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Criteria for Selection of Seed Motions to Envelop Design Response Spectra

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Introduction

- Recently, *CJC&A* has performed several studies regarding seed record selection used in the development of acceleration time histories for input into seismic analyses.
  - Primary issue – how does the seed record affect computed structural response.
- This presentation is the result of two publications, as well as insights developed from the following DOE projects:
  - SSI analysis of the Uranium Processing Facility (Y12)
  - Probabilistic SSI analysis of PF4 (LANL)
  - Preliminary SSI analysis of CMRR (LANL)

Background

- Current design procedures used to develop synthetic time histories for the analysis of nuclear facilities are:
  - Define seismic input into system as 5% damped Design Response Spectrum (DRS) based on Uniform Hazard Spectrum (UHS)
  - Select a seed record to be used in fitting process to provide phasing content of the synthetic record (usually based on magnitude, distance and site characteristic defined in PSHA).
  - Use ASCE 43-05 fitting procedures to develop synthetic motion to fit target 5% damped DRS.
  - This process is repeated to produce 1 set of three time histories for structural response calculations (2 horizontal and 1 vertical record).
- The primary issue of concern at the outset of the studies is what role does seed record selection have on computed structural response.
  - Are current criteria of magnitude/distance binning important?
  - Can seed characteristics be correlated to response?

Discussion Topics

- Outline of the methodology and results of published studies regarding time history development and SSI response.
- Examination of project specific results from analyses performed by *CJC&A*.
- Current draft criteria in ASCE 4 regarding seismic input.

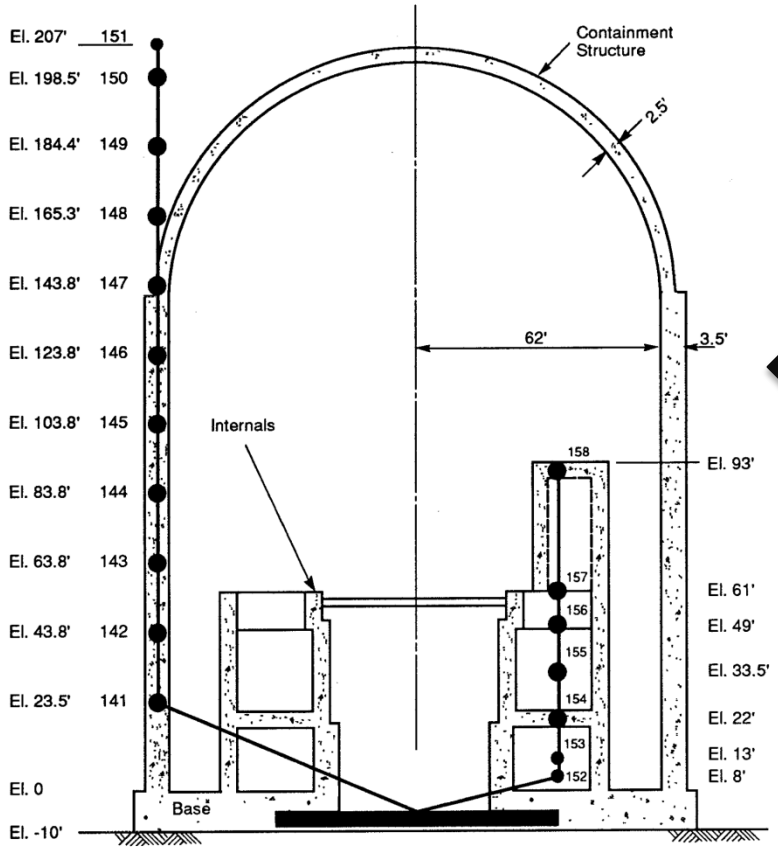
Publications

- CJC&A has published two recent papers discussing this topic:
  - Houston, T., et al, "*Investigation of the Impact of Seed Record Selection on Structural Response*," PVP2010-25, ASME 2010 Pressure Vessels and Piping Division, July 2010.
  - Costantino, M., et al, "*Case Study of the Sensitivity of Structural Response to Seismic Event Parameters*," ICONE19-44137, 19th International Conference on Nuclear Engineering, May 2011.

Study Methodology

- Evaluation of seed records was performed through SSI analyses for multiple sites and structures.
- Site specific SSI transfer functions were developed for each site and structure.

SSI Problem Definitions

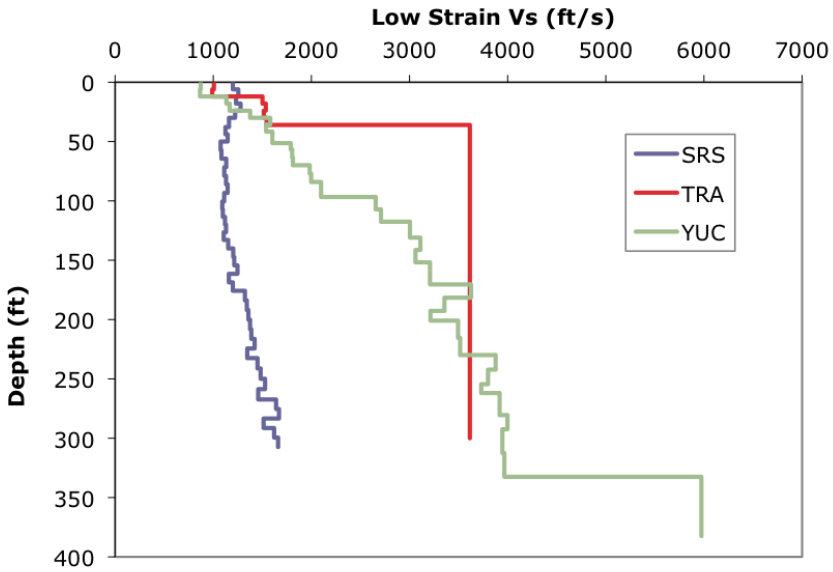


Definition of the structure is varied:

- Surface and embedded
- Natural frequency of superstructure is varied

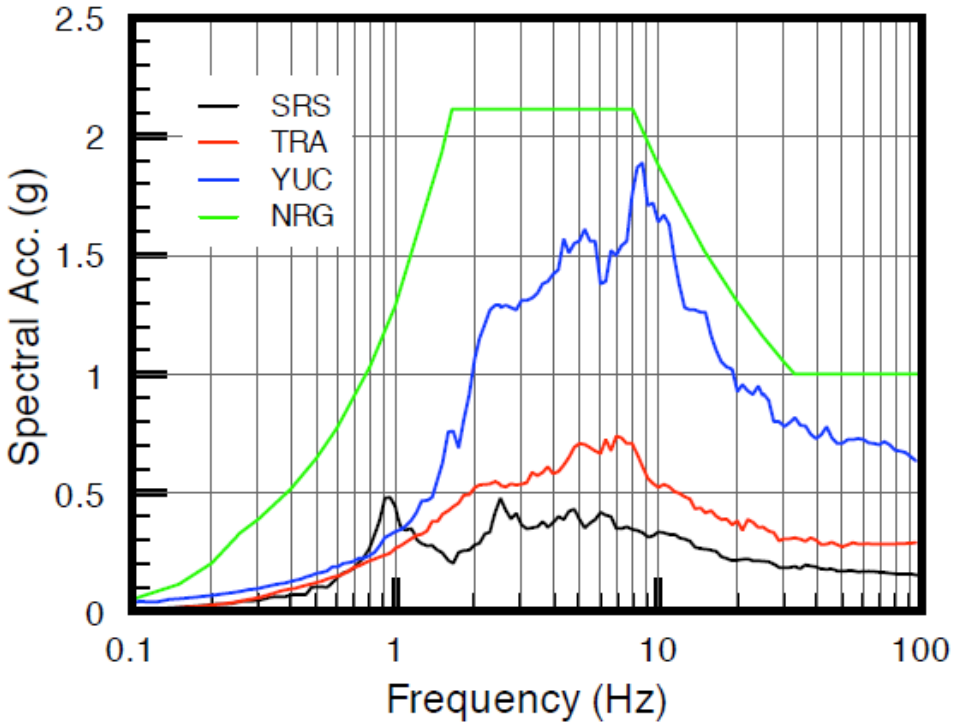
Three free field site definitions:

- Soft soil site typical of a Savannah River Site (SRS) profile
- Layered alluvial site typical of the Test Reactor Area (TRA) of INL
- A deep stiff site typical of the Yucca Mountain project (YUC)



Surface 5% Damped Design Response Spectra

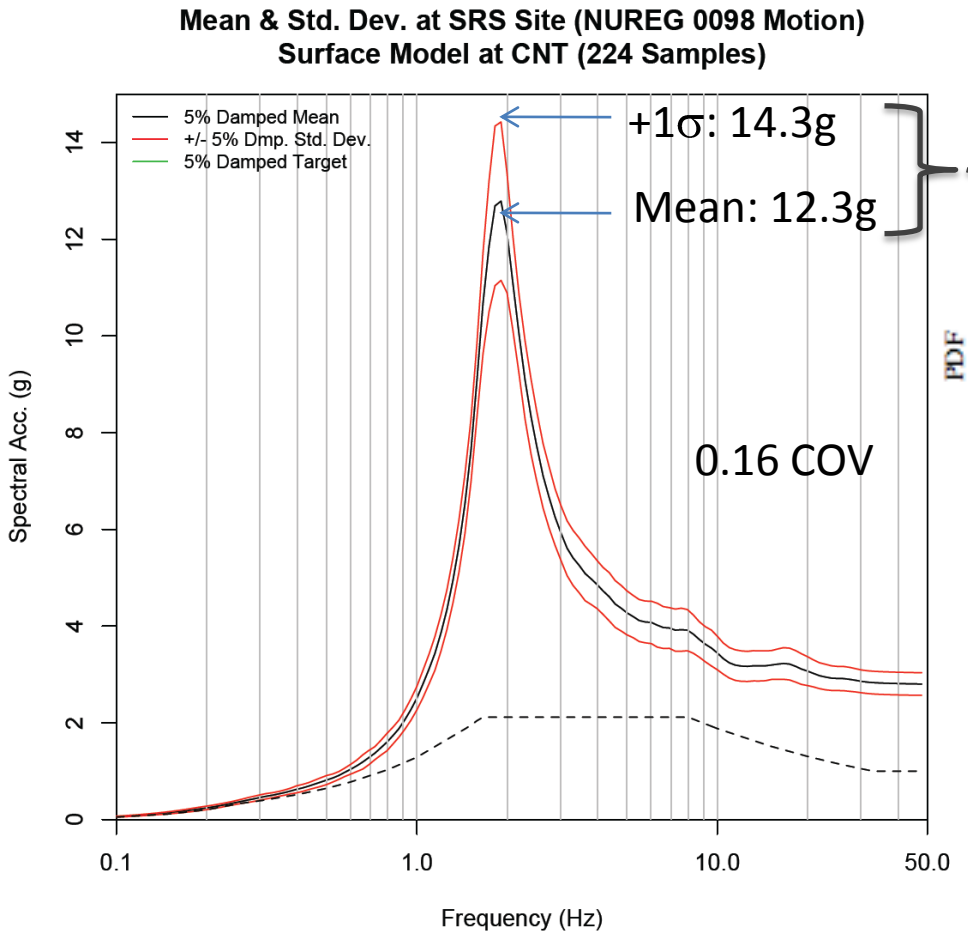
- Three site specific DRS were generated for each site.
- One generic DRS (NUREG-0098) shape was applied to the SRS SSI analysis.
- Selected seed records were modified to match the target DRS according to procedures defined in ASCE 43-05.

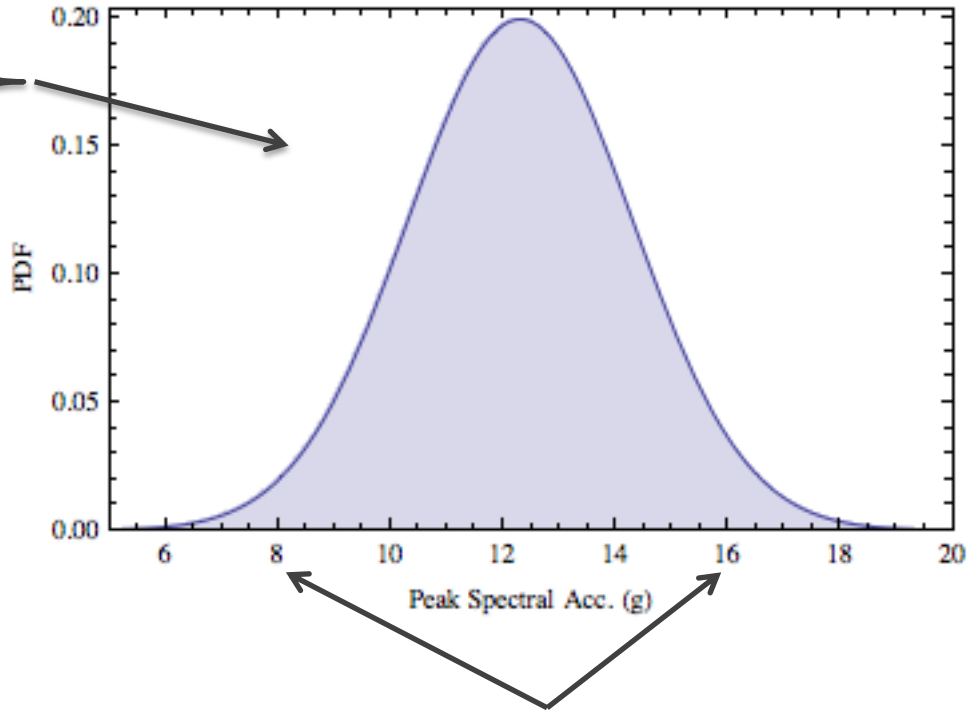


Seed Record Selection

- Seed records were selected from the following sources:
  - NUREG CR/6728 empirical database
  - Next Generation Attenuation (NGA) database
- The 6728 database consists of 324 seismic records separated by “bins” delineated by region, site type, magnitude and distance.
- The NGA database contains over 3500 records from approximately 170 events.
  - The NGA database provides a larger data source with specified parameters which makes it a good tool for statistical regression/analysis.
- Several hundred seed records were selected at random for each SSI case.
  - Each seed is modified to fit the target DRS
  - SSI response is computed through convolution of the fitted motion with the SSI transfer function
  - Statistics of response are computed for each SSI case

Typical Results





Ratio of peak spectral structural response between any two records can be as high as a factor of two or more.

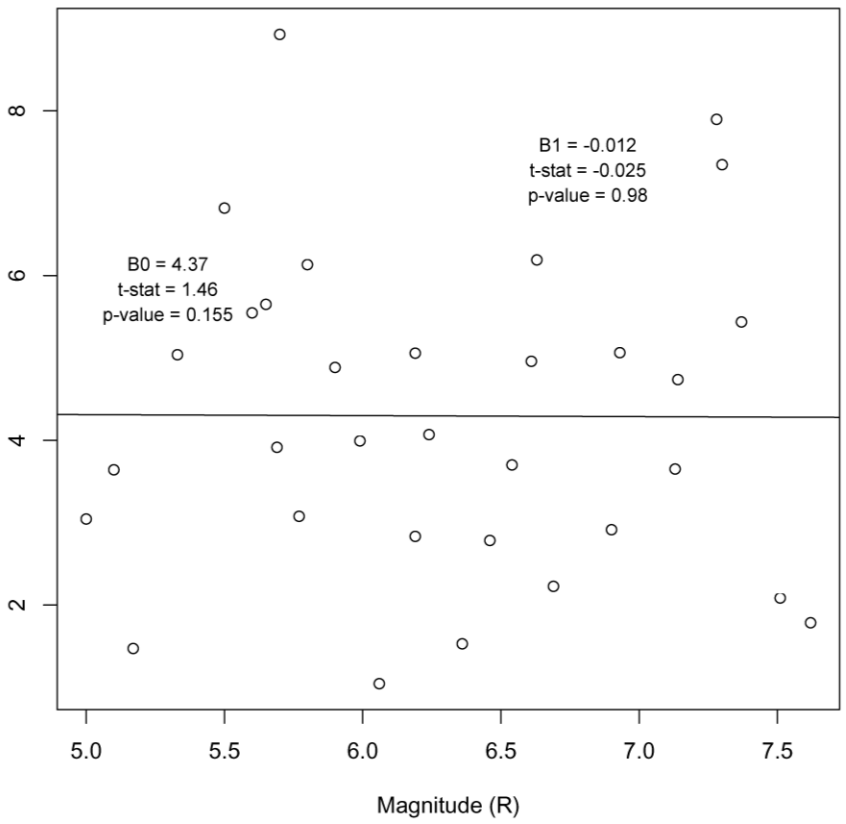
Typical Results (2)

- The study indicates that SSI (structural) response can be very sensitive to seed record selection.
- Computed in-structure response can be significantly conservative or unconservative.
- Lower damped SSI responses show greater variability in average peak spectral response.
- Caused by localized spikes and valleys in the power spectral density of the fitted motions.

Seed Record Characteristics

- According to procedures defined in ASCE 43-05, seed records selected for modification are chosen based on seismicity appropriate for the site (magnitude, distance, etc.).
- The average peak spectral response of the SSI results are regressed against seed record characteristics.
- Seed characteristics chosen for regression are:
  - Magnitude
  - Distance
  - Seed direction (horizontal or vertical)

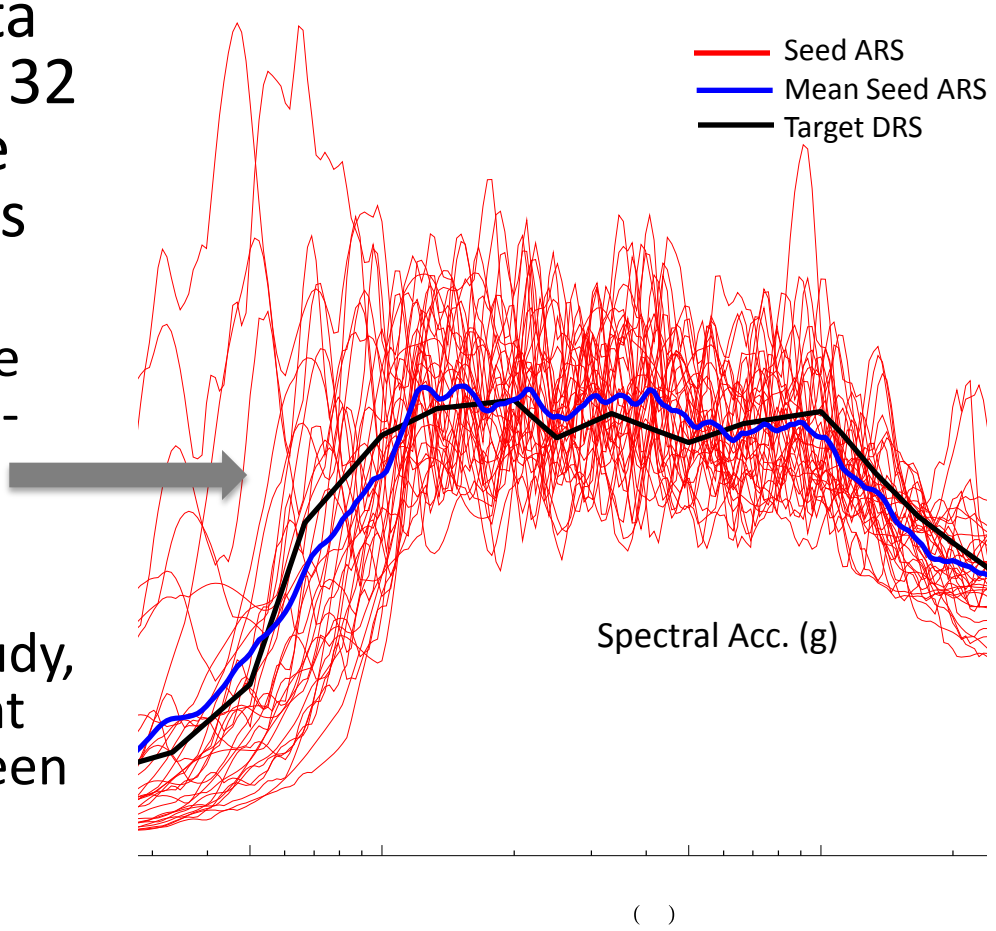
Typical Results



- Plot shows a linear regression of average peak spectral response versus magnitude for the embedded structure at the TRA site.
- No correlation can be made between magnitude and peak spectral response.
- This was typical for all seed characteristics.

Results of Study of Seed Characteristics

- An additional set of data was analyzed based on 32 fitted motions from the probabilistic SSI analysis of PF4 at LANL.
  - Seed time histories were selected based on "best-fit" shape of the seed spectrum to the target DRS.
  - Similar to the full SSI study, no statistically significant correlation found between seed mag./distance or direction.



Conclusions from Studies

- Structural response from 1 synthetic input motion can be significantly unconservative.
- Seismological characteristics are not important for seed selection in linear response analysis (magnitude, distance, direction, etc).
- Seed selection based on spectral shape ensures that the seed records have energy in the frequency range of interest.
  - Selection ignoring shape can result in records with no energy in important frequency range (scaling of white noise)

Recommendations from Studies

- A suite of input motions should be used from multiple seed records (currently 5 input time histories have been used).
- Spectral shape of the seed record should be included as a factor for seed selection.
- A methodology was proposed for selection of a single set of time histories.
  - Fit to 5% damped DRS
  - Develop alternate target DRS (2% and 20% damped targets)
  - Alternate targets are developed based on mean spectral ratios from “best-fit” seed records.
  - Alternate damped spectra of single fitted records must be checked against alternate damped DRS.
  - Input motion can be scaled at specific frequencies to ensure computed spectra are conservative relative to DRS.
  - This can result in conservative input motions for lower damped systems.

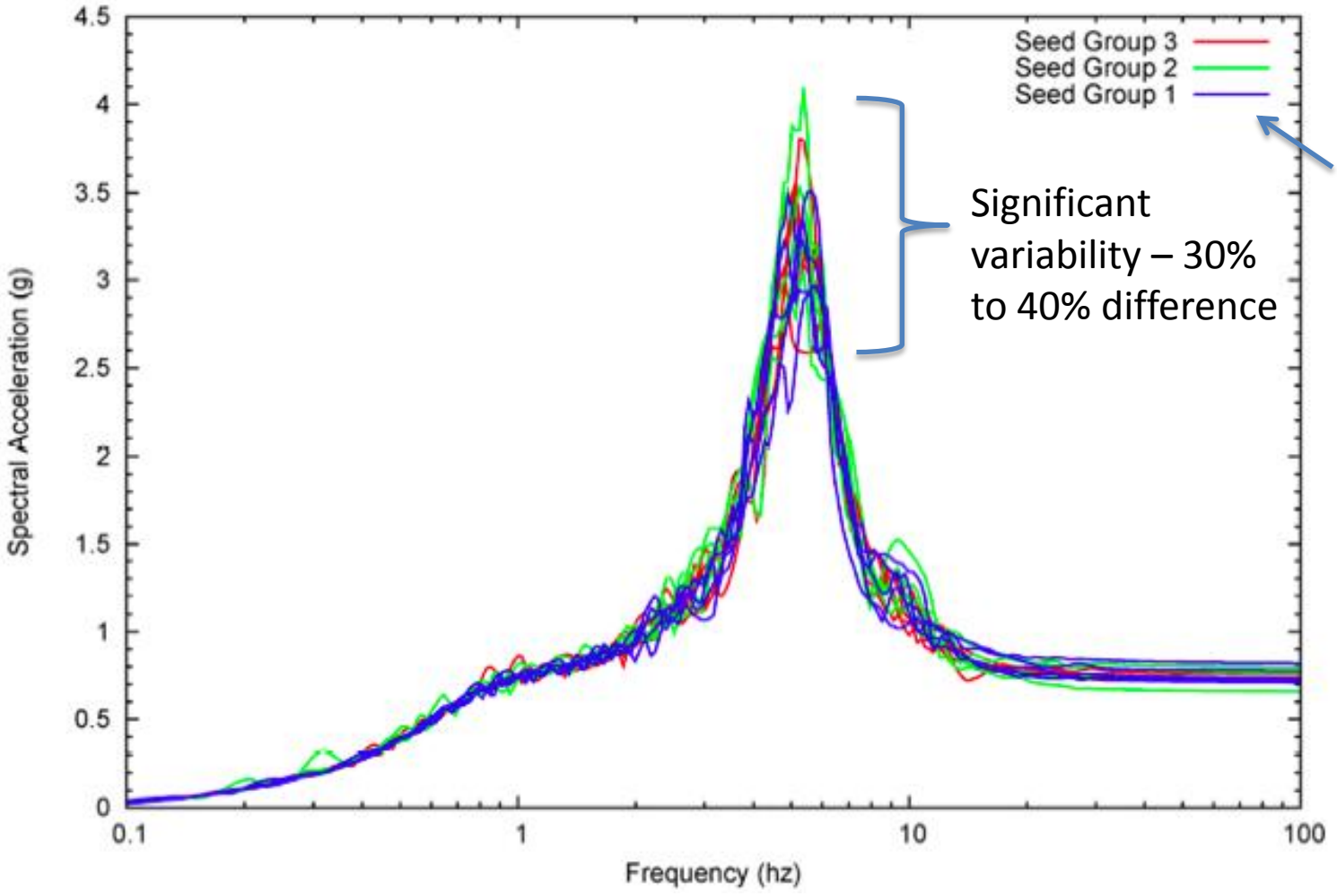
Results from Project Specific Analyses

- The following slides examine project specific results regarding seed selection.
- The projects considered are:
  - Preliminary SSI analysis of CMRR (LANL)
  - SSI analysis of UPF (Y12)

CMRR Preliminary SSI Analysis

- A study was performed for the CMRR project which groups synthetic input time histories by various seed selection methods.
- The subsequent figures provide the following insights:
  - Consistent with the previous studies, significant variability of response is observed between individual seed records.
  - The average response due to 5 input time histories provides stable results.

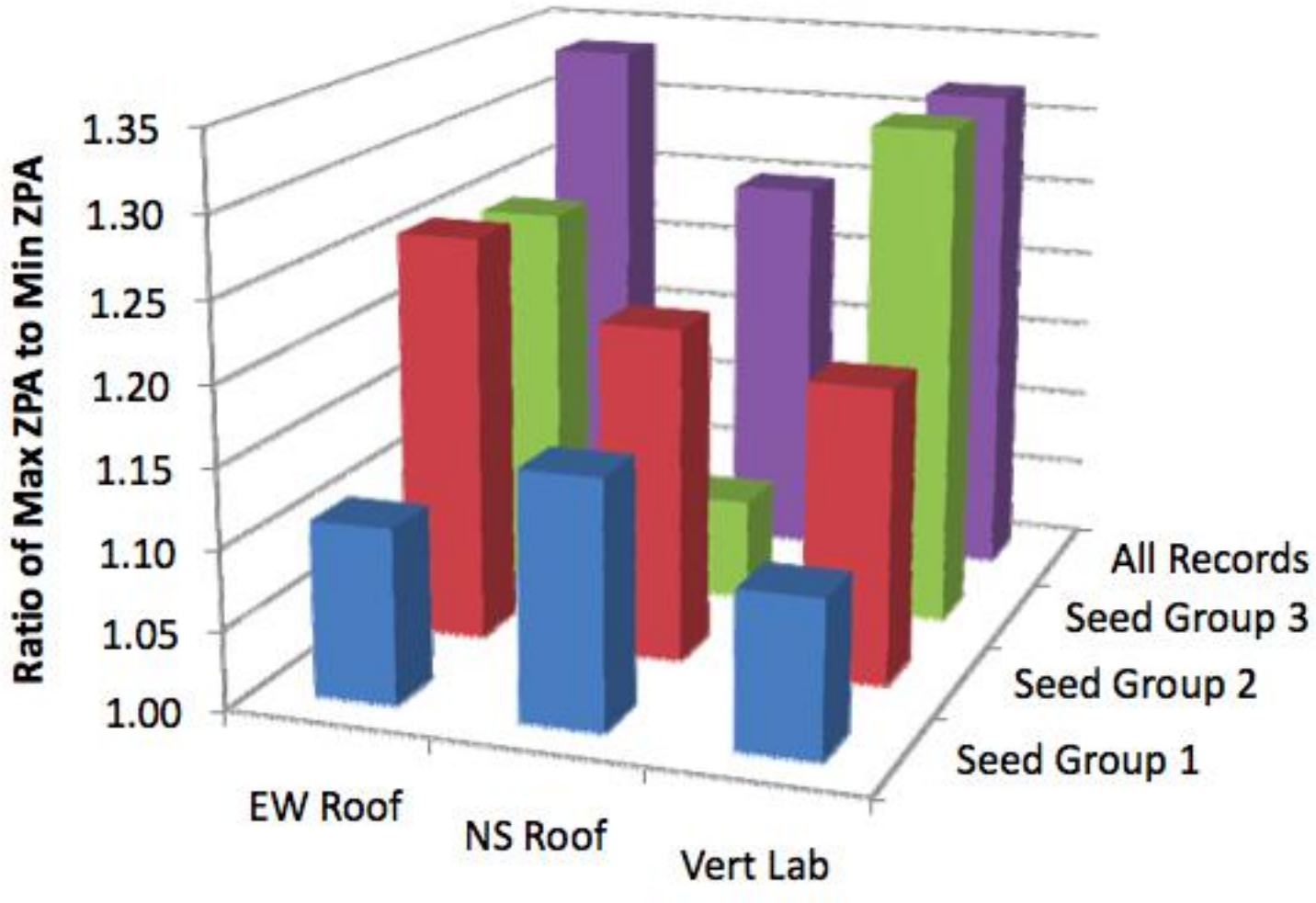
CMRR Horizontal 5% Damped Roof ISRS for Various Seeds



Significant variability – 30% to 40% difference

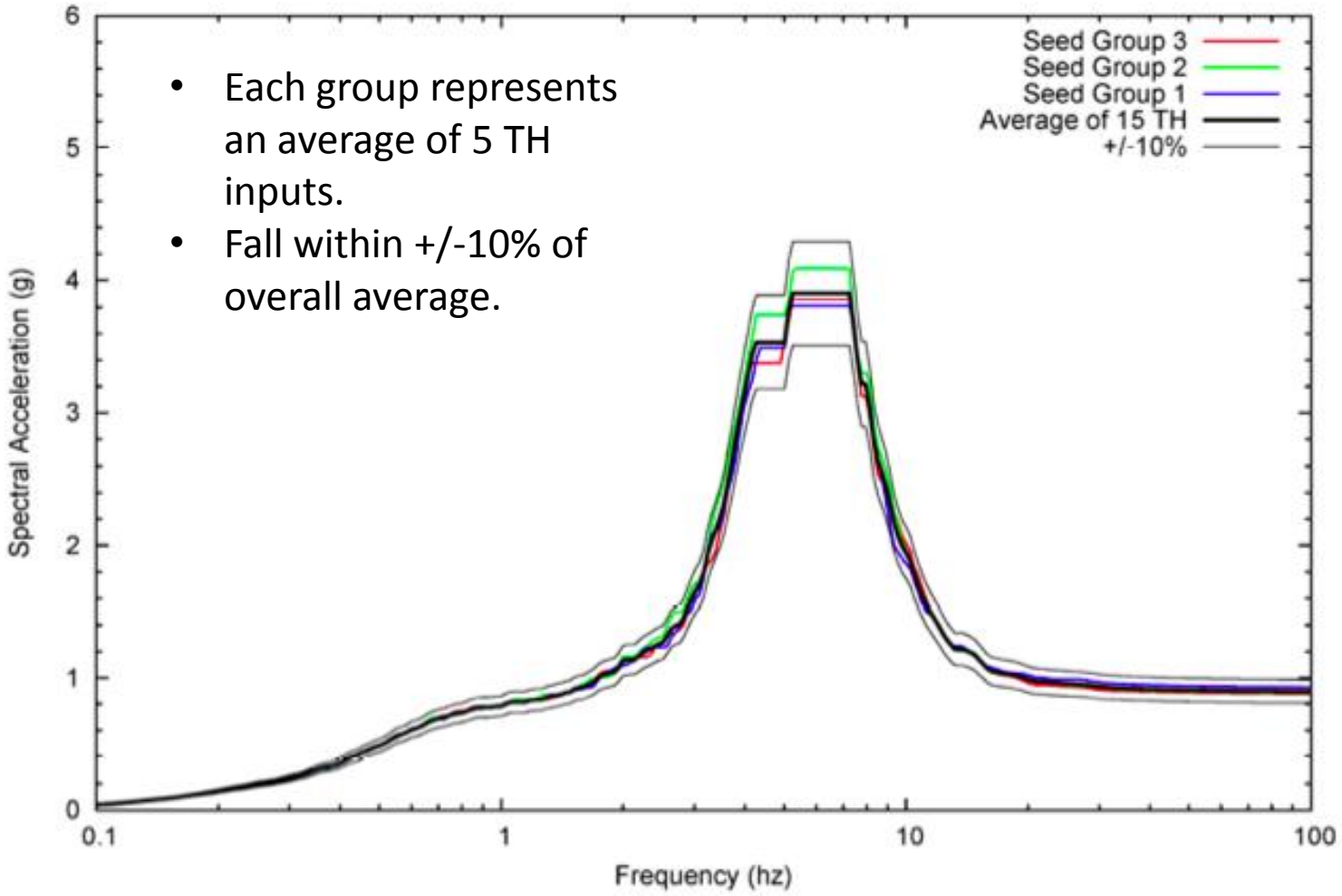
5 Time Histories In Each Group

CMRR Ratio of Maximum To Minimum Peak Acceleration due to Seeds

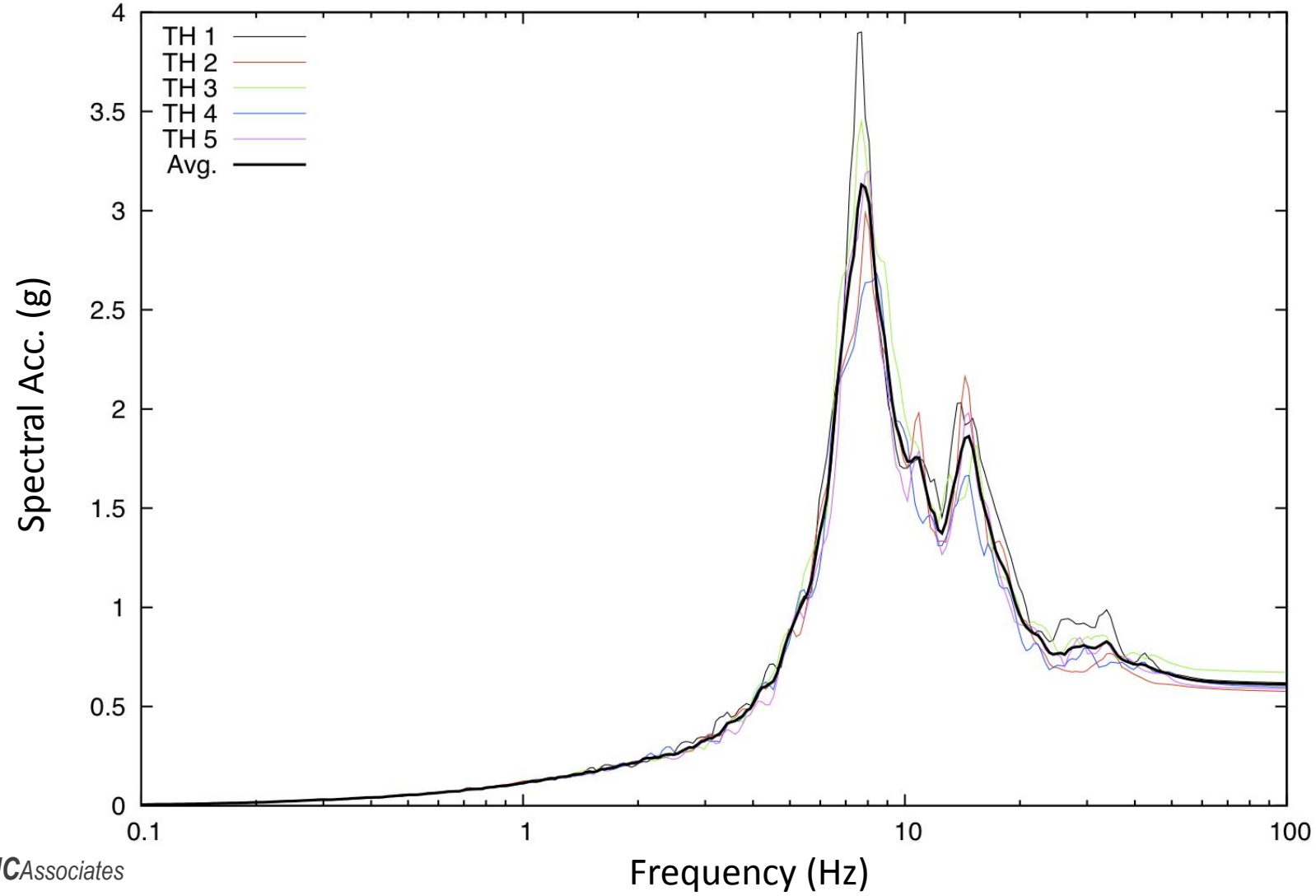


CMRR Comparison of Enveloped/Broadened ISRS due to Average of 5 Time History Seeds

- Each group represents an average of 5 TH inputs.
- Fall within +/-10% of overall average.



UPF – EW 5% Damped ISRS at Intermediate Floor Level



Status of Draft ASCE 4

- The draft version of ASCE 4 deals with time history variability through the following methods:
  - For linear elastic analyses, computed response shall be the average of five input time histories.
  - Or, the analyst may use a single set of time histories but its use must be justified through appropriate analysis/sensitivity studies.
- Selection of seed records must include spectral shape as a selection parameter.