Chile Earthquake of February 27, 2010

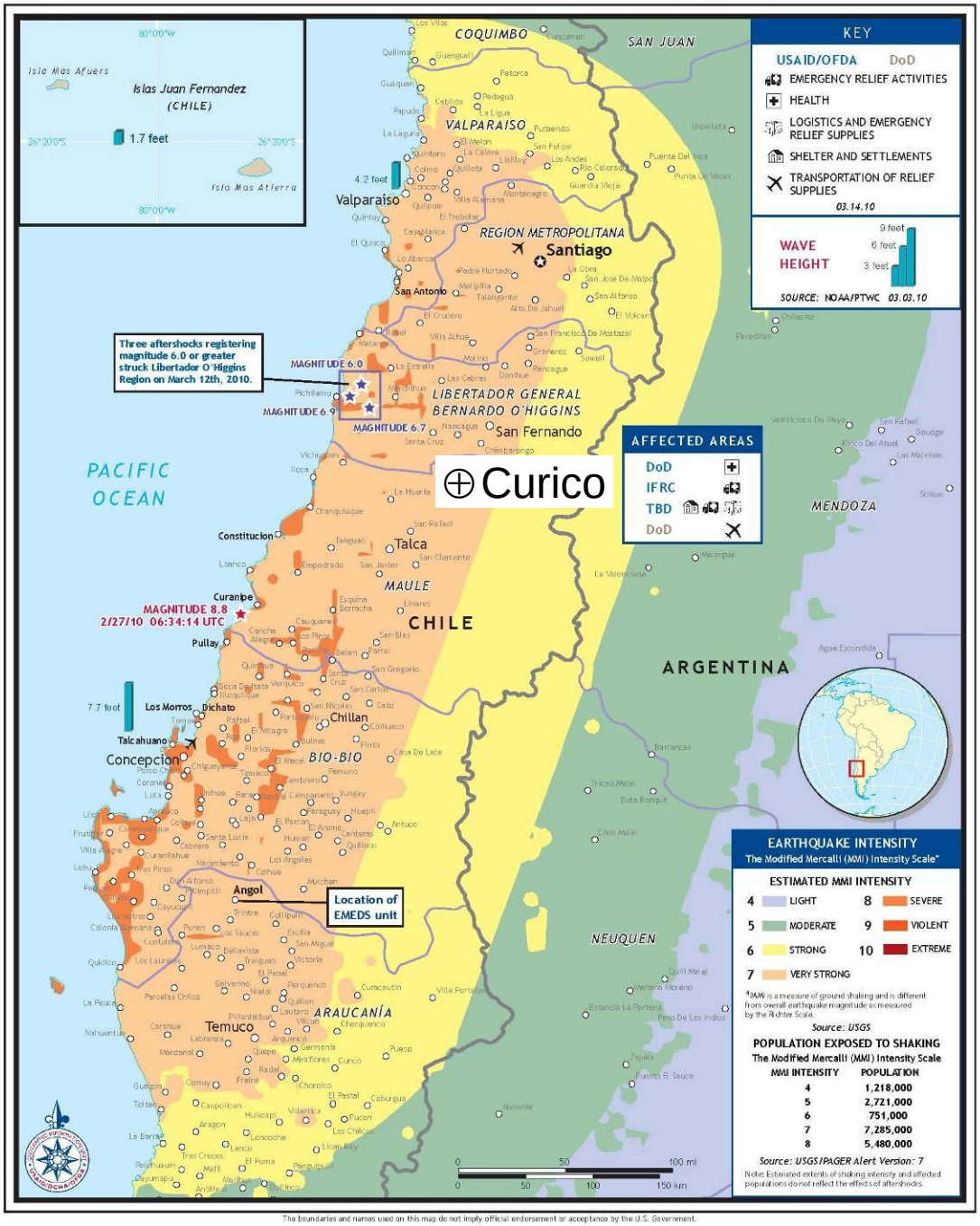
Damage Observations

Farzin Zareian, University of California - Irvine

Majid Sarraf, PARSONS Engineering

Iranian American Society of Engineers and Architects (IASEA)

Irvine, April 7th, 2010



2010 Chile earthquake

3:34 am local time
27 February 2010

M_w 8.8

Fault rupture 100km x 500 km

Population affected > 8M*

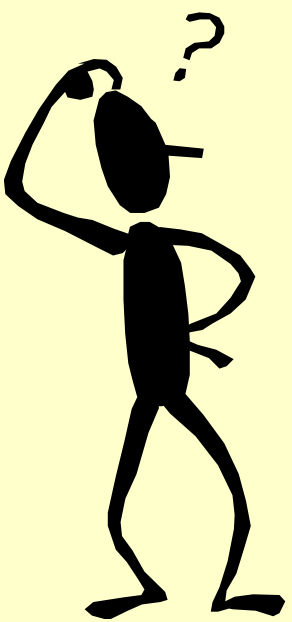
452 confirmed deaths**

~800,000 homeless

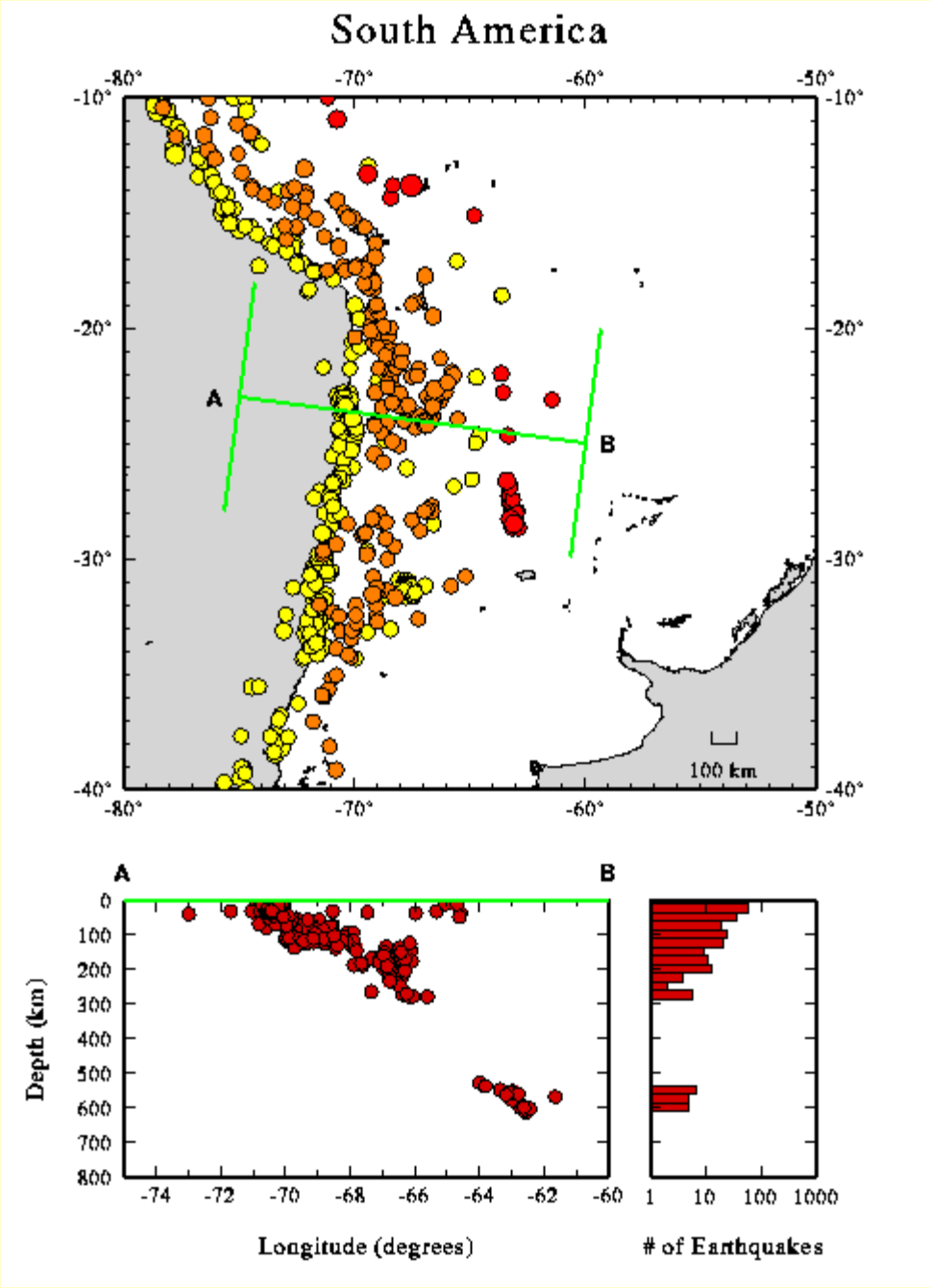
~$30B damages

* ACHISINA
**USAID, 3/25/10

Challenges in collapse prediction

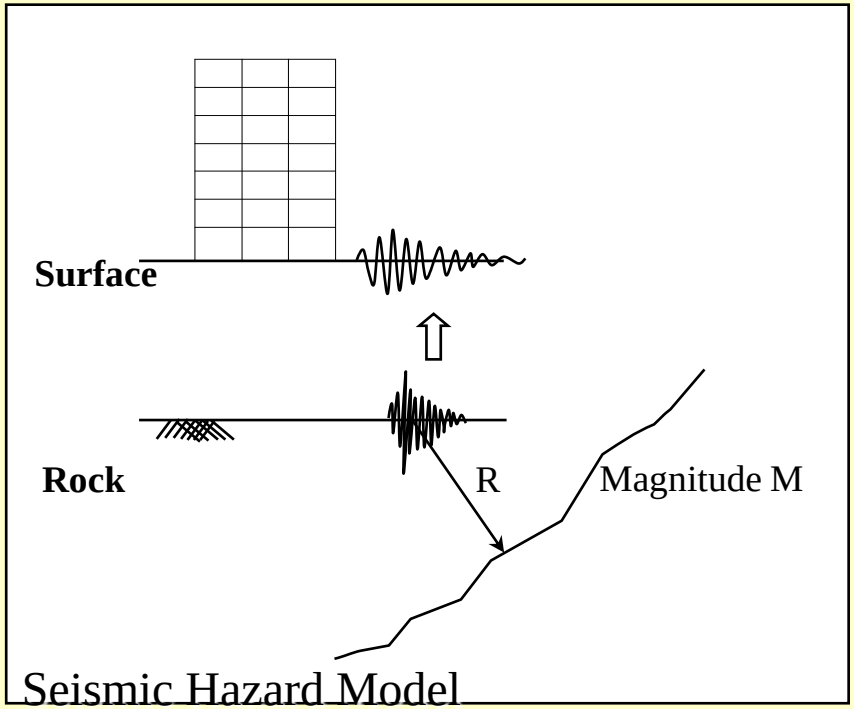


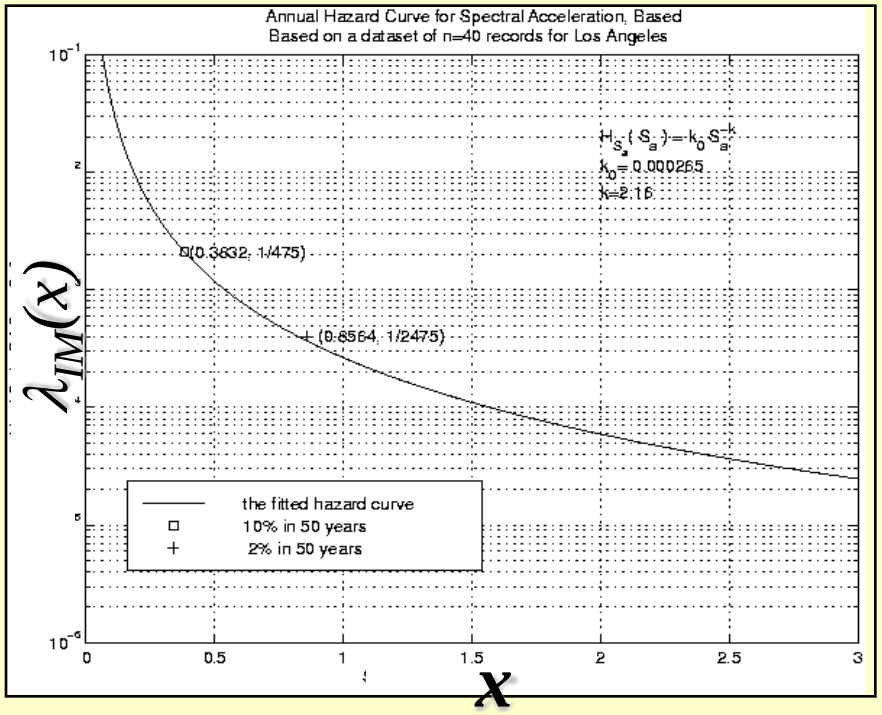
- We'll never be able to do it right
- Even if we knew how, what difference does it make in the context of structural design decisions?
- We can not codify design for collapse safety
- All structures have a finite probability of collapse (because of the uncertainty in the earthquake hazard)
- Most older structures have a significant probability of collapse
- Collapse has economic and social consequences and it should be considered in a performance-based design decision process



Depth of epicenter of earthquakes (1991-1996, CNSS Earthquake Maps).

Hazard analysis → Hazard curve





$\lambda_{IM}(x)$: Mean Annual Rate of Events With Site Intensity IM $\geq x$

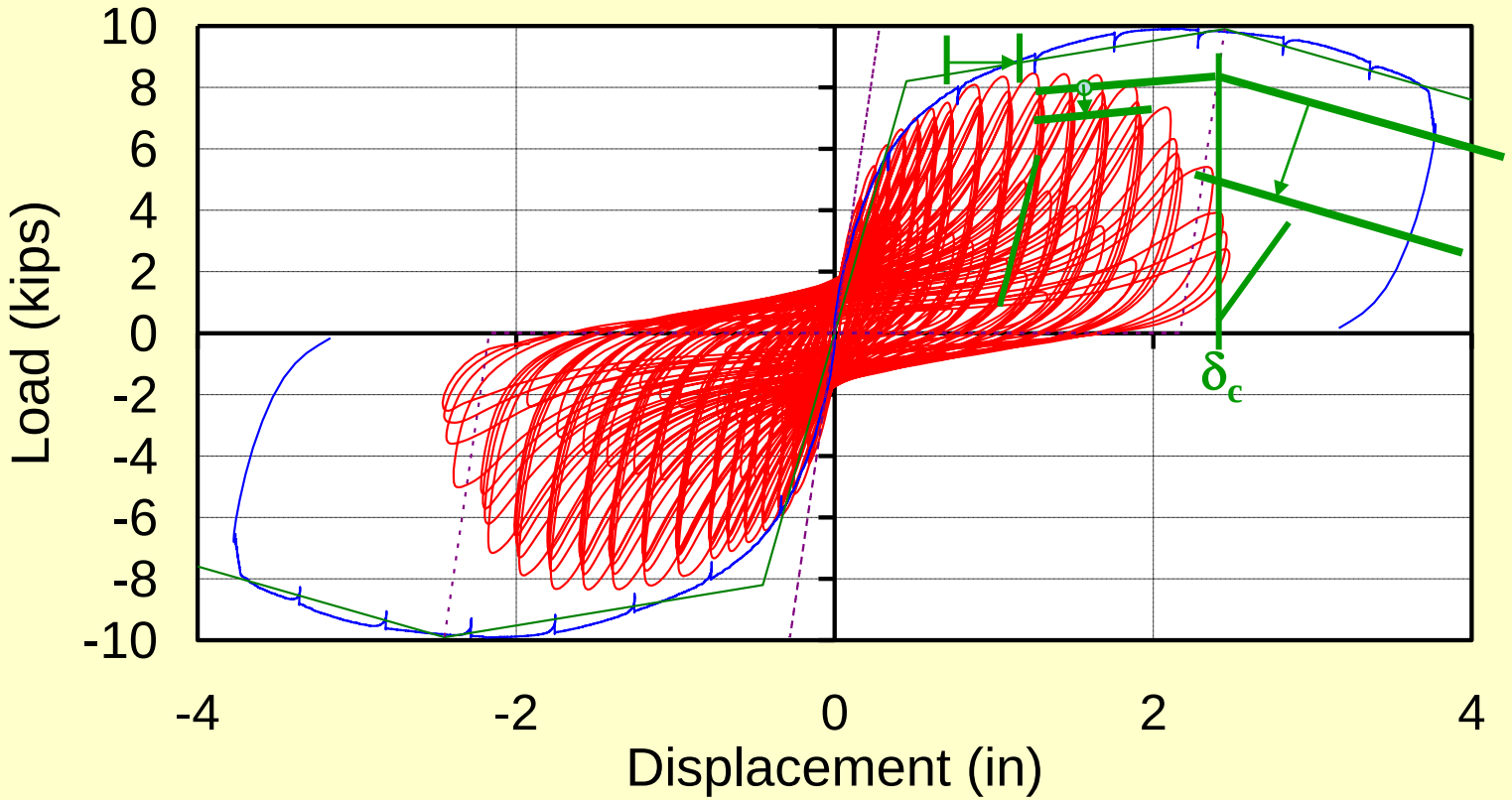
Collapse capacity analysis

1. Develop realistic analytical model of structure that permits prediction of the response till collapse occurs (required modeling of deterioration)
2. Subject model of structure to ground motion of increasing intensity until collapse occurs (evaluate collapse capacity)
3. Subject structure to sufficient number of ground motions to perform statistical evaluation of collapse capacity (obtain collapse fragility curve accounting for aleatory variability)
4. Modify fragility curve for modeling (epistemic variability) uncertainties

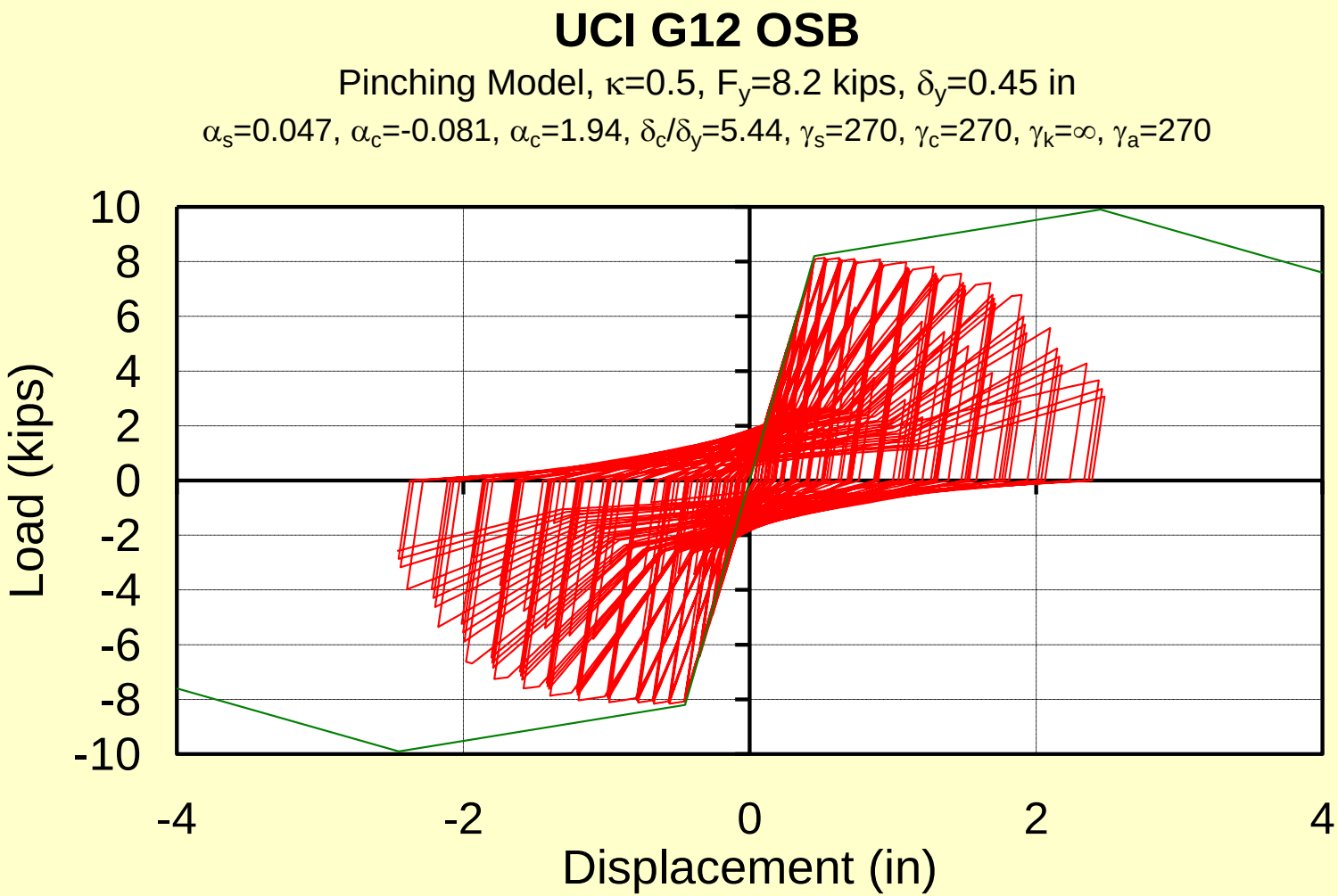
Component modeling : Basic modes of deterioration

UCI G12 OSB

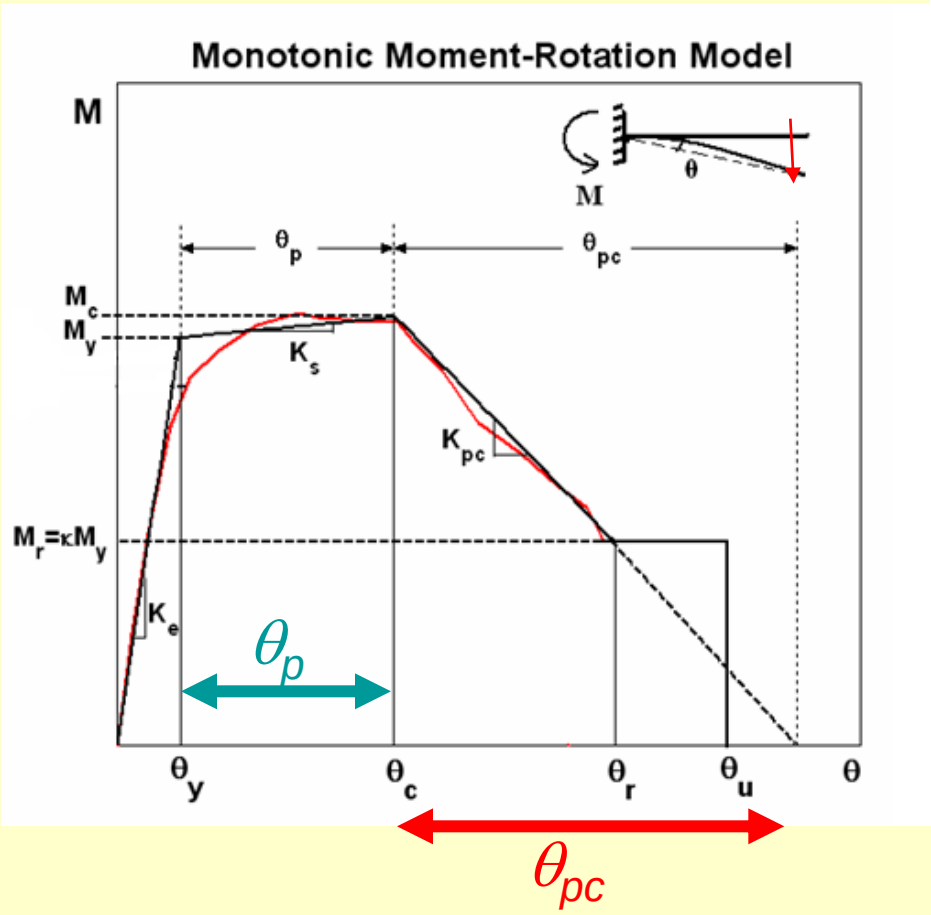
F_y=8.2 kips, δ_y=0.45 in, α_s=0.047, α_c=-0.081, α_u=1.94, δ_c/δ_y=5.44

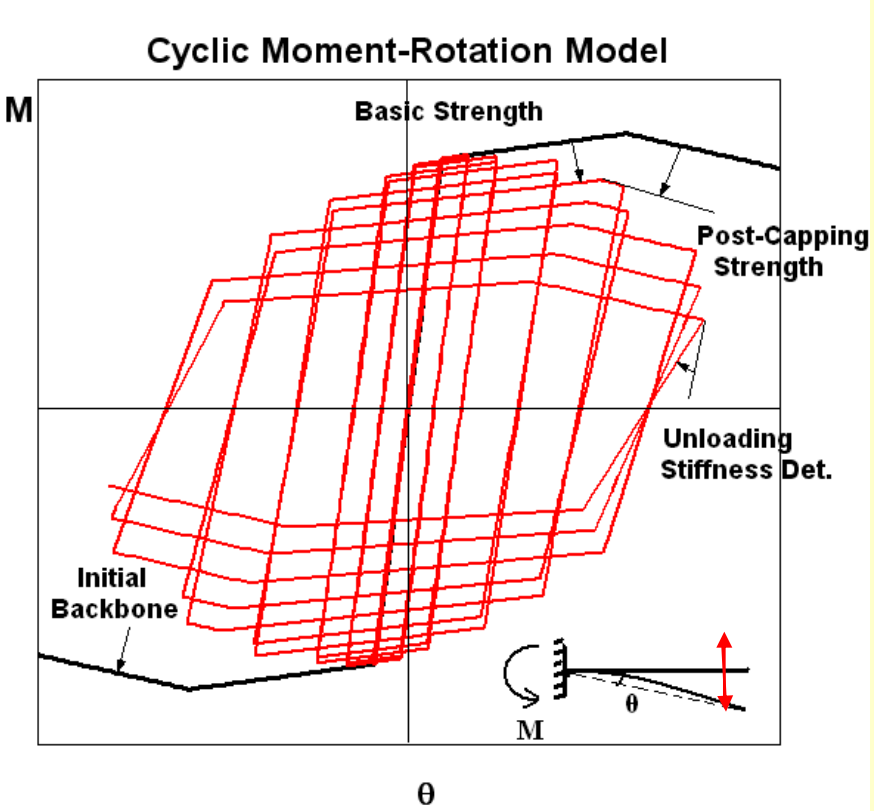


Component modeling : Basic modes of deterioration

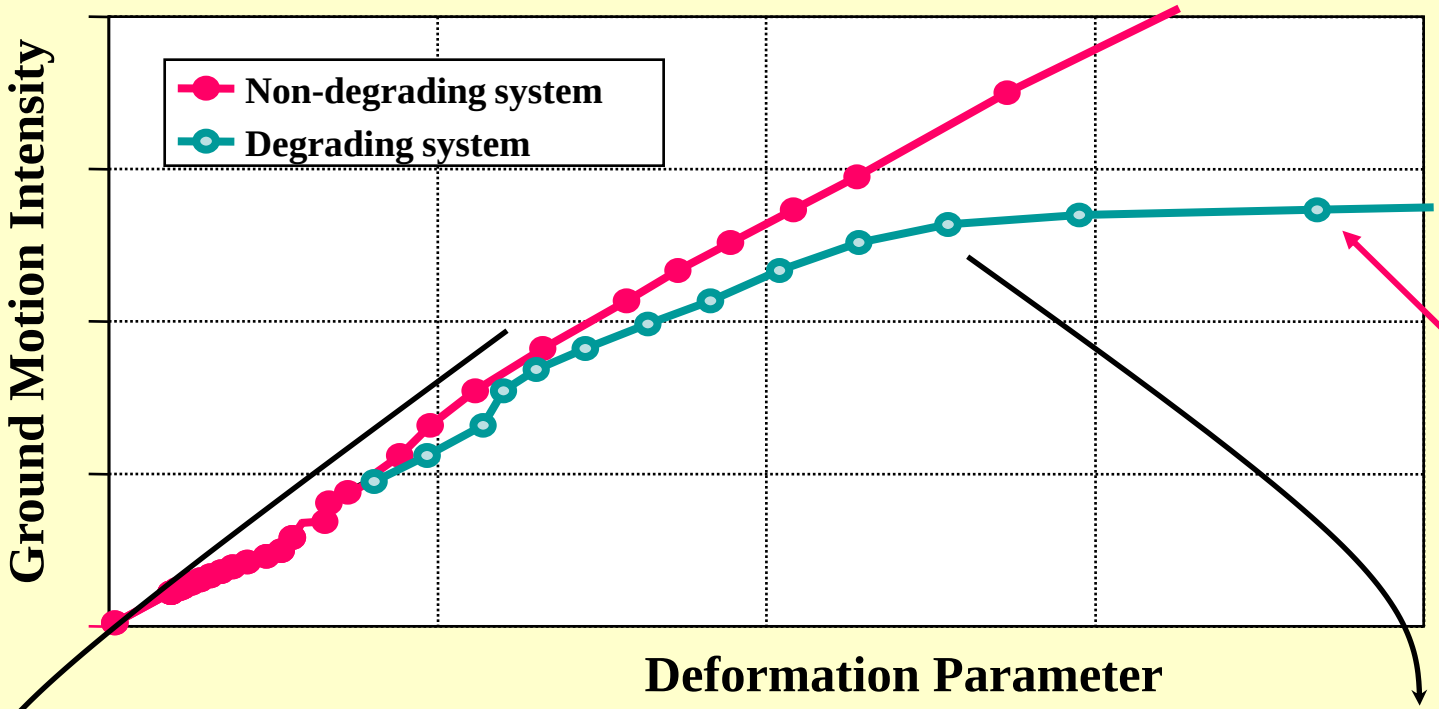


Component modeling : Basic modes of deterioration

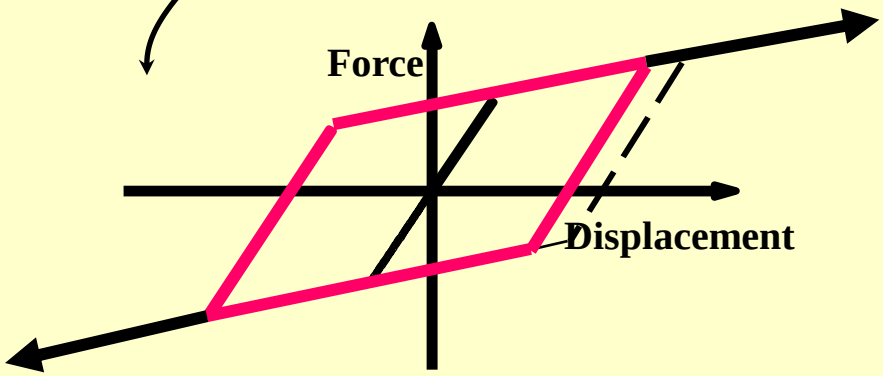




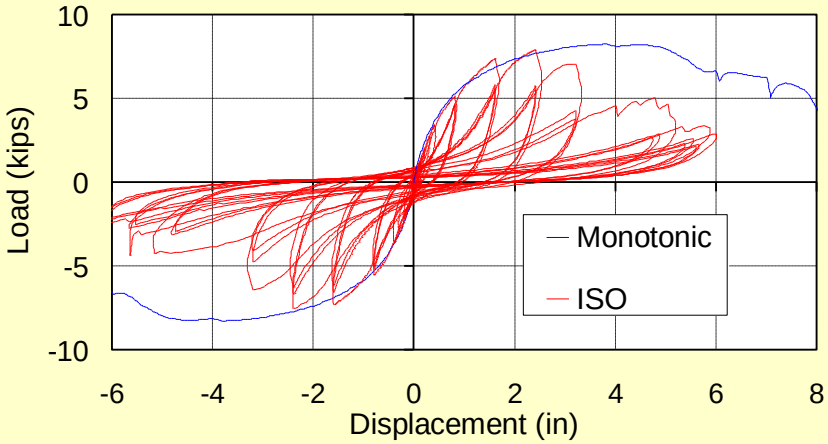
Deterioration and Collapse (MDOF)



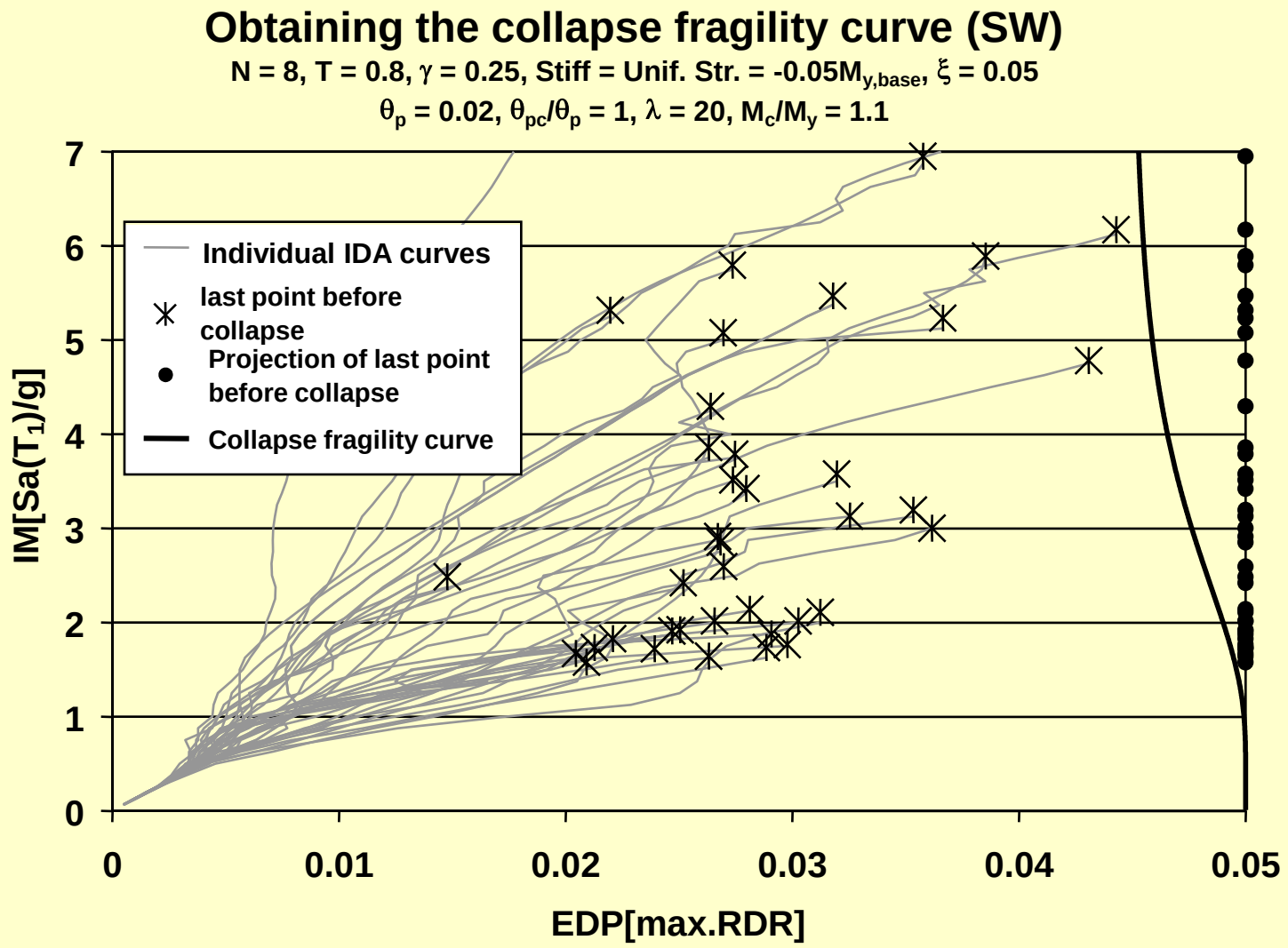
Collapse Capacity



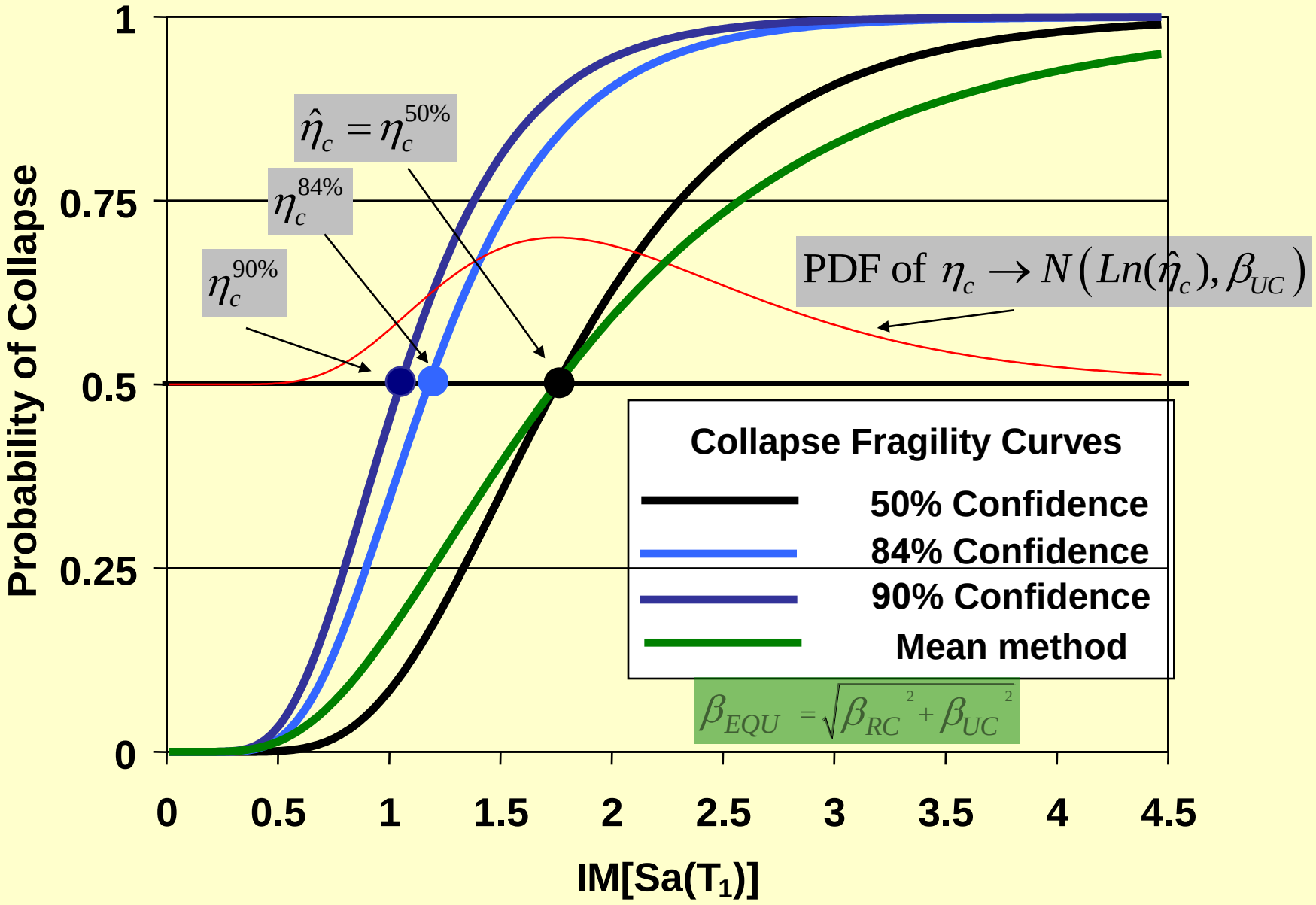
After H. Krawinkler



Developing Collapse Fragility Curve

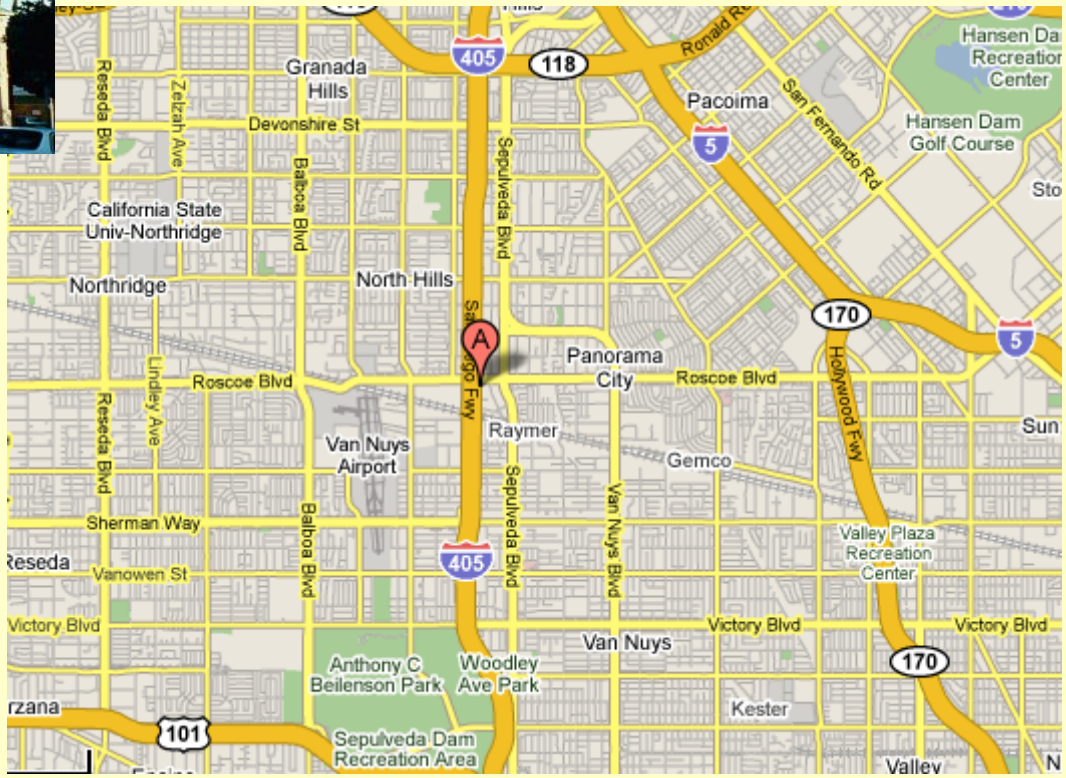


Effect of uncertainty on prob. of collapse



Assessment of probability of collapse at certain hazard level

Van Nuys Hotel Structure

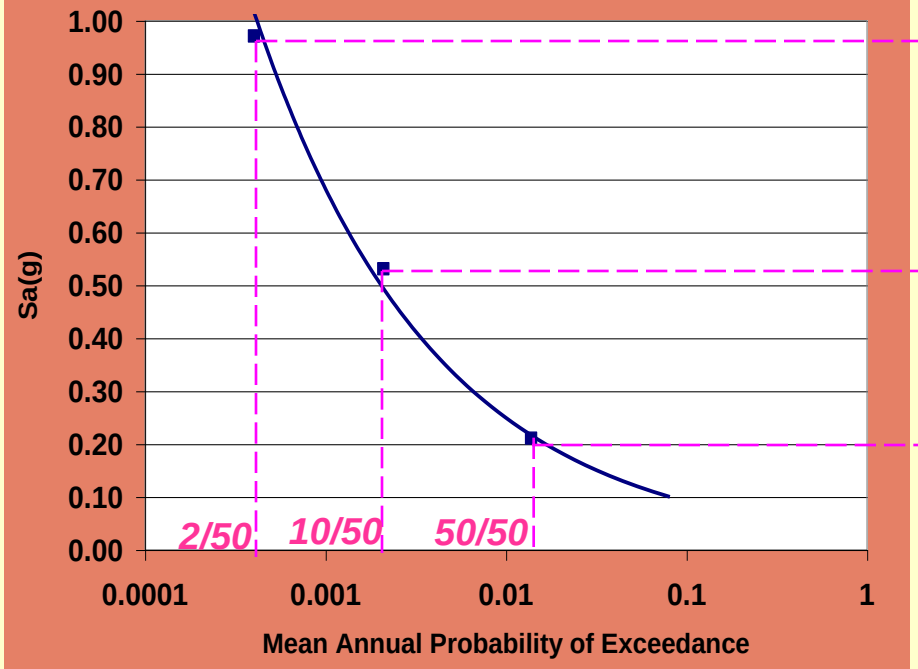


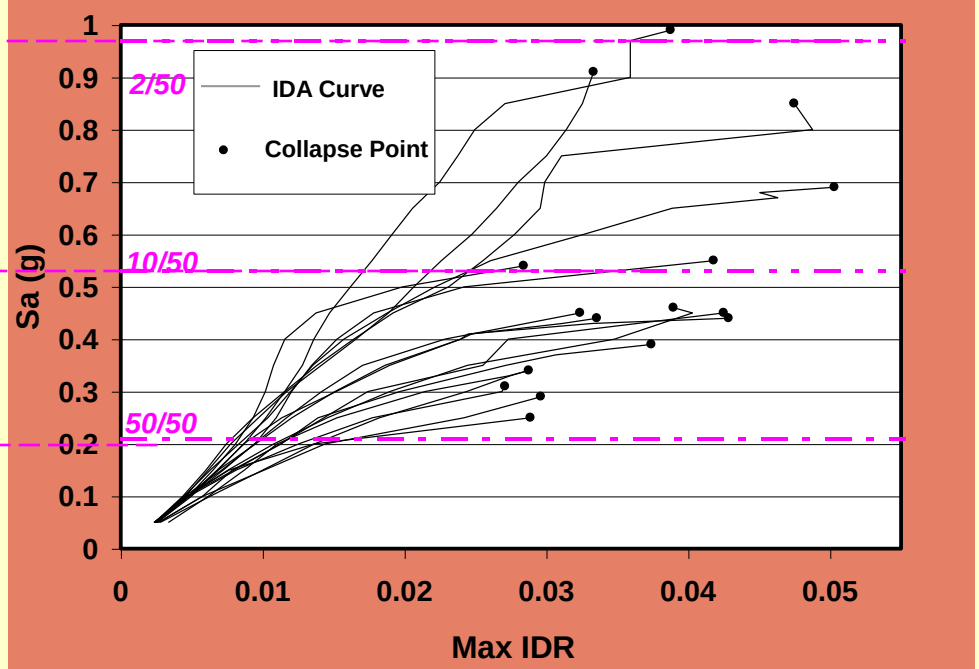
Assessment of probability of collapse at certain hazard level

Hazard Curve

$\lambda(Sa)$

Incremental Dynamic Analysis





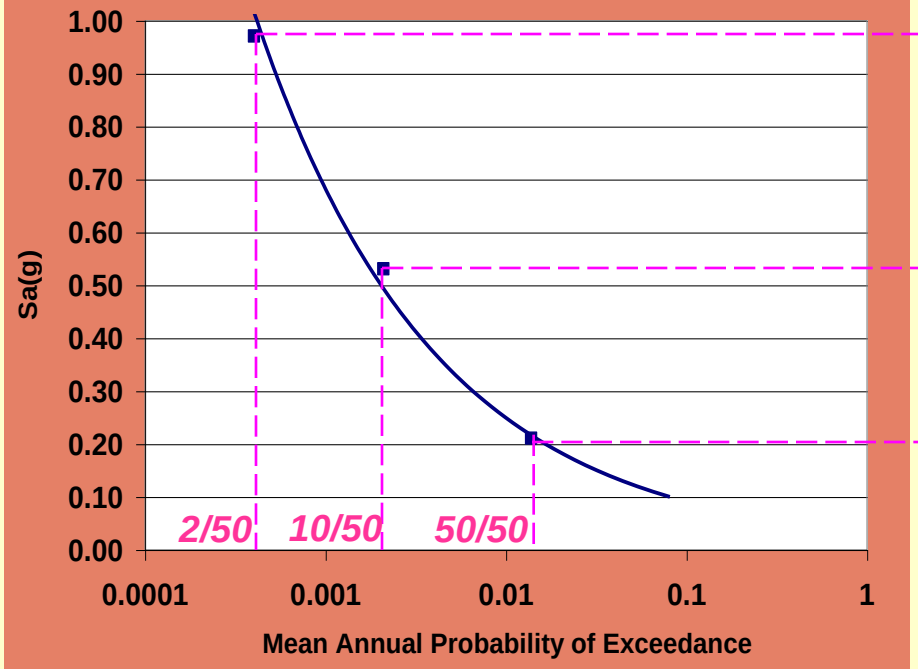
Assessment of probability of collapse at certain hazard level

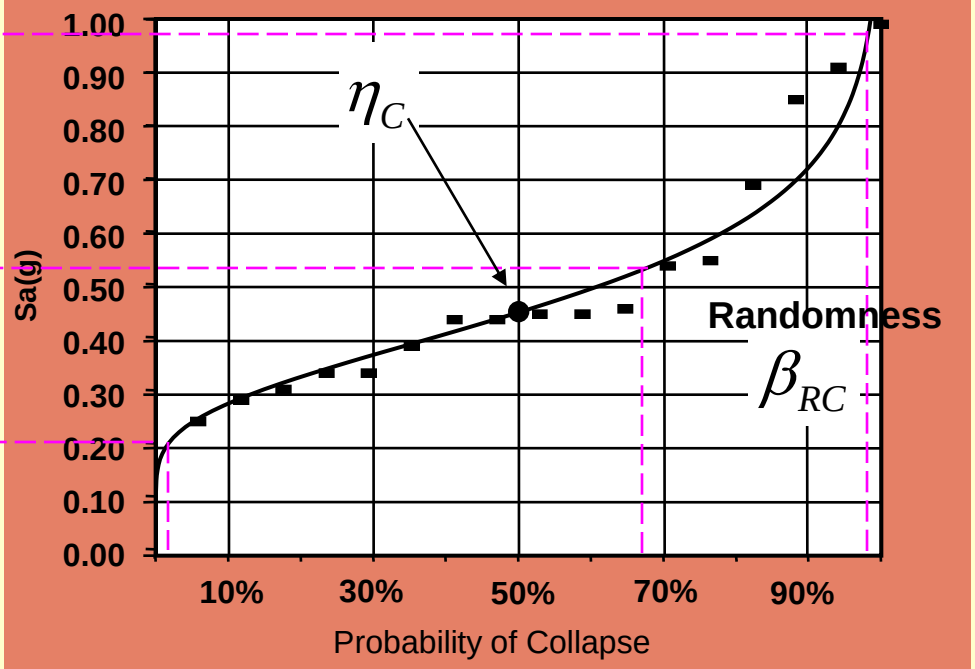
Hazard Curve

$\lambda(Sa)$

Collapse fragility curve

$P(C \mid Sa)$





Assessment of probability of collapse at certain hazard level

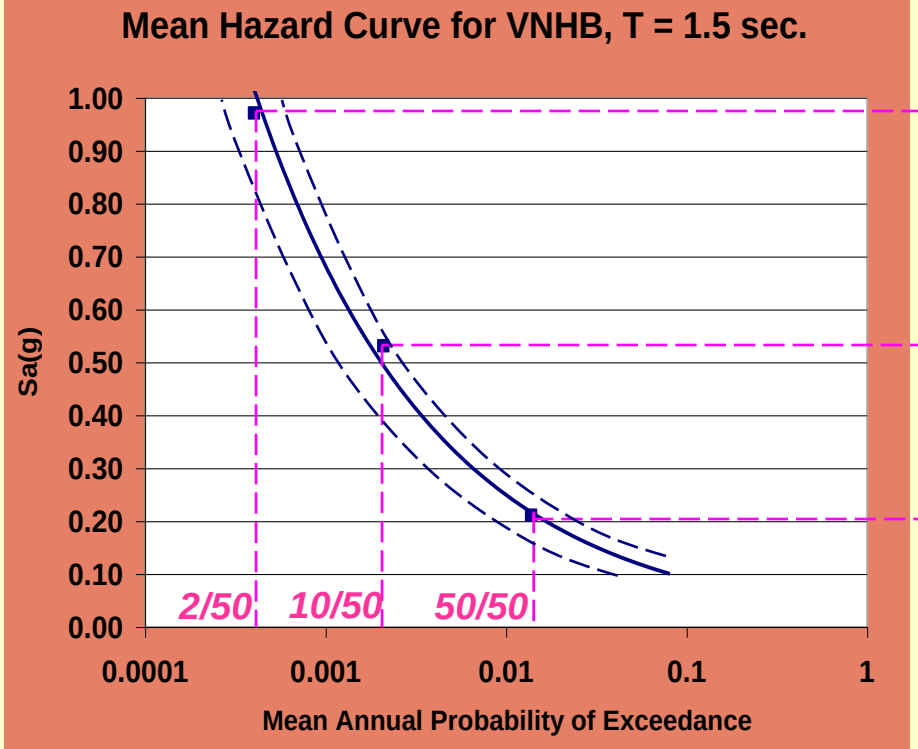
Hazard Curve

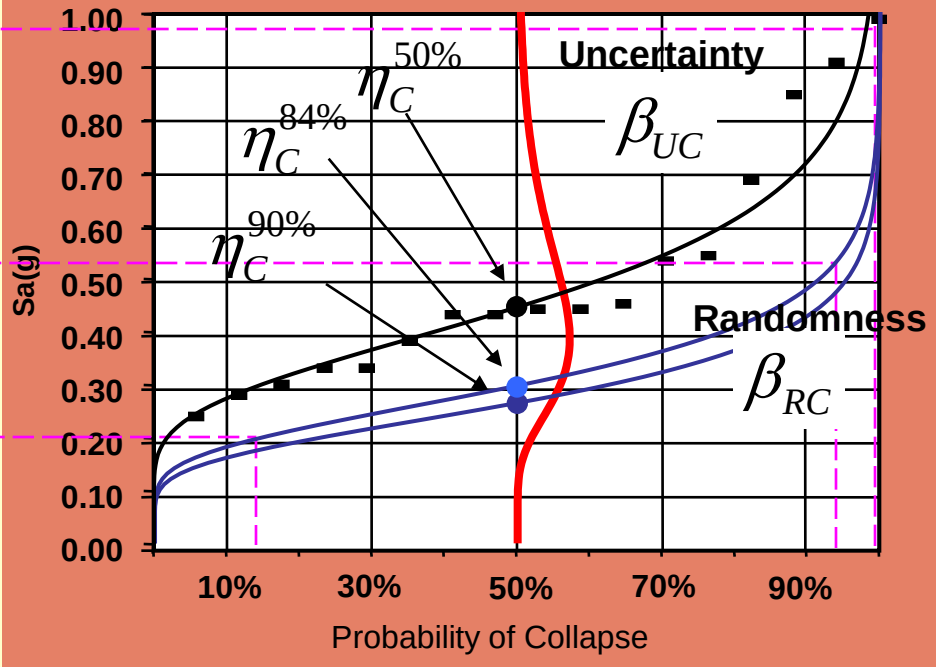
$\bar{\lambda}(Sa)$

Uncertainty

Collapse fragility curve with *Y* confidence

$P_Y(C \mid Sa)$





Assessment of MAF of collapse

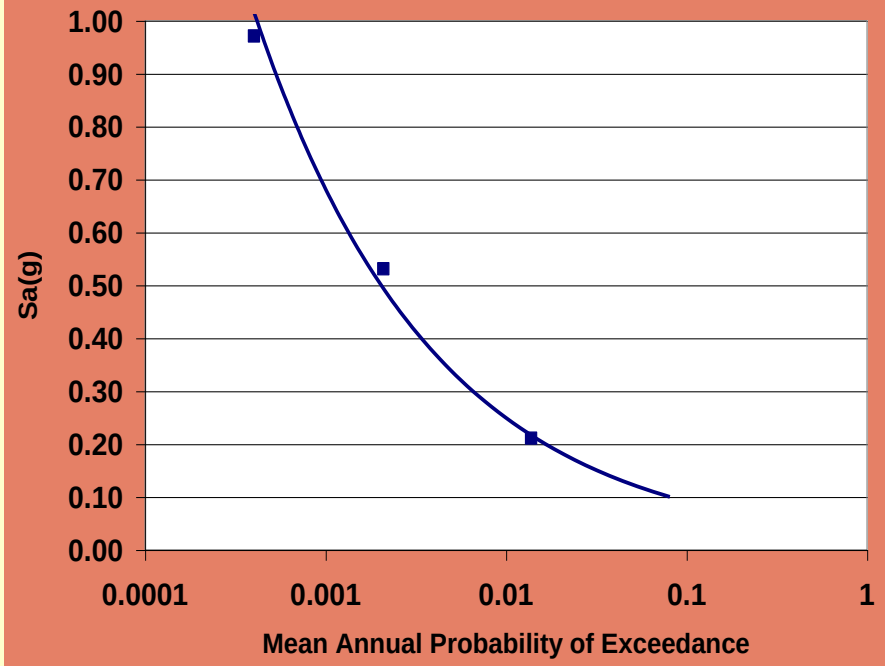
Hazard Curve

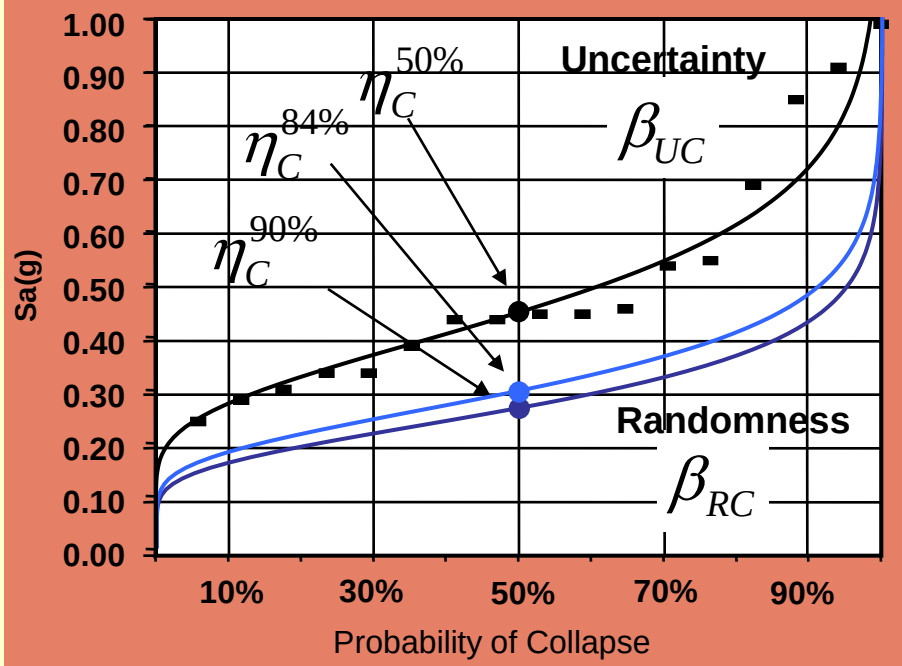
$\bar{\lambda}(Sa)$

$$\lambda_C^Y = \int_{Sa} P_Y(C \mid sa) \left| d\bar{\lambda}_{Sa}(Sa) \right|$$

Collapse fragility curve with confidence

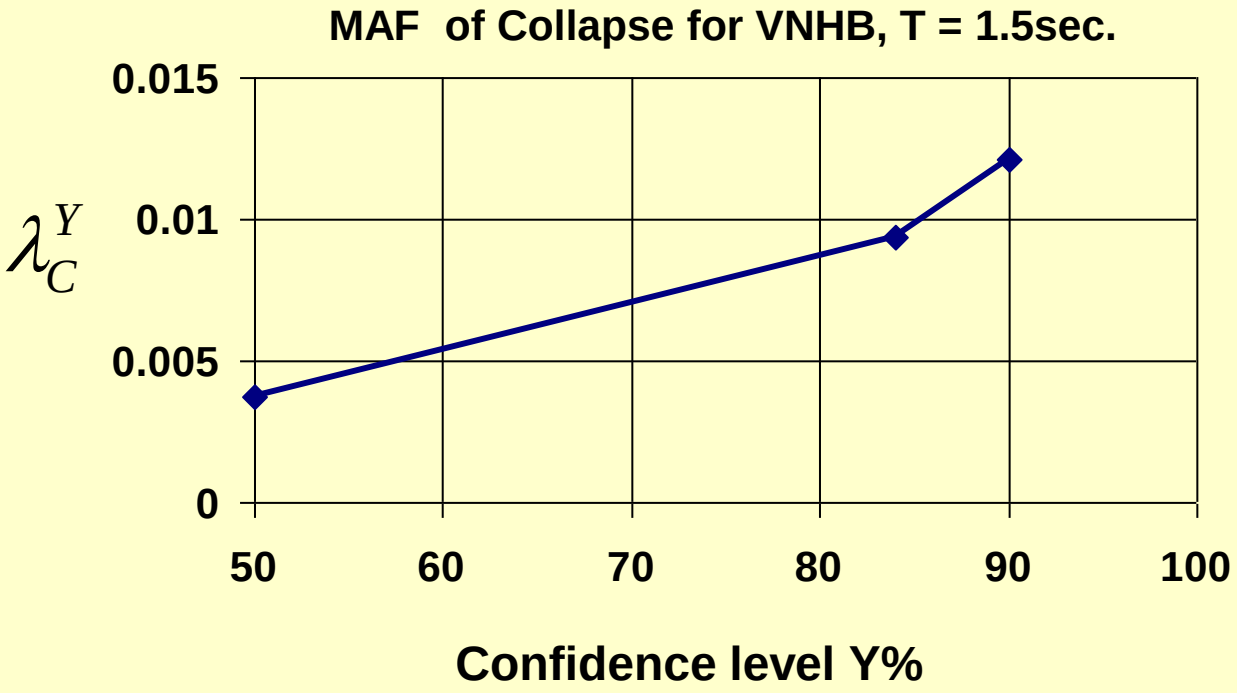
$P_Y(C \mid Sa)$



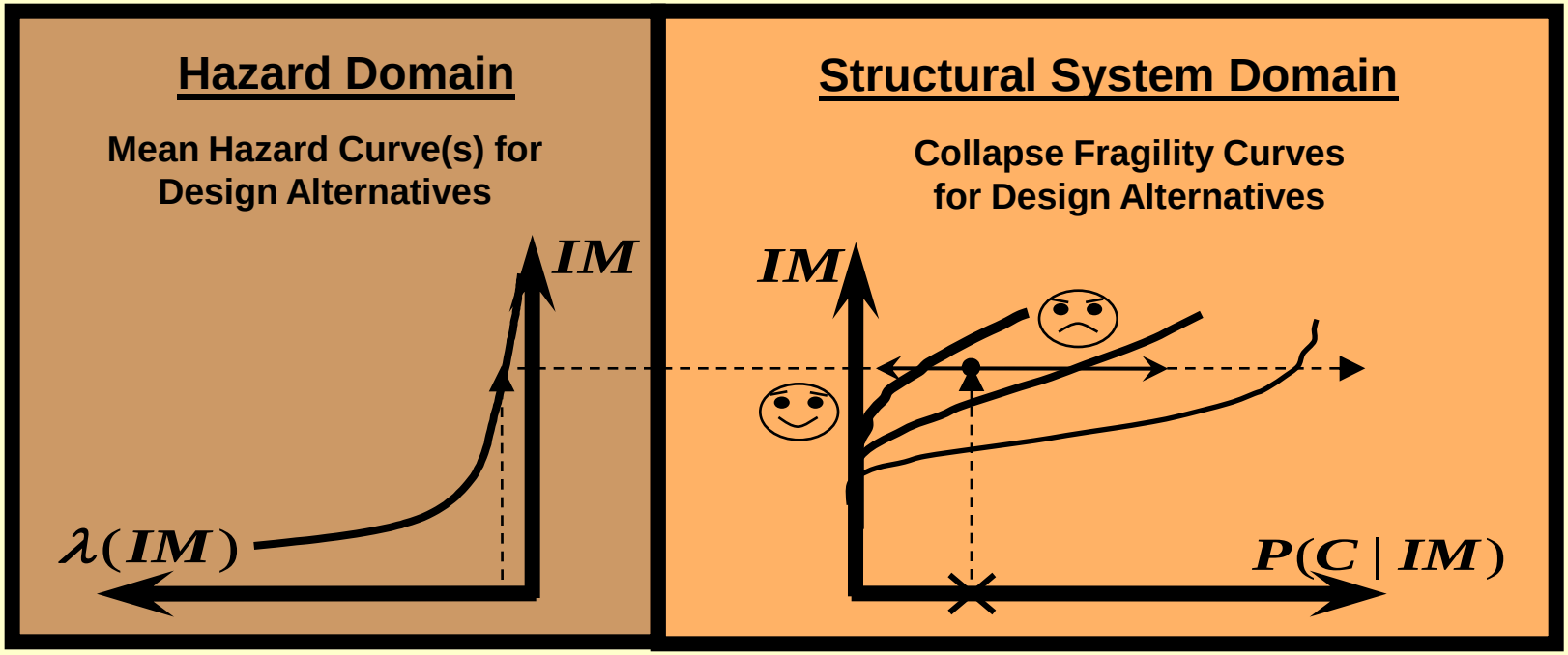


Assessment of MAF of collapse

$$\lambda_C^Y = \int_{Sa} P_Y\left(C \mid Sa\right)\left|d\bar{\lambda}_{Sa}\left(Sa\right)\right|$$



Performance-based design for collapse safety

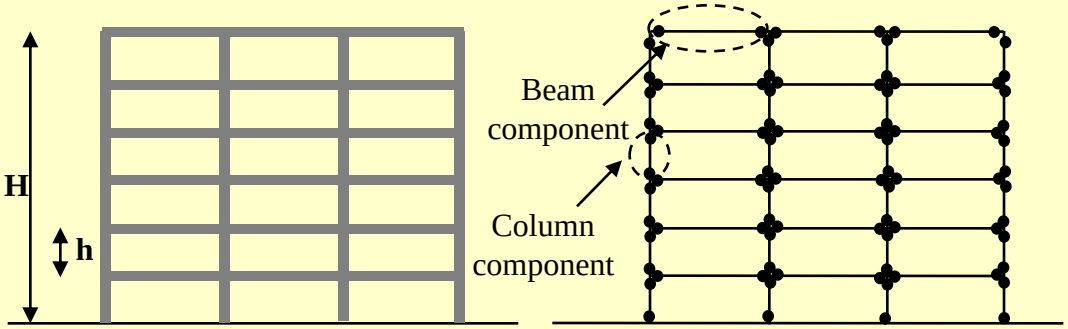


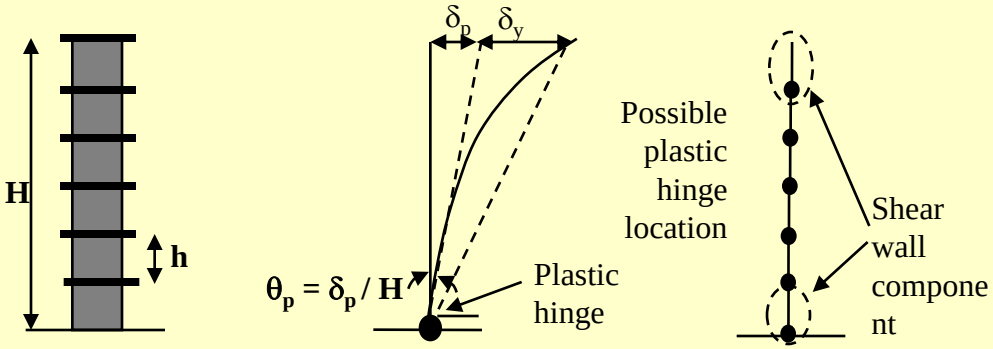
$$\lambda_C = \int_{Sa} P\left(C \mid sa\right) \left| d\bar{\lambda}_{Sa}\left(Sa\right) \right|$$

Structural Parameters Matrix

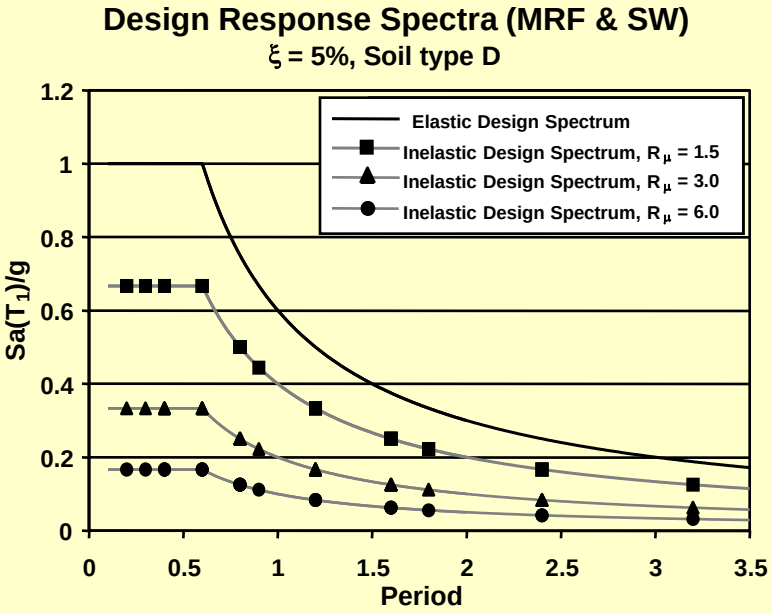
Major Design Decision Parameters:

Generic Frame & Wall structures





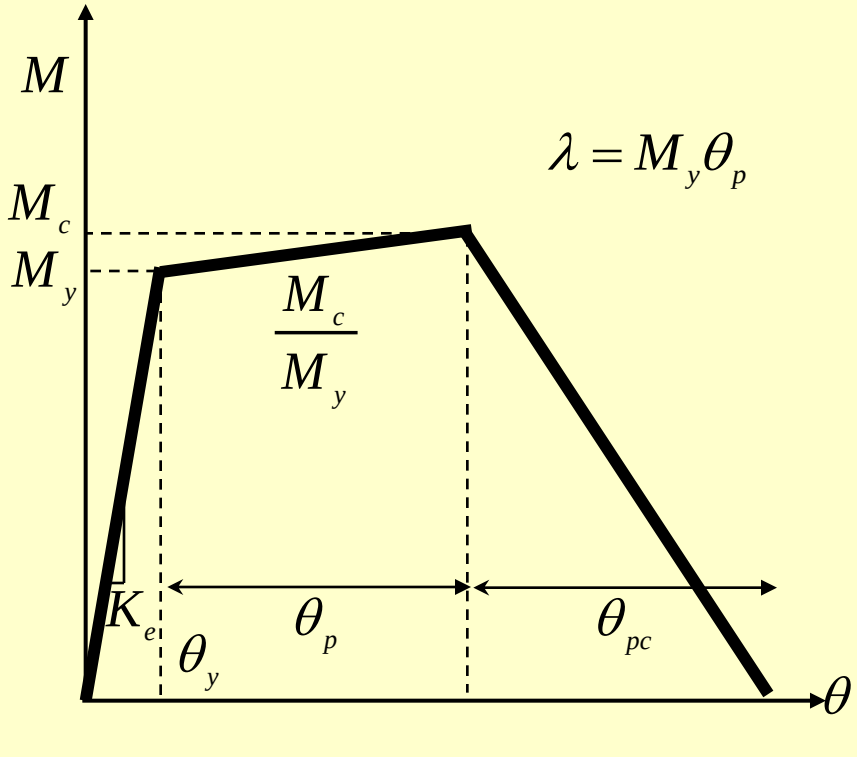
Period and Yield Base Shear Coefficient

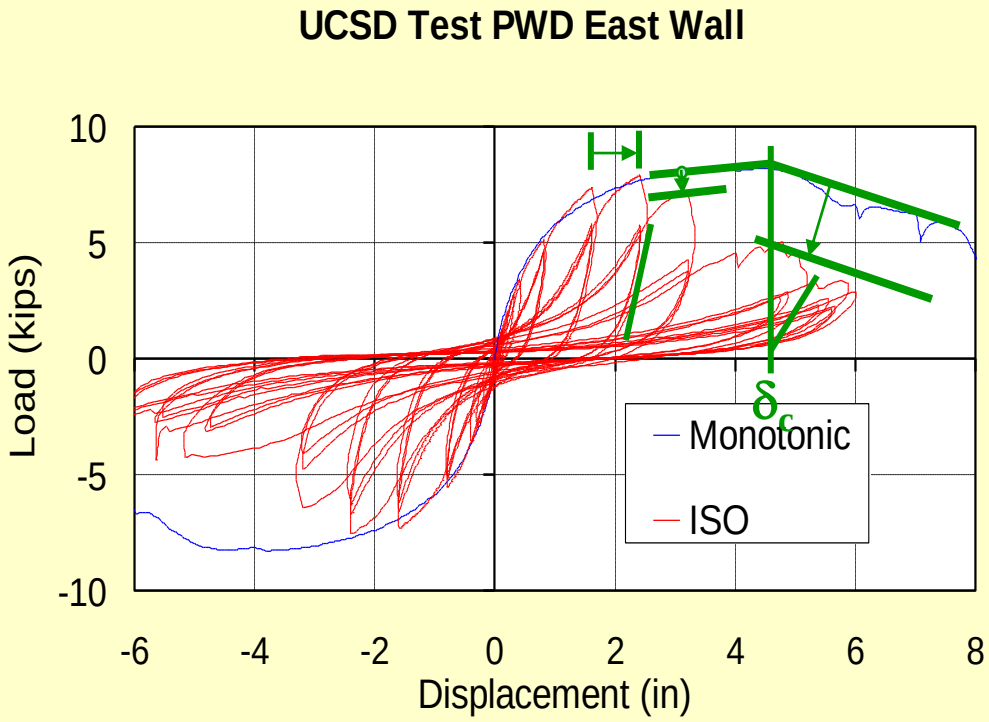


Structural Parameters Matrix

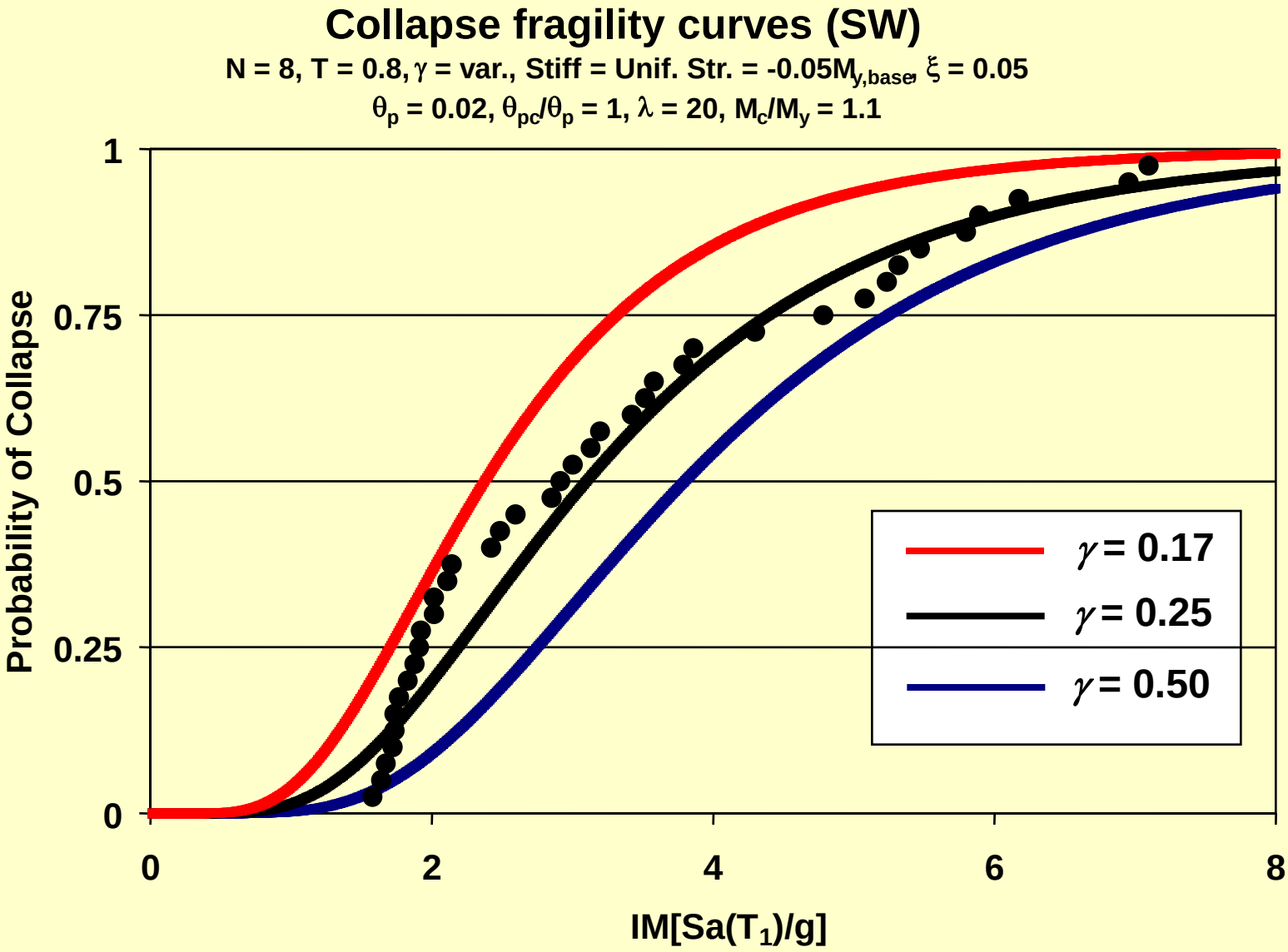
Major Design Decision Parameters:

Component Model

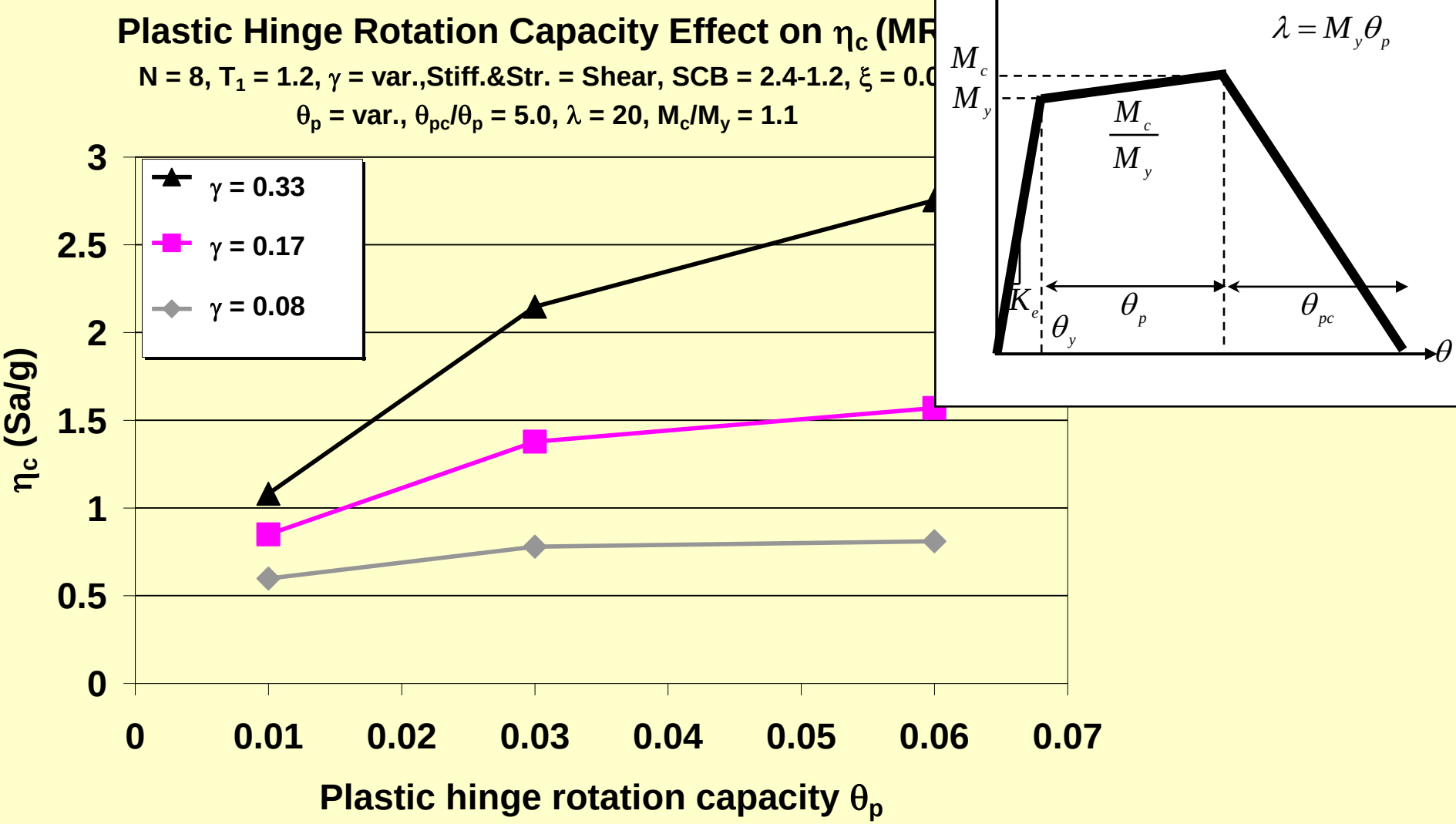




Development of collapse fragility curves



PBD for Collapse Safety (Design Aids)



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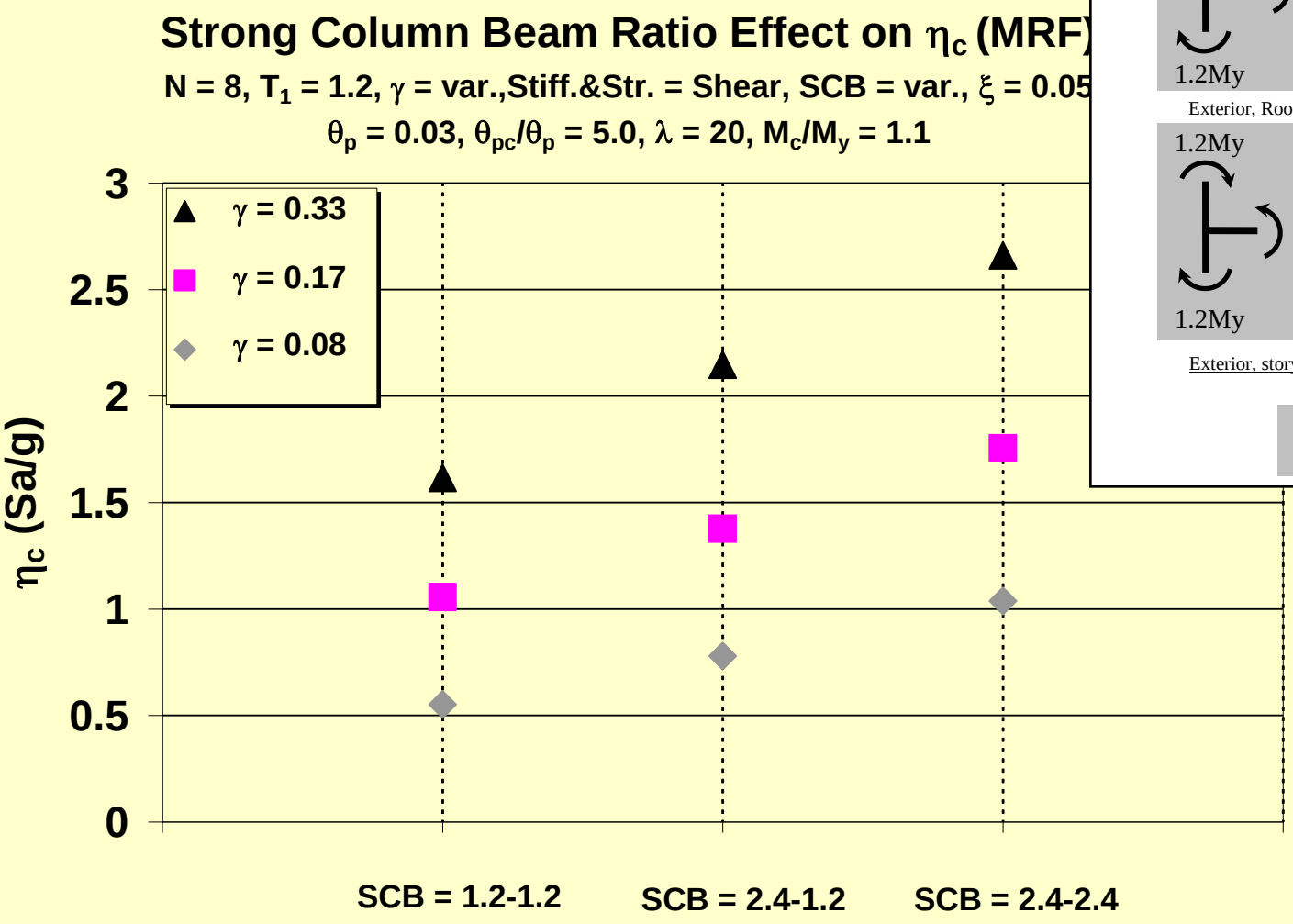
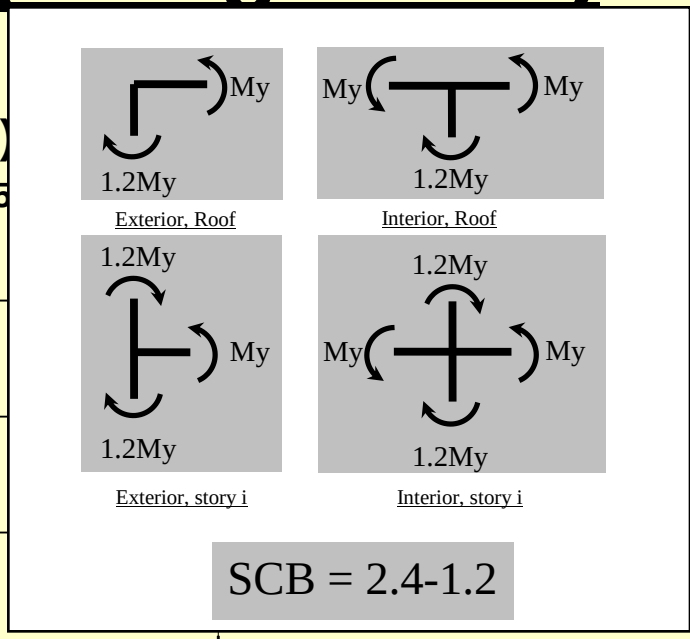
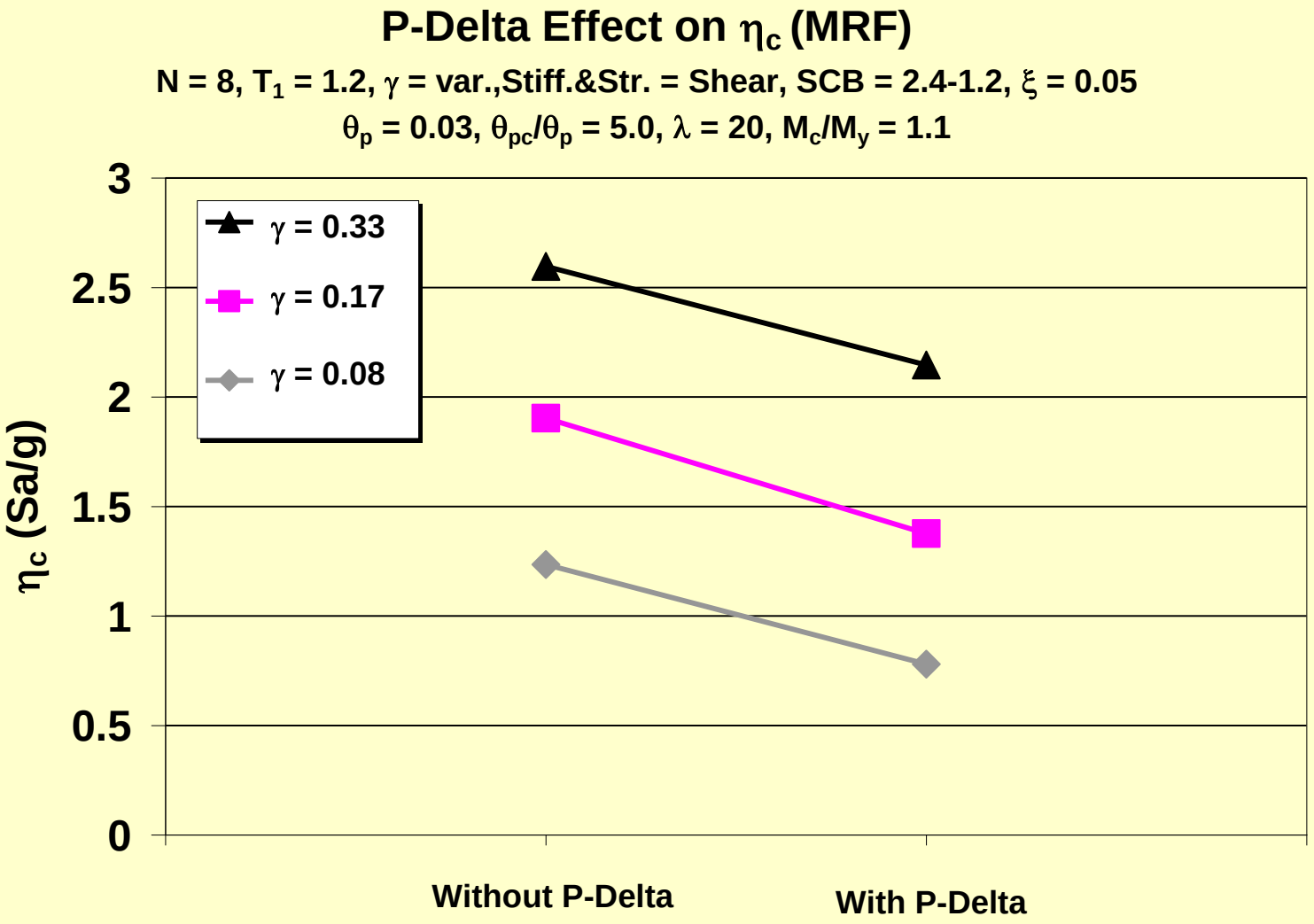




PBD for Collapse Safety (Design Aids)



PEER SPEE

IM-EDP (Single story/floor)	Obtain relationship between IM and EDP for a specific story/floor level
IM-EDP (Maximum among all stories/floors)	Obtain relationship between IM and EDP for a maximum EDP among all stories/floors
EDP Profile	Obtain EDP at different story/floor levels given IM
Mean Loss Estimation (per floor/story)	Design Decision Support System (DDSS)
Mean Loss Estimation (Average among all stories/floors)	Design Decision Support System (DDSS)
Probability of Collapse Estimation	Obtain probability of collapse and its sensitivity to variation in structural paramaeters

Comments and Suggestions

http://spee.eng.uci.edu

PEER spee

Sensitivity of Probability of Collapse to Variation in Basic Structural Parameters

Number of Stories — N = 9.0

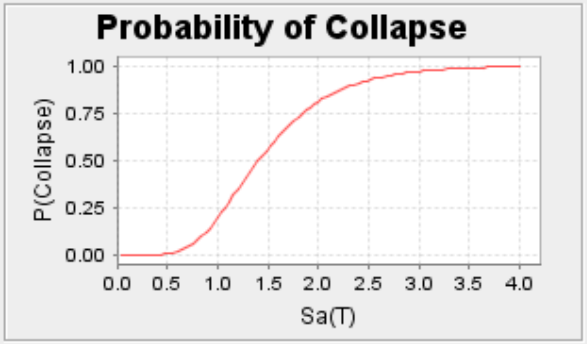
First Mode Period — T = 1.35

Base Shear Coefficient — gamma = 0.222

Plastic Hinge Rotation Capacity — qp = 0.03

Post-Capping Rotation Capacity — qpc = 0.15

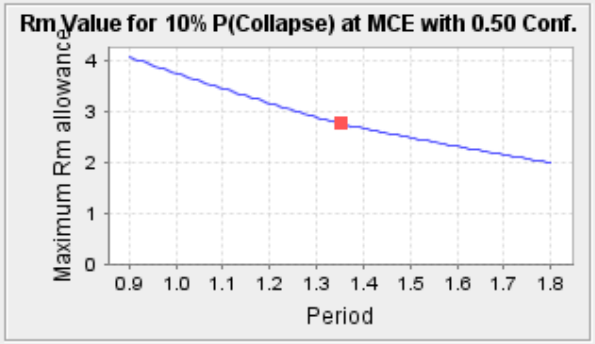
Cyclic Deterioration Parameter — lambda = 20

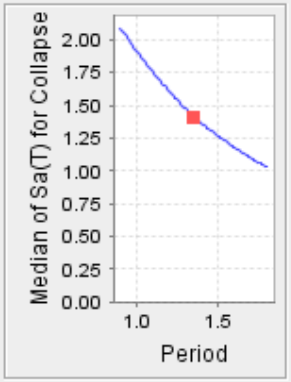


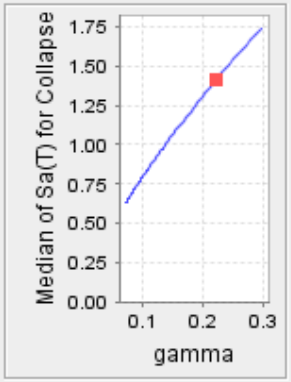
Disp. (Randomness) = 0.40

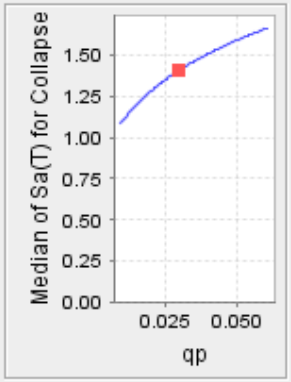
Disp. (Uncertainty) = 0.00

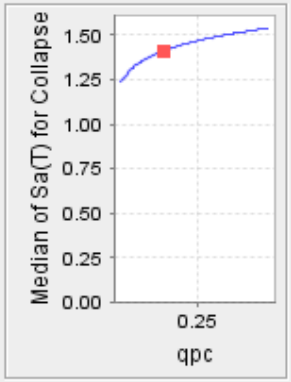
Confidence Level = 0.50

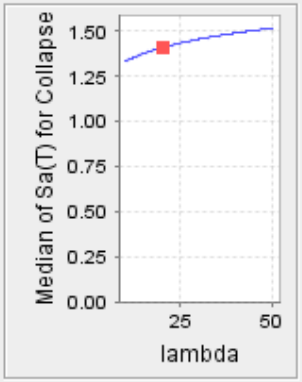












Concluding remarks

Can Collapse be Predicted?

- If we are capable of modeling deterioration characteristics of all important structural components
- If we are capable of modeling all collapse modes (local, story, global)
- If we are capable of predicting propagation of local collapse
- If we are capable of incorporating all “intangible” contributions that delay collapse

Concluding remarks

Given all constraints and assumptions

- Deterioration of structural components and P-Delta effects are fundamental causes of collapse.
- Including *Epistemic* uncertainty (i.e., confidence statements), increases the probability of collapse of a given building and increases the required strength and deformation capacity in conceptual design for collapse safety.
- Sensitivity of probability of collapse to variation of structural system and structural parameters were investigated
- A graphical tool to exercise Performance-Based Design for collapse safety is developed.

Acknowledgements

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Thank You