Determination of Site-Specific Ground Motions per Chapter 16.2 of ASCE 7-16 and 2017 Tall Building Initiative Guidelines

C. B. Crouse

November 22, 2019
- **Target Response Spectrum/Spectra**
  - Multiple target spectra
  - 1\textsuperscript{st} & higher building modes

- **Time-History Selection & Scaling**
  - Use of 3-D numerical simulations
  - Spectral matching (?) in Amplitude scaling
Target Response Spectra

- Method 2 (multiple response spectra) – ASCE 7-16, Sect. 16.2.1.2
  - Conditional Mean Spectra
  - Scenario Response Spectra

“target response spectra"
Method 2 Requirements - ASCE 7-16, Sect. 16.2.1.2

\[ S_a \]

- \( MCE_R \) (Method 1)
- Target Spectra
- \( S_a(T_i) \geq MCE_R \)

\( T_2 \)
\( T_1 \)

\( \geq 2 \) Conditioning Periods
PEER (2017) TBI says:

- When both natural periods for similar modes in the two building directions are similar, one scenario spectrum can be used.
- In that case the scenario spectrum should match or exceed the $MCE_R$ between these two periods.

Purpose

- Only need one set of time histories
- Otherwise, two sets would be required
Illustration for Scenario Spectrum for 1st Mode Periods

- CMS for $T_{1X}$
- CMS for $T_{1Y}$
- Scenario Spectrum

Advantage: Only one set of $\geq 11$ time histories is required
Method 2 Requirements - ASCE 7-16, Sect. 16.2.1.2

\( T_{LB} \) to \( T_{UB} \) = Period Range of Interest, Sect. 16.2.3.1

Envelope of Target \( S_a \) \( \geq 75\% \) MCE\(_R\) (Method 1)
Period Range for Modification – Sect. 16.2.3.1

\[ S_a \]

\[ T_{LB} \leq 0.2T_{1\text{smallest}} \]

\[ 1.5T_{1\text{largest}} \leq T_{UB} \leq 2.0T_{1\text{largest}} \]

90% Modal Mass in \( T_{LB} - T_{UB} \) Band

Justified by Dyn. Analysis
No. of records ≥ 11 for each target spectrum

Record characteristics

- From same tectonic regime as site
- Consistent with disaggregations
- Simulated ground motions permitted “when required number of recorded motions is not available”
Quiz: Which are M9 synthetics & actual records from Maule & Tohoku Earthquakes?

Velocity waveforms (0.25-1.0 Hz)
Velocity waveforms (0.25-1.0 Hz)

Maule EQ, CRMA near Santiago

Tohoku EQ, MYGH12 EW

M9

M9

M9

M9

m/s

Time (s)
3-D Ground Motion Simulations

- M9 EQs on Cascadia Subduction Zone
  - Contact N. Marafi (U of WA)

- M8 EQs on S. San Andreas fault & M7 EQs on local L.A. faults
  - J. Baker is developing records for L.A. area (SCEC-UGMS)

- Simulations cover broad period band
  - Stochastic high frequency motions added

- Maintain Directionality for Specific Sites
  - Rotations not allowed; transformations permitted
Ground Motion Modification – Sect. 16.2.3

- Amplitude-Scaled – Sect 16.2.3.2
- Spectrally Matched – Sect. 16.2.3.3
Amplitude Scaling – Sect 16.2.3.2

Ave. Scaled Max-Direction $S_a(T)$

~ to Target, but ≥ 90% Target

Target
90% of Target

$T_{LB}$  $T_{UB}$

$S_a$  $T$
Amplitude Scaling – Sect 16.2.3.2

- Should minor spectral matching be permitted?

![Graph showing seismic data with various events and target values.](image)

- 1940 Imperial Valley, El Centro (2.00)
- 1971 San Fernando, 8244 Orion Blvd. (1.74)
- 1979 Imperial Valley, El Centro Diff Array (1.74)
- 1989 Loma Prieta, Saratoga Aloha Ave. (1.88)
- 1992 Landers, Yermo Fire Station (2.00)
- 1994 Northridge, Sylmar Hospital (1.10)
- 1999 Duzce, Turkey, Duzce Station (1.36)
Spectral Matching – Sect 16.2.3.3

- criteria as amplitude scaling except

Ave. Matched Max-Direction $S_a(T)$
Must Envelope 110% Target

$S_a$

110% of Target

$T_{LB}$

$T_{UB}$
Near Field Motions – Sect. 16.2.4

- $a(t)$ provided in FN & FP directions
- Transformed to principal bldg. directions, x & y
- Site-specific simulated motions (near & far field) also should be transformed
Non Near Field Criterion for Ave. $S_{a}^{x}(T)$ & $S_{a}^{y}(T)$ - Sect 16.2.4

Mean = $\frac{1}{2} \left[ S_{a}^{x}(T) + S_{a}^{y}(T) \right]$
Conclusions

- Per PEER TBI, only one set of $a(t)$ needed for scenario $S_a(T)$ covering both $T_{ix}$ & $T_{iy}$ of a given $i^{th}$ mode

- Broadband 3-D simulations are permitted

- Minor spectral matching not permitted when using Amplitude Scaling
  - Proposal to permit it may be developed