Should Design Spectra in Building Codes Be Specified from the Maximum Component or the Average Horizontal?

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Outline

• Problem definition
• Background on the code change
• Directionality in structural response
• Logic behind bias concern
• Technical summary
• Where to go from here?
• References
Problem Definition

- Three-component ground motions
- $\ln(GM) = \text{avg}(\ln H_1, \ln H_2)$
  - Basis for most pre-NGA GMPEs
Problem Definition

• Three-component ground motions
• $\ln(GM) = \text{avg}(\ln H_1, \ln H_2)$
• $\text{GMRotI50}$
Problem Definition

- Three-component ground motions
- $\ln(GM) = \text{avg}(\ln H_1, \ln H_2)$
- GMRotI50
Problem Definition

- Three-component ground motions
- $\ln(GM) = \text{avg}(\ln H_1, \ln H_2)$
- GMRot150
Problem Definition

- Three-component ground motions
- $\ln(GM) = \text{avg}(\ln H_1, \ln H_2)$
- $GMRotI50$
Problem Definition

- Three-component ground motions
- $\ln(GM) = \text{avg}(\ln H_1, \ln H_2)$
- GMRotI50
  - GMRotD50 = Median($GM_i$)
  - Find single rotation angle with GM closest to GMRotD50
- Basis for NGA GMPEs
- Values similar to GM

Boore et al., 2006
Problem Definition

- Three-component ground motions
- $\ln(GM) = \text{avg}(\ln H_1, \ln H_2)$
- GMRotI50
- Max Direction (MD)
  - Used in 2009 code
  - Median converted from GMRotI50
  - Sigma ($\sigma$) larger than for GM or GMRotI50

Huang et al., 2008, 2009
Problem Definition

- Three-component ground motions
- $\ln(GM) = \text{avg}(\ln H_1, \ln H_2)$
- GMRotI50
- Max Direction (MD)
- Arbitrary Component
  - Larger $\sigma$ than for GM or GMRotI50

Huang et al., 2008, 2009
Problem Definition

This presentation:
• Was the change to MD appropriate?
• Could it bias the hazard levels intended for application in design?
Background on the Code Change

• Change to MD is part of broad revisions
  – Update to NGA GMPEs
  – Adoption of risk targeted ground motions
  – Change to MD from GM

• Full disclosure
  – I opposed the change because of MD issue
  – Co-authored EERI letter justifying institutional “No” vote to NEHRP Provisions Update Comm.
Directionality in Structural Response

• Azimuth-independent response
  – Flagpole

www.flagpolesetc.com
Directionality in Structural Response

- Azimuth-independent
  - Flagpole
  - Buildings with similar str/stiffness in both directions -- ?

Christovasilis et al., 2009
Directionality in Structural Response

- Azimuth-independent
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  - Buildings with similar str/stiffness in both directions -- ?

Christovasilis et al., 2009
Directionality in Structural Response

- Azimuth-independent
  - Flagpole
  - Buildings with similar str/stiffness in both directions -- ?
  - Can conceptualize MD controlling collapse, but...
  - Research has not demonstrated this
Directionality in Structural Response

- Azimuth-independent
- Azimuth-dependent response
Directionality in Structural Response

- Azimuth-independent
- Azimuth-dependent
Directionality in Structural Response

- Azimuth-independent
- Azimuth-dependent
  - Both directions contribute, but...
  - Out of phase
  - Modal combination
    (Sec. 12.9.3 ASCE7)

Transv: $\tilde{T} = 0.74$ sec
Long.: $\tilde{T} = 1.25$ sec

Stewart et al., 1999
Directionality in Structural Response

- Azimuth-independent
- Azimuth-dependent
- Azimuth-specific response requires directional ground motions
Logic Behind Bias Concern

• MD arbitrary for $R_{rup} > 3-5$ km

Watson-Lamprey et al., 2007
Logic Behind Bias Concern

• MD arbitrary for $R_{rup} > 3$-5 km

• 2D analysis: best to use arb. comp or GM (same $\mu$, different $\sigma$)

$Baker$ and $Cornell$, 2006
$Watson-Lamprey$ et al., 2007
Logic Behind Bias Concern

- MD arbitrary for $R_{rup} > 3$-5 km
- 2D analysis: best to use arb. comp or GM (same $\mu$, different $\sigma$)
- USGS hazard maps use GMRotI50 ($\sim$ GM)
Logic Behind Bias Concern

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Logic Behind Bias Concern

- MD arbitrary for $R_{rup} > 3$-5 km
- 2D analysis: best to use arb. comp or GM (same $\mu$, different $\sigma$)
- USGS hazard maps use GMRotI50 ($\sim$ GM)
- If MD, using lower APE (return period $\uparrow$)
Change of M

- Beyer and Bommer (2006): MD/GM $\sim 1.2$-$1.3$
Change of Median

- Beyer and Bommer (2006): MD/GM $\sim 1.2$-$1.3$
- Huang et al. (2008): 1.2-1.5

Huang et al., 2008
Effect of NGA on USGS Maps
NEHRP Revision Process

- Procedure
  - Technical Subcommittee drafts proposal
  - PUC feedback
  - Revision in Subcommittee
  - PUC approval
  - Member balloting
  - Final edits and approval
NEHRP Revision Process

• Procedure
• “Conservative” process
NEHRPRevisionProcess

- Procedure
- “Conservative” process
- Peculiarities in this case:
  - No technical basis for revisions
  - PUC input ignored
  - Member ballot objections ignored
NEHRP Revision Process

- Procedure
- “Conservative” process
- Peculiarities in this case
- The unwritten last bullet...
Technical Summary

- MD motions can be rationalized for structures with equal stiff./str. in both directions
  - Research needed to justify
  - Rarely the case in real buildings
Technical Summary

• MD motions can be rationalized for structures with equal stiff./str. in both directions

• MD motions should bias the APE used in design for structures with azimuth-dependent props.
  – If motivation was to avoid decreased motions from NGA, better to phase in adoption of NGA
  – Bias concern is widely held and was presented to NEHRP PUC
Technical Summary

• MD motions can be rationalized for structures with equal stiff./str. in both directions
• MD motions should bias the APE used in design for structures with azimuth-dependent props.
• USGS maps do not account for additional uncertainty of MD
  – Will lead to additional future increases of design spectra
Where to go from here?

- NEHRP Provisions and Commentary approved
- ASCE-7 updated approved
- IBC re-write in process
- IBC does not become “code” until adopted
  - Adoption can occur with revision
- Inform leaders in design profession; seek input
- Document concerns
- Bring concerns to regulatory agencies
References


Watson-Lamprey, J and DM Boore (2007). “Beyond Sa\textsubscript{GMRot}: Conversion to Sa\textsubscript{Arb,} Sa\textsubscript{SN,} and Sa\textsubscript{MaxRot,}” Bull Seism Soc Am, 97 (5), 1511-1524.