PEER

Toward Probabilistic Performance-based Seismic Design of Concrete Bridges

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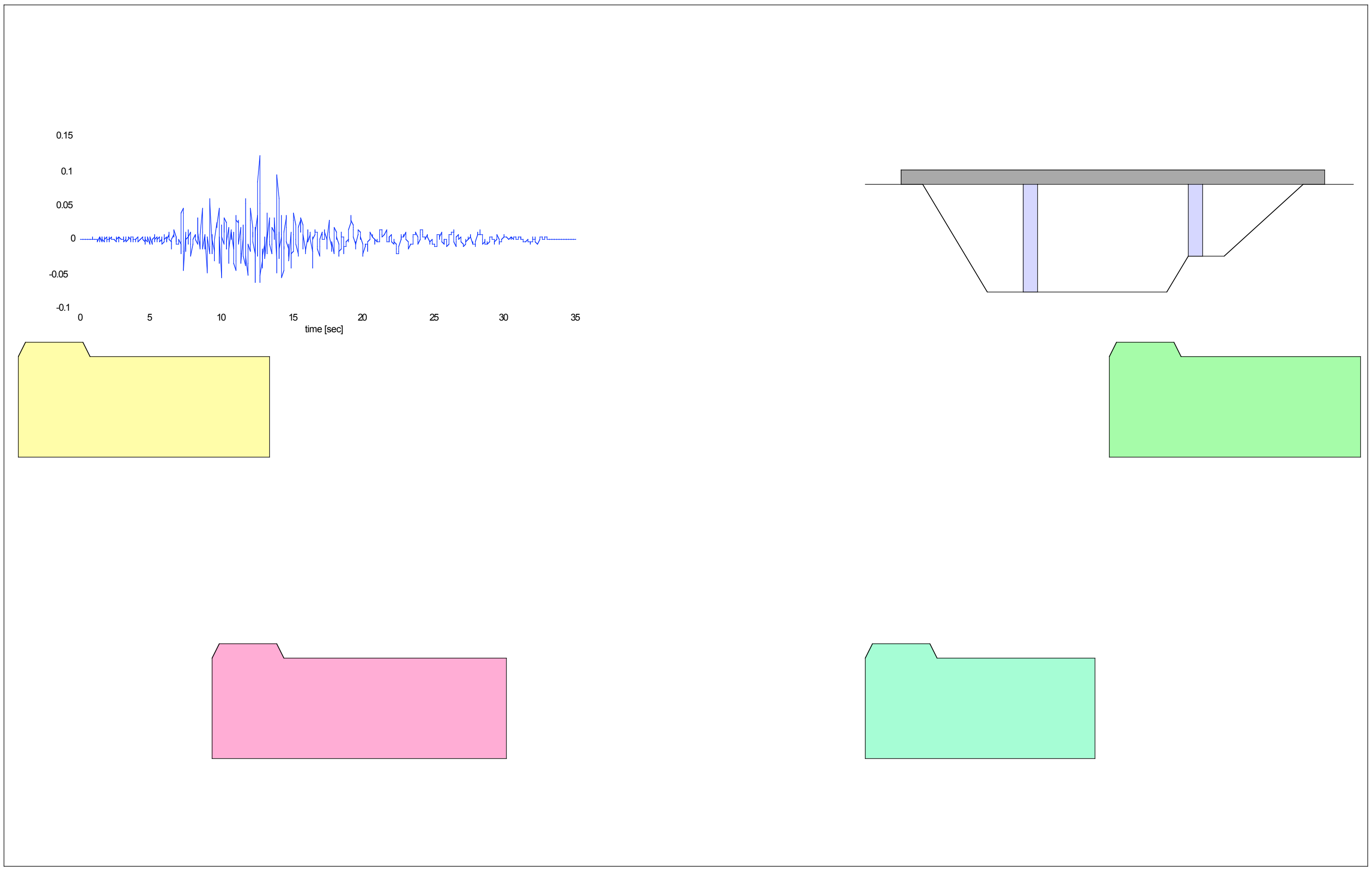
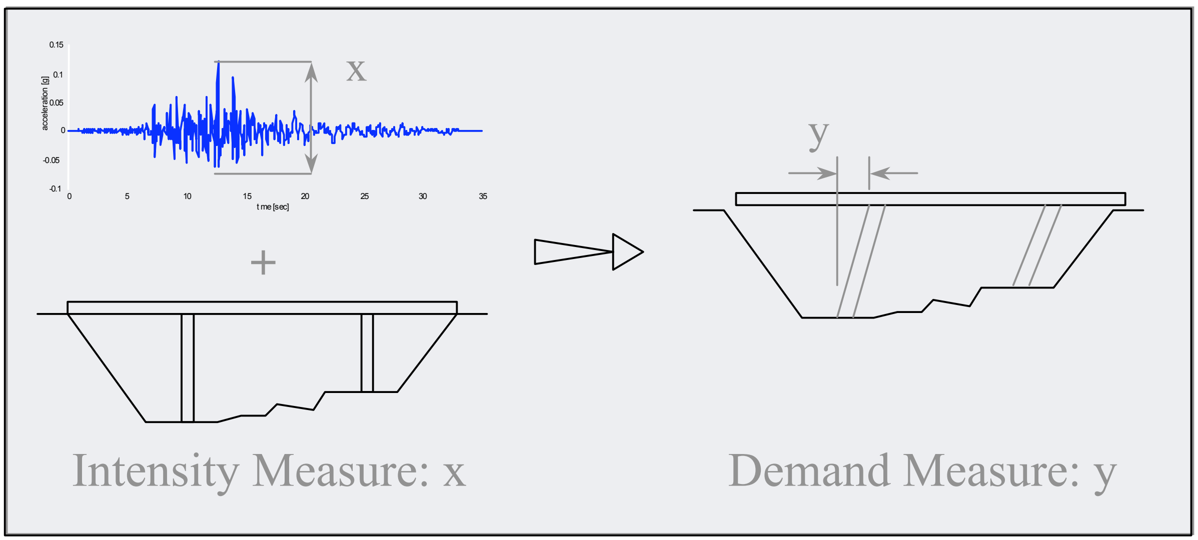
PEER PBD Framework



Why a demand model?

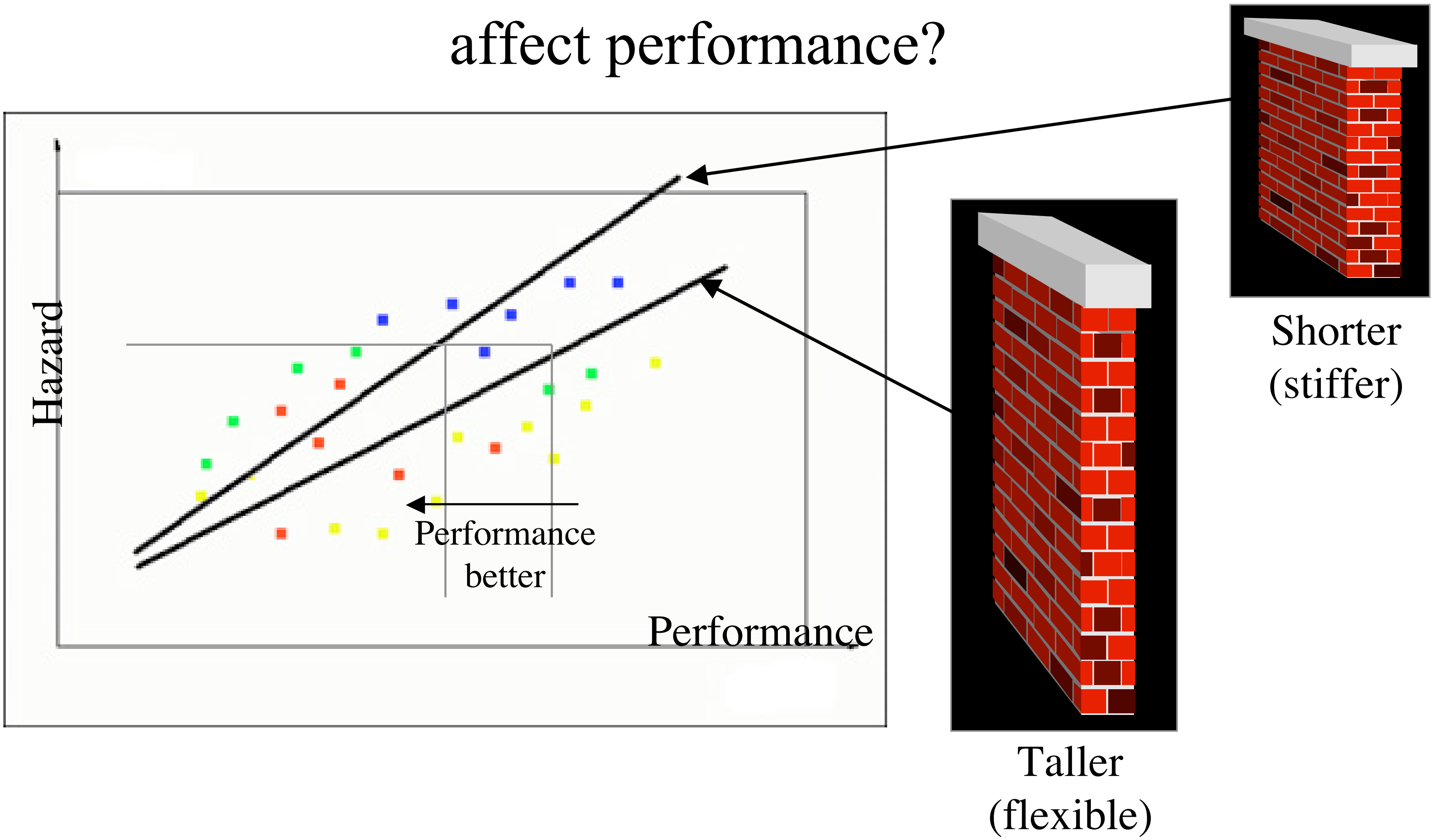
1.) Quantitative Performance Based Earthquake Engineering tool for designers of bridges



What is probability of y, given x?

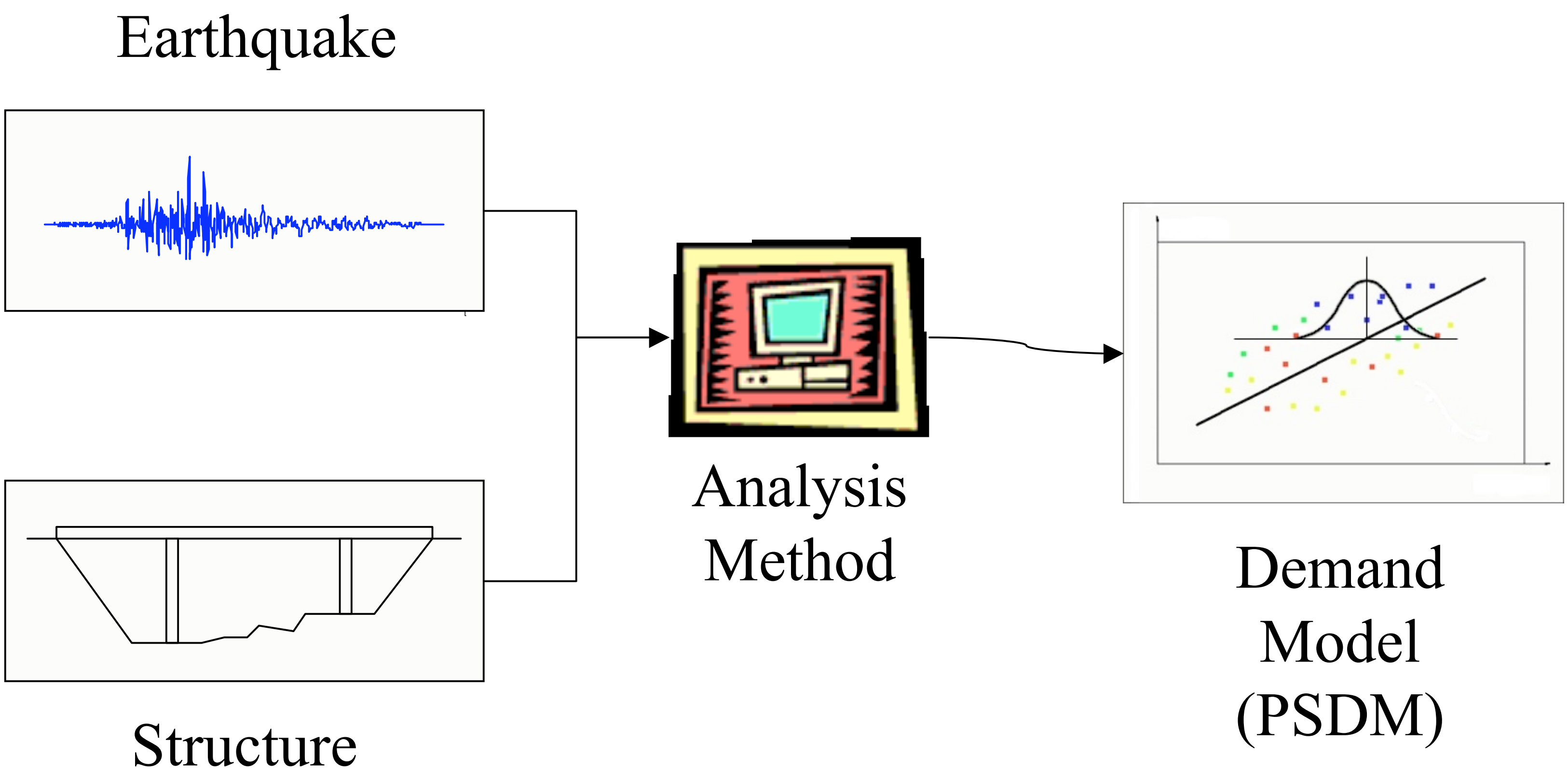
Why a demand model?

2.) How do design parameters affect performance?



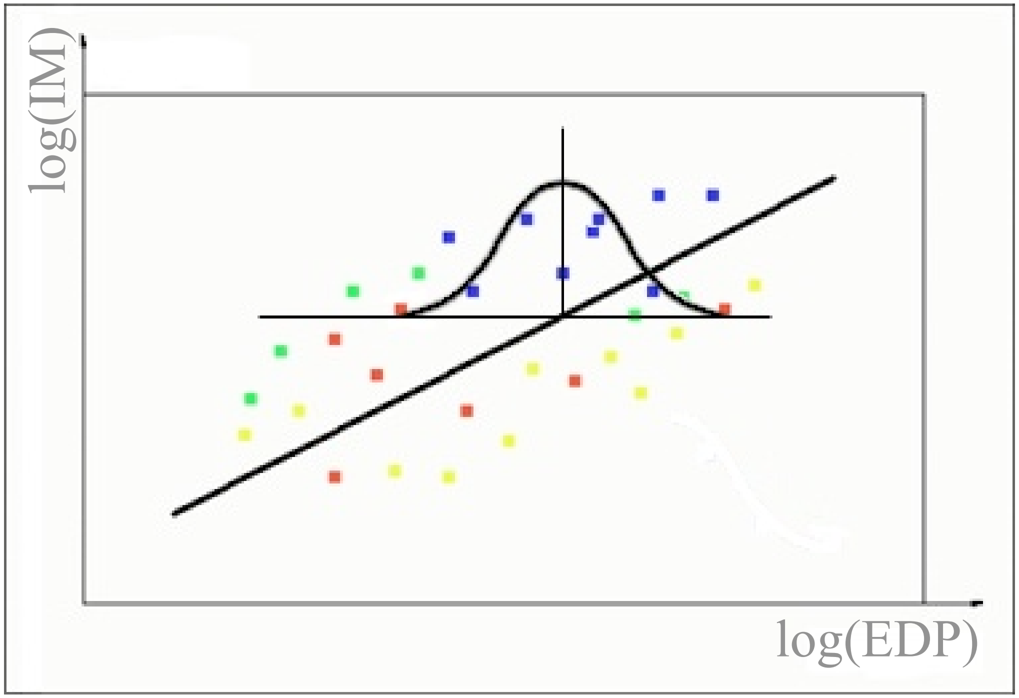
The Big Picture

General Probabilistic Seismic Demand Analysis



What is a PSDM?

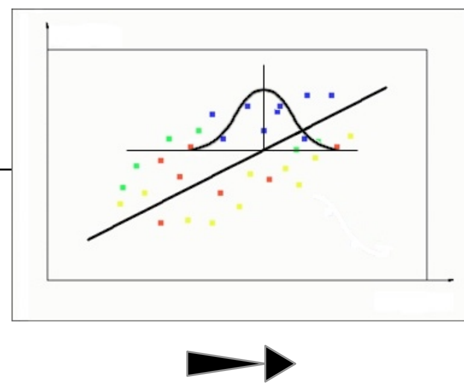
PSDM = Probabilistic Seismic Demand Model



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

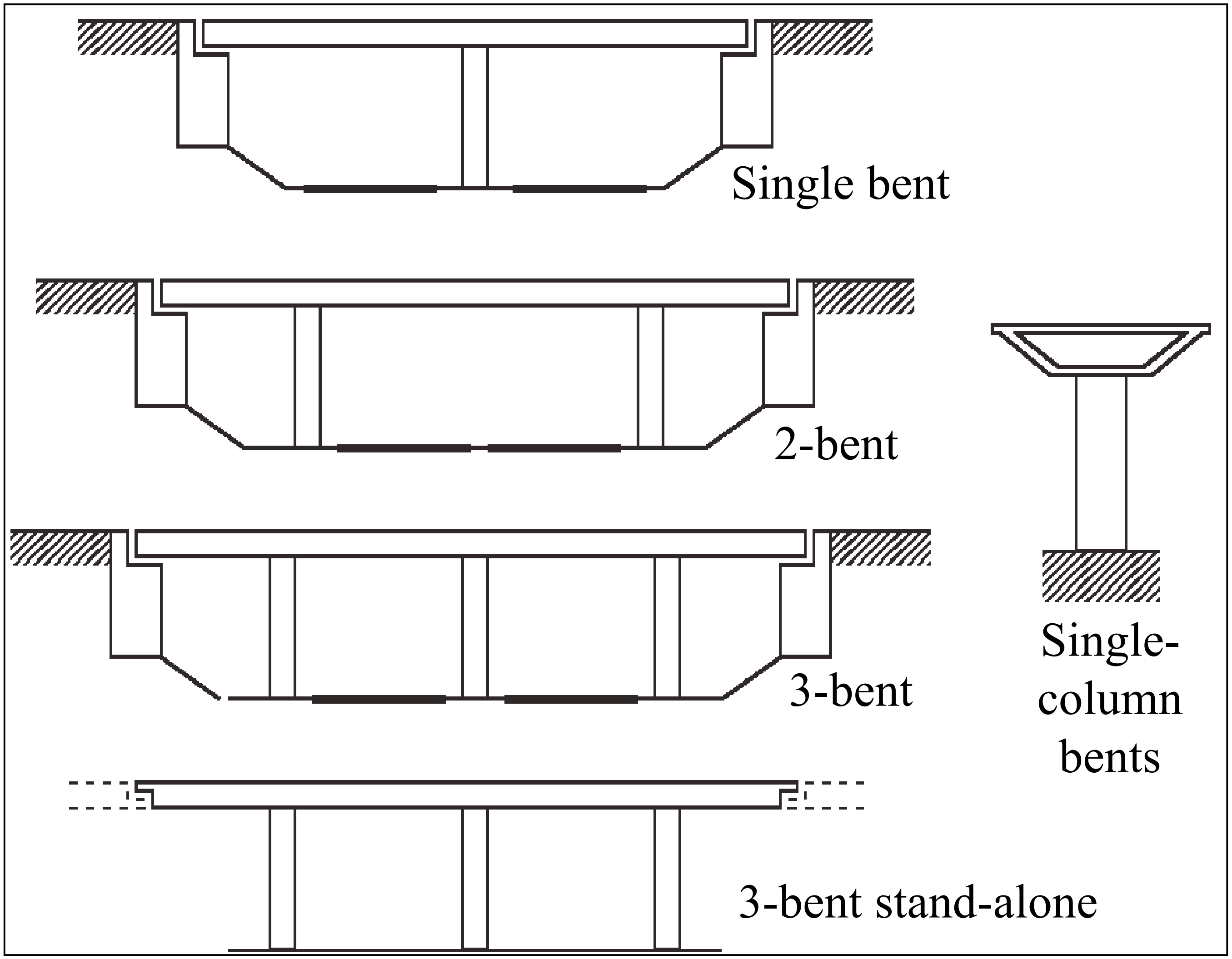
Probabilistic Seismic Demand Analysis

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



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

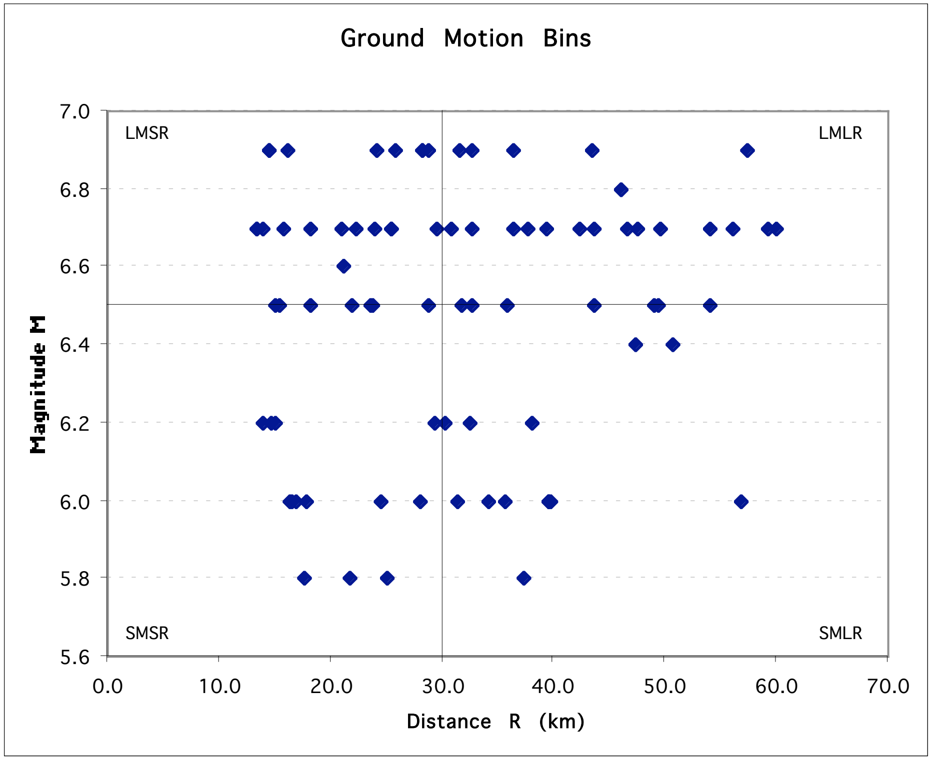
Demand: Bridge Classes



Seismicity: Ground Motions & IMs

- Period Independent Intensity Measures (in this study)
  - Arias intensity
  - PGA, PGV, PGD
- Period Dependent Intensity Measures
  - Sa, Sv, Sd
  - $Sd_{,inelastic}$
  - Spectral combinations (Cordova, 2000)

$$Sa_C = Sa(T_1)\sqrt{\frac{Sa(2T_1)}{Sa(T_1)}}$$

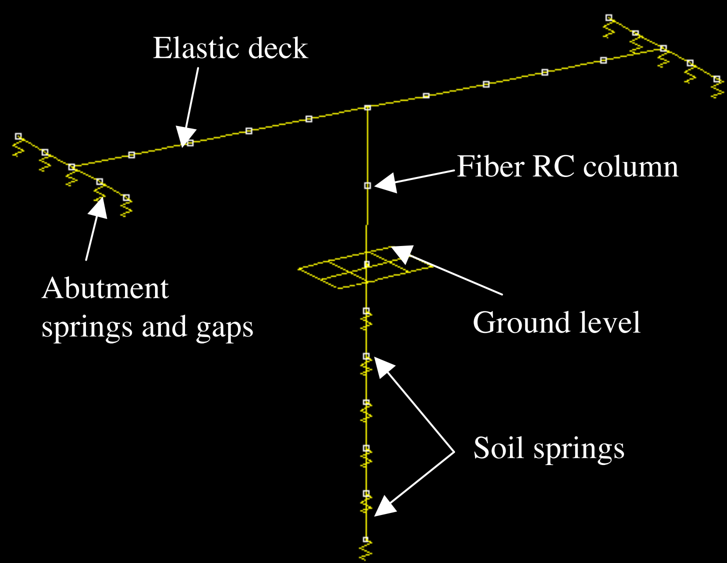


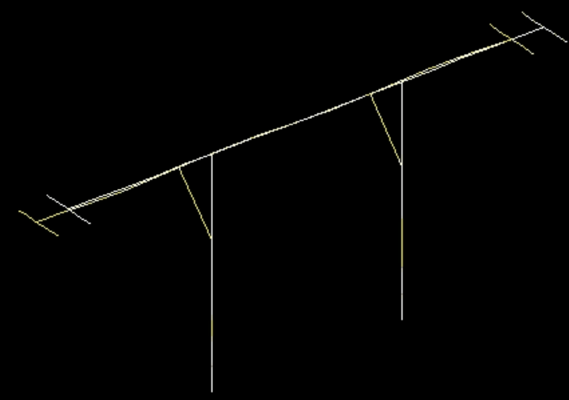
Demand: EDPs

- 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

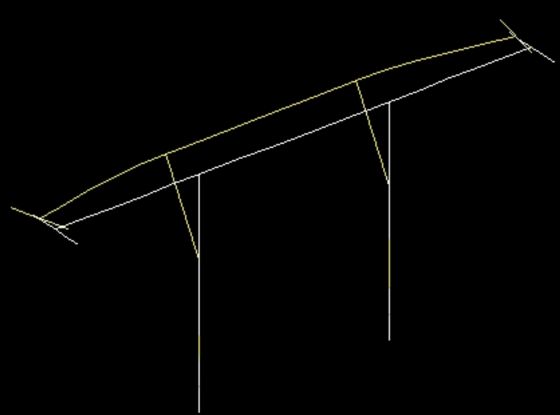
Single column/bent highway overpasses in California

OpenSees Bridge Model

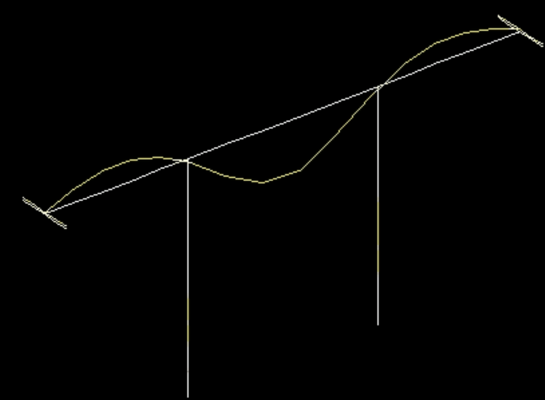




Mode 1 - Longitudinal

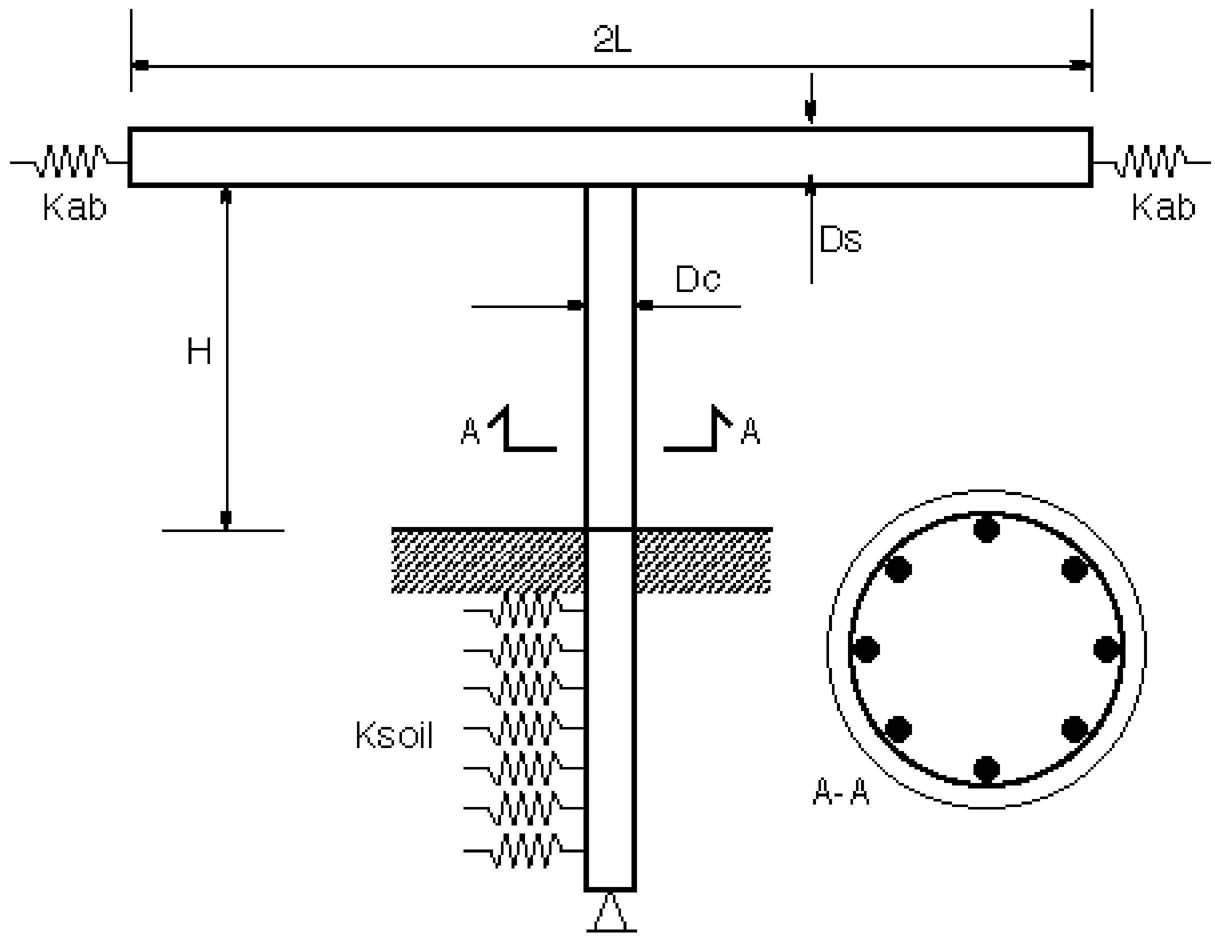


Mode 2 - Transverse



Mode 3 - Vertical

Bridge Design Parameters



Single-column, single-bent bridges

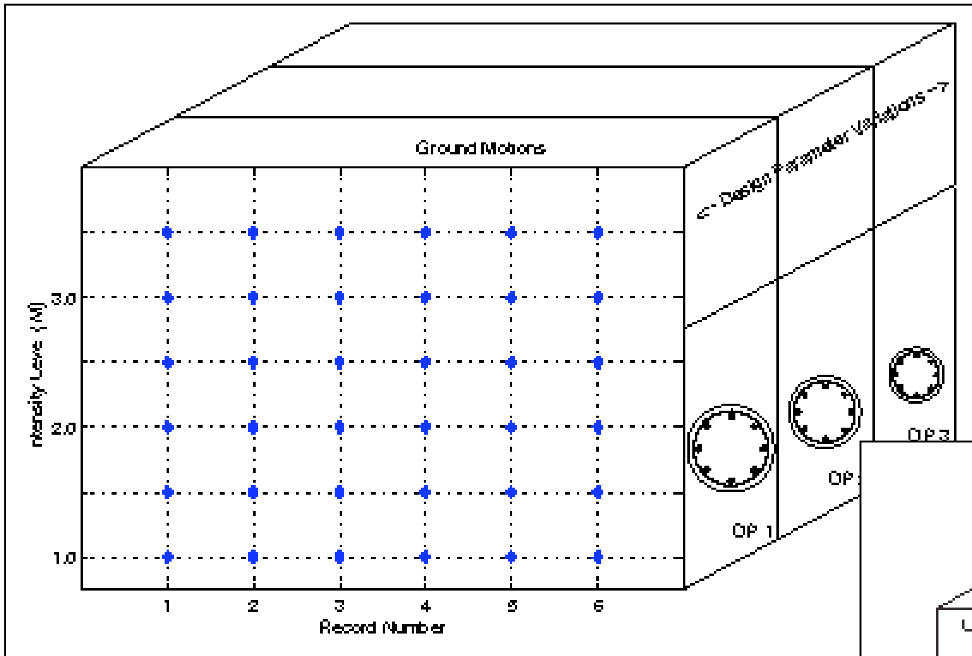
Bridge Design Parameters

Range of design parameter variations

• 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

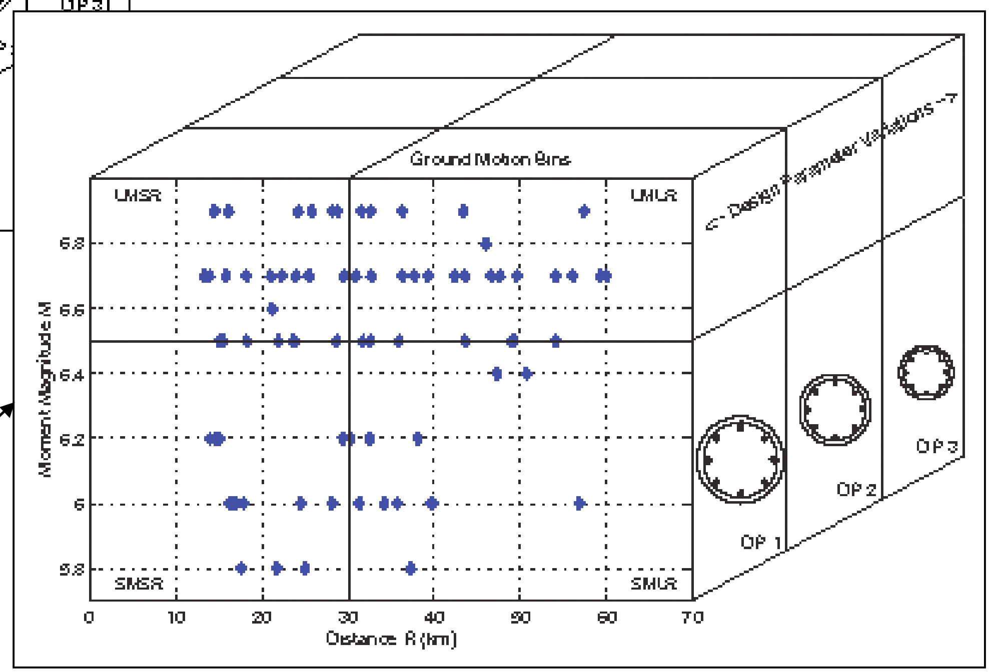
• $\rho_{s,trans}$	column transverse reinforcement	0.4-1.2%
• Wt	additional superstructure weight	10-150%
• K_{soil}	soil stiffness	USGS A-D
• Abut	abutment mass/stiffness models	various

Analysis Method



Incremental Dynamic Analysis (IDA)

Probabilistic Seismic Demand Analysis (PSDA)



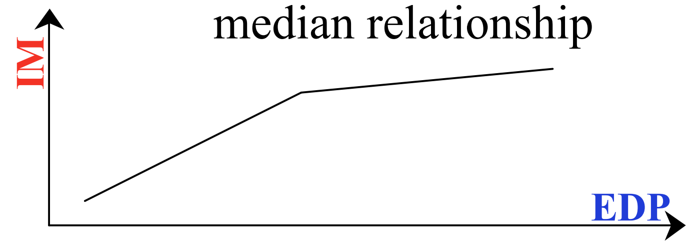
Demand Model Criteria

Practical

- Definition: Makes engineering sense
- Practical: column drift
- Not practical: steel stress

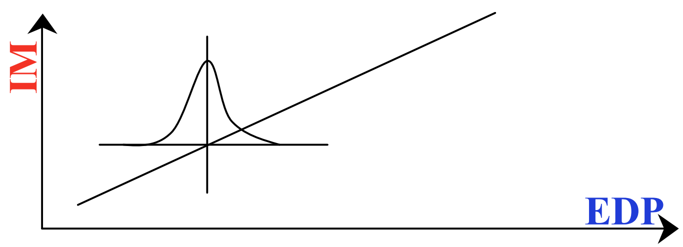
Effective

- Definition: linear or mult-linear median relationship



Efficient

- Definition: low variability

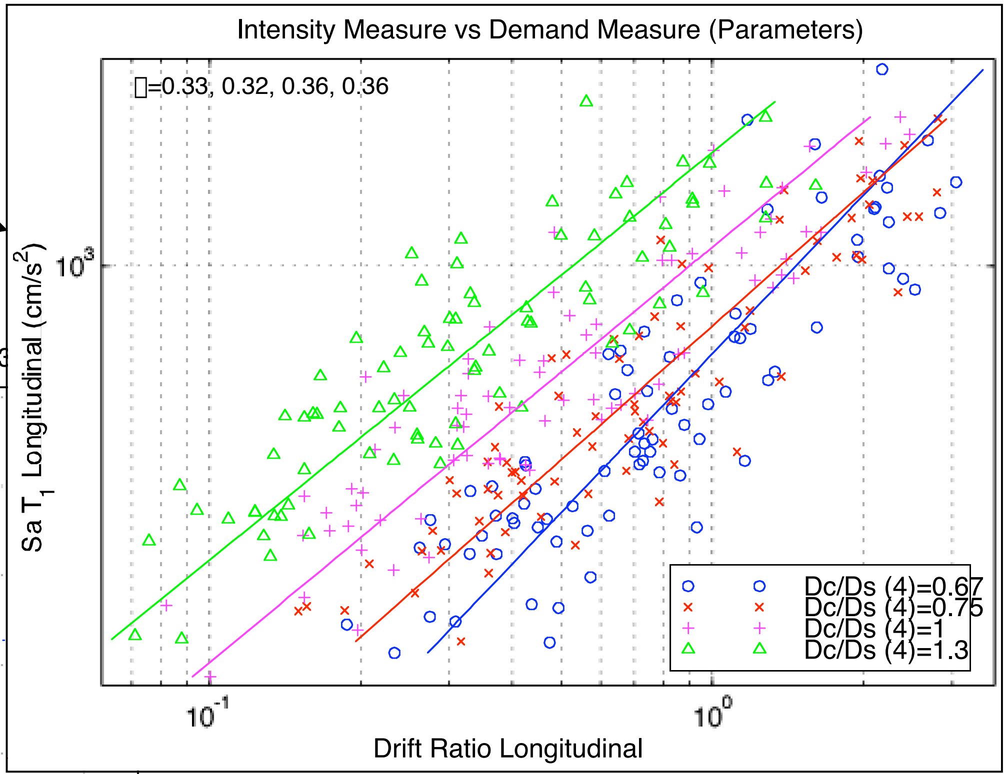


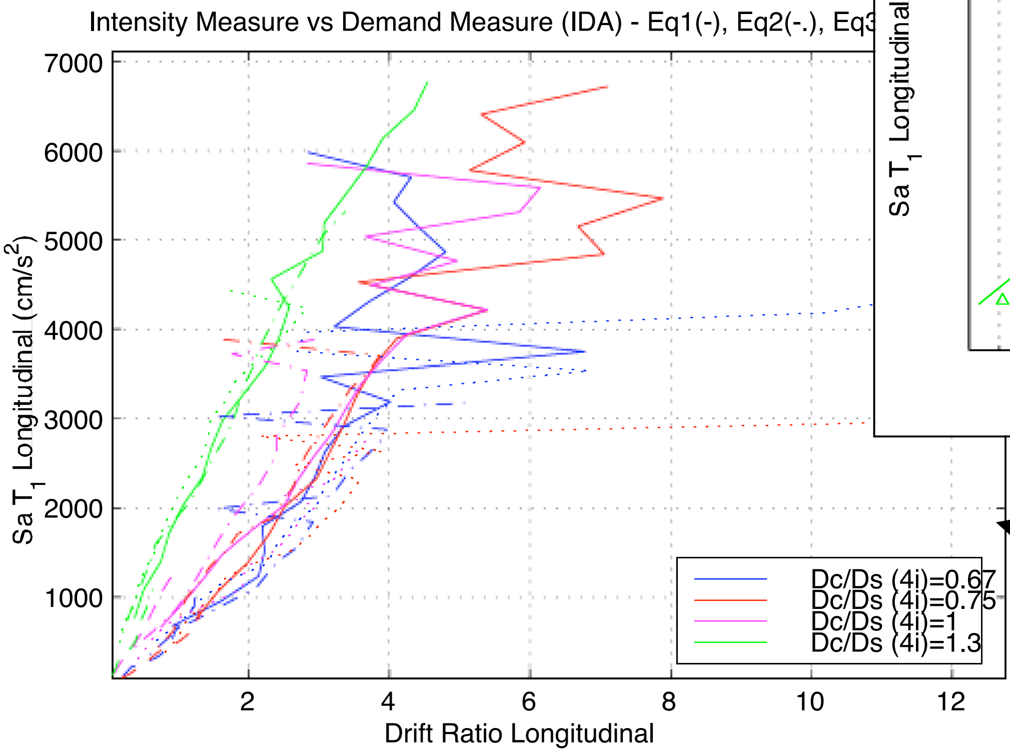
Sufficient

- Definition: No conditional dependence on M, R
- P[EDP|IM,M,R]=P[EDP|IM]
- Can also be applied to strong motion duration

Resulting Demand Models

PSDA

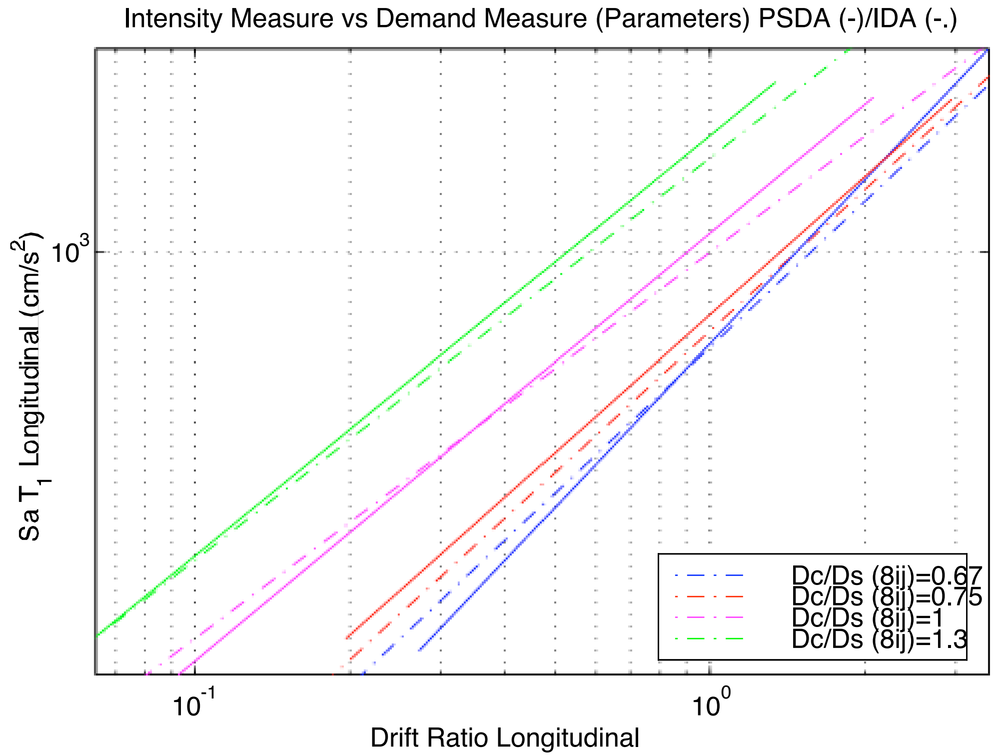




IDA

IDA-PSDA Median Comparison

Sa_{T1}-Drift ratio (linear), 8x10 IDA matrix



PSDA solid

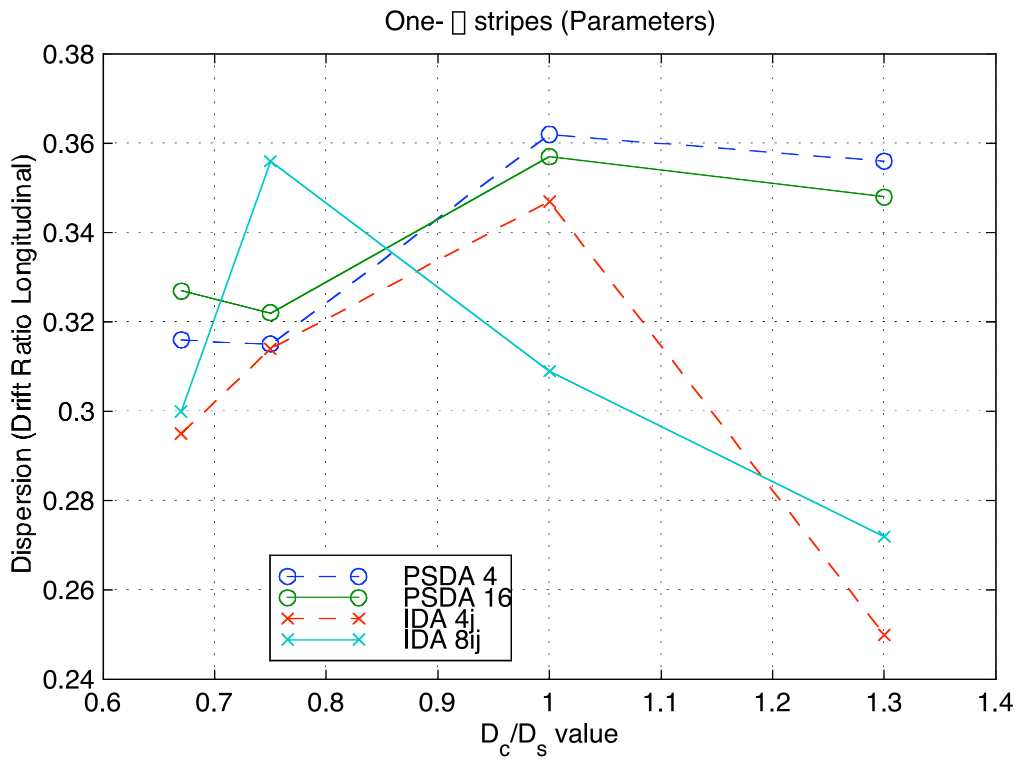
IDA dashed

Superstructure depth to column diameter ratio (Dc/Ds)

1-bent bridge with abutments

IDA-PSDA Dispersion

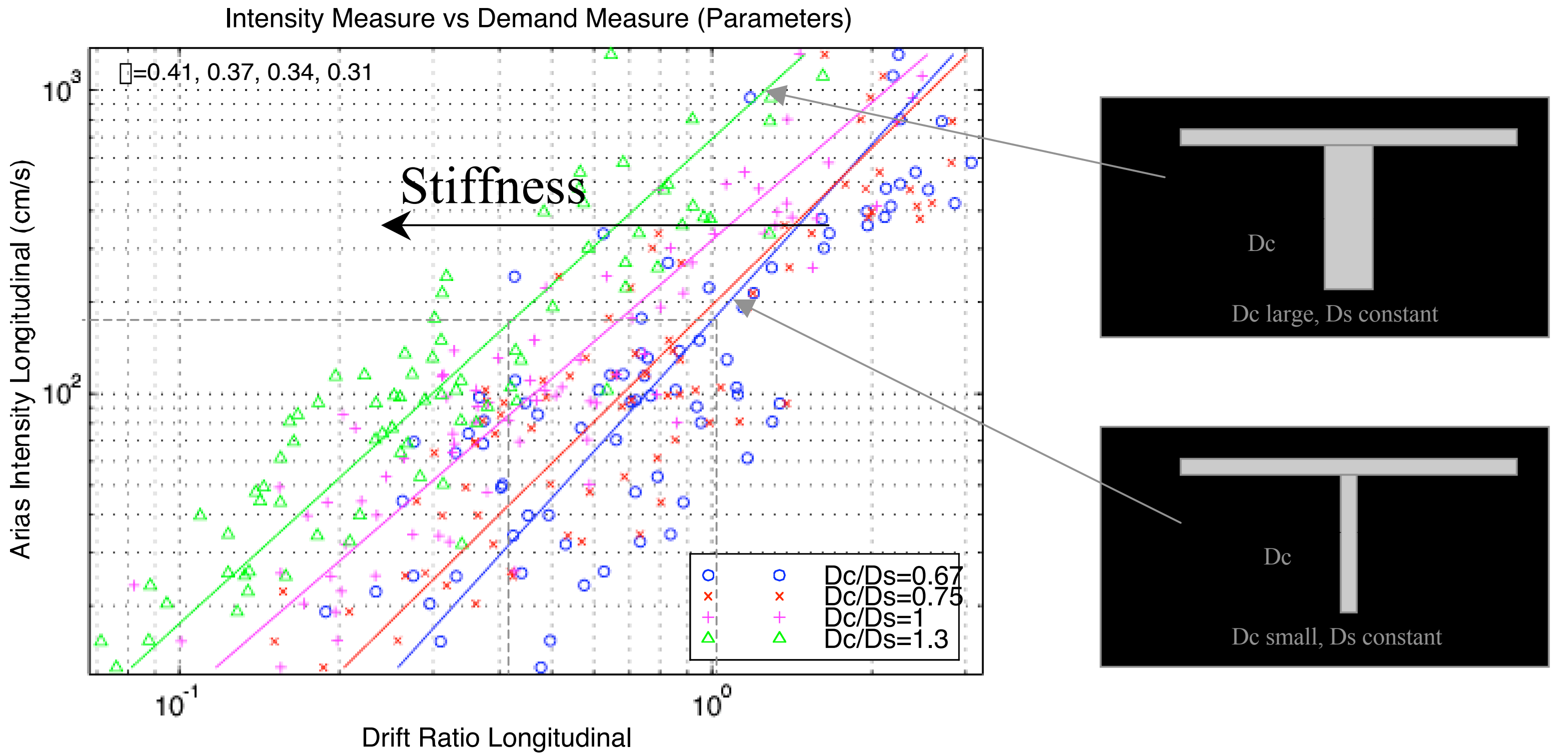
Sa-Drift ratio, 8x10 IDA matrix



- IDA 4x20 under-predicts dispersion
- IDA 8x10 approaches real dispersion

Design Parameter Sensitivity

Superstructure depth to column diameter ratio (Dc/Ds)

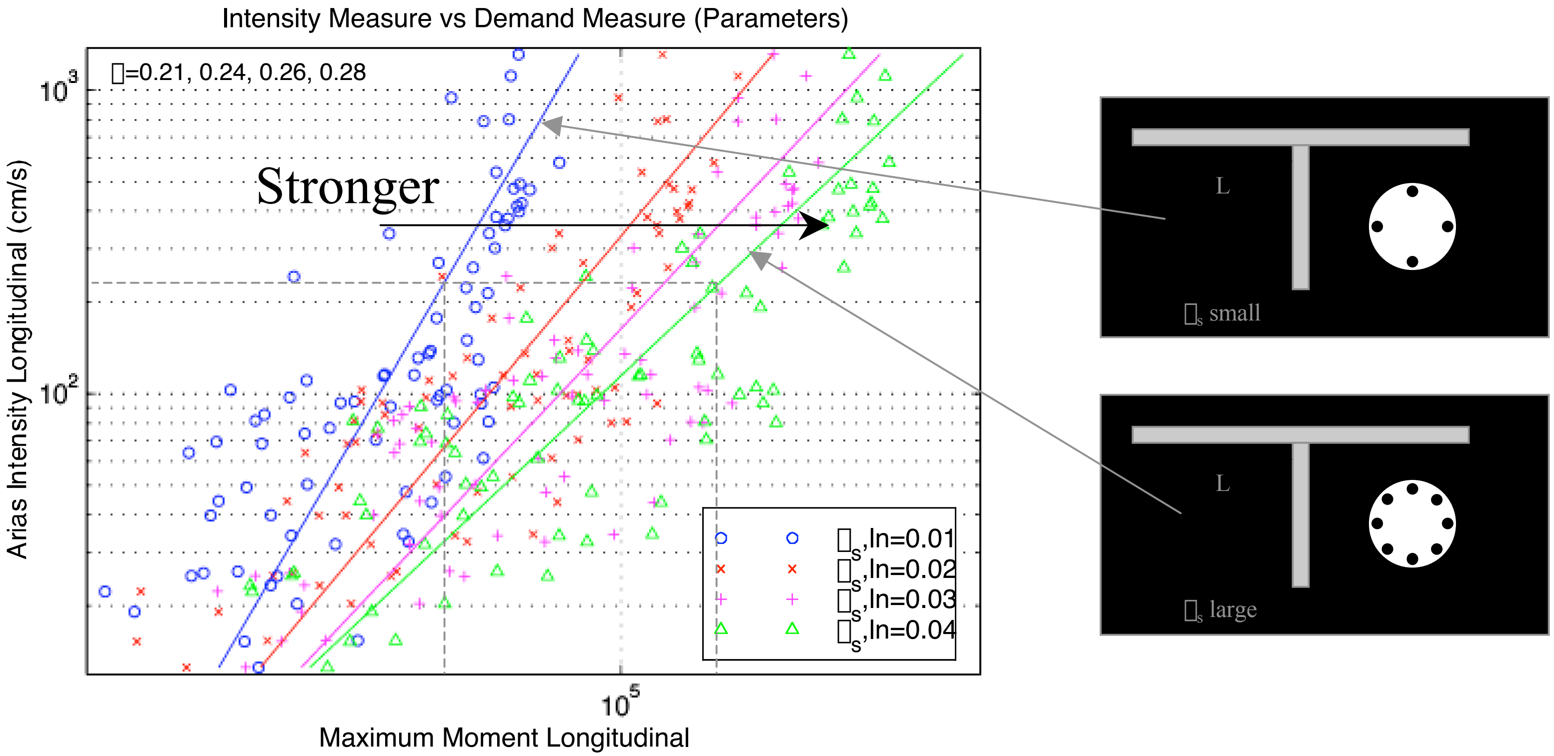


Decreasing column height increases drift (decreases max. displ.)

1-bent bridge with abutments

Design Parameter Sensitivity

Column longitudinal steel ratio (□$_s$)

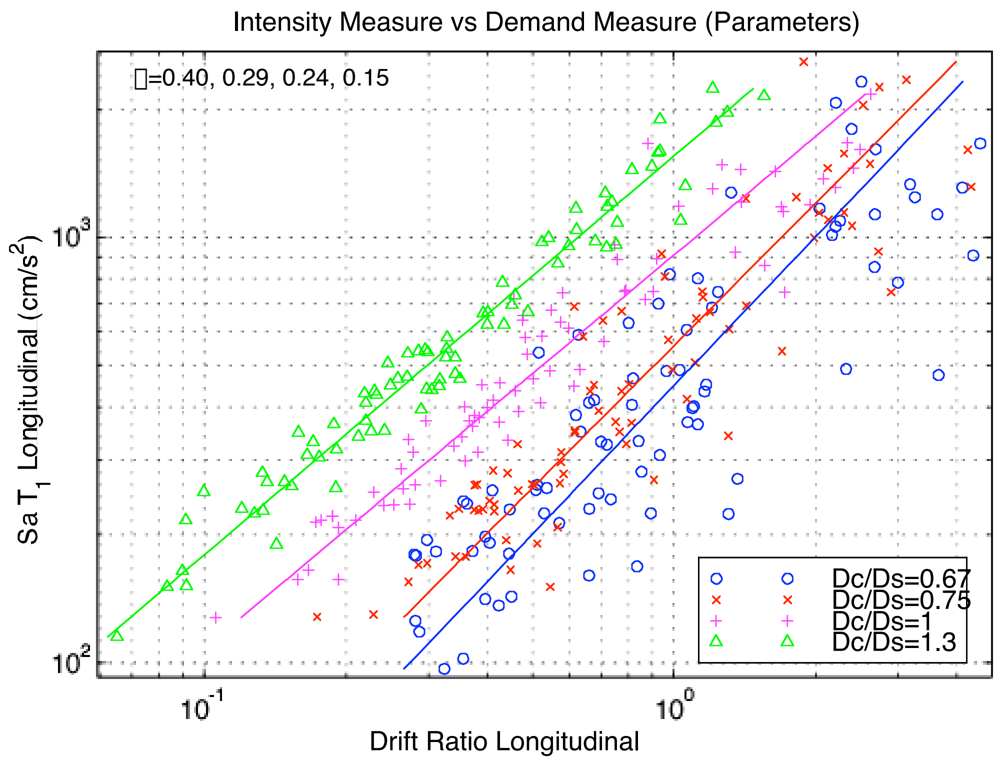


Increasing steel increases column moment demand

1-bent bridge with abutments

Sensitivity with Optimal IMs

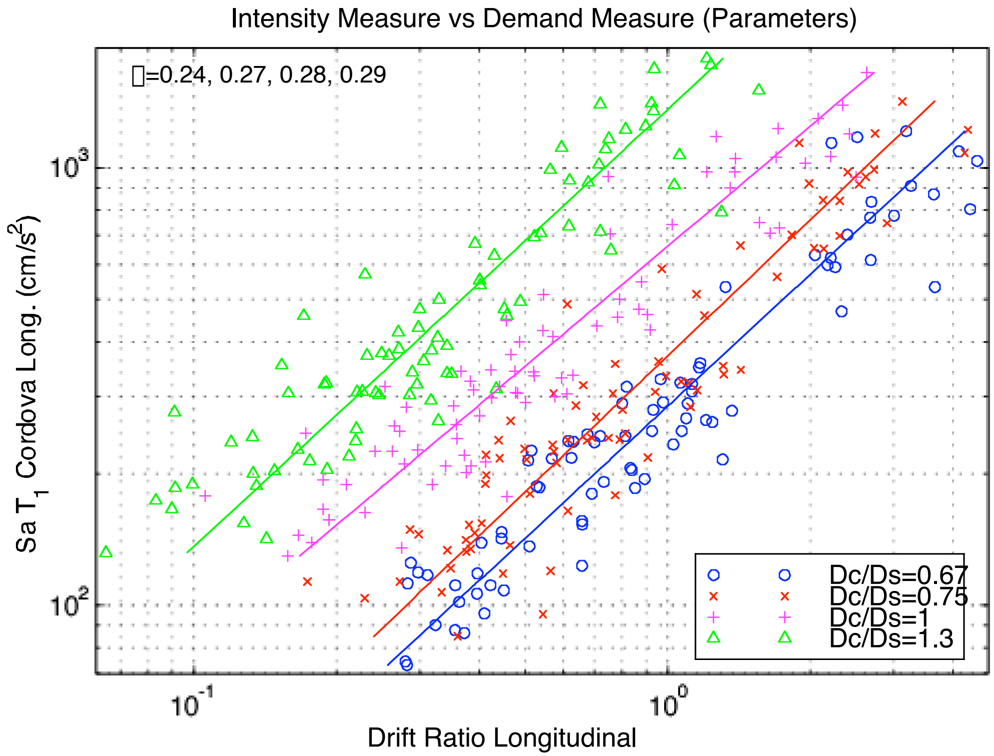
SaT1-Drift sensitivity to Dc/Ds design parameter



Arias	0.41	0.37	0.34	0.31
Sa(T1)	0.40	0.29	0.24	0.15

Sensitivity with Optimal IMs

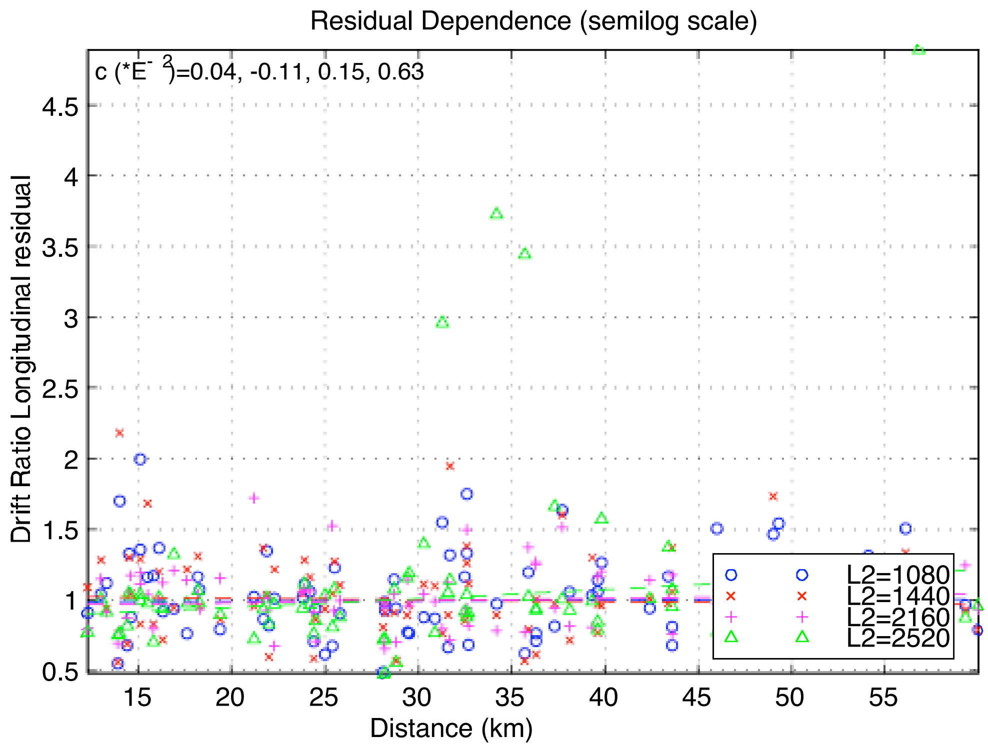
Sa(Cordova)-Drift sensitivity to Dc/Ds design parameter



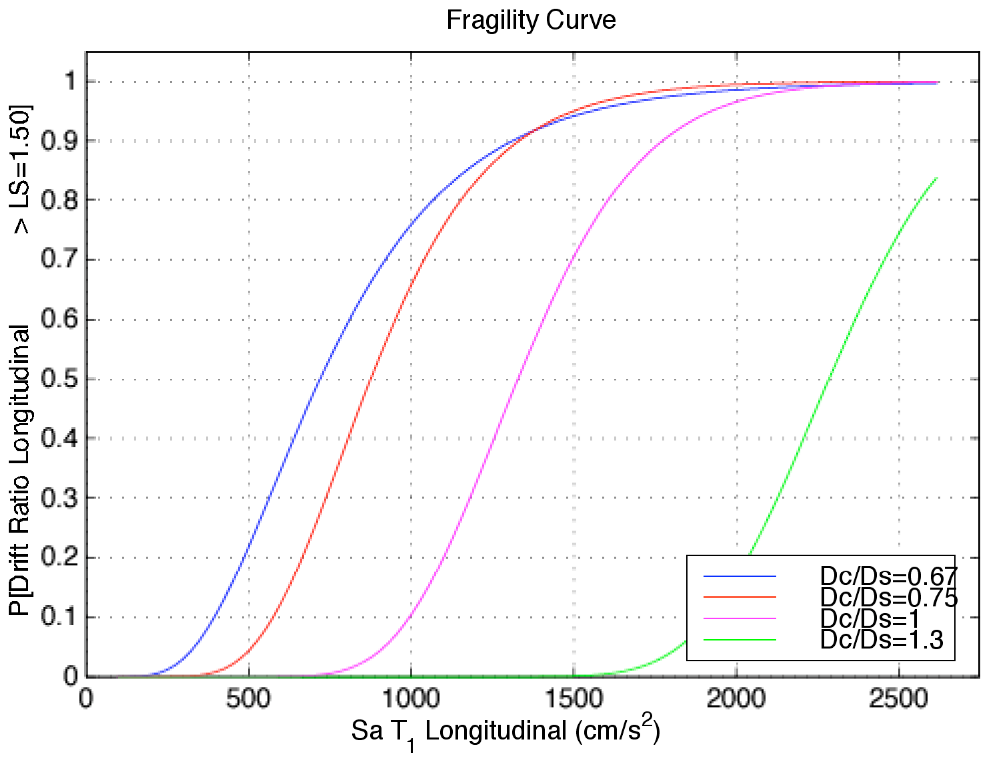
Arias	0.41	0.37	0.34	0.31
Sa(T1)	0.40	0.29	0.24	0.15
SaC	0.24	0.27	0.28	0.29

Sufficiency

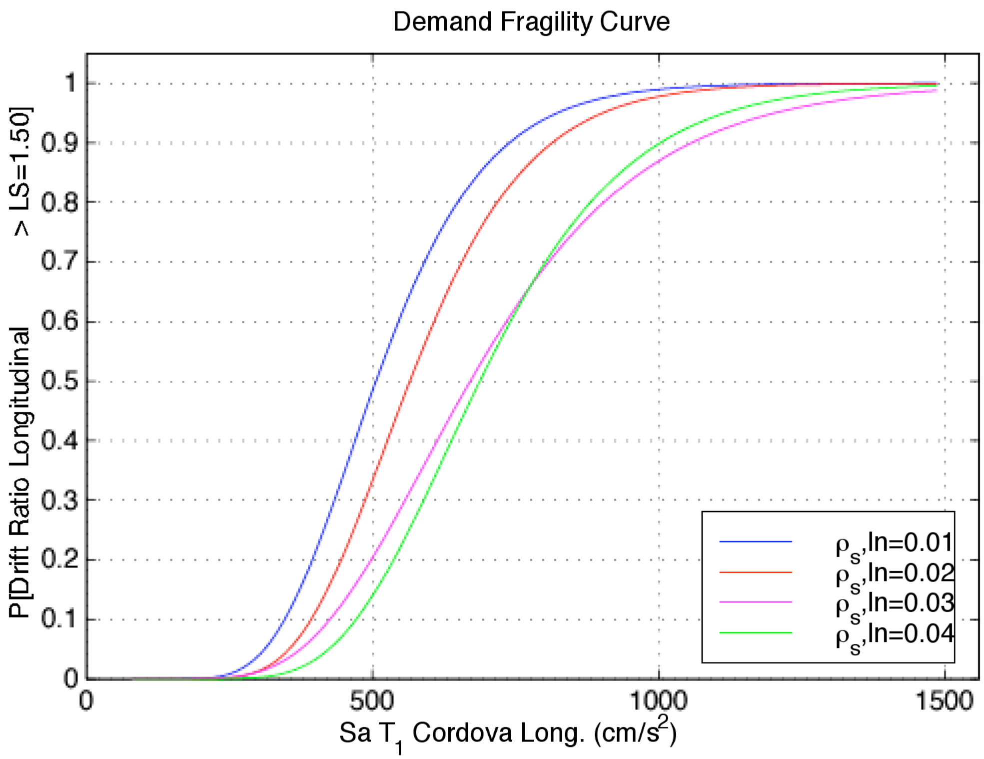
Distance (R) dependence



Demand fragility

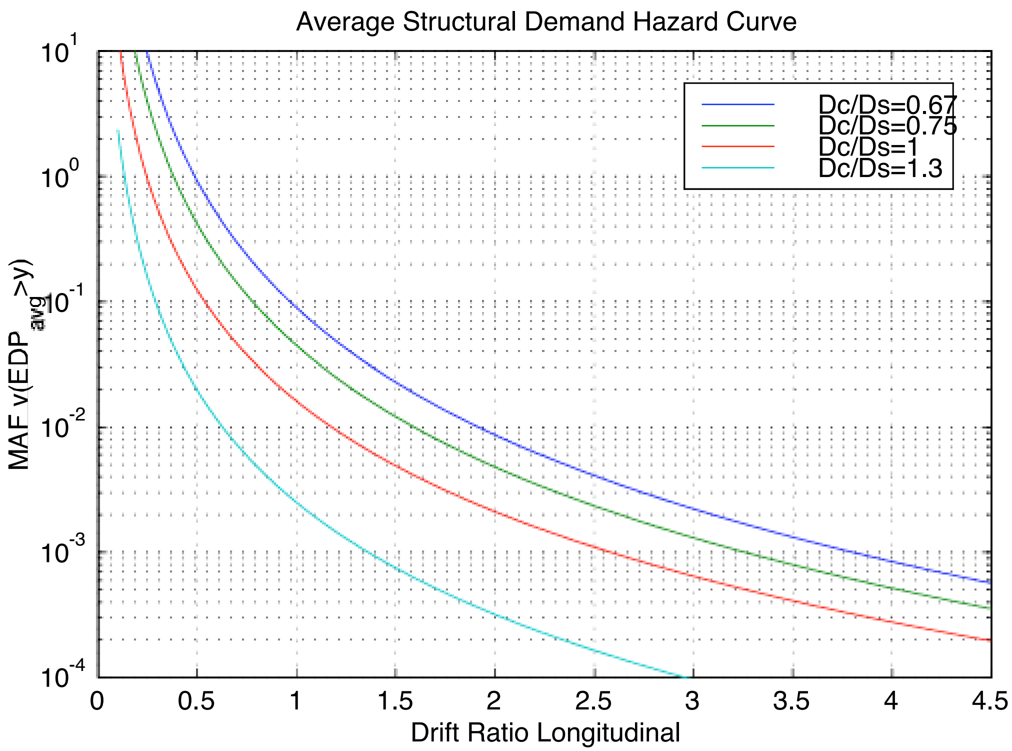


Demand Fragility



PSDM Extensions

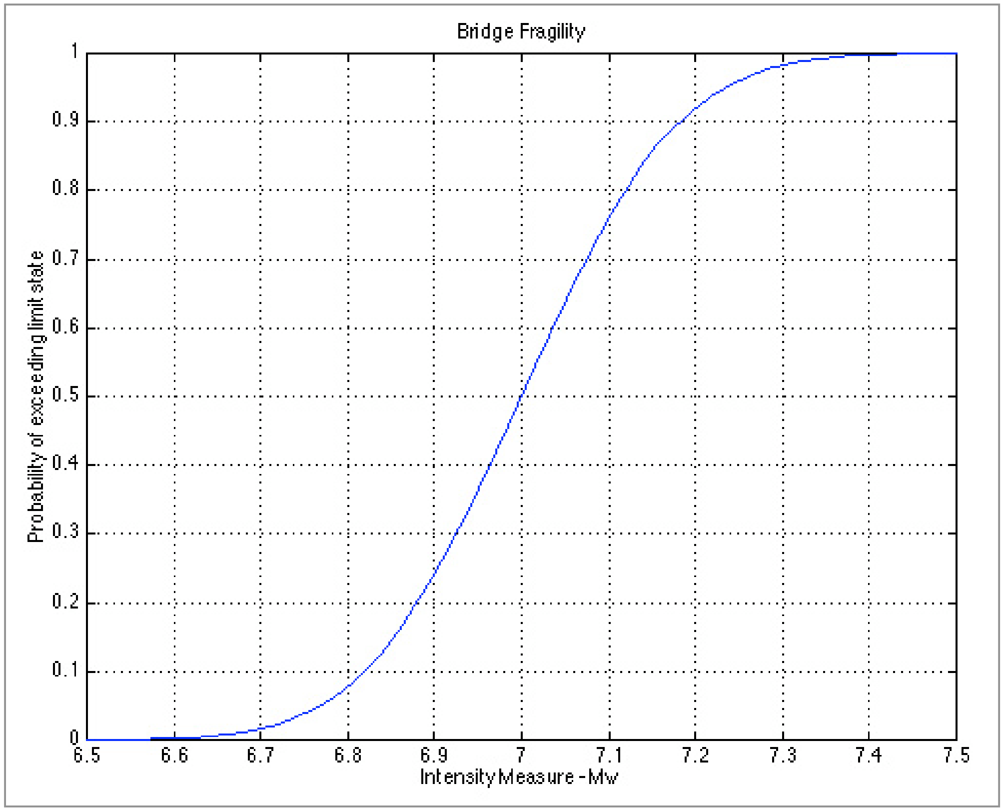
Structural Demand Hazard Curves



PSDM Extensions

Functional EDPs

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



Conclusions

- PEER PBD framework is completely general with a probabilistic basis
- Demand models can be represented by:
  - PSDA
  - IDA
  - Demand fragility
- Criteria for acceptance of a demand model
  - Practical, efficient, effective, sufficient
- Damage fragility easily incorporated using capacity models

Thank You!

- Questions?

- For more information contact:
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