Concepts for Evaluating Spectrally Matched Time Histories for Performance Based Design of Tall Buildings

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Nonlinear Response History Analysis

1. Develop Response Spectrum
2. Select and Match EQ Time Histories
3. Calculate Response
Hazard in Los Angeles, PGA to ~2s
Hazard in Los Angeles, $T > 2s$
Sample Population

Developing a suite of at least 11 THs to capture a broad range of EQ characteristics

Define your sample space carefully

✓ Are pulses expected?
✓ If so, how likely and what pulse period range?
✓ How many distant Eqs are needed (higher M, longer dur)?

ARP = 2,475 yrs
SA(3.5s) = 0.19g
Seed Record Selection

Based on:
- Magnitude
- Distance
- Site Class
- Source Type
- PGV
- Spectral Shape
- Sig. Duration
Seed Time History Spectra
Long Period CMS
Seed Time History Spectra
Short Period CMS
Spectrally Match Time Histories
Is Spectral Matching Still Worth It?

The newest wrinkle in Chapter 16 of the ASCE 7-16 code is the removal of the previous Square-Root-Sum-of-Squares (SRSS) check.

The updated ASCE 7-16, Section 16.2.3.3 also enforces a penalty for spectral matching, requiring that the avg maximum direction spectra for the suite equal or exceed 110% of the target spectrum (MCE$_R$).
Orbital Spectral Displacement

$M_W 7.4$

$R_{RUP} 2km$

$R_{JB} 0km$

Pulse-like
Orbital Spectral Displacement

$M_W 7.4$
$R_{RUP} 2\text{km}$
$R_{JB} 0\text{km}$
Pulse-like

As-Recorded 4s SD
Orbital Spectral Displacement

$M_W 7.4$
$R_{RUP} 2\text{km}$
$R_{JB} 0\text{km}$
Pulse-like

After Matching 4s SD
Orbital Spectral Displacement
Orbital Spectral Displacement
Matched Pair RotD100

When oriented pairs are developed as FN matched to the RotD100 and FP matched to RotD50, the results inherently meet the spirit of ASCE 7-16 in that the overall demand in the principal directions of the building is above the MCEₕ on average.
What about distant EQs?

Oriented ground motion would not be expected

Seeds much more “balanced” overall

Using RotD100 as one of the targets implies some certainty that the max demand will correspond with a principal orientation of the building

Using RotD50 as the matching target for both components with balanced seed can result in an overall response that max excursion undershoots the RotD100
Balanced Pairs Impacted Significantly

To meet the requirement of ASCE 7-16 (matched RotD100 110% of MCE\textsubscript{R}) both components would need to be scaled up by \textasciitilde20%.

This is a very serious penalty and further evaluation of the directional characteristics of the pair is warranted.
Basis of Penalty?

Stated purpose of penalty is variability is reduced and median response biased low due to spectral matching

Implication is in 2D the demand is lower on average when the excursions are smoothed in each component independently

*This can be checked for any pair and compared to the expected distribution*
So What About Scaling Then?

Limitations:
- More difficult to develop a stable median response
- Model convergence issues for GMs with outlier excursions
- Tendency to select smoother spectra seeds and bias away from pulse-like GMs
- Uncertainty within suite can be higher than uncertainty in the PSHA for given hazard level
Happy Medium?

Mean Spectrum Matching Approach proposed by Mazzoni et al., 2012

- Match to the target spectrum on average
- Minimizes modification to the ground-motion records
- Preserves time domain characteristics of the individual record
- Parameterization of the uncertainty enables control over the dispersion of spectral acceleration
Practical Example
Conclusions

Seed selection and sample population have first order importance to developing a reasonable sample of time histories.

Spectral Matching can be done in a way that appropriately represents the natural phenomena without creating the issues that would require penalties.

Scaling in lieu of matching has been incentivized and should be considered and explored by design teams.

Hybrid approaches, where average demand and uncertainty are achieved, represent the future of this practice, however, more work is needed to define the target uncertainty.
Q&A
Discussion