



EVALUATIONS OF COLUMN SPLICES IN PRE-NORTHRIDGE STEEL MOMENT FRAME BUILDINGS

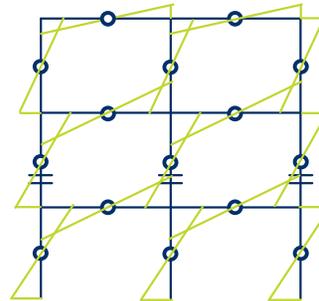
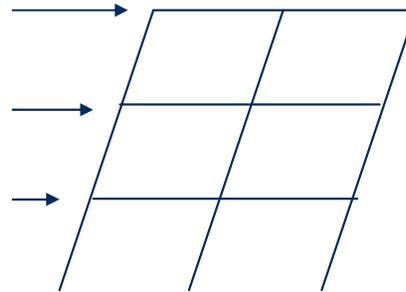
NICK SKOK, S.E.

BACKGROUND

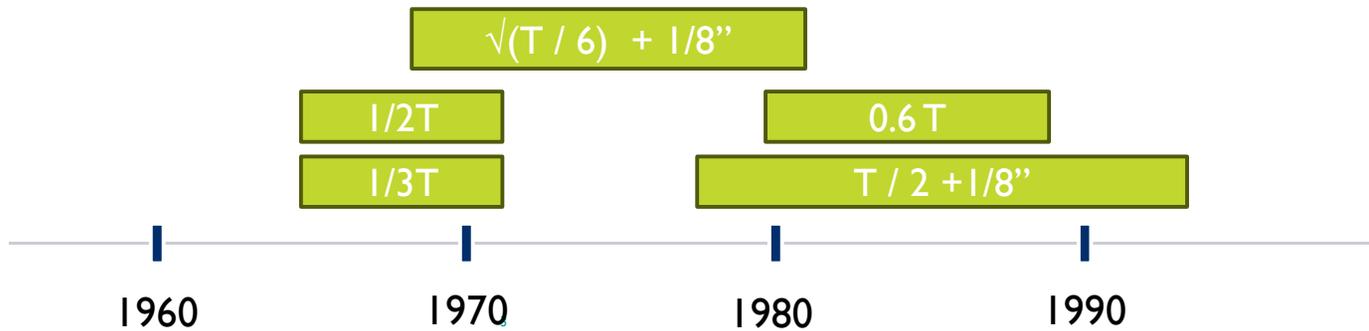
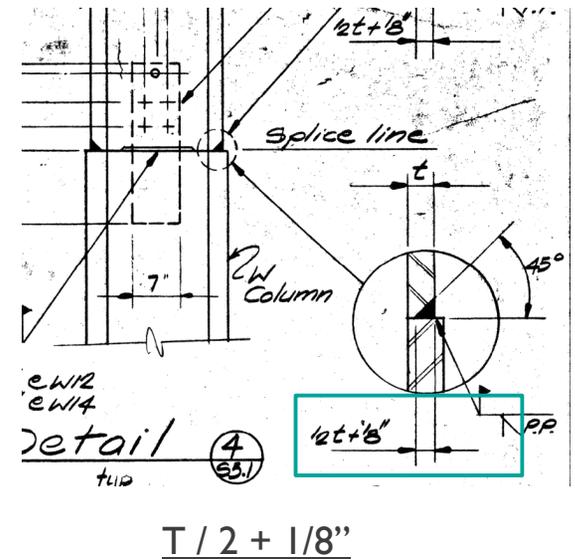
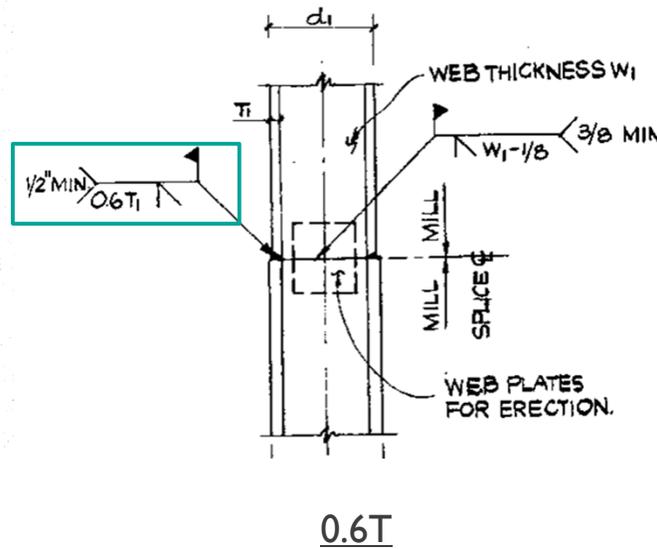
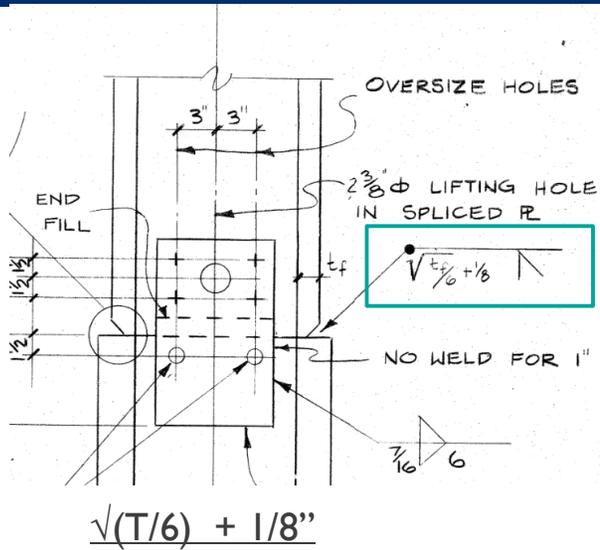
- Partial joint penetration (PJP) splices
- Low-toughness filler metals
- Limited analysis capabilities



- Underestimated demands
- Inadequate capacities
- Column fractures observed in Kobe



COMMON PRE-NORTHRIDGE SPLICE DETAILS



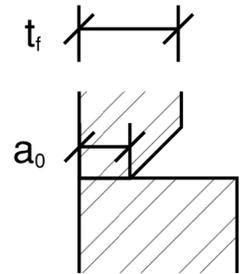
ESTIMATES OF SPLICE CAPACITY

- Critical stress equation per AISC 342-22 & NIST GCR 17-917-46v2 (ATC 114)
- Toughness of filler metal – K_{IC}
- Internal flaw formed by unfused flange – a_0
- Capped by base metal rupture and yield

$$\sigma_{cr} = \frac{K_{IC}}{\left[F\left(\frac{a_0}{t_{f,u}}\right) \right] \sqrt{\pi a_0}} \leq F_{ue} \left(1 - \frac{a_0}{t_{f,u}} \right) \leq F_{ye}$$

where

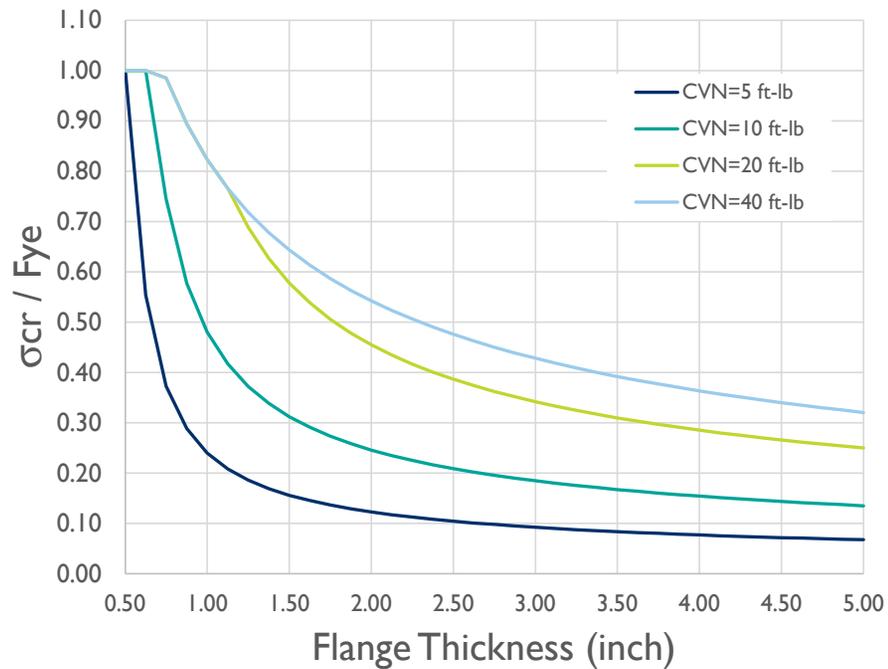
$$F\left(\frac{a_0}{t_{f,u}}\right) = \left(2.3 - 1.6 \frac{a_0}{t_{f,u}} \right) \left(4.6 \frac{a_0}{t_{f,u}} \right)$$



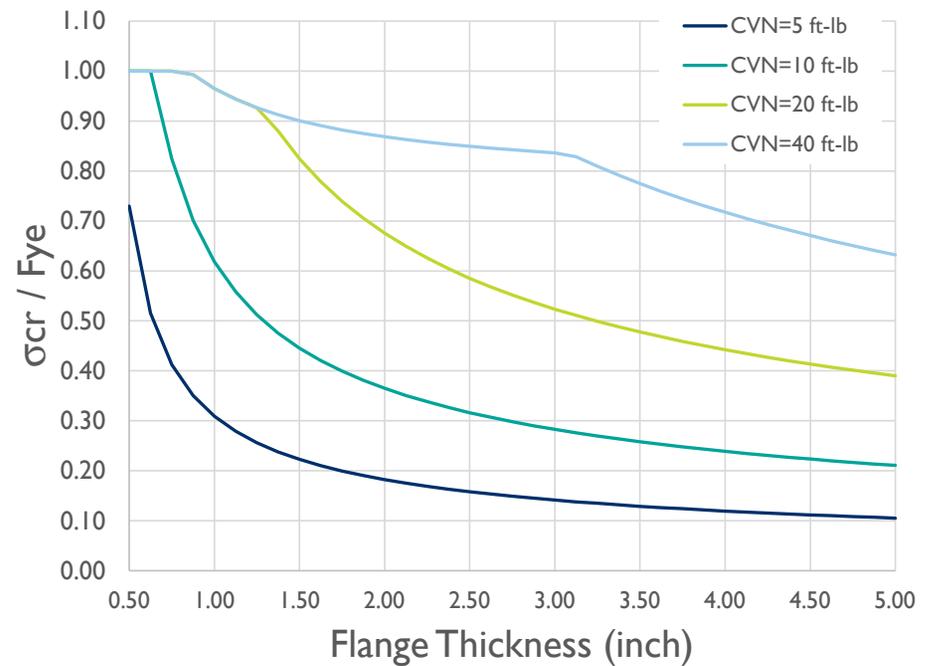
Charpy V-Notch at Lowest Anticipated Service Temperature (LAST), ft-lb (J)	K_{IC} , ksi $\sqrt{\text{in.}}$ (MPa $\sqrt{\text{mm}}$)
5 (6.8)	50 (1 700)
10 (14)	100 (3 500)
20 (27)	185 (6 400)
40 (54)	300 (10 000)

WELD TOUGHNESS SENSITIVITY

$\sqrt{t/6} + 1/8$ PJP Normalized Tensile Stress vs Plate Thickness

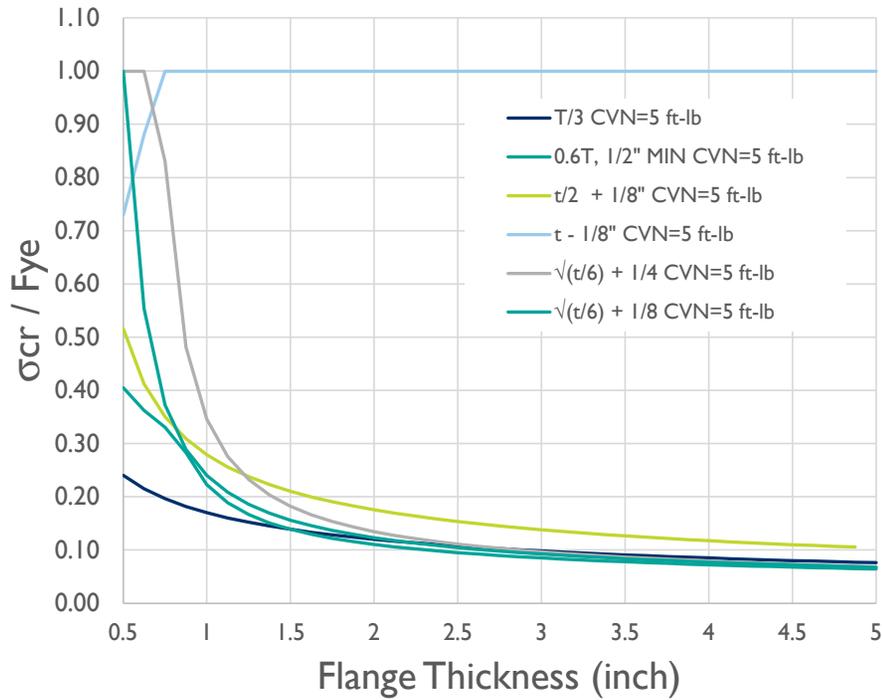


$t/2 + 1/8$ PJP Normalized Tensile Stress vs Plate Thickness

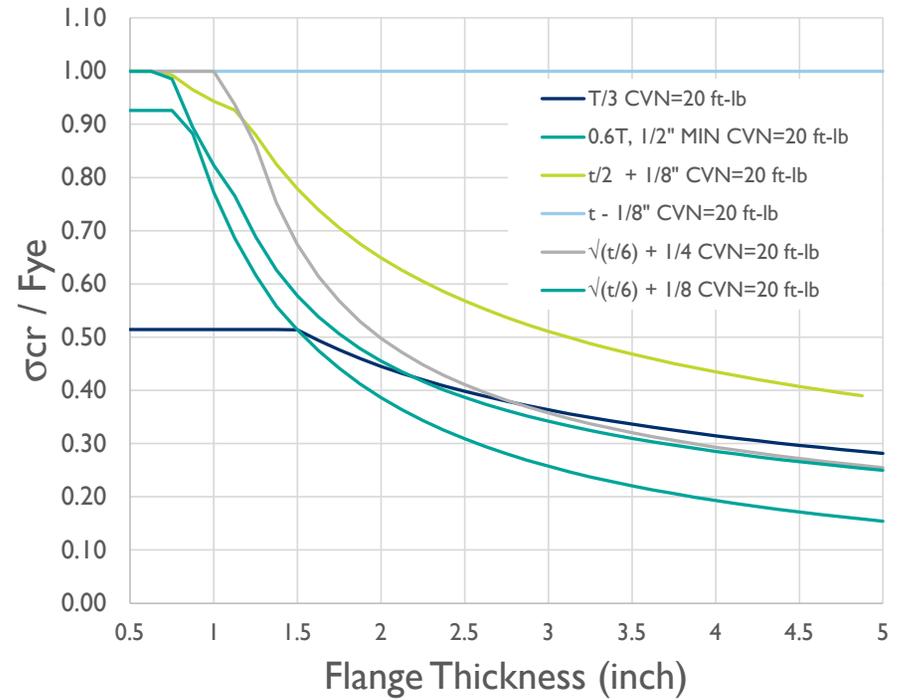


SPLICE DETAILING SENSITIVITY

CVN = 5 ft-lb PJP Detail Comparison

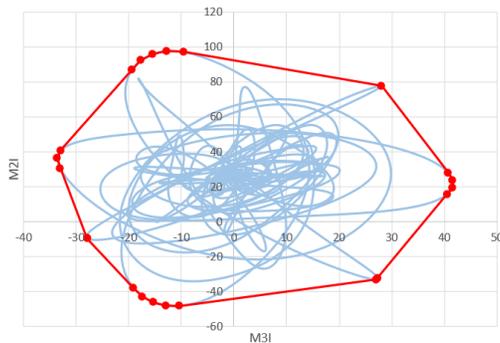


CVN = 20 ft-lb PJP Detail Comparison



ANALYTICAL COLUMN SPLICE DEMANDS

- Critical force-controlled action per ASCE 41
- Linear Analysis - superposition of demands
- NLRHA
 - Calculation of demand at each timestep
 - Critical factored average & maximum demand



$$\sigma_{UF} = \left(\frac{P_{UF}}{A_g} \right) \pm \left(\frac{M_{UF,x}}{S_x} \right) \pm \left(\frac{M_{UF,y}}{S_y} \right)$$

Stress demand per AISC 342

$$Q_{UF} = Q_G \pm \frac{\chi Q_E}{C_1 C_2 J}$$

Linear analysis force-controlled demand per ASCE 41

$$\gamma \chi (Q_{UF} - Q_G) + Q_G \leq Q_{CL}$$

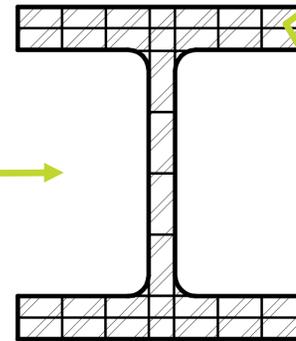
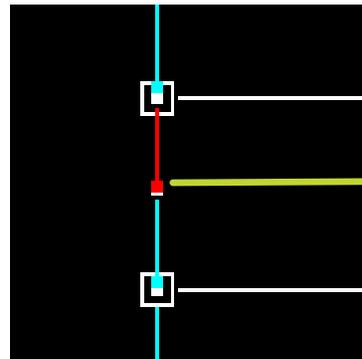
Nonlinear analysis force-controlled demand per ASCE 41

Table 7-8. Load Factor for Force-Controlled Behaviors

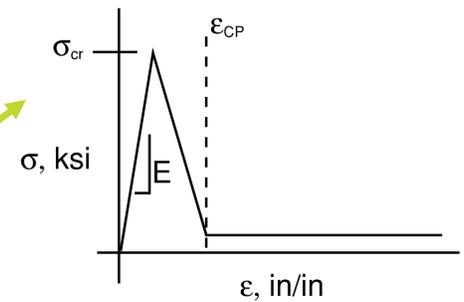
Action Type	γ
Critical	1.3
Ordinary	1.0
Noncritical	1.0

PERFORM3D SPLICE FIBER MODEL

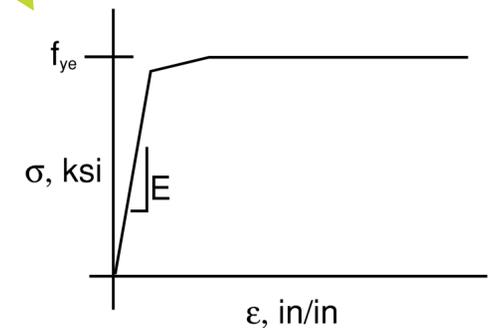
- Fiber hinge at splice locations
- Overlapping tension-only & compression-only fiber elements
- Tension material with strength loss after critical stress
- Collapse prevention limit set at loss of tensile capacity
- Reduces the amount of post-processing



Tension

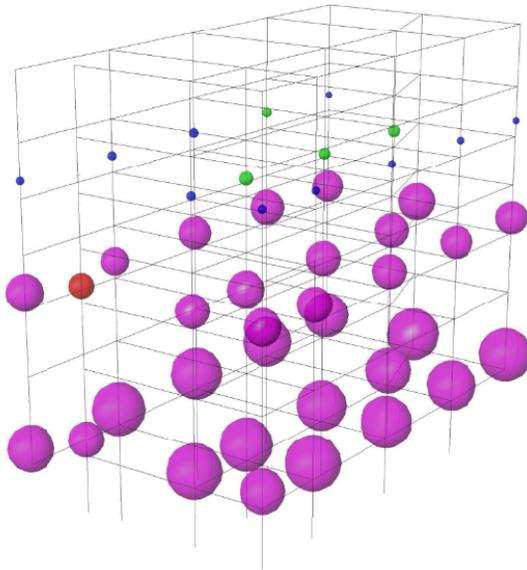


Compression

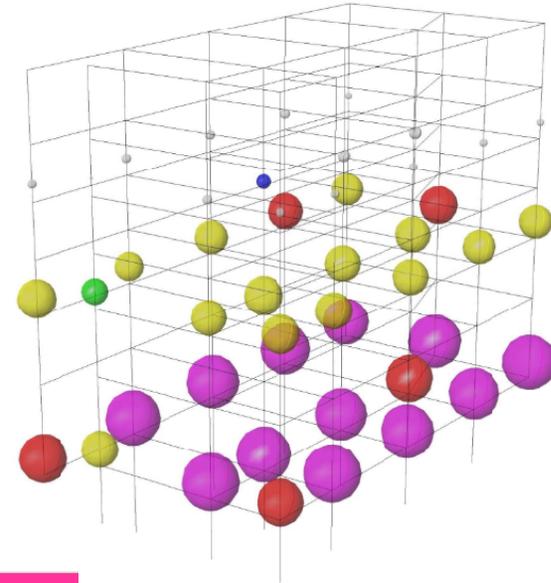


ANALYSIS EXAMPLE

Critical Factored Average DCR
CVN = 10 ft-lb



Critical Factored Average DCR
CVN = 20 ft-lb



DCR Color Coding Legend

