Current Practices in Time History Selection in the Near Field Region

Debra Murphy, PE
Process for Selecting Time Histories

• Key Issues:
  – Time history selection is based on tectonic properties, but the analysis is of an earthen or built structure.
  – Non-linear response of structures is sensitive to the selected time histories
  – How do we know which to select? Do we want average response or a reliable estimate of variability?
  – What is the appropriate method of modification that is consistent with the design spectrum and the planned analysis?
Process

- Geologist
- Seismologist
- Structural Engineer
- Geotechnical Engineer
Development of Design Ground Motions

- Regulatory and Guiding Documents
  - NUREG 1.208 (PBE)
  - ASCE/SEI 7
  - ASCE/SEI 41
  - ASCE/SEI 4
  - California Building Code
  - Tall Building Initiative
  - Local Codes
  - NUREG 6728
  - NEHRP
  - NEA/CSNI/R(2015)9

COSMOS Technical Session
November 22, 2019
Development of Design Ground Motions

- Probabilistic
- Deterministic
- Code-based $MCE_R$ and DE
- Risk-based
- Multiple Conditional Mean Spectra
What are Key Features of Near-Fault Ground Motions?

- What does your structure respond to?
- Does the second mode dominate nearly as much as the first?
- What is a pulse trying to model?
  - Large amplitude arriving over a short time
  - Pulse period should be relevant to the structure
Directivity

- Related to the direction of the rupture
  - Forward directivity: rupture toward the site (site away from the epicenter)
  - Backward directivity: rupture away from the site (site near the epicenter)

- When should directivity be considered?

- Which models should be applied?
  - Rowshandel, B. (2013)
  - Spudich, P. and Chiou, B. (2013)
Fling

• One-sided velocity pulse due to tectonic deformation
• Occurs at sites located near the fault rupture independent of the epicenter location
Velocity Pulses

• Pulses Records
    • Objective approach
    • Limitations
      – Need multiple parameters
        » Pulse exists
        » Period of pulse
        » Amplitude of pulse
      – Related to amplitude, but not strong correlation with structural response given the same amplitude
  – Quantification of pulses
    • 2011 NEHRP JV (ATC + COSMOS)
    • 2014 Hayden, C., Bray, J., and Abrahamson, N.
Velocity Pulses

Example: Wavelet Decomposition for Pulses

(From: Baker, J. 2007)
Velocity Pulses

Large Variability in Pulse Period
Instantaneous Power

• How do we identify records with a significant amounts of energy in a short amount of time?
  – Parameters of a full record miss this characteristic

• Instantaneous Power – is a measure of the energy per second at the time of the peak velocity
  – Intended to captures key damaging features of near-fault ground motions
  – Models the relevant response to the structure

From: N. Abrahamson
Record Rotation

- **Pulse Orientation**
  - Since 1990s, directivity has been explained as being polarized on the FN component
    - Over sold this concept
  - Wide range of orientation of maximum PGV
    - Tendency for FN to be the largest PGV for forward directivity, but large range

Note: Larger IDP means Forward directivity

From: Hayden et al. (2014)
Record Rotation

• Rotation of time histories
  – When should you rotate?
    • Building code: Sites within 15 km of an active fault
  – Fault Normal/Fault Parallel
    – H1 is the positive x direction
    – H2 is the positive y direction – which should be 90 degrees counterclockwise
    • Maximum component can be either Fault Normal or Fault Parallel or neither
  – Randomized rotation
    • At what distance is this applicable?
Record Rotation

![Graph showing spectral acceleration vs period with different rotation methods]

- Fault Normal - Rotated per Right Hand Rule
- Fault Normal - Rotated Alternate Method

Following previous slide

Alternative rotation
Scaling vs. Matching

• Scaled time histories  
  – Per a single component  
  – SRSS of the horizontal components  
  – Vertical component

• Spectral Matching  
  – Maintain component to component variability  
  – Tight match  
  – Loose match
Spectral Matching - Maintaining H1-H2 Differences

- PSA (g)
- Period (sec)
- Geometric Mean Target
- Geometric Mean matched
- H1 Matched
- H1 Initial scaled
- H2 Matched
- H2 Initial scaled

COSMOS Technical Session
November 22, 2019
Process for Selecting Time Histories

Example Code Guidelines:
• CBC 2018 modifications to ASCE/SEI 7-10 & 41-13

Is there an active fault within 5km of site?

- Yes: Select 7 time histories
- No: Select 10 time histories

Rotate time histories to FN/FP

Scale time histories per FN component

Scale time histories per SRSS
Process for Selecting Time Histories

Example Code Guidelines:

- ASCE/SEI 41-13
Example Code Guidelines:

- ASCE/SEI 7-16

* Exception: Faults with SR <0.04in/yr or surface projections shall not include portions of the fault at depth >10km
Example Code Guidelines:

- ASCE/SEI 7-16

* Exception: Faults with SR <0.04in/yr or surface projections shall not include portions of the fault at depth >10km
Process for Selecting Time Histories

• Proposed ASCE/SEI 7-22
  – Additional Site Classifications added at the boundaries of existing Site Classifications
  – Proposed Code-Based MCE$_R$ and Design Spectra will be multi-period
  – Proposed new Deterministic Lower Limit uses $M_w$ 8 at about 12.5 km across the entire US and utilizes the default PEER NGA-West2 basin parameters.
  – Other items
    • Time history modification criteria under committee discussion
    • Proposed commentary may be added regarding rotation of time histories
Example Code Guidelines:

- **ASCE/SEI 4-16**
  - Compare median ratio per component to the target, no coordinate shall exceed 0.1 and the log standard deviation should not exceed 0.2.
  - The average ratio of the spectral accelerations to the target in the frequency range of interest is equal to 1.0
  - The minimum and maximum ratios of the acceleration to the target shall be 0.75 and 1.3, respectively
Time History Selection

Considerations:

- Tectonic setting
  - Active
  - Stable continental
  - Subduction

- $M_w$

- Rupture distance

- Style of faulting

- $V_{s30}$

- Free-field recording

- Spectral shape

- Duration

- Scale factor

- Structure-specific GM parameters

Graphic From:
Time History Selection

- Southern California
- Pacific Northwest
Time History Selection

Technical Basis for Revision of Regulatory Guidance on Design Ground Motions: Hazard- and Risk-consistent Ground Motion Spectra Guidelines

PEER Ground Motion Database
Pacific Earthquake Engineering Research Center

Strong-motion Seismograph Networks (K-NET, KiK-net)
Ground Motion Intensity Parameters

Considerations:

• Estimate $D_{5-75}$, $D_{5-95}$, PGA, PGV, PGD, CAV, AI using controlling sources

• Compare final suite parameters to expected values

References

• 1996 - Abrahamson & Silva
• 2001 – NUREG 6728 – Risk Engineering
• 2003 - Travasarou, Bray & Abrahamson
• 2006 – Kempton & Stewart -> 2016 - Afshari & Stewart
• 2009 – Bommer et al.
• 2011 – Foulser-Pigott & Stafford
• 2012 – Campbell & Bozorgnia
• 2016 – Abrahamson, C., Shi, Yang
• 2019 – Macedo, Abrahamson & Bray
Conclusions

• Understanding the project needs and requirements is essential for selecting a strong suite of time histories
  – Engineers should run simpler models with larger numbers of GMs to understand what dominates the response of their structure

• What are the objectives?
  – Is the analyst looking for an average response or a reliable estimate of variability?

• For near-fault ground motions is it time to replace the velocity pulse?

• COMMUNICATION COMMUNICATION COMMUNICATION COMMUNICATION