Probabilistic Seismic Demand Model for California Highway Bridges

Kevin Mackie
Bozidar Stojadinovic

Session 6A:

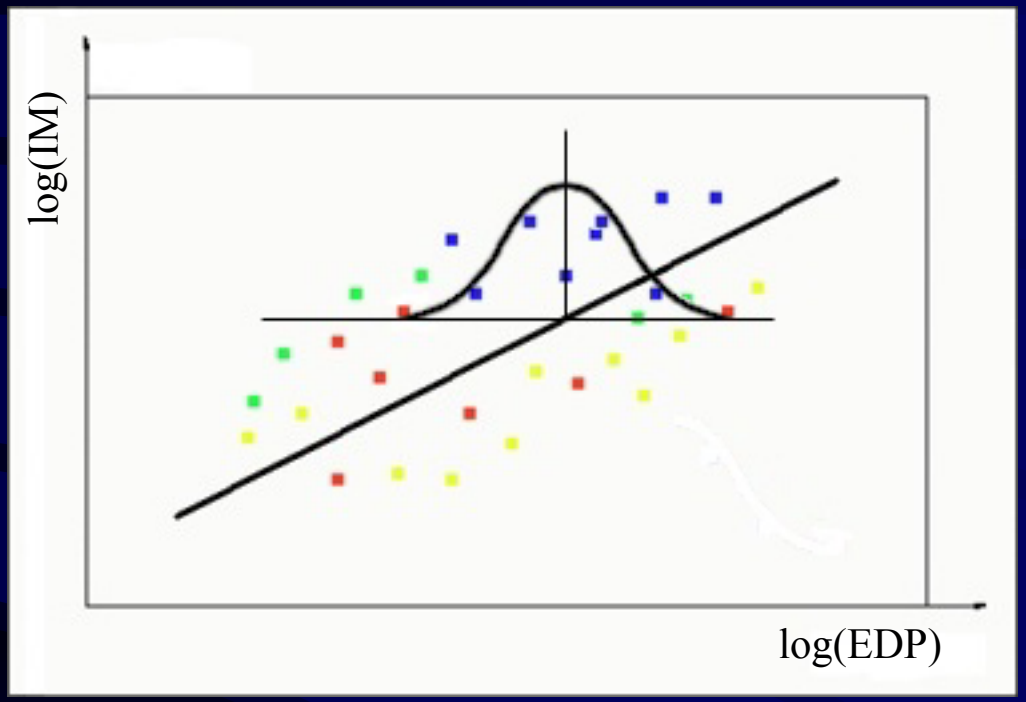
Seismic Design and Retrofit II

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

New York City Bridge Conference
October 29-30, 2001

What is a PSDM?

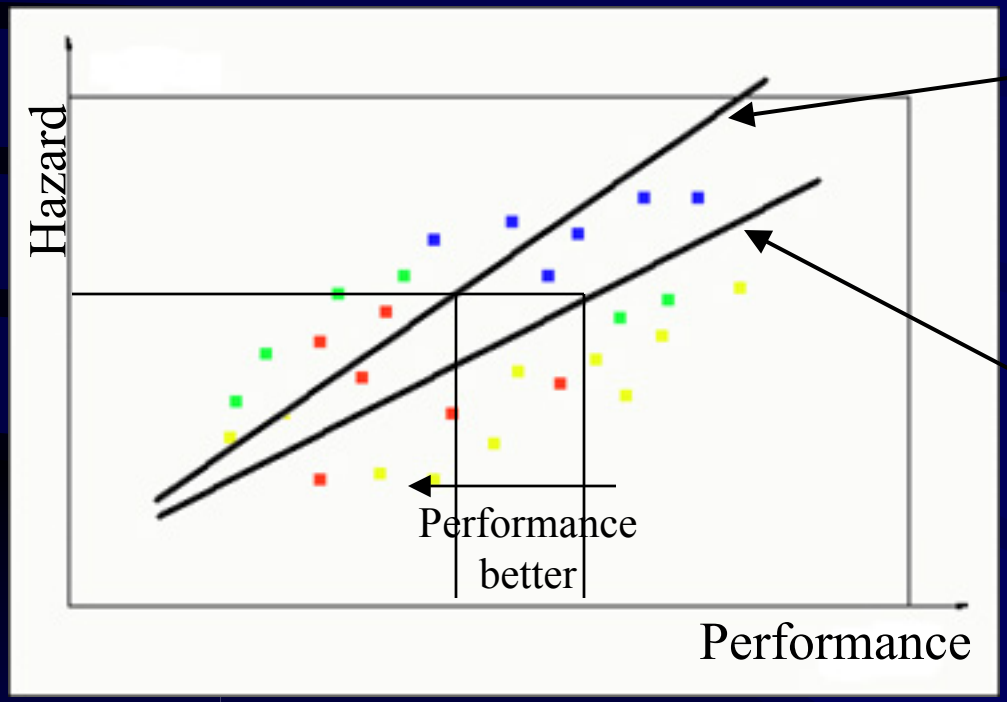
PSDM = Probabilistic Seismic Demand Model

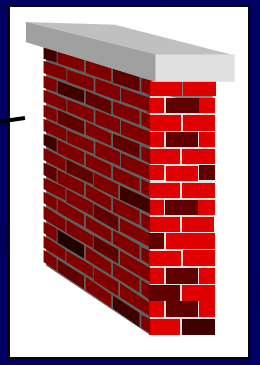


Relationship of seismic Intensity Measures (IM) to structural Engineering Demand Parameters (EDP)

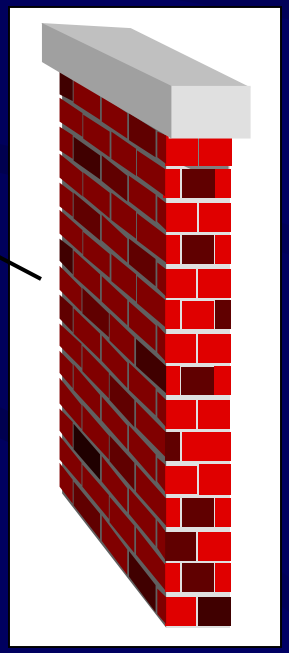
Practical Uses

How do design parameters affect performance?





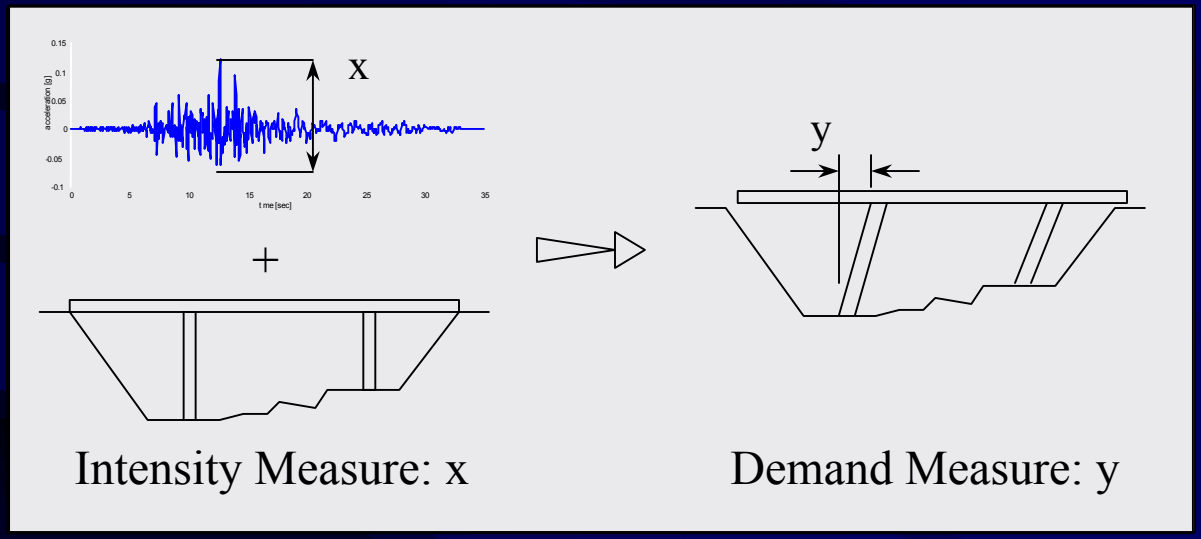
Shorter
(stiffer)



Taller
(flexible)

Why a demand model?

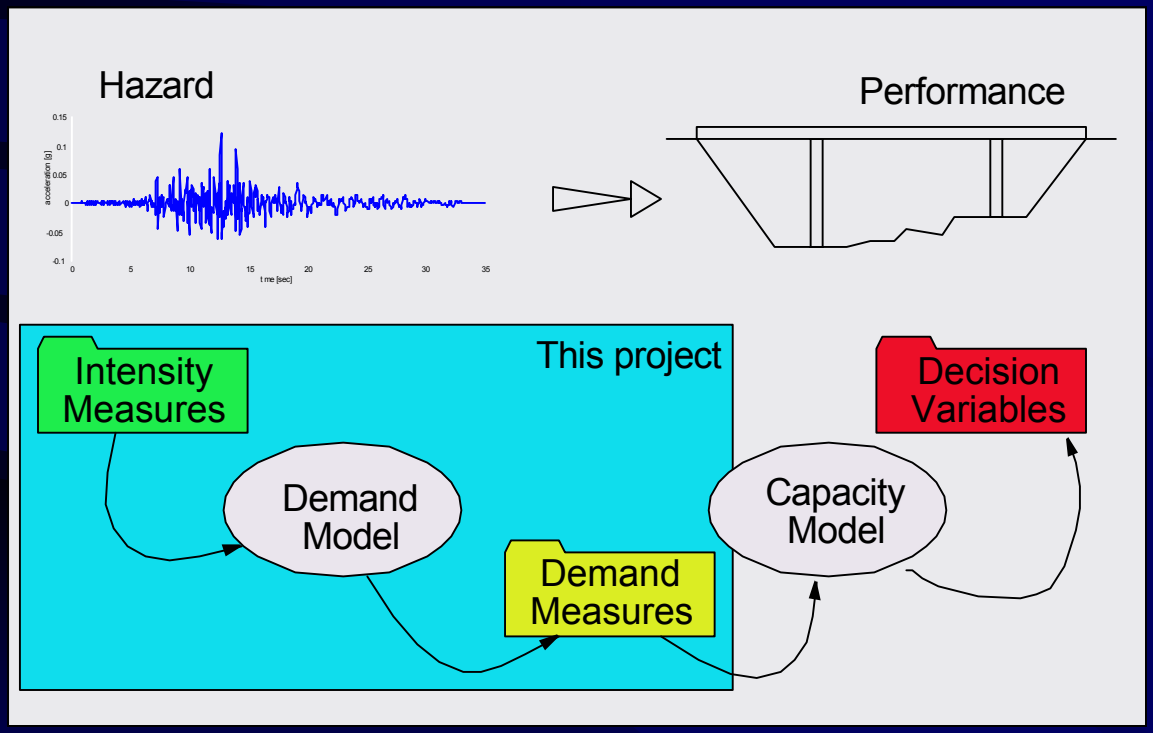
1.) Quantitative Performance Based Earthquake Engineering tool for designers of bridges



What is probability of y, given x?

Why a demand model?

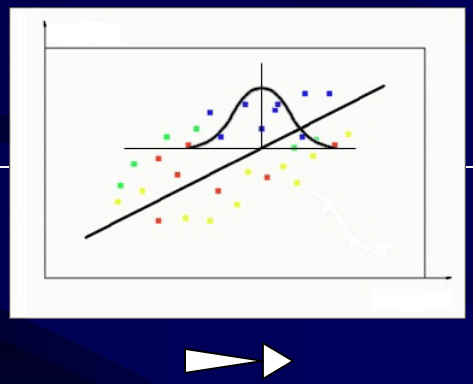
2.) Module in Pacific Earthquake Engineering Research Center (PEER) probabilistic framework



PEER Performance based earthquake engineering framework

Probabilistic Seismic Demand Analysis

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

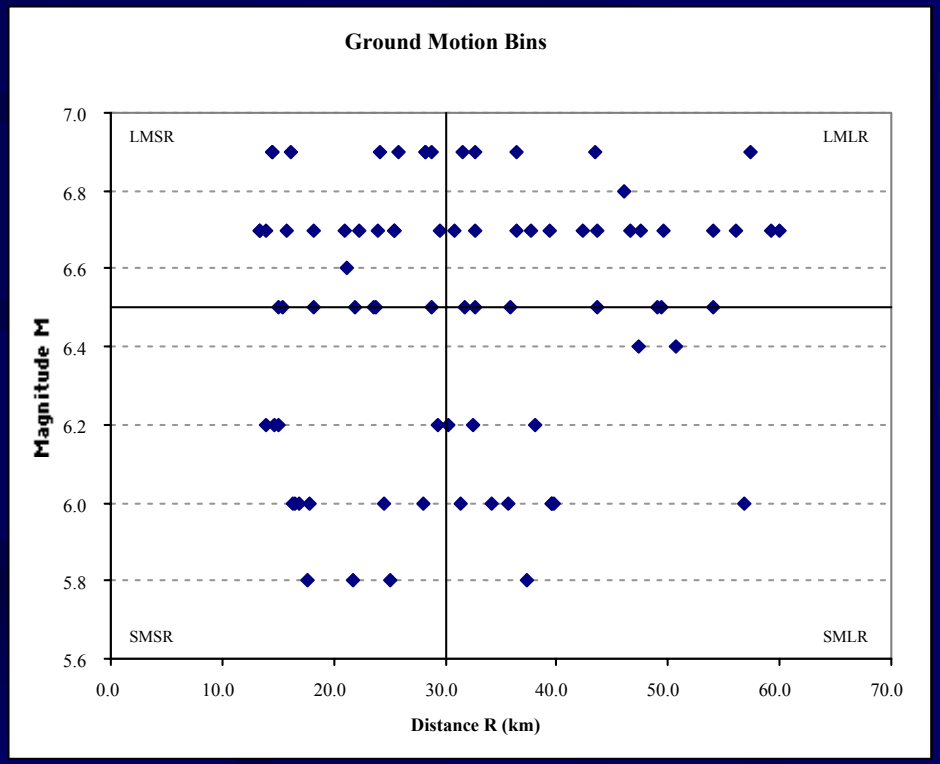


- Design parameter sensitivity
- Ground motion bin sensitivity
- Residual dependence (M, R)

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
  - $Sd_{,inelastic}$



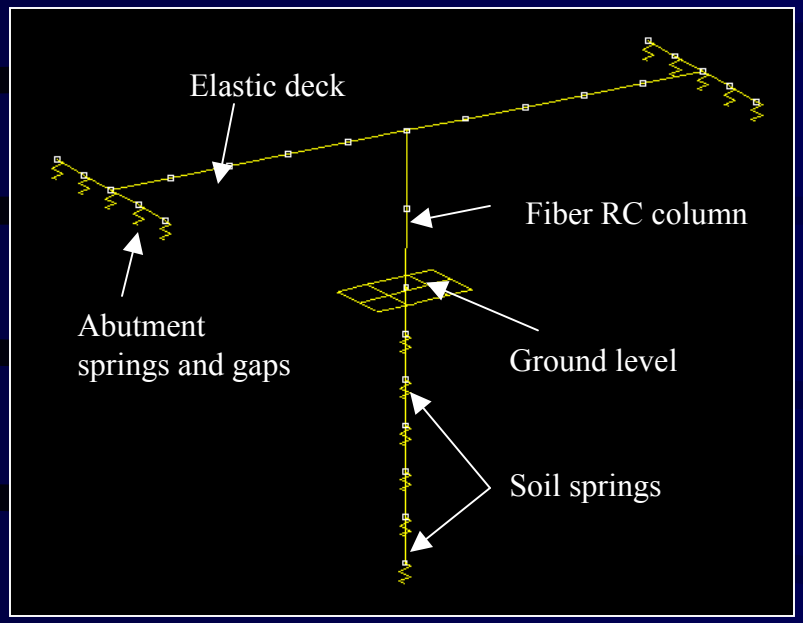
Demand: Bridges & EDPs

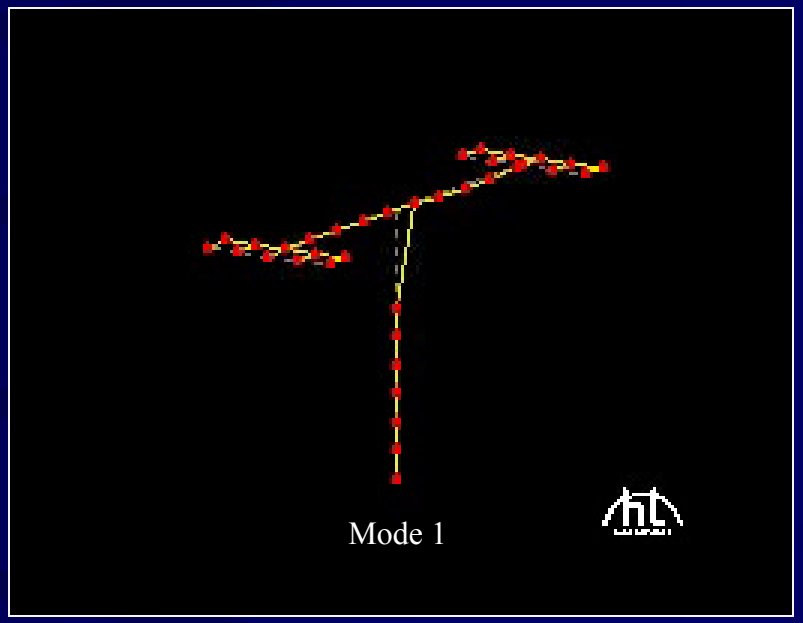
- Local EDPs
  - Steel stress & strain
  - Concrete stress & strain
- Intermediate EDPs
  - Column curvature ductility
  - Maximum column moment
  - Plastic rotation
  - Hysteretic energy

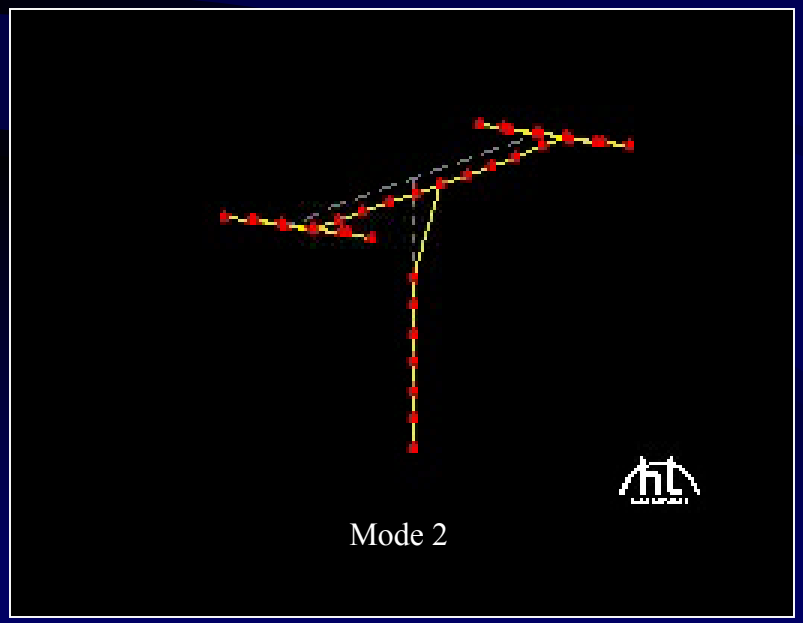
- Global EDPs
  - Displacement ductility
  - Drift ratio
  - Residual displacement index

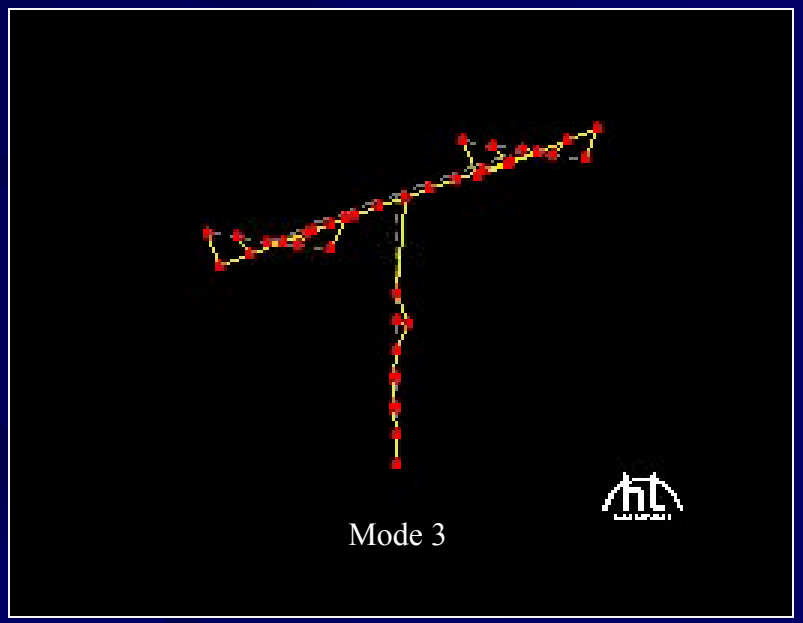
Single column/bent highway overpasses in California

OpenSees Bridge Model

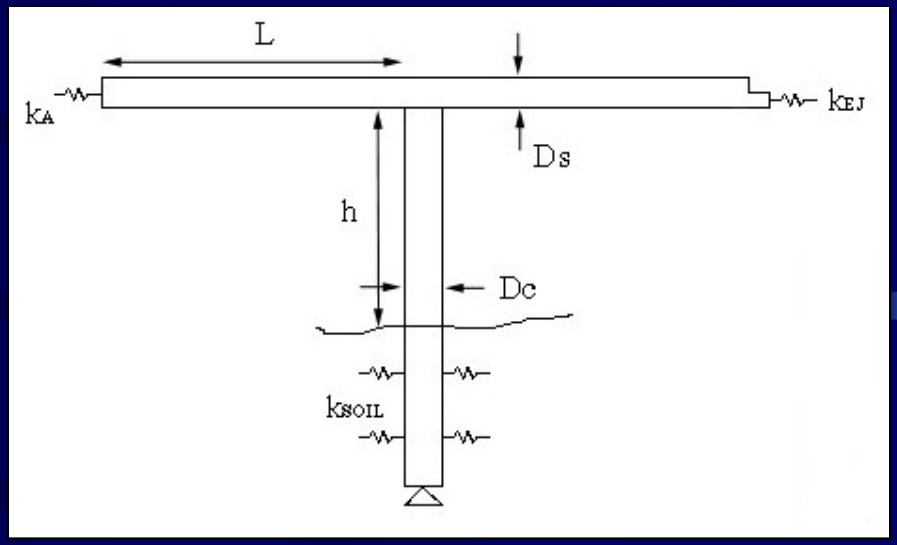








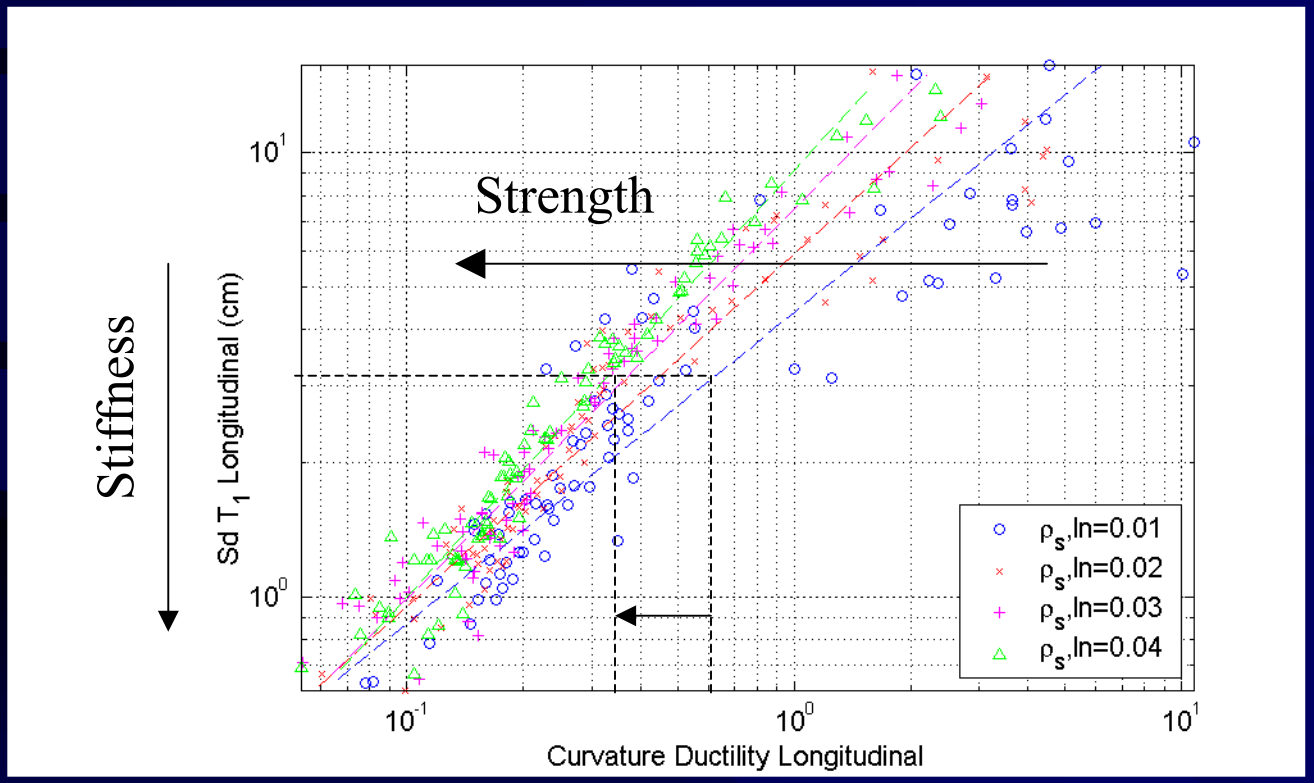
Bridge Design Parameters



• L	span length	60-180 ft
• L/h	span to column height ratio	1.2-3.5
• fy	steel strength	68-95 ksi
• f'c	concrete strength	3-8 ksi
• $\rho_{s,long}$	column longitudinal reinforcement	1-4%
• Dc/Ds	column to superstructure dimensions	0.67-1.33
• Ksoil	USGS soil group	A,B,C,D
• Wt	additional superstructure weight	10-150%
• $\rho_{s,trans}$	column transverse reinforcement	0.4-1.1%
• Abut	abutment mass/stiffness models	various

Design Parameter Sensitivity

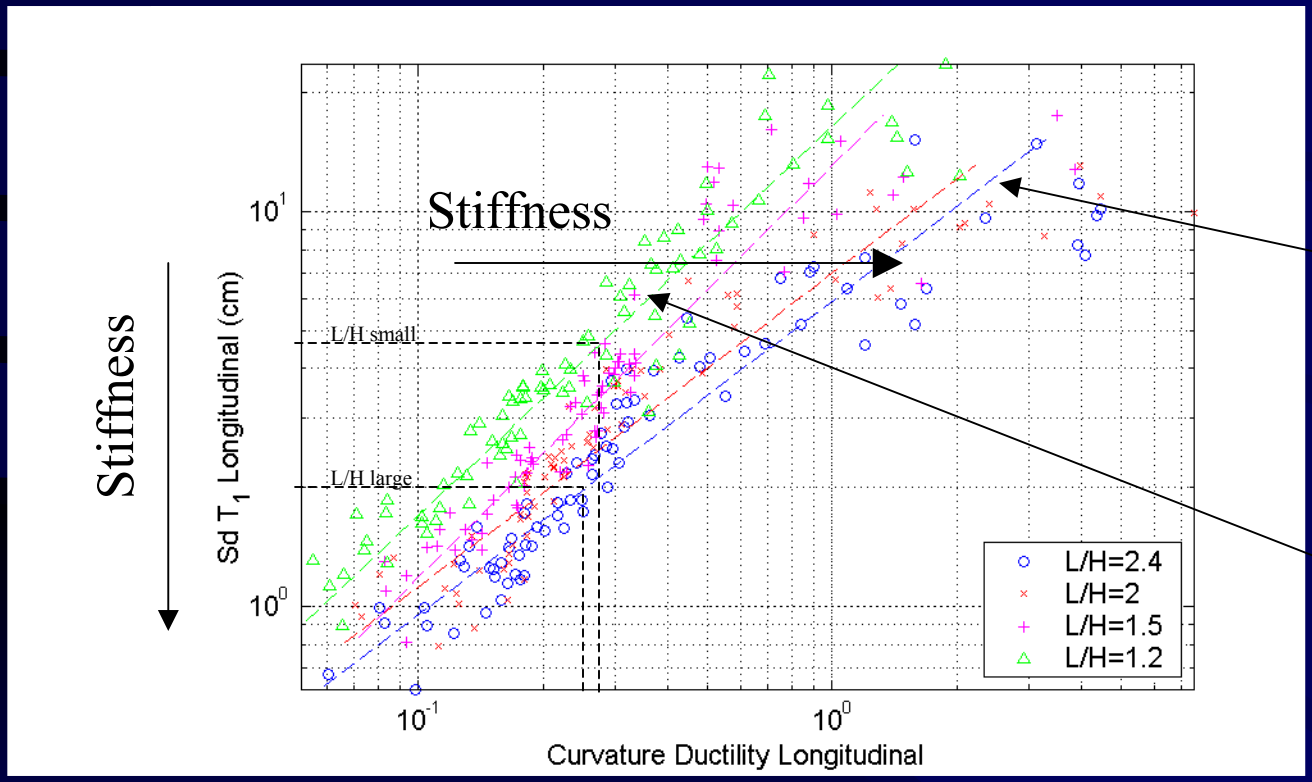
Longitudinal steel reinforcement ratio (ρ_s)

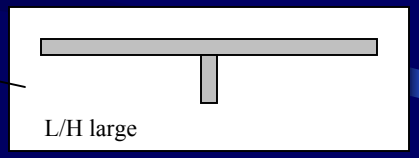


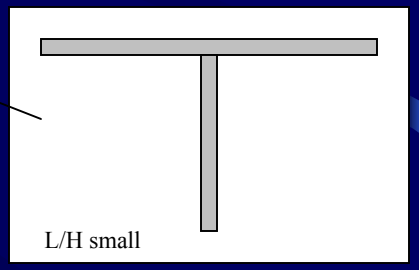
Increasing strength decreases demand

Design Parameter Sensitivity

Span length (L) to column height (H) ratio



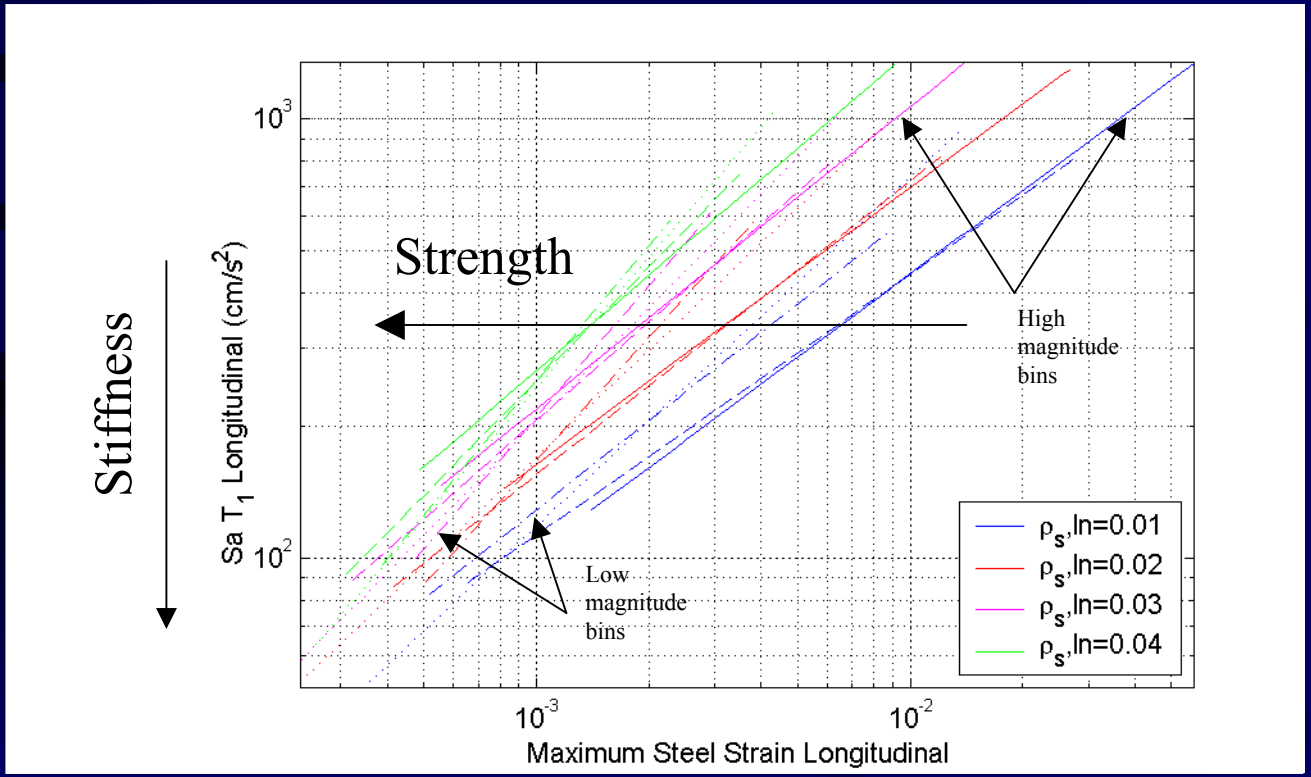




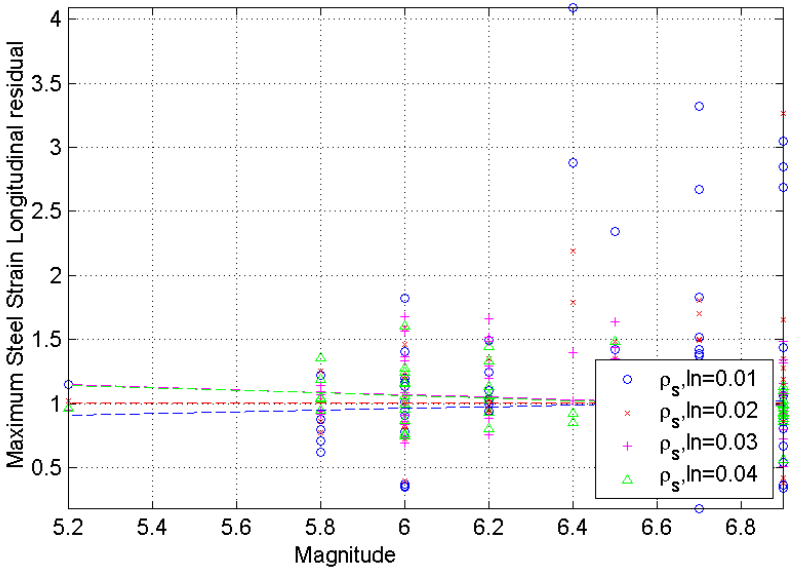
Increasing stiffness has negligible effect on demand

Seismicity

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

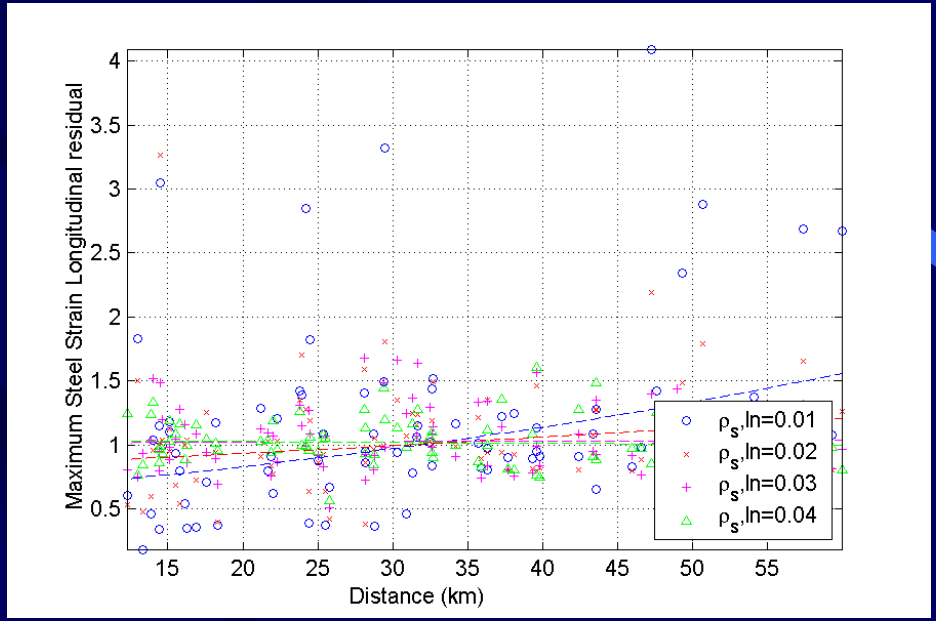


Sufficiency



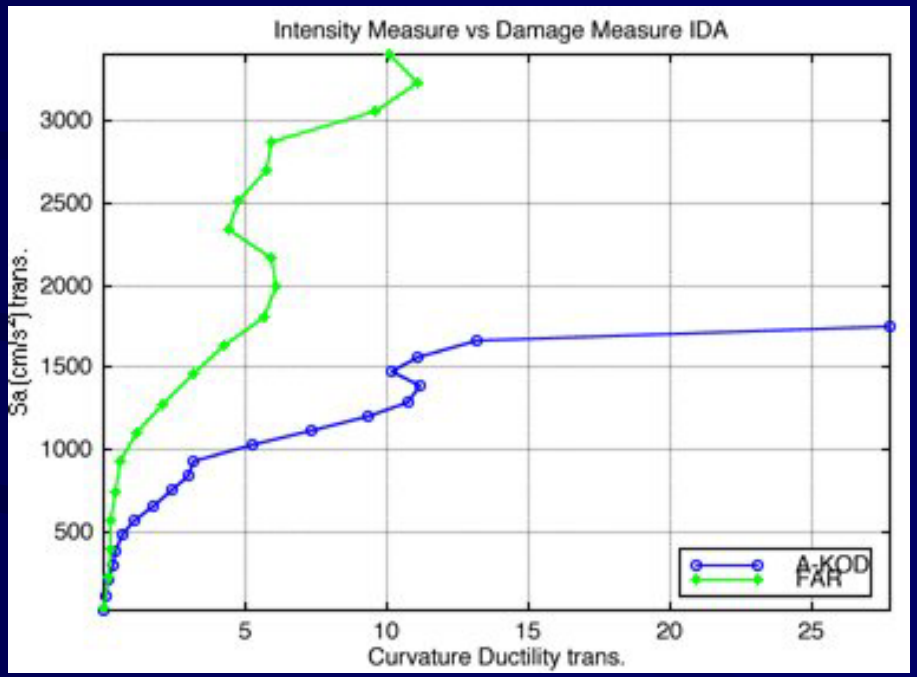
- Magnitude dependence

- Distance dependence

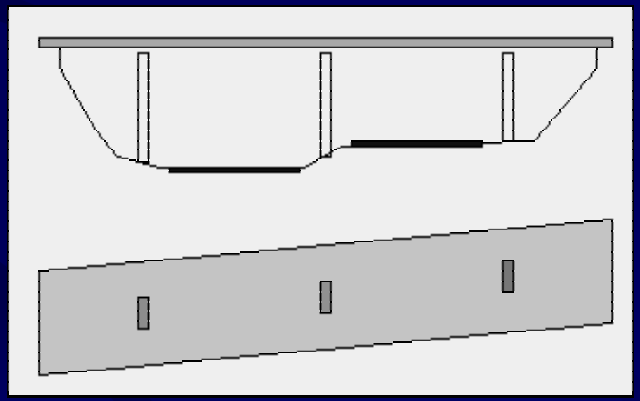


PSDM Extensions

- Use of Incremental Dynamic Analysis (IDA) in place of PSDA

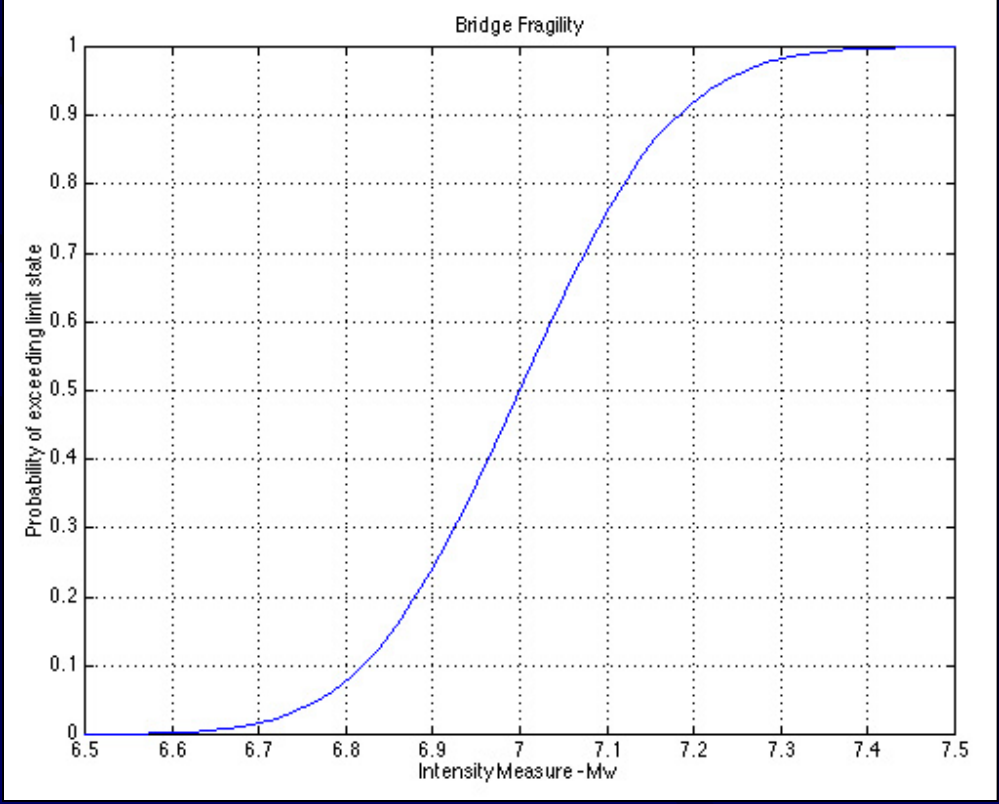


- Other bridge configurations (two bent, 3 bent, no bent)



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
- PSDM methodology can be applied to other types of hazard...

PSDM for Other Hazards

- Consider other hazards:
  - East coast seismic events
  - Blast loading
  - Fire rating
- Develop Hazard models for these hazards
- Develop Demand models as shown in this presentation

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