PEER

Design Parameter Sensitivity in Bridge PSDMs

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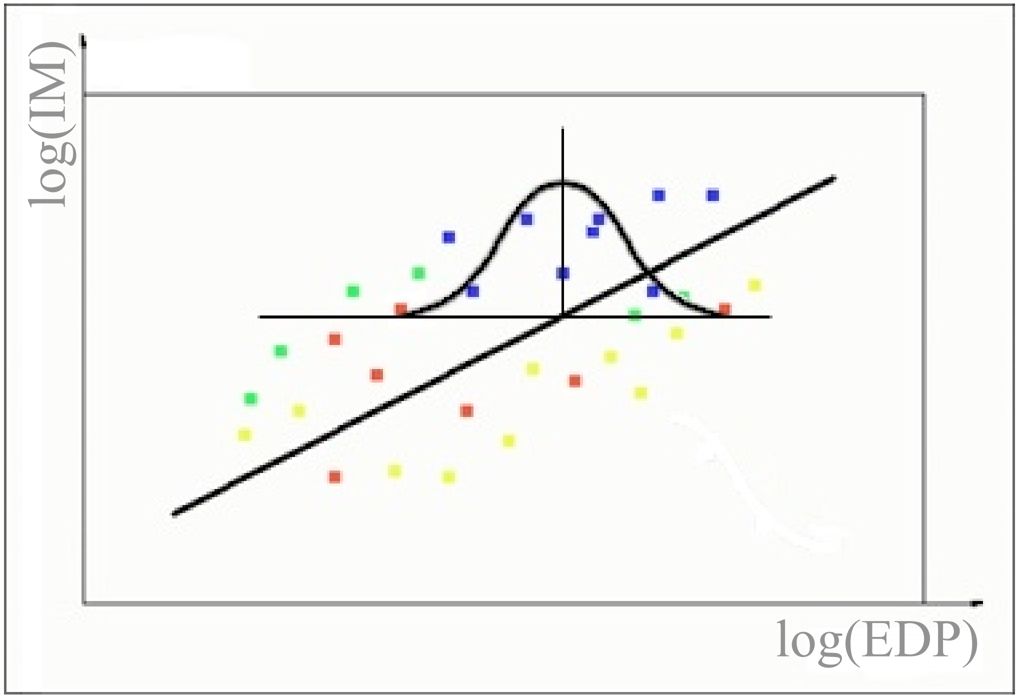
What is a PSDM?

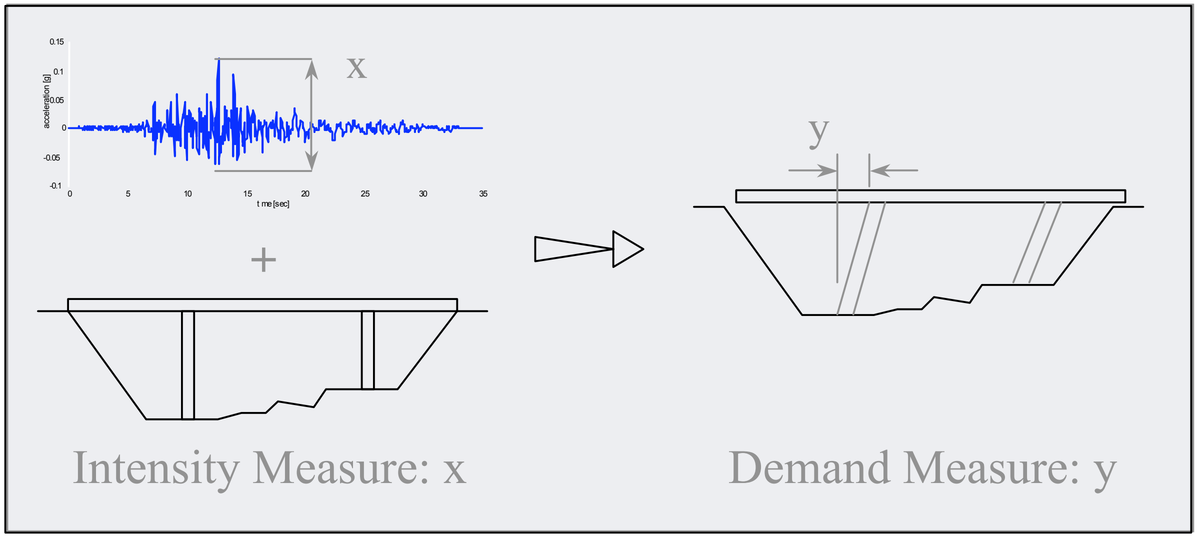
PSDM = Probabilistic Seismic Demand Model



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

Why a Demand Model?

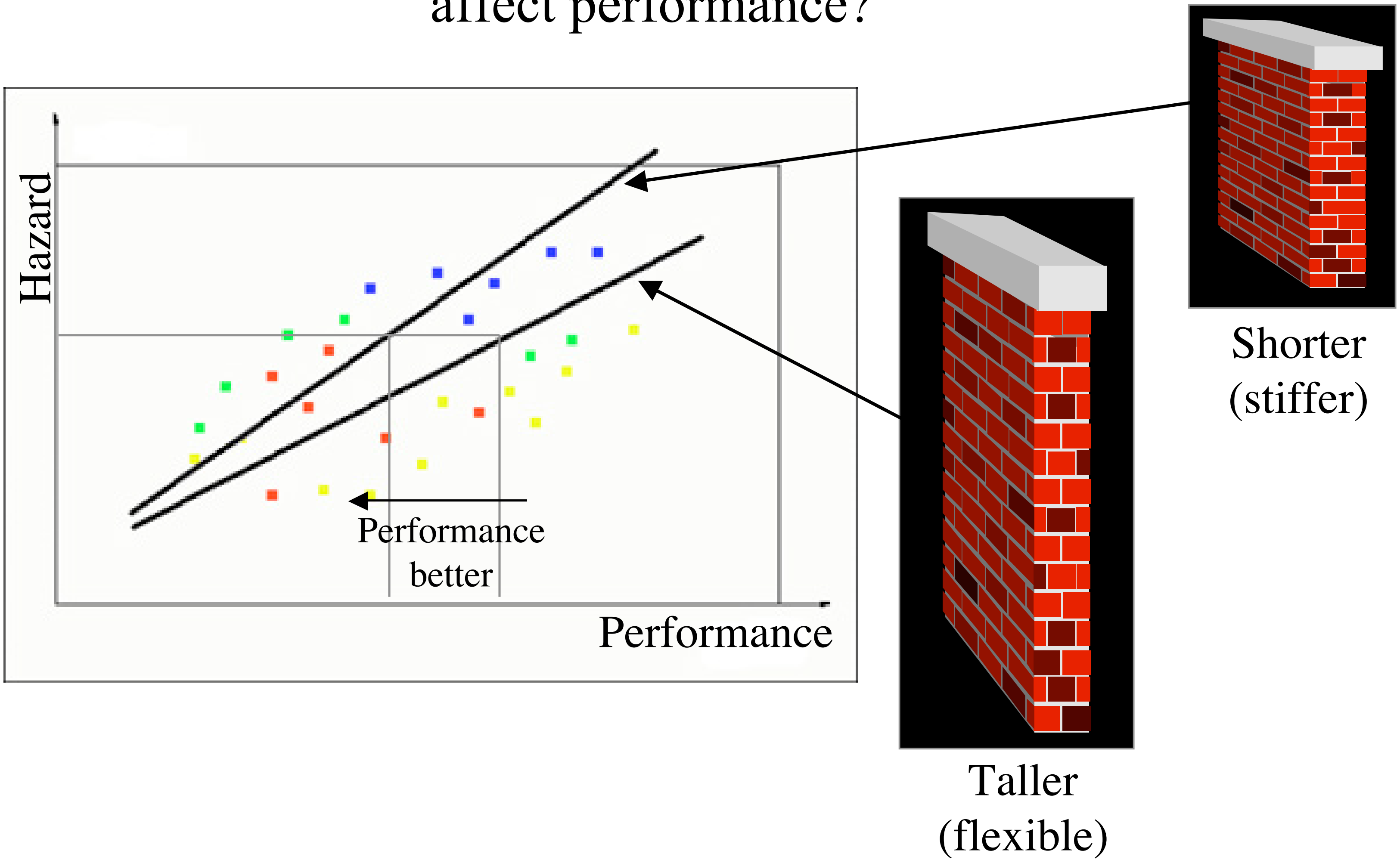
1) Quantitative Performance Based Earthquake Engineering tool for designers of bridges



What is probability of y, given x?

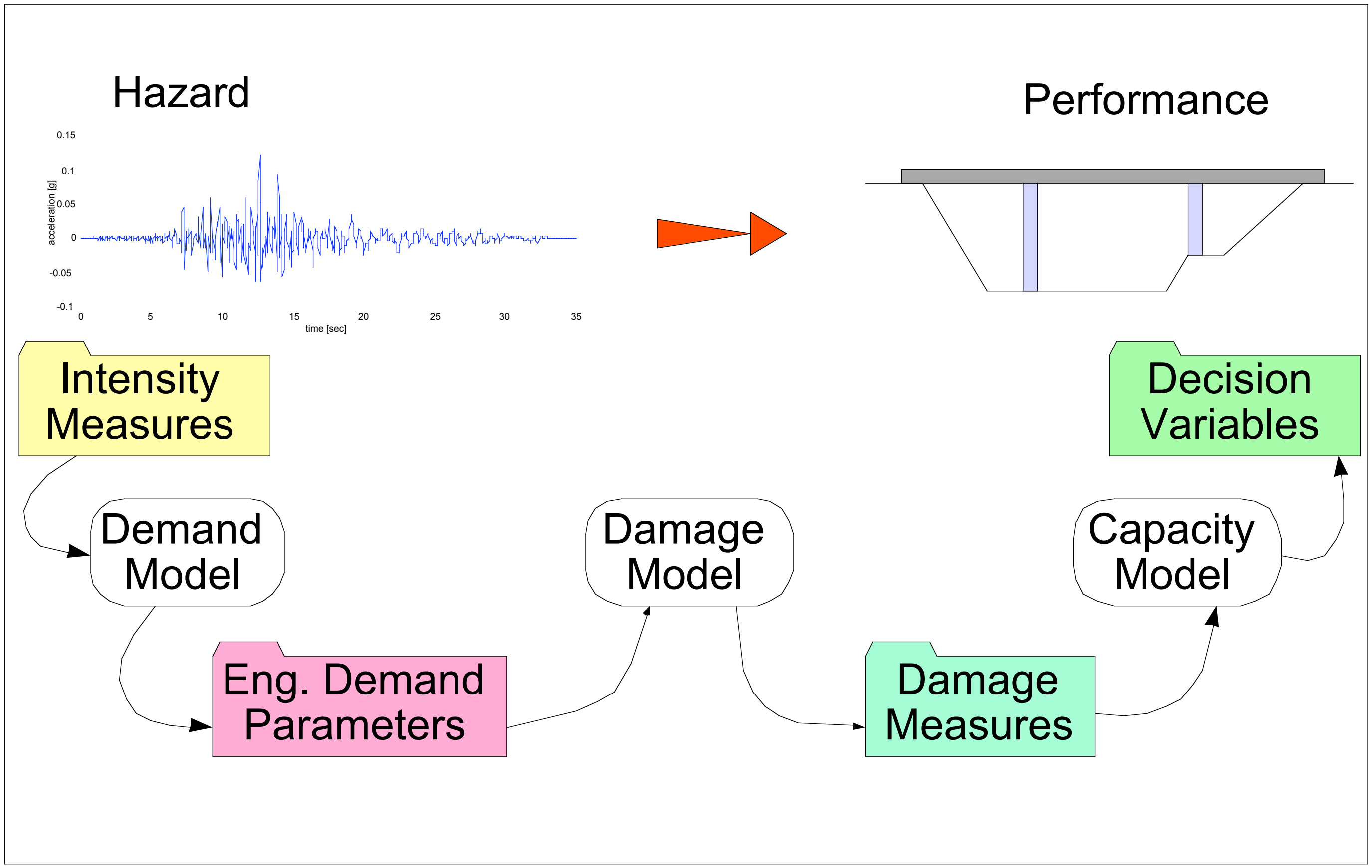
Why a Demand Model?

2) How do design parameters affect performance?



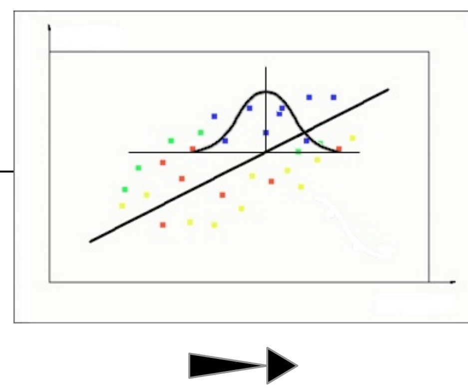
Why a Demand Model?

3) Module in PEER performance-based desing framework



Probabilistic Seismic Demand Analysis

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

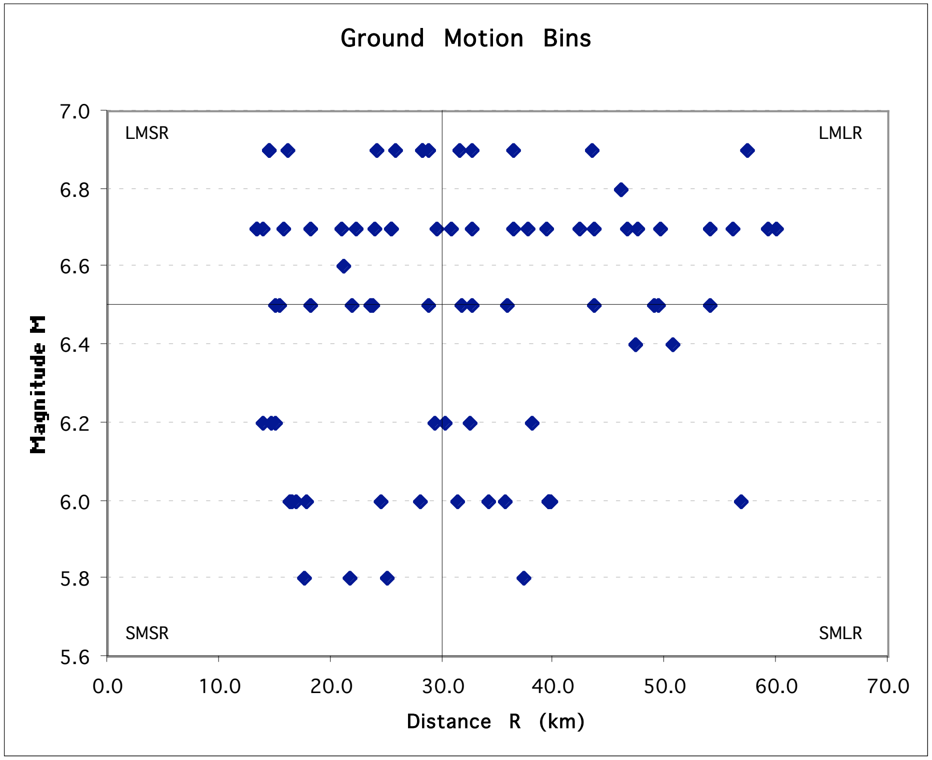


- Design parameter sensitivity
- Ground motion bin sensitivity
- Residual dependence (M, R)

Seismicity: Ground Motions & IMs

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

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

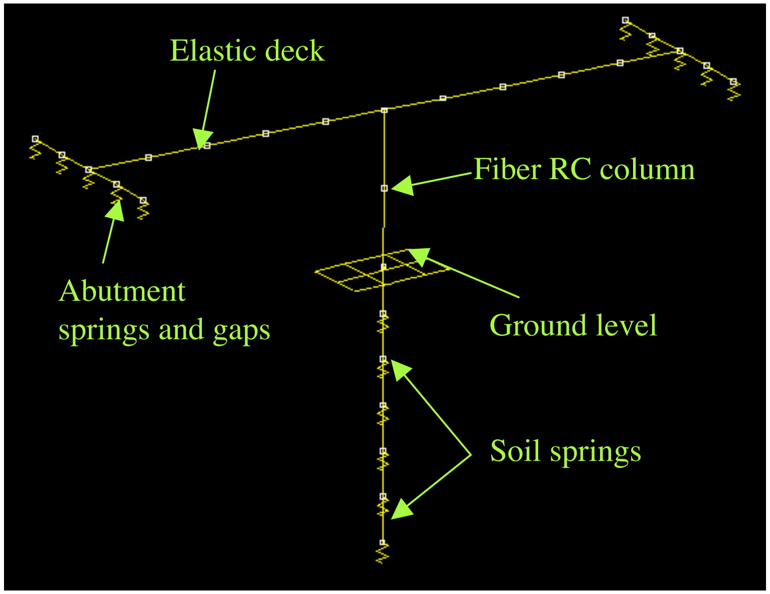


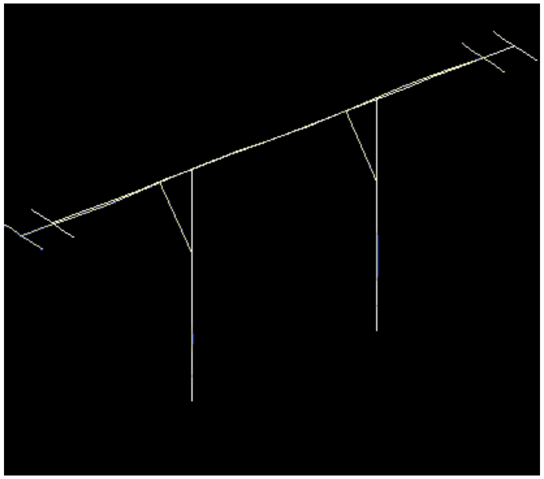
Demand: EDPs

- 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

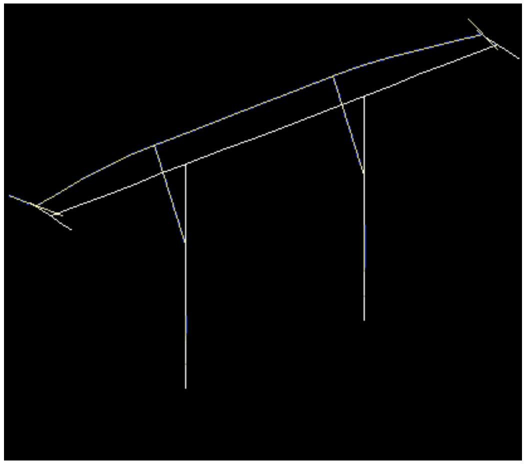
Single column/bent highway overpasses in California

OpenSees Bridge Model

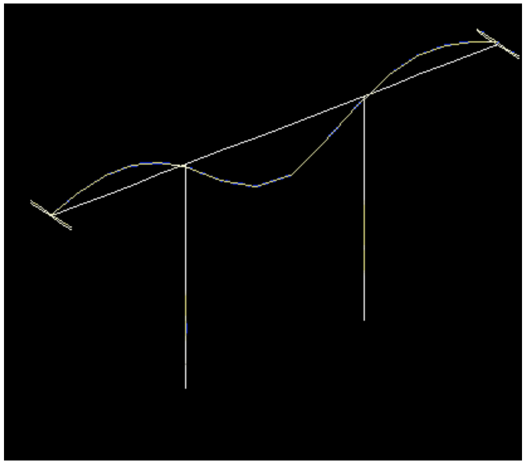




Mode 1 - Longitudinal

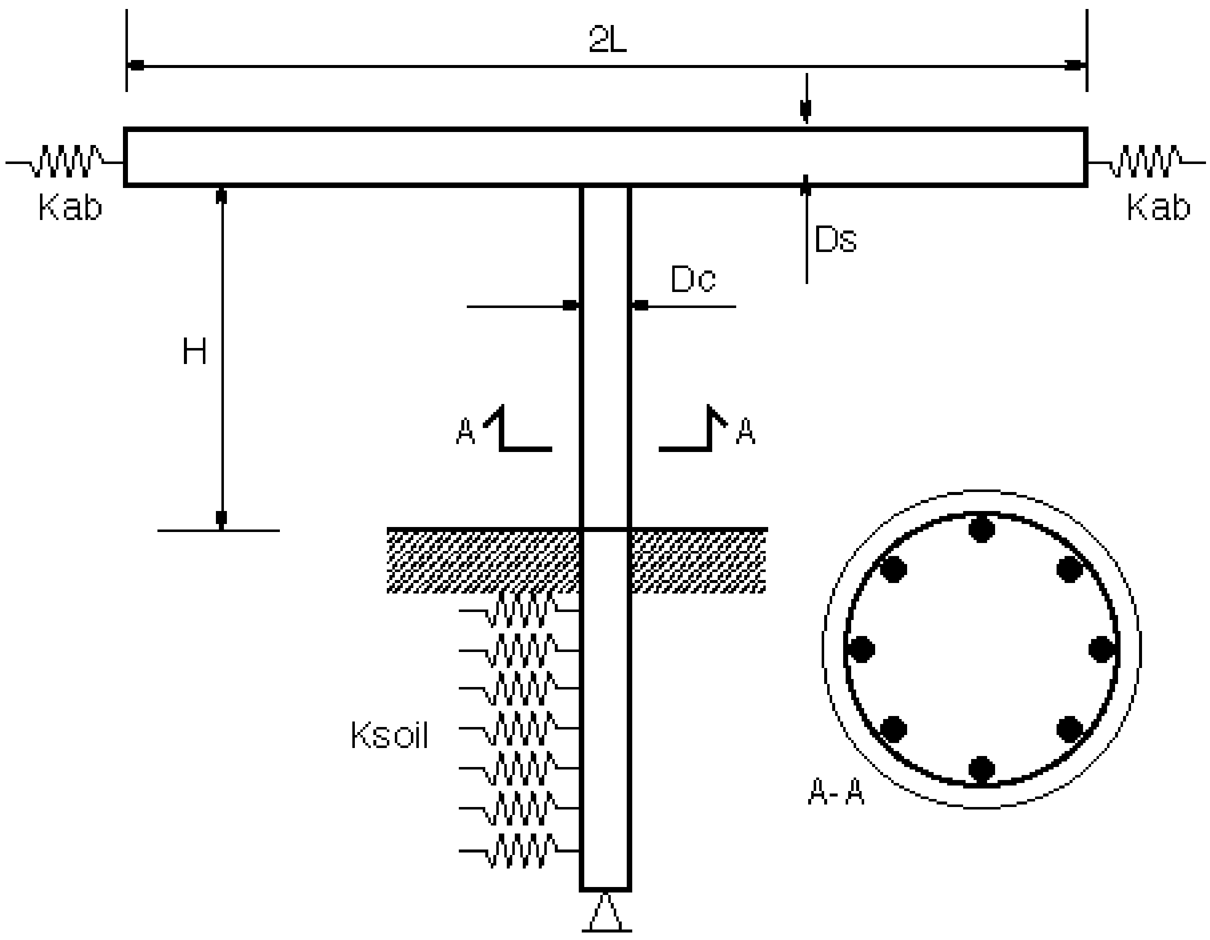


Mode 2 - Transverse



Mode 3 - Vertical

Bridge Design Parameters



Single-column, single-bent bridges

Bridge Design Parameters

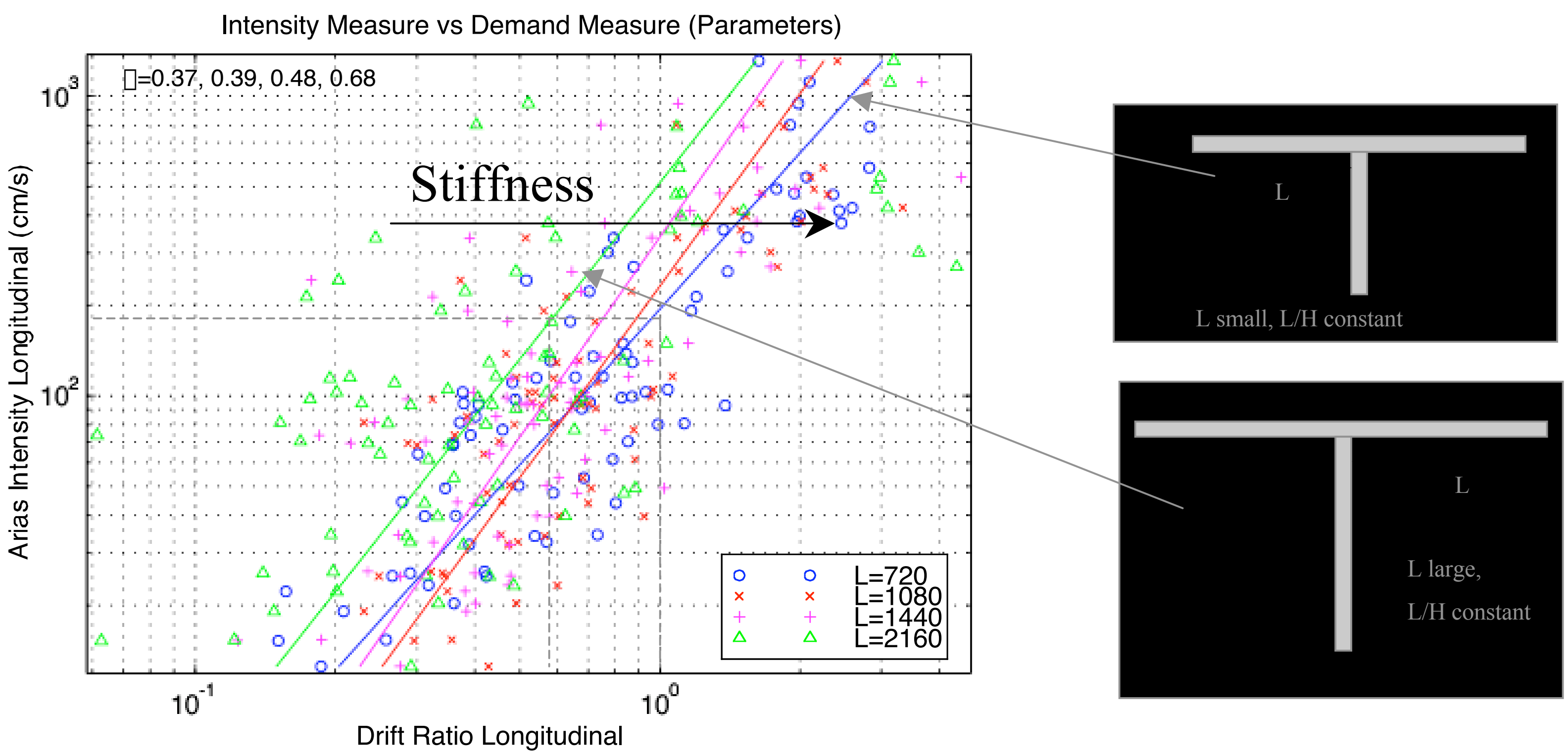
Range of design parameter variations

- 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

Design Parameter Sensitivity

Span length (L)

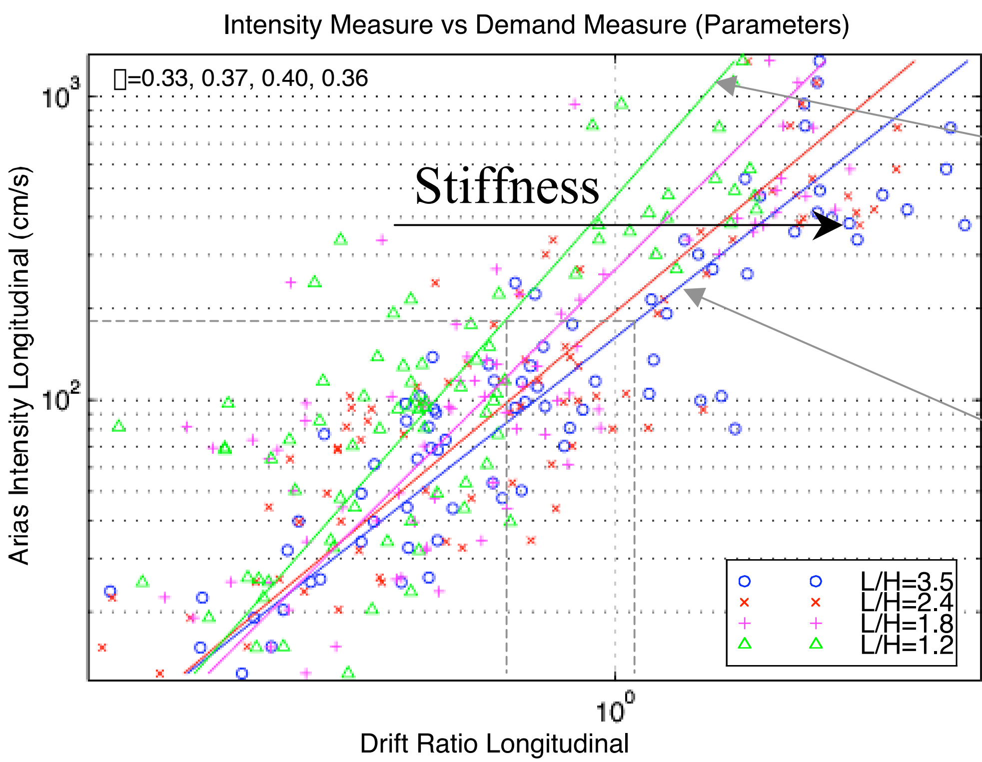


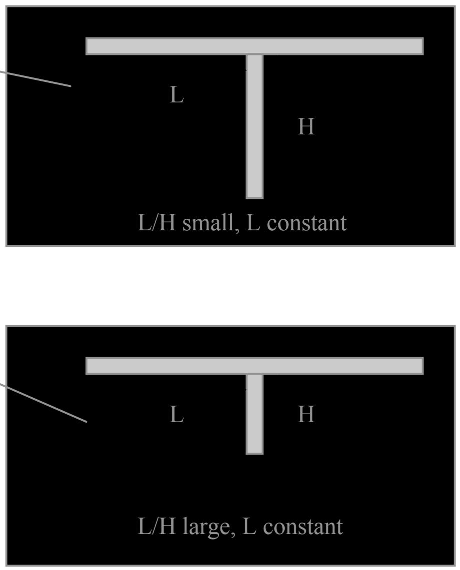
Increasing size (span & column height) decreases drift (increases max. displ.)

1-bent bridge with abutments

Design Parameter Sensitivity

Span length to column height ratio (L/H)



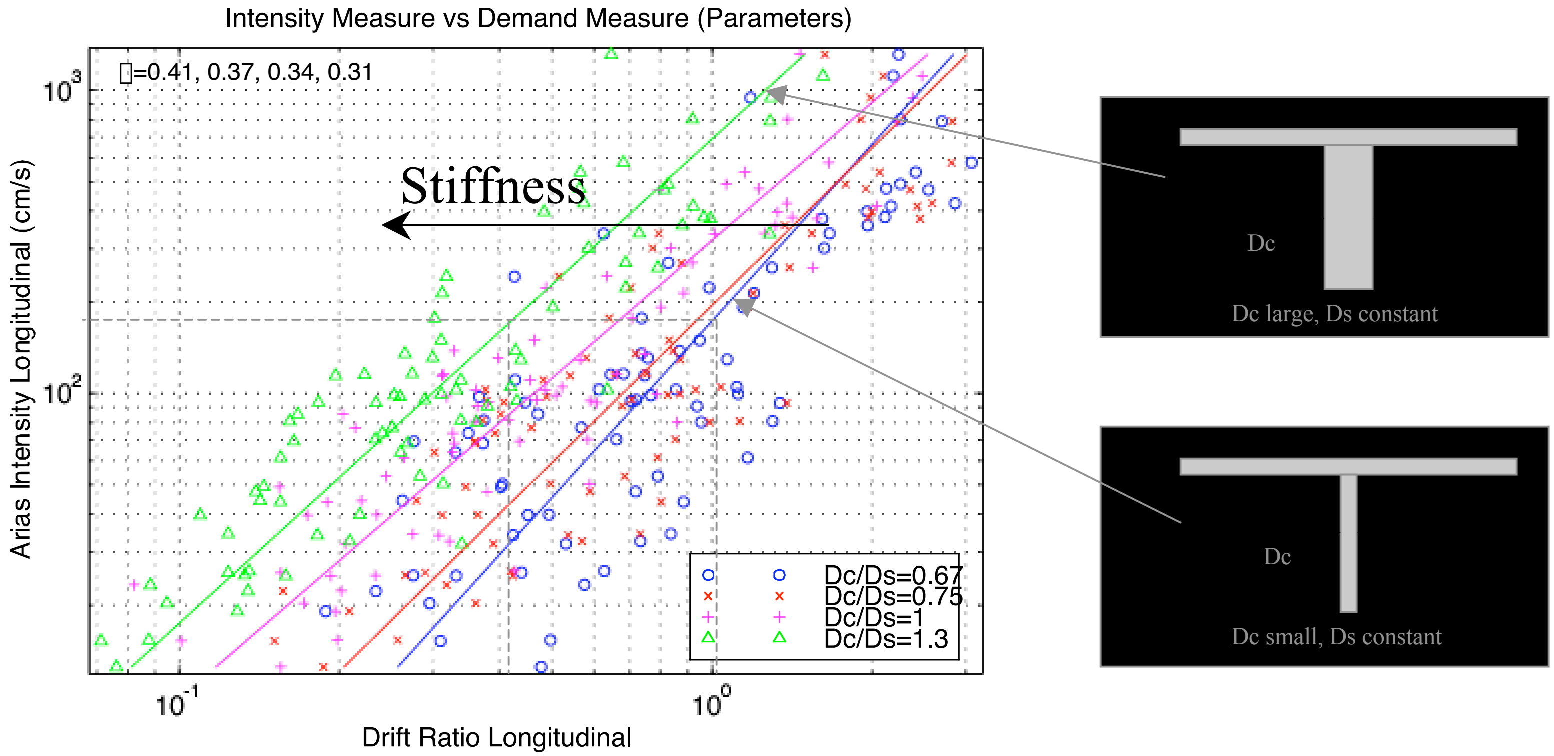


Decreasing column height increases drift (decreases max. displ.)

1-bent bridge with abutments

Design Parameter Sensitivity

Superstructure depth to column diameter ratio (Dc/Ds)

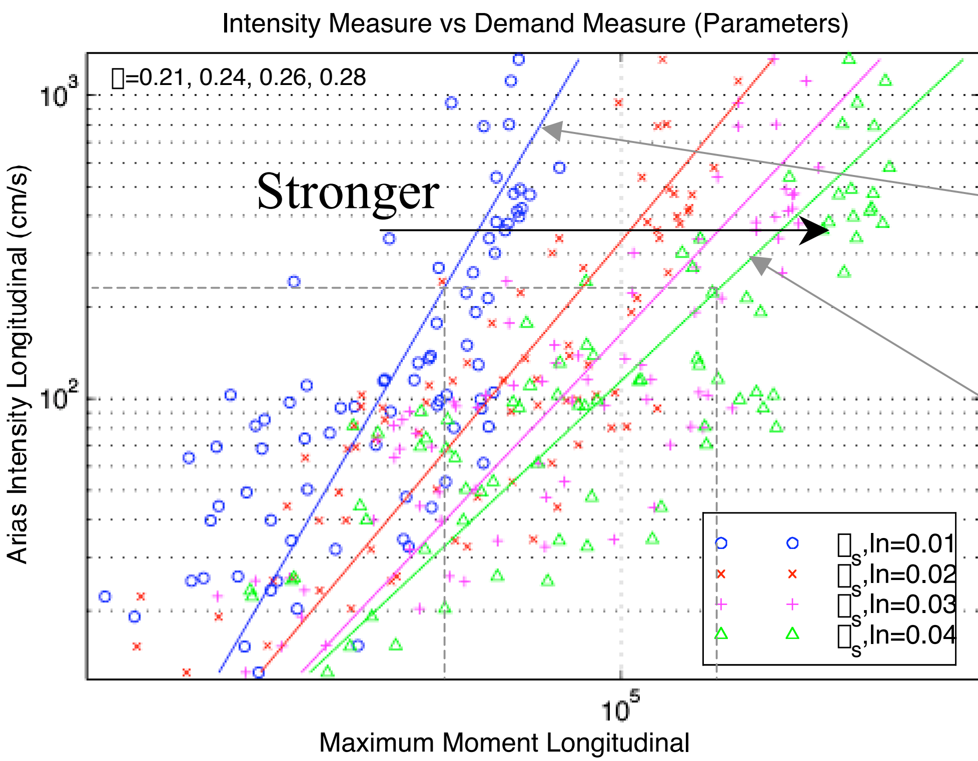


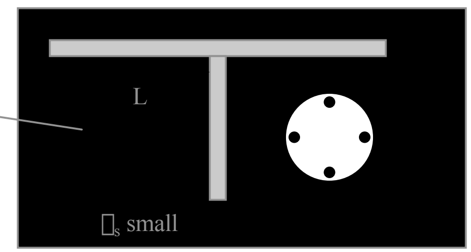
Decreasing column height increases drift (decreases max. displ.)

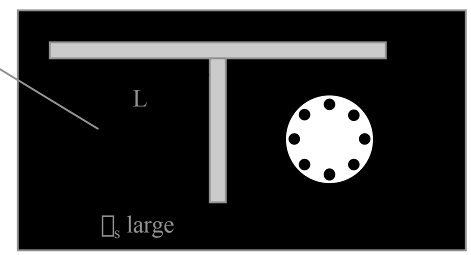
1-bent bridge with abutments

Design Parameter Sensitivity

Column longitudinal steel ratio ($□_s$)





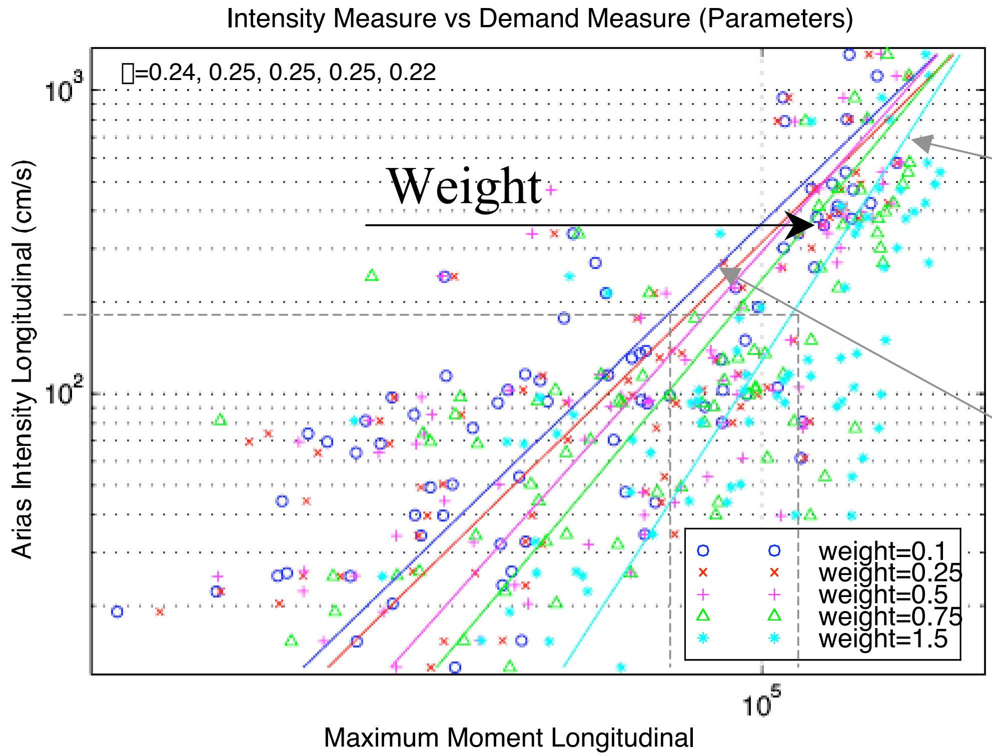


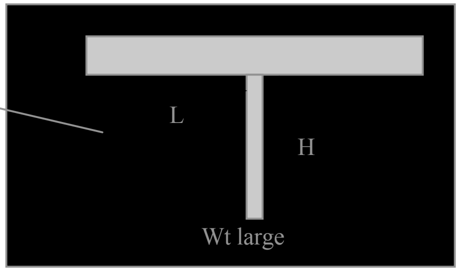
Increasing steel increases column moment demand

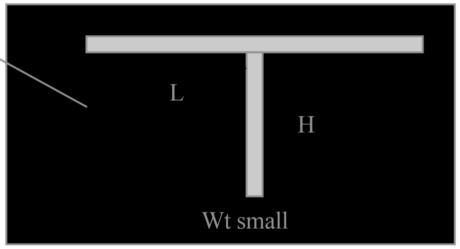
1-bent bridge with abutments

Design Parameter Sensitivity

Additional superstructure dead load (Wt)





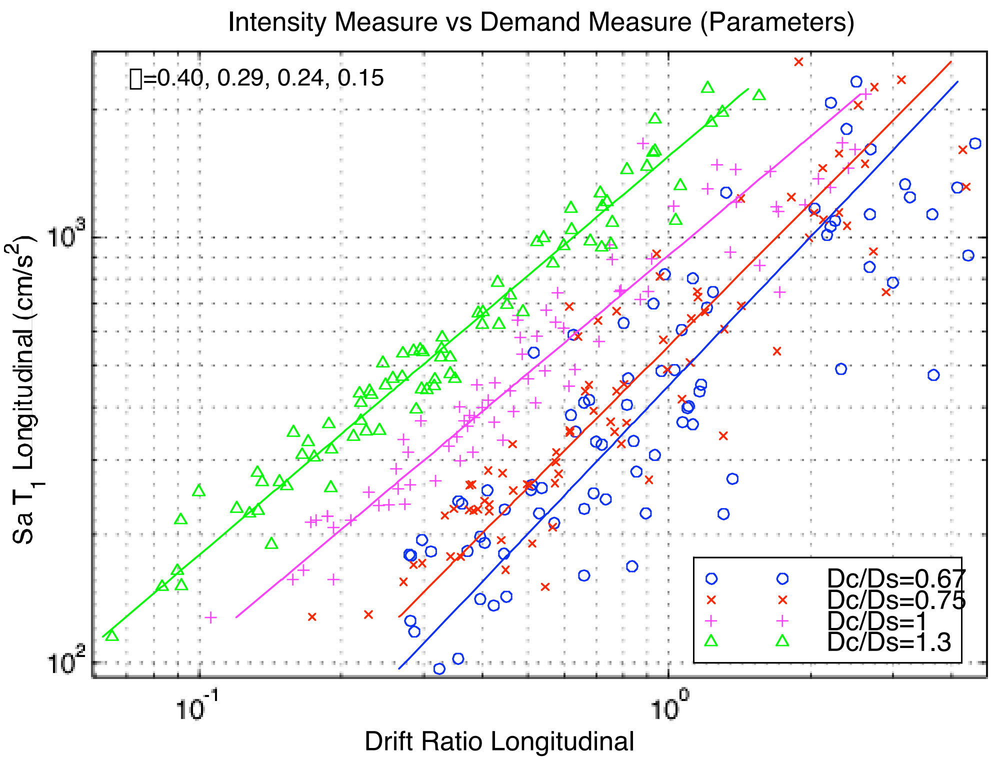


Increased mass increases column moment demand

1-bent bridge without abutments

Sensitivity with Optimal IMs

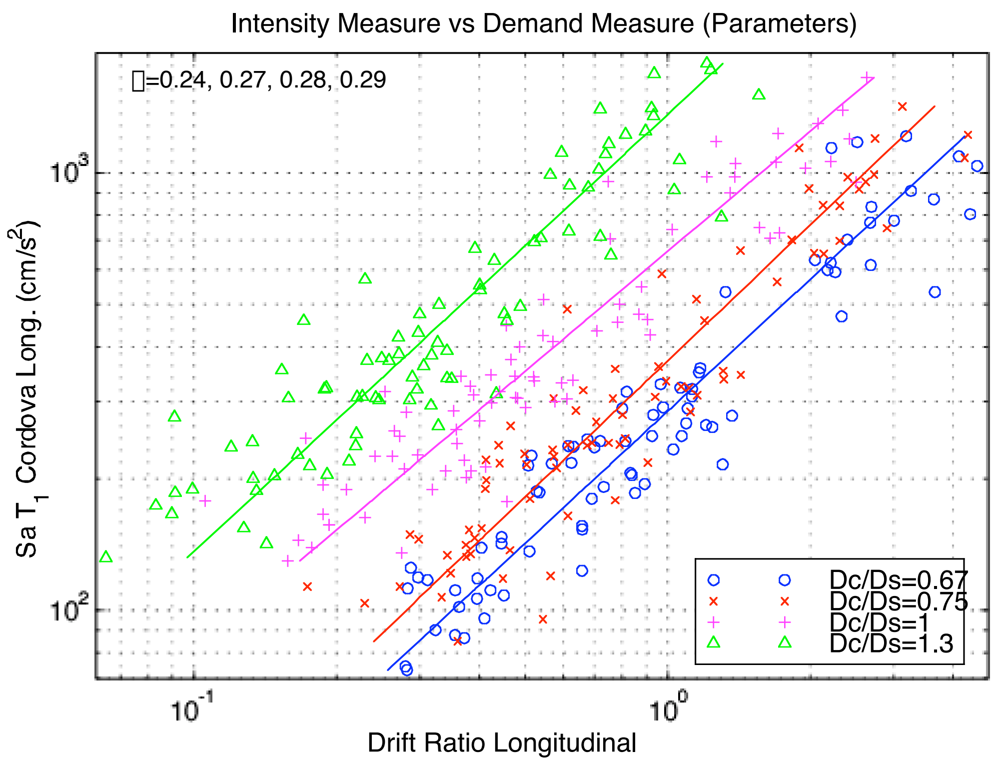
SaT1-Drift sensitivity to Dc/Ds design parameter



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

Sensitivity with Optimal IMs

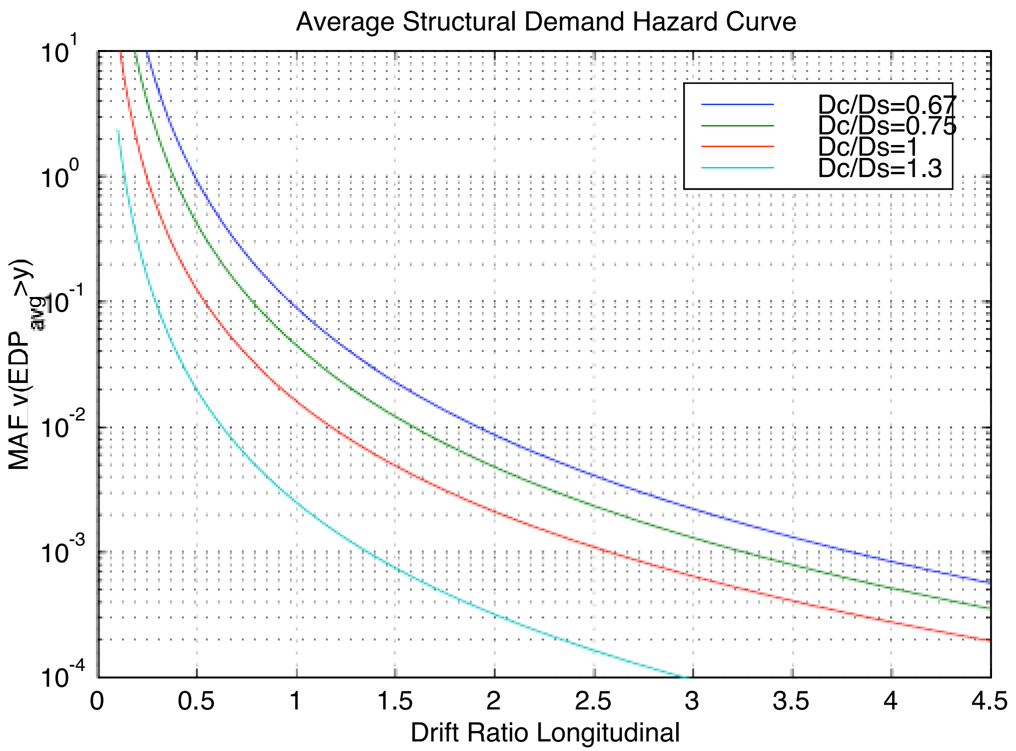
Sa(Cordova)-Drift sensitivity to Dc/Ds design parameter



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

PSDM Extensions

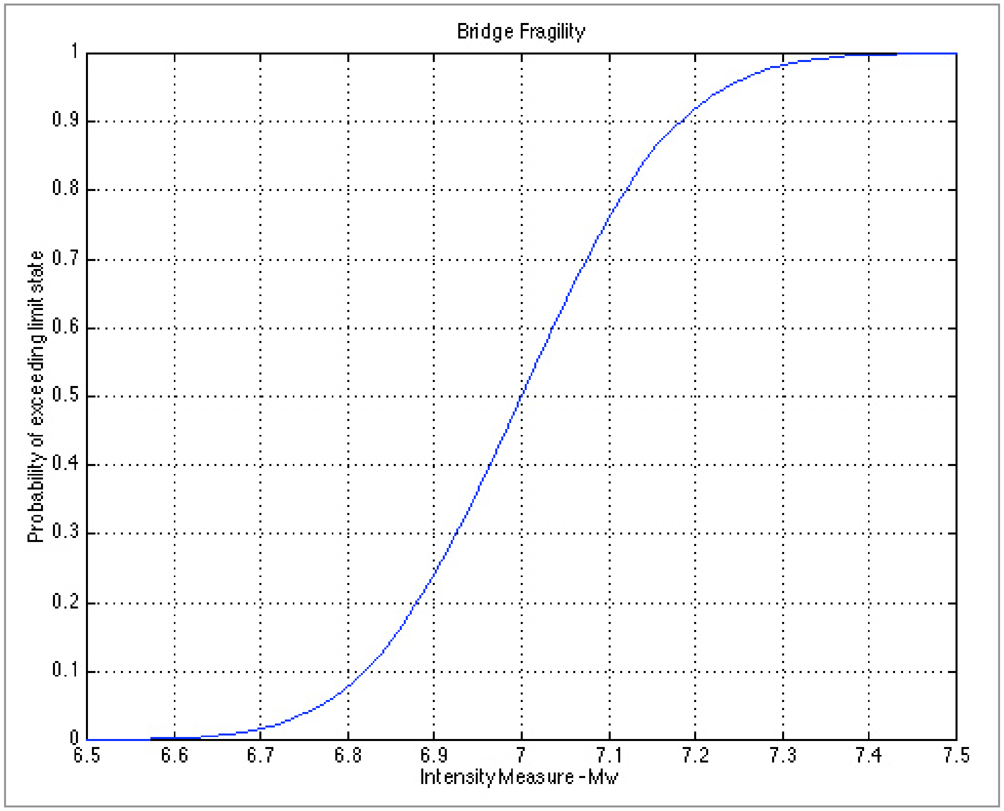
Structural Demand Hazard Curves



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
- Period-independent IMs allow easy quantification of performance changes
- PSDMs fit into PEER performance-based design framework
- Sa(T1)-D optimal PSDM reduces demand model dispersion

Thank You!

- Questions?

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