EVALUATION OF TWO GROUND MOTION SCALING METHODS TO ESTIMATE MEAN STRUCTURAL DEMANDS

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Synopsis & Outline

Dynamic analyses as a part of performance based evaluation often require ground motion scaling

Common Scaling Methods:

- Scaling to same PGA or Sa(T_1)
- Intensity scaling of 3 or 7 time-series (FEMA-356)
- Spectral matching procedure (in time or frequency domain)

This presentation follows:

- **Ground motion data sets used for evaluation**
- **Building details including calibration of its analytical model**
- **Brief description of FEMA intensity scaling method and Spec. matching procedures**
- **Comparison of results accounting for different scaling methods**
- **Concluding remarks**

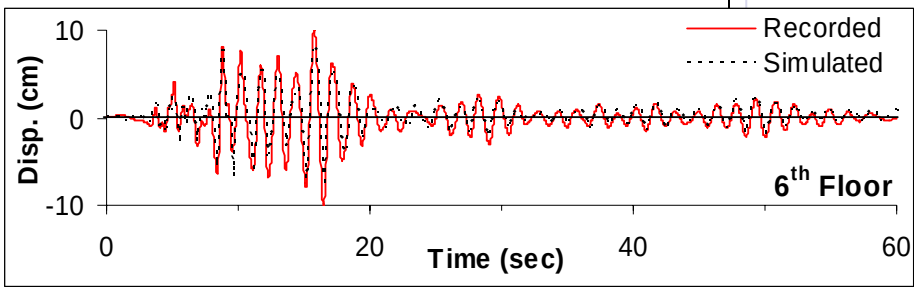
Ground Motion Data Sets

Seven records in two sets were selected from an identical Mag.-Dist.-Soil Bin

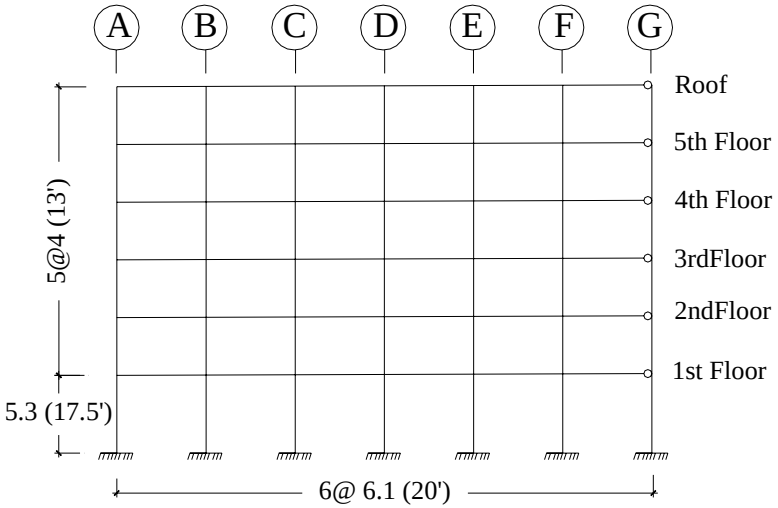
GM-Bin: Mag.-Dist.-Soil
Magnitude (Mw): 6.5 - 7.0
Distance (km) : 5 - 10
NEHRP Soil Class: D

No.	Year	Earthquake	M_W	Station	Dist. (km)
1	1979	Imperial-Valley	6.5	El Centro Diff. Array	5.6
2	1979	Imperial-Valley	6.5	El Centro Imp. Co. Cent.	7.6
3	1989	Loma Prieta	7.0	Gilroy STA #3	6.3
4	1994	Northridge	6.7	Rinaldi Rec. Stn.	8.6
5	1994	Northridge	6.7	Jensen Filt. Plant	6.2
6	1994	Northridge	6.7	Newhall LA Fire Stn.	7.1
7	1994	Northridge	6.7	Sylmar Olive View Hospital	6.4
1	1979	Imperial-Valley	6.5	Holtville Post Office	8.8
2	1994	Northridge	6.7	Slymar Converter Sta.	6.2
3	1994	Northridge	6.7	Slymar Converter Sta East	6.1
4	1994	Northridge	6.7	Sepulveda Va. Hospital	9.5
5	1994	Northridge	6.7	Newhall Pico Canyon	7.1
6	1989	Loma Prieta	7.0	Corralitos	5.1
7	1994	Northridge	6.7	Arieta Nordhoff Ave. Fire Stn.	9.5

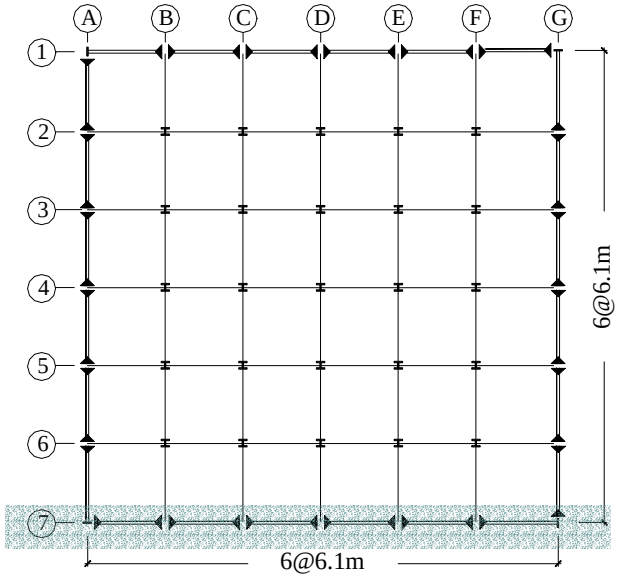
Six-story Instrumented Moment Frame Steel Building at Burbank, CA



Comparison of recorded and computed response (a) at channel 2 (EW direction) at 6th storey level



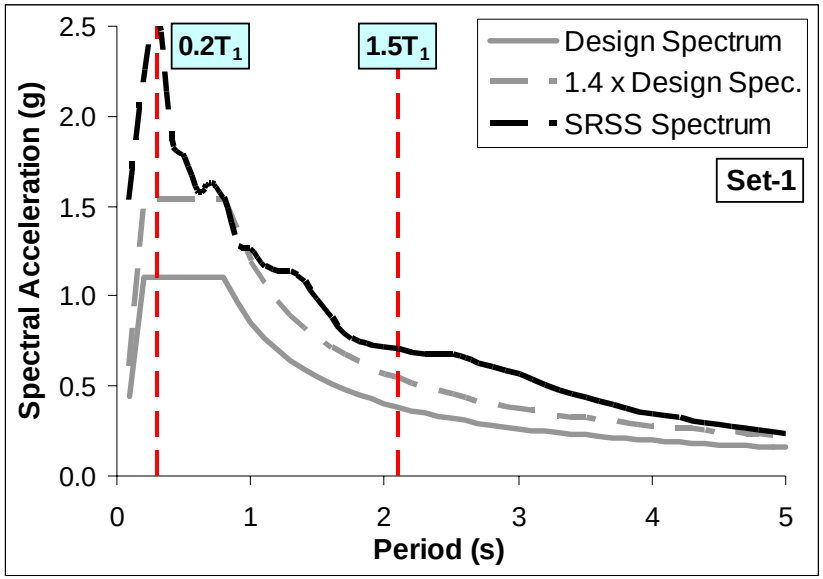
(a) Elevation view

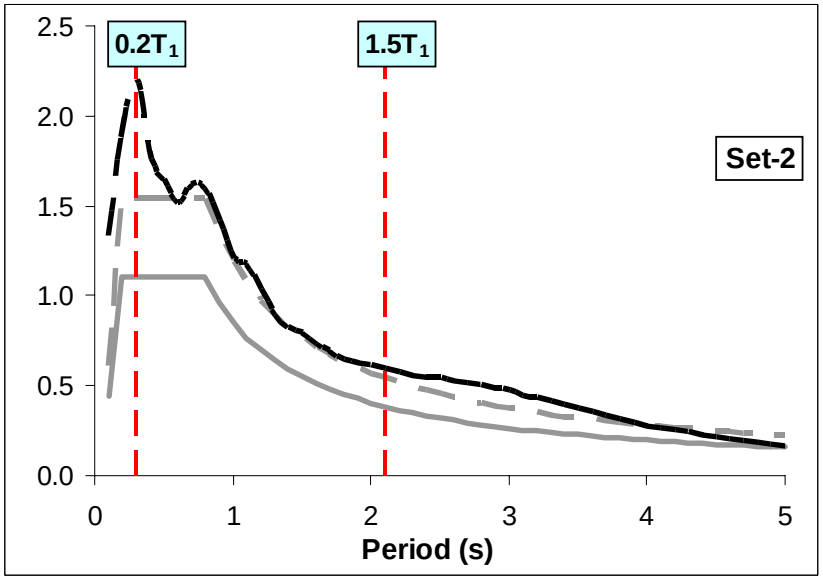


(b) Plan view

Scaling Method (1): FEMA-356 Intensity Scaling

- Current provisions (e.g. FEMA-356) prescribe the use of intensity scaling of **three** or **seven** time-series so that the mean acceleration spectrum of the ground motion ensemble is not less than 1.4 times a target spectrum in the period range between **0.2T and 1.5T**

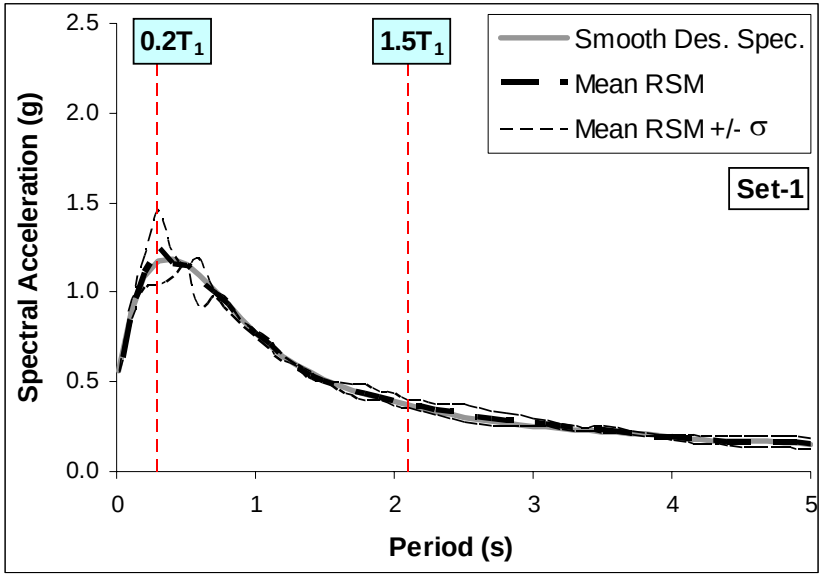


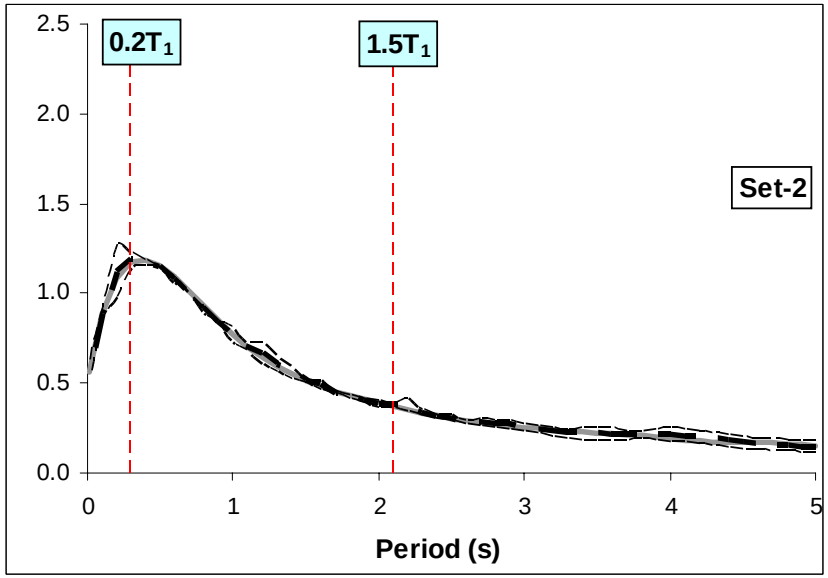


Scaling Method (2): Spectral Matching

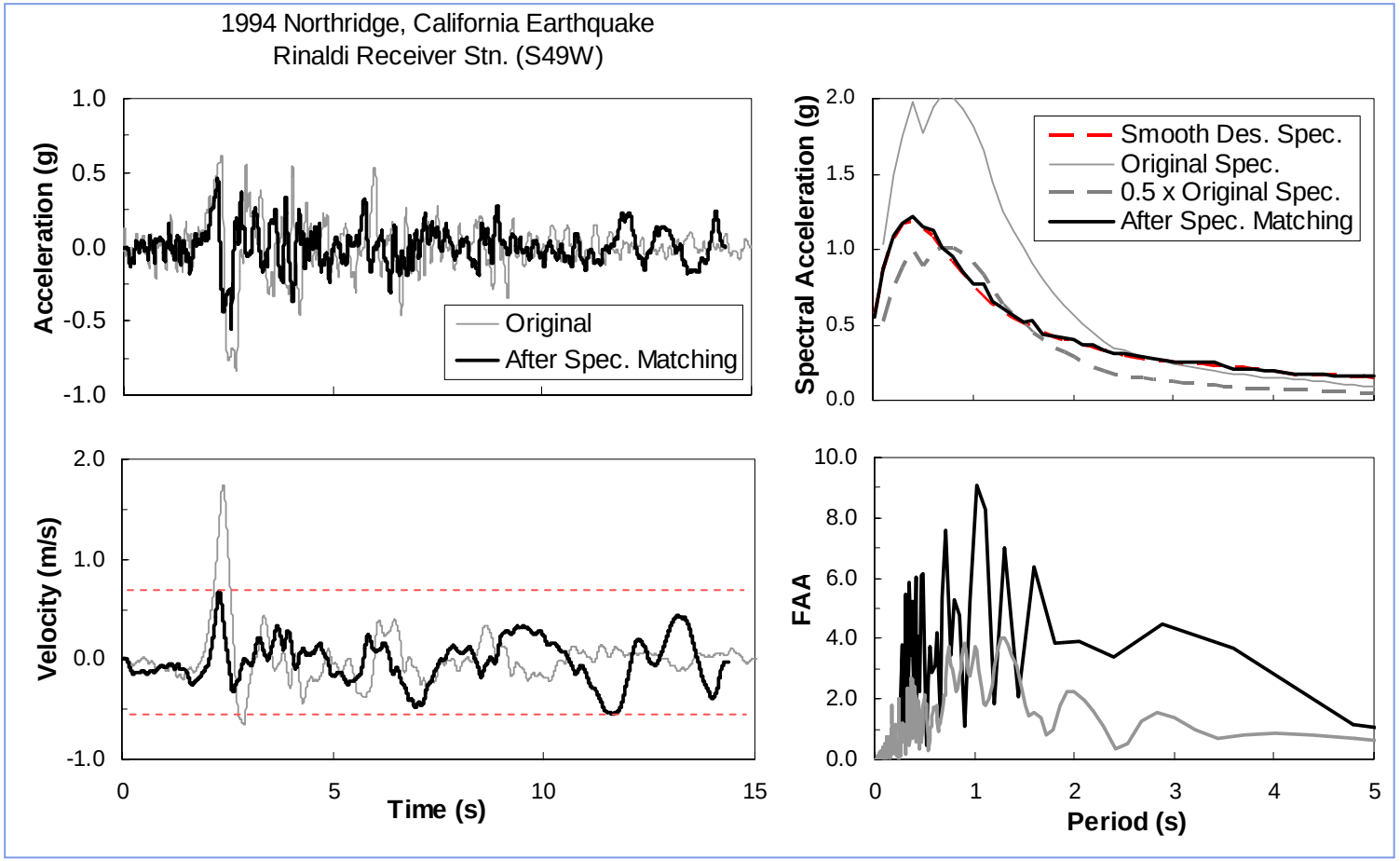
- This method modifies the frequency content and phasing of actual recordings to directly match a smooth target spectrum.

Prior to spectral matching, we fitted a higher order polynomial to smooth the original design spectrum to avoid any localized abrupt transitions in the corner periods



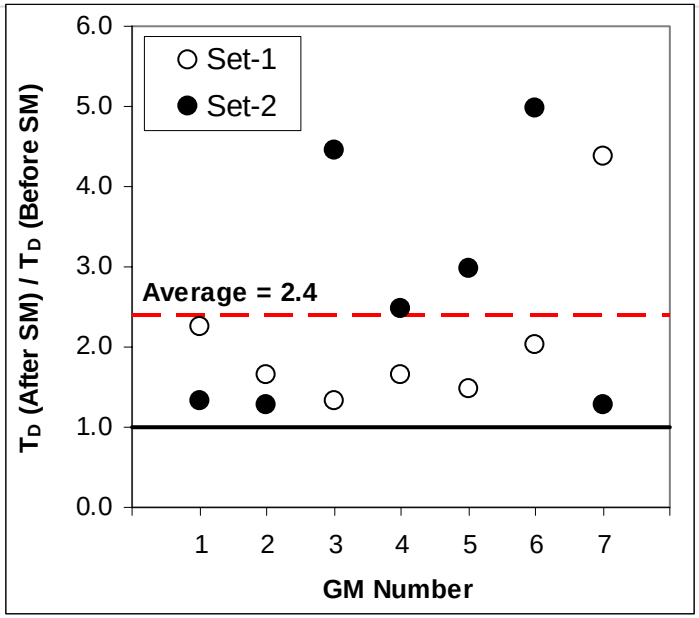


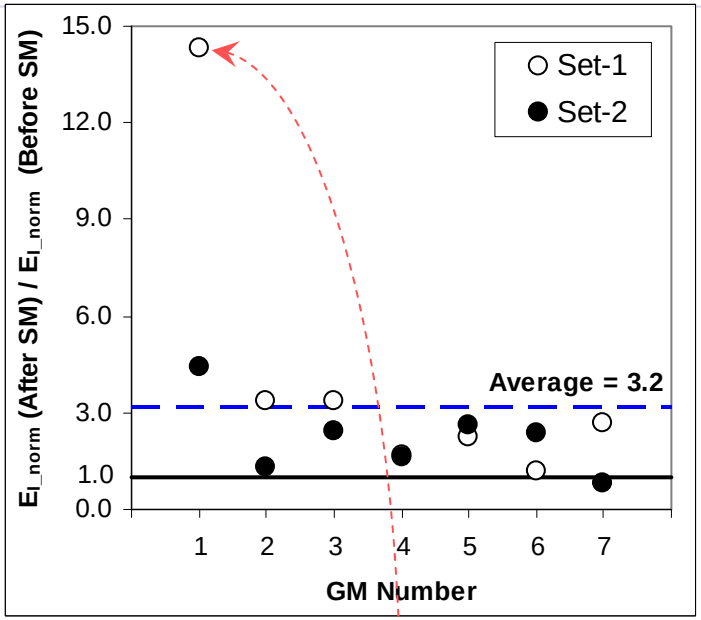
What happens to original records after time-domain SPECTRAL MATCHING ?

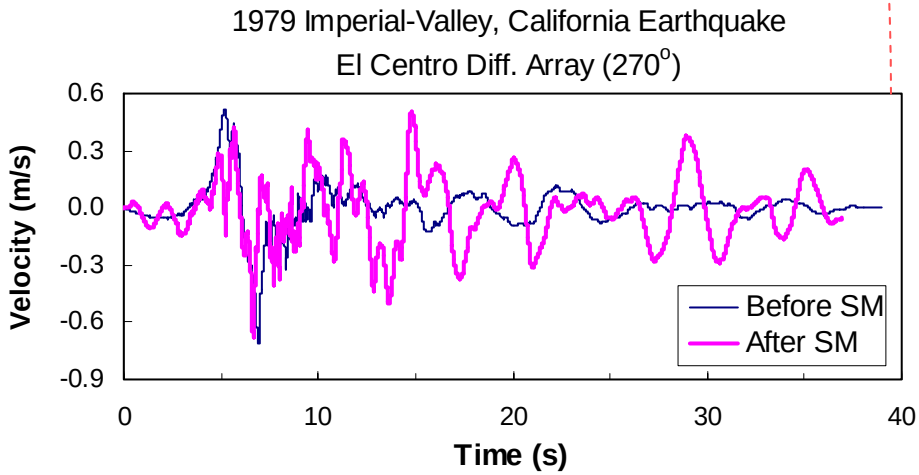


Modifying the frequency content and phasing of actual recording may introduce significant long period intense velocity pulses into modified record

Energy and Strong Motion Duration before / after SPECTRAL MATCHING







Energy is computed for the elastic system with T=1.0s and normalized by mass as well as square root of peak spectral velocity of each record

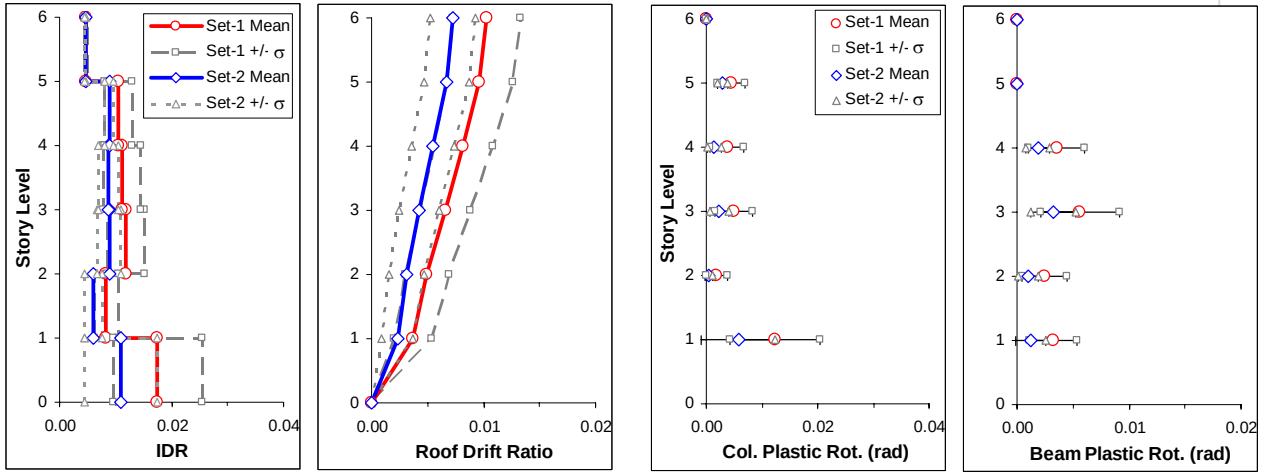
Comparisons of Results

- First set of results compares: 16, 50 (mean) and 84 percentile values of primary response parameters (IDR, roof drift ratio, column and beam plastic rotations) *between Set-1 and Set-2.*

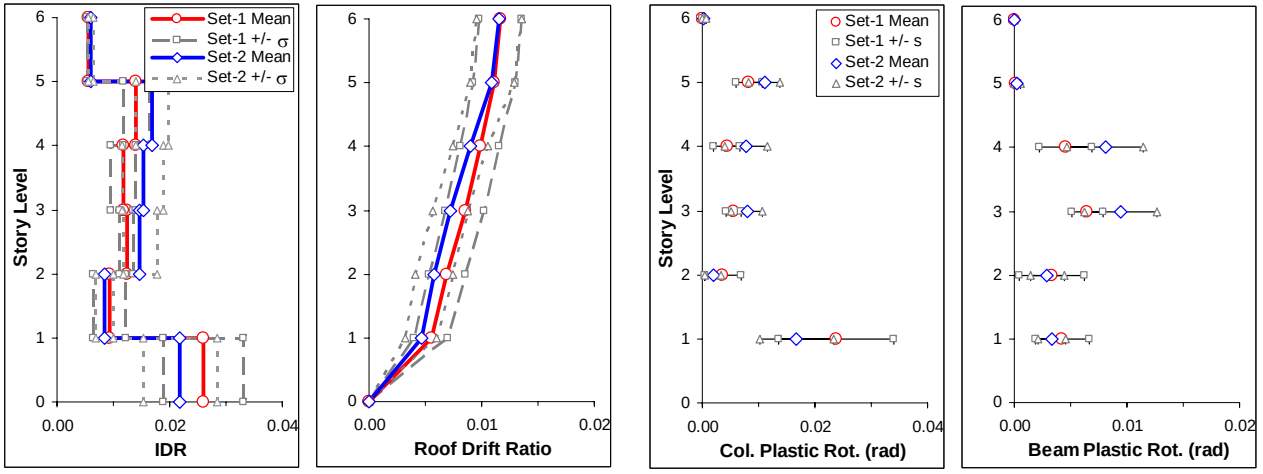
- Second set of results compares: 16, 50 (mean) and 84 percentile values of primary response parameters *between different scaling methods* for Set-1 and Set-2.

Comparison of results between Set-1 and Set-2

FEMA-356 Intensity Scaling

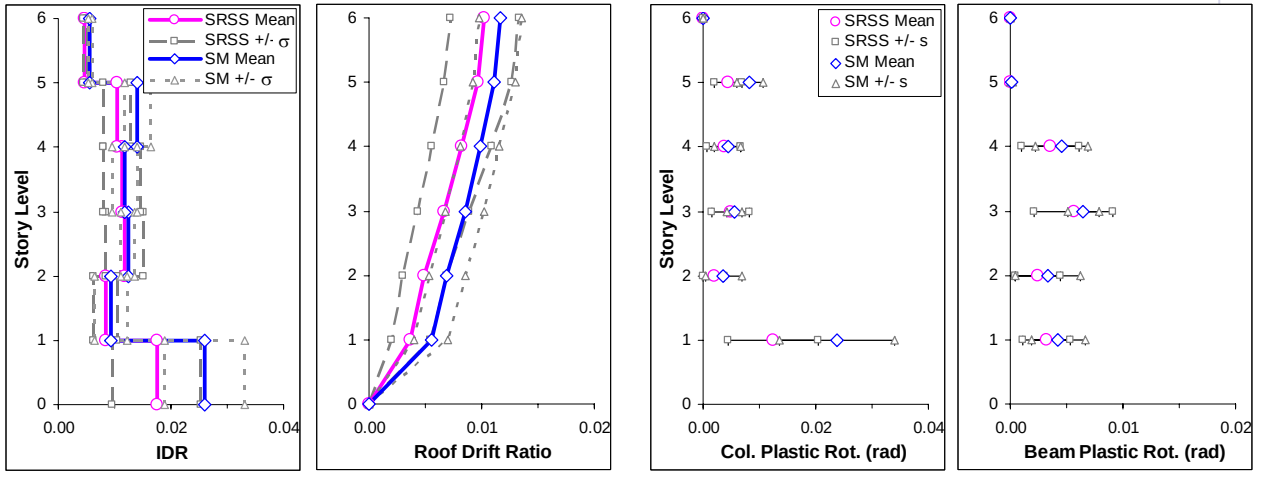


Spectral Matching

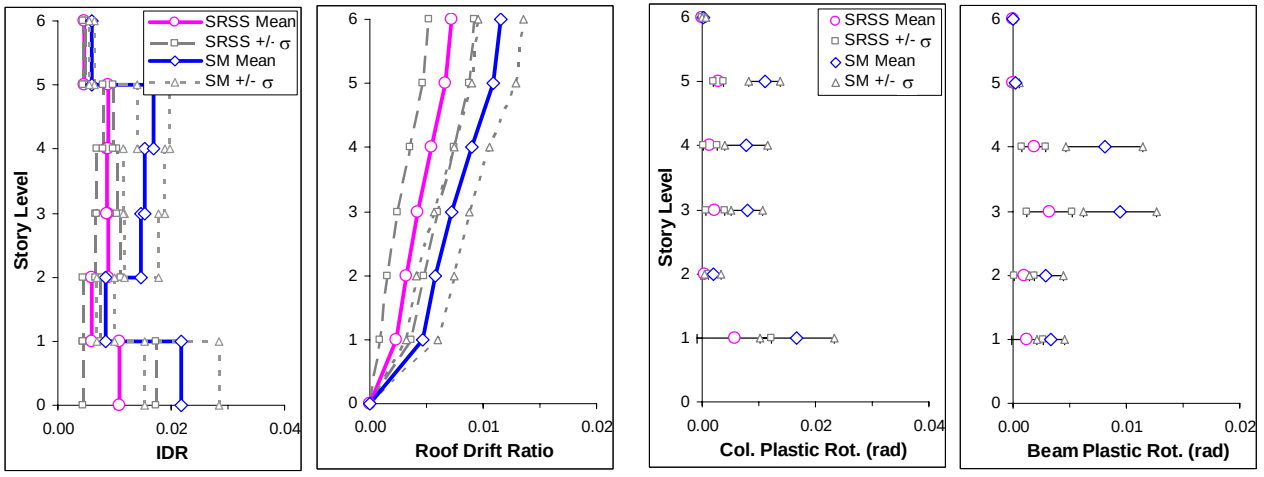


Cross-comparison between FEMA-356 Intensity Scaling and Spectral Matching

Set-1 Records



Set-2 Records



Concluding Remarks: Spectral Matching

- Spectral Matching (SM) to design spectrum (e.g., IBC2000) alters the ground motions characteristics by inducing random long period waves. Although acceleration spectra seem to be matched with the target spectrum, Fourier spectra of original records and modified records differ significantly.
- Directivity and soil characteristics of the original record again change after spectral matching.
- SM also increase the energy content of the record by inducing long period velocity pulses (in some cases these intense pulses homogenously continue towards the end of records without dying out and they resemble the stationary motions).
- Strong motion duration (Trifunac and Brady, 1975) significantly amplifies after spectral matching.
- Unlike the common belief, spectral matching does not necessarily minimize the dispersion in the mean demand estimates at least for the case study presented here.

Concluding Remarks: FEMA Intensity Scaling

- FEMA-Intensity scaling generated smaller demand but the dispersion between two ground motion scaling procedures is almost identical.

- SRSS rule renders unrealistic conservatism in generating maxima if it is misapplied to systems with closely spaced parameters.

  It means that although mean SRSS spectra becomes 1.4 times larger than target spectrum within critical period range, mean spectra of motions may unsafely fall below the target spectrum if the ground motions have closely spaced spectral accelerations.