National Institute of BUILDING SCIENCES

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Building Seismic Safety Council

IT-2 Report

4/5/2018

PUC Meeting

San Francisco, CA

nehrp FEMA

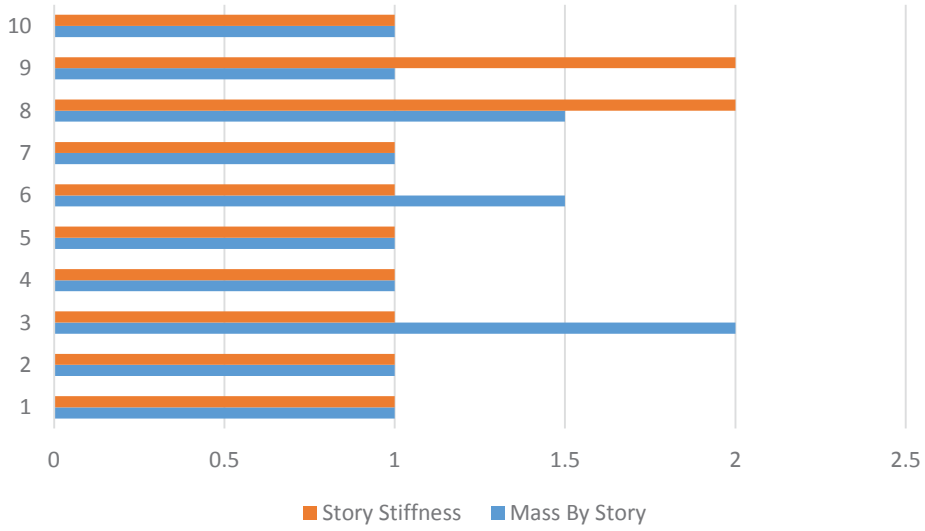
- Mass Irregularity Elimination
- Torsion ATC 123 Update
- Cd = R Proposal Comment Resolution

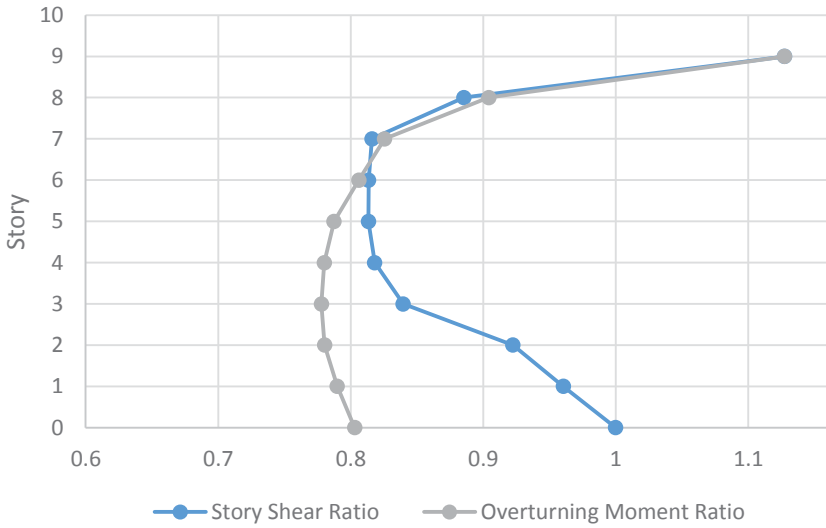
Mass Irregularity

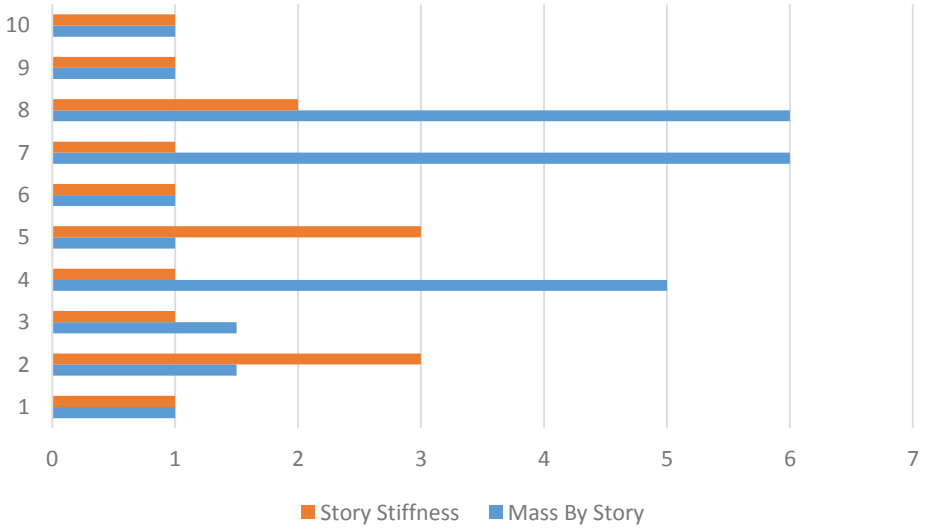
- PUC Concerns with ATC 123 Process
  - 300% Mass Irregularity Too Small
  - Only Moment Frames Studies

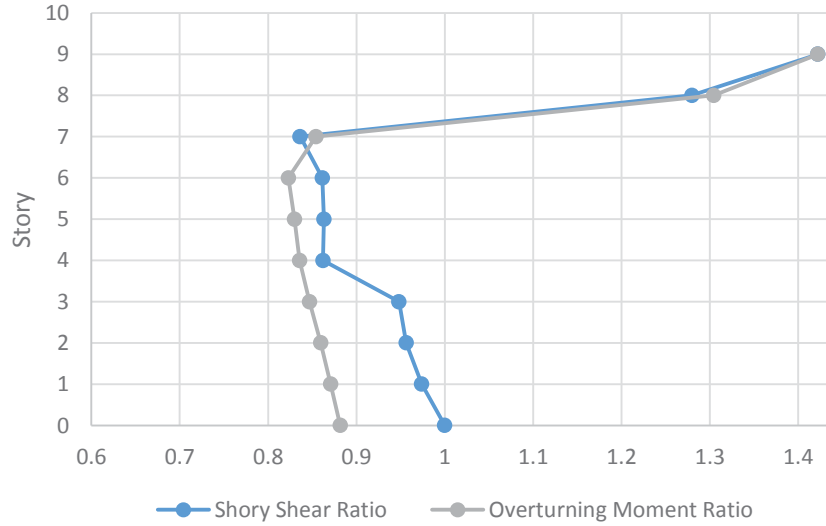
- Sabelli et. al study
  - Eigenvalue Analysis MRSA vs ELF
  - System Independent Stiffness & Mass Only Based Approach
  - Normalized to 2% Drift

Mass Irregularity – 10 Story Models

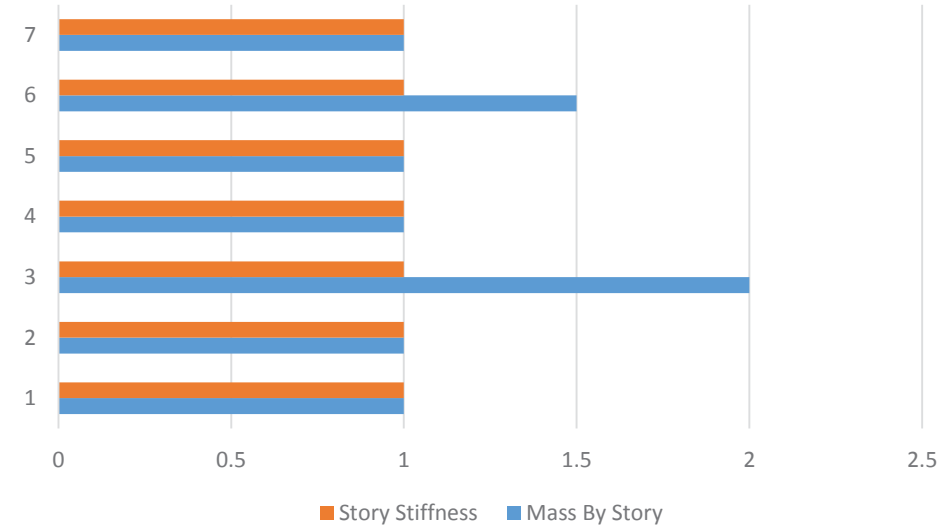


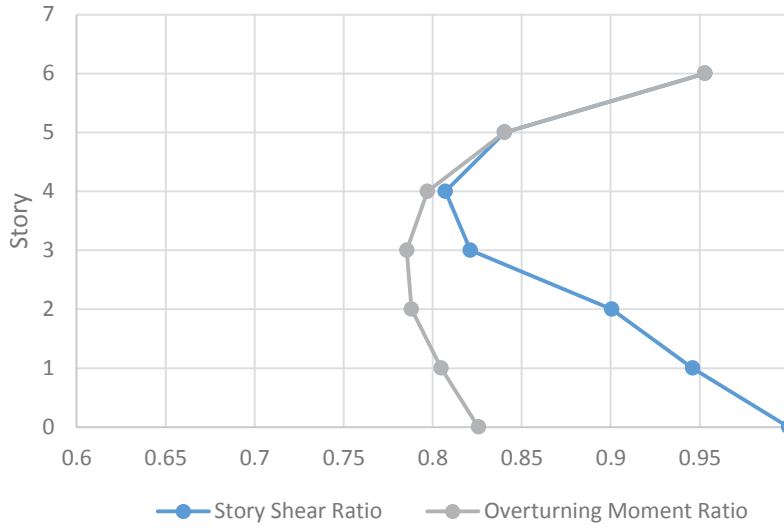


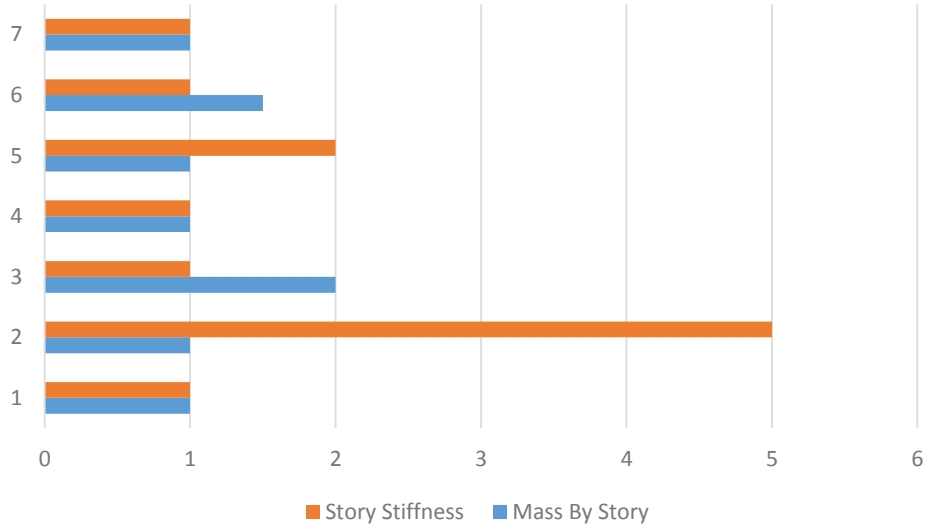


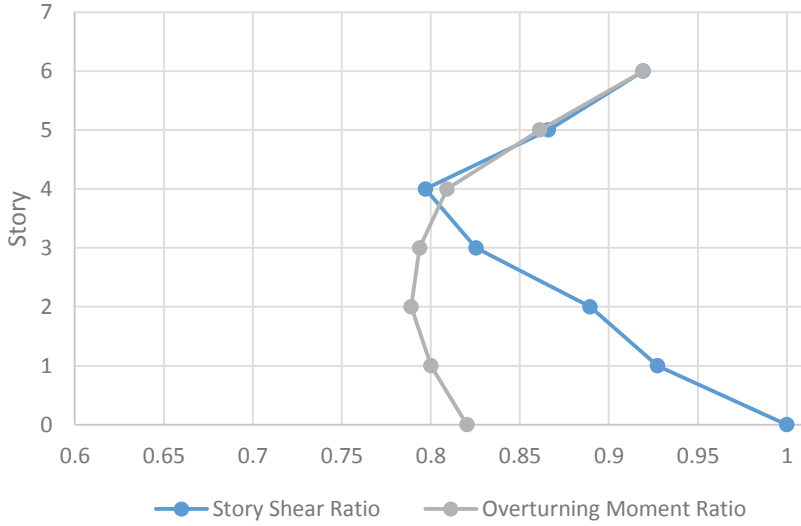


Mass Irregularity – 7 Story Models

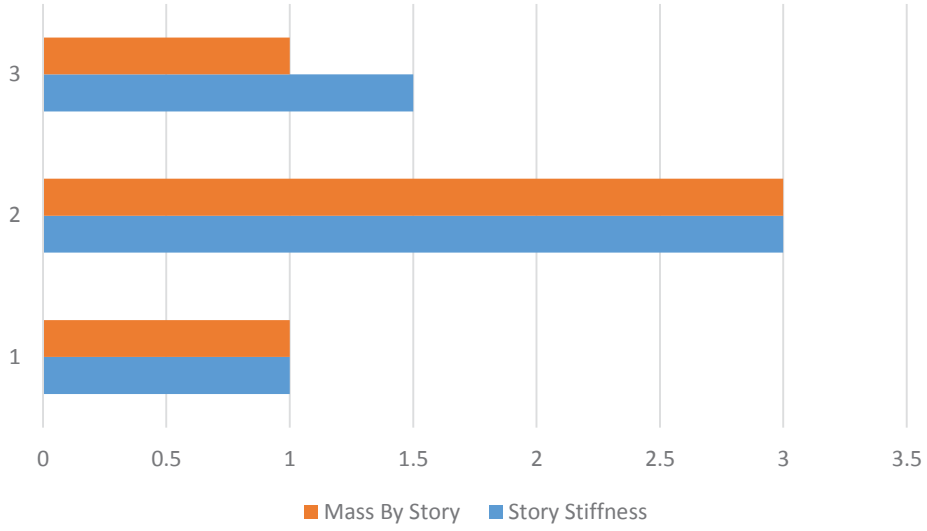


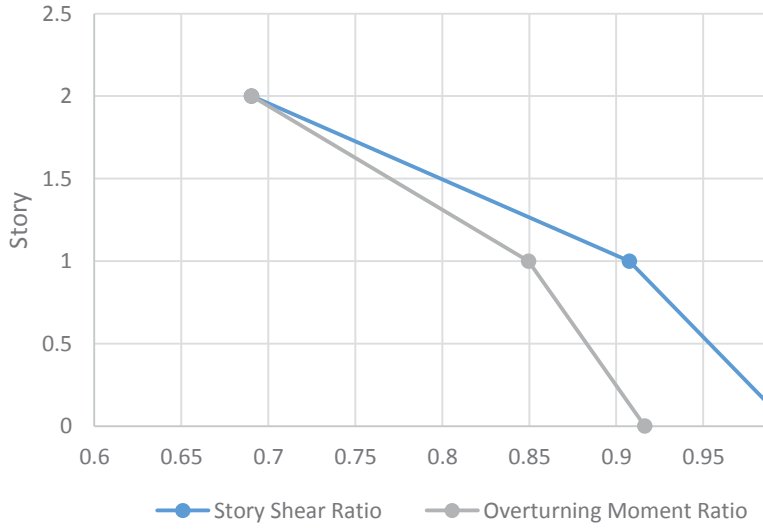


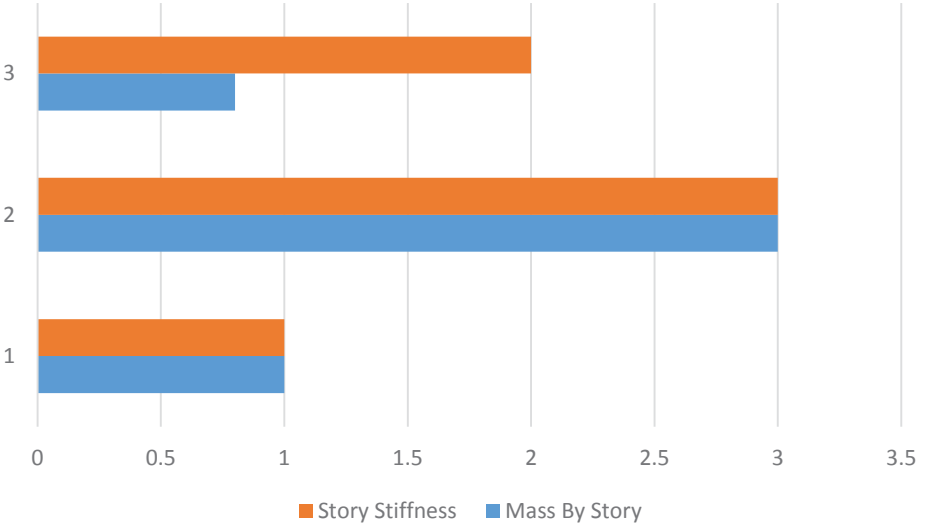


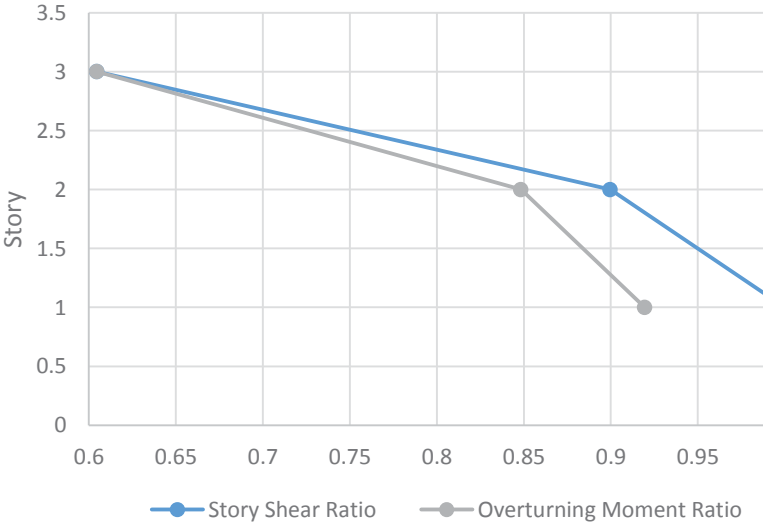


Mass Irregularity – 3 Story Models









Mass Irregularity

- Sabelli et. al study
  - Eigenvalue Analysis MRSA vs ELF
  - System Independent Stiffness & Mass Only Based Approach
  - Normalized to 2% Drift

- ELF Generally Conservative Story Shear and OTM Compared to MRSA with Some Exceptions

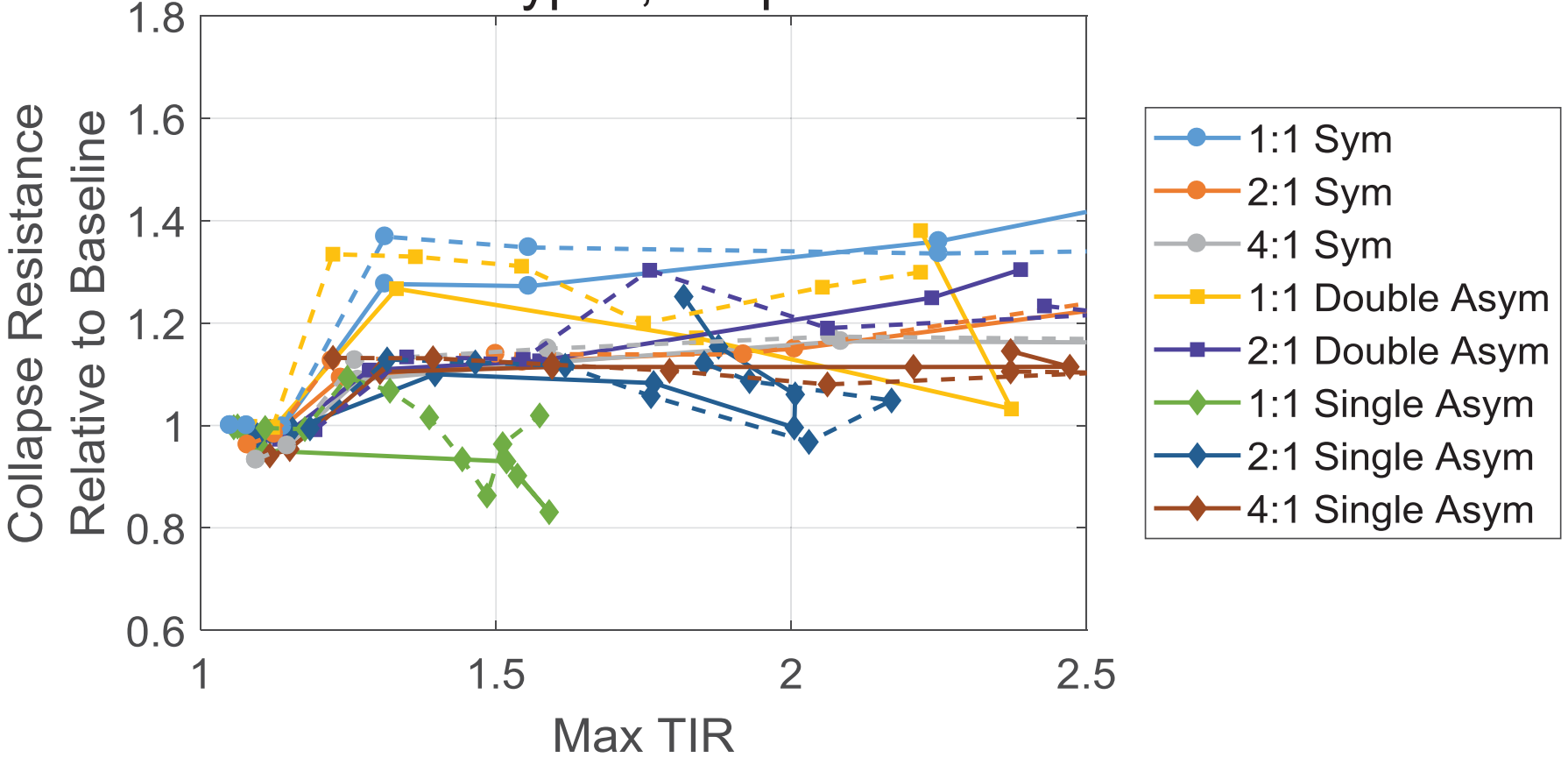
Mass Irregularity

STUDIES ON EFFECTS OF TORSIONAL IRREGULARITIES

ATC-123: Improving Seismic Design of Buildings with Configuration Irregularities

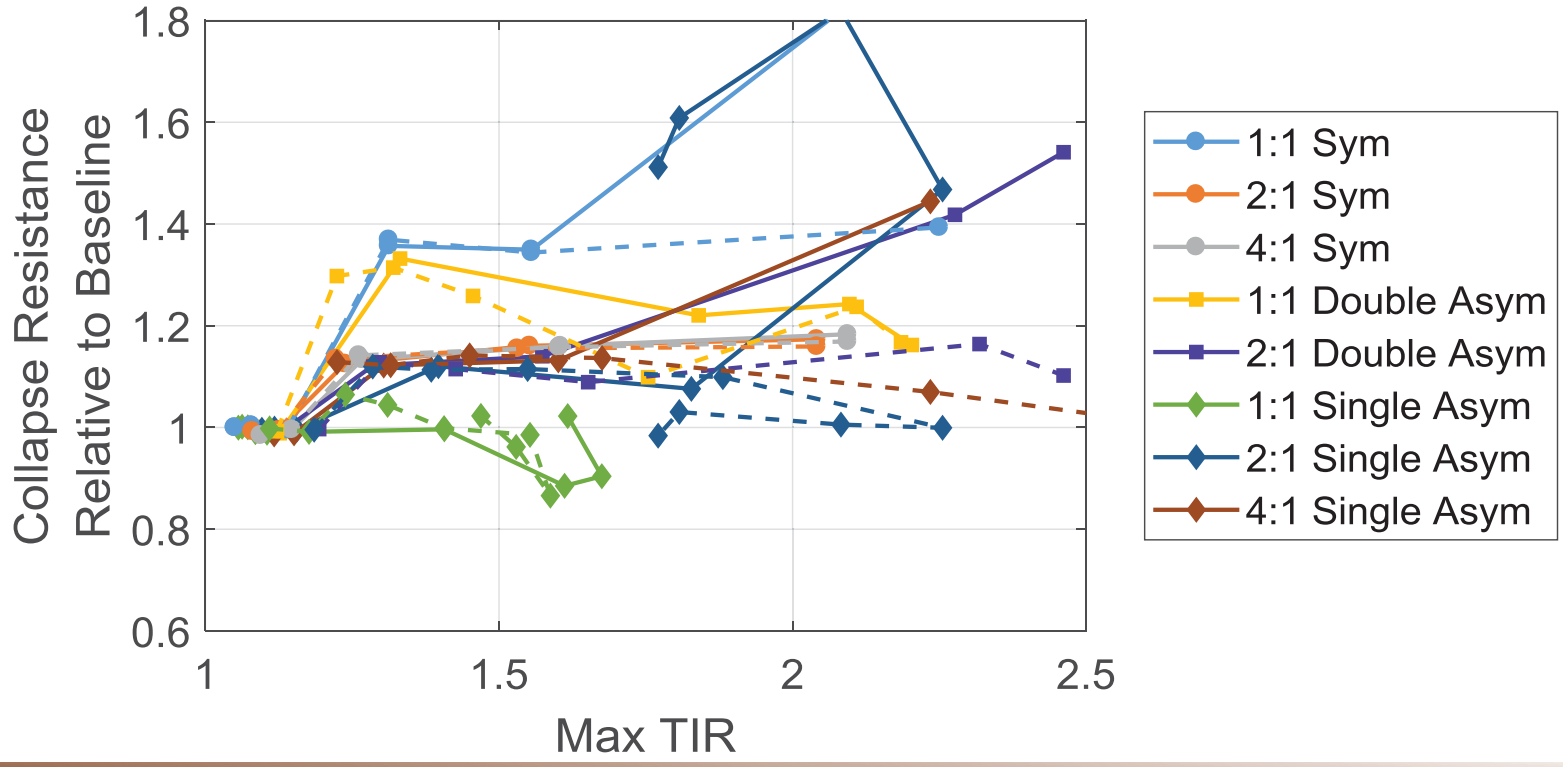
Results: Use ASCE 7 Design Provisions

- "Short" archetypes, coupled is dashed



Results: Use ASCE 7 Design Provisions

- "Mid-rise" archetypes with P-θ modeling conservatism removed, dashed lines are for coupled strength and stiffness

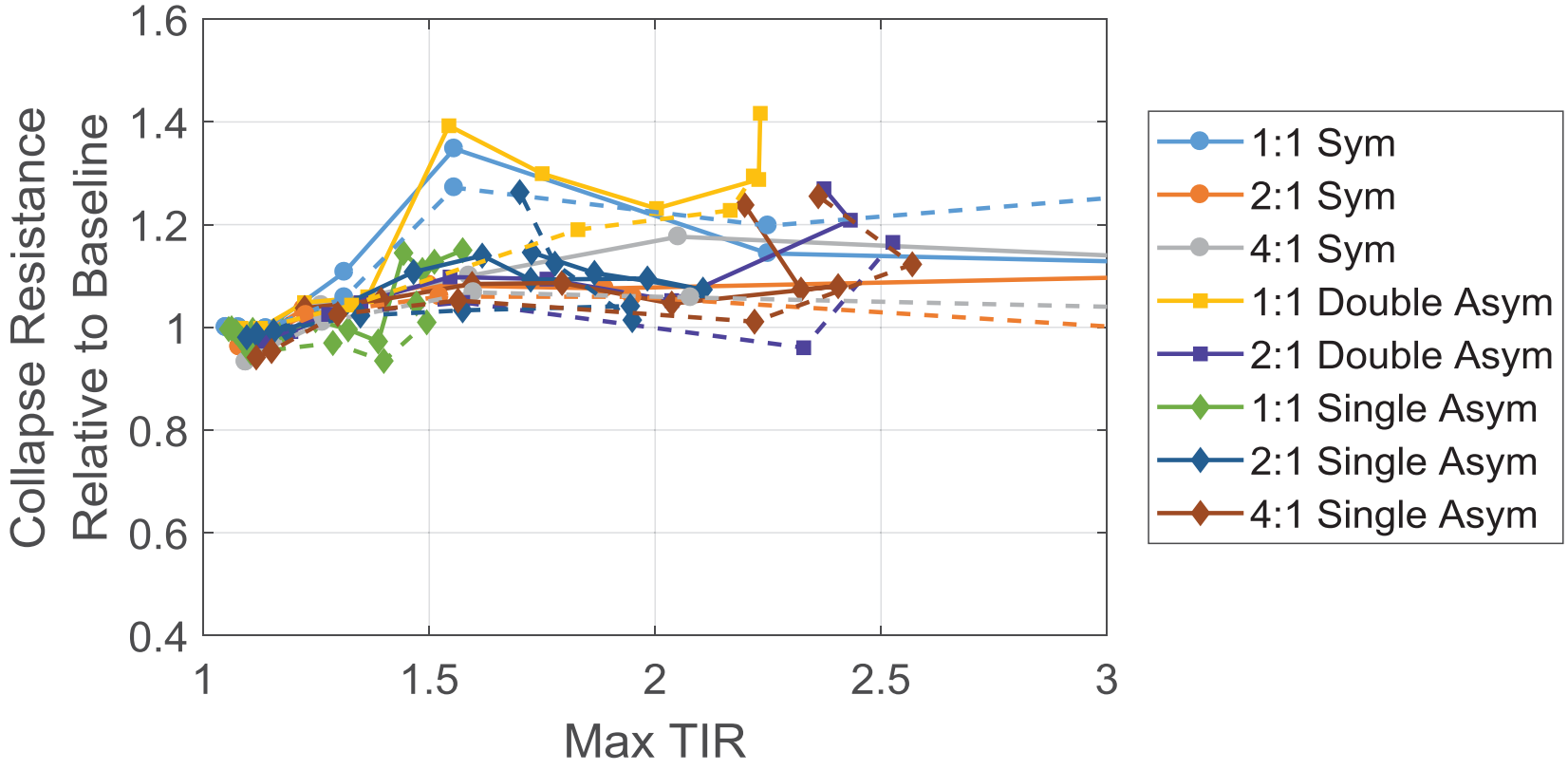


Possible (Minimum) Torsion Provisions

Torsional irregularity classification	Criteria	Add Requirements	Remove Requirements
Type 1a. Torsional irregularity	TIR > 1.2	NA	NA
Type 1b. Extreme torsional irregularity	TIR > 1.4	-100%-30% ortho load combo for strength	-ρ = 1.3 -Prohibit SDC E and F -Prohibit ELF -Ax ≤ 3.0 (replace with Ax ≤ 2.0)
Take care of with Code Text	Meets Type 1b AND one or more of the following: -TIR > 2.0 -TIR > 1.4 in ortho direction -Lines of lateral resistance all on same side of CM	-100%-30% ortho load combo for strength -ρ = 1.3	-Prohibit SDC E and F -Prohibit ELF -Ax ≤ 3.0 (replace with Ax ≤ 2.0)

Results For Proposed Torsion Provisions

- "Short" archetypes, dashed lines are coupled
  - Apply ρ only in direction that triggers it



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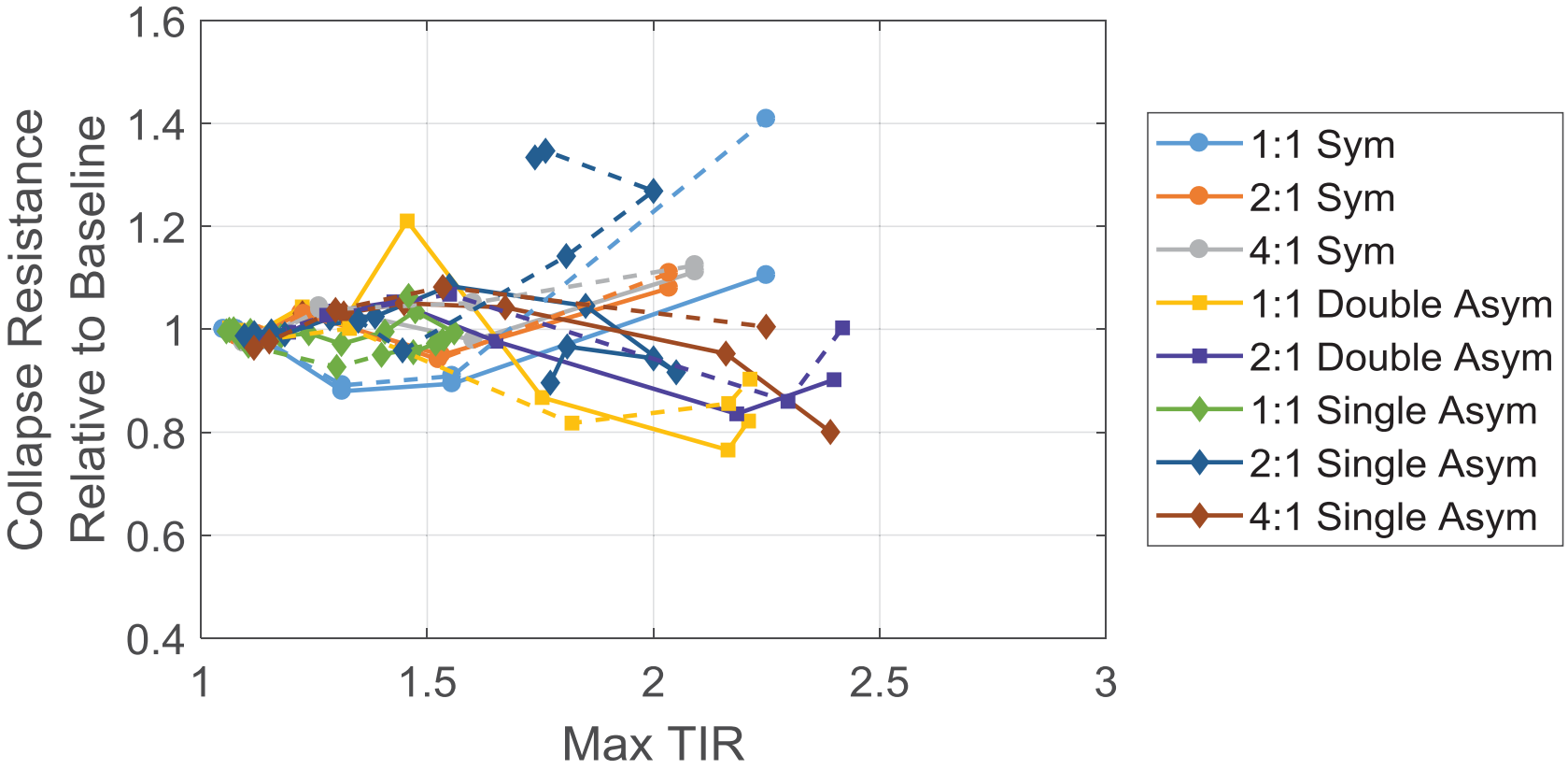
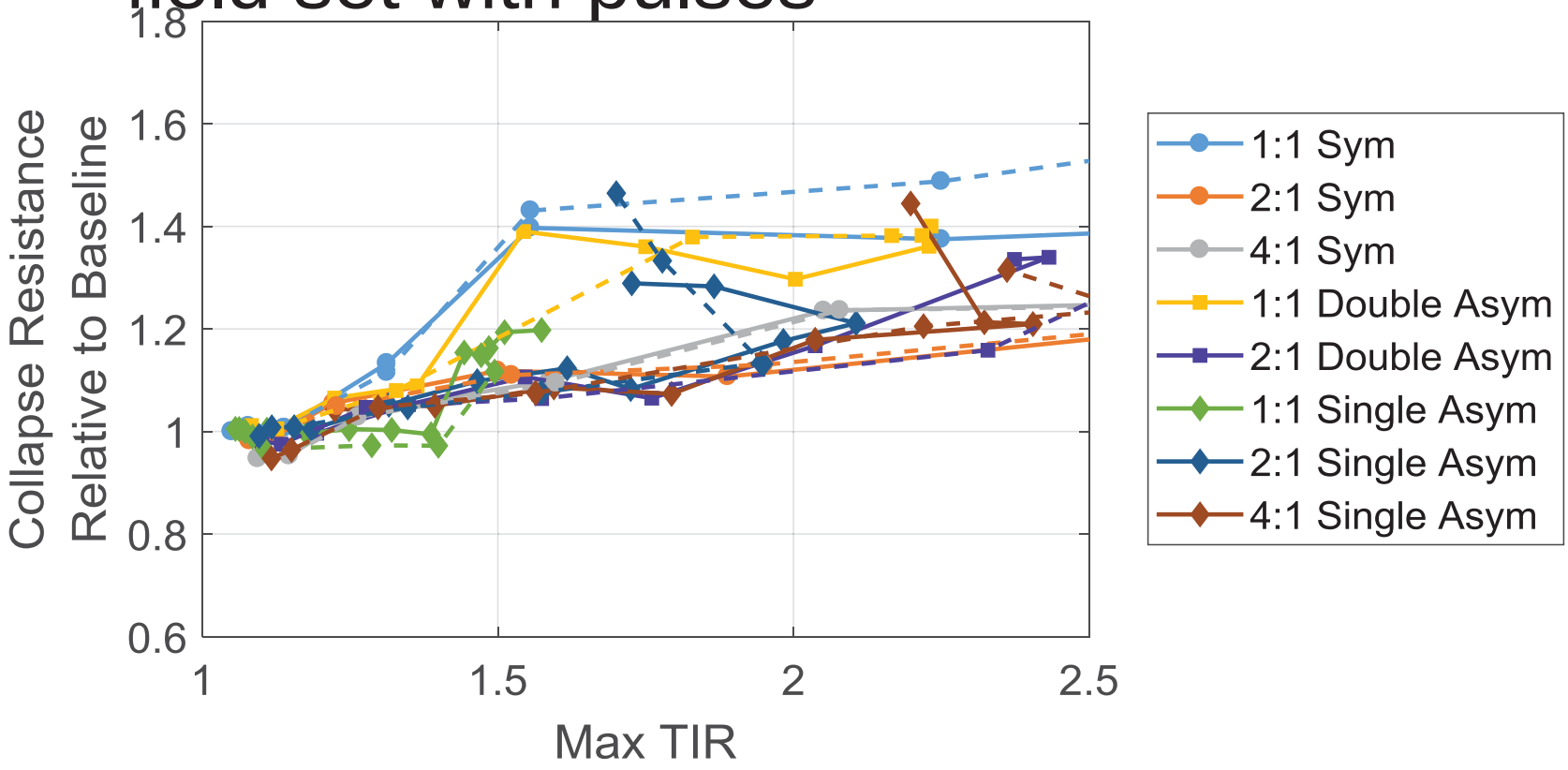


Analysis with Pulse Ground Motions: Short Archetypes

- Use 12 GM pairs from FEMA P695 near-field set with pulses



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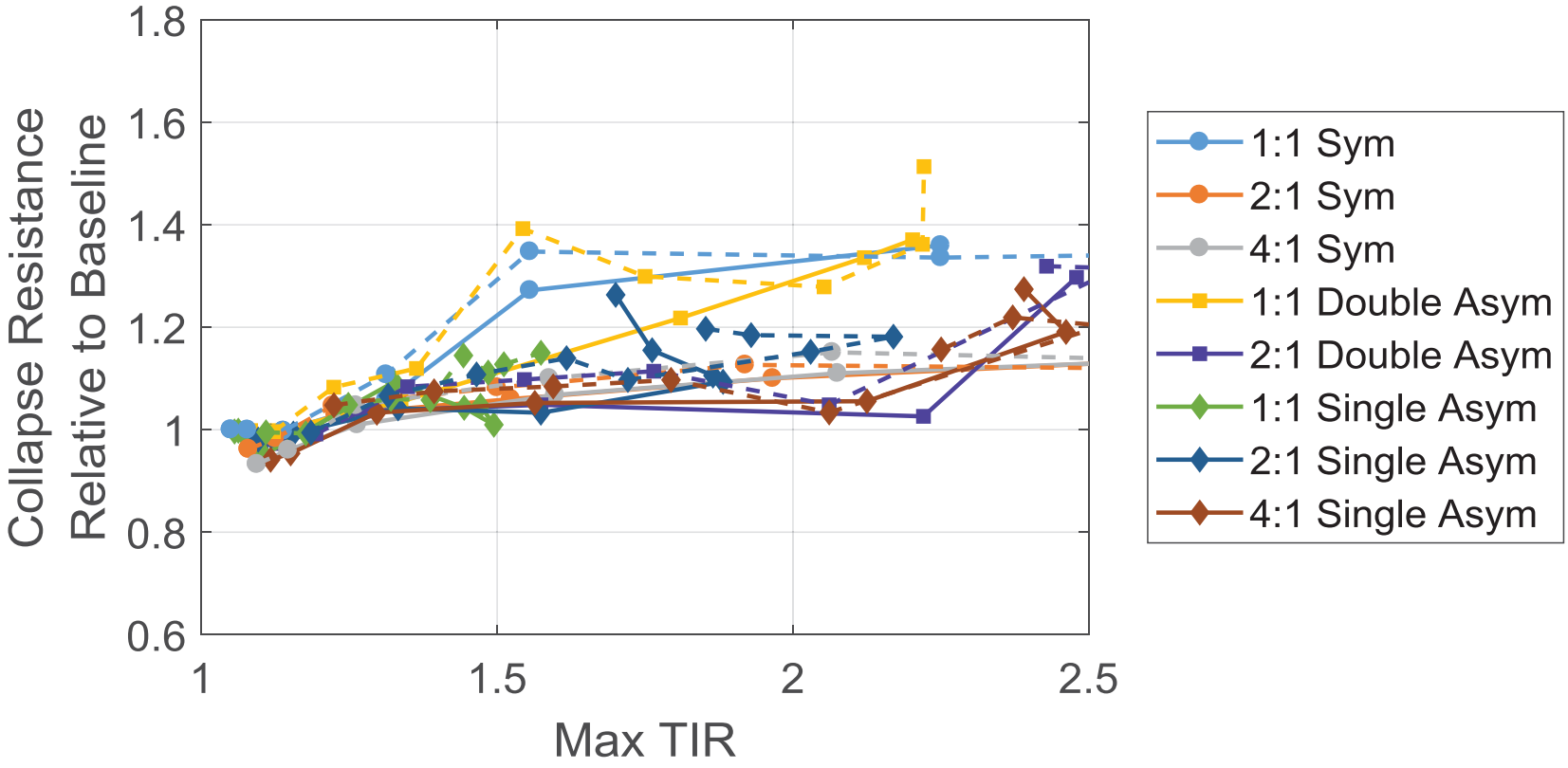
Take care of with Code Text	Meets one or both of the following: -TIR > 1.4 in both ortho directions -Lines of lateral resistance all on same side of CM	-ρ = 1.3	NA

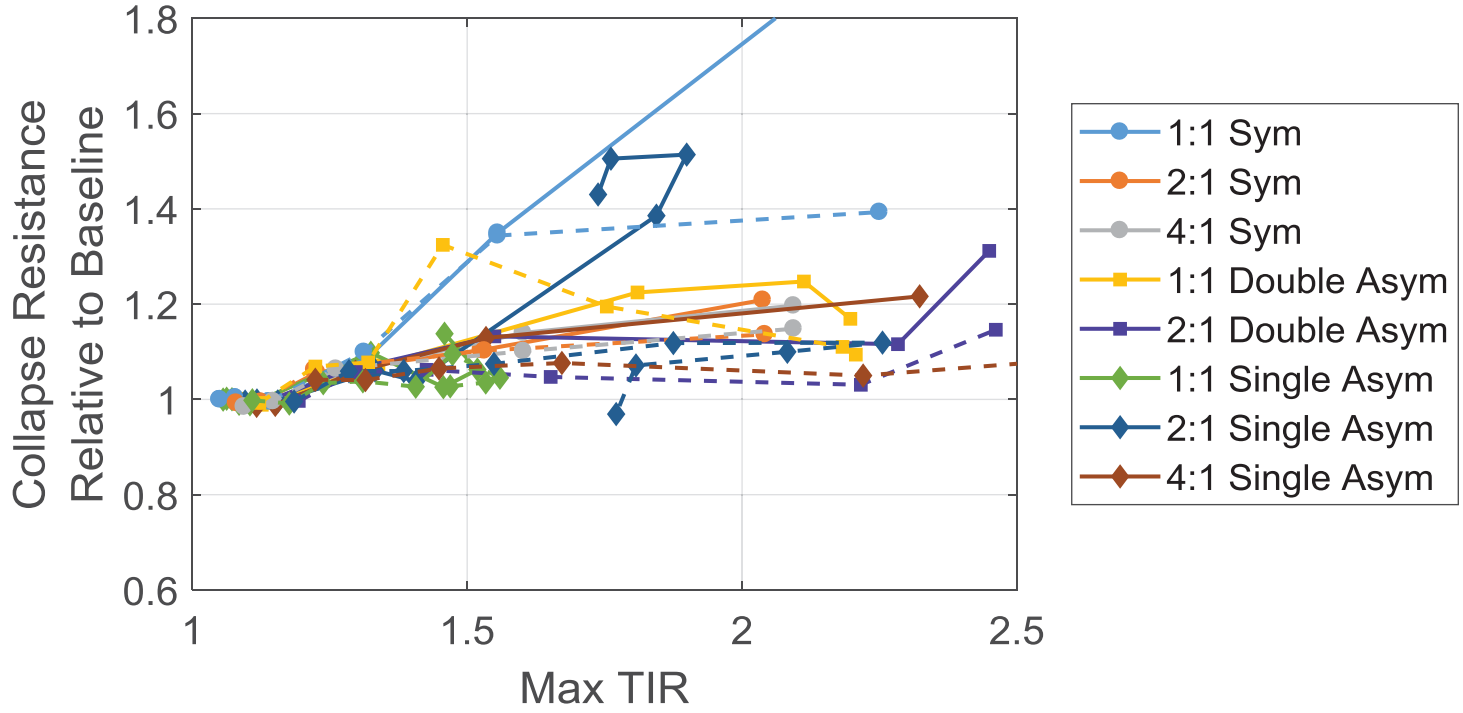
Results For Proposed Torsion Provisions

- "Short" archetypes, dashed lines are coupled
  - Apply ρ only in direction that triggers it



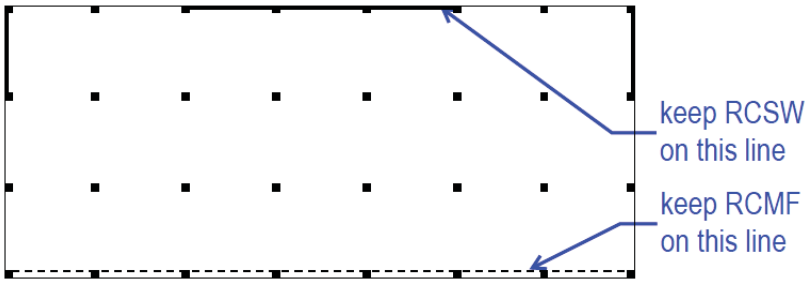
Results For Proposed Torsion Provisions

- "Mid-rise" archetypes with P-θ modeling conservatism removed, dashed lines are for coupled strength and stiffness



Additional Studies to Verify the Conclusions and Recommendations

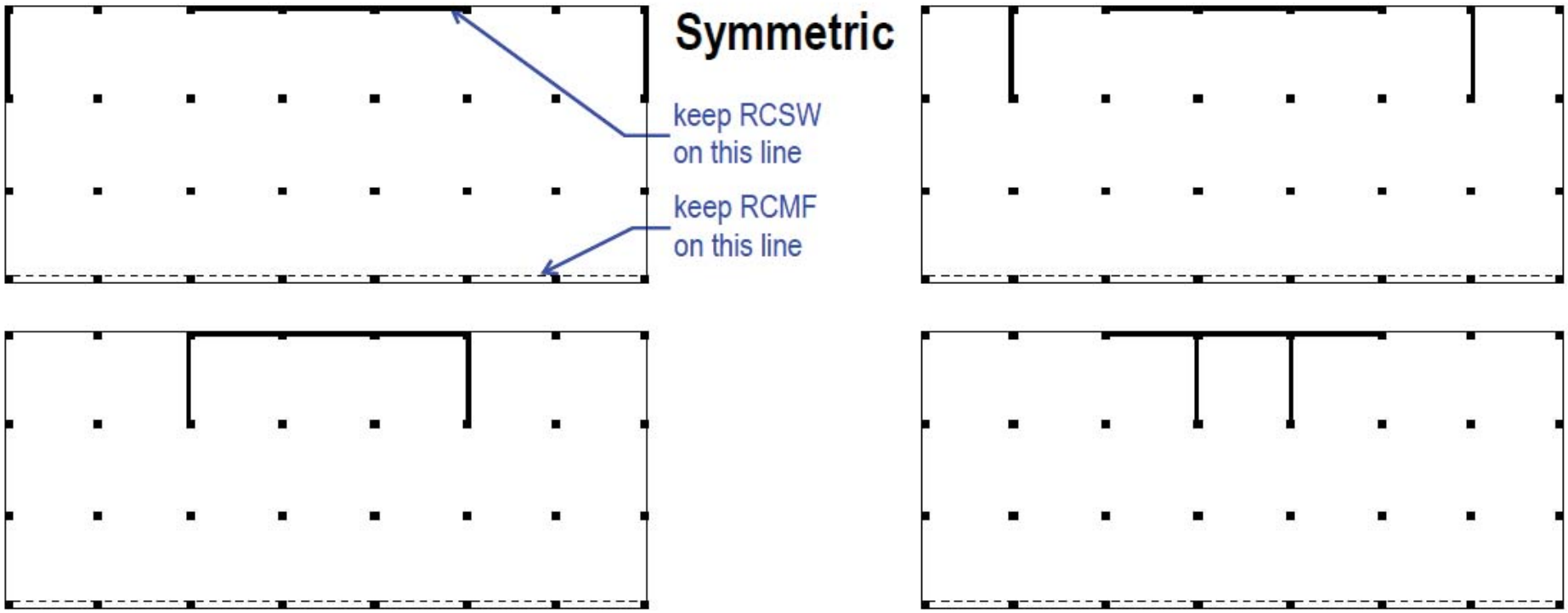
- Mixed systems: 7:3 aspect ratio
  - 8-story RC shear wall building with moment frame on one side (Layouts by Mike V.)



- Three wall systems: Same layouts as the RC walls in the mixed system, but with the frame removed.

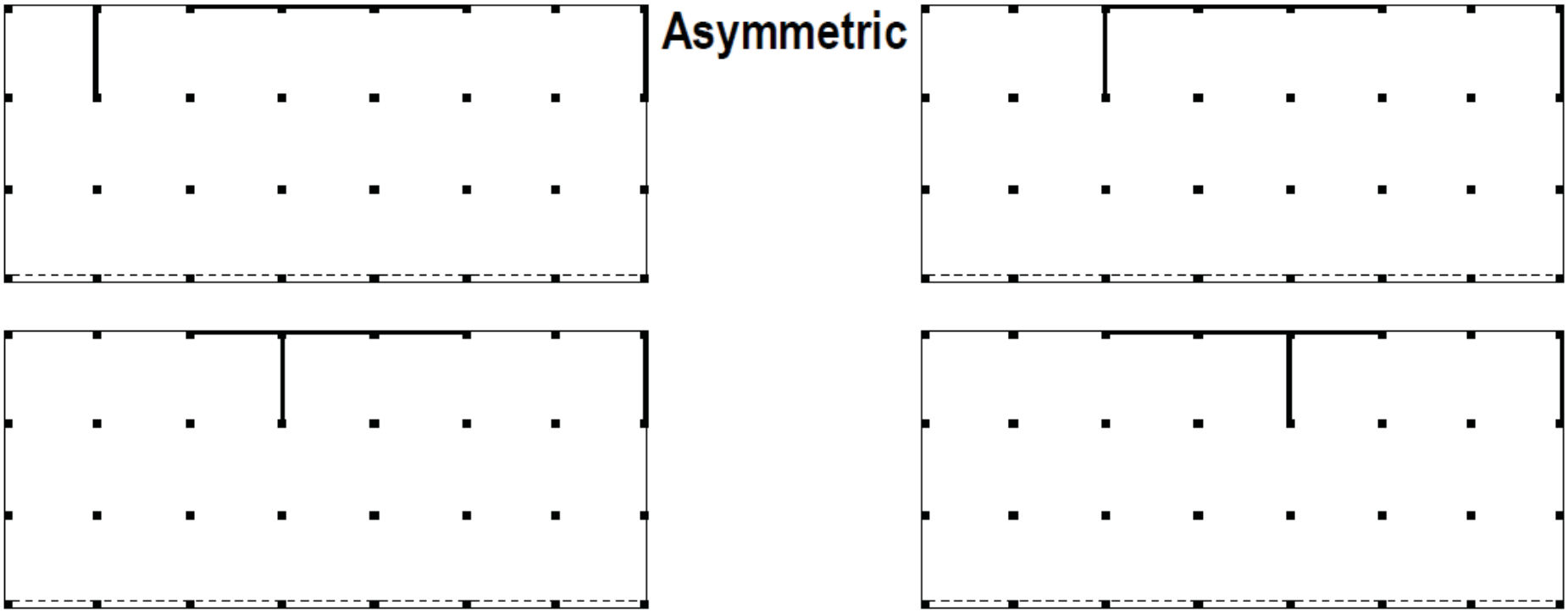
Mixed System Layouts

- Set 1: “Symmetric” layouts



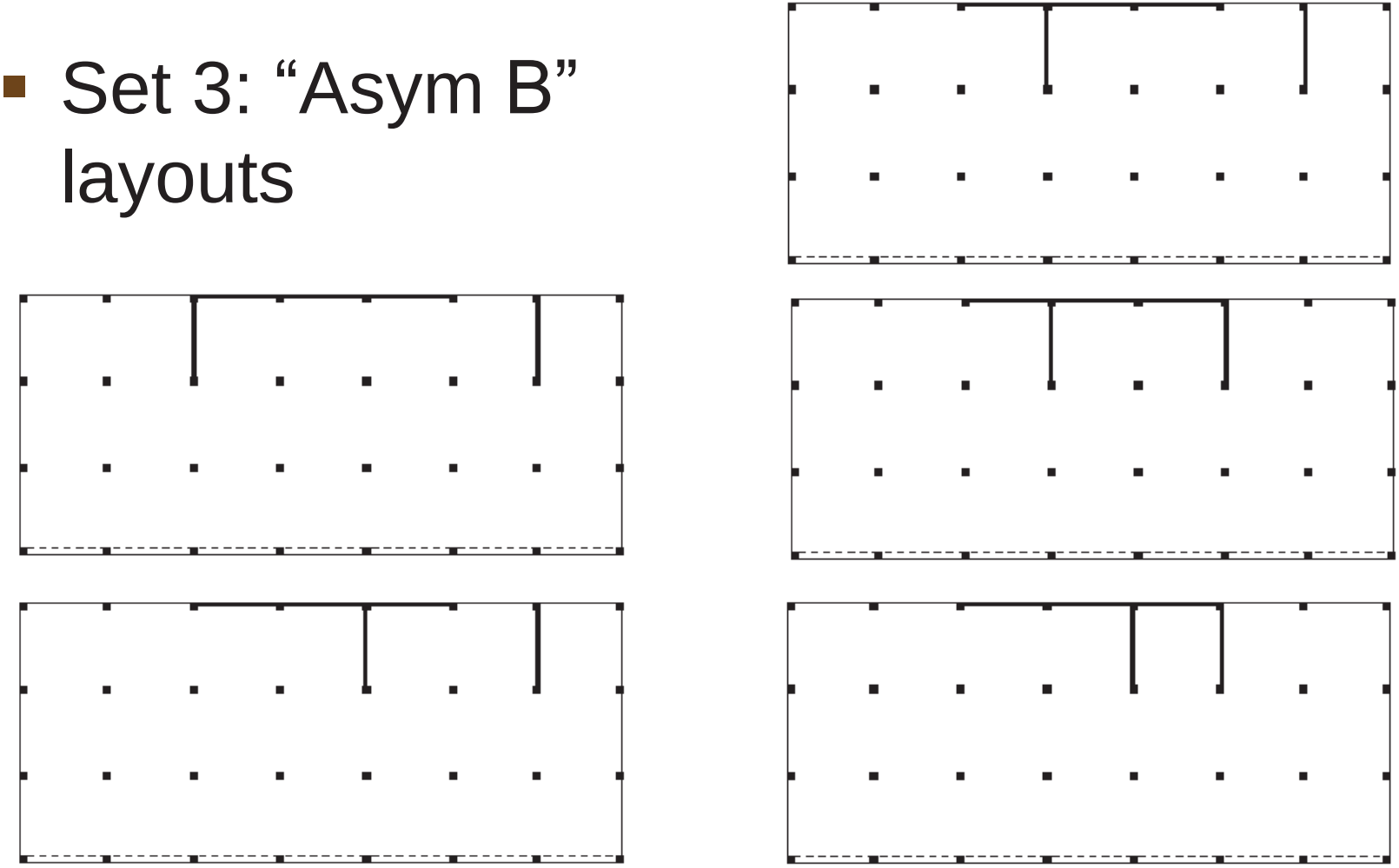
Mixed System Layouts

- Set 2: “Asym A” layouts



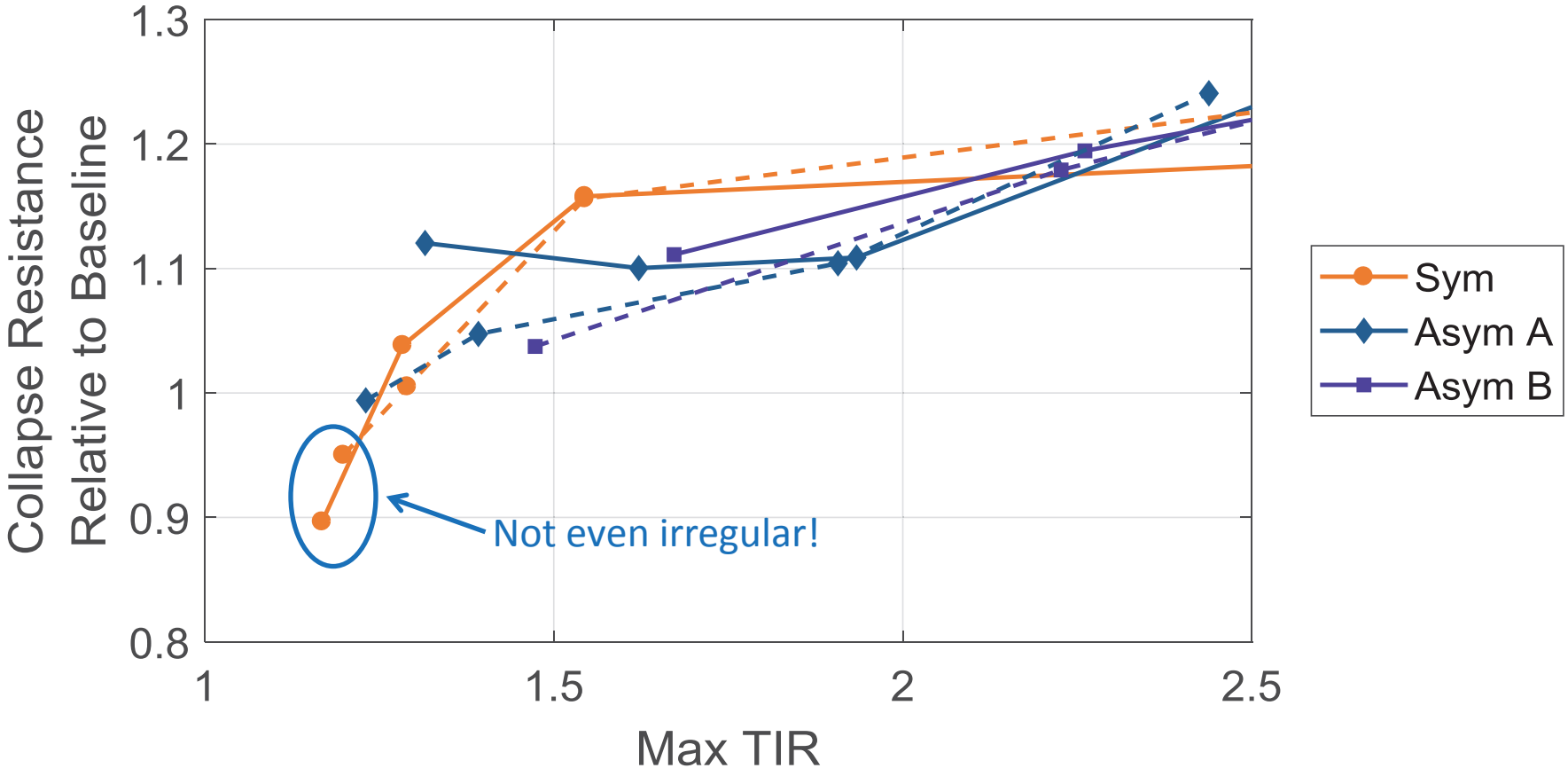
Mixed System Layouts

- Set 3: “Asym B” layouts



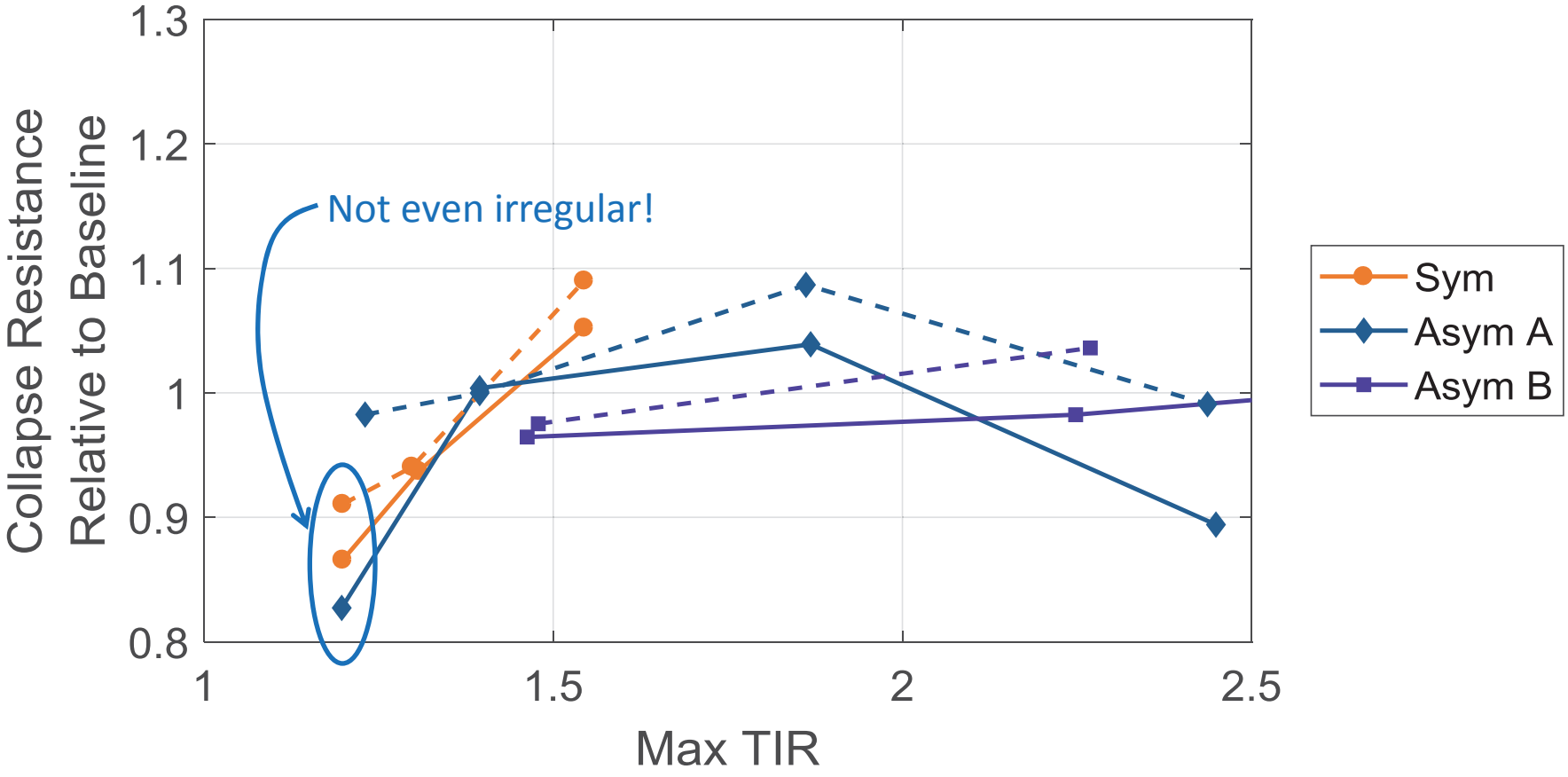
3-wall, “Short”

- Originally proposed minimum req’s

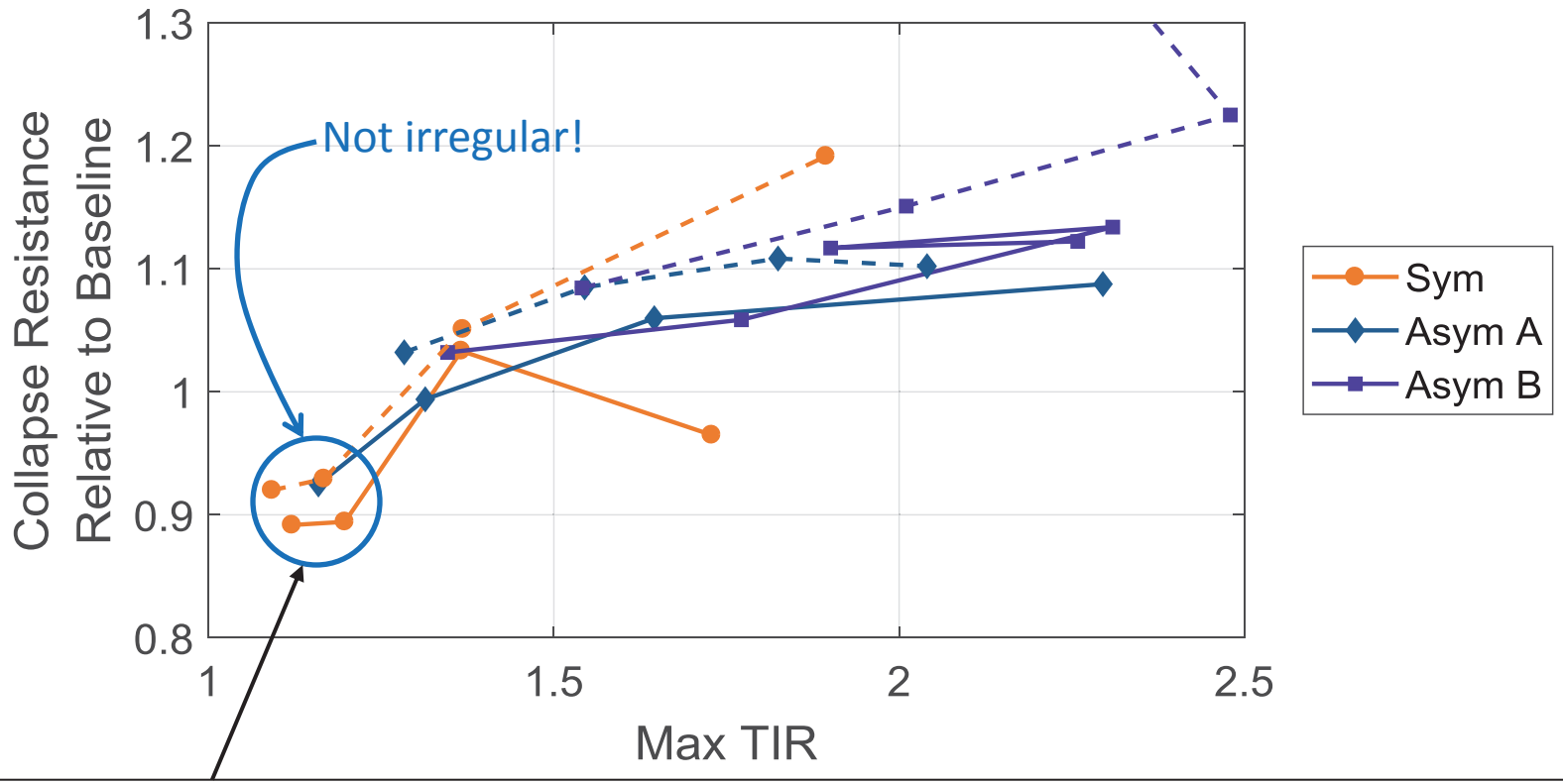


3-wall, “Mid-rise”

- Originally proposed minimum req’s



Mixed System Designs



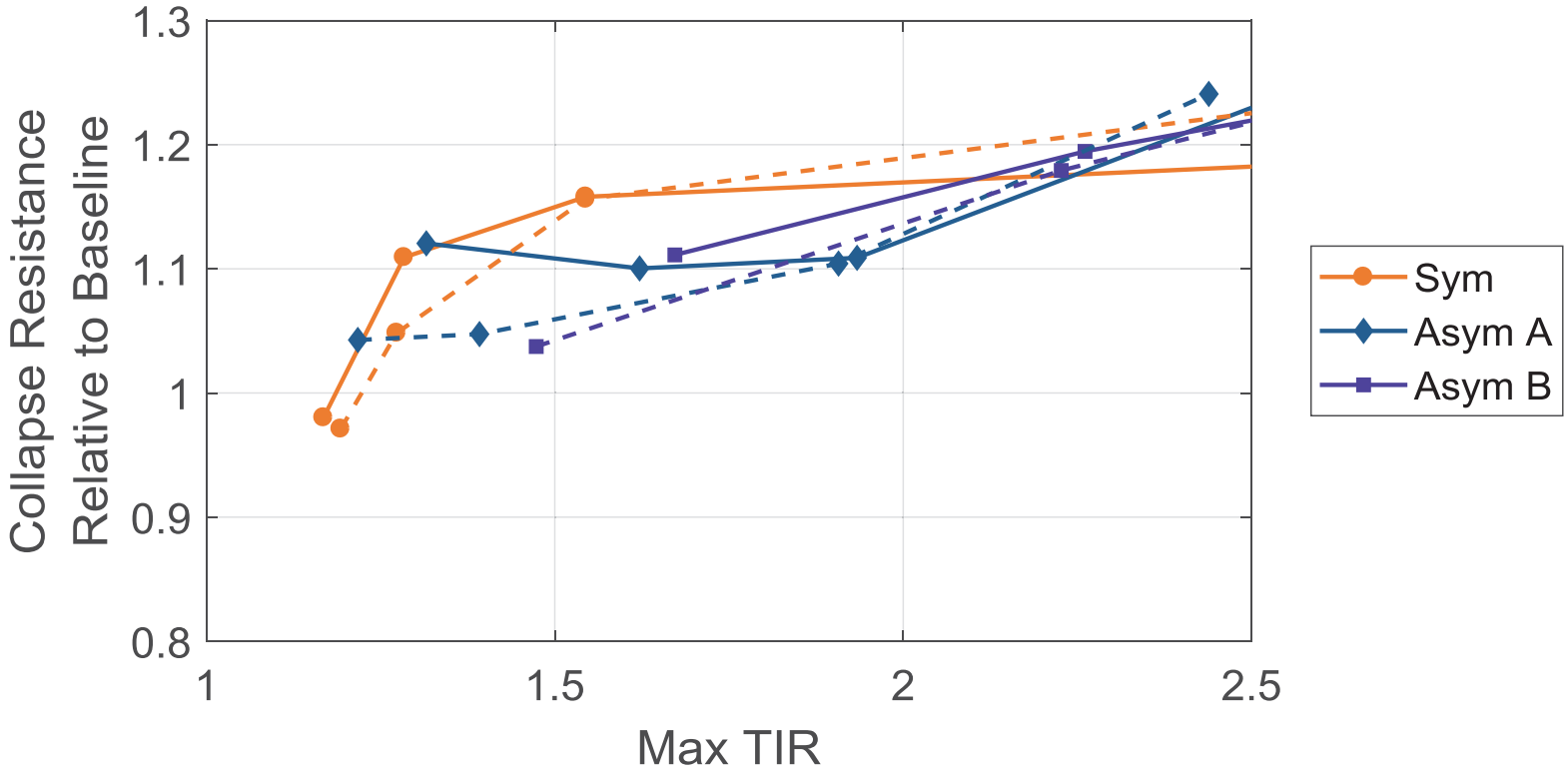
Some Caveats: (1) I used R = 7 for dual system direction, but the MF is actually not quite strong enough to qualify for that, (2) ρ = 1.0, but would be 1.3 if we change the language to "75% of resistance on same side of CM" rather than "all lines of resistance on same side of CM" (3) Whatever we decide to do to address the 3-wall building issue should work for the mixed systems as well.

Problems Identified

1. Some “torsionally regular” buildings perform poorly
   - Reason: Significant inherent torsion resisted by orthogonal walls
   - Solution 1: Require accidental torsion
     - This is an indirect solution
   - Solution 2: Require 100%-30% ortho load combo
     - This solution addresses the actual problem (i.e. ortho loads are not actually decoupled when there is inherent eccentricity)
   - Possible trigger (for solution 1 or solution 2): >75% of lateral resistance on same side of the CM

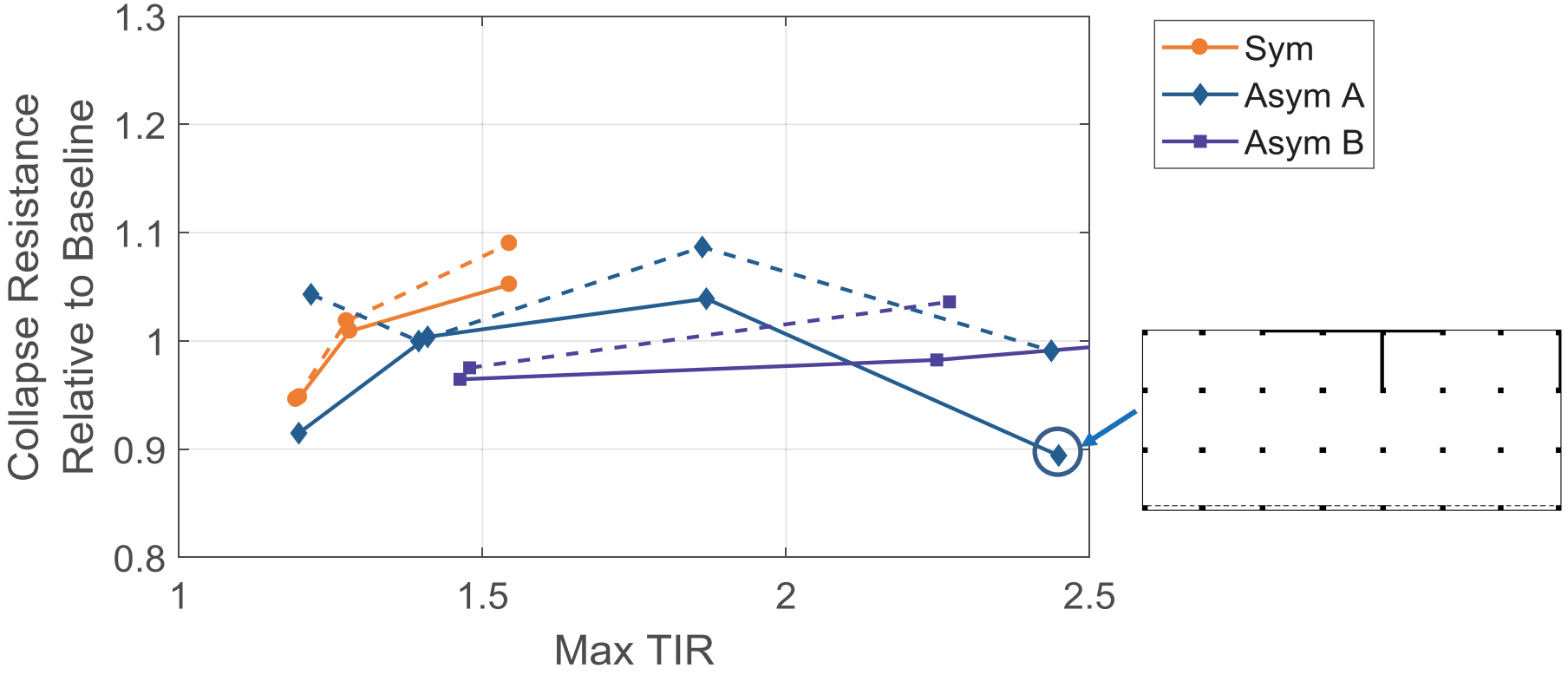
3-wall, “Short”

- Apply Accidental torsion in both orthogonal directions.



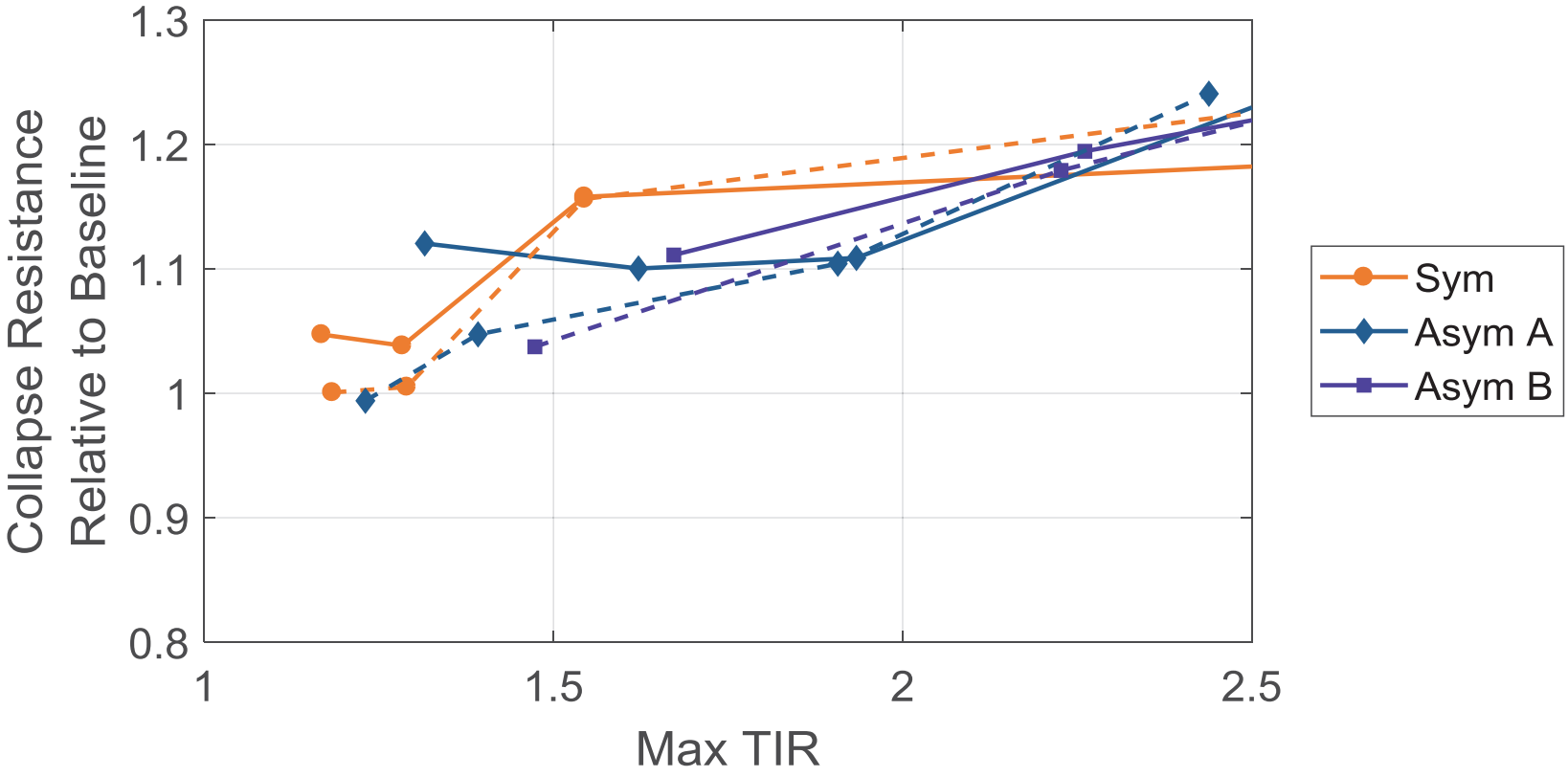
3-wall, “Mid-rise”

- Apply Accidental torsion in both orthogonal directions if >75% of resistance on same side of CM (even if “regular”)



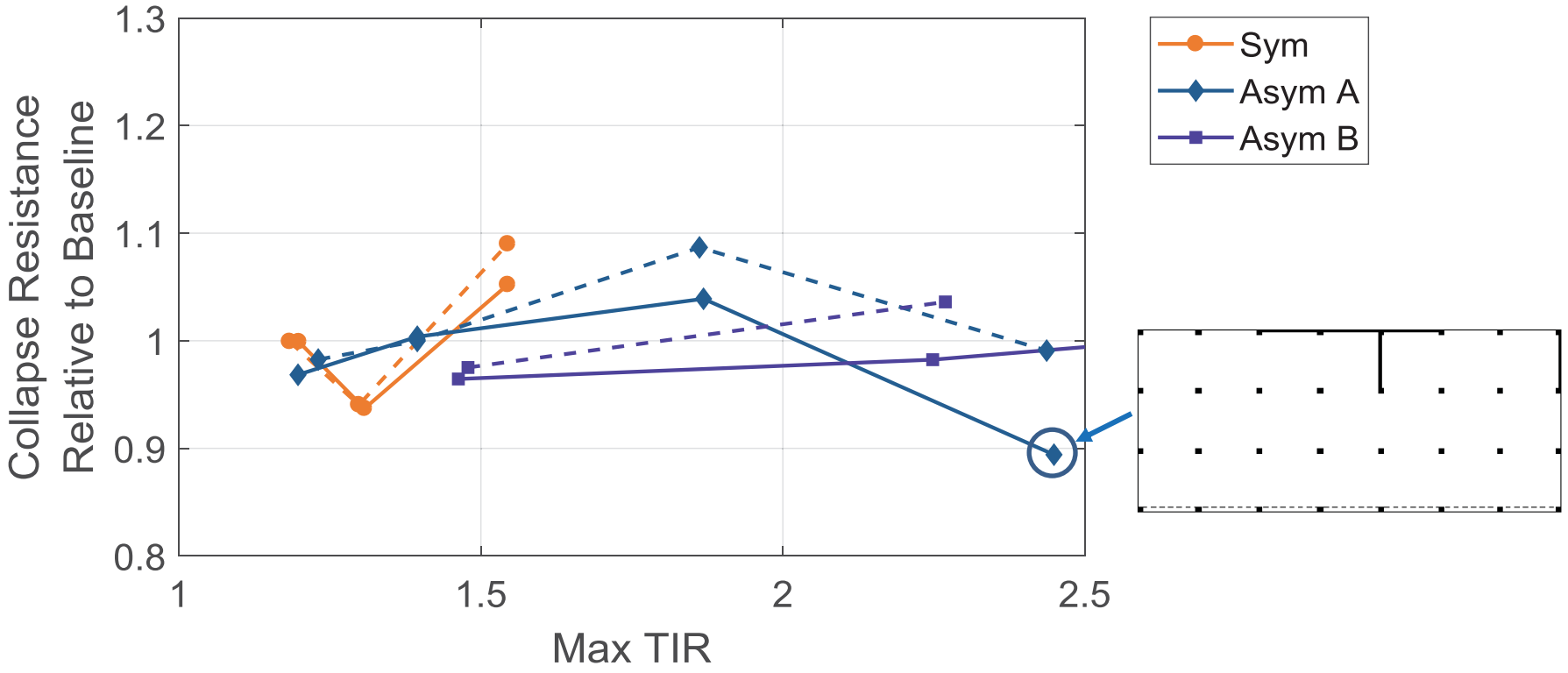
3-wall, “Short”

- 100%-30% ortho combo if >75% of resistance on same side of CM (even if “regular”)



3-wall, “Mid-rise”

- 100%-30% ortho combo if >75% of resistance on same side of CM (even if “regular”)



Proposed Solution

Type	Description	Reference Section	Seismic Design Category Application
1a.	**Torsional Irregularity:** Torsional irregularity is defined to exist where more than 75% of the story lateral strength is provided on one side of the center of mass or where the maximum story drift, computed including accidental torsion with $A_x = 1.0$, at one end of the structure transverse to an axis is more than 1.2 times the average of the story drifts at the two ends of the structure. Torsional irregularity requirements in the reference sections apply only to structures in which the diaphragms are rigid or semirigid.	12.3.3.4	D, E, and F

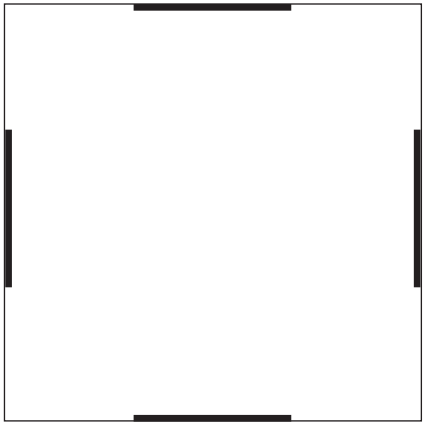
Methodology

- Compare collapse resistance of regular and irregular archetype configurations
  - Consistent with “Life-safety” goal of ASCE 7
- Archetype design space
  - ~1800 variants and counting
  - Torsionally regular (“Baseline”)
  - Torsionally irregular
    - Various sources of torsional irregularity
    - Non-code-conforming, code-conforming, modified-code-conforming

Archetype Models: "Baseline"

- Baseline building properties
  - Square plan
  - Lines of lateral resistance at each edge
  - *One-story

- Two categories
  1. "Short": $C_u T_a$ = 0.3 sec
  2. "Mid-rise": $C_u T_a$ = 2.0 sec

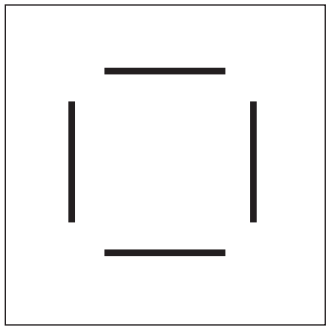


Baseline Plan View

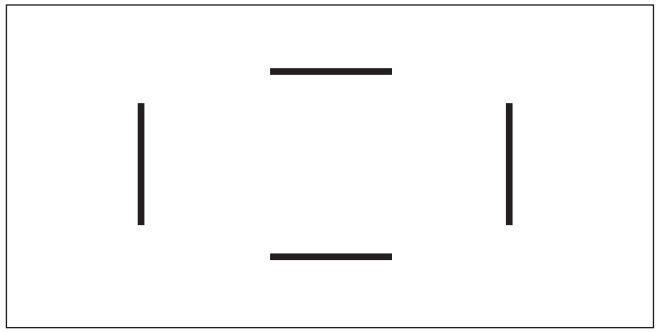
* Single-story models for studying torsion have been abused in the past. Great care is taken in this study to avoid the pitfalls of using one-story models inappropriately.

Archetype Models: Symmetric

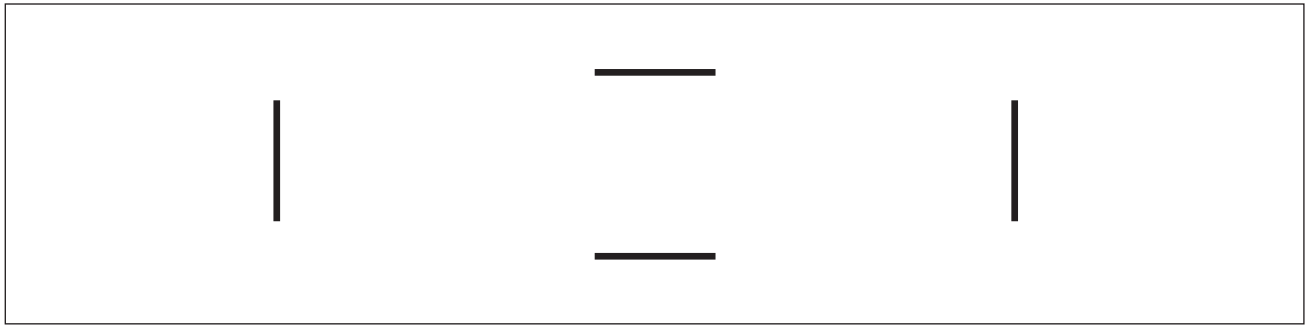
- Source of torsional irregularity
  - ✓ Torsional flexibility



"1:1 Sym"



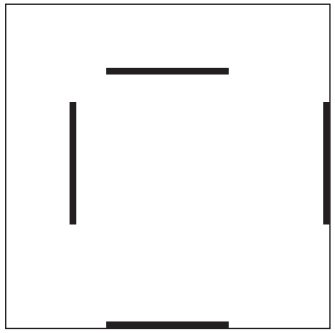
"2:1 Sym"



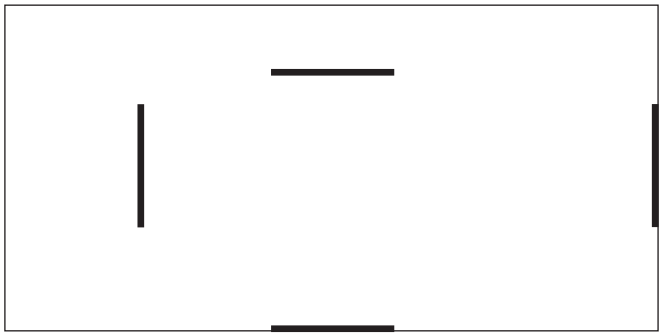
"4:1 Sym"

Archetype Models: Double Asymmetric

- Sources of torsional irregularity
  - ✓ Torsional flexibility
  - ✓ Eccentricity in both directions



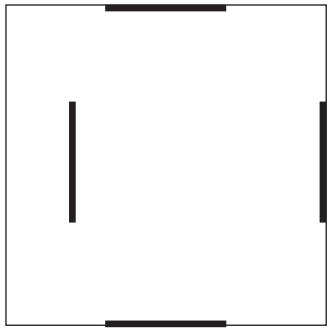
"1:1, Double Asym"



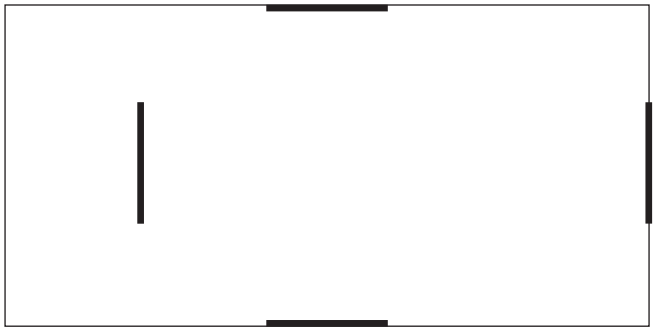
"2:1, Double Asym"

Archetype Models: Single Asymmetric

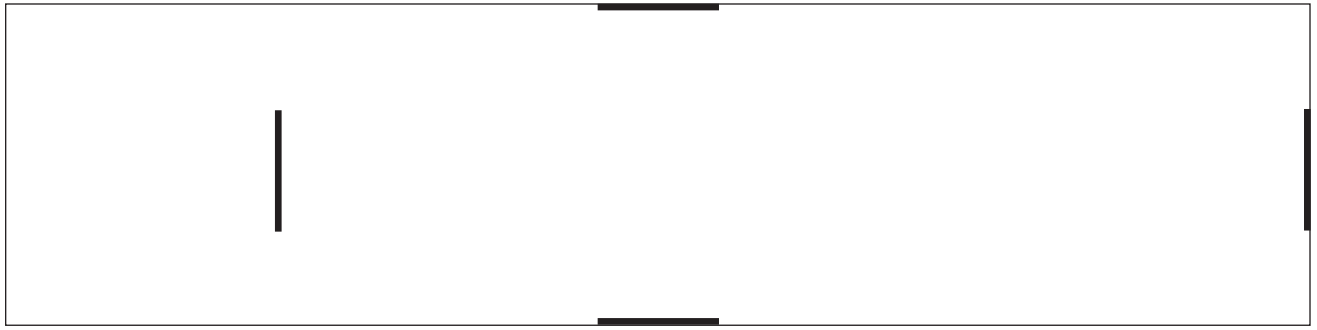
- Sources of torsional irregularity
  - ✓ Torsional flexibility
  - ✓ Eccentricity in one direction



"1:1, Single Asym"



"2:1, Single Asym"



"4:1, Single Asym"

Proportioning The Lateral System

Method 1: Decoupled Strength and Stiffness

1. Start with a “Baseline” lateral resistance
2. Adjust stiffness (if necessary) to meet drift requirements
3. Adjust strength to exactly match strength requirements
4. Adjust strength and/or stiffness to meet stability requirements

Method 2: Coupled Strength and Stiffness

1. Start with a “Baseline” lateral resistance
2. Scale strength and stiffness by exactly the same amount until design requirements are met.