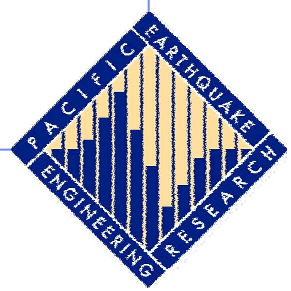
Framework for Performance-Based Earthquake Engineering

Helmut Krawinkler, Stanford U.

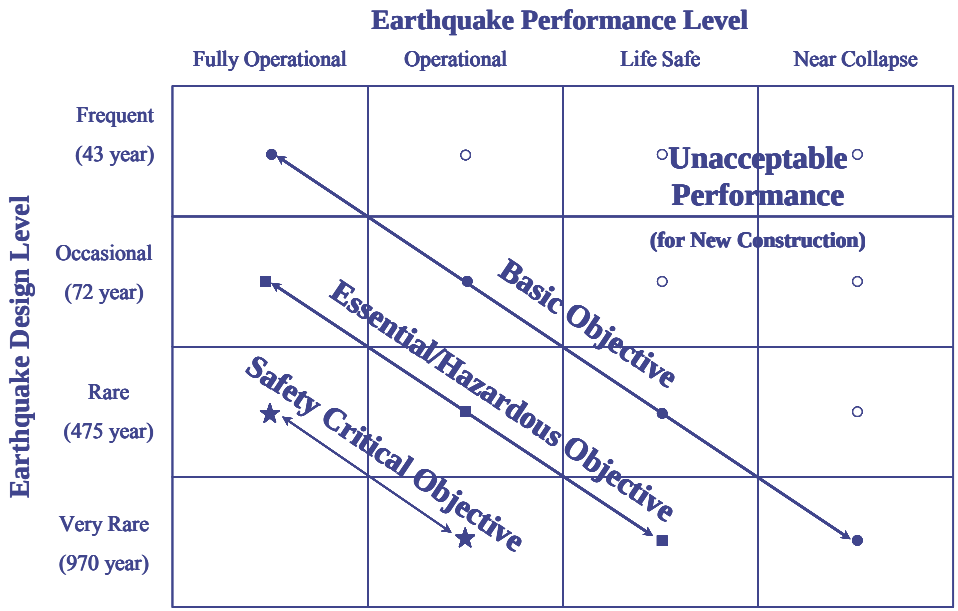


PEER Summative Meeting – June 13, 2007

Where were we 10 years ago?

SEAOC Vision 2000, FEMA 273, ATC-40

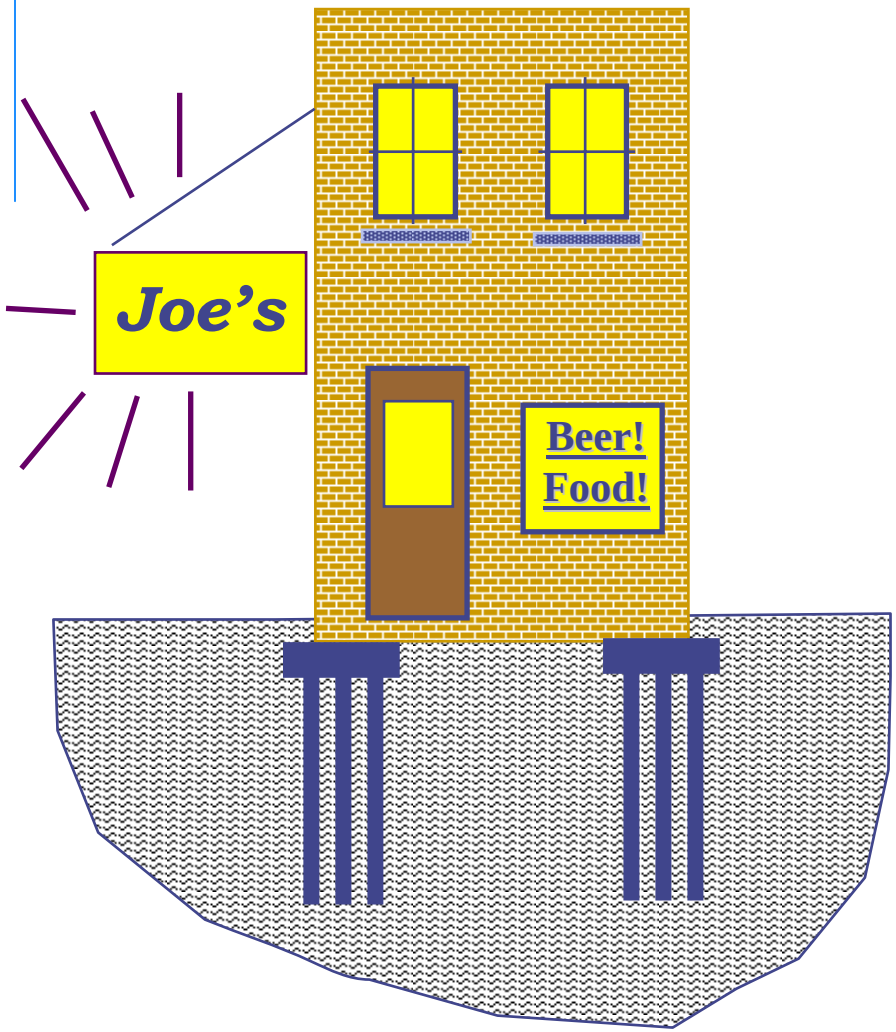
- Descriptive performance levels (IO, LS, CP, etc.)
- Associated with specific hazard levels → Performance Objectives
- Qualitative (and a few quantitative) damage measures
- Limited consideration of uncertainties
- Implementation in terms of **FORCES and DEFORMATIONS**



Measures of Performance - PBEE

- **Forces and deformation?**
  - Yes, but **only** for engineering calculations
  - Intermediate variables
  - Not for communication with clients and community
- **Communication in terms of the three D's:**
  - Dollars (direct economic loss)
  - Downtime (loss of operation/occupancy)
  - Death (injuries, fatalities, collapse)
- **Quantification**
  - Losses for a given shaking intensity
  - Losses for a specific scenario (M & R)
  - Annualized losses
  - With or without rigorous consideration of uncertainties

Vision of PBEE



1. Complete simulation
2. Defined performance objectives
   - Quantifiable performance targets
   - Annual probabilities of achieving them
3. Informed owners

Sources: G. Deierlein, R. Hamburger

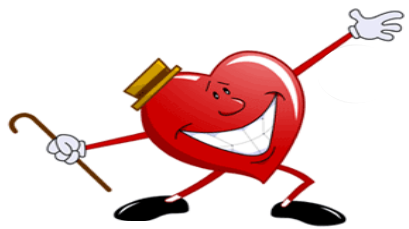
The Peer Framework Equation - 1999

$$v(DV) = \iiint G\langle DV \mid DM \rangle \mid dG\langle DM \mid EDP \rangle \mid dG\langle EDP \mid IM \rangle \mid d\lambda(IM)$$

Impact | **Performance (Loss) Models and Simulation** | **Hazard**

Curse?

Blessing



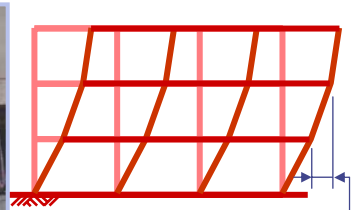
Performance-Based Methodology – Bldgs.

Measures of Performance

- Collapse & Casualties
- Direct Financial Loss
- Downtime

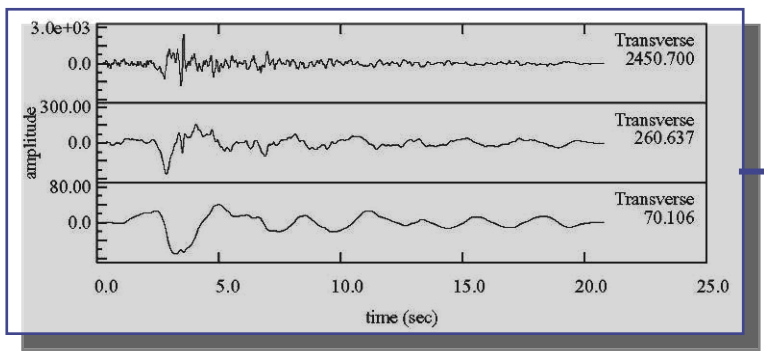
Decision Variable

Damage Measure



drift as an EDP

Engineering Demand Parameter



Intensity Measure

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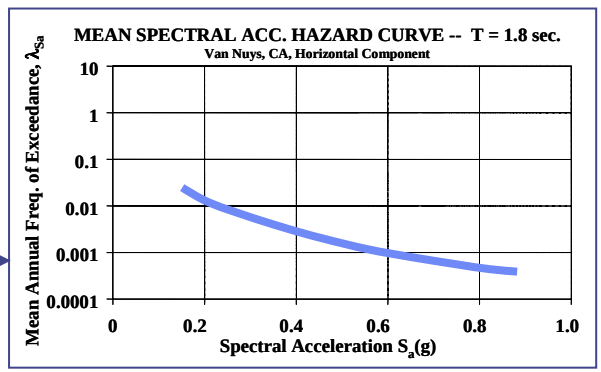
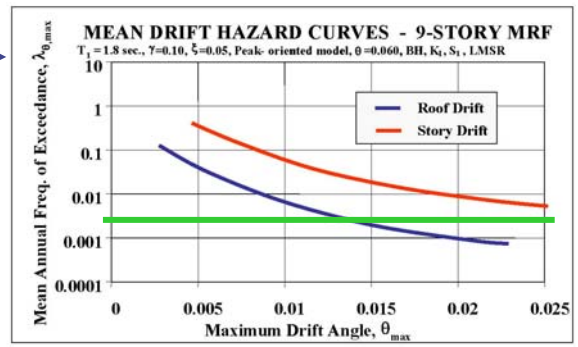
Performance-Based Methodology

Engineering Demand Parameter

Intensity Measure





Medina & Krawinkler

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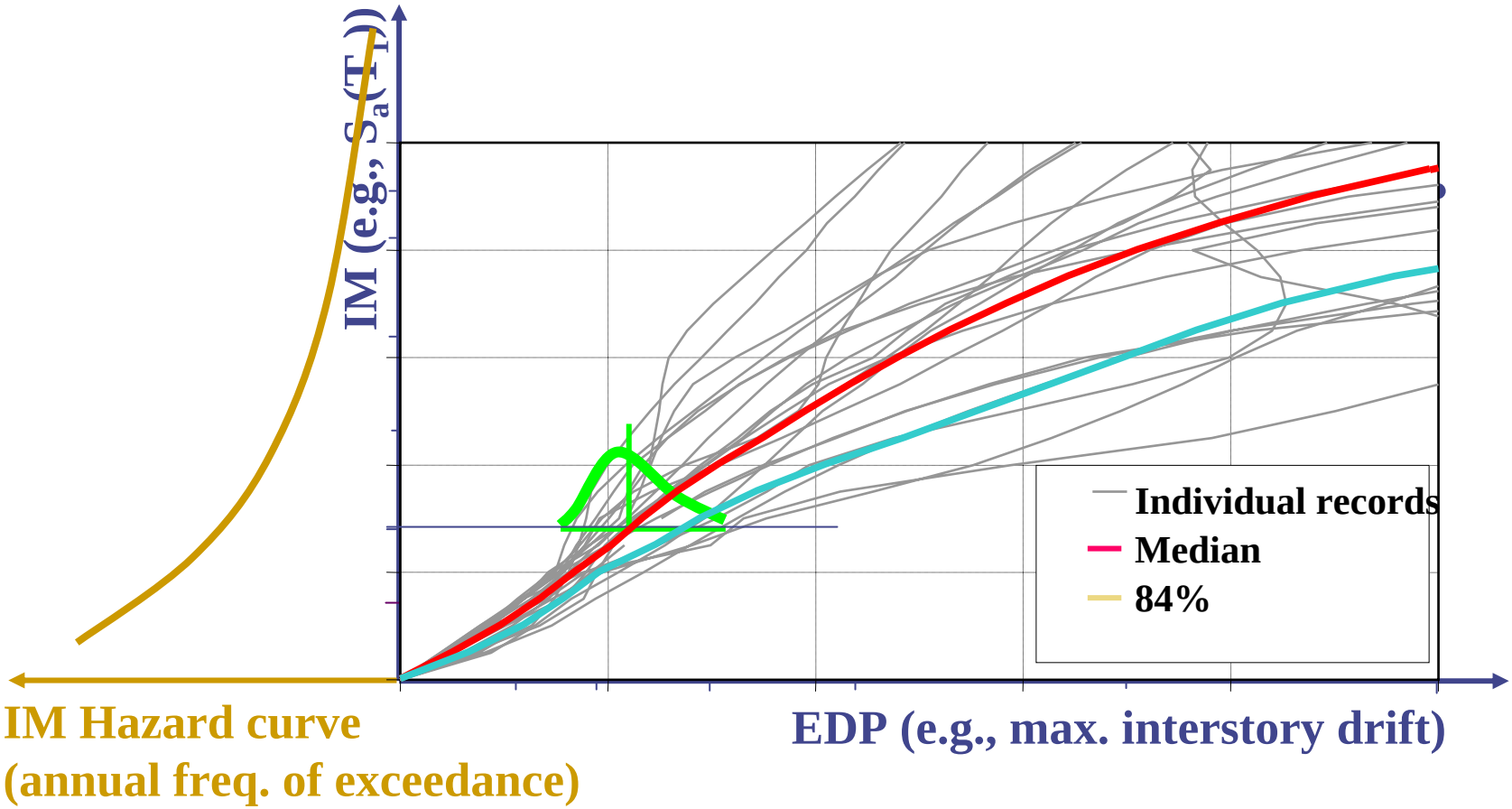
Incremental Dynamic Analysis



$$\lambda_{EDP}(y) = \int P[EDP \geq y \mid IM = x] \left| d\lambda_{IM}(x) \right|$$

Performance-Based Methodology

Decision Variable

Damage Measure

Engineering Demand Parameter

Intensity Measure

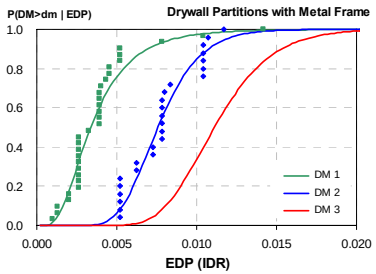
Performance Assessment types (ATC-58 definitions):

Intensity-based: Prob. facility perf., given intensity of ground motion

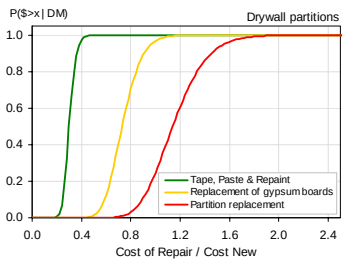
Scenario-based: Prob. facility perf., given a specific earthquake scenario

Time-based: Prob. facility perf. In a specific period of time

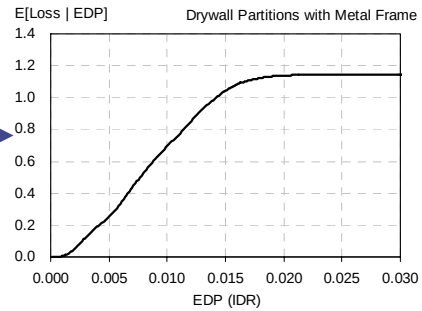
Damage Fragility Curves:



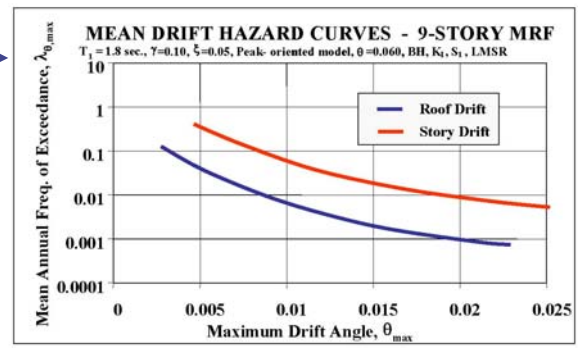
Cost Functions:



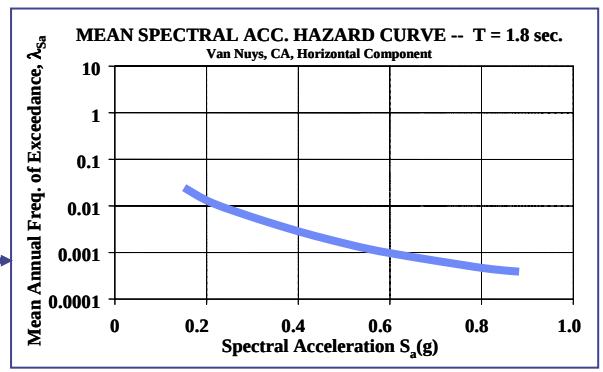
Mean Loss Curve:



Aslani & Miranda



Medina & Krawinkler



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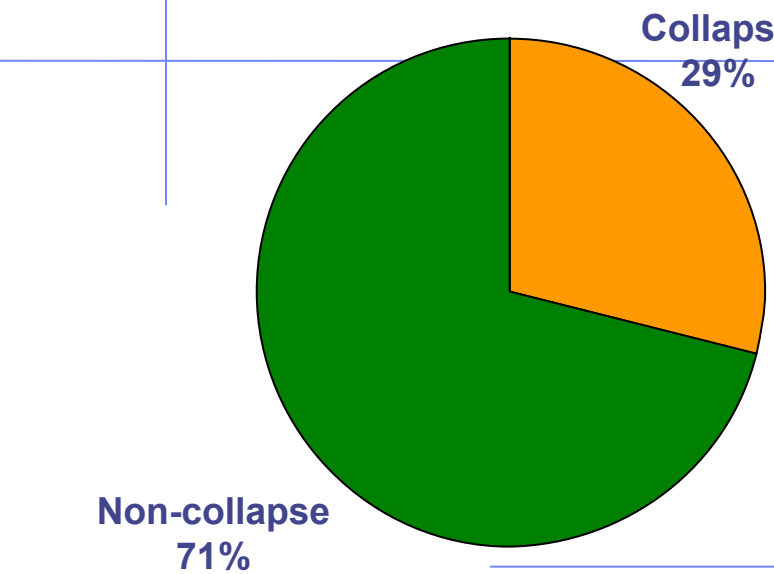
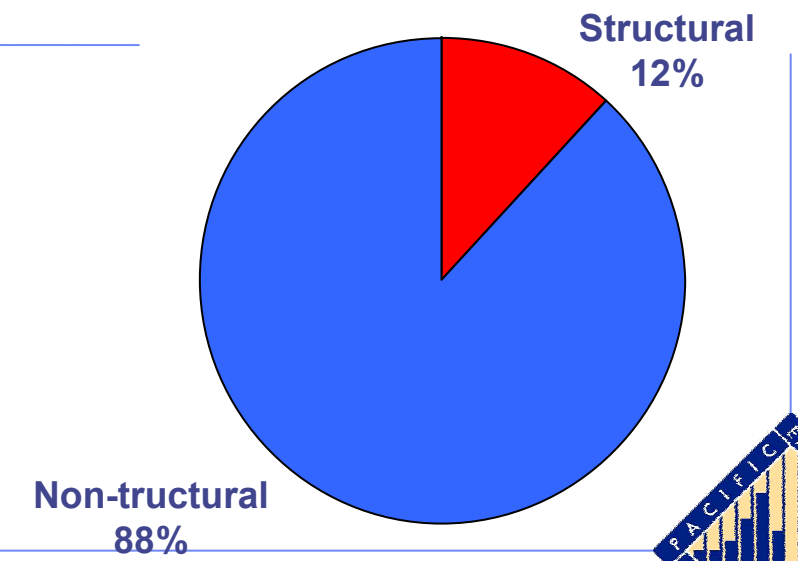
Deaggregation of Expected Annual Loss

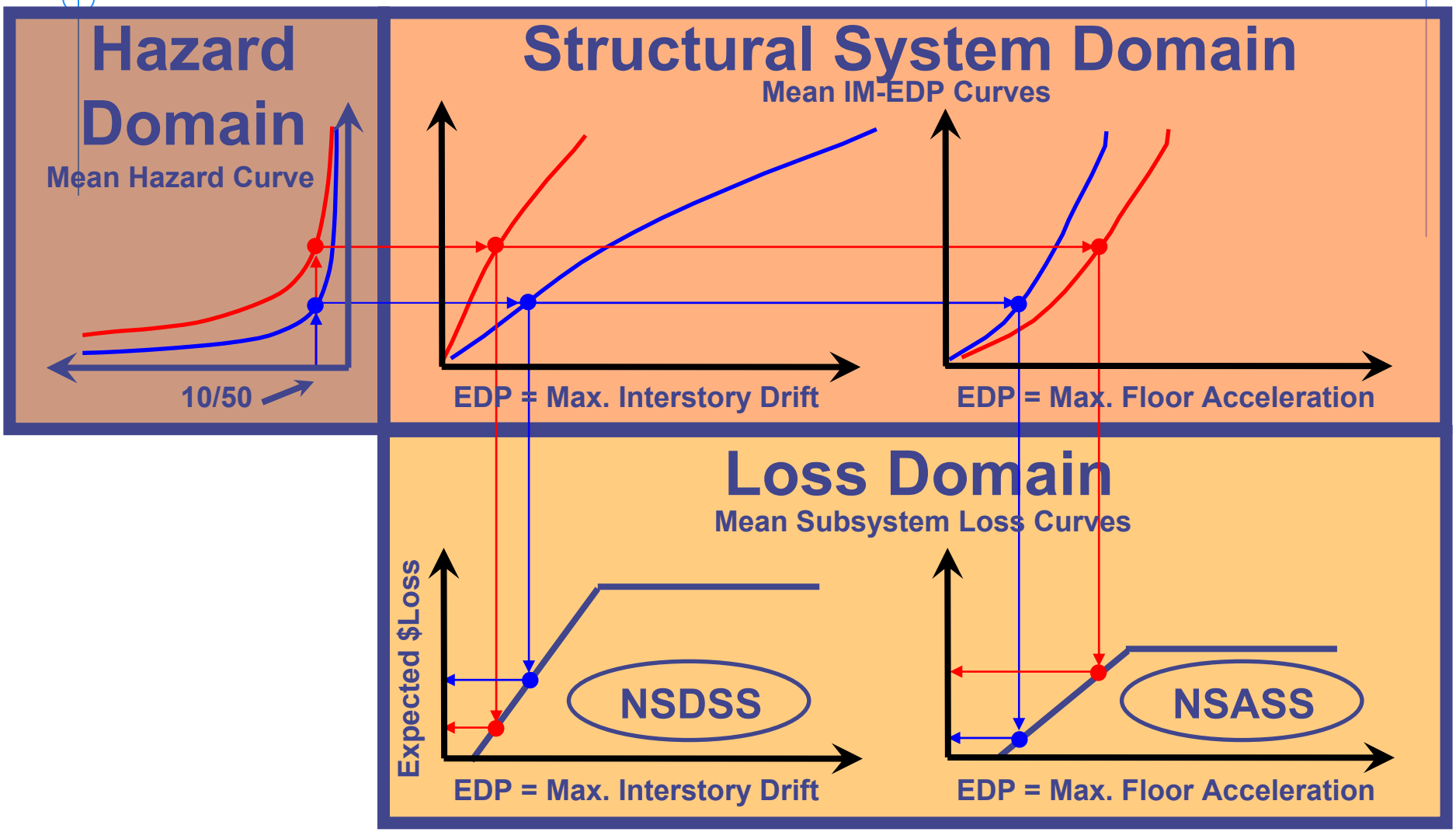
Example: Van Nuys Testbed Building





Source: E. Miranda

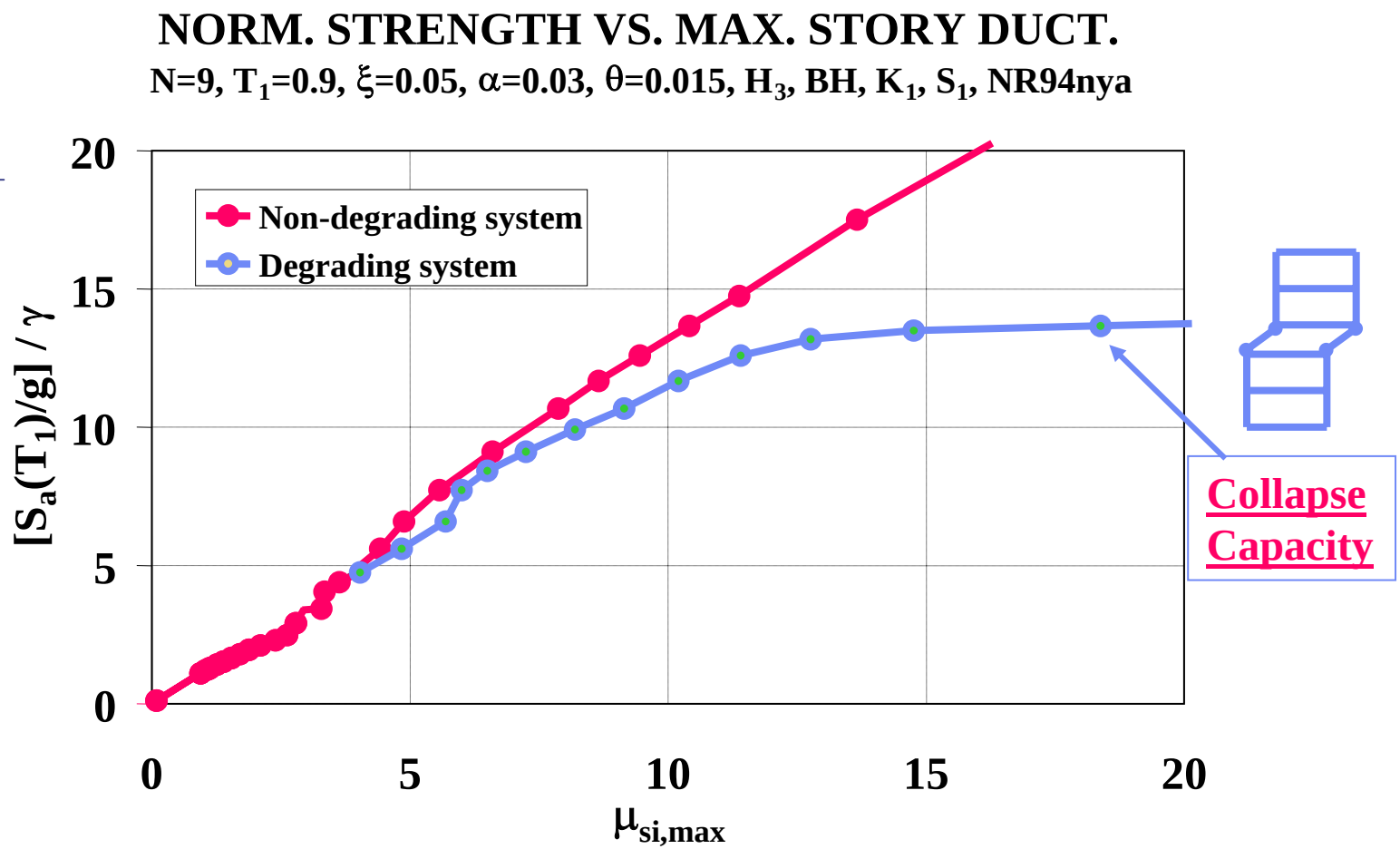
Design Decision Support



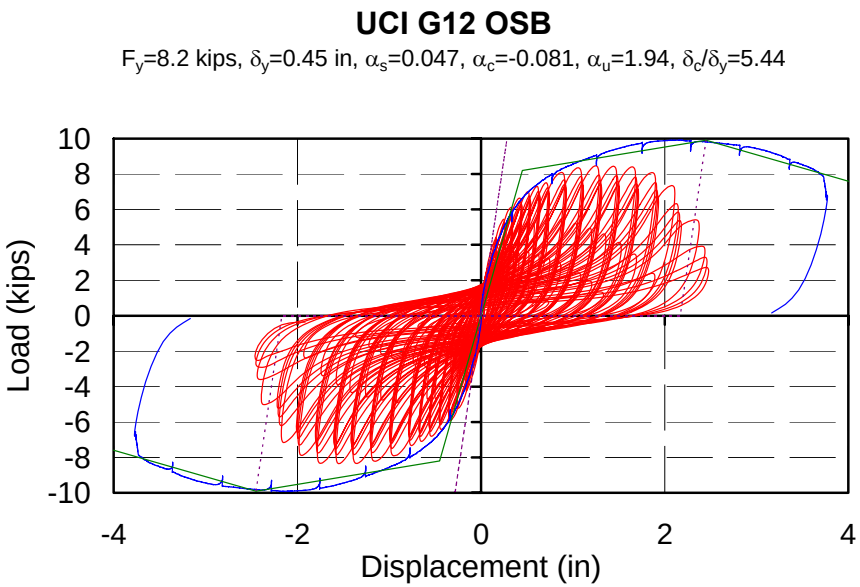
Zareian & Krawinkler (2005)

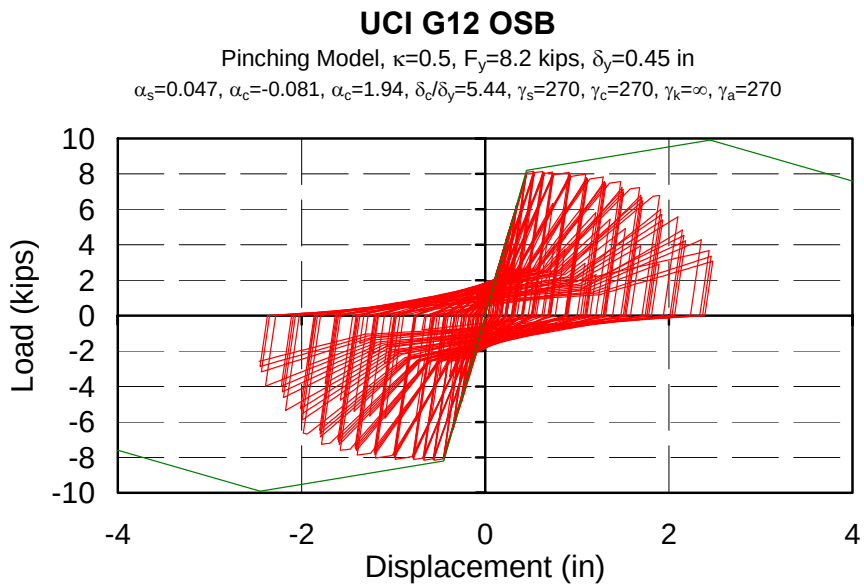
Assessment of Collapse Potential

$$\gamma = \frac{V_y}{W}$$

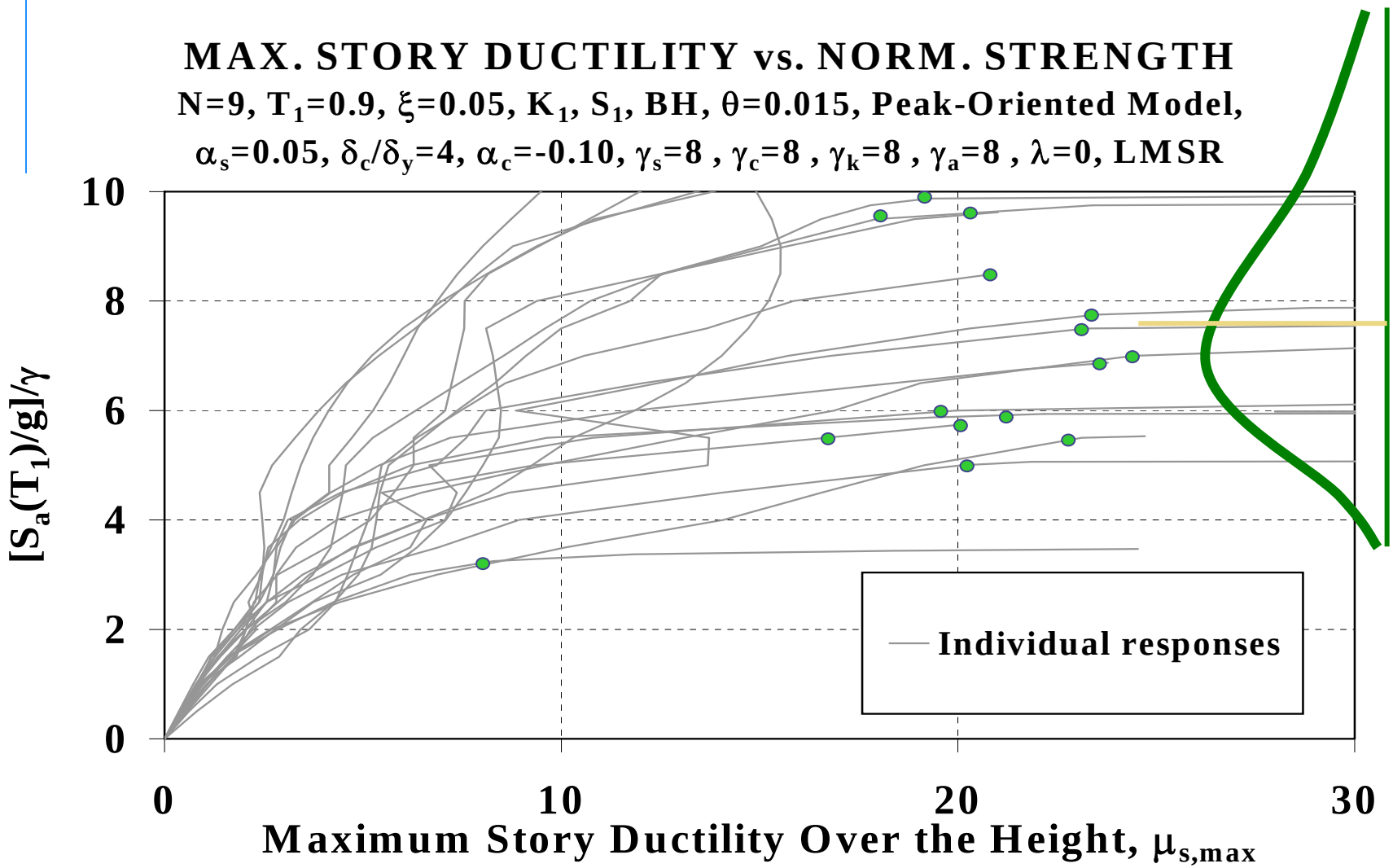


Modeling of Deterioration

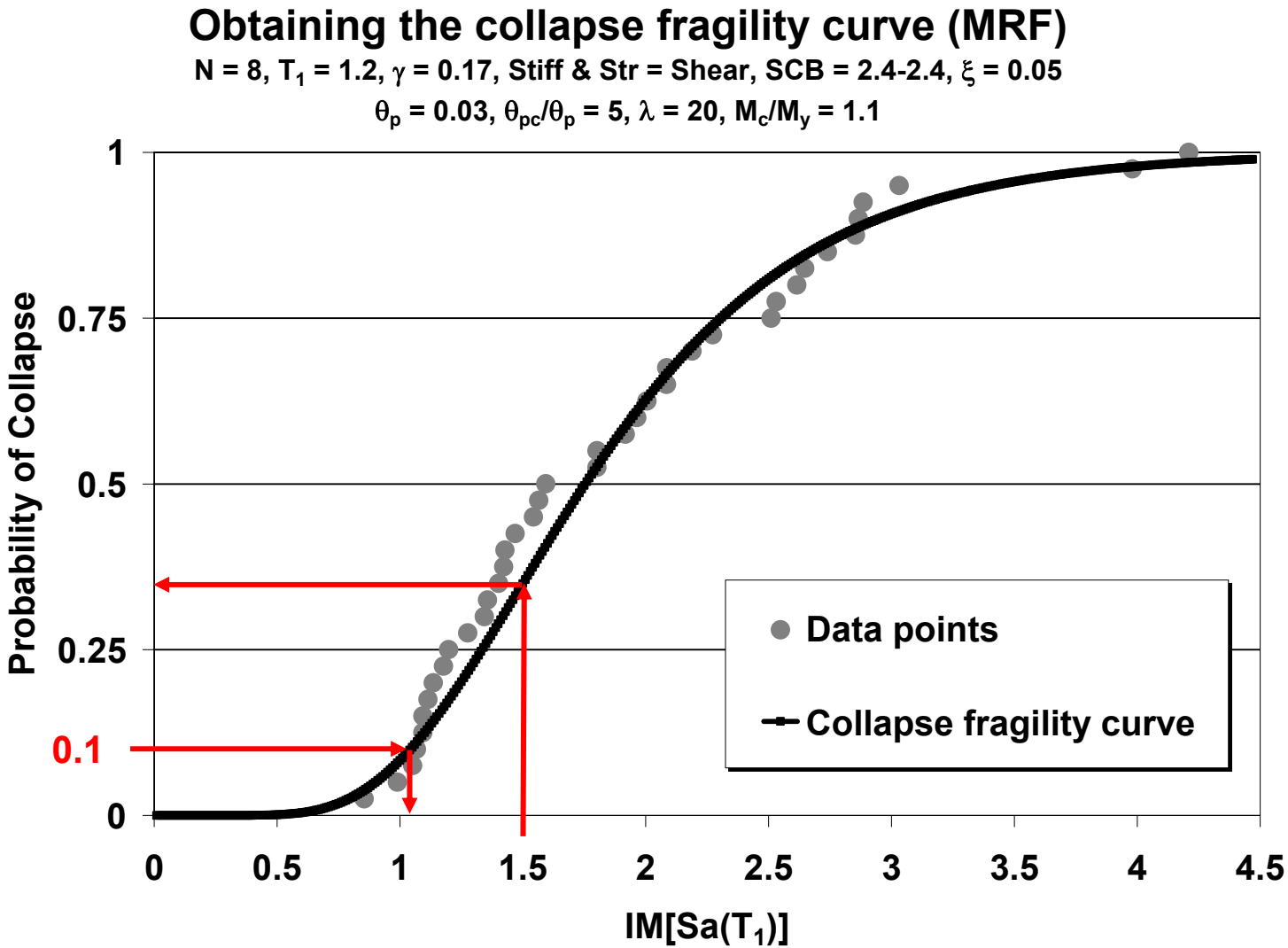




Collapse Capacity for a Set of Ground Motions

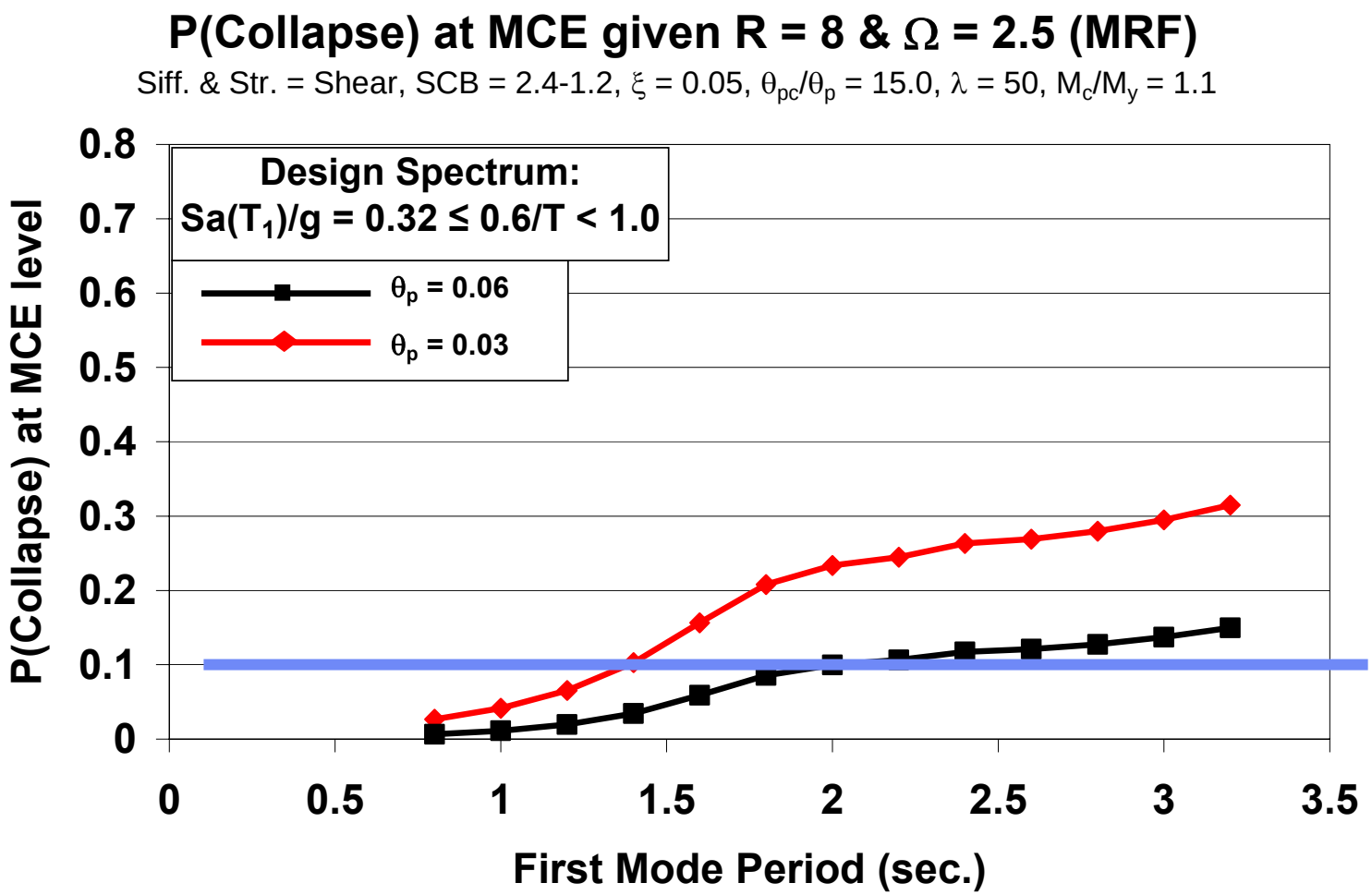


Collapse Fragility Curve



Zareian & Krawinkler (2004)

Probability of Collapse at MCE, for MRFs with R = 8



Zareian & Krawinkler (2007)

Implementation of Framework

- ***ATC-58*** – Guidelines for Seismic Performance Assessment of Buildings
- ***ATC-63*** – Recommended Methodology for Quantification of Building System Performance
- ***TBI*** – Tall Building Initiative
- ***LRFD*** for bridge design

Concluding Remarks - 1999

- **Performance based engineering is here to stay**
- **It enforces a transparent design/assessment approach**
- **Much more emphasis must be placed on $ losses and loss of function (downtime)**
- **Performance based design should be reliability based**
- **We have a long road ahead of us**