Epsilon Capping: A new procedure for deterministic capping of probabilistic MCE\textsubscript{R} ground motions

Project ‘17 Deterministic Capping Subcommittee

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2018 USGS National Seismic Hazard Model (NSHM)

- NGA-East
- Basin effects (empirical) in Los Angeles, Seattle, San Francisco, and Salt Lake City
- Updated catalog of past earthquakes (outside California)

BSSC/FEMA-USGS Project ’17 Recommendations

- Seismic Design Category maps (for stability)
- Additional structural periods and site classes from USGS
- Deaggregation-based procedure for deterministic capping
21.2.3 Site-Specific MCE\(_R\). The site-specific MCE\(_R\) spectral response acceleration at any period, \(S_{aM}\), shall be taken as the lesser of the spectral response accelerations from the probabilistic ground motions of Section 21.2.1 and the deterministic ground motions of Section 21.2.2.
21.2.2 Deterministic (MCE_R) Ground Motions. The deterministic spectral response acceleration at each period shall be calculated as an 84th-percentile 5% damped spectral response acceleration in the direction of maximum horizontal response computed at that period. The largest such acceleration calculated for the characteristic earthquakes on all known active faults within the region shall be used. The ordinates of the deterministic ground motion response spectrum shall not be taken as lower than the corresponding ordinates of the response spectrum determined in accordance with Fig. 21.2-1.
Example: ASCE 7-16 Deterministic Capping

San Andreas Fault
Distance = 8.4 km
Magnitude = 8.2
$S_{SD}$ (Deterministic) < 2.3g

San Jacinto Fault
Distance = 1.9 km
Magnitude = 7.8
$S_{SD}$ (Deterministic) = 2.3g

$S_{S}$ (MCE$_{R}$) = min($S_{SRT}$, Largest $S_{SD}$) = min(2.6g, 2.3g) = 2.3g

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Issues: ASCE 7-16 Deterministic Capping

- Choosing “active faults”.
- Choosing “characteristic earthquake” *ruptures* (e.g. multi-fault ruptures).
- Choosing “characteristic earthquake” *magnitudes*.
- Multi-period deterministic lower limit.
- Additional (to Probabilistic Seismic Hazard Analysis) software, review.
Definition: Epsilon

-2.5 -2 -1.5 -1 -0.5 0 0.5 1 1.5 2 2.5

Epsilon

0 10 20 30 40 50 60 70 80 90 100

Ground Motion Percentile [%]

50th Percentile (Median)

84th Percentile

(a.k.a. # standard deviations)
Proposal: “Epsilon Capping”

Where earthquakes occur relatively often, the ASCE 7-16 probabilistic MCE\textsubscript{R} ground motions correspond to higher than the 84\textsuperscript{th} percentile for the earthquakes that contribute most to the risk. Like ASCE 7-16 does, we propose to cap these ground motions at the 84\textsuperscript{th} percentile, but with a procedure that is simpler to implement now that “characteristic earthquakes” are no longer defined for California.
Example: San Bernardino, $S_{SRT} = 2.6g$
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August 10, 2018
Example: San Bernardino, $S_{SRT} = 2.6g$

Deterministic scenarios that could result in 2.6g ...

<table>
<thead>
<tr>
<th>Source Name</th>
<th>Distance (km)</th>
<th>Magnitude</th>
<th>Epsilon</th>
<th>Relative Likelihood</th>
</tr>
</thead>
<tbody>
<tr>
<td>San Jacinto</td>
<td>1.9</td>
<td>8.0</td>
<td>1.1</td>
<td>46%</td>
</tr>
<tr>
<td>San Andreas</td>
<td>8.4</td>
<td>7.6</td>
<td>1.7</td>
<td>34%</td>
</tr>
</tbody>
</table>

Capping the epsilons of these scenarios at 1.0 results in 84th-percentile deterministic ground motions.

Following the current ASCE 7-16 deterministic capping procedure, use the largest 84th percentile ground motion.

ASCE 7-16

$S_S = 2.3g$
(from San Jacinto, $M=7.7$)

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## Summary: Epsilon-Capped vs. ASCE 7-16 $S_s$

<table>
<thead>
<tr>
<th>City</th>
<th>ASCE 7-16 $S_s$ (g)</th>
<th>Epsilon-Capped $S_s$ (g)</th>
<th>% Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Santa Rosa</td>
<td>2.4</td>
<td>2.6</td>
<td>7%</td>
</tr>
<tr>
<td>San Bernardino</td>
<td>2.3</td>
<td>2.5</td>
<td>8%</td>
</tr>
<tr>
<td>Concord</td>
<td>2.2</td>
<td>2.5</td>
<td>11%</td>
</tr>
<tr>
<td>Oakland</td>
<td>1.9</td>
<td>1.9</td>
<td>0%</td>
</tr>
<tr>
<td>San Mateo</td>
<td>1.8</td>
<td>1.9</td>
<td>7%</td>
</tr>
<tr>
<td>Northridge</td>
<td>1.7</td>
<td>1.8</td>
<td>5%</td>
</tr>
<tr>
<td>Vallejo</td>
<td>1.5</td>
<td>2.1</td>
<td>40%</td>
</tr>
<tr>
<td>San Jose</td>
<td>1.5</td>
<td>1.3</td>
<td>-13%</td>
</tr>
<tr>
<td>San Francisco</td>
<td>1.5</td>
<td>1.4</td>
<td>-6%</td>
</tr>
<tr>
<td>Riverside</td>
<td>1.5</td>
<td>1.3</td>
<td>-16%</td>
</tr>
</tbody>
</table>

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### Locations NOT Capped in ASCE 7-16

(Deterministic > Probabilistic > Plateau)

<table>
<thead>
<tr>
<th>City</th>
<th>ASCE 7-16 $S_S (g)$</th>
<th>Epsilon-Capped $S_S (g)$</th>
<th>% Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Santa Barbara</td>
<td>2.1</td>
<td>2.1</td>
<td>0%</td>
</tr>
<tr>
<td>Century City</td>
<td>2.1</td>
<td>2.1</td>
<td>0%</td>
</tr>
<tr>
<td>Ventura</td>
<td>2.0</td>
<td>2.0</td>
<td>0%</td>
</tr>
<tr>
<td>Los Angeles</td>
<td>2.0</td>
<td>2.0</td>
<td>0%</td>
</tr>
<tr>
<td>Long Beach</td>
<td>1.7</td>
<td>1.7</td>
<td>0%</td>
</tr>
<tr>
<td>Santa Cruz</td>
<td>1.6</td>
<td>1.5</td>
<td>-7%</td>
</tr>
<tr>
<td>San Diego</td>
<td>1.6</td>
<td>1.6</td>
<td>0%</td>
</tr>
<tr>
<td>Salt Lake City</td>
<td>1.5</td>
<td>1.5</td>
<td>0%</td>
</tr>
</tbody>
</table>

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Proposal: Procedure at Each Location

1. Compute Risk-Targeted Ground Motion (RTGM).

2. At RTGM return period, deaggregate hazard.

3. From deaggregation, obtain deterministic scenarios that could result in RTGM (i.e., fault/source names, magnitudes, distances, epsilons, relative likelihoods).

4. Adjust each deterministic scenario to 84th-percentile ground motion by dividing RTGM by ...
   \[ \frac{\exp(Epsilon \cdot \sigma)}{\exp(1 \cdot \sigma)} \]

5. Use largest 84th-percentile ground motion amongst deterministic scenarios with relative likelihood ≥x%.
Advantages of Epsilon Capping

✓ Deaggregation of probabilistic ground motions is useful for review and communication.

✓ Project ’17 and PUC would not need to choose active faults, characteristic earthquake ruptures & magnitudes, and deterministic lower limits.

✓ USGS would not need to continue developing deterministic software, which requires additional review.

✓ Results would be consistent with hazard model for probabilistic ground motions (e.g., UCERF3) and its deaggregation.