Probabilistic Seismic Demand Models for Multi-Span Highway Bridges

Kevin Mackie

Bozidar Stojadinovic

Session:

Seismic Response of Bridges

University of California, Berkeley
Department of Civil and Environmental Engineering &
Pacific Earthquake Engineering Research Center

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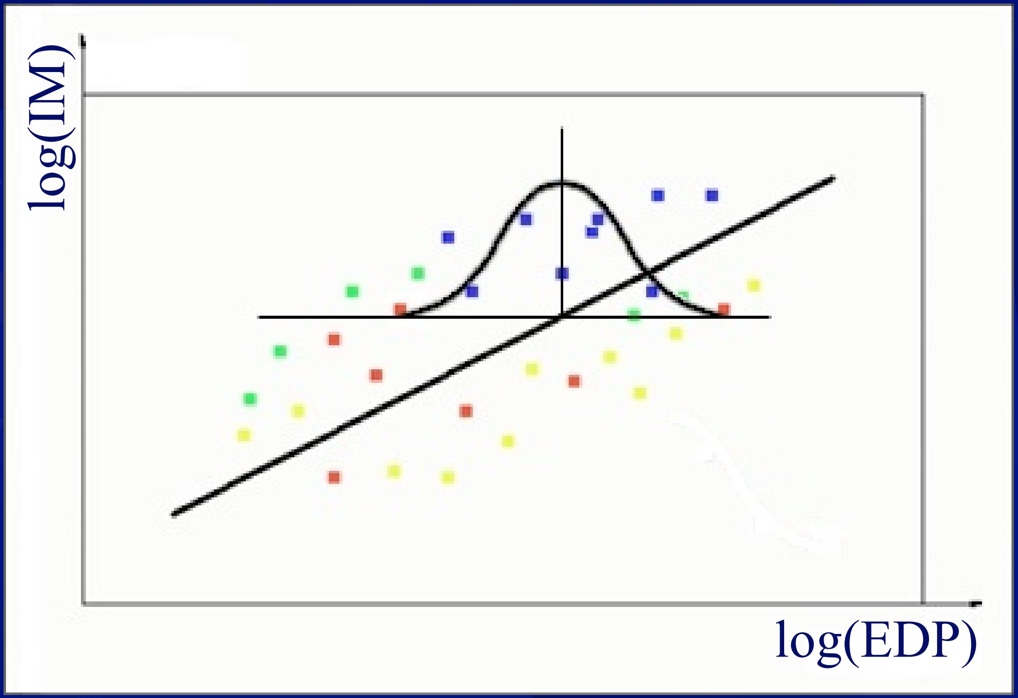
What is a PSDM?

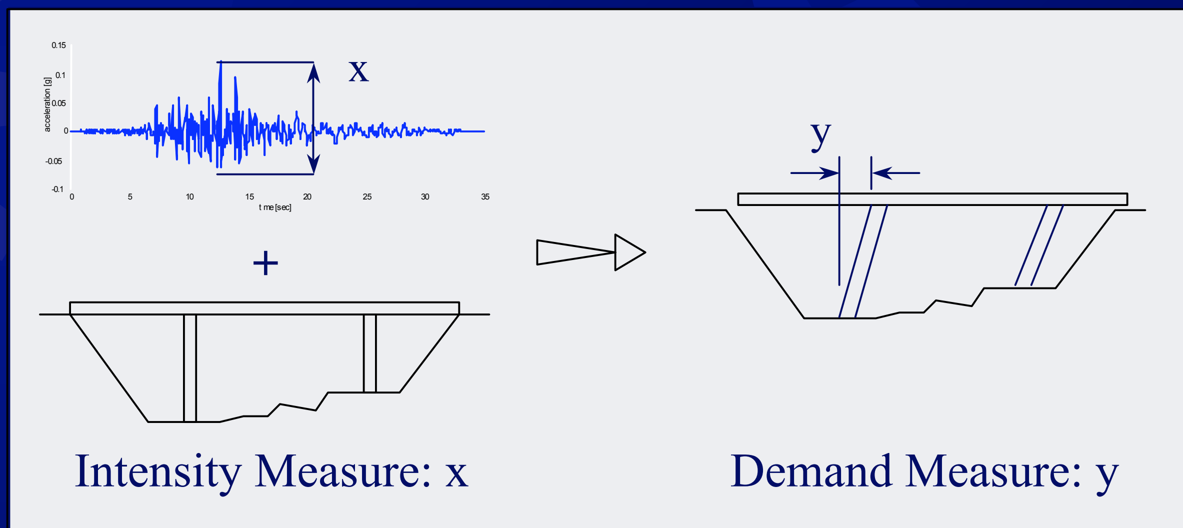
PSDM = Probabilistic Seismic Demand Model



Relationship of seismic Intensity Measures (IM) to structural Engineering Demand Parameters (EDP)

Why a demand model?

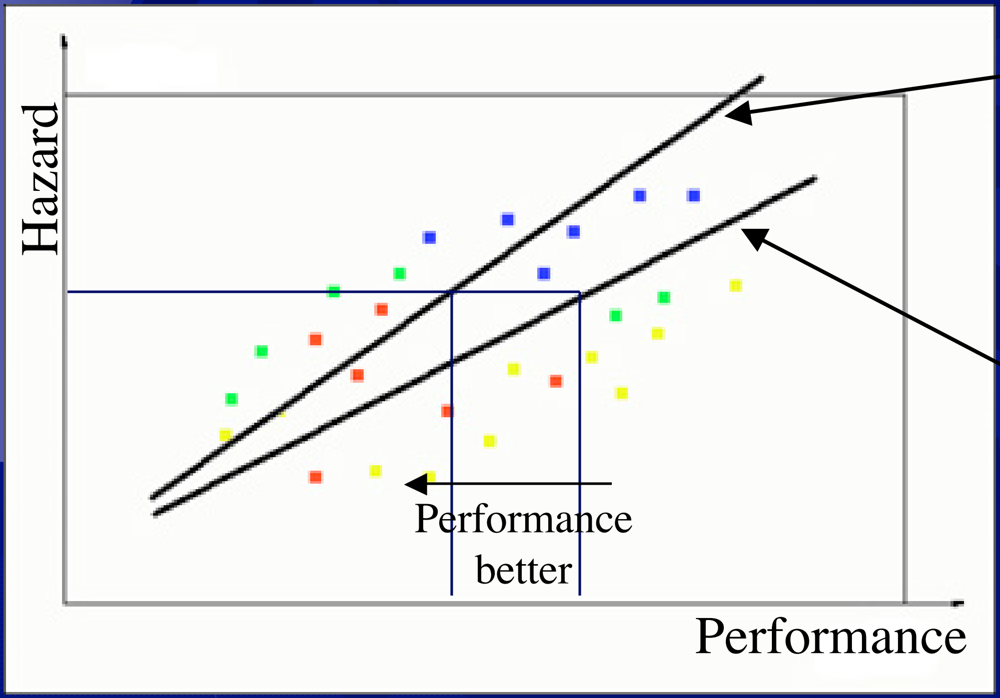
1.) Quantitative Performance Based Earthquake Engineering tool for designers of bridges

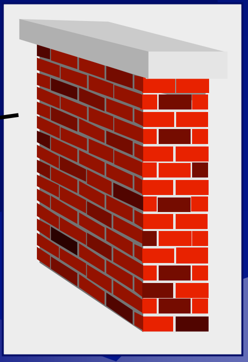


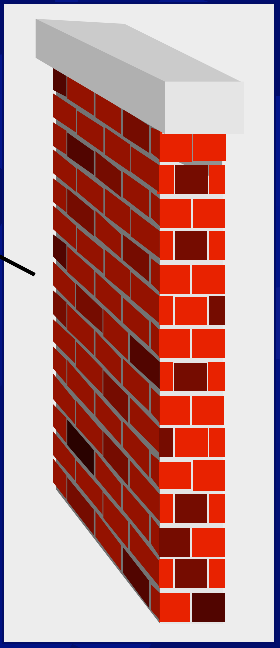
What is probability of y, given x?

Why a demand model?

2.) How do design parameters affect performance?

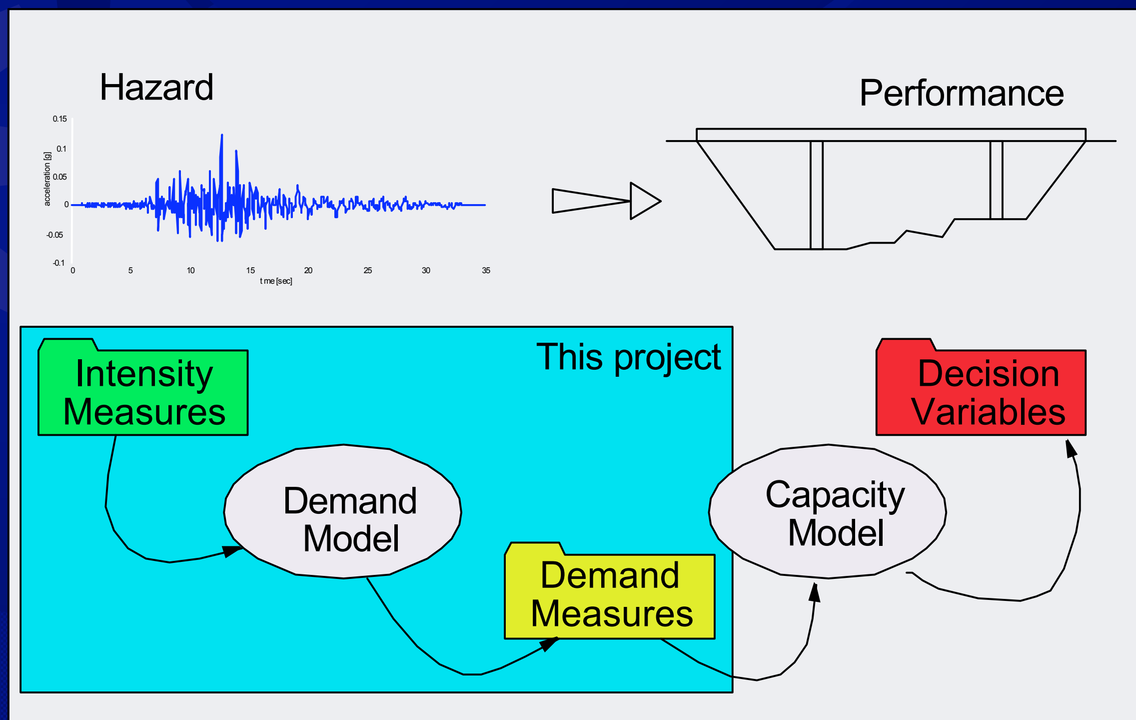






Why a demand model?

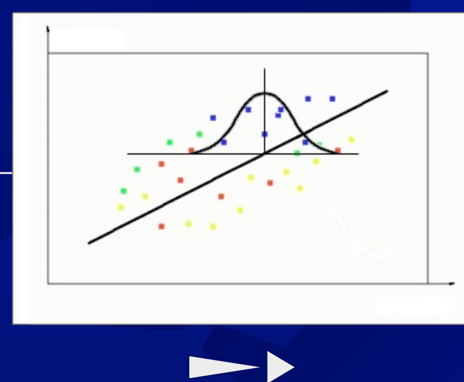
3.) Module in Pacific Earthquake Engineering Research Center (PEER) probabilistic framework



PEER Performance based earthquake engineering framework

Probabilistic Seismic Demand Analysis

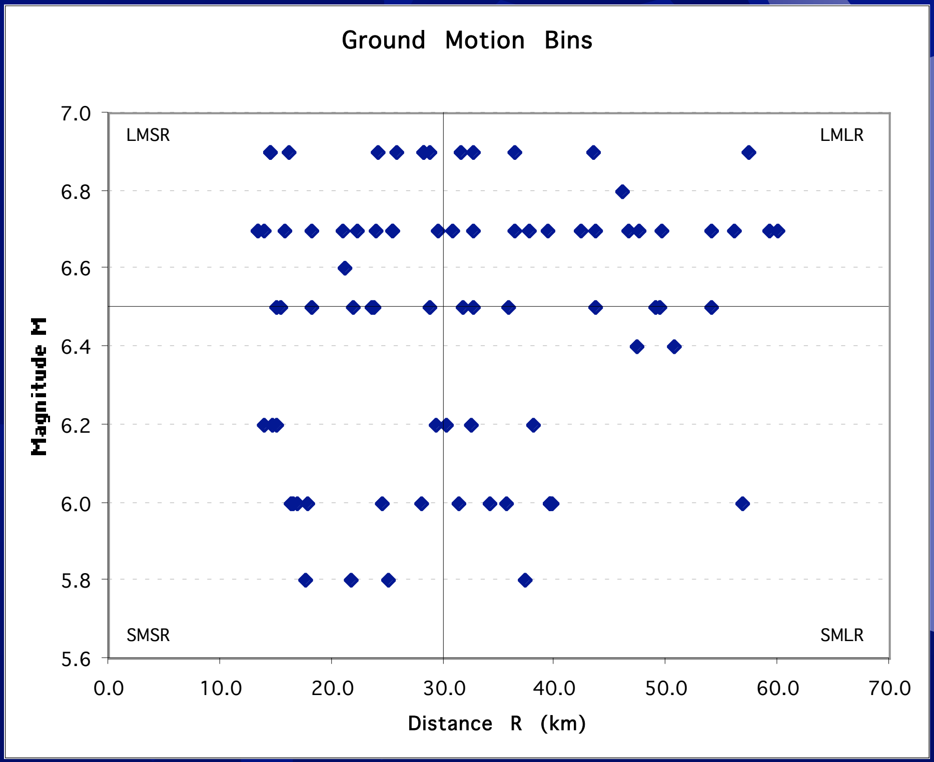
- Define motions (IM)
- Define class of structures (EDP)
- Define analysis model
- Nonlinear analysis



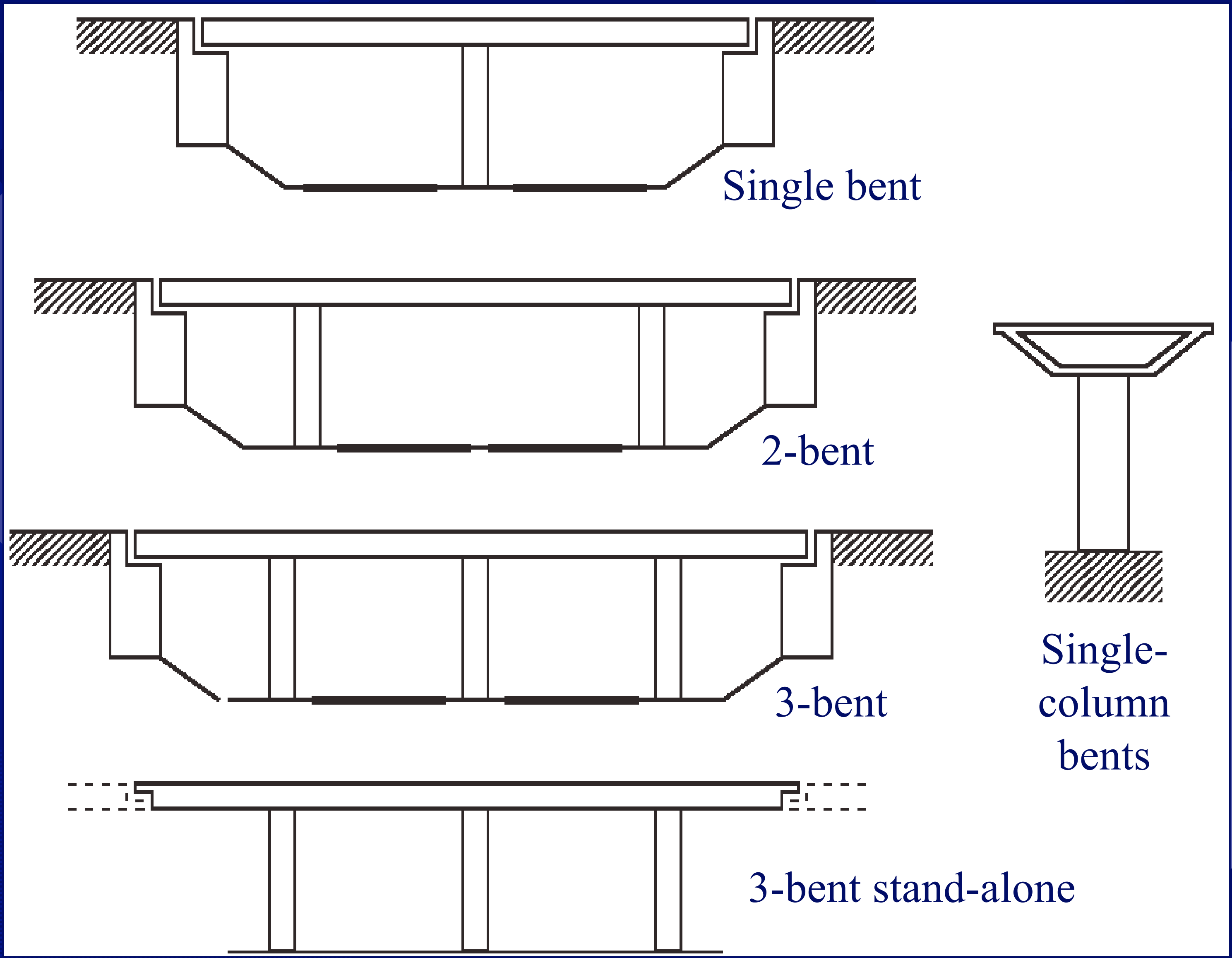
- Design parameter sensitivity
- Ground motion bin sensitivity
- Residual dependence (M, R)

Seismicity: Ground Motions & IMs

- Period Independent Intensity Measures
  - Magnitude, Distance, Strong motion duration
  - Cumulative absolute velocity
  - Cumulative absolute displacement
  - Arias intensity
  - Frequency ratios
  - RMS acceleration
  - Characteristic intensity
  - PGA, PGV, PGD
- Period Dependent Intensity Measures
  - Sa, Sv, Sd
  - Spectral combinations
  - $Sd_{,inelastic}$



Demand: Bridges

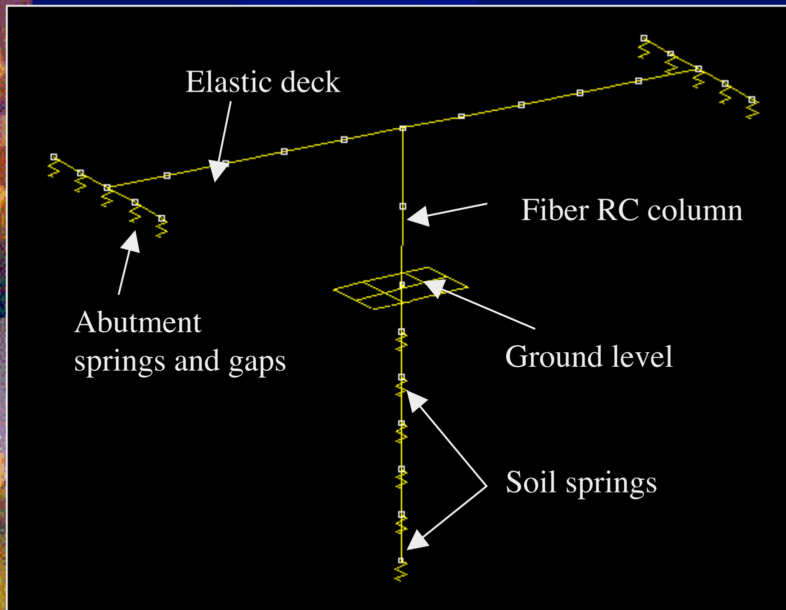


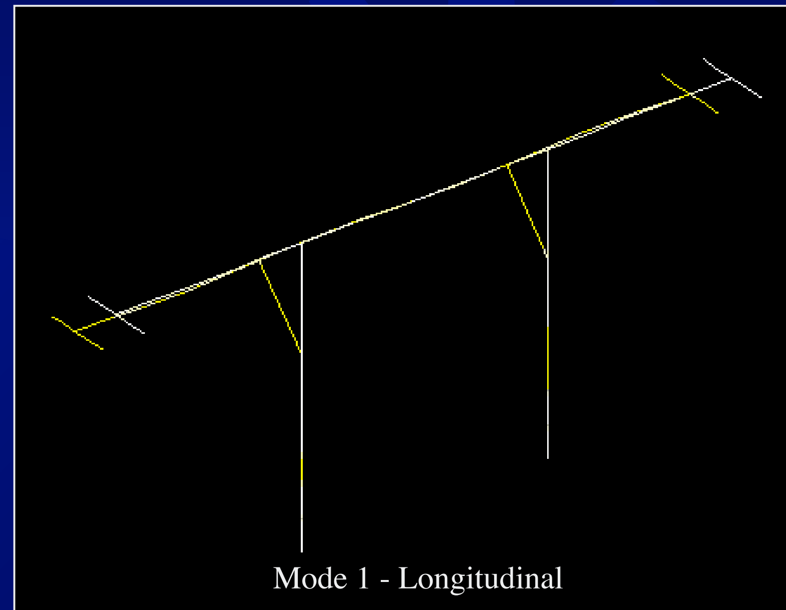
Demand: EDPs

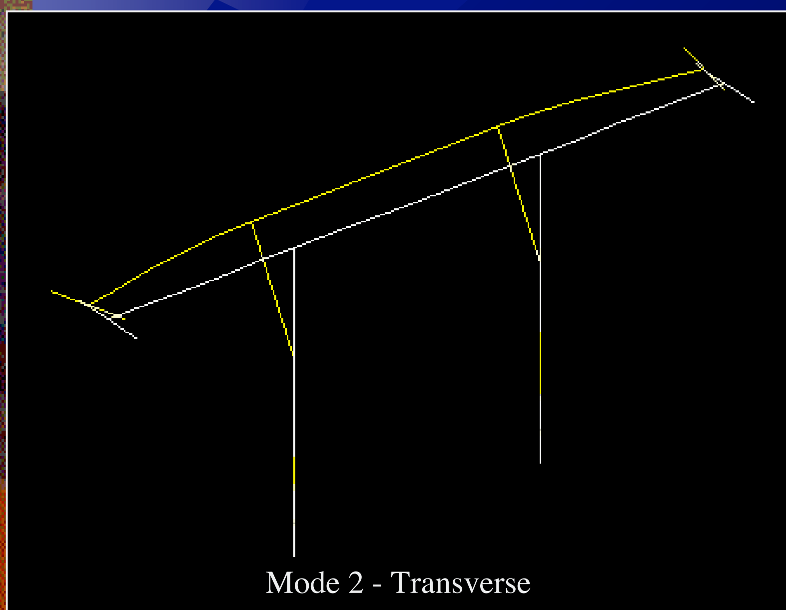
- Local EDPs
  - Steel stress & strain
  - Concrete stress & strain
- Intermediate EDPs
  - Column curvature ductility
  - Maximum column moment
  - Plastic rotation
  - Hysteretic energy
- Global EDPs
  - Displacement ductility
  - Drift ratio
  - Residual displacement index

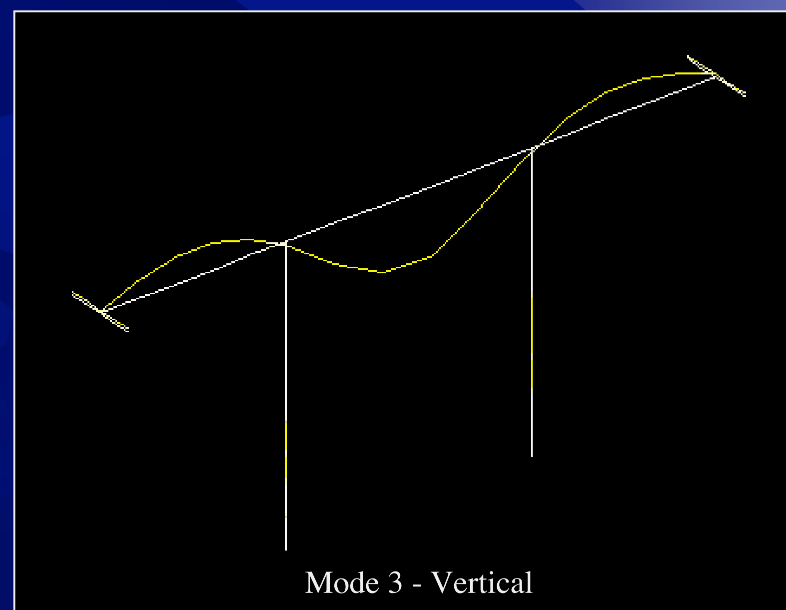
Single column/bent highway overpasses in California

OpenSees Bridge Model

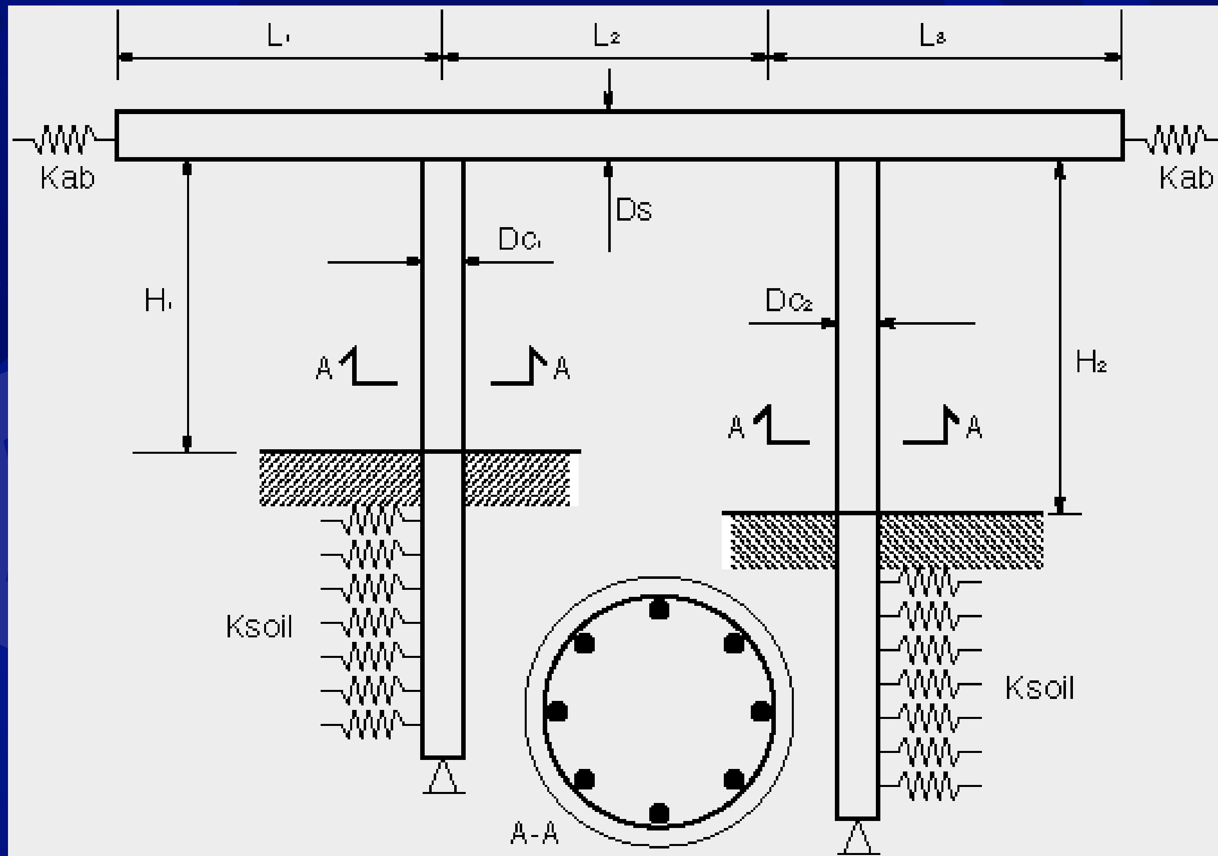








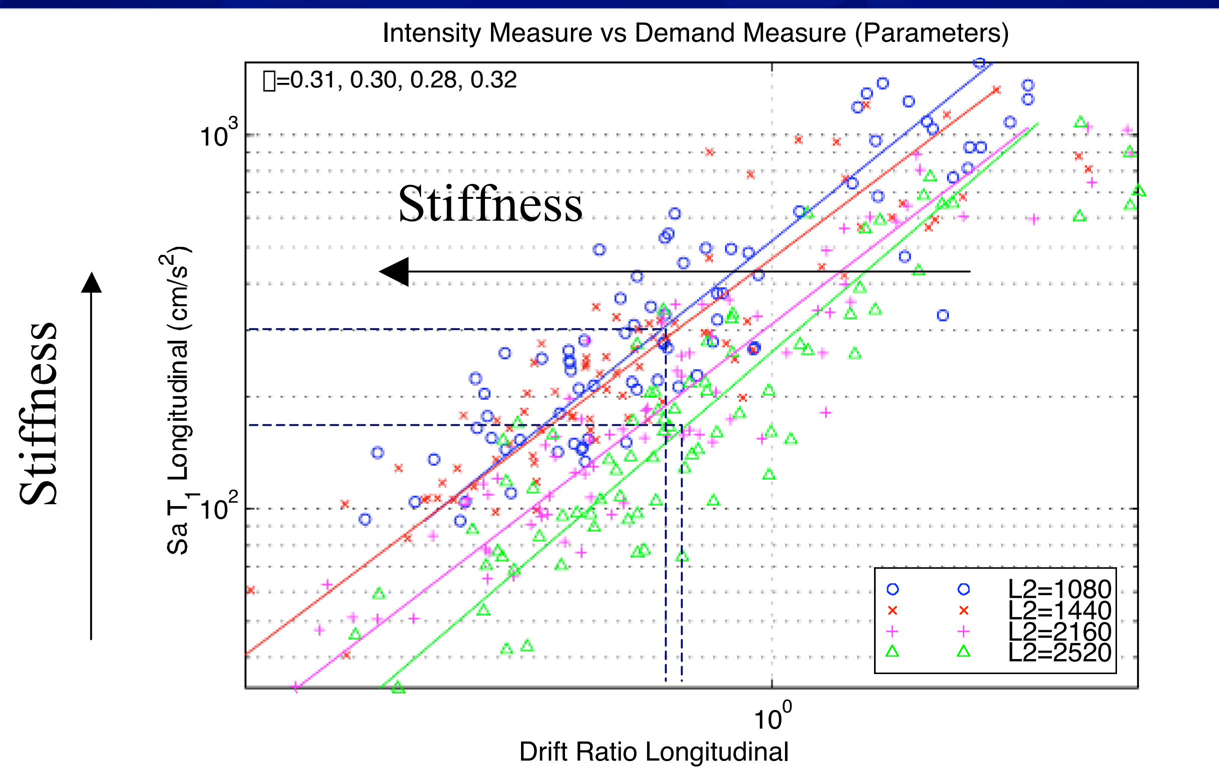
Bridge Design Parameters



• L	span length	60-180 ft
• L/H	span to column height ratio	1.2-3.5
• $\rho_{s,long}$	column longitudinal reinforcement	1-4%
• Dc/Ds	column to superstructure dimensions	0.67-1.33
• Abut	abutment mass/stiffness models	various

Extending Optimal PSDM to Multi-bent bridges

Period-dependent IM with Global response parameter

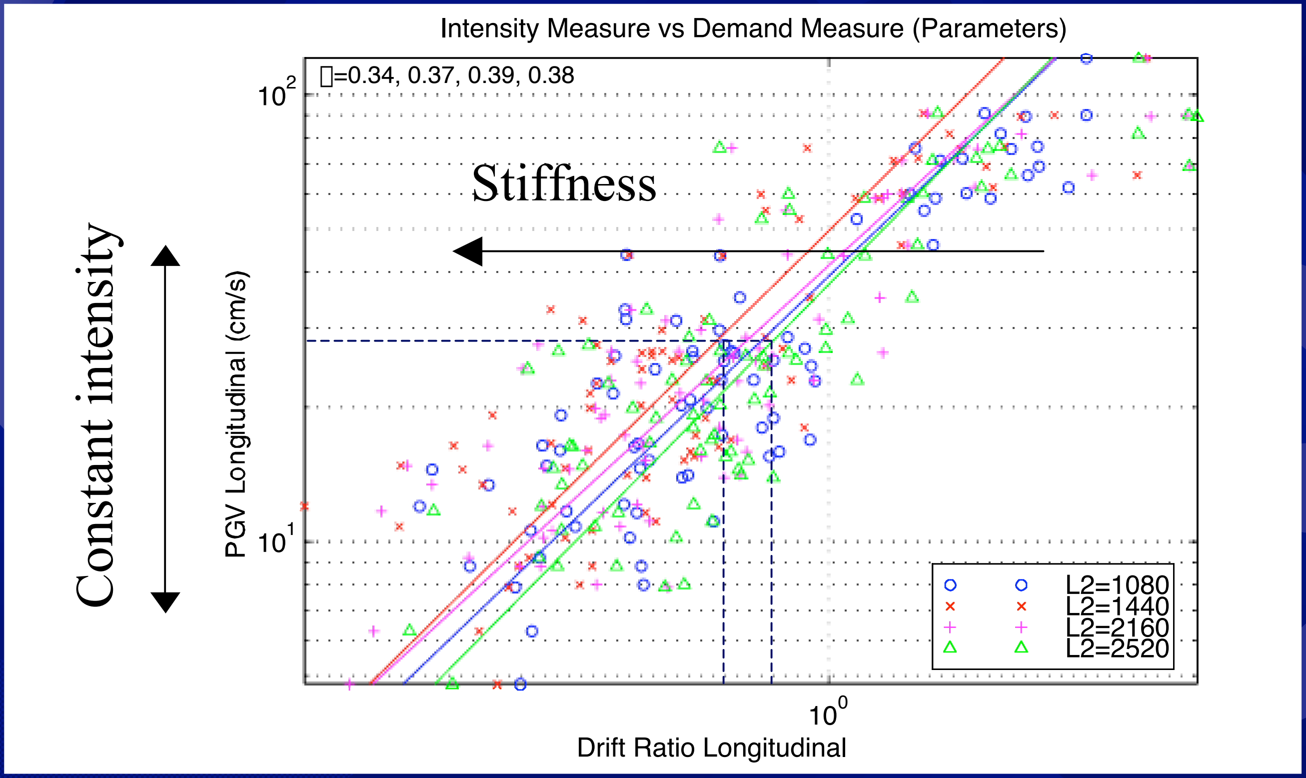


Practical, effective, efficient

2-bent bridge with abutments

Extending Optimal PSDM to Multi-bent bridges

Period-independent IM with Global response parameter

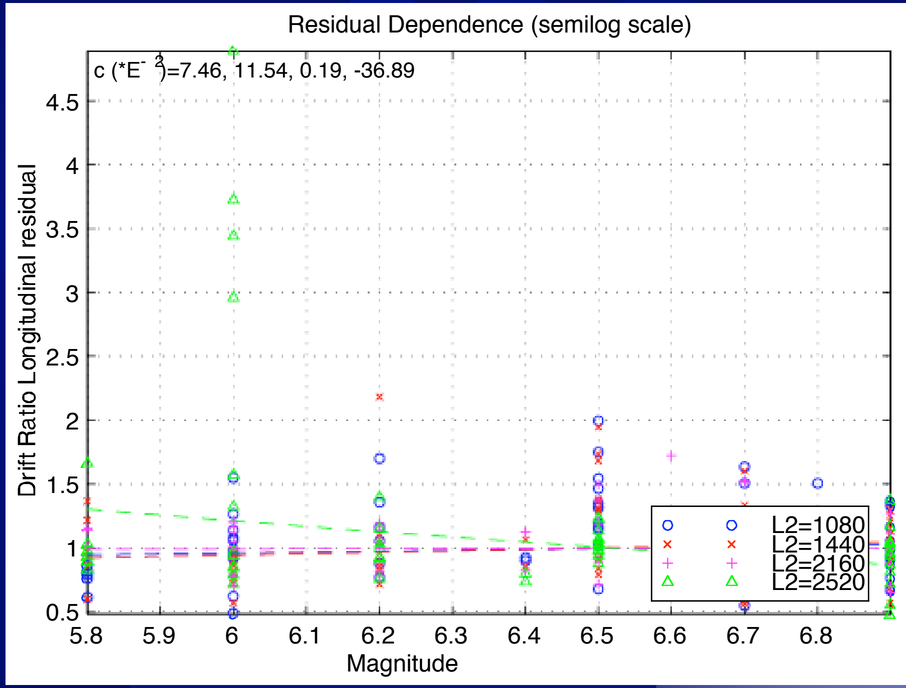


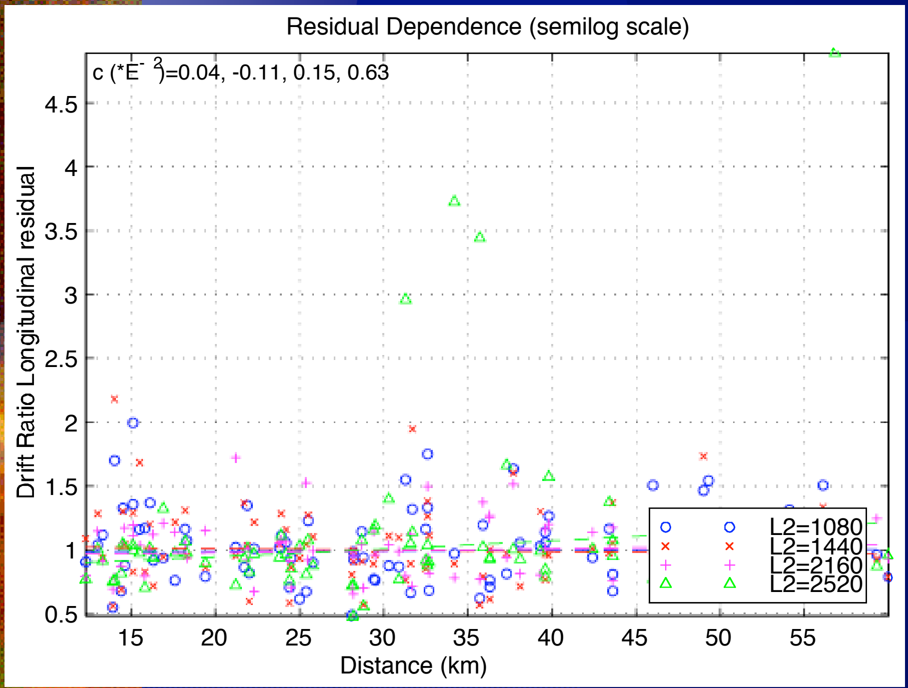
Practical, effective, efficient in short period range

2-bent bridge with abutments

Sufficiency

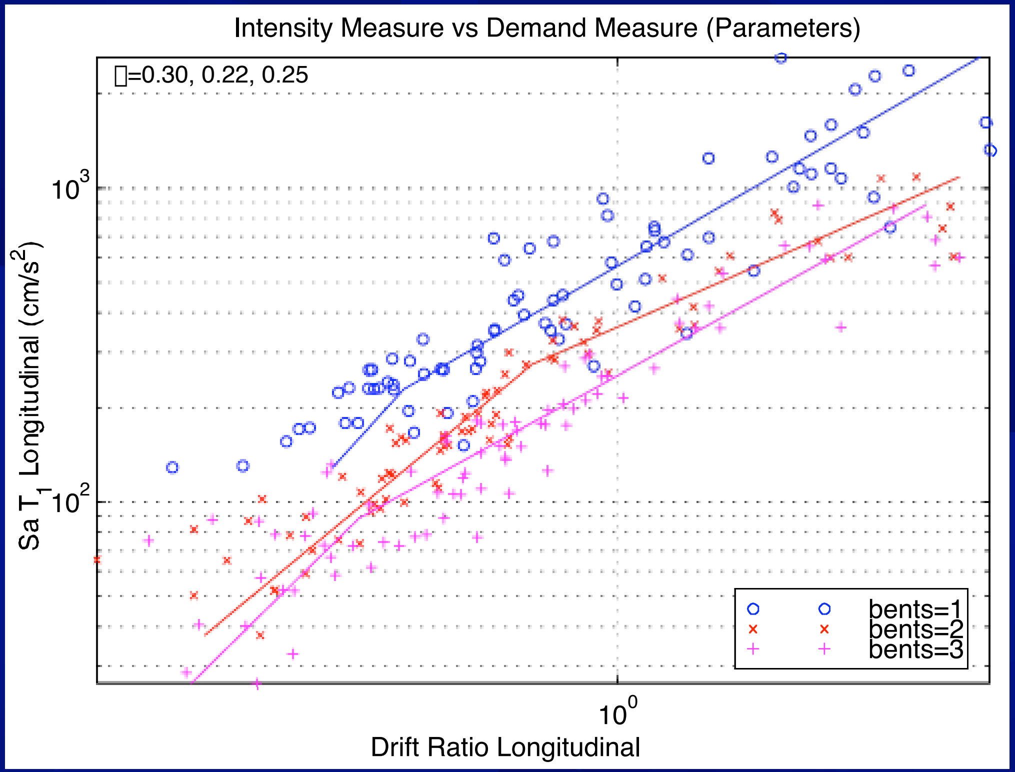
Magnitude dependence





Distance dependence

Bent Configuration Comparison



- Longitudinal demand ⇩ as bents ⇧
- Transverse demand approx. same

Design Parameter Sensitivity

Intermediate Span length (L2)

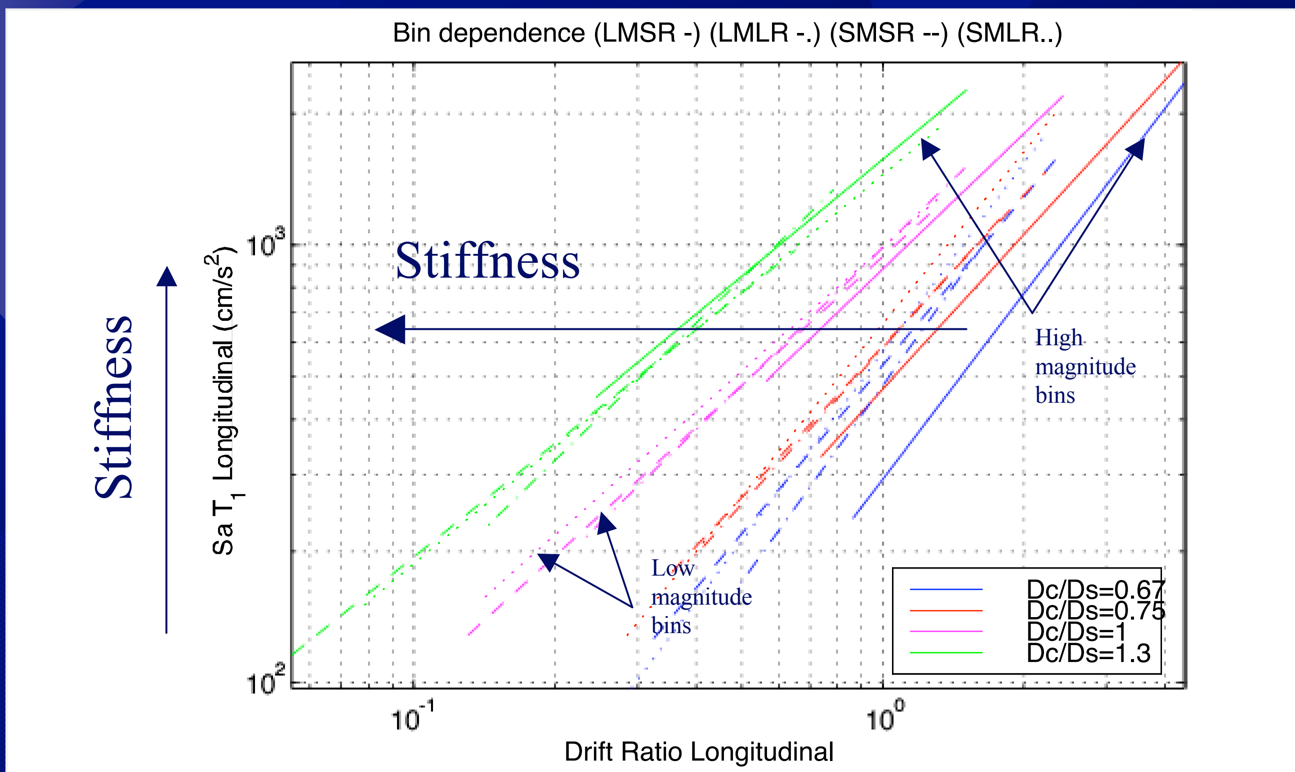
Increasing stiffness lowers demand slightly

3-bent bridge no abutments

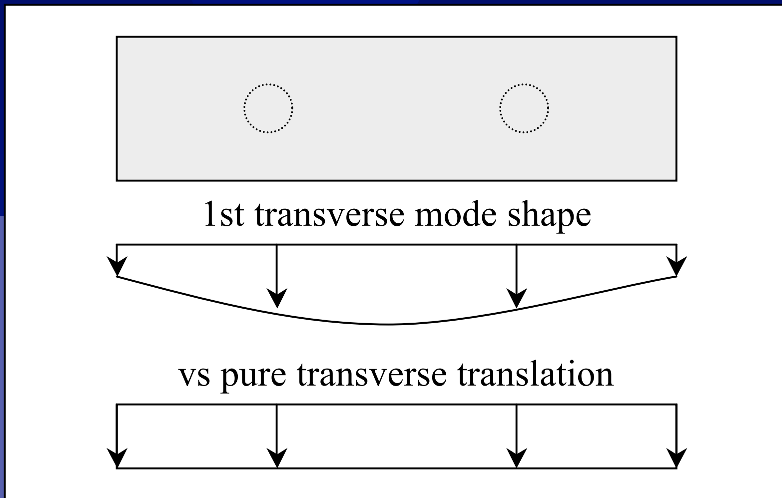
Seismicity

- Parameter sensitivity to bins
- All lines of same color should have same slope at given intensity
- Higher demand for higher magnitude bins

Column diameter to superstructure ratio (DcDs)

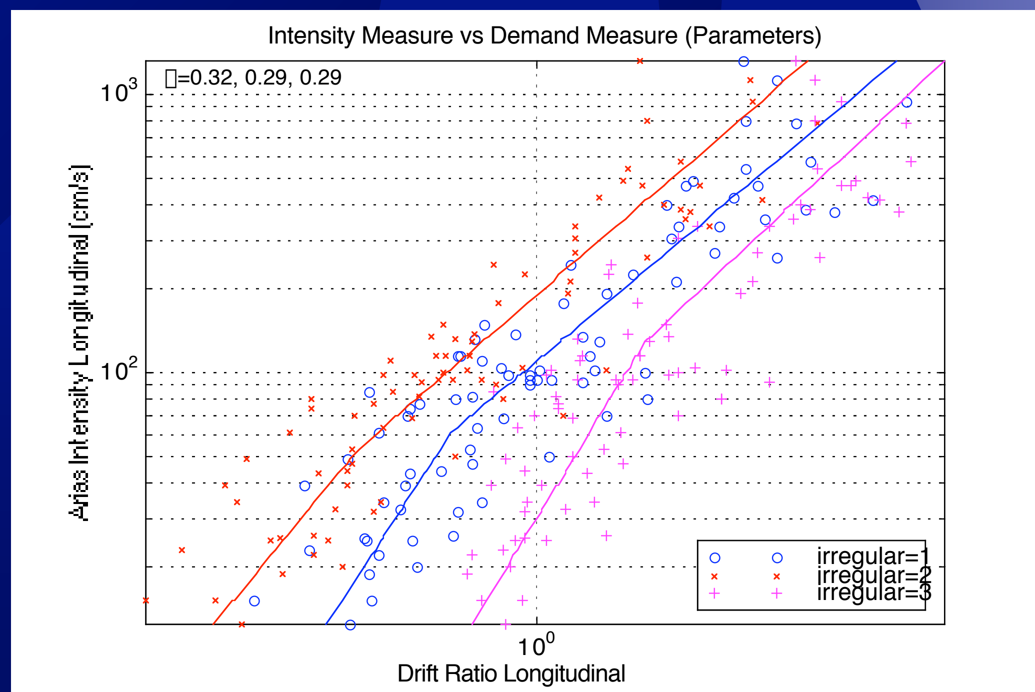


Transverse Irregularity RI*



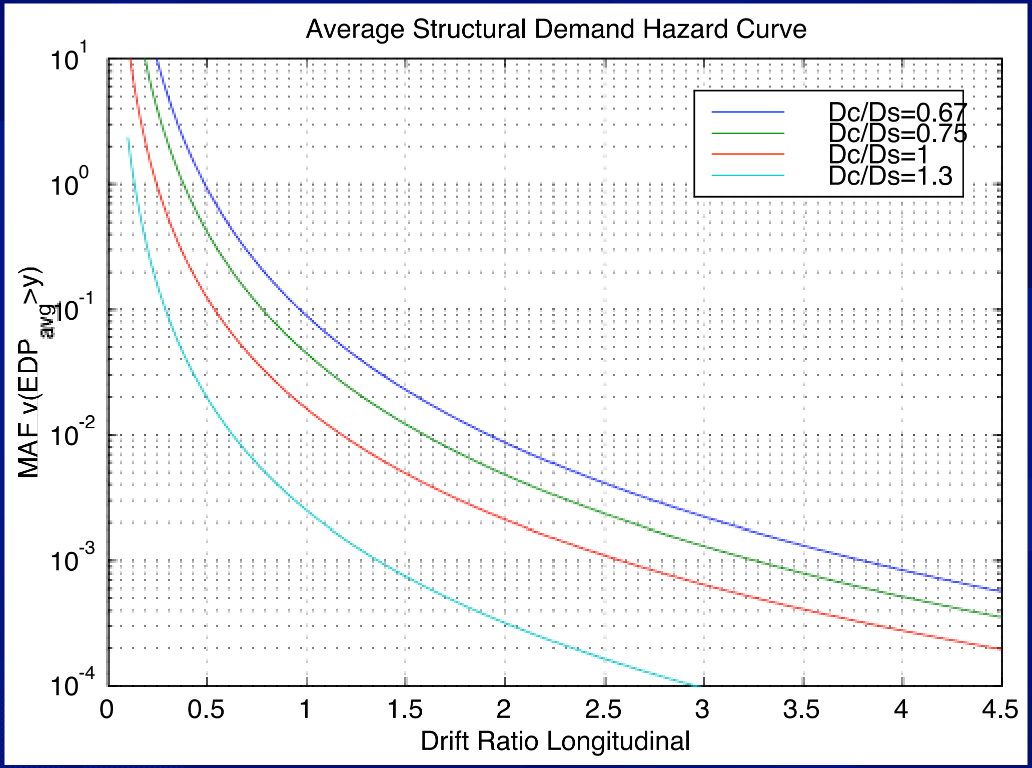
$$RI^* = \left[\frac{1}{L} \int_0^L \square(x)dx \right] * 100\%$$

No loss of efficiency with period independent IM



PSDM Extensions

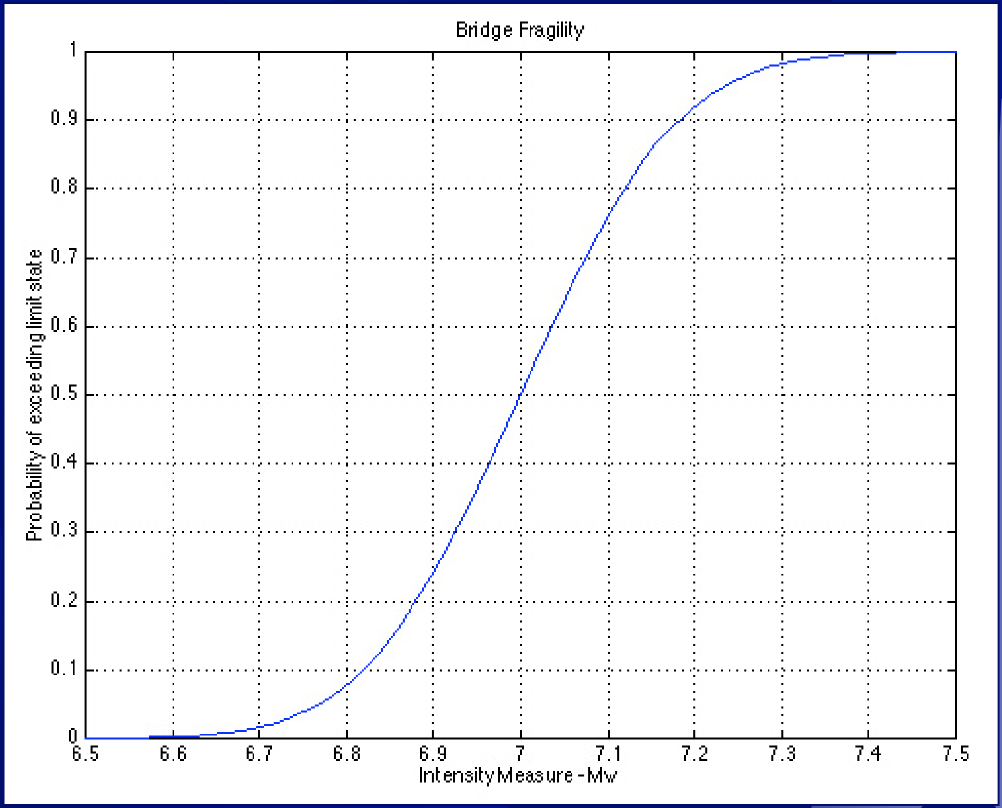
Structural Demand Hazard Curves



PSDM Extensions

Functional EDPs

- Maximum post-earthquake functionality (traffic load, eg)
- Probability of exceeding a given damage state (fragility)



Conclusions

- PSDMs allow designers to see the effects of:
  - seismicity
  - design parameters

  on seismic performance of a bridge
- PSDMs fit into PEER performance-based design framework, Sa(T_1)-□ optimal PSDM reduces demand model dispersion
- Optimal single-bent models remain optimal for multi-bent
- Transverse irregularity (RI*) adequately predicted by Sa(T_1)

Thank You!

- Questions?
- For more information contact:
  - Kevin Mackie: mackie@ce.berkeley.edu
  - Boza Stojadinovic: boza@ce.berkeley.edu
- Visit http://millerbird.ce.berkeley.edu