.
- \( \text{F_a} \) and \( \text{F_v} \) are soil-specific factors.

# Site Effects and Site Classification (4/5)
Determination of Response Spectrum for Seismic Design

- Determination of Design Response Spectrum
- Determination of Site Response Spectrum
- Determination of Seismic Zone
- Determination of Seismic Coefficients ($C_a, C_v$)
- Categorization of Soil Profile Type (Korean Guide based on NEHRP and UBC)
- Quantification of Site Amplification
- Surface motion resulting in hazard analysis
- INCONSISTENT in the Korean Sites

Earthquake by Fault Movement

Soil profile at site of interest

Site Response Analysis

Bedrock motion

Attenuation with geological distance

Rock outcropping motion for design

Site Effects and Site Classification (5/5)
Seismic Site Response in Korea
Vs Profiles in Korea and Western US (WUS)

Mean Vs to 30 m (Vs30) of soil deposit in Korea (Site Class C; 448.6 m/s)

Mean Vs to 30 m (Vs30) of soil deposit in WUS (Site Class C; 510.0 m/s)

Boundary of Vs30 to Classify Site C and D (360.0 m/s)

Mean Vs to 30 m (Vs30) of soil deposit in Korea (Site Class D; 346.9 m/s)

Mean Vs to 30 m (Vs30) of soil deposit in WUS (Site Class D; 304.3 m/s)

Boundary of Vs30 to Classify Site C and D (360.0 m/s)

Korea; Average
Korea; Average + Standard Deviation
Korea; Average - Standard Deviation

WUS; Average
WUS; Average + Standard Deviation
WUS; Average - Standard Deviation

Average of WUS
Average of Korea

30 m ≈ 100 ft

Site Class C
Site Class D

Si
Vi
Vd

Mean Vs to 30 m (Vs30)
of soil deposit in Korea
(Site Class C; 448.6 m/s)

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Boundary of Vs30
to Classify
Site C and D
(360.0 m/s)
Distribution of Site Period ($T_G$)

- Somewhat different for C sites; Significantly different for D sites
Response Spectra from Analyses

- In C and D sites, the spectral accelerations of response spectra are significantly higher than those of design spectra near resonant periods.
- The resonant periods of D sites are longer than C sites.
Maximum spectral accelerations of C and D sites are higher, respectively, than those of design spectrum for site classes D and E, near resonant period.
In site class C in Korea

- $F_a$ on current code is significantly underestimated.
- $F_v$ on current code is considerably overestimated.

In site class D in Korea

- $F_a$ on current code is underestimated.
- $F_v$ on current code is considerably overestimated.
Site Coefficients According to Vs30

- **In $F_a$ for short-periods in Korea**
  - $F_a$ ranging 1.0 to 2.7 are larger than those on current code.

- **Site Coefficients, $F_a$ and $F_v$, show similar values, regardless of rock acceleration levels of CLE and OLE.**

- **In $F_v$ for mid-periods in Korea**
  - $F_v$ ranging 1.0 to 1.6 are smaller than those on current code.
Summary
Site characterizations in Korea were performed to evaluate the seismic site response characteristics, and the following conclusions were obtained:

✓ Depth to bedrock → Korea << WUS
   Soil stiffness → Korea > WUS

✓ Site period → Korea (0.1 to 0.4 sec) << WUS (0.2 to 1.8 sec)

✓ Spectral acceleration in response spectra from site response analyses
   → Analyses for C and D sites in Korea > Design code (near the site periods)

✓ Site coefficients, $F_a$ & $F_v$, from site response analyses
   → $F_a$ (1.0 to 3.0) in Korea > $F_a$ in Design code
   → $F_v$ (1.0 to 1.5) in Korea < $F_v$ in Design code
Thank You !!