



Designing Reinforced Concrete Structures to a Performance Criterion

Presented by

Robert E. Englekirk, Ph.D., S.E.

*Englekirk Partners Consulting
Structural Engineers, Inc.*



40 years of solitude and counting

- 1960's – Park & Paulay
(*Reinforced Concrete Structures*, John Wiley & Sons, Inc., New York, New York, 1975)
- 1960 ACI – $\epsilon_c = 0.003$ in./in.
- 1990's – Paulay and Priestley
- 2003 – Englekirk



Design procedures for the foreseeable future
will remain *strength based/prescriptive*





A Performance Criterion and Design Approach are essential to the

- improved design of R.C. buildings and
- development of systems of improved behavior



Paramount Apartments, San Francisco

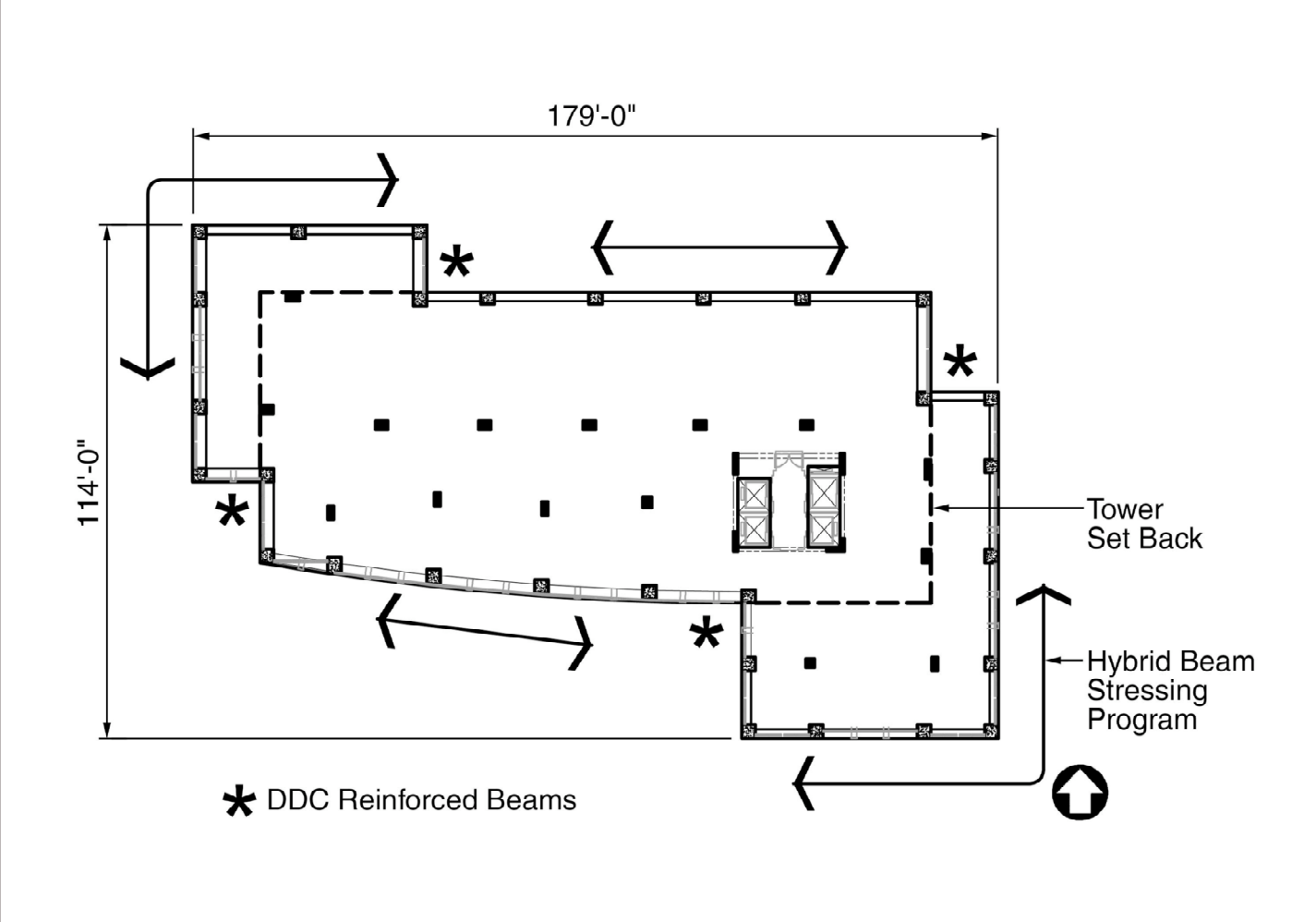
- 37 story precast concrete braced building
- Hybrid/DDC frame braced building



Paramount Apartments



Paramount Apartments



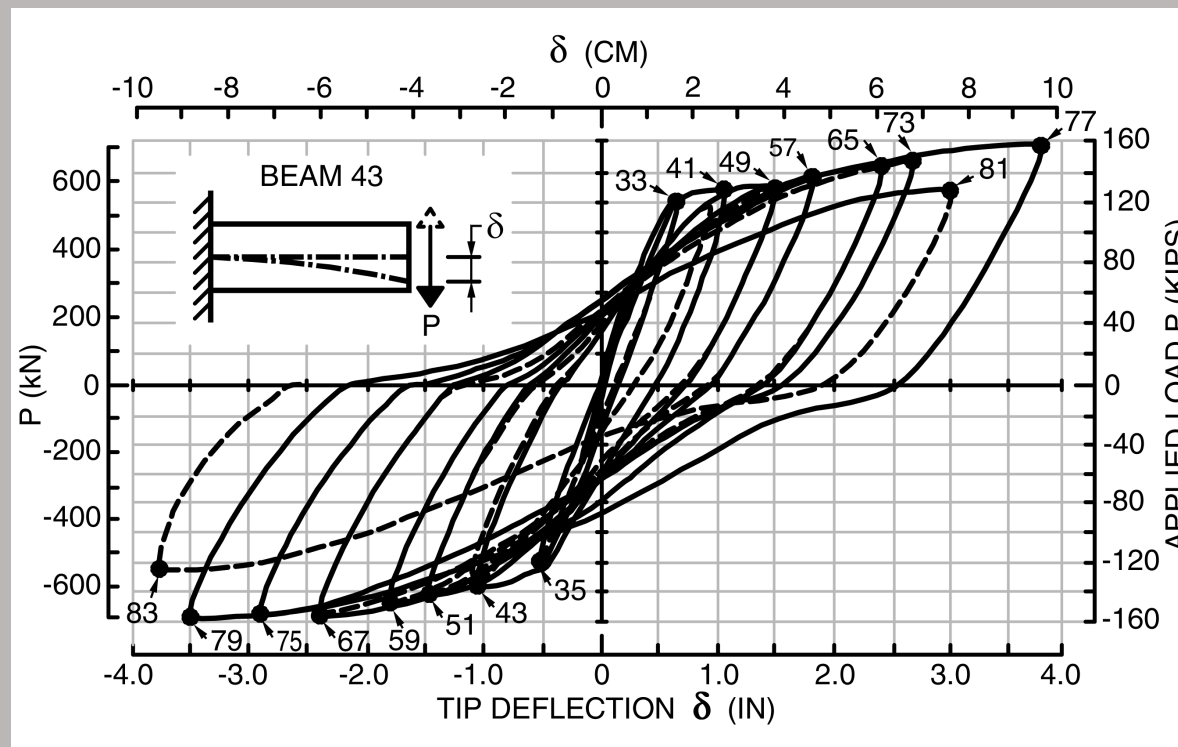
Design Challenges

- System validation – ACI draft acceptance criterion
 - Two tests of each condition – 8 total

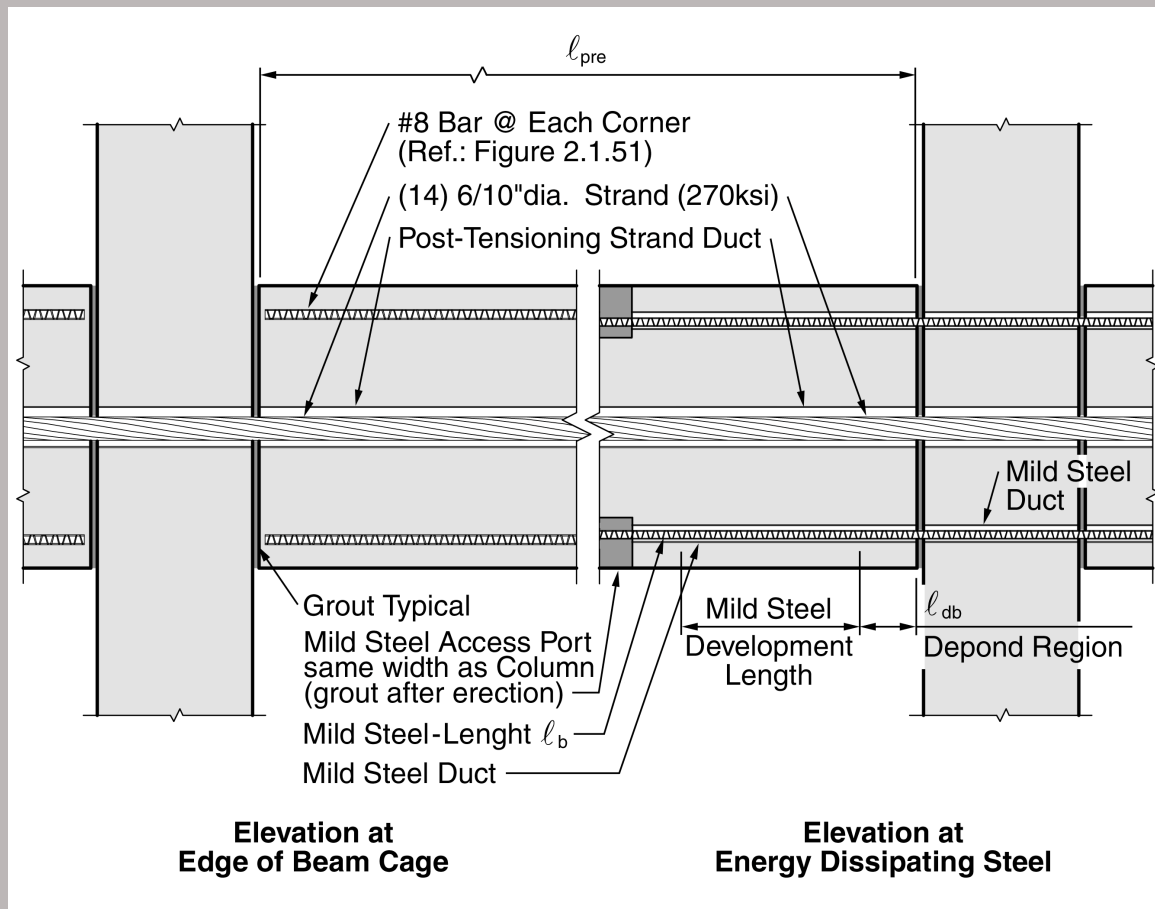


Design Challenges

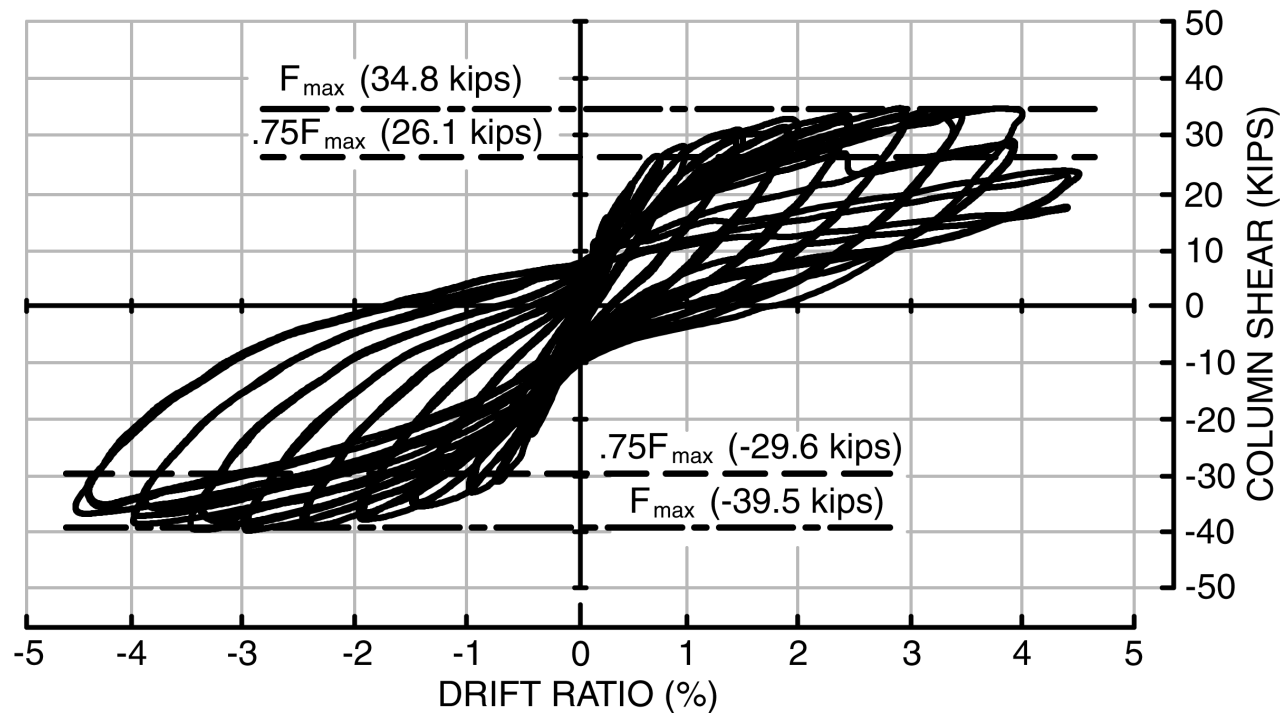
- Baseline – not a consideration by ACI (3.2%)



Hybrid System



Hybrid System

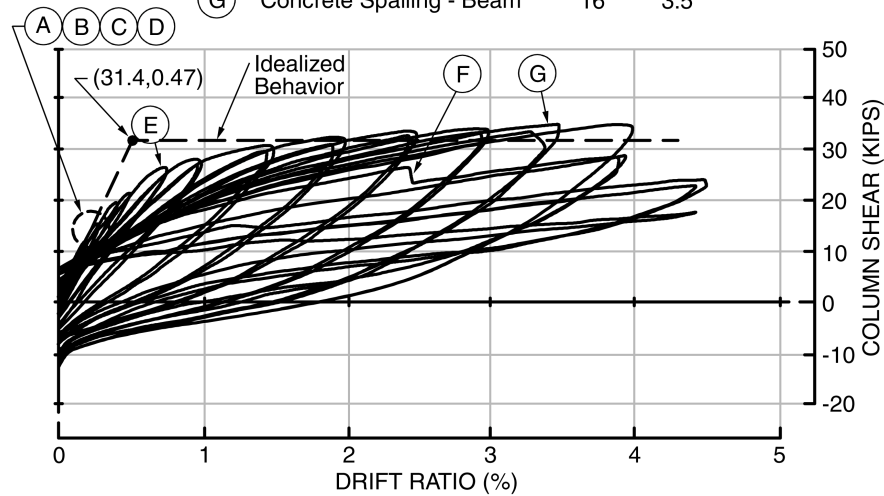


(a) Full Hysteretic Behavior



Hybrid System

Mark	Event	Set	Drift Ratio
(A)	Grout Cracking - Interface	4	0.10
(B)	Grout Lift-off - Interface	5	0.15
(C)	Surface Cracking - Joint	5	0.15
(D)	Surface Cracking - Beam	6	0.20
(E)	Bar Yield - Continuity Bar	10	0.75
(F)	Bar Fracture - Continuity Bar	17	4.0
(G)	Concrete Spalling - Beam	16	3.5



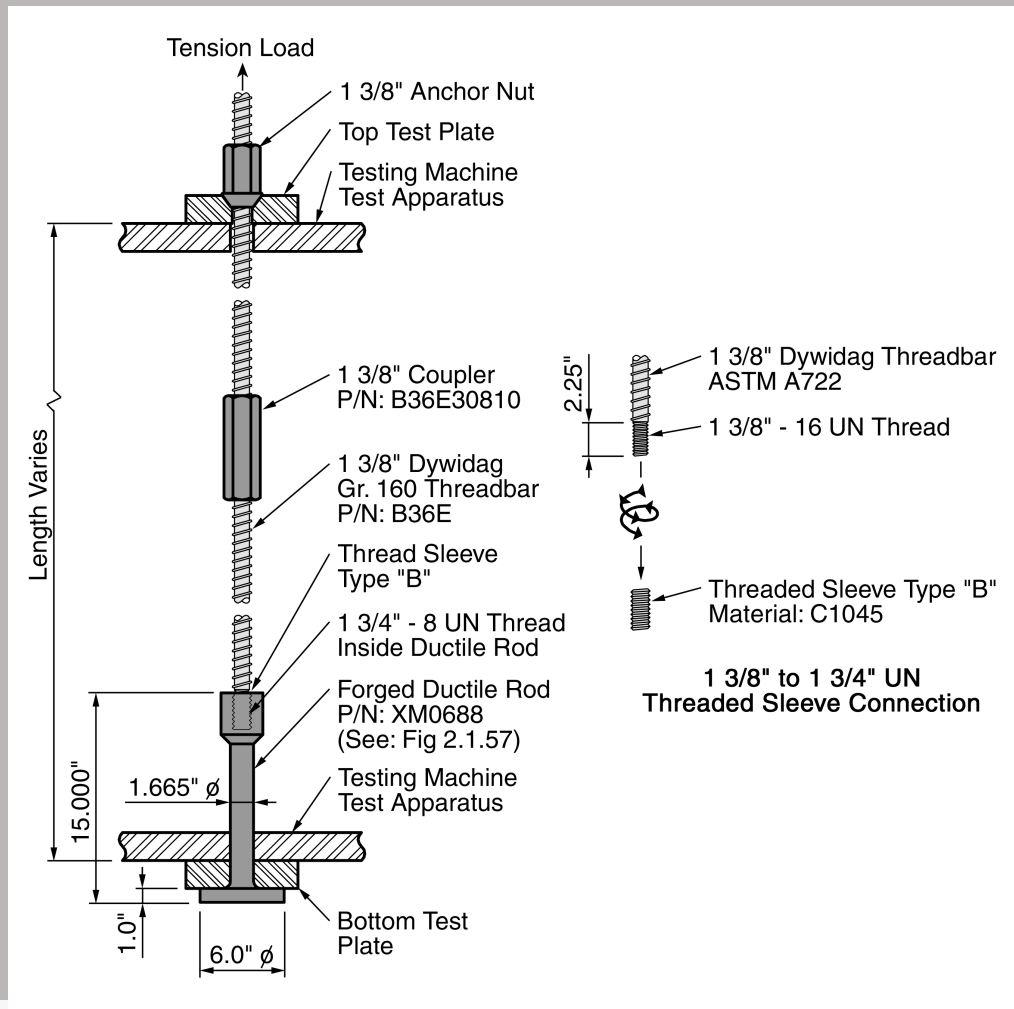
3.4%



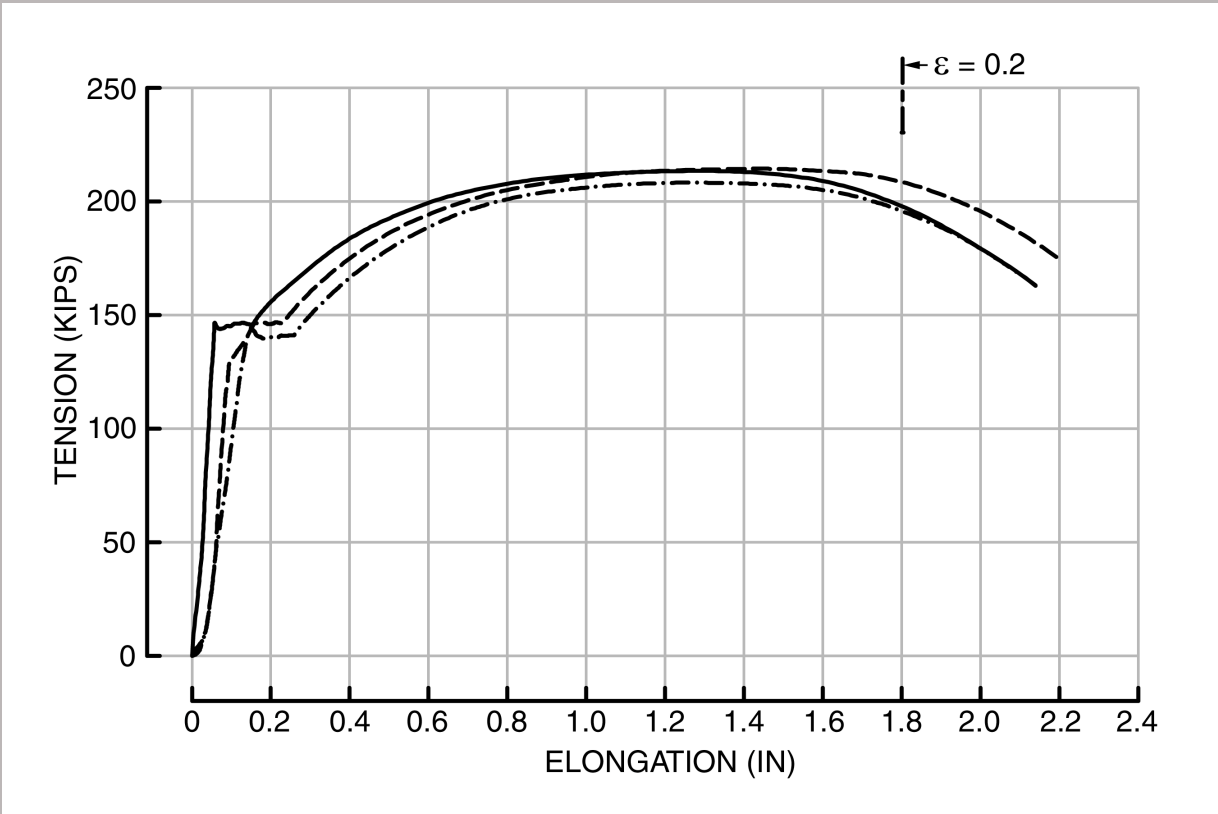
Ductile Rod System



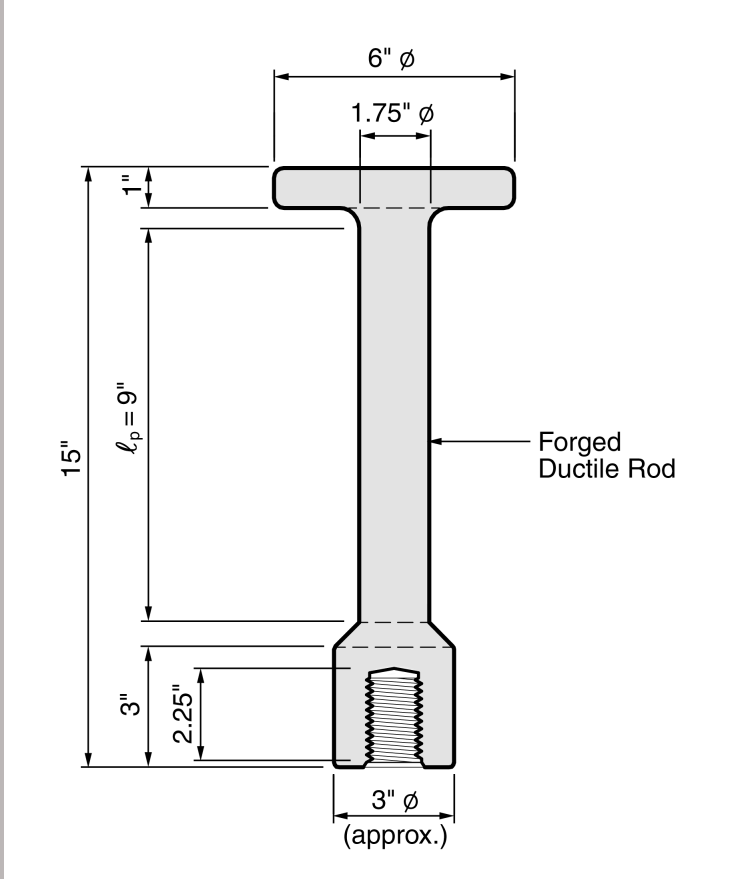
Ductile Rod System



Ductile Rod System



Ductile Rod System



6%



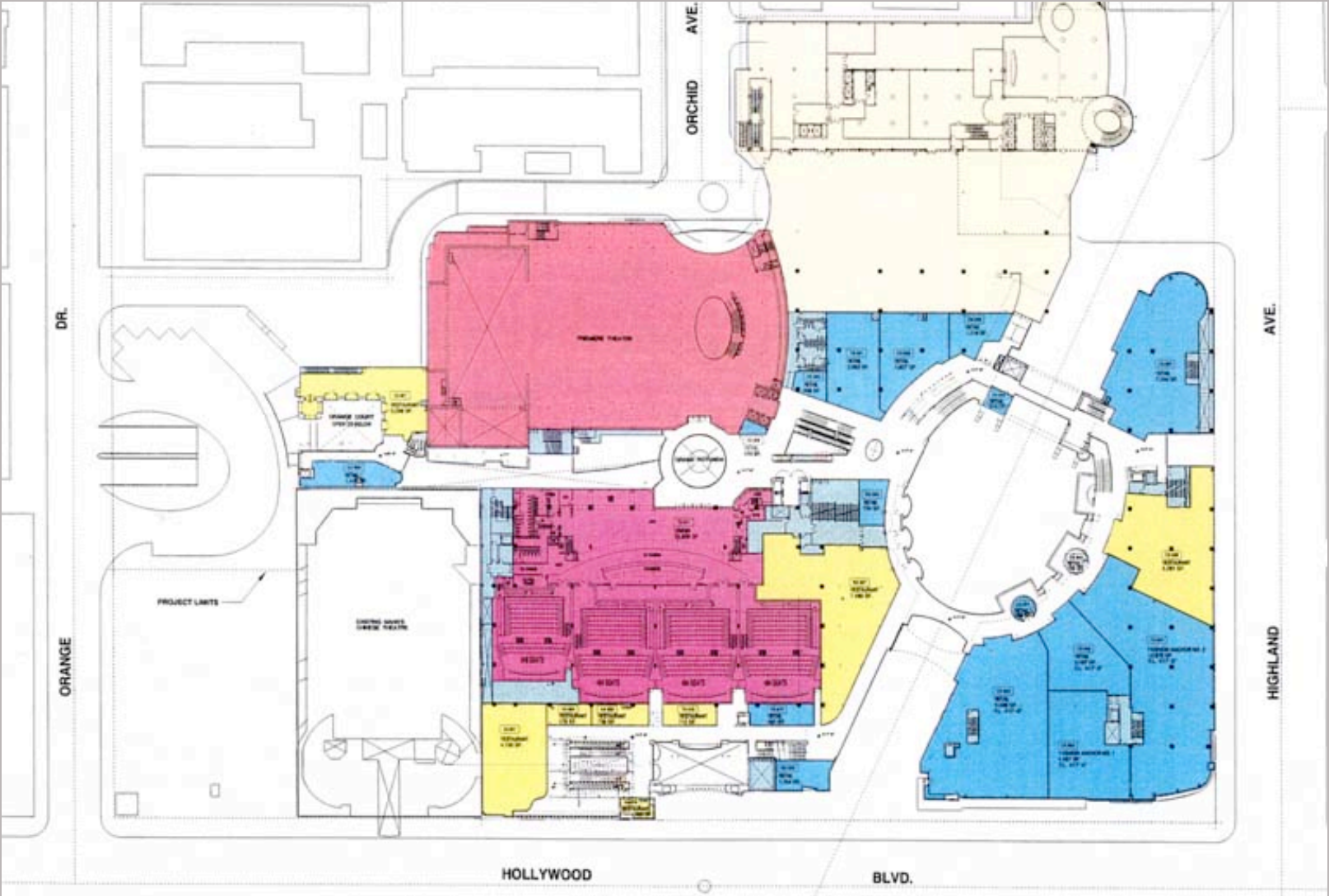
Conclusion: Cost and Risk are seldom acceptable to owners or contractors.



Hollywood & Highland

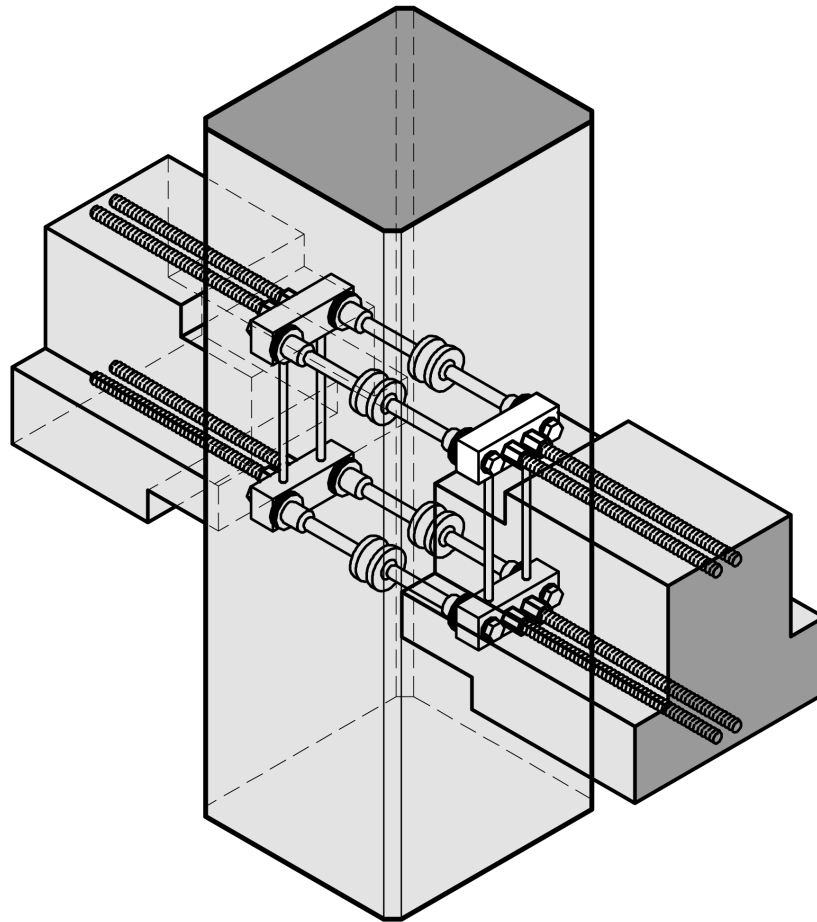


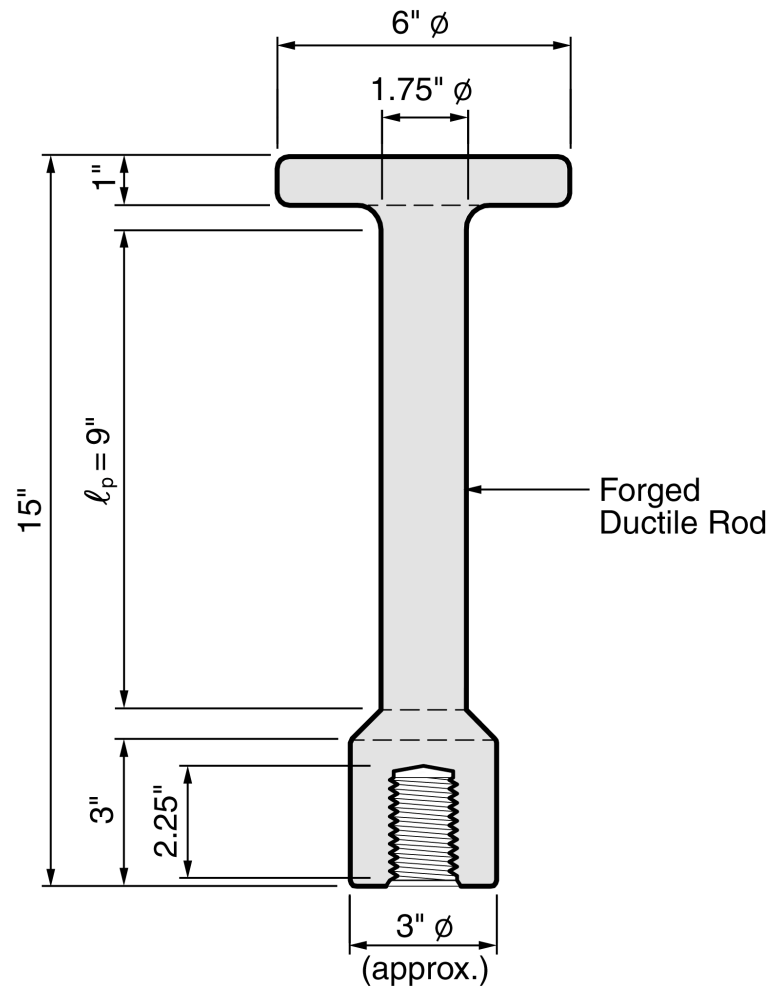
Hollywood & Highland



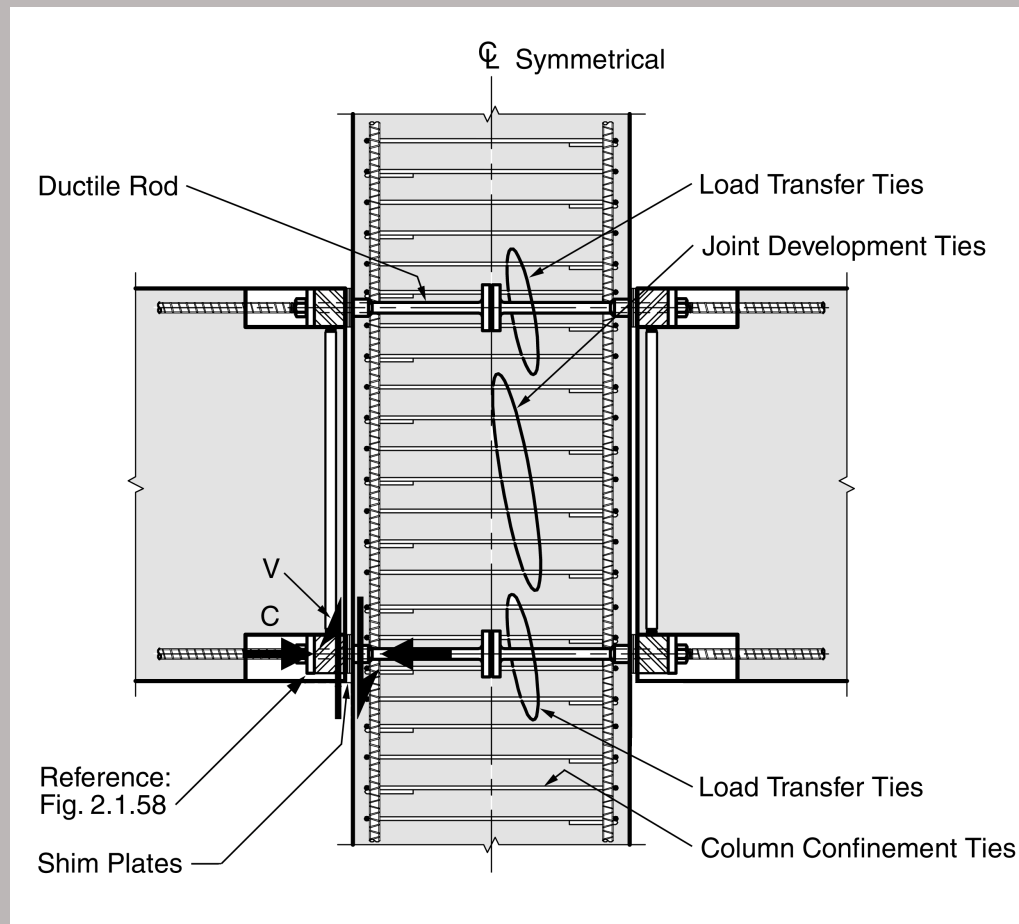
Hollywood & Highland



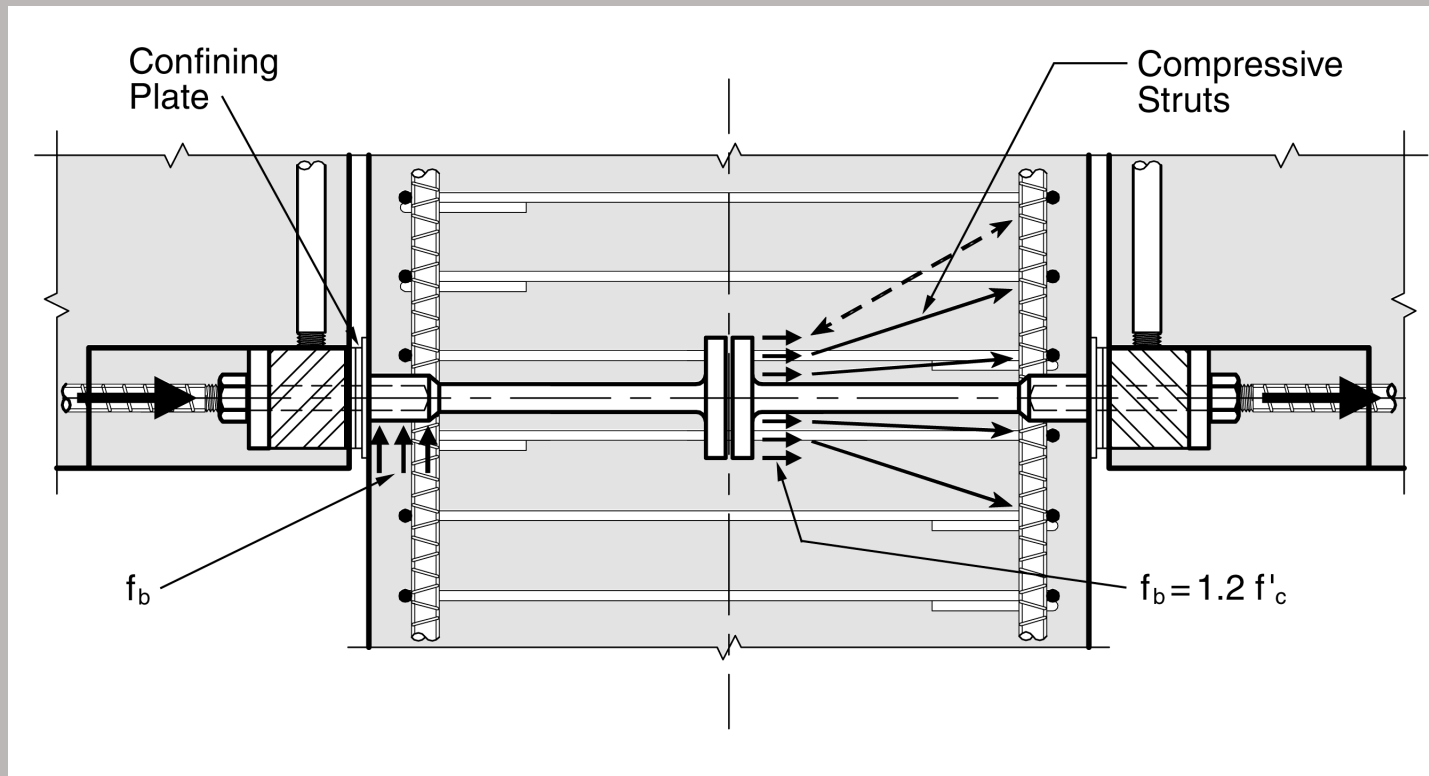




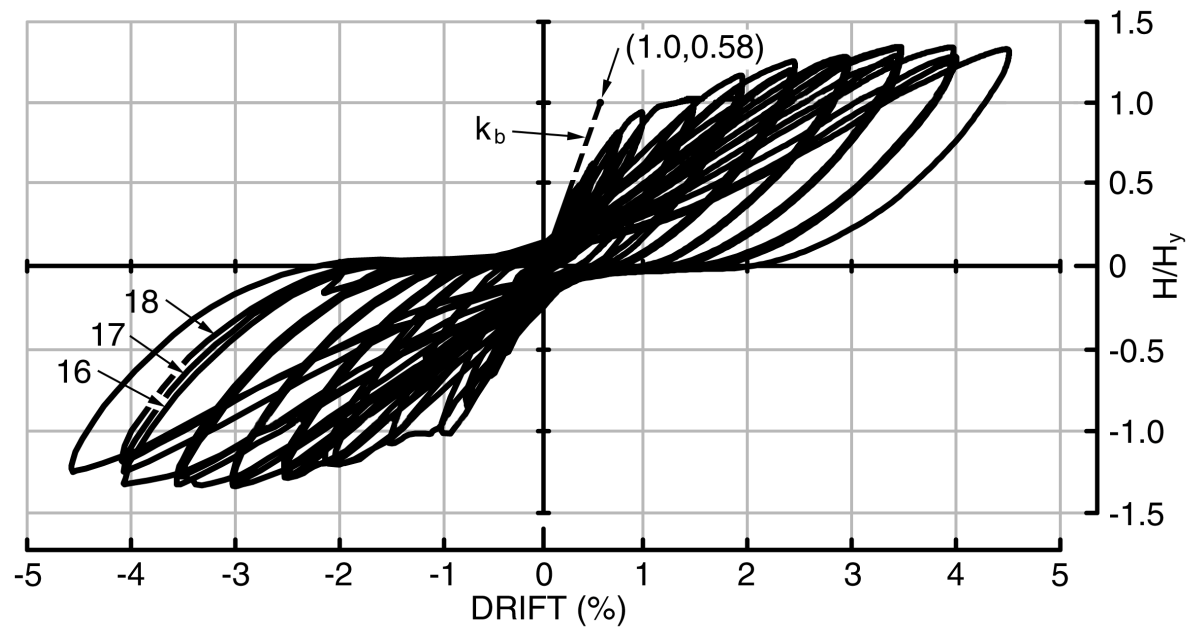
Analytically Developable per ACI



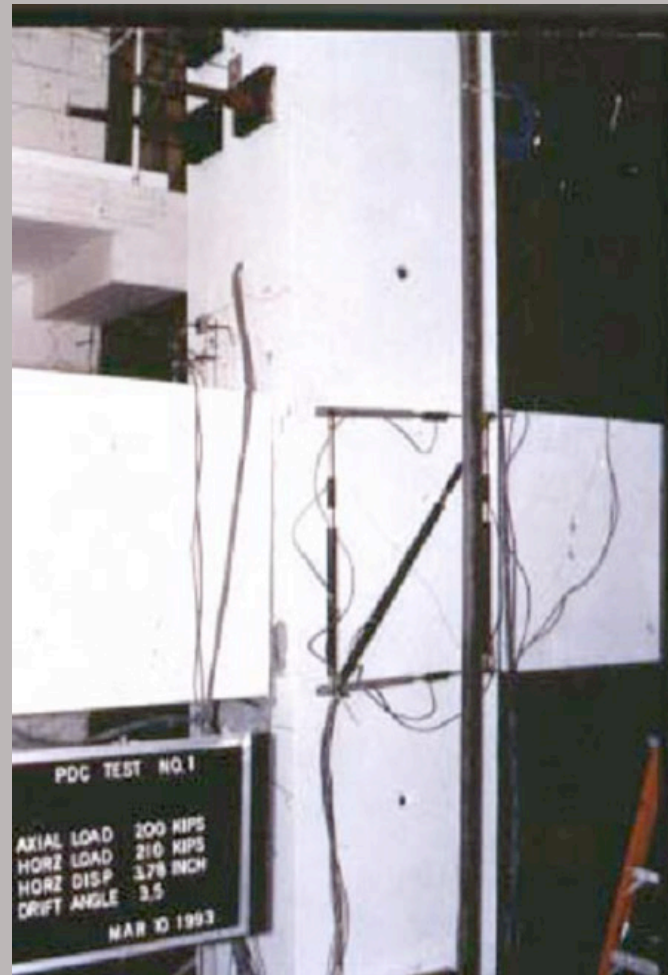
Analytically Developable per ACI



Analytically Developable per ACI



Analytically Developable per ACI



Quality Control Issues



PEER Research topics

- Basic identification of strain based limit states
- Analytical model development
- Education
- System testing – NEEC Program



Concluding Remarks

- Incentive programs do not work.
- Prescriptive procedures will not replace a considered design approach.
- *A strain based performance criterion* is the only answer, but it cannot be overly restrictive.



The Englekirk Companies

