Predicting structural response when using code-based record selection
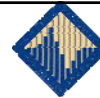
Jack Baker
Stanford University

Curt Haselton
California State University, Chico

Scope

⇨ To understand what we get from modern building codes, an effort was made to obtain records using "Building Code Methods," and predict the resulting structural response

⇨ Some debate emerged as to:
   ⇨ What is "*the*" code-based method
   ⇨ What is current best practice for code-based record selection

⇨ This study selects ground motions using a variety of methods that might be considered "code-based," and compares the differences in resulting structural response

IBC (ASCE 7-05) building code requirements

From ASCE 7-05, section 16.1.3.1:

"Each ground motion shall consist of a horizontal acceleration history, selected from an actual recorded event"

"obtained from records of events having magnitudes, fault distance, and source mechanisms that are consistent with those that control the maximum considered earthquake."

"The ground motions shall be scaled such that the average value of the 5 percent damped response spectra for the suite of motions is not less than the design response spectrum for the site for periods ranging from $0.2T$ to $1.5T$ "

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Number of ground motions

From ASCE 7-05, section 16.1.4:

"If at least seven ground motions are analyzed, the design member forces … and the design story drift … is permitted to be taken respectively as the average of the … values determined from the analyses"

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Site-specific design spectrum

From ASCE 7-05, section 21.2.1:

⇨ "The probabilistic MCE spectral response accelerations shall be taken as the spectral response accelerations represented by a 5 percent damped acceleration response spectrum having a 2 percent probability of exceedance within a 50-yr. period."
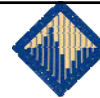
⇨ Here we use the +2 σ response spectrum at all periods, to facilitate comparison and since that has a ~2% probability of exceedance, given the scenario magnitude and distance.

⇨ The 150%-of-median deterministic cap is ignored here to allow comparison with other results.

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Analysis approach

⇨ Start with the NGA ground motion library (7038 horizontal components)

⇨ Eliminate records not meeting specified criteria (e.g., magnitude and distance ranges)

⇨ Select four sets of seven records (total = 28 records) that most closely match the target spectra after scaling

⇨ Perform structural analysis and compare the median max interstory drift ratios from the four sets to determine "within-method" variability

⇨ Compare the median responses among the various methods to determine which selection criteria have the most impact on structural response

⇨ We also have a "Point of Comparison" response (based on many more dynamic analyses), that we can consider as a benchmark response value

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Test structure considered: Building C

⇨ 20-story special reinforced concrete moment resisting perimeter frame

⇨ Design by modern building codes (ASCE7-02, and ACI318-02)
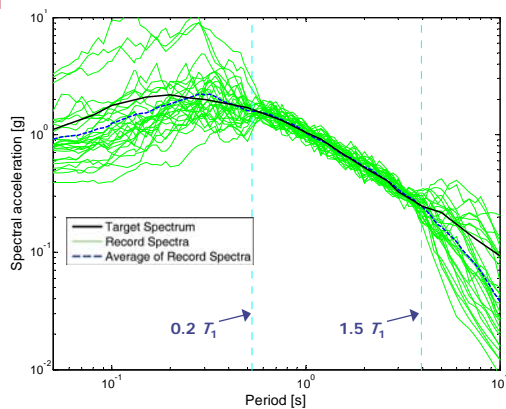
⇨ First-mode period = 2.63 seconds

13 ft (typ)

15 ft
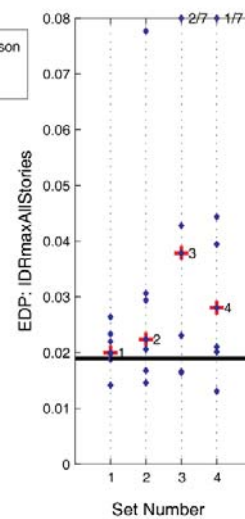
20 ft (typ)
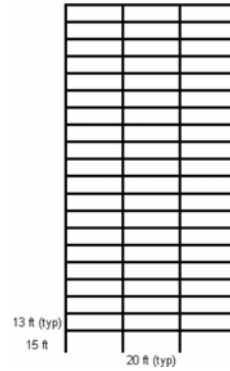
120'x120' plan

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Case 1

⇨ No M/R/Mech. Restrictions
⇨ No filter frequency restriction
⇨ 7038 records available

Method Tag 9980

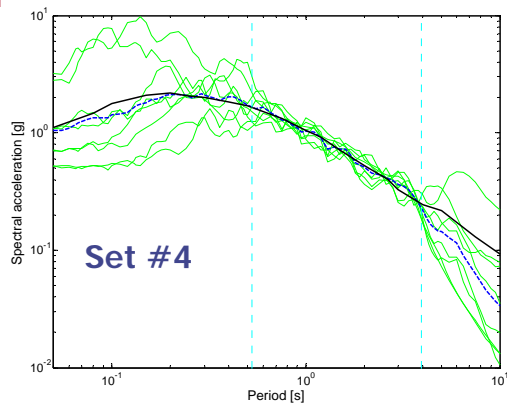Point of Comparison
Counted Median
Data Point

Spectral acceleration [g]

Target Spectrum
Record Spectra
Average of Record Spectra

$0.2\ T_1$ $1.5\ T_1$

Period [s]

EDP: IDRmaxAllStories

Set Number

8

Case 2

⇨ No M/R/Mech. Restrictions
⇨ Restricted filter frequencies
⇨ 3454 records available (50%)

Method Tag 9981

Point of Comparison
Counted Median
Data Point

Target Spectrum
Record Spectra
Average of Record Spectra
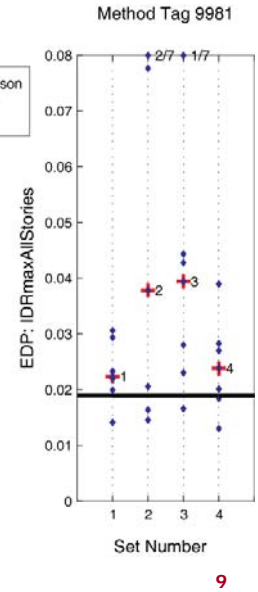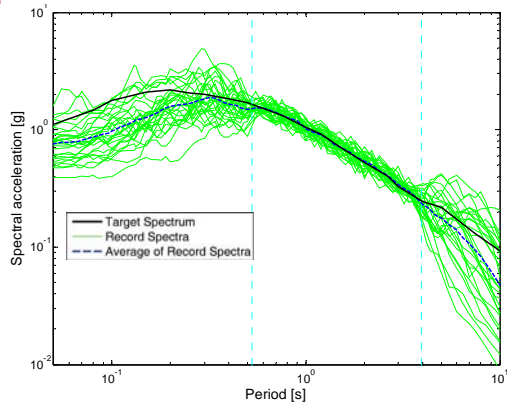
9

Case 3
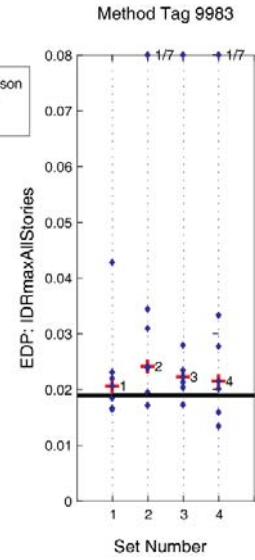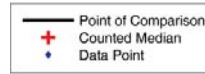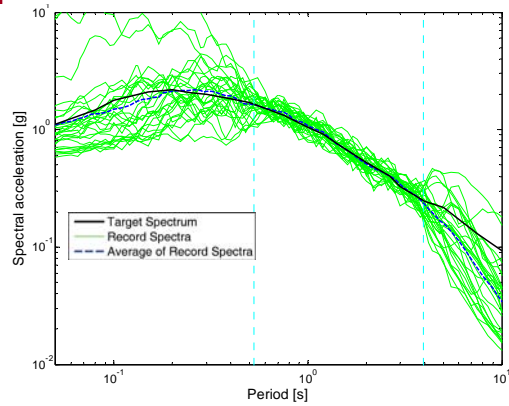
⇨ 6.5 < M < 7.6
⇨ No Dist./Mech. Restrictions
⇨ 1122 records available (16%)

Method Tag 9982

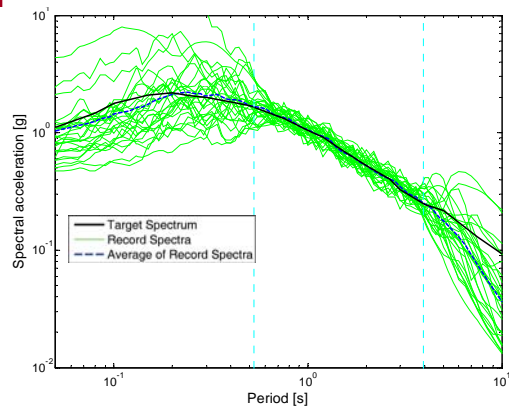Point of Comparison
Counted Median
Data Point

Set #4
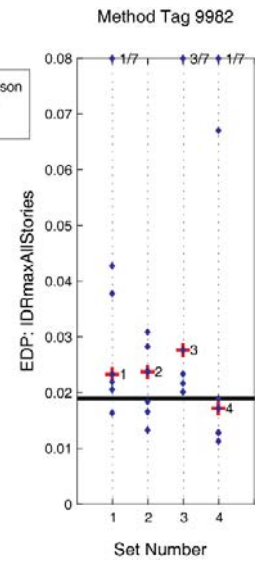
10

Case 4

⇨ 0 < R < 30 km
⇨ No Mag./Mech. Restrictions
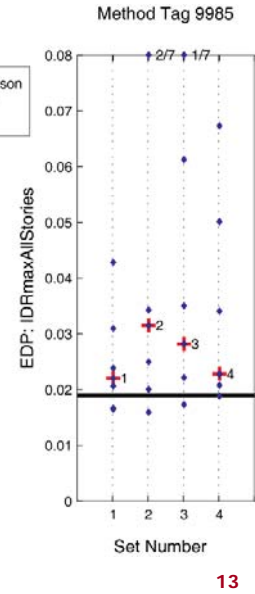⇨ 856 records available (12%)

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Case 5
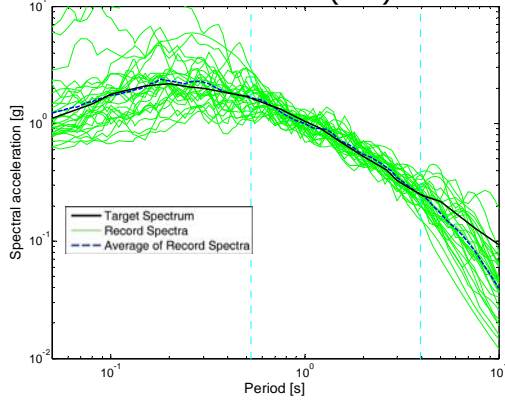
⇨ Strike slip events only
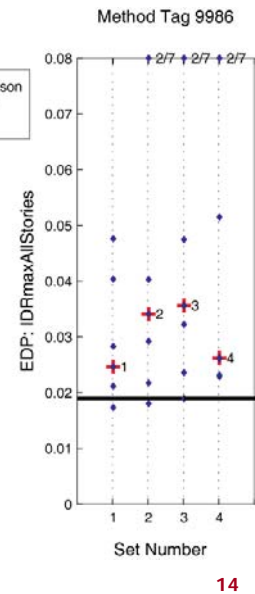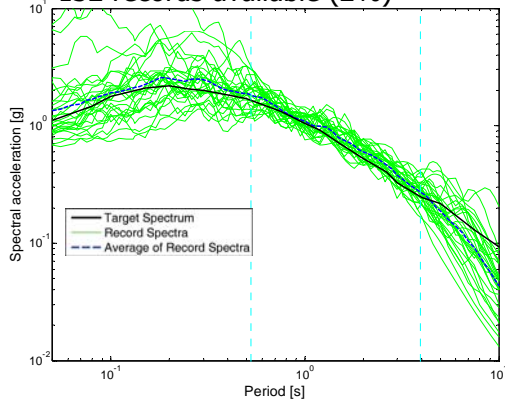⇨ No Mag./Dist. Restrictions
⇨ 978 records available (14%)
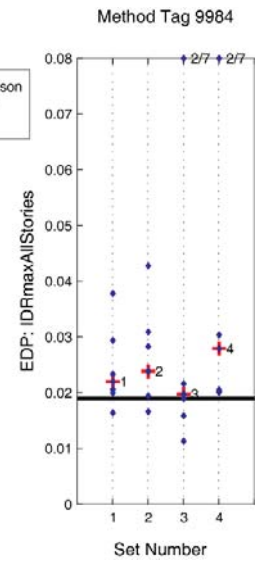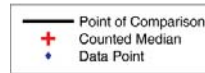
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Case 6

⇨ 6.5 < M < 7.6,
⇨ 0 < R < 30 km
⇨ Strike slip events only
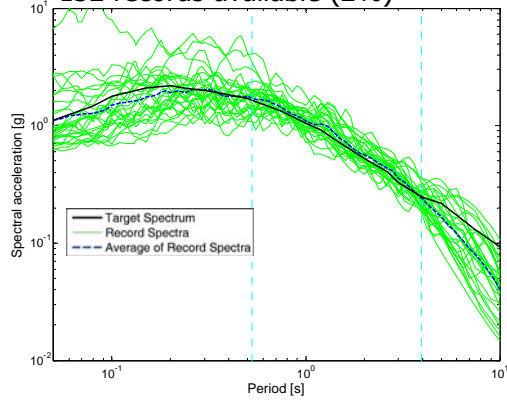⇨ Target spectrum not always exceeded
⇨ 132 records available (2%)

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Case 7

⇨ 6.5 < M < 7.6
⇨ 0 < R < 30 km
⇨ Strike slip events only
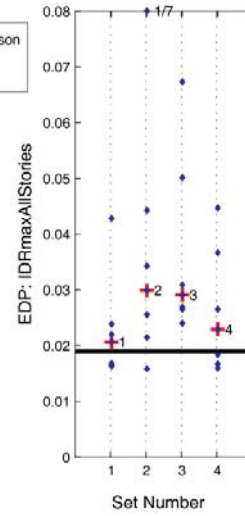⇨ Target spectrum exceeded
⇨ 132 records available (2%)

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Case 8

⇨ 6.5 < M < 7.6
⇨ 0 < R < 30 km
⇨ Strike slip events only
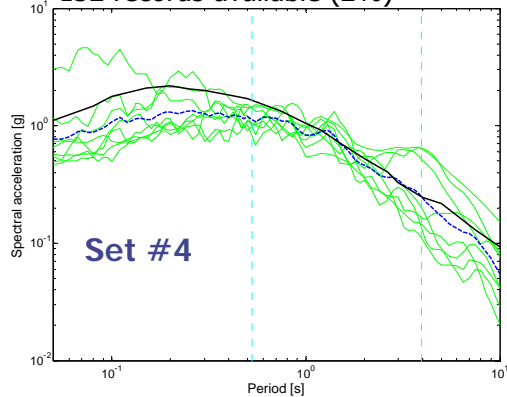⇨ Max scale factor = 4
⇨ 132 records available (2%)

Method Tag 9975

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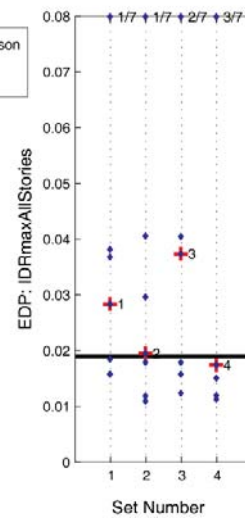
Case 9

⇨ 6.5 < M < 7.6
⇨ 0 < R < 30 km
⇨ Strike slip events only
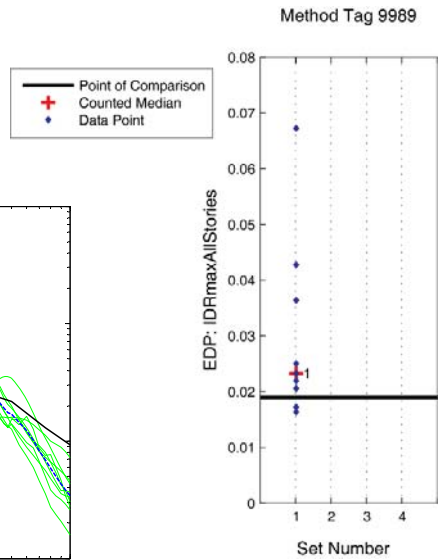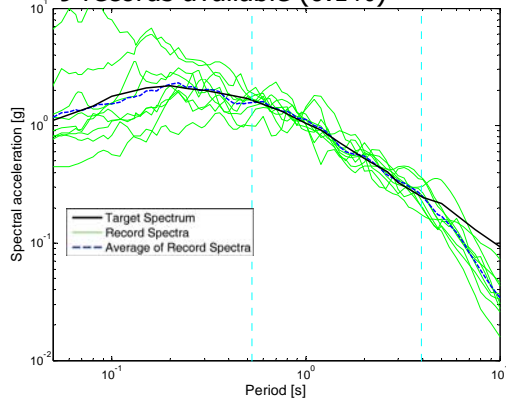⇨ Max scale factor = 2
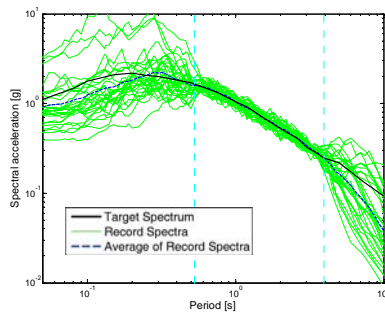⇨ 132 records available (2%)

Set #4

Method Tag 9976

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Case 10

⇨ 6.5 < M < 7.6
⇨ 0 < R < 30 km
⇨ Strike slip events only
⇨ Max one record per event
⇨ 9 records available (0.1%)

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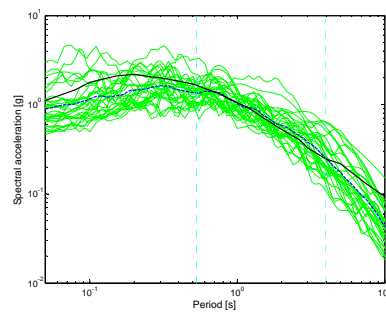# Case 1:

⇨ No M/R/Mech. Restrictions
⇨ 7038 records available

Case 9:

⇨ 6.5 < M < 7.6
⇨ 0 < R < 30 km
⇨ Strike slip events only
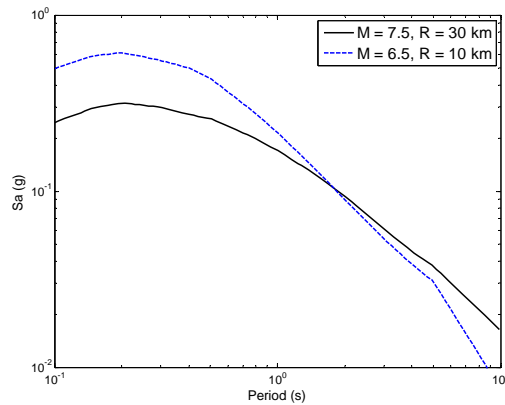⇨ Max scale factor = 2
⇨ 132 records available (2%)

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Observations
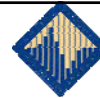
⇨ Are the magnitude/distance/mechanism restrictions needed?

⇨ We know they affect spectral shape, but we are already specifying a target spectral shape

Median response spectra from events with differing magnitudes and distances

Observations

⇨ Are scale factor restrictions needed?
  ⇨ They don't seem to have an effect. Again, this may result from the target spectrum requirement
  ⇨ Note that no such restriction is given in the code

⇨ Is the one-record-per-event restriction needed?
  ⇨ It doesn't seem to have an effect, and severely limits the available number of records
  ⇨ Note that no such restriction is given in the code

Observations

⇨ Is the filter frequency limitation needed?

  ⇨ Presumably over-filtered motions will not match the design spectrum, so the target spectrum should ensure we have records with proper filtering (assuming that 0.2T to 1.5T are the only periods we need to worry about)

  ⇨ Note that no such restriction is given in the code
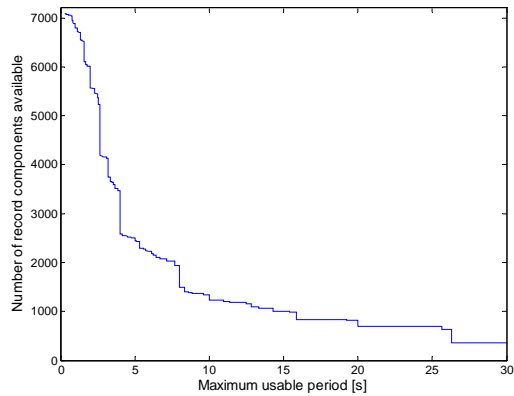
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Conclusions regarding code criteria

⇨ Responses seem to be controlled by the target spectral shape, rather than the other selection criteria

⇨ This suggests that the choice of the target spectrum is a more important consideration than the choice of additional criteria

⇨ Benefit of the additional criteria: more "insurance" that you have appropriate record properties

⇨ Disadvantage of the additional criteria: a reduced number of records to chose from, meaning that you will not be able to match the target spectrum as closely

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General conclusions

⇨ The code-based methods generally produce higher structural responses than the baseline response prediction

⇨ This is due to the inherent conservatism of the UHS, which envelopes extreme spectral amplitudes at all periods

⇨ Alternative methods can avoid this conservatism, as will be seen in the following presentation

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