Influence of Uncertainties in Site Response Analysis on Seismic Assessment of a Tall Building

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Performance Based Design in Earthquake Engineering

Seismic Hazard

- Earthquake
- Ground Motion
- System Response

Seismic Risk

- Physical Damage
- Loss

Structural Response of Two Mix-Use Towers (25- and 20-stories)

- Maximum Story Shear
- Maximum Story Drift
- Peak Floor Acceleration

Seismic Hazard (2% PE in 50 years)

PSHA-Rock

Soil Motion

Bedrock

Code Based Approach

Hybrid Approach

Convolution Approach
Site-Specific Ground Motion

**Code Based Approach**

USGS Seismic Design Maps 2475-year

Seismic Design Parameters $S_s$ & $S_1$

Site Factors $F_a$ & $F_v$

$S_s \cdot F_a$

$S_1 \cdot F_v$

**Hybrid Approach**

Rock UHS

CMS PGA

CMS $T=1$s

CMS $T=2$s

**Convolution Approach**

PSHA - Rock

AFE (1/yr)

Vs Realizations

Vs (m/s)

Depth (m)

Depth (m)

Vs (m/s)

Vs (m/s)

PGA

PSHA - Soil

AFE (1/yr)

Vs Realizations

Vs (m/s)

Depth (m)

Depth (m)

Vs (m/s)

Vs (m/s)

PGA

\[ \ln(\text{AFE}) = a_1 + \sum a_k \cdot \ln(\text{PGA}) \]

\[ (S_{u\max} > z) = \sum P \cdot \left( \frac{z}{S_{u\max}} \cdot (S_{u\max} - P(S_{u\max})) \right) \]
Comparison of Site Response Approaches

**Code Based Approach**
- Accounts for variability of rock ground motions
- Not directly accounts for uncertainty in soil profile
- **Not accurately represent Target Hazard Level**

**Hybrid Approach**
- Accounts for variability of rock ground motions
- Not directly accounts for spatial variability in soil profile
- Demonstrate the sensitivity of site response to stiffer and softer soil profiles
- **Not accurately represent Target Hazard Level**

**Convolution Approach**
- Accounts for variability of rock ground motions
- Accounts for spatial variability in soil profile
- Accounts for uncertainties in Site Response
- **Accurately represents Target Hazard Level**
Site-Specific Site Response

Convolution Approach vs Hybrid Approach

~ 45% higher at the Site Period (T = 0.8 s)
~ 120% higher at Predominant Period of the structure (T = 2.0 s)

Convolution Approach predicts up to 19% higher at short periods
At T = 2.0 s the Design SA based on convolution method is 35% higher than that based on hybrid approach

The soil-structure interaction (SSI) effects due to kinematic interaction are considered separately with analytical effects.
Structural Response

### Linear Response Spectra Analysis

<table>
<thead>
<tr>
<th>Approach</th>
<th>Base Shear (kN)</th>
<th>Roof Drifts (% of height)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hybrid</td>
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<tr>
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<td>Y</td>
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<tr>
<td>Convolution</td>
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<tr>
<td>Y</td>
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<td>1.72</td>
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</table>

Based on the NLRH analysis results, less structural enhancements are required to ensure adequate performance when compared to the RS analysis (for a design in Montreal).

### Nonlinear Response History (NLRH) Analyses

Performance Based Design

Peak Floor Accelerations & Drift Ratios are observed to be more sensitive to the Site Response Approach employed.

Convolution Approach produces drifts up to 35% higher than the Hybrid Approach.
Thank You

For Questions:

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