The Role of Performance-Based Engineering in Tall Building Design

Helmut Krawinkler

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Personal Observations

Tall buildings are special

- Socio-economic perspective -- DVs
  - Potential huge impact of the three D's (Dollars, Downtime, Deaths)
  - A disaster can change the landscape of cities
- Engineering perspective -- EDPs
  - Higher mode effects may control structural response
  - P-delta effects may control collapse potential
  - Deterioration together with P-delta will control collapse potential
  - Innovative protective measures deserve much consideration
  - There are phenomena that are not detected in a code analysis
    - plastic hinges in columns
    - Story mechanisms and multiple story mechanisms
    - Importance of gravity system
    - shear amplification in shear walls
- Ground motion/hazard perspective -- IMs
  - Unfortunately we don't know enough about long period frequency content

Design/Assessment Options

Equiv. Static Force Procedure

- Designing for an elastic code base shear and elastic drift limit will result in structures with vastly different damage potential and collapse probability

Linear Dynamic Procedure

- Still the same problems, except accounts for higher mode effects

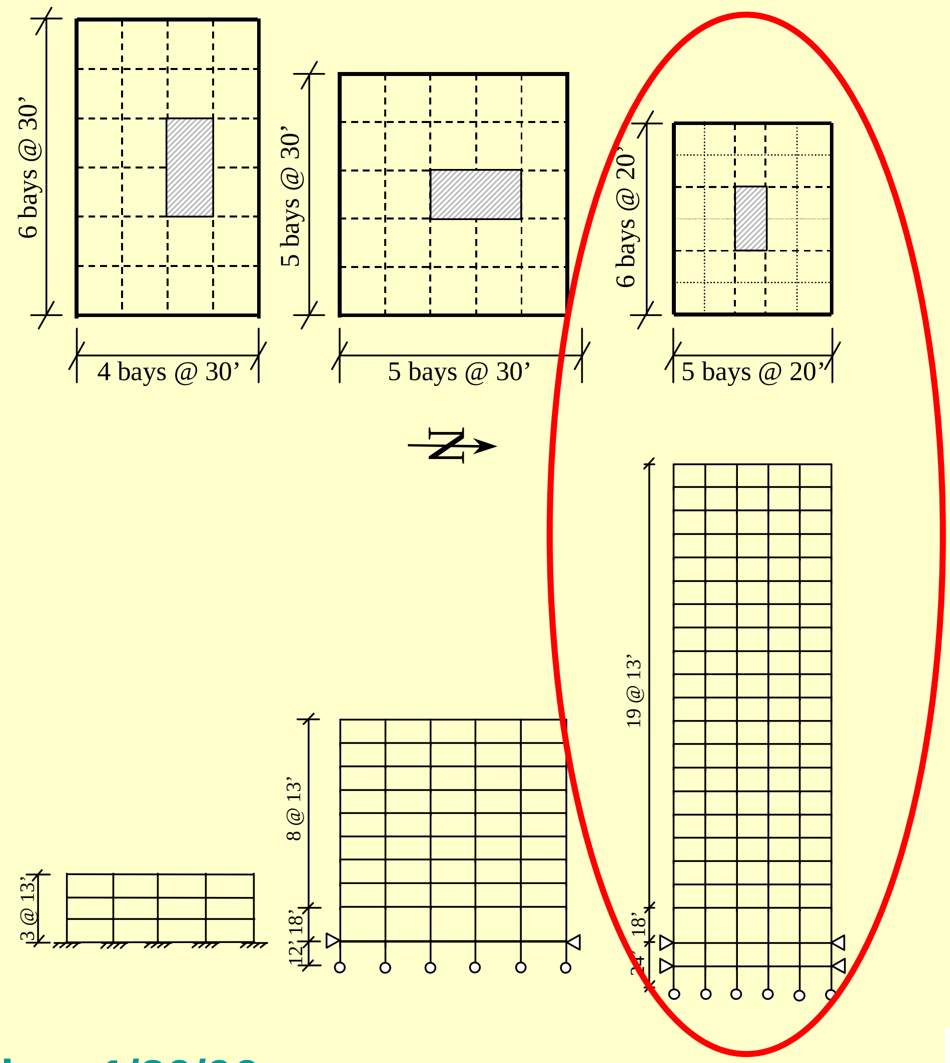
Nonlinear Static Procedure (NSP)

- Problems with higher mode effects
- Does not detect dynamic redistribution problems such as shear force amplification in wall structures
- Does not capture collapse potential

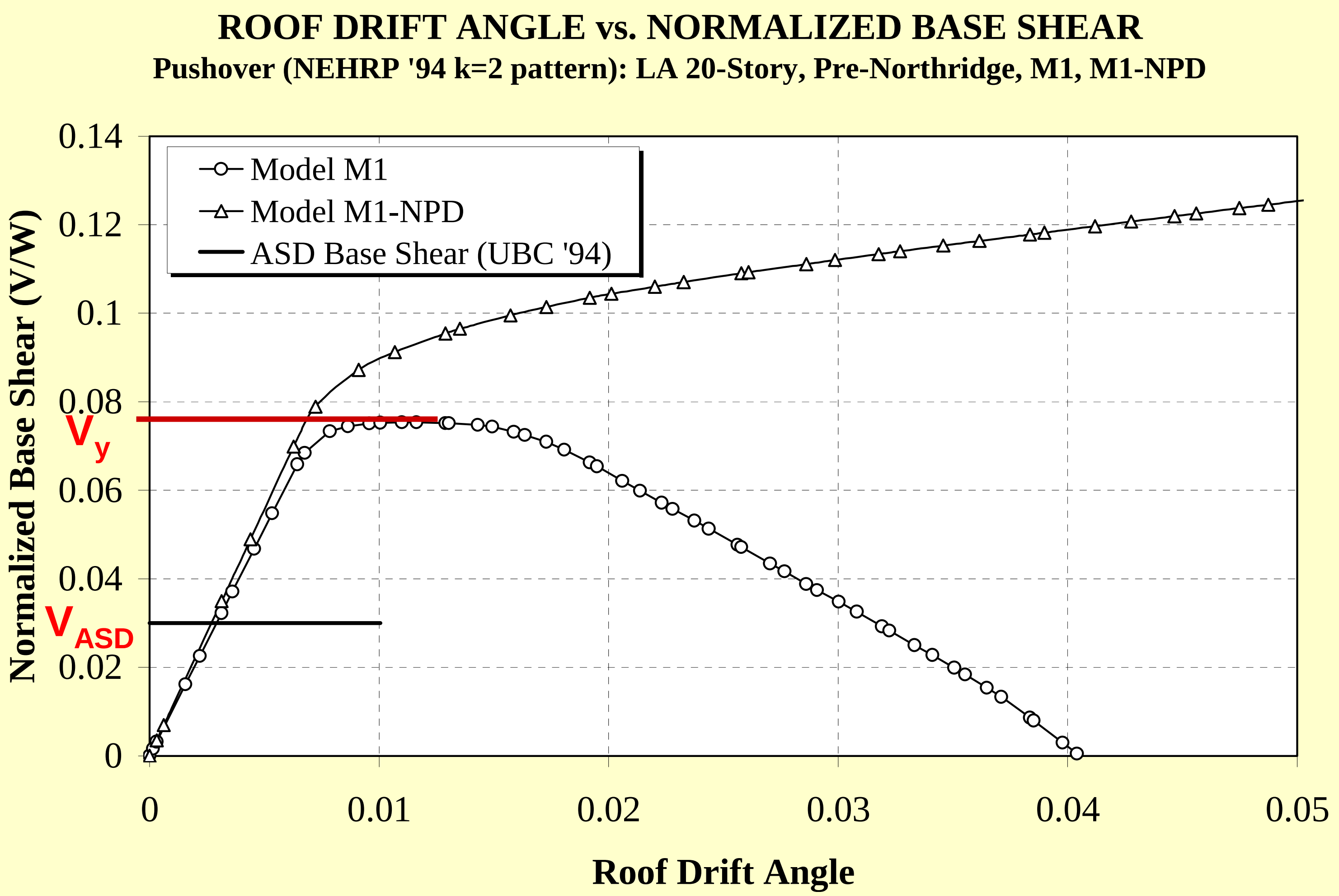
Nonlinear Dynamic Analysis (NDP)

- Addresses most of the issues, BUT needs performance criteria

SAC Structures



Global Pushover Curve, LA-20, without and with P-Δ



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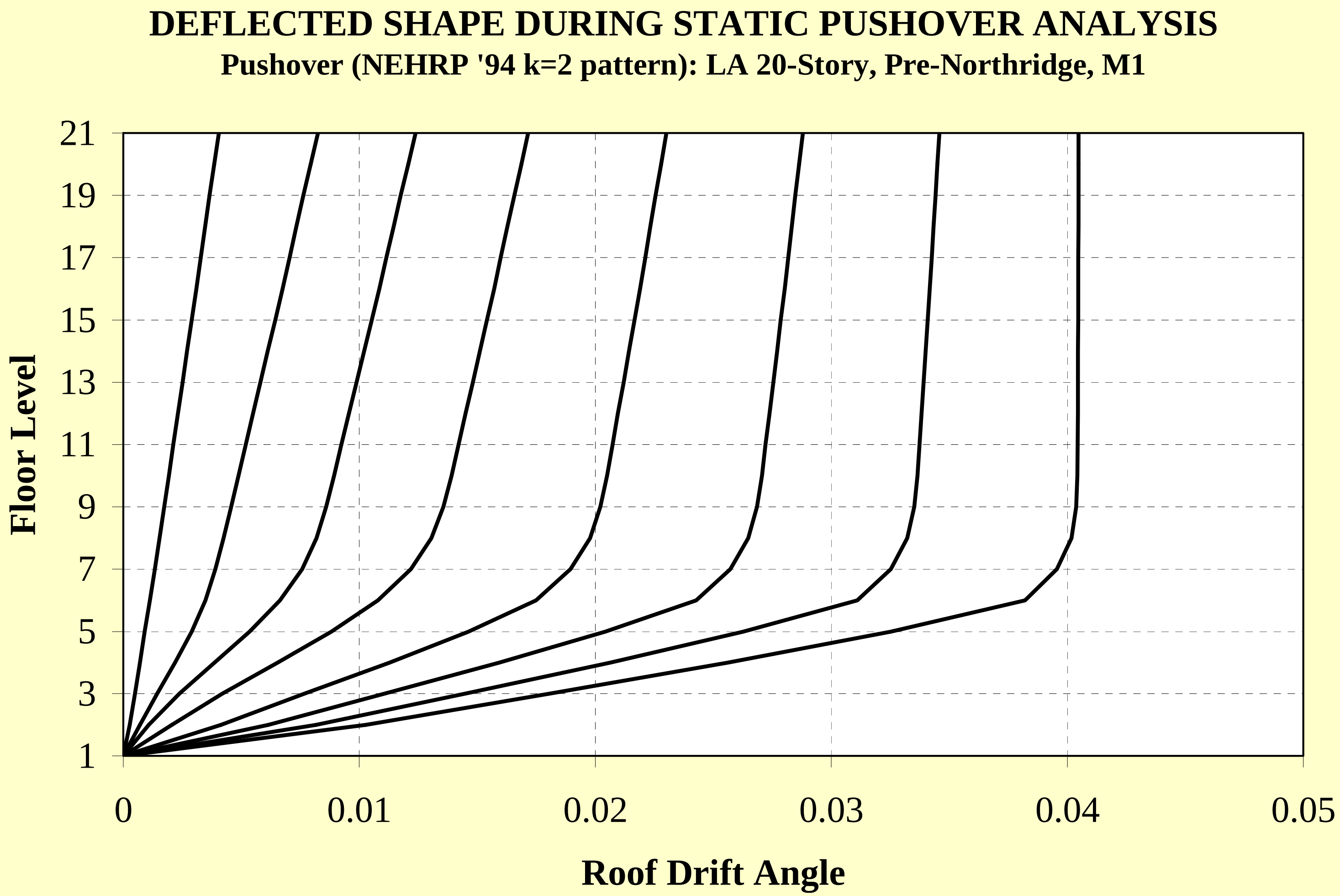
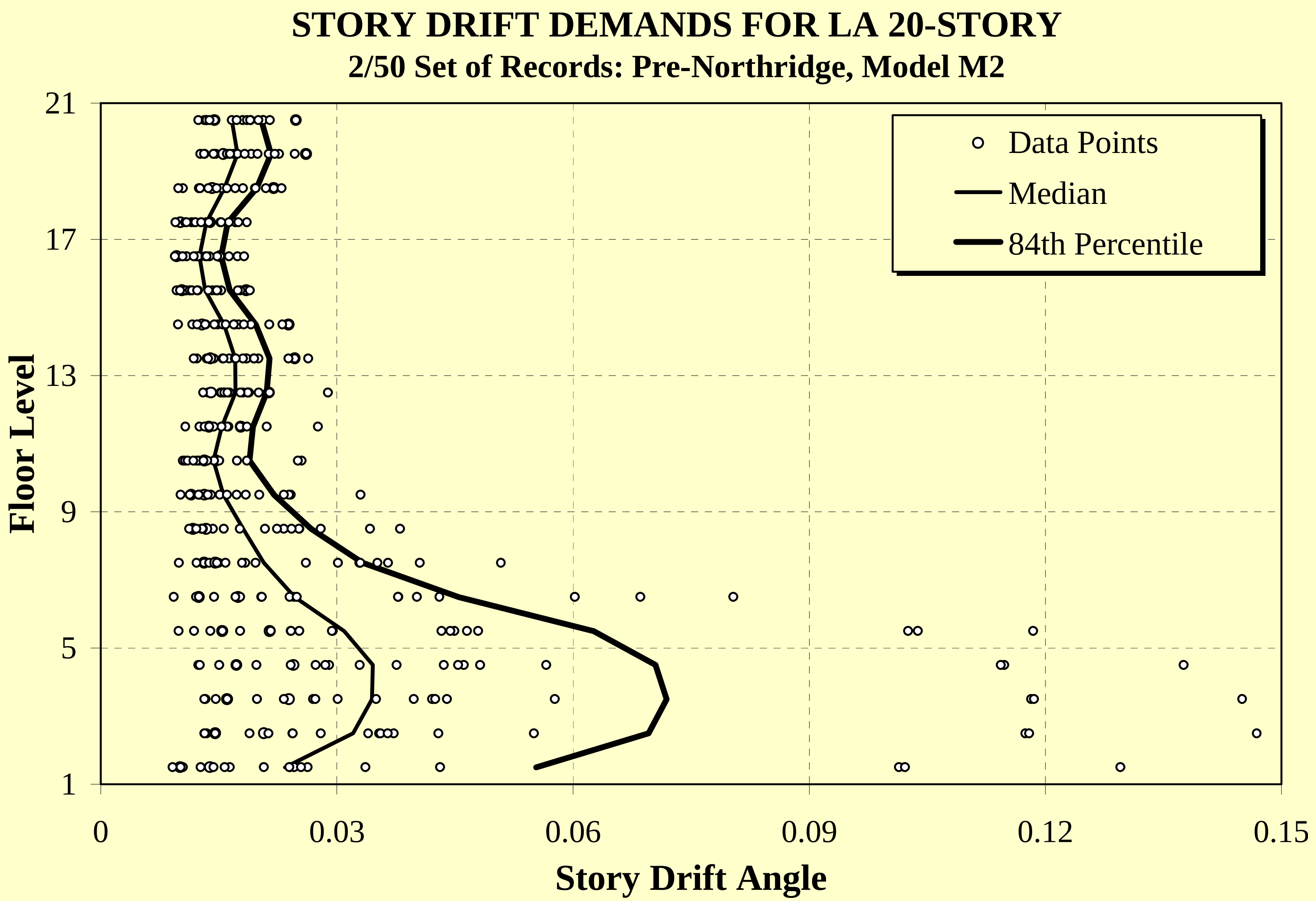
Pushover Deflection Profiles, LA 20-story Structure



Dispersion in Story Drifts, LA-20, 2/50 Records



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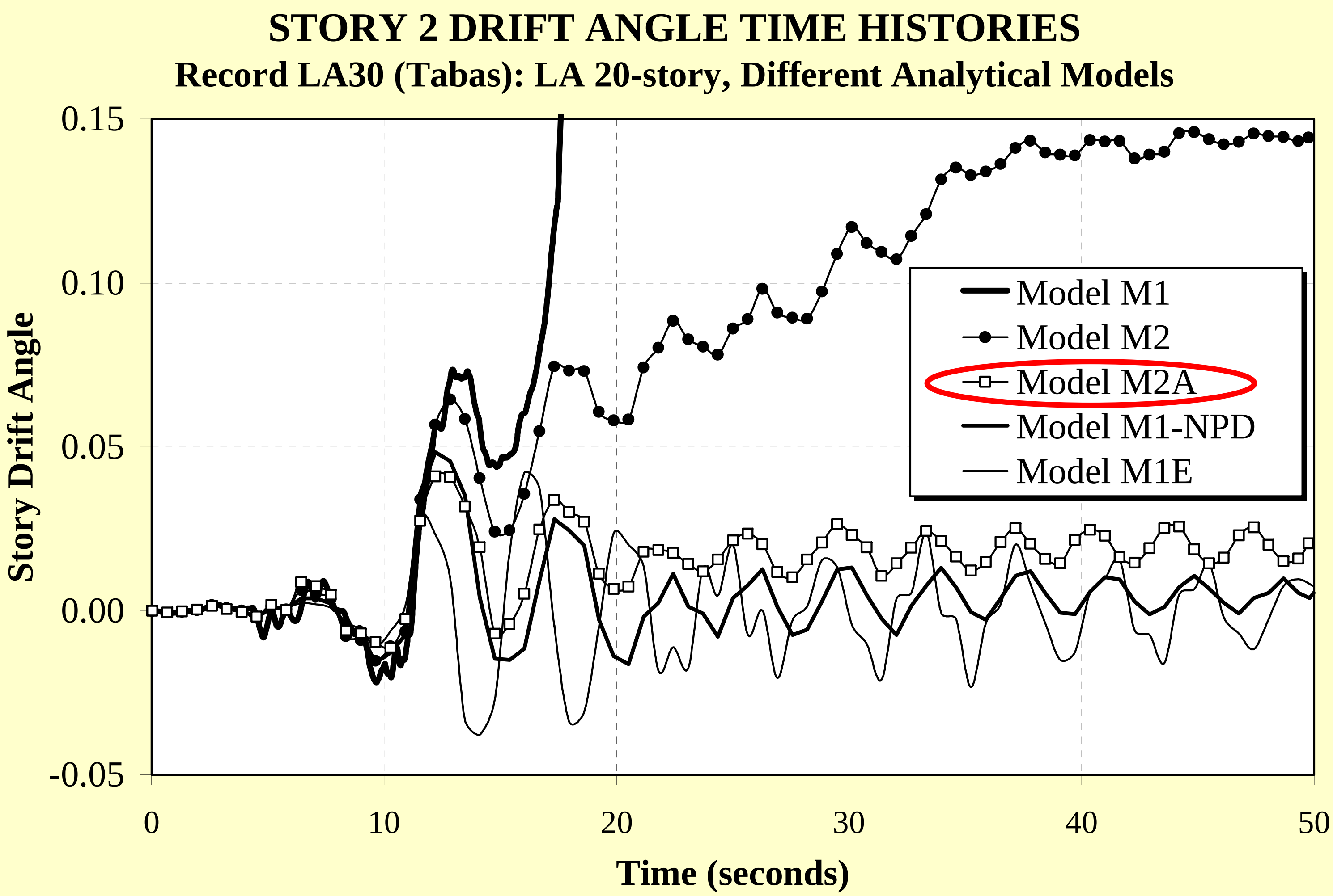
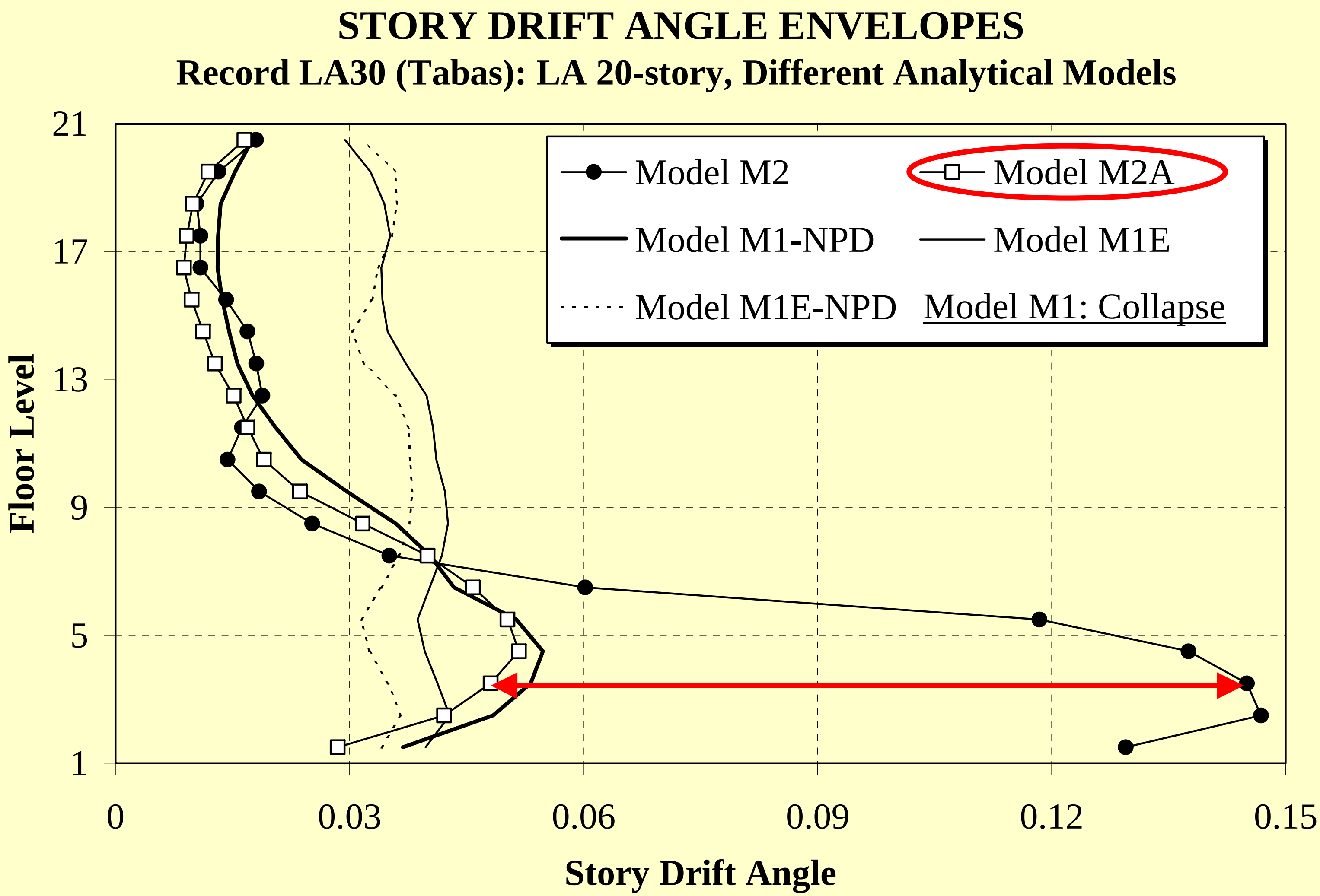
Story 2 Drift Response, LA-20, Various Models



Story Drift Demands – Various Models



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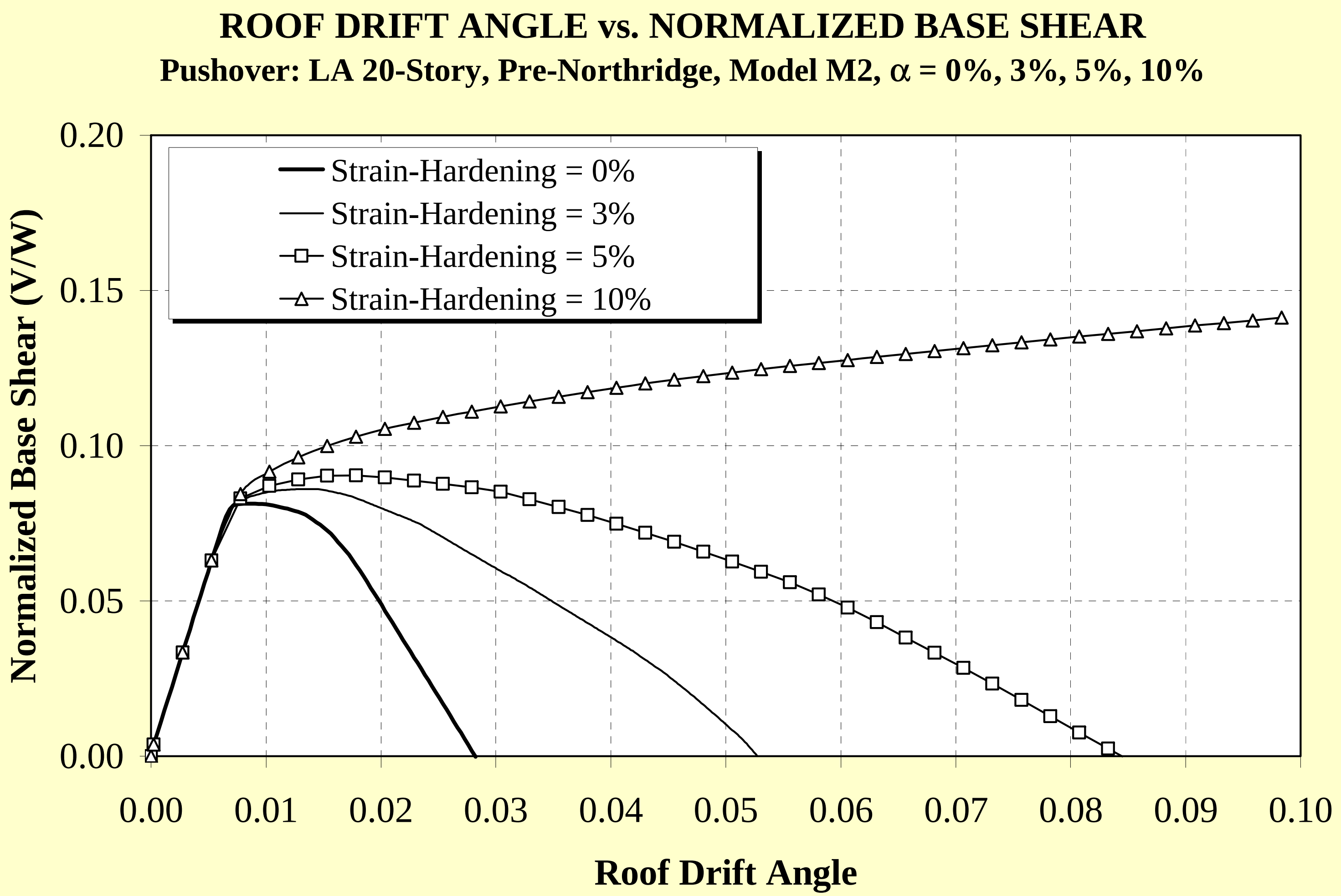
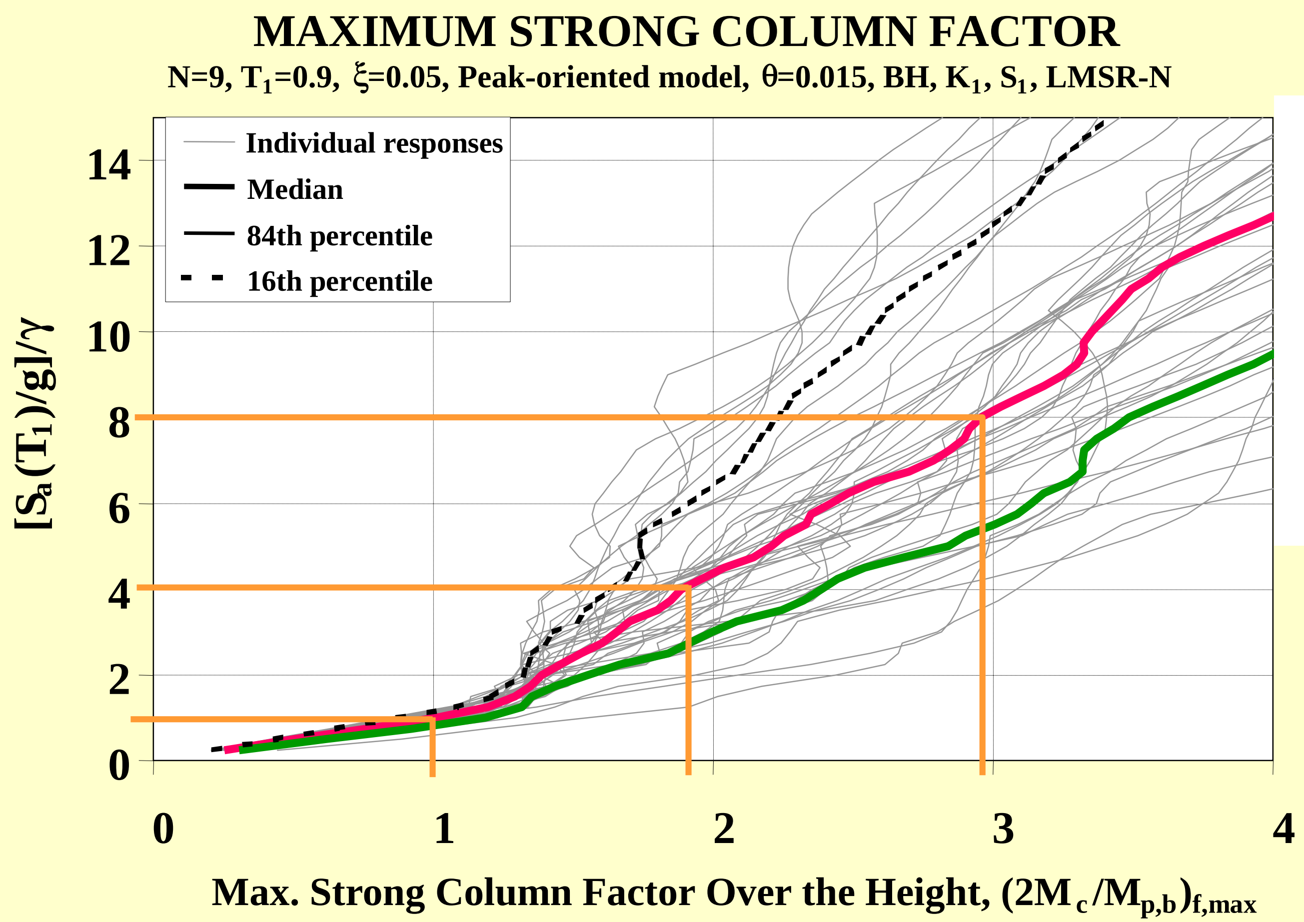
Sensitivity to Strain Hardening, Pushover, LA-20



Dependence of Strong Column Factor on R_μ

9-Story, T_1 = 0.9 sec.



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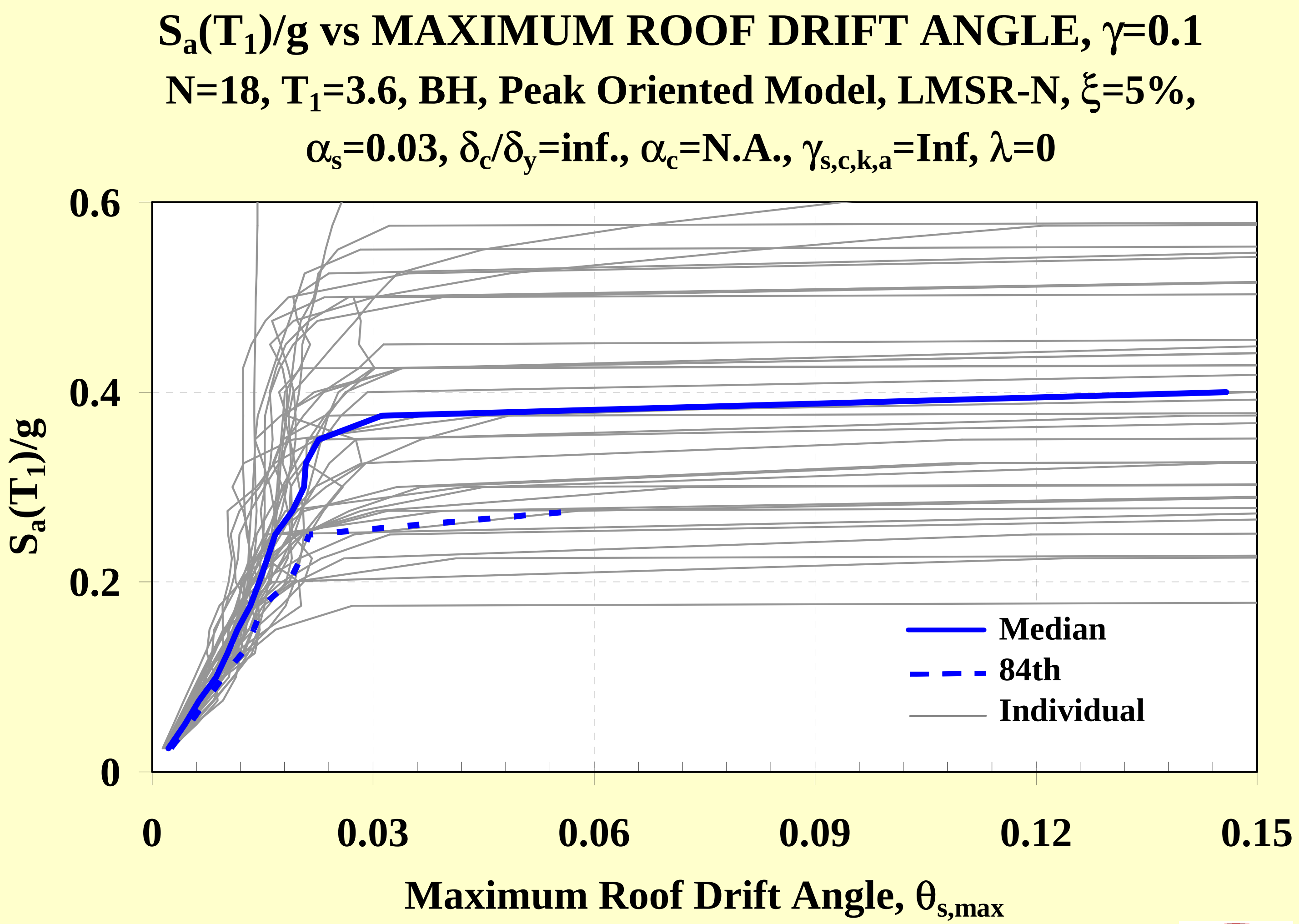
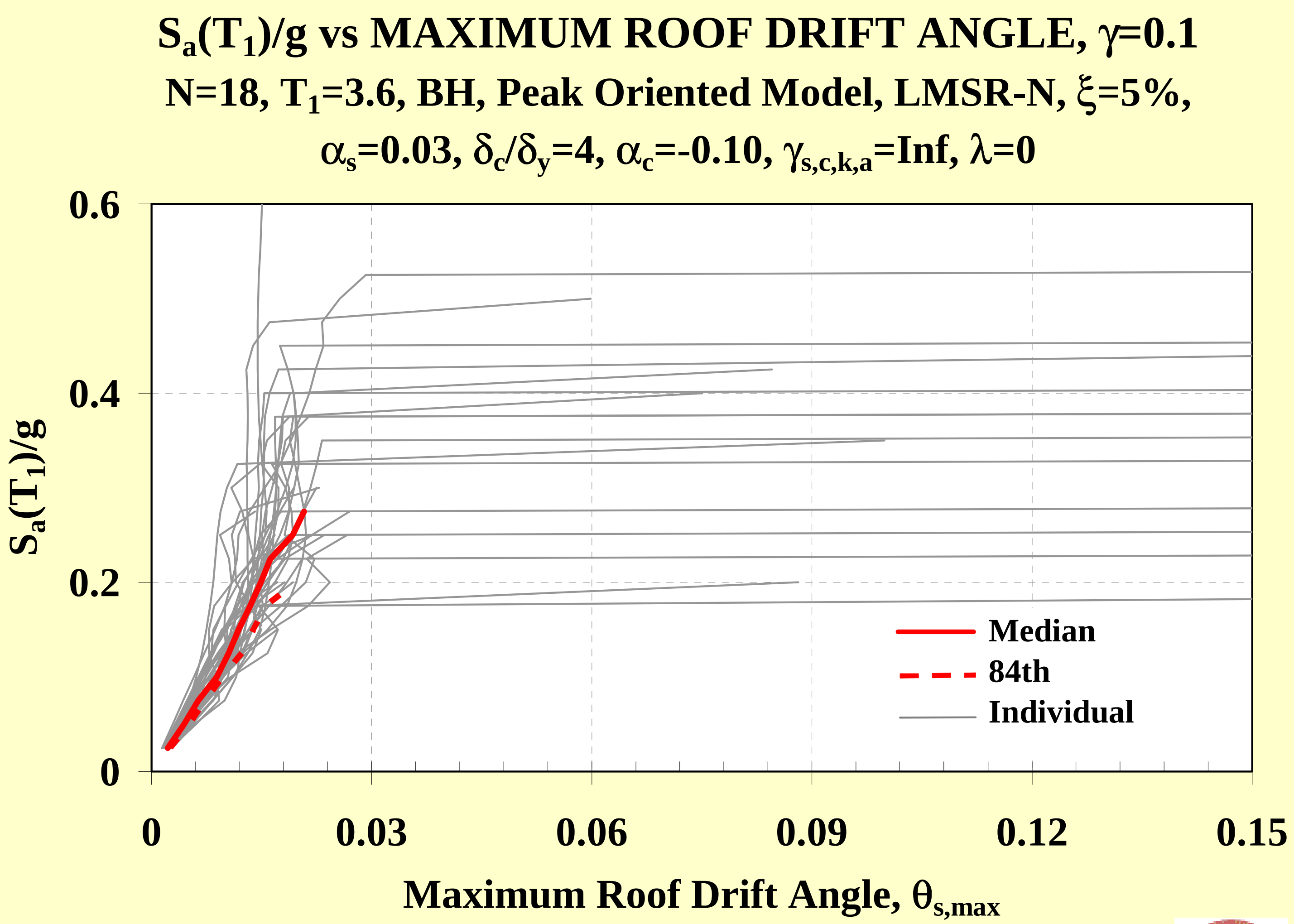
IDAs to Collapse
P-Delta Included, no Deterioration



IDAs to Collapse
P-Delta Included, with Deterioration



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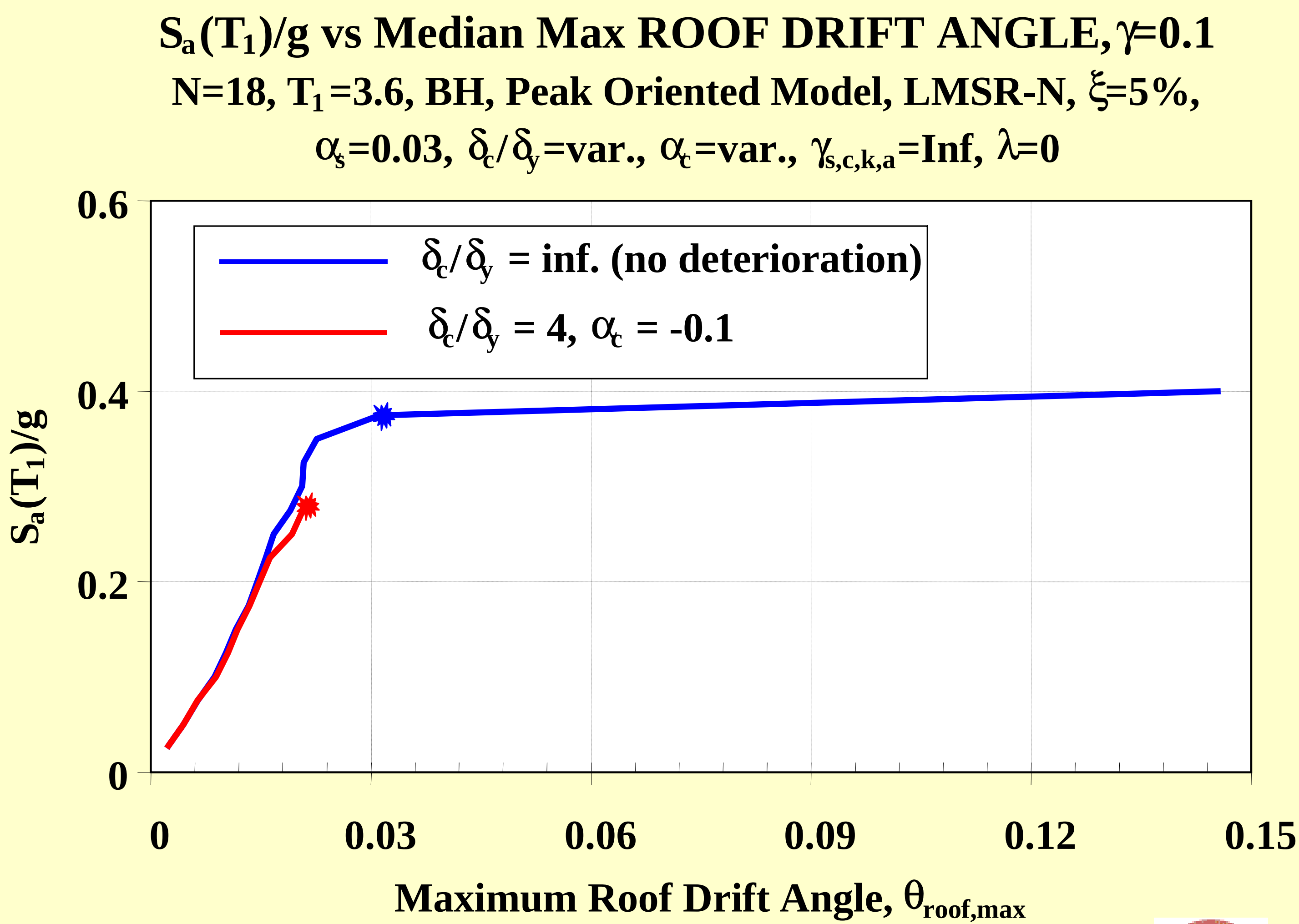
Median IDAs to Collapse
P-Delta without and with Deterioration



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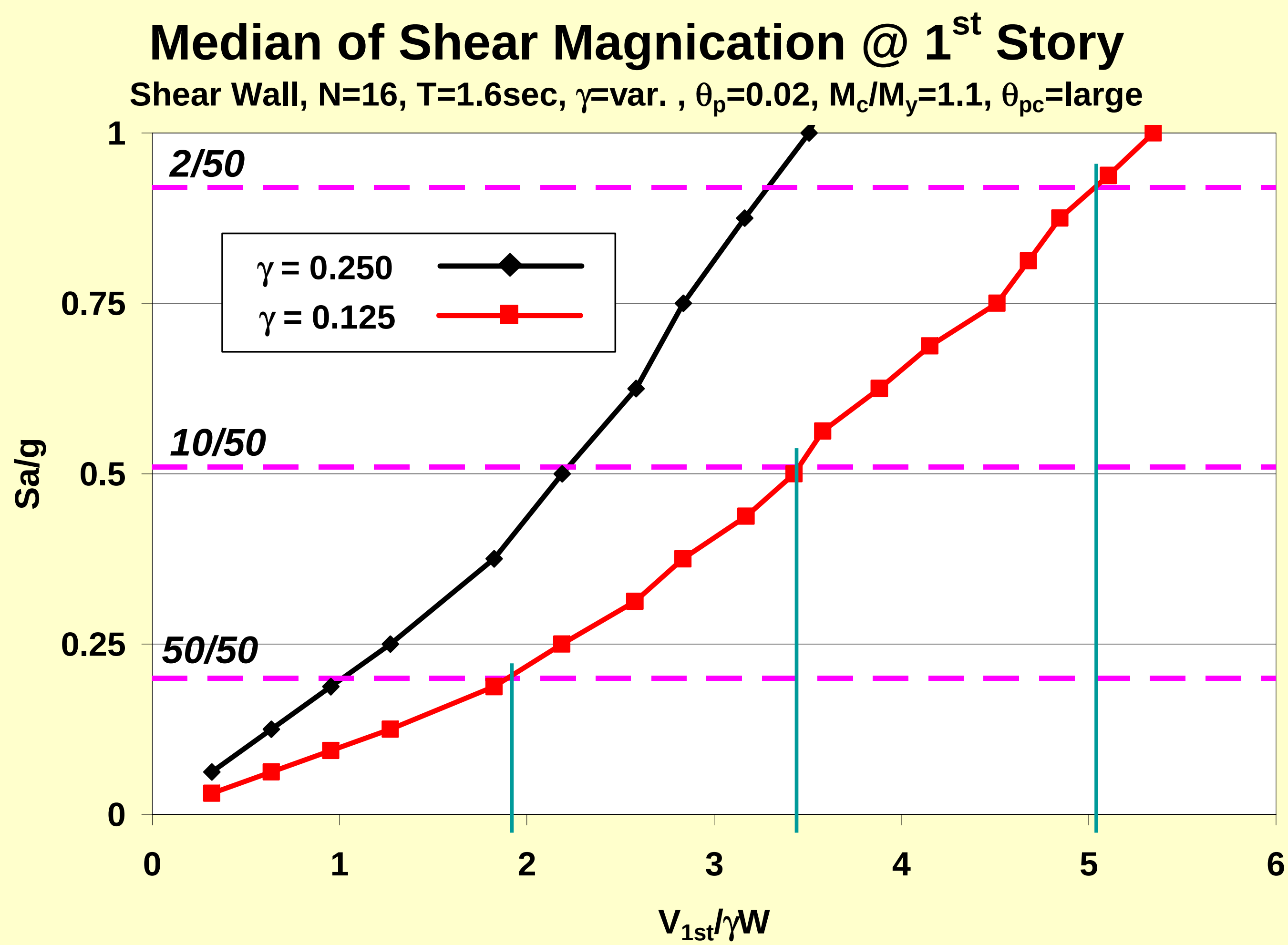
Amplification of Shear Demand in Tall Wall Structures



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Does NDP Solve all the Problems

- **Not without performance criteria for**
  - Acceptable direct ($) loss
  - Acceptable downtime loss
  - Tolerable probability of collapse
- **Not without consideration of uncertainties**
  - Aleatory uncertainties due to RTR variability
  - Epistemic uncertainties inherent in
    - Structural modeling assumptions
    - DM-EDP fragility functions
    - Repair cost functions
    - Economic consequence analysis
- **Not without modeling of deterioration for collapse assessment (better analytical models)**
- **Not without better probabilistic description of ground motion hazard in long period range**
  - **PGV = 1 - 2 m/sec??!!**