Beam-Column Connections

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with contributions from
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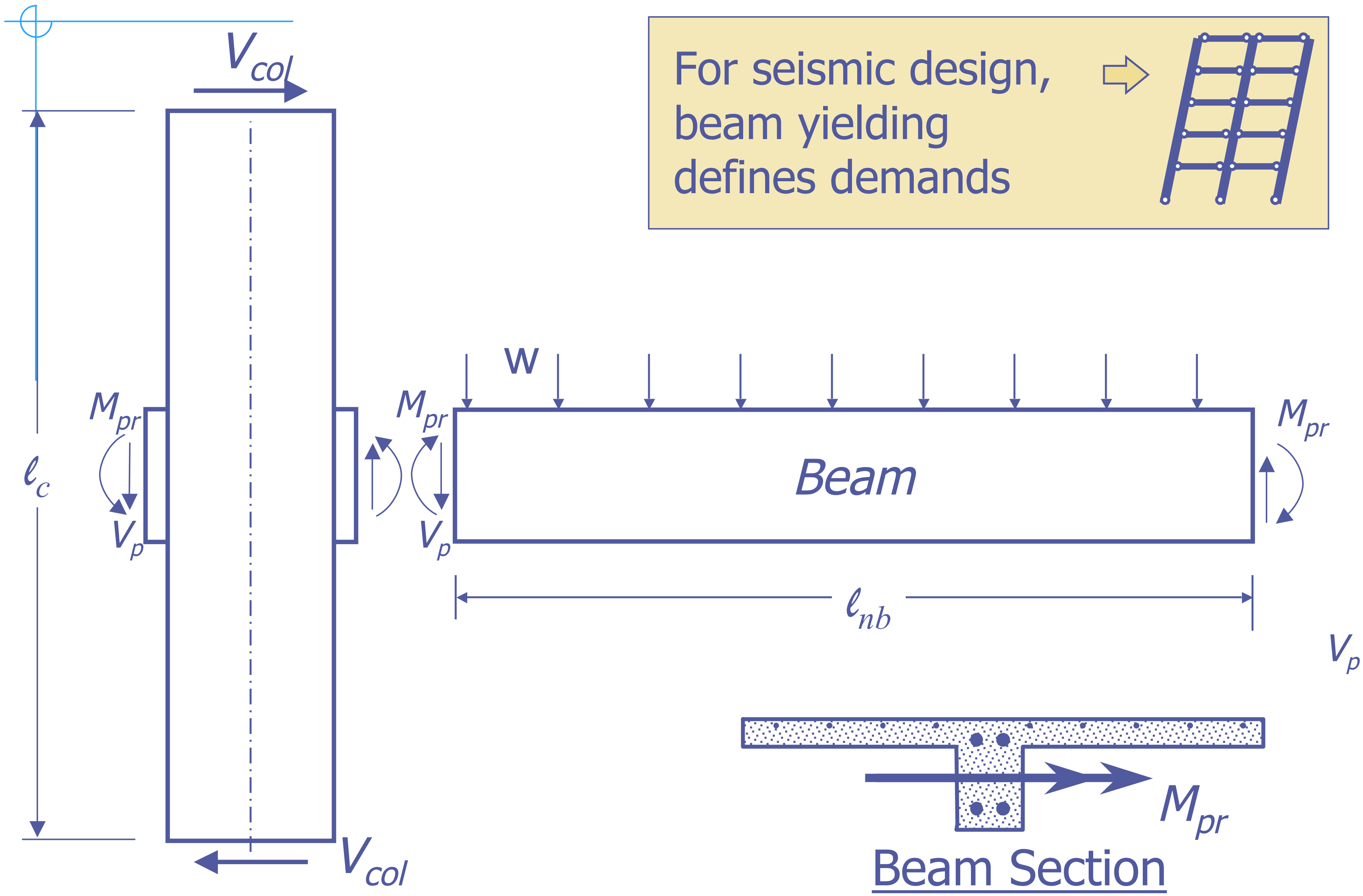
Outline

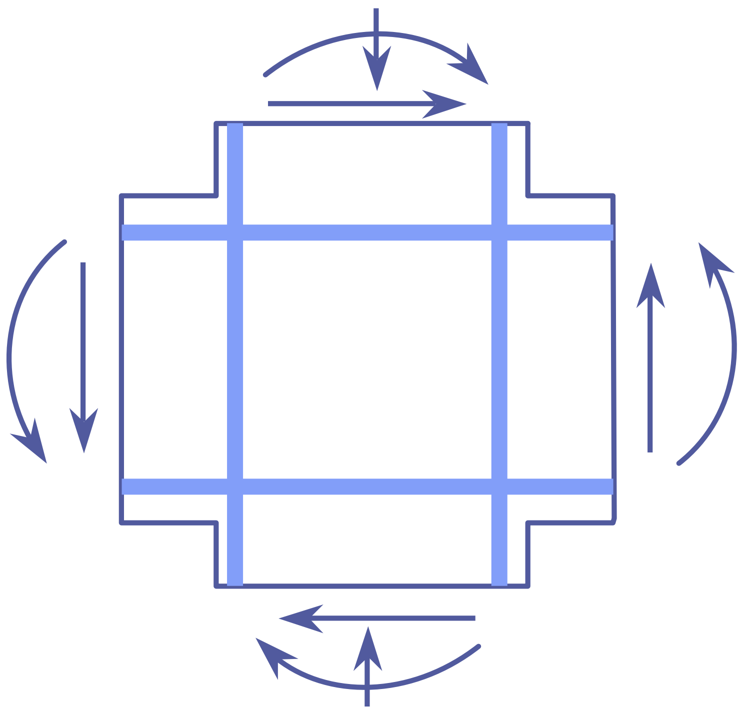
- design of new joints
- existing joint details
- failure of existing joints in earthquakes
- general response characteristics
- importance of including joint deformations
- stiffness
- strength
- deformation capacity
- axial failure

Special Moment-Resisting Frames
- Design intent -

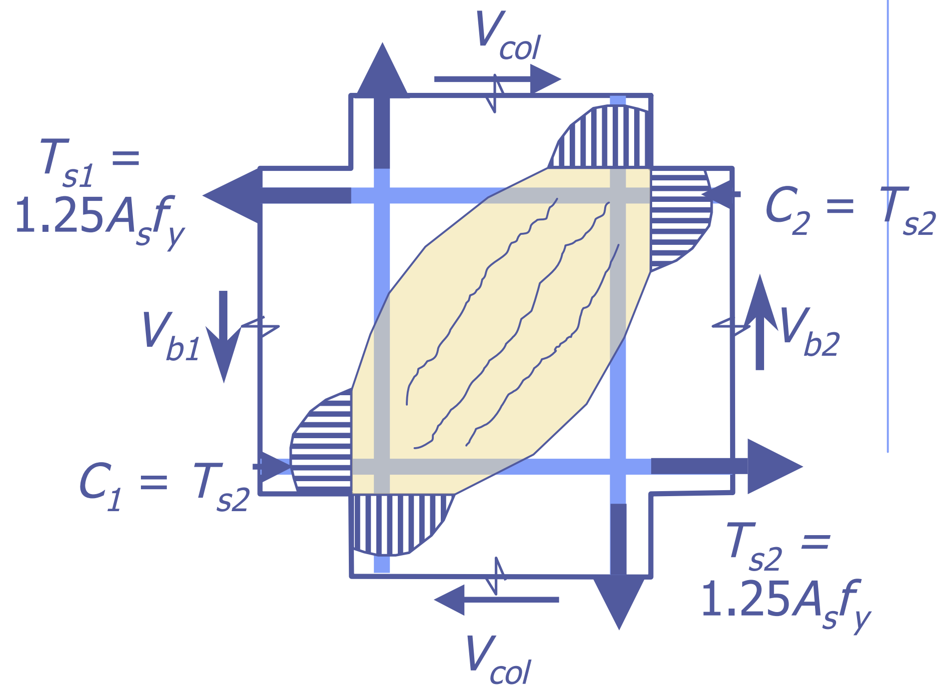
For seismic design, beam yielding defines demands



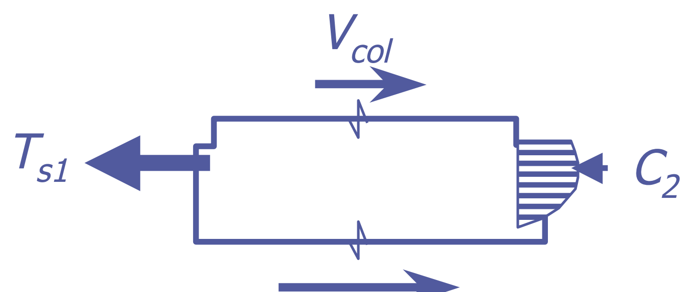
Joint demands



(a) moments, shears, axial loads acting on joint



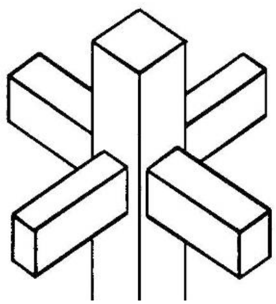
(b) internal stress resultants acting on joint



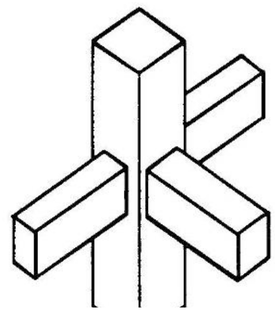
$$V_u = V_j = Ts1 + C_1 - V_{col}$$

(c) joint shear

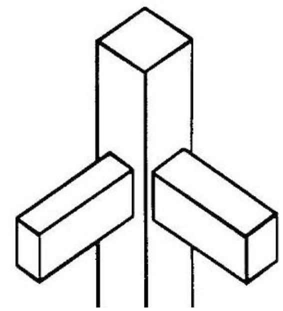
Joint geometry
(ACI Committee 352)



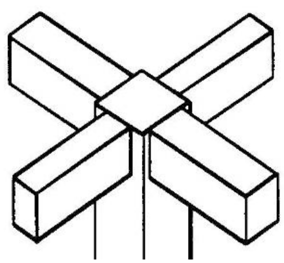
a) Interior
A.1



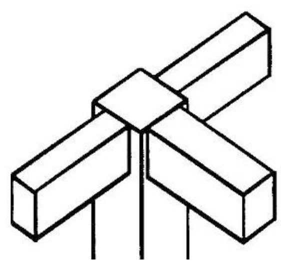
b) Exterior
A.2



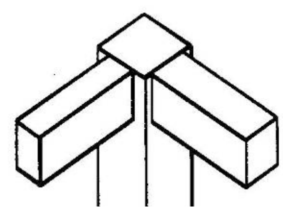
c) Corner
A.3



d) Roof
Interior B.1



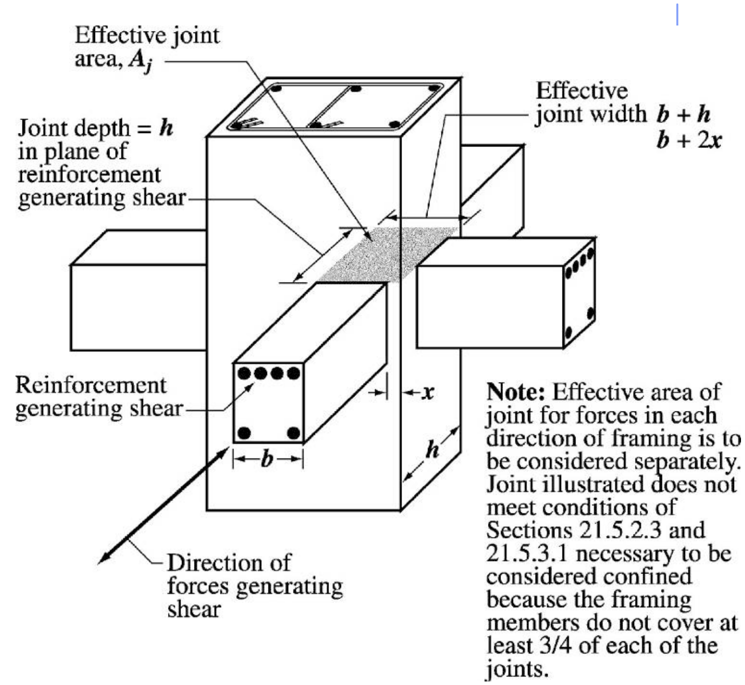
e) Roof
Exterior B.2



f) Roof
Corner B.3

Joint shear strength

- code-conforming joints -



$$V_u = \phi V_n = \phi \gamma \sqrt{f_c'} b_j h$$

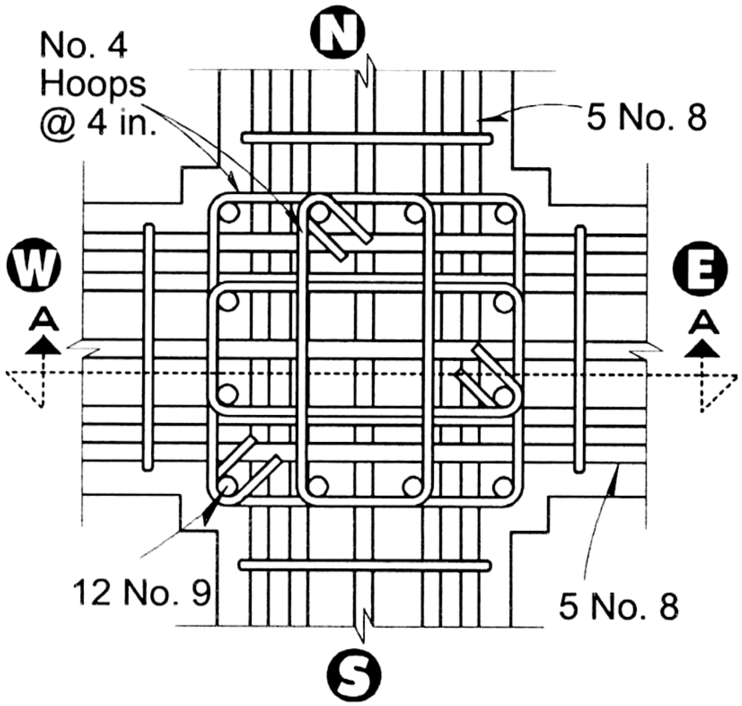
$$\phi = 0.85$$

Values of γ (ACI 352)

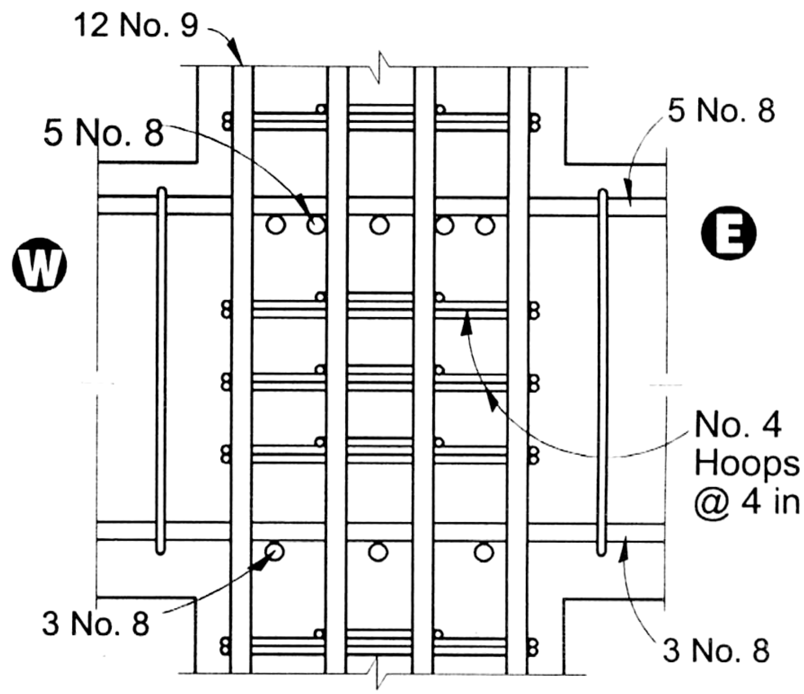
Classification /type	interior	exterior	corner
cont. column	20	15	12
Roof	15	12	8

ACI 352

Joint Details - Interior



Plan View of Connection
(Top beam bars)

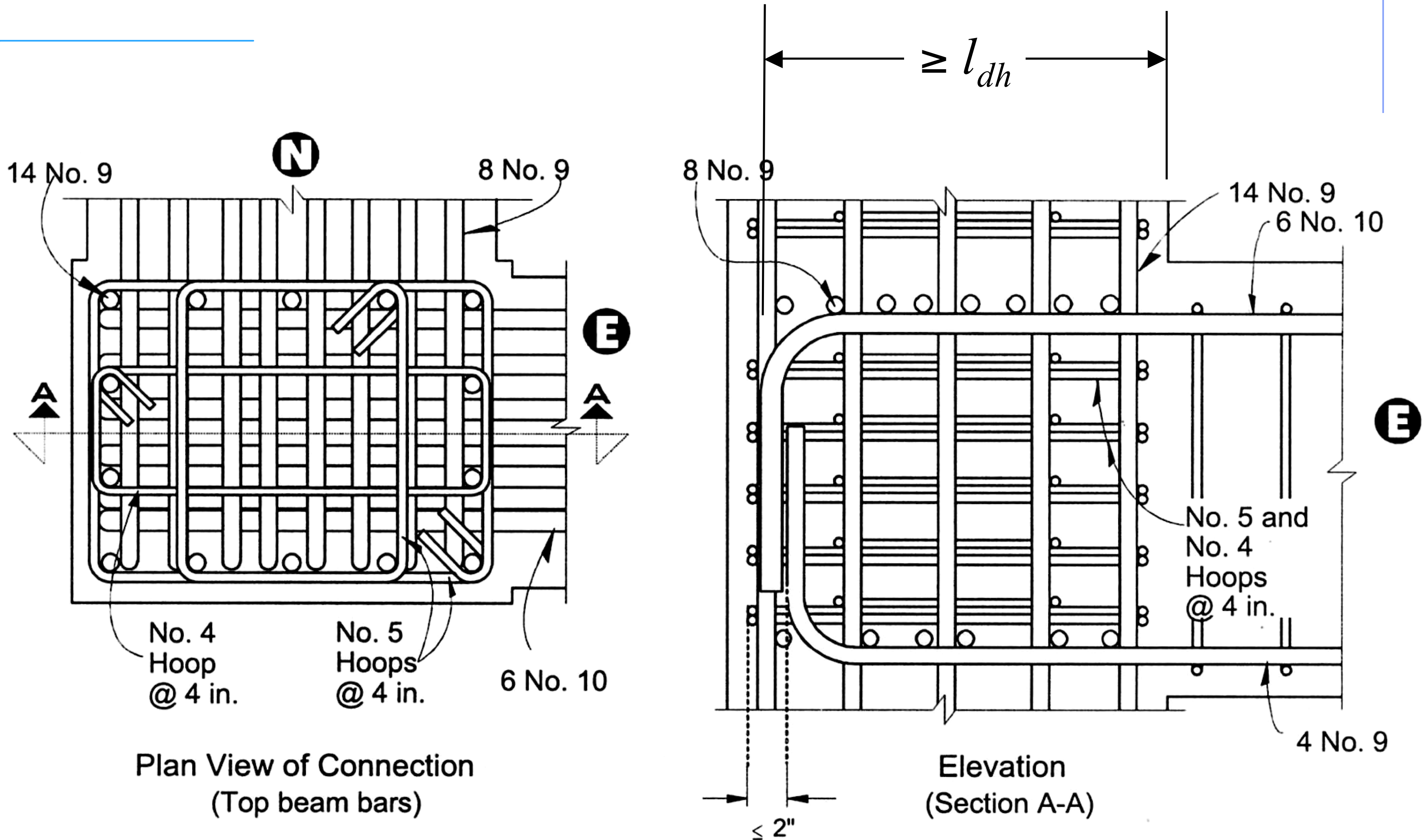


Elevation
(Section A-A)

$h_{col} \geq 20d_b$

ACI 352

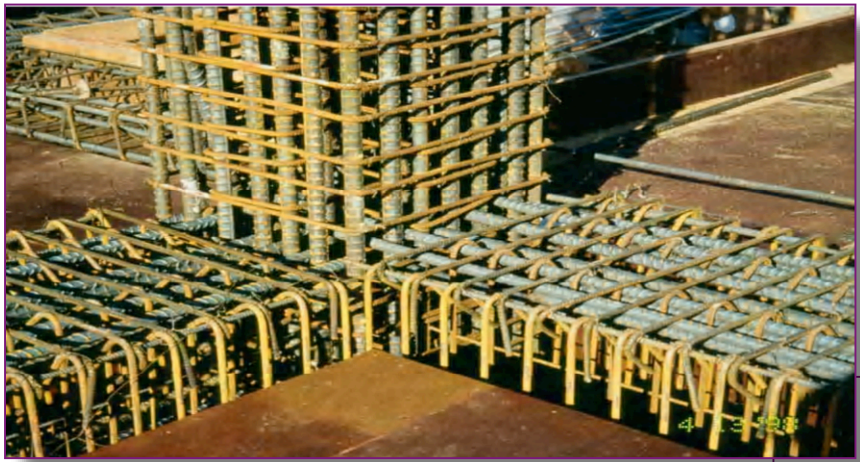
Joint Details - Corner



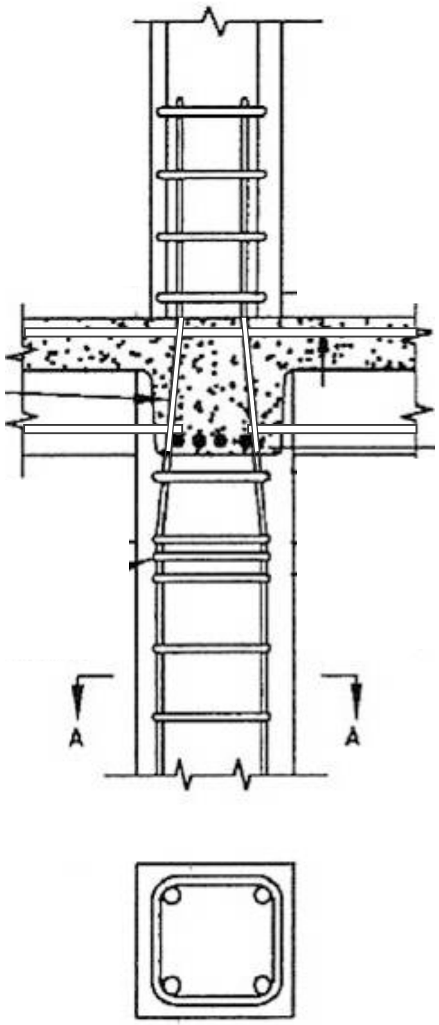
Plan View of Connection
(Top beam bars)

Elevation
(Section A-A)

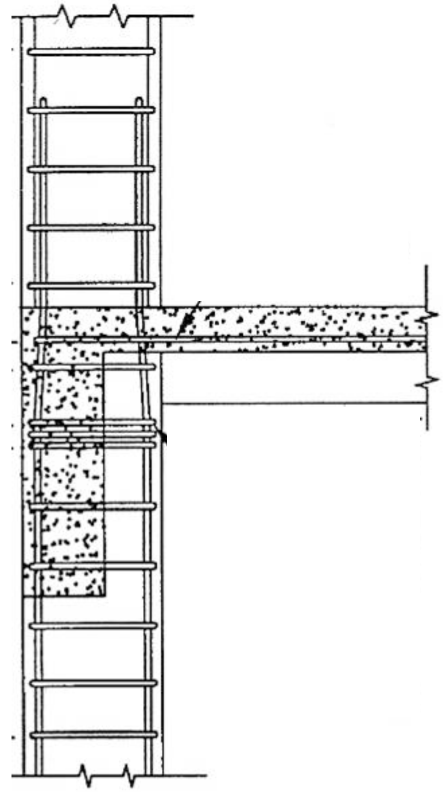
Code-conforming joints

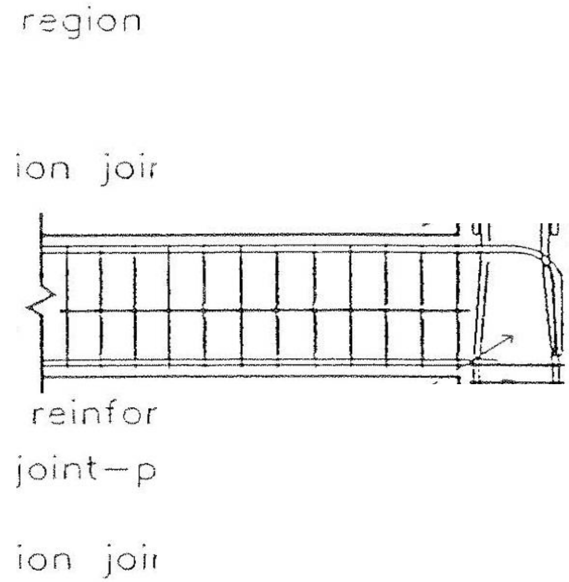


Older-type beam-column connections



SECTION A–A





Survey of existing buildings

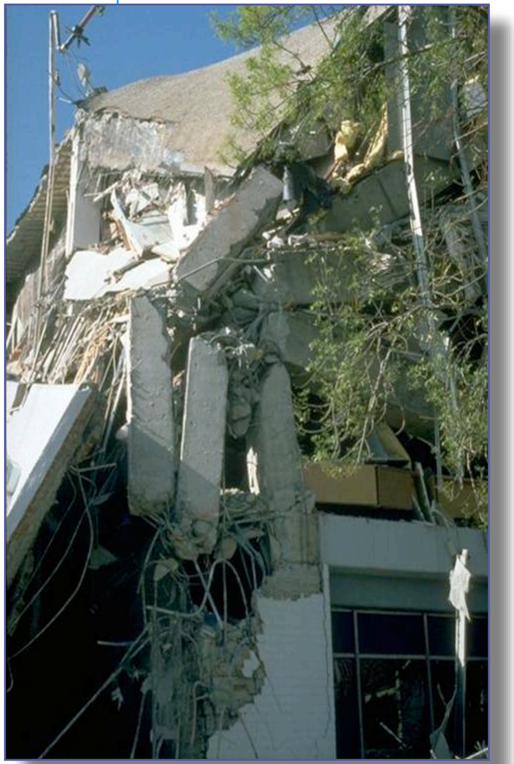
Table 3.3: Average Parameters for Pre 1967 Buildings

	Axial Load Ratio	Column Bar Splice Length (db)	Vol. Joint Reinf. Ratio	/
Average:				
Standard Deviation:				
Minimum:				
Maximum:				

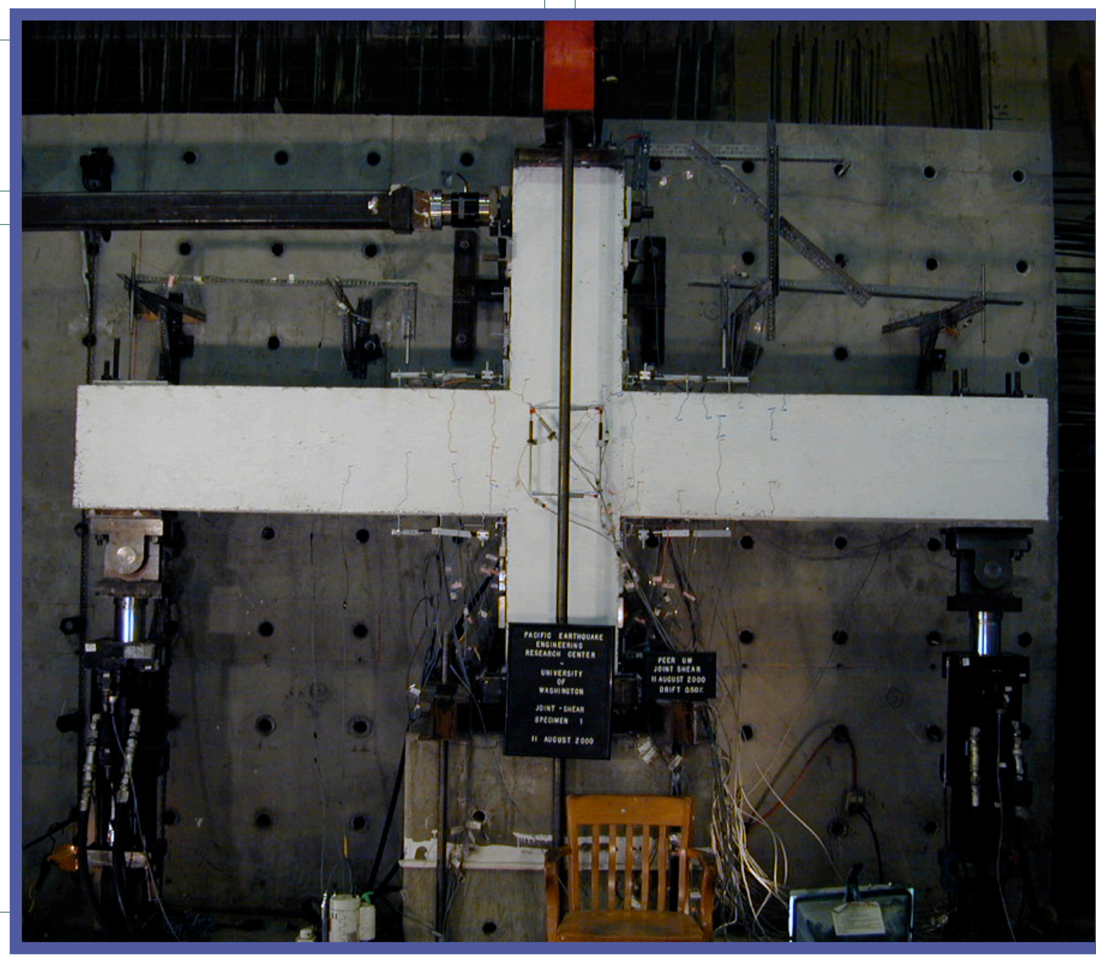
Table 3.4: Average Parameters for 1967-1975 Buildings

	Axial Load Ratio	Column Bar Splice Length	Vol. Joint Reinf. Ratio	/
Average:				
Standard Deviation:				
Minimum:				
Maximum:				

Joint failures



Studies of older-type joints



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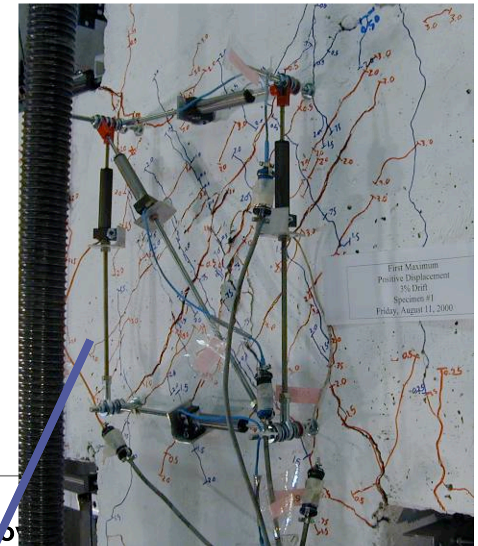
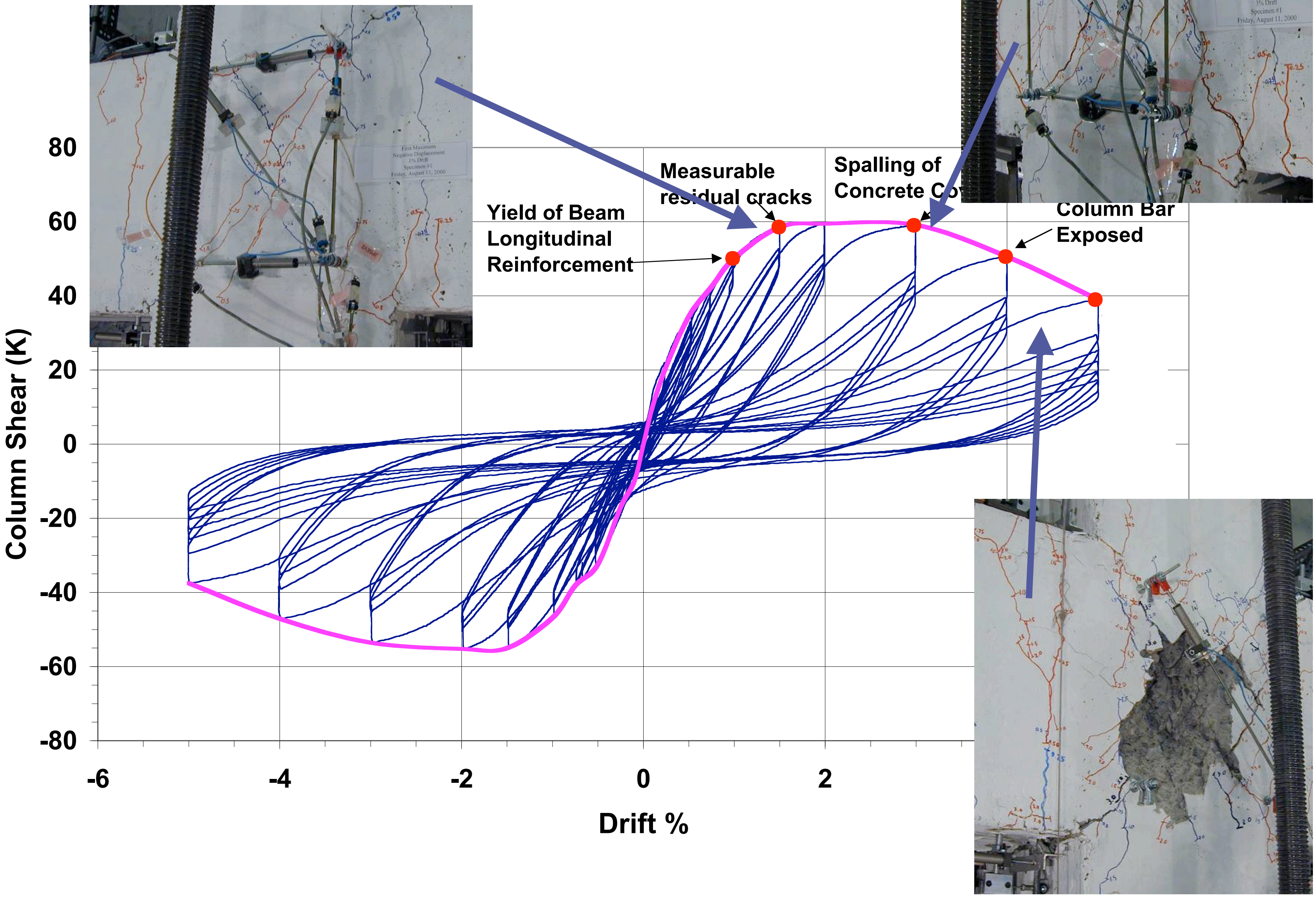
Damage progression

interior connections





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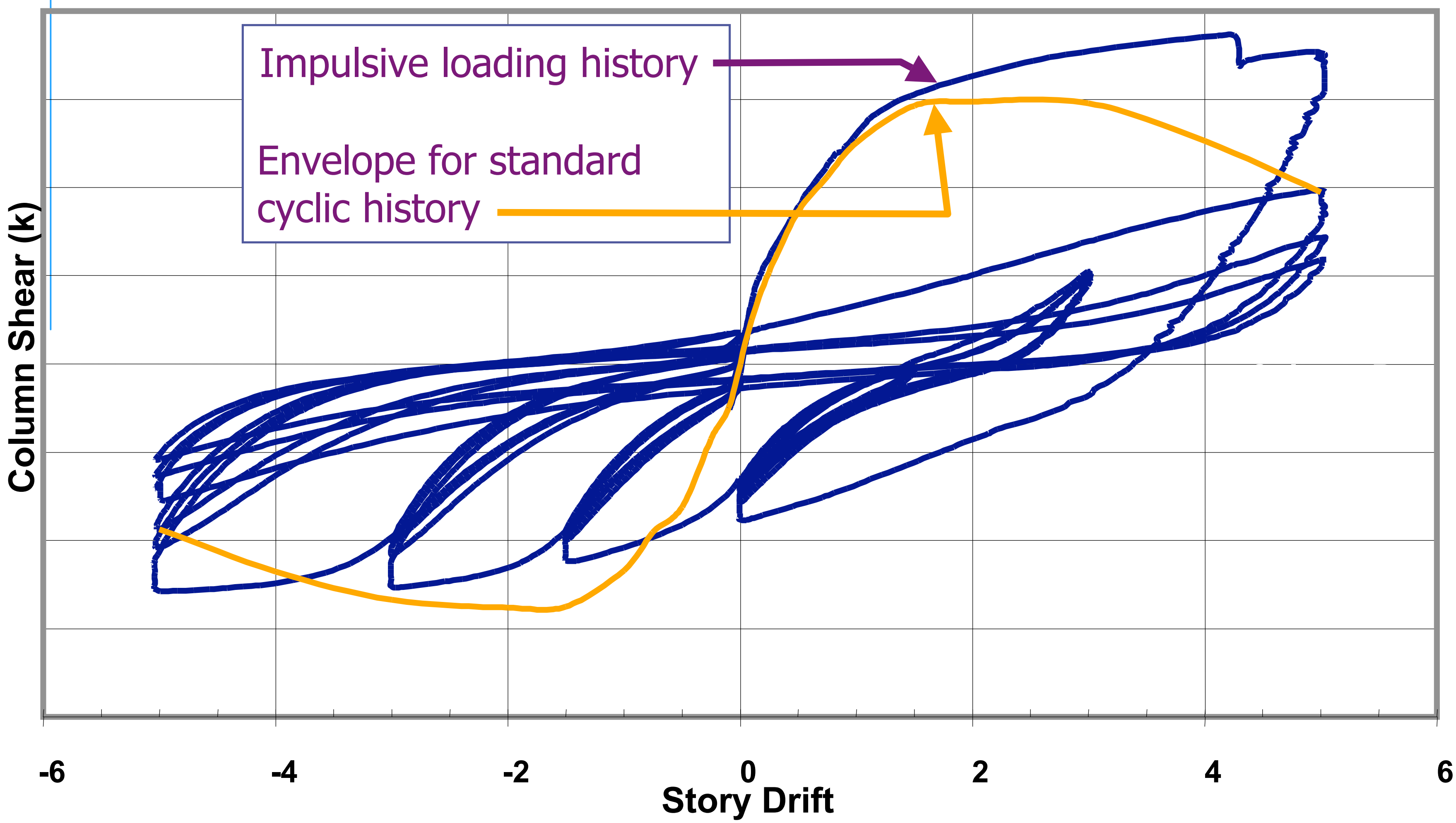
Effect of load history

interior connections



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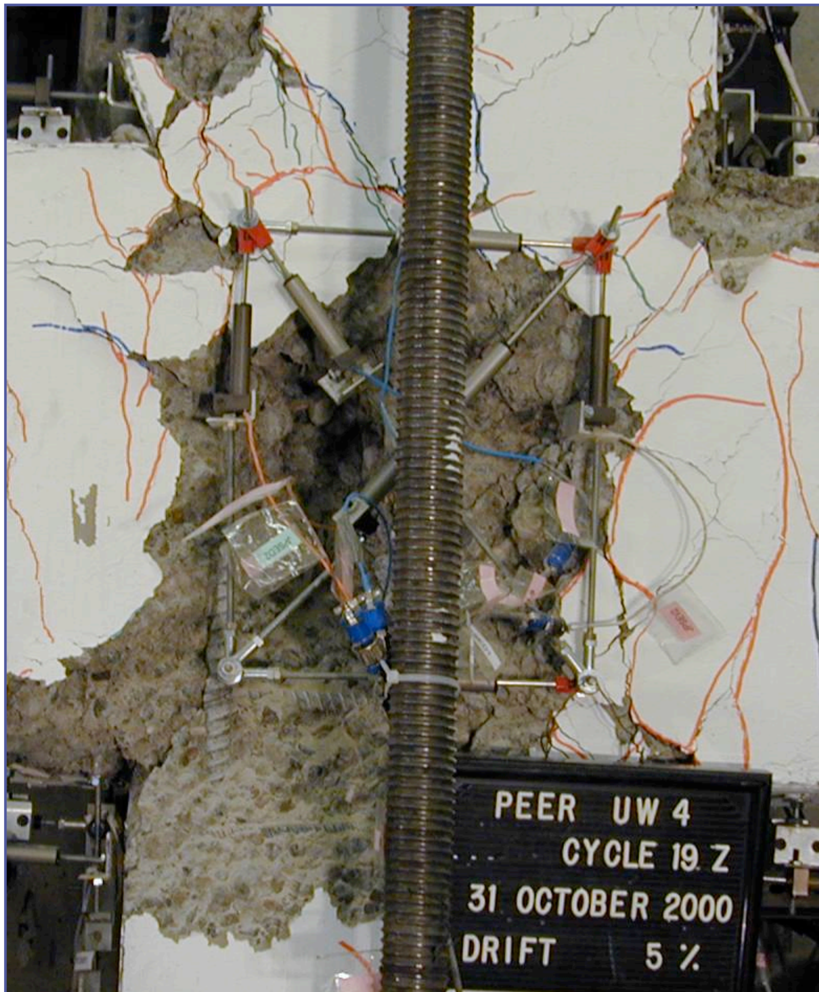
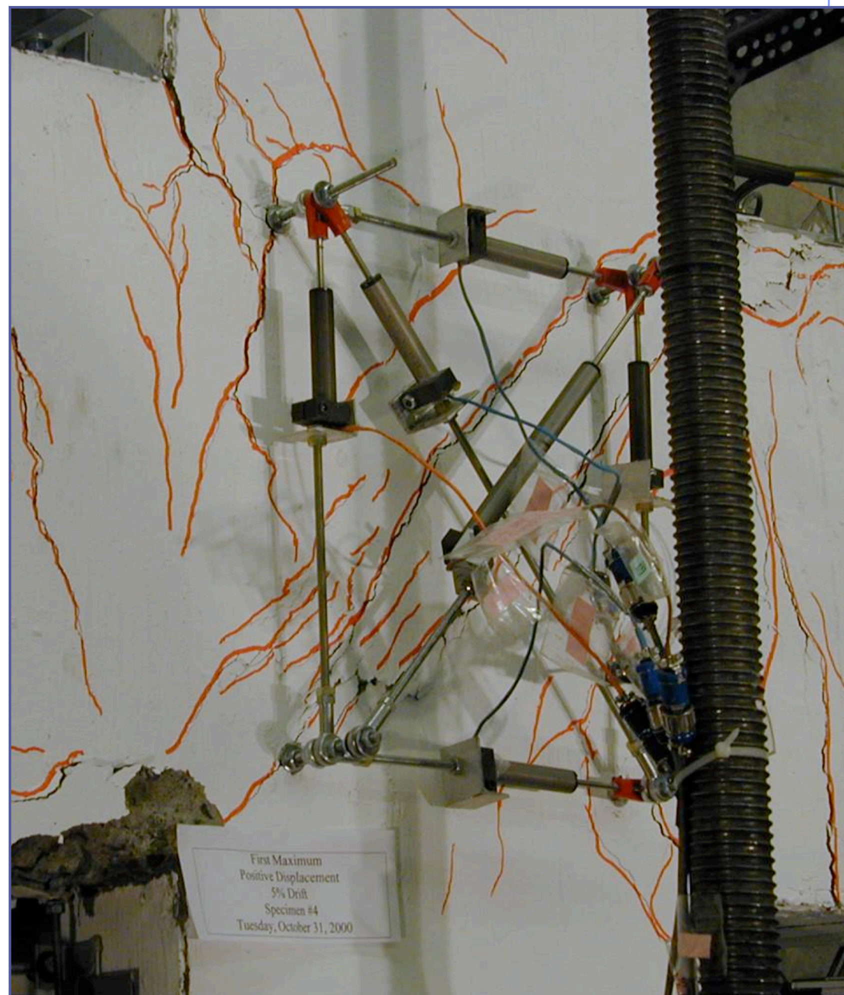
Damage at 5% drift

Standard Loading



Impulsive Loading



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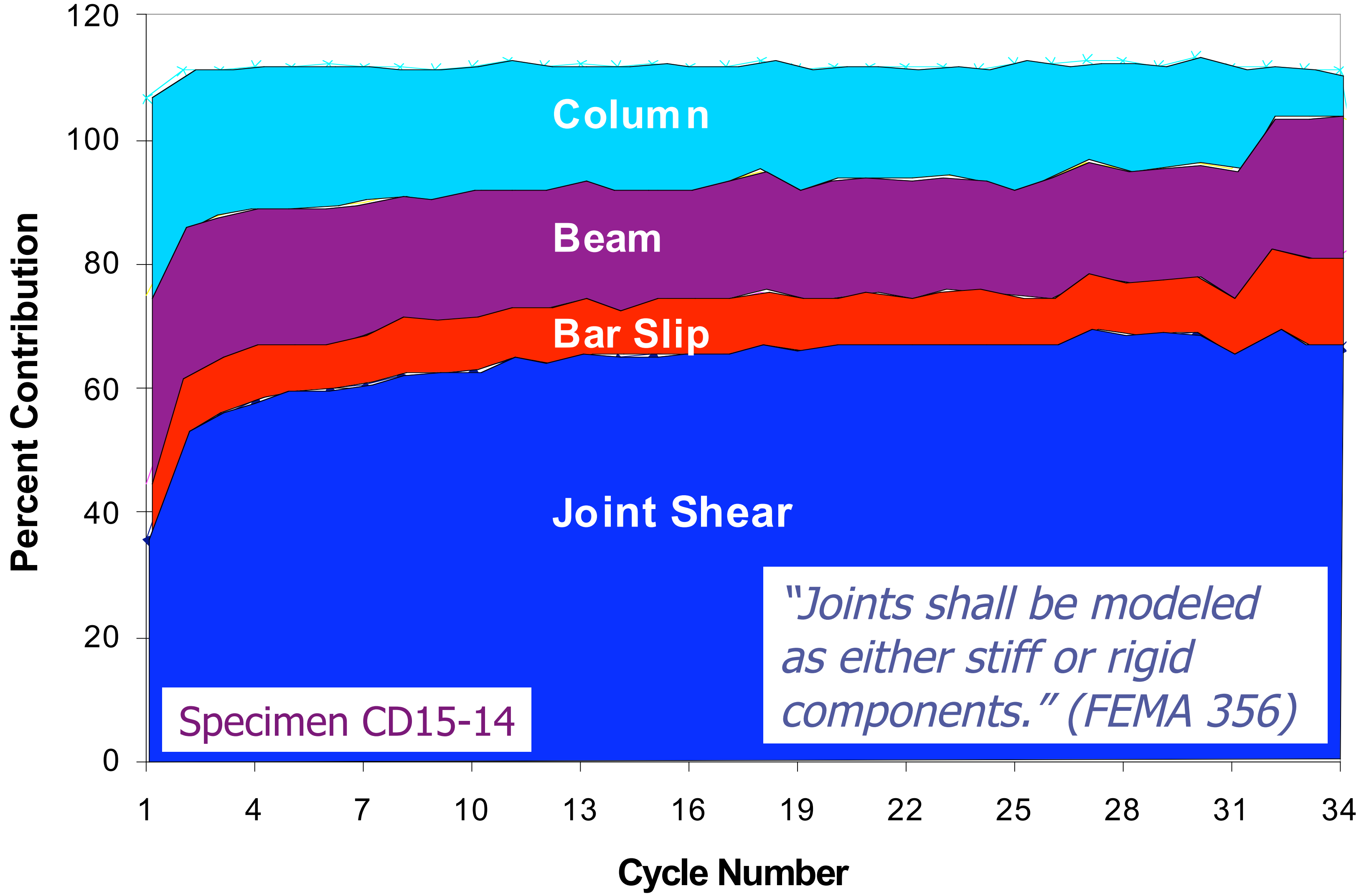
Contributions to drift
interior connections



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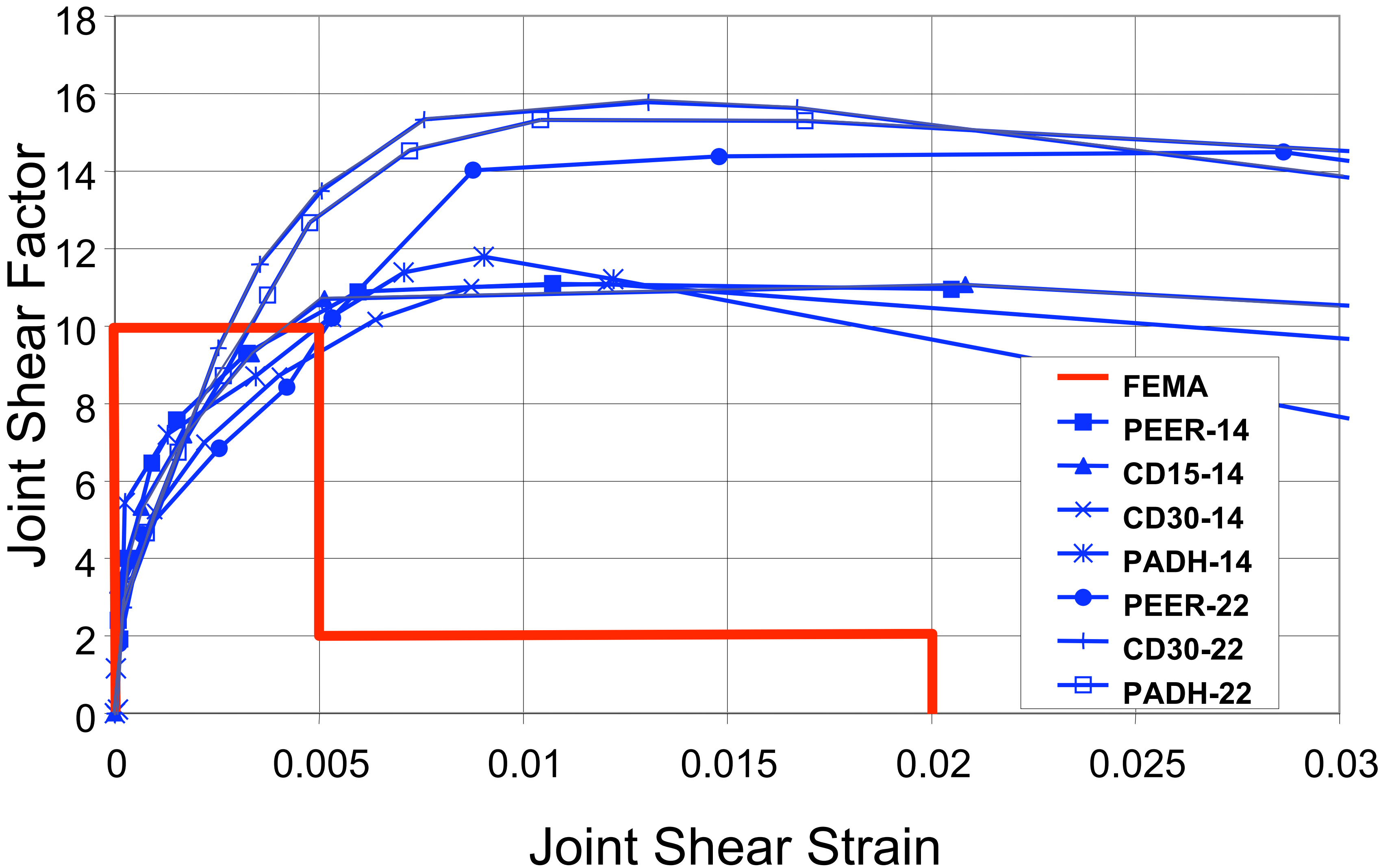
Evaluation of FEMA-356 Model

interior connections



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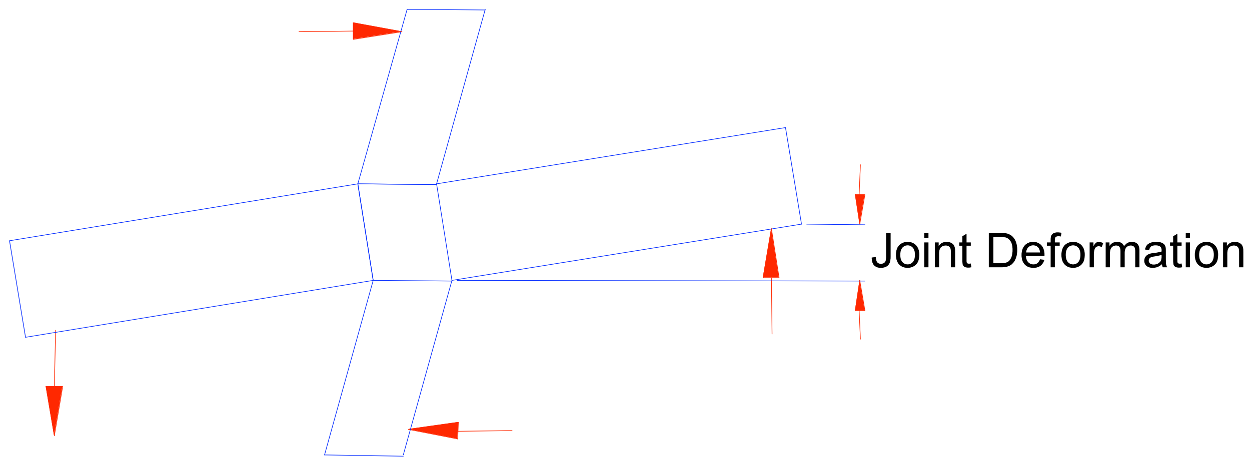
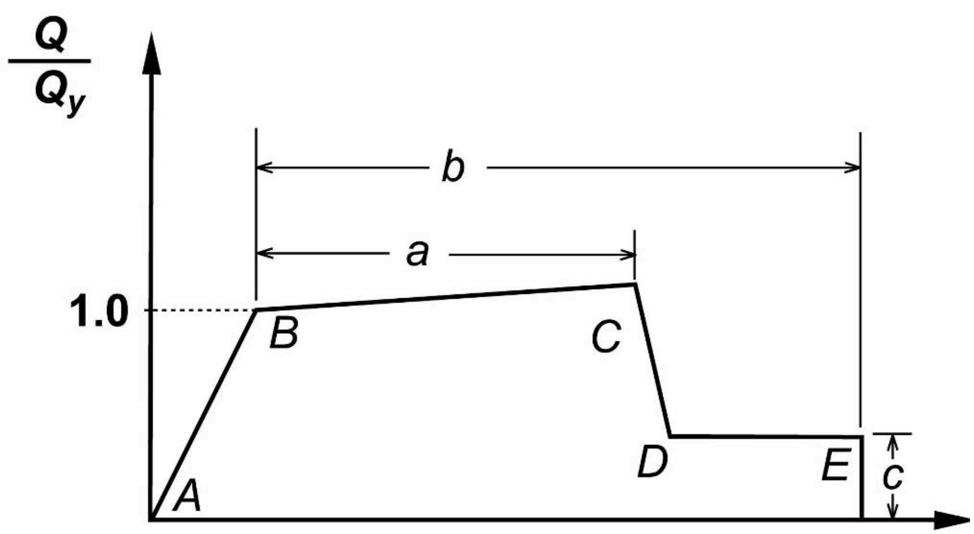
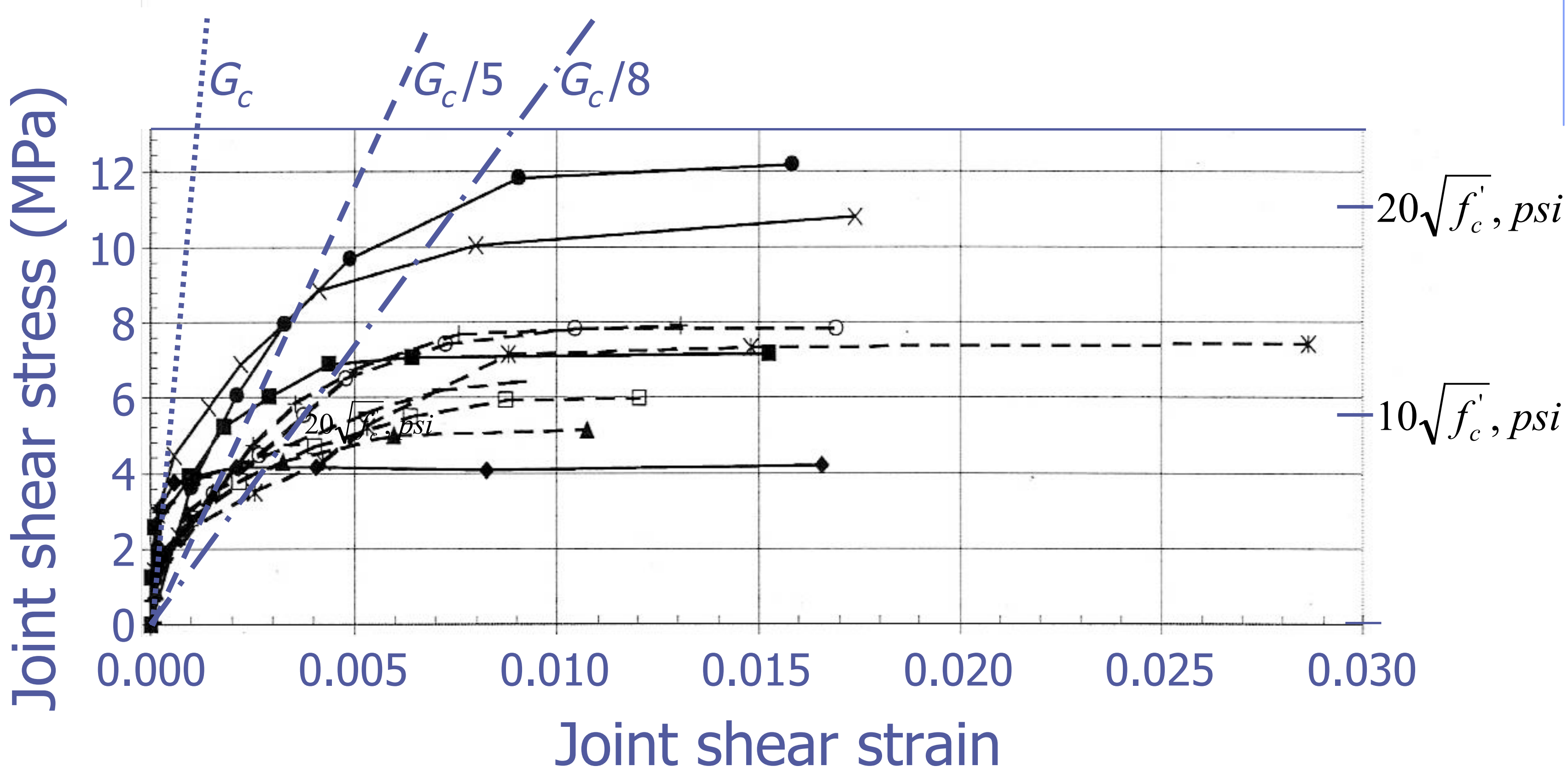
Joint panel deformations





Joint shear stiffness
interior connections



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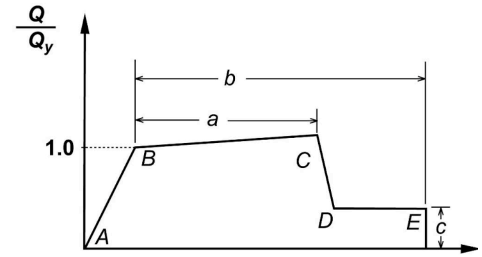
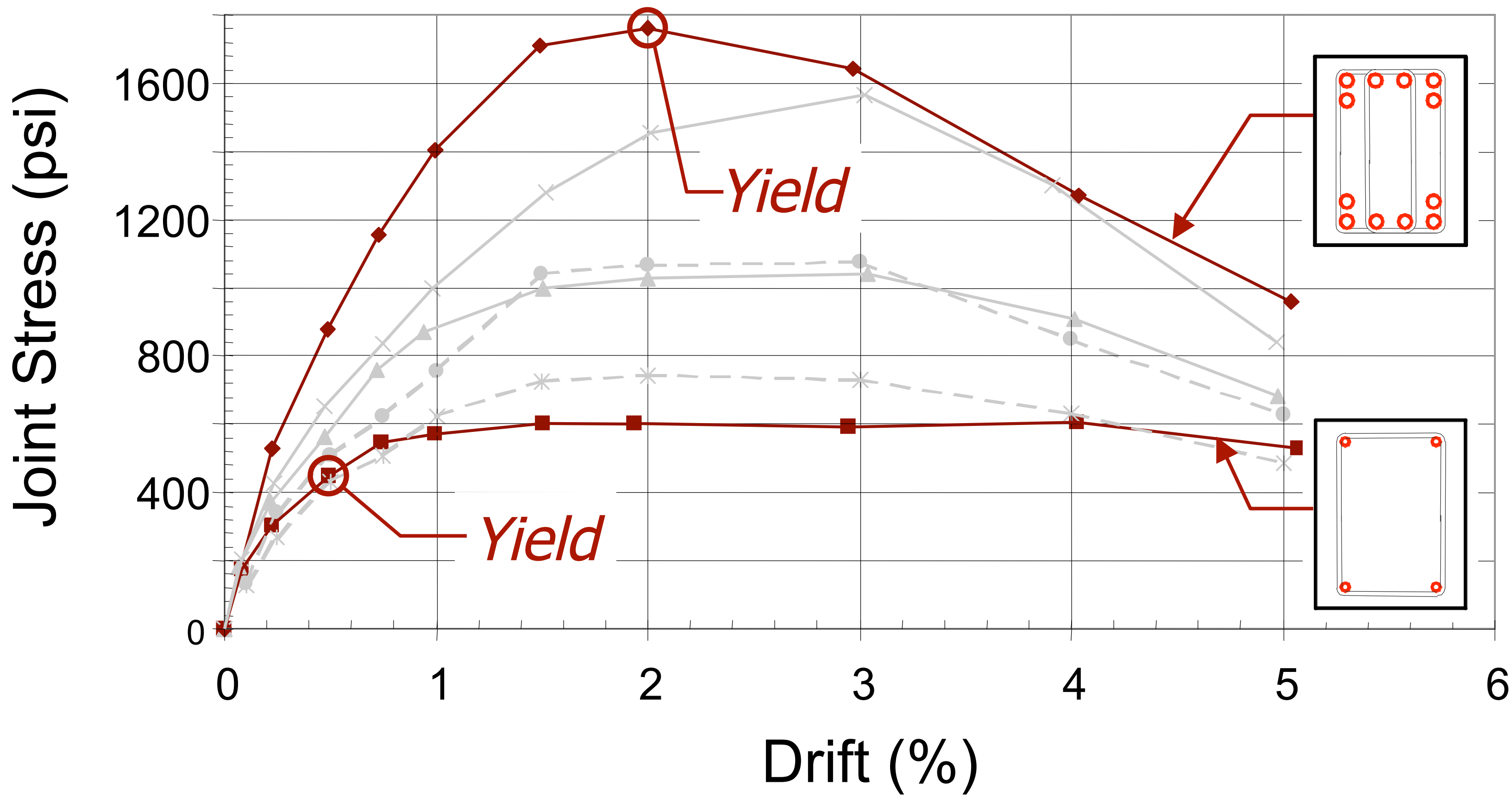
Joint strength

effect of beam yielding





- Joint strength closely linked to beam flexural strength
- Plastic deformation capacity higher for lower joint shear

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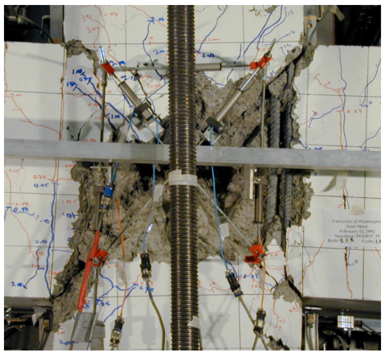
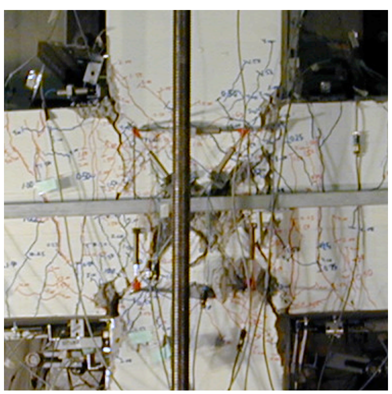
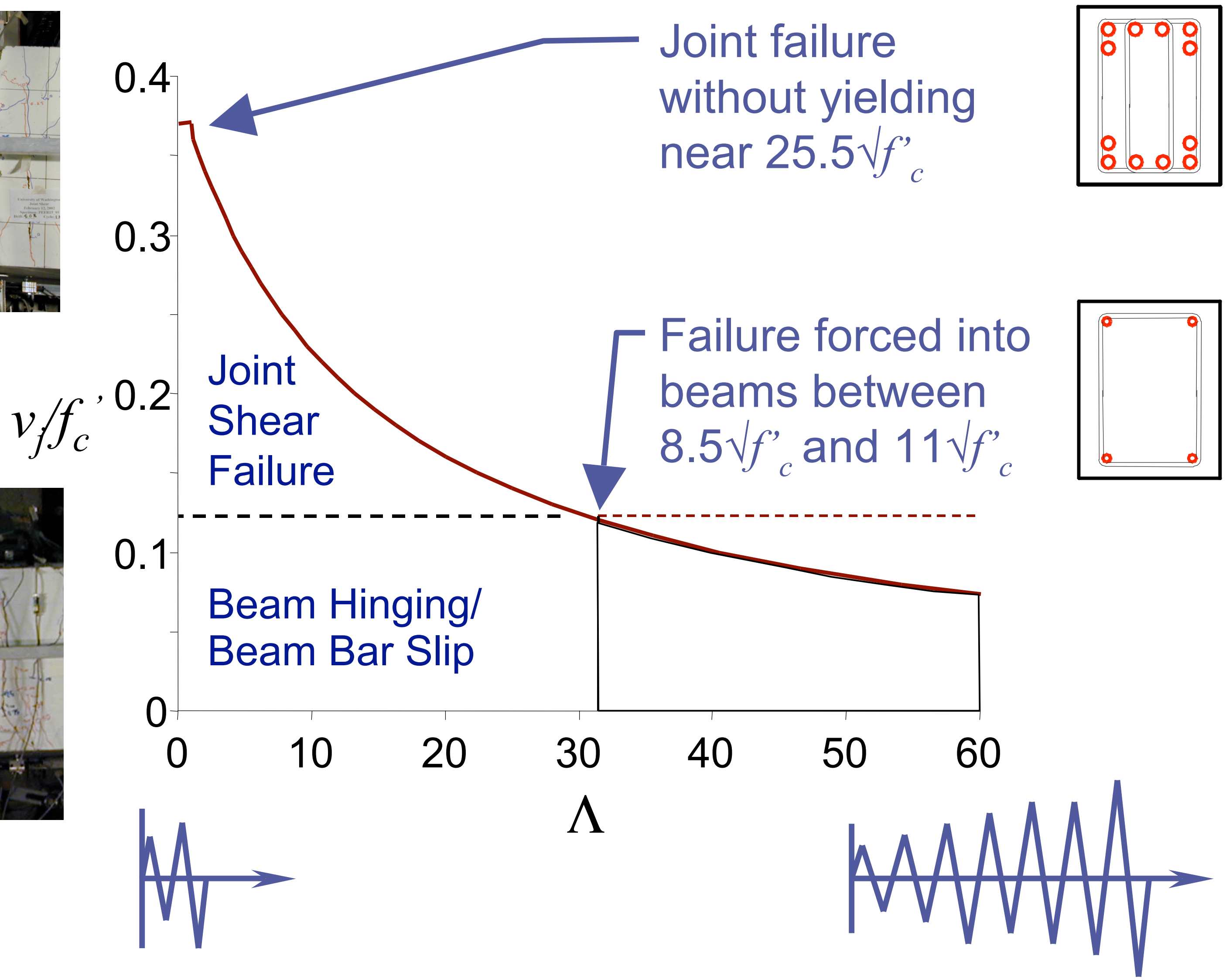
Joint strength

interior connections - lower/upper bounds







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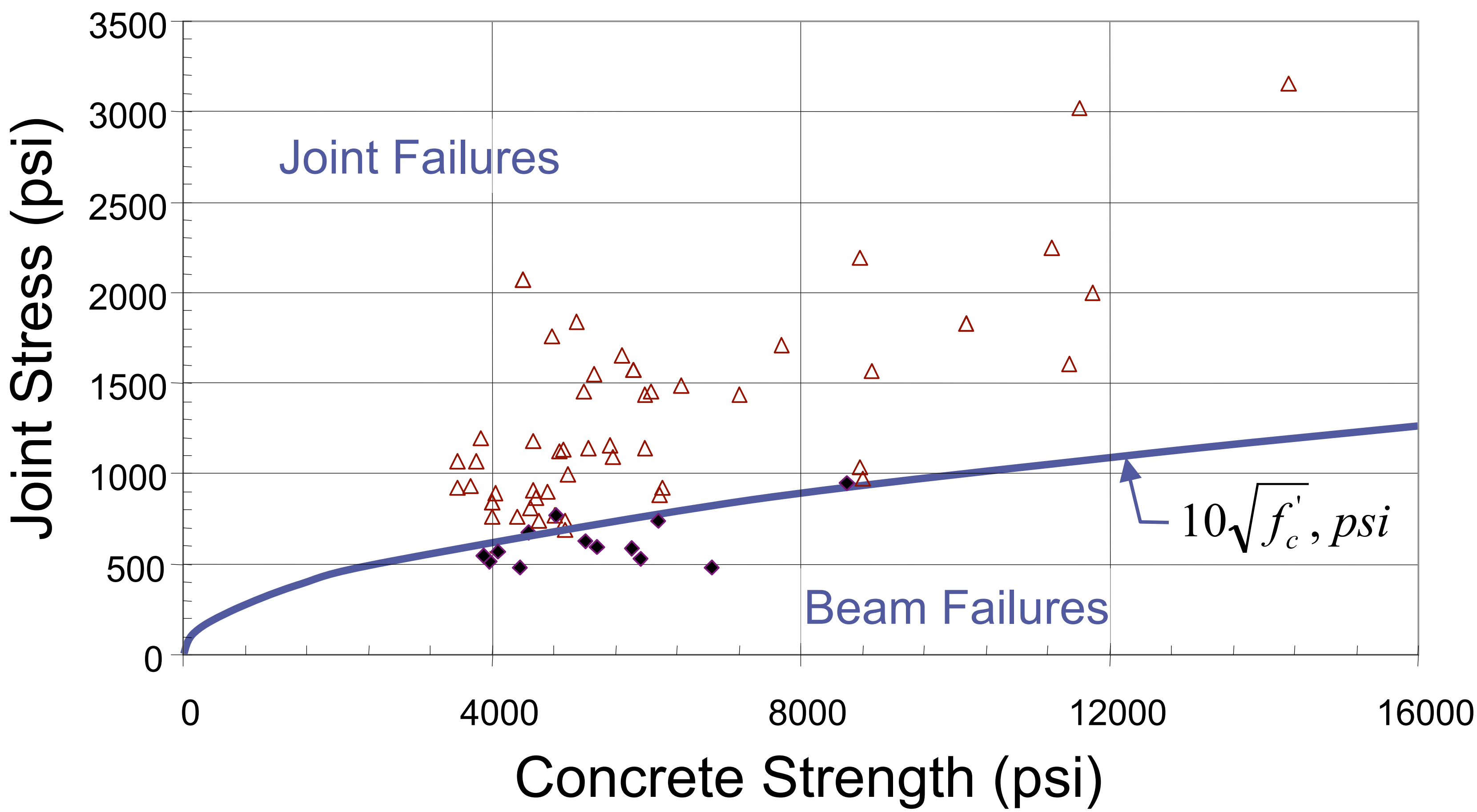
Joint strength

interior connections



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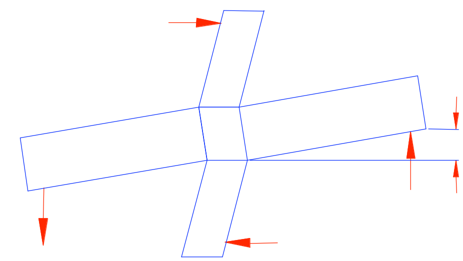
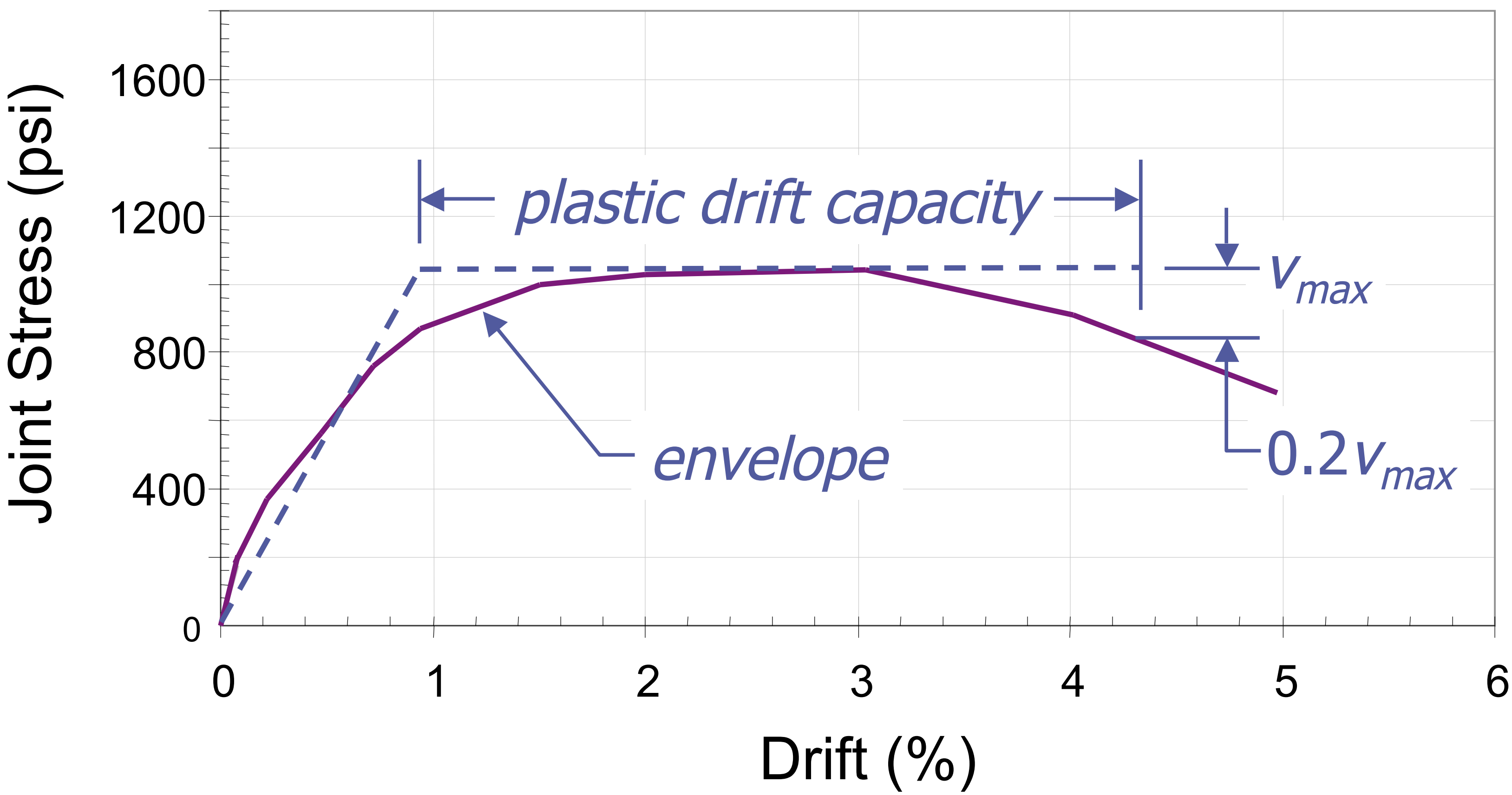
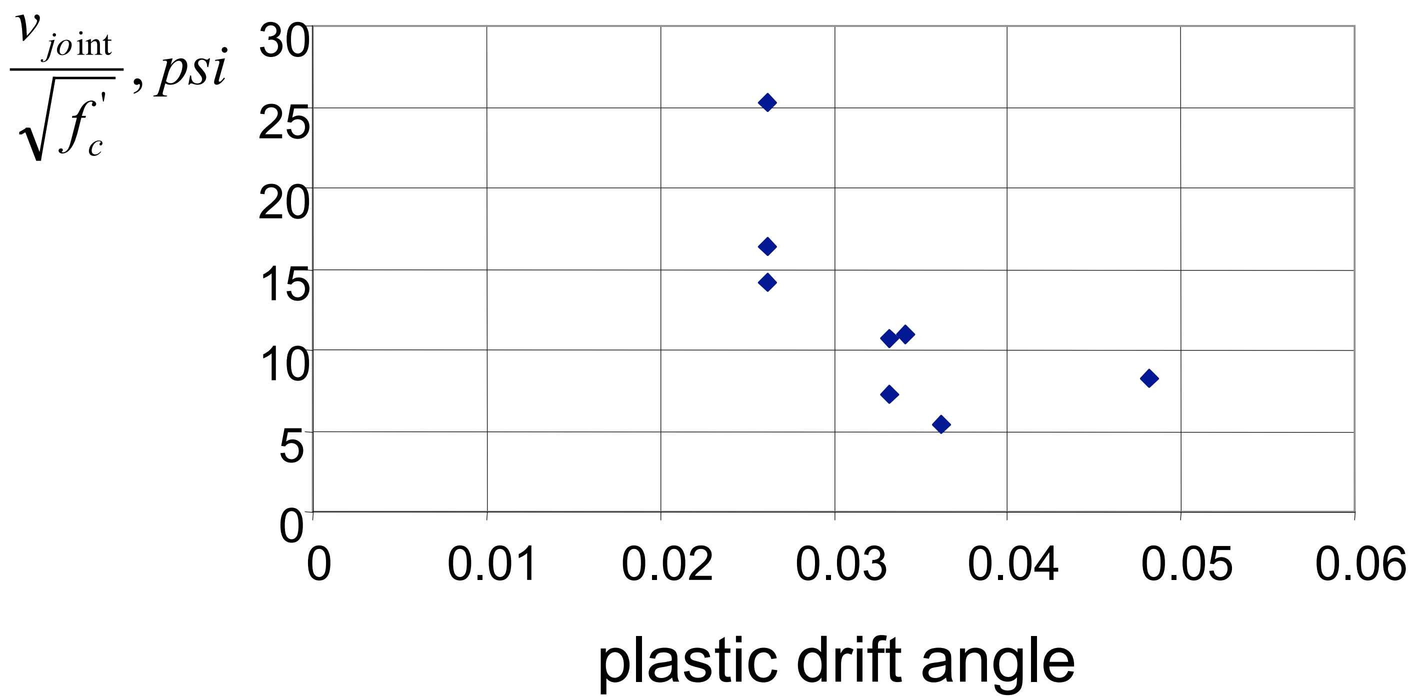
Joint deformability





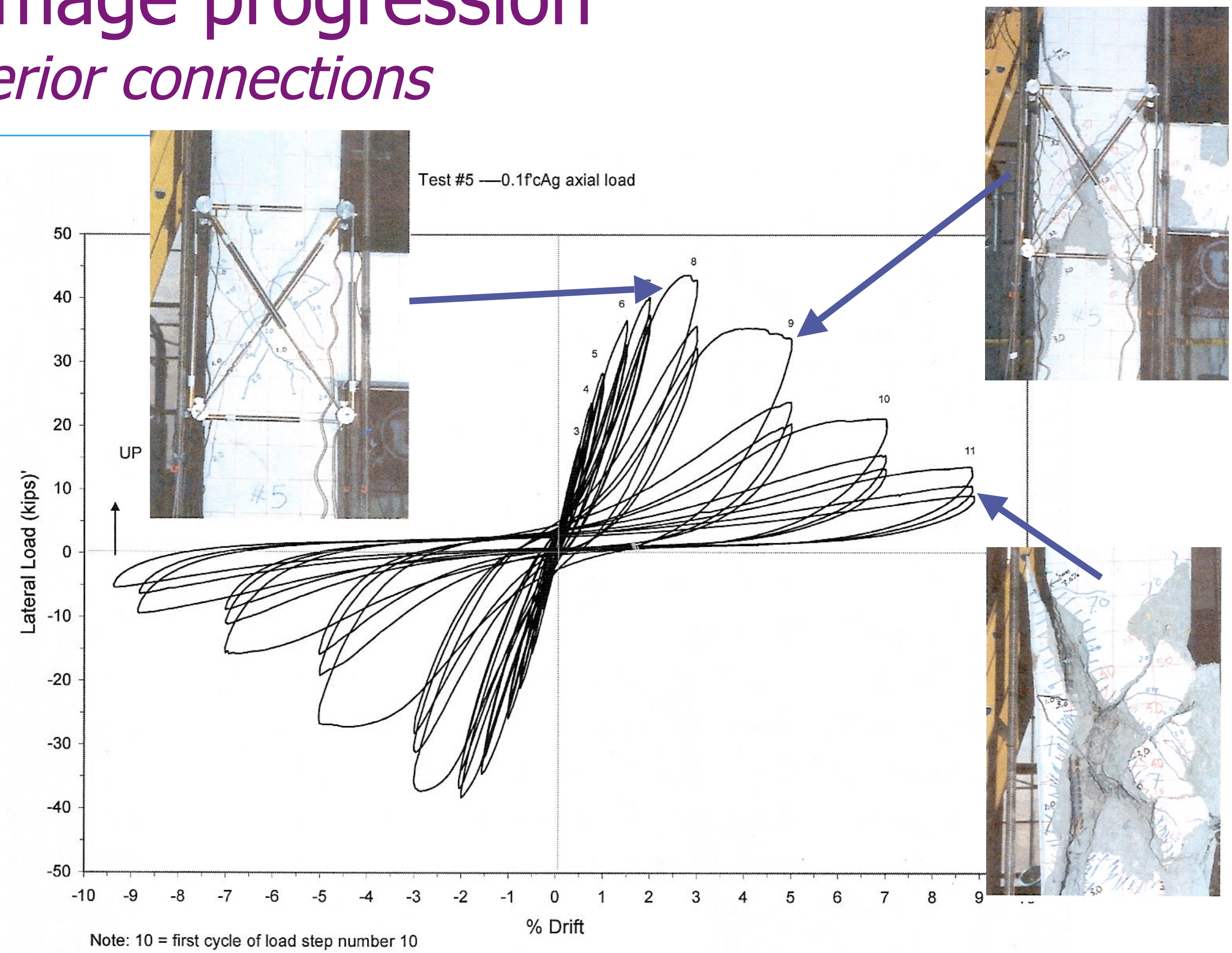
Plastic drift capacity

interior connections



Note: the plastic drift angle includes inelastic deformations of the beams

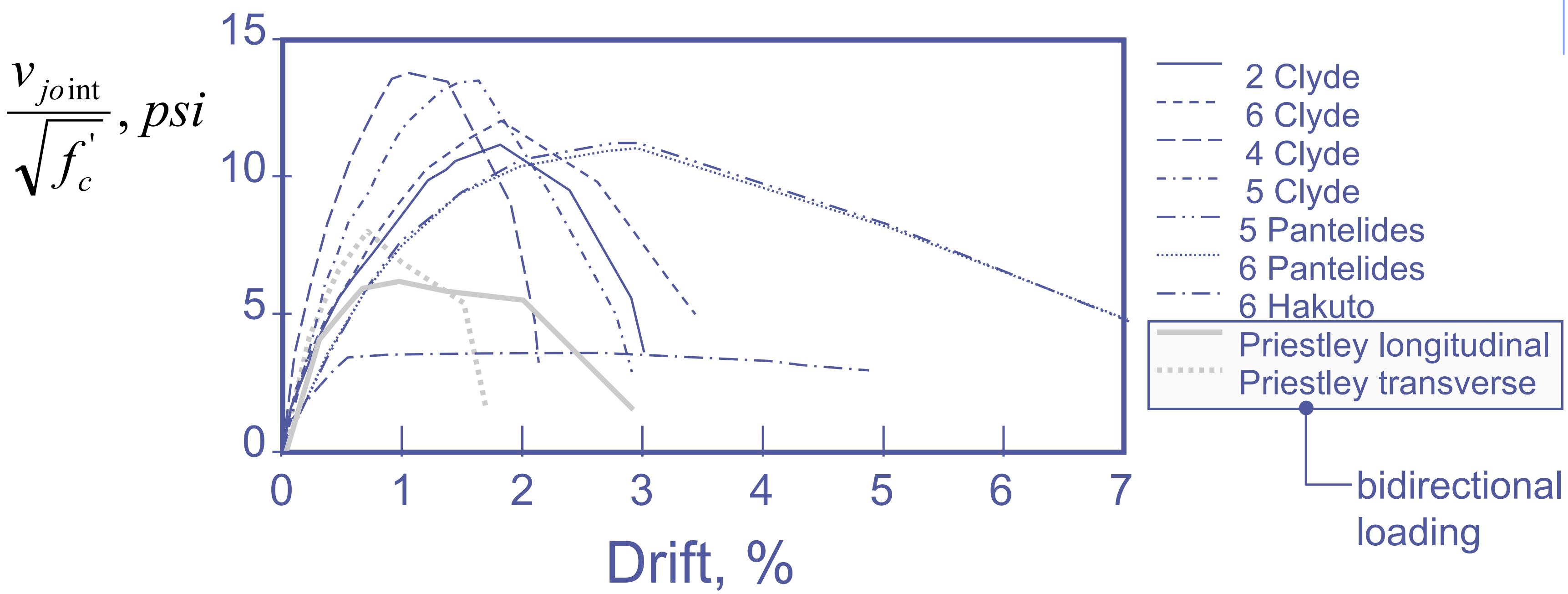
Damage progression
exterior connections



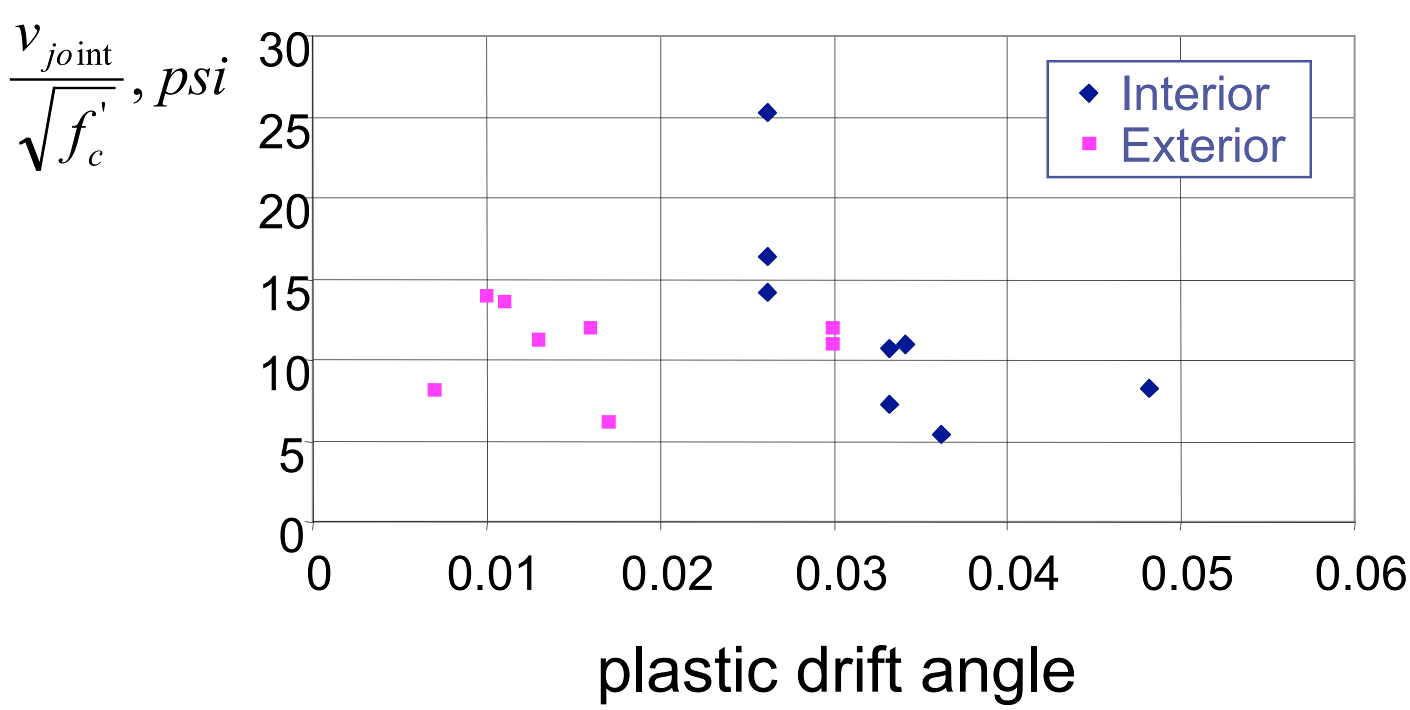
Pantelides, 2002

Joint behavior

exterior connections



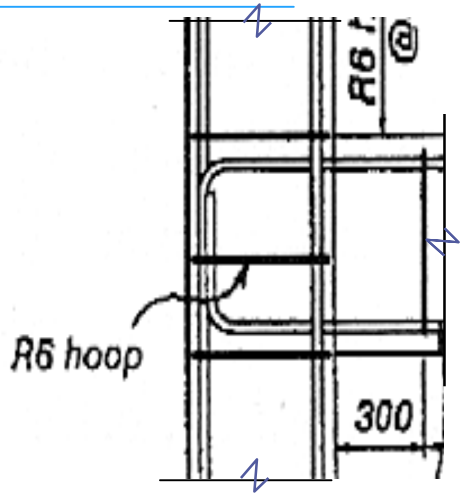
Plastic drift capacity



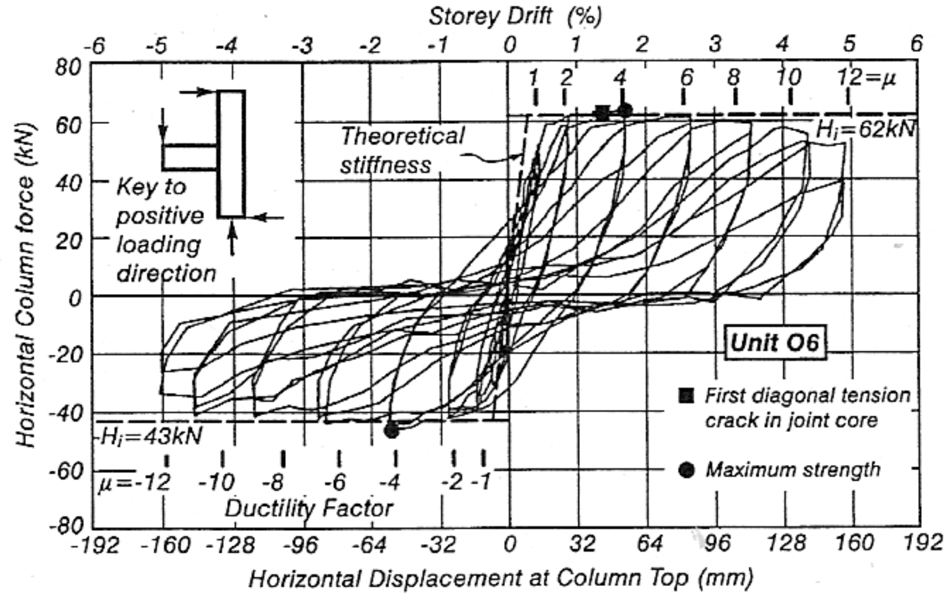
Note: the plastic drift angle includes inelastic deformations of the beams

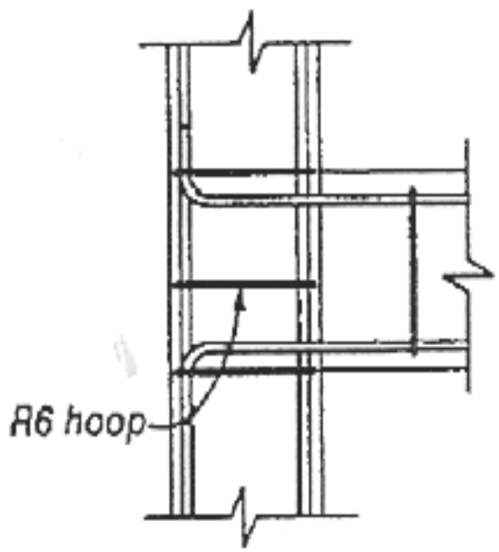
Exterior joint

hook detail

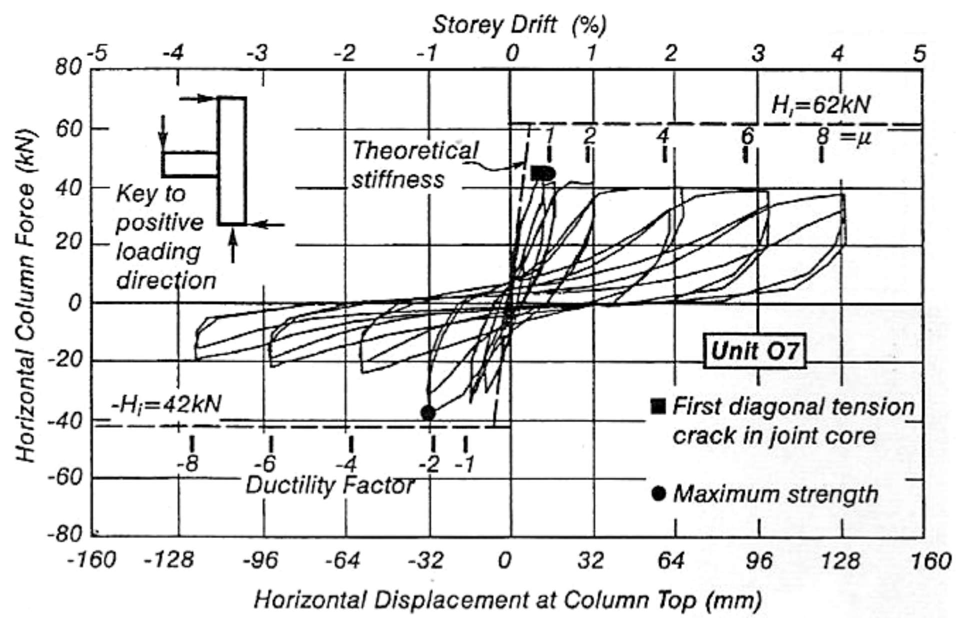


hook bent into joint

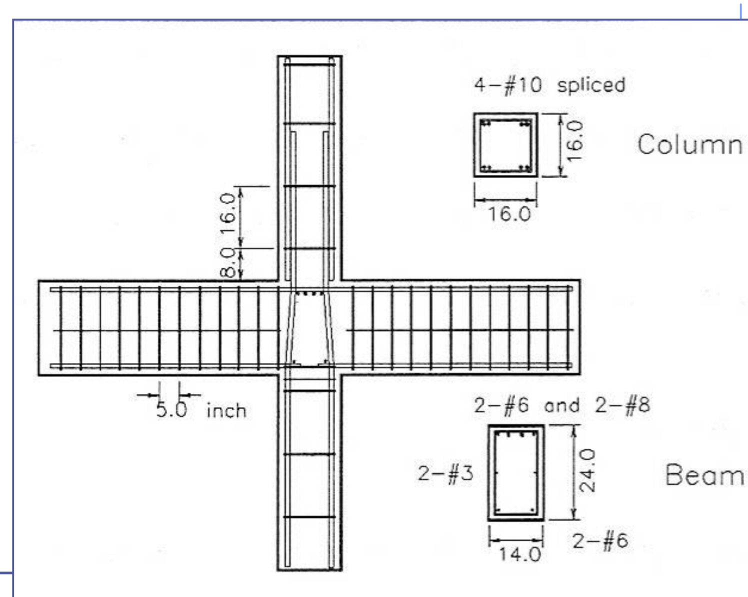


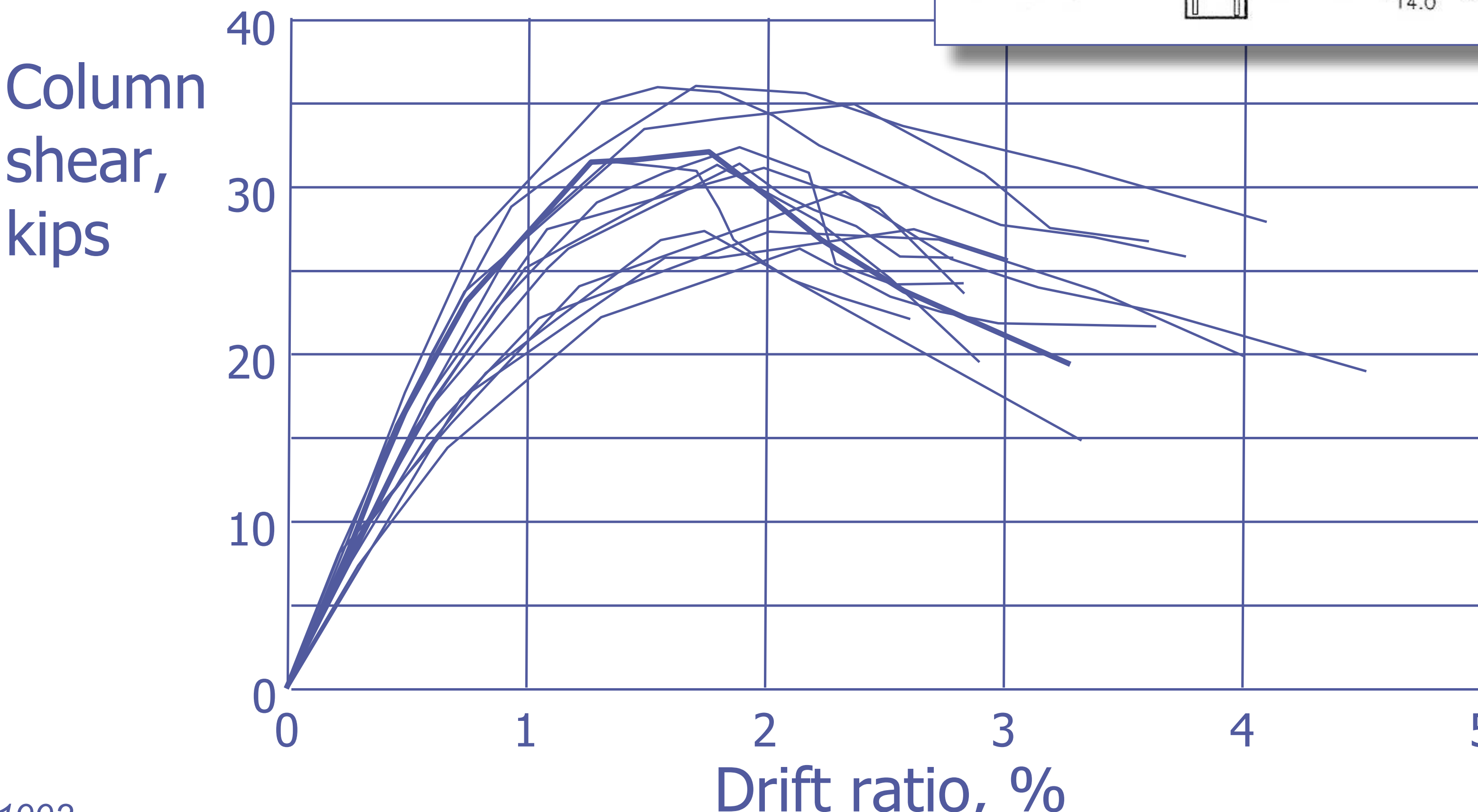


hook bent out of joint



Interior joints with discontinuous bars



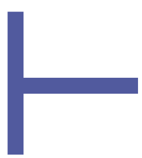
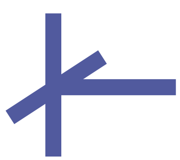
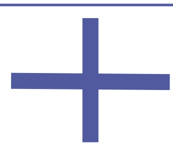
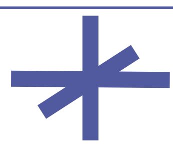


Beres, 1992

Unreinforced Joint Strength

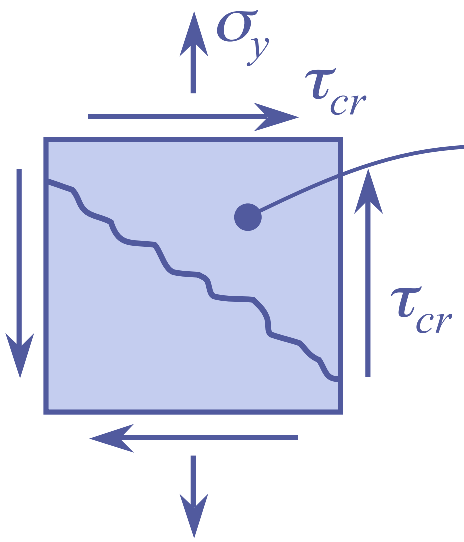
FEMA 356 specifies the following:

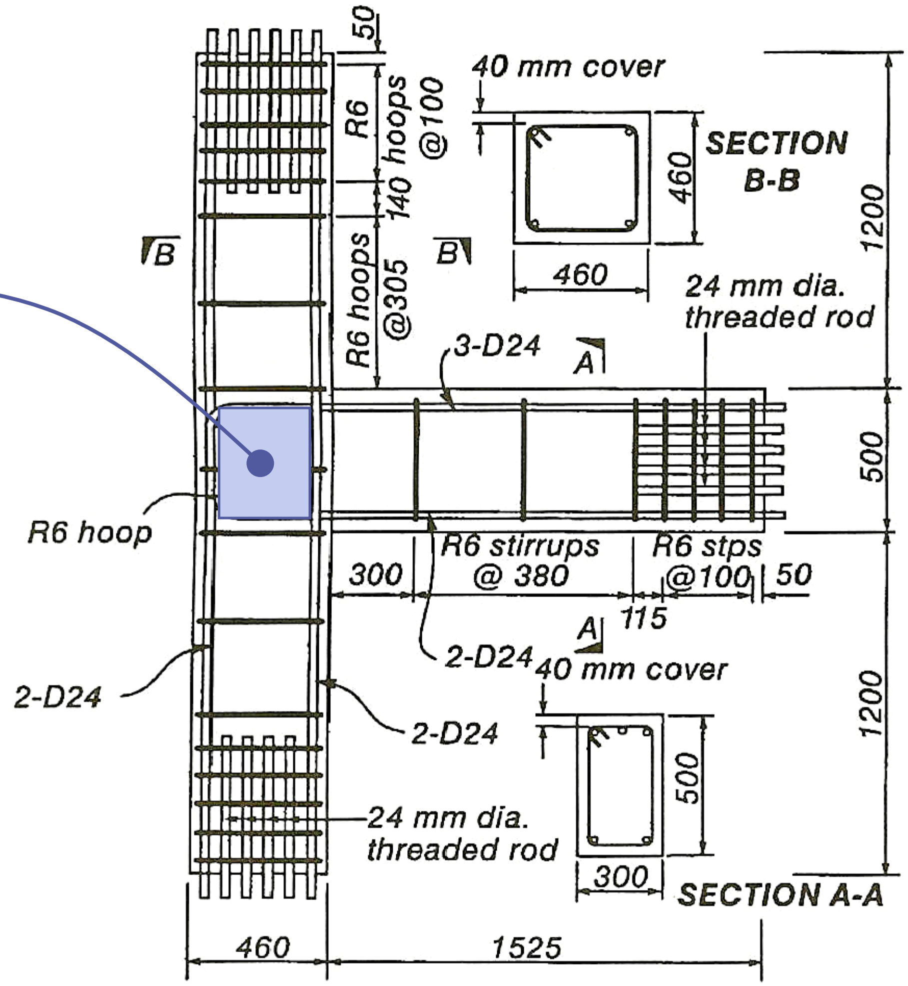
$$V_j = \gamma \sqrt{f_c'}\, bh$$

joint geometry	γ
	4
	6
	8
	10
	12

- No new data. Probably still valid.
- Assuming bars are anchored in joint, strength limited by strength of framing members, with upper-bound of $\gamma \approx 15$. For $15 \geq \gamma \geq 4$, joint failure may occur after inelastic response. For $\gamma \leq 4$, joint unlikely to fail.
- Assuming bars are anchored in joint, strength limited by strength of framing members, with upper bound of $\gamma \approx 25$. For $25 \geq \gamma \geq 8$, joint failure may occur after inelastic response. For $\gamma \leq 8$, joint unlikely to fail.

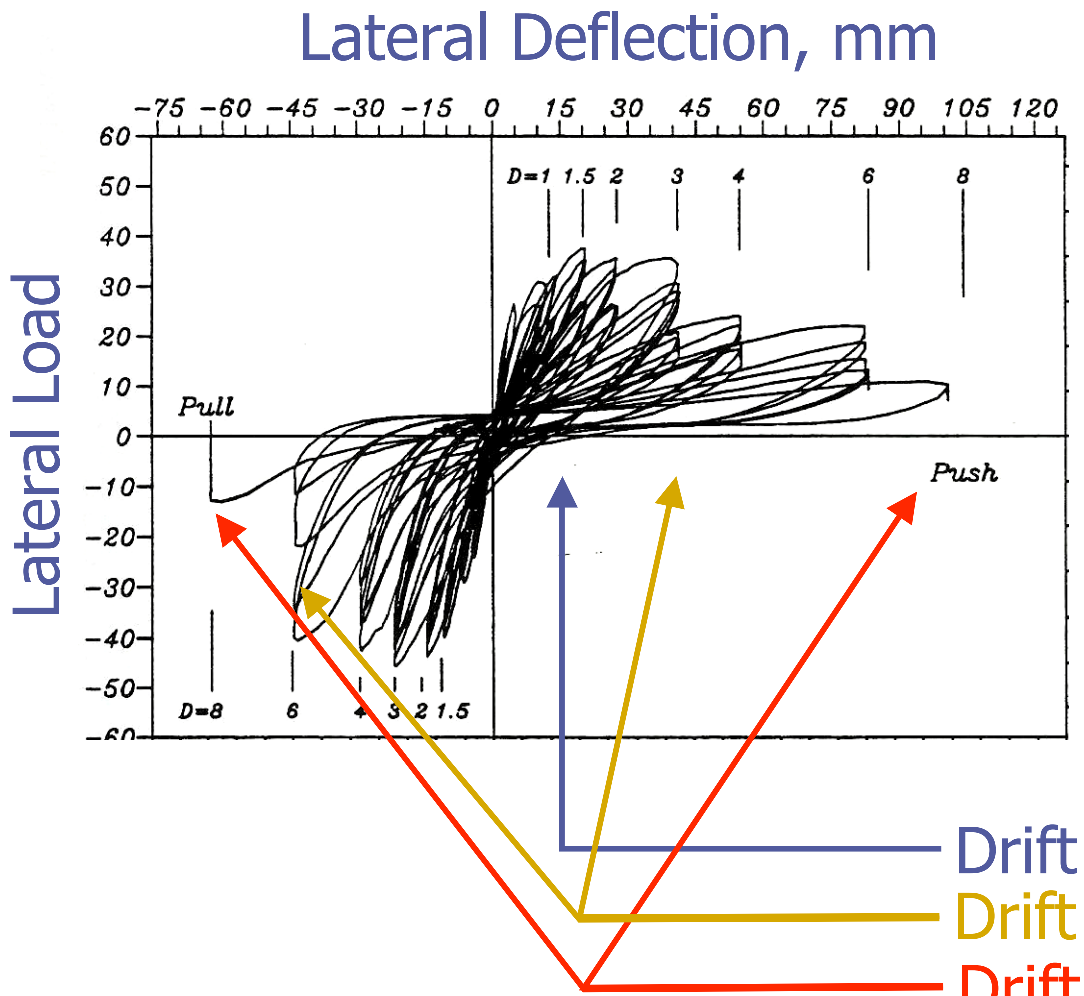
Joint failure?

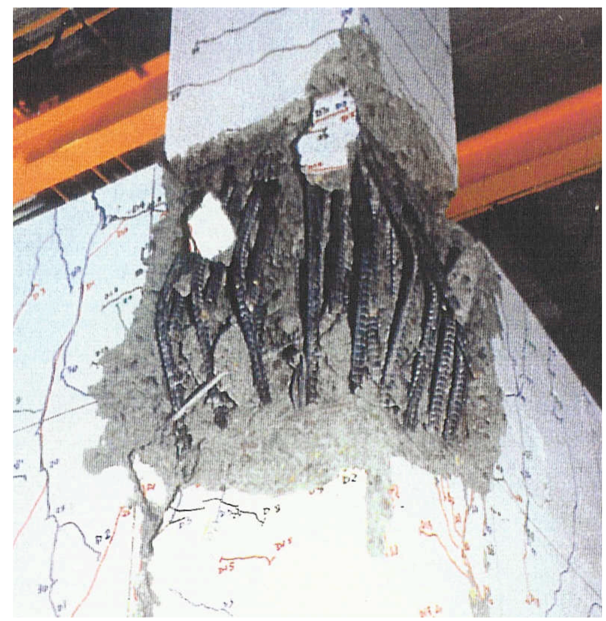




$$\tau_{cr} = 6\sqrt{f_c^{'}}\sqrt{1 - \frac{\sigma_y}{6\sqrt{f_c^{'}}}}$$, psi

Joint failure?

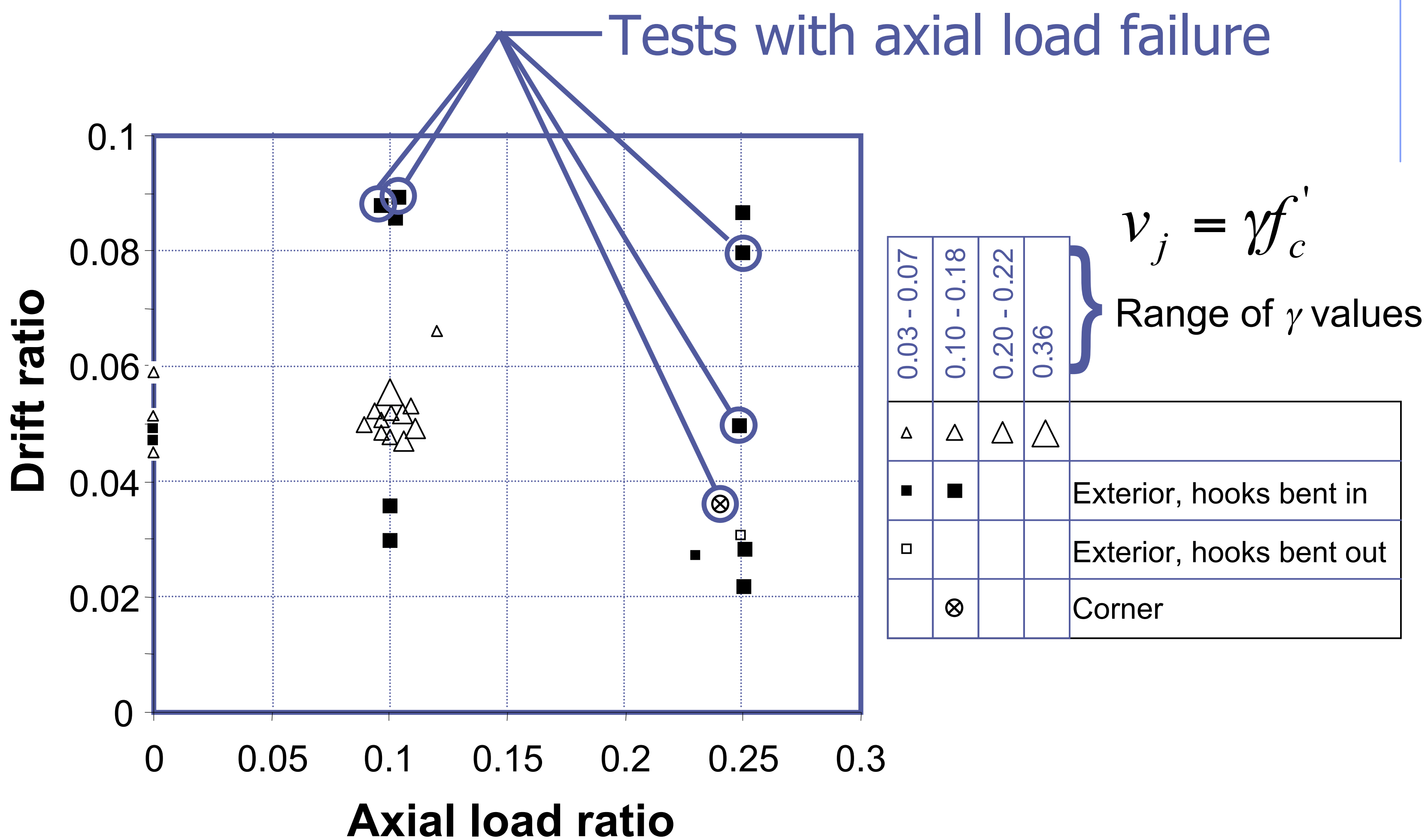




Priestley, 1994

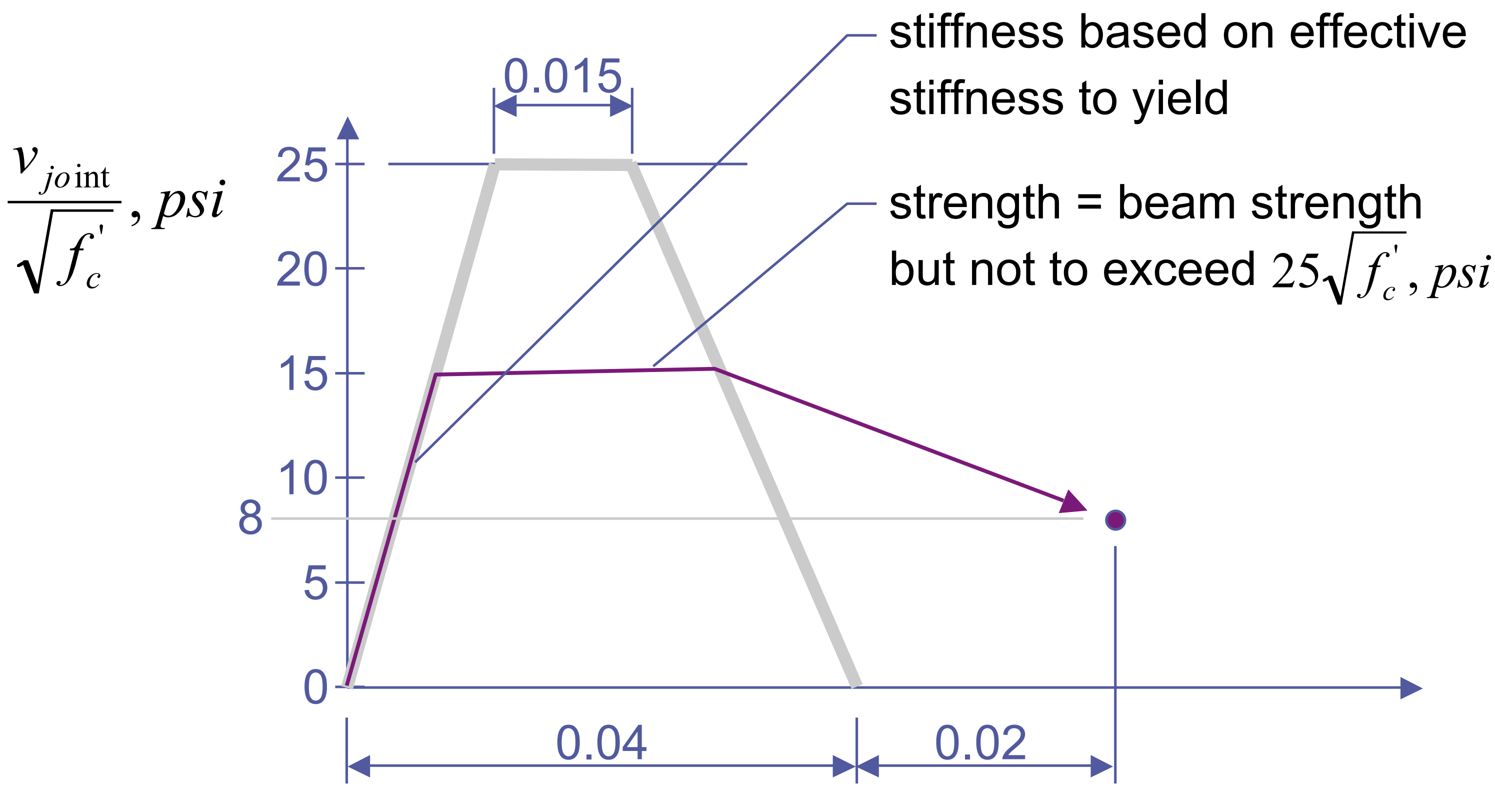
Joint test summary

axial failures identified



Suggested envelope relation

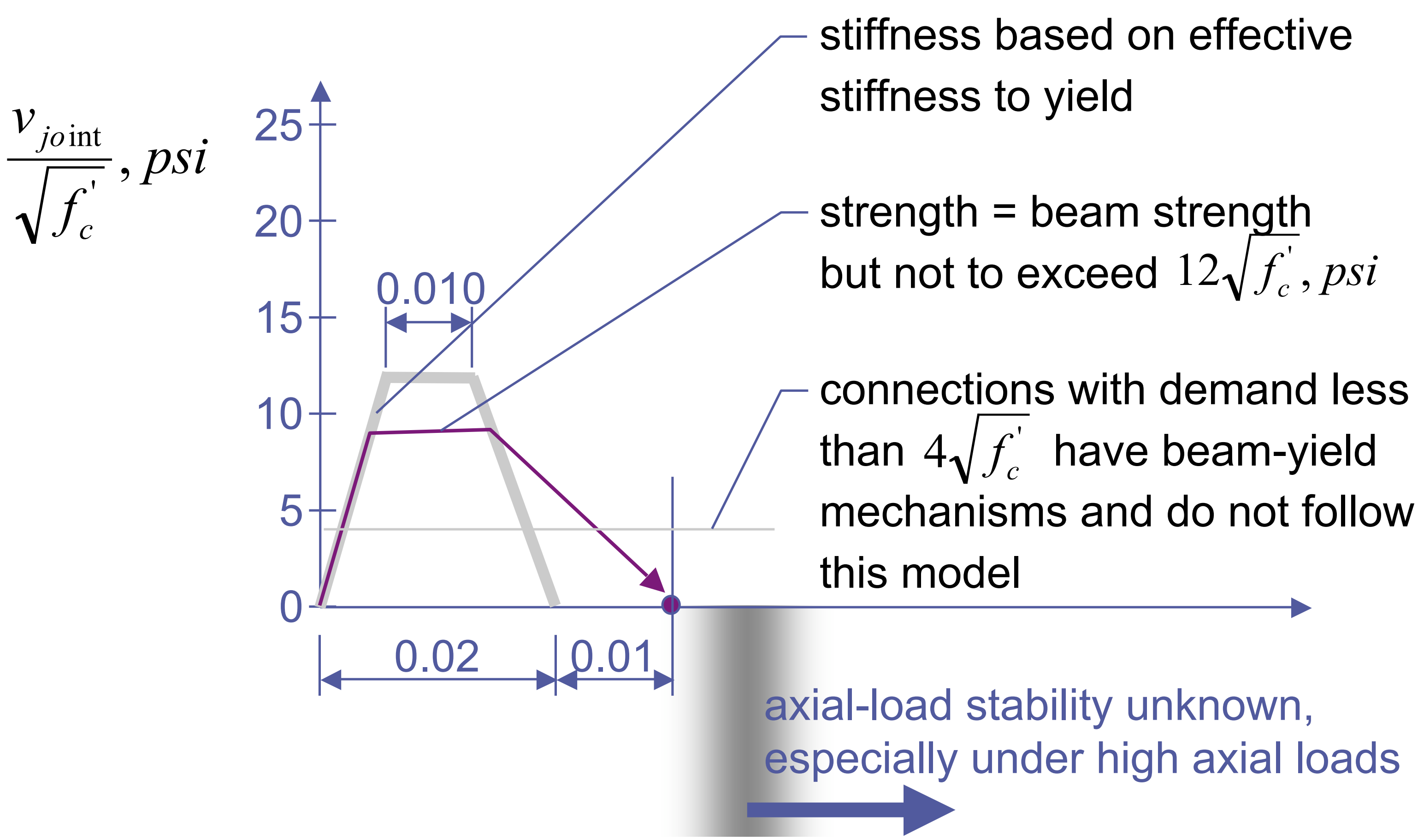
interior connections with continuous beam bars



Note: the plastic drift angle includes inelastic deformations of the beams

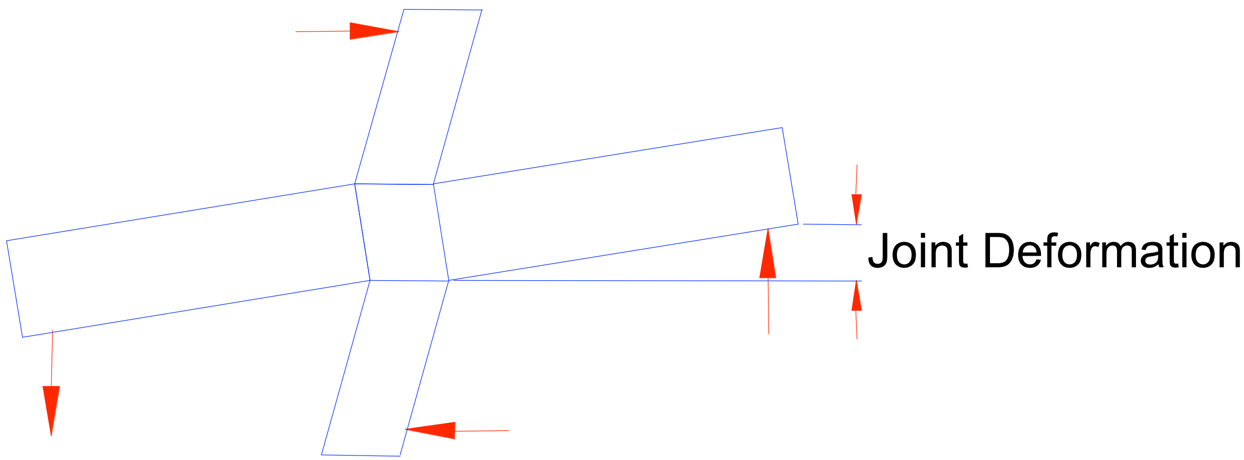
Suggested envelope relation

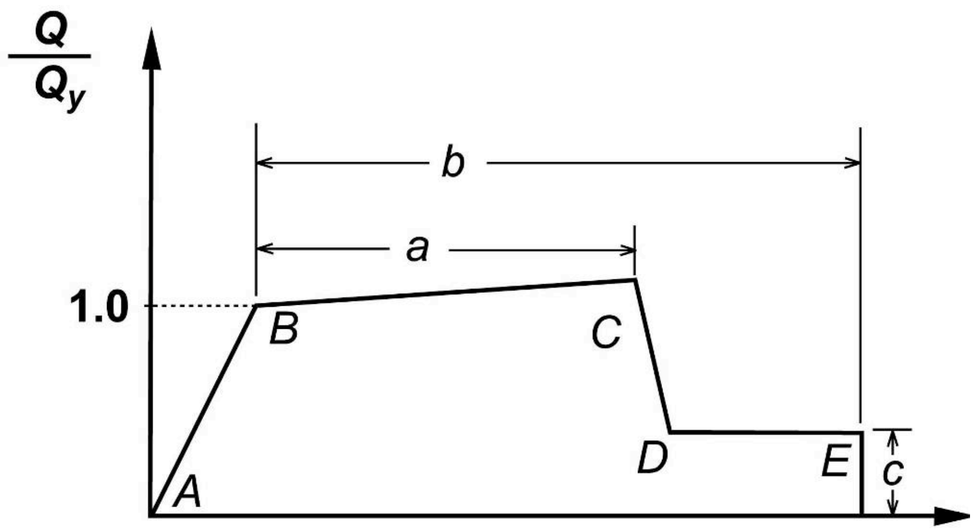
exterior connections with hooked beam bars



Note: the plastic drift angle includes inelastic deformations of the beams

Joint panel deformations



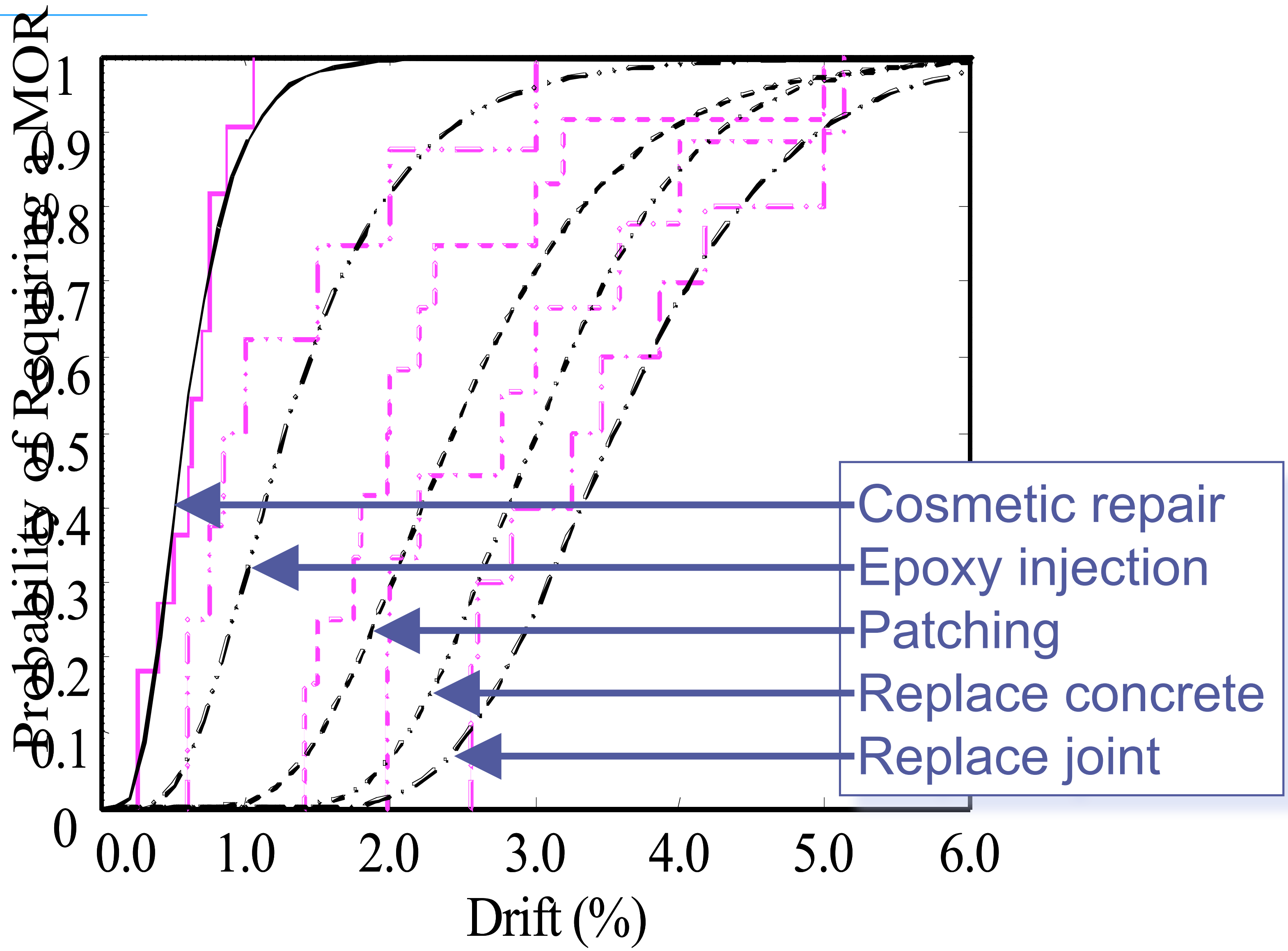


Methods of Repair (MOR)

Method of Repair	Activities	Damage States
0. Cosmetic Repair	Replace and repair finishes	0-2
1. Epoxy Injection	Inject cracks with epoxy and replace finishes	3-5
2. Patching	Patch spalled concrete, epoxy inject cracks and replace finishes	6-8
3. Replace concrete	Remove and replace damaged concrete, replace finishes	9-11
4. Replace joint	Replace damaged reinforcing steel, remove and replace concrete, and replace finishes	12

Pagni

Interior joint fragility relations



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with contributions from
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University of Washington, Seattle

References

- Clyde, C., C. Pantelides, and L. Reaveley (2000), “Performance-based evaluation of exterior reinforced concrete building joints for seismic excitation,” *Report No. PEER-2000/05*, Pacific Earthquake Engineering Research Center, University of California, Berkeley, 61 pp.
- Pantelides, C., J. Hansen, J. Nadauld, L Reaveley (2002, “Assessment of reinforced concrete building exterior joints with substandard details,” *Report No. PEER-2002/18*, Pacific Earthquake Engineering Research Center, University of California, Berkeley, 103 pp.
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