Western Bridge Engineers' Seminar

The Link Slab

Solution to Widening the I-5 Bridge in Everett, WA

Warren Wilson, PE, SE

Jeff McGuire, PE

BERGER/ABAM Engineers

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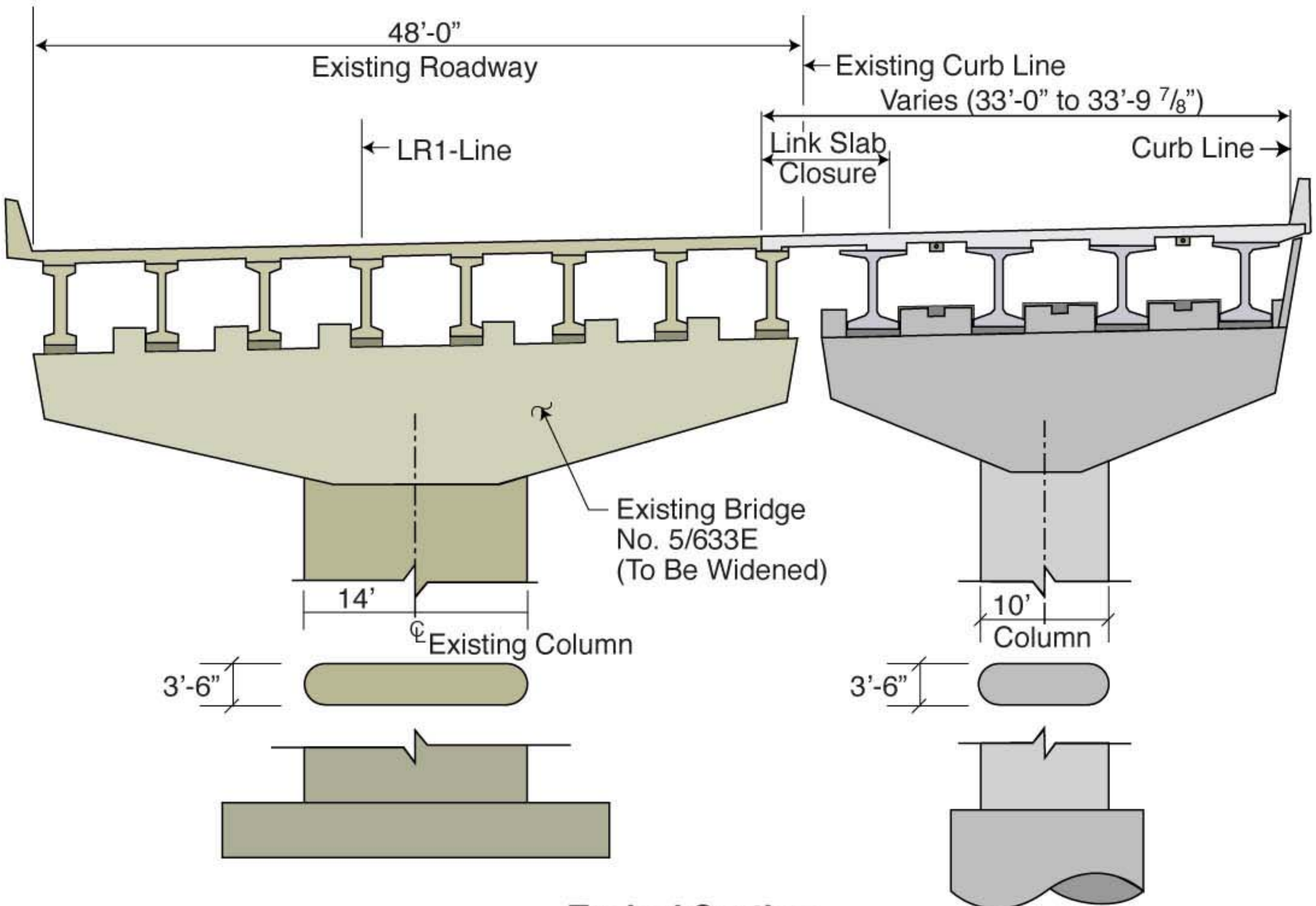
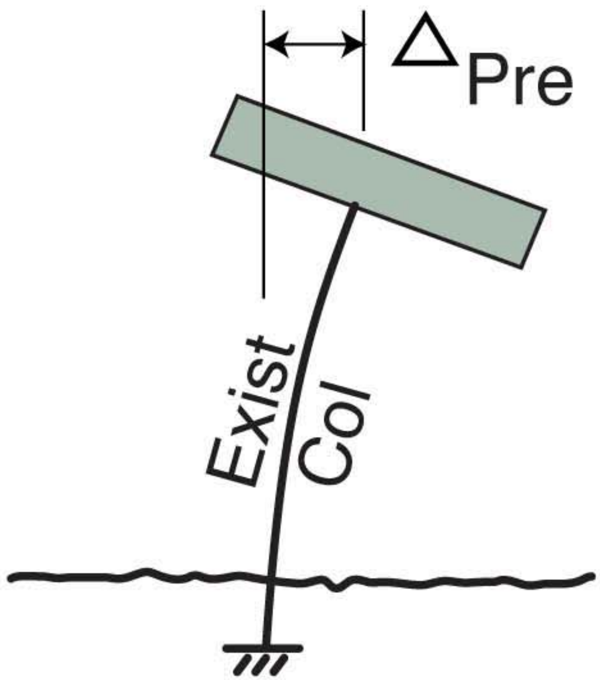
Typical Section



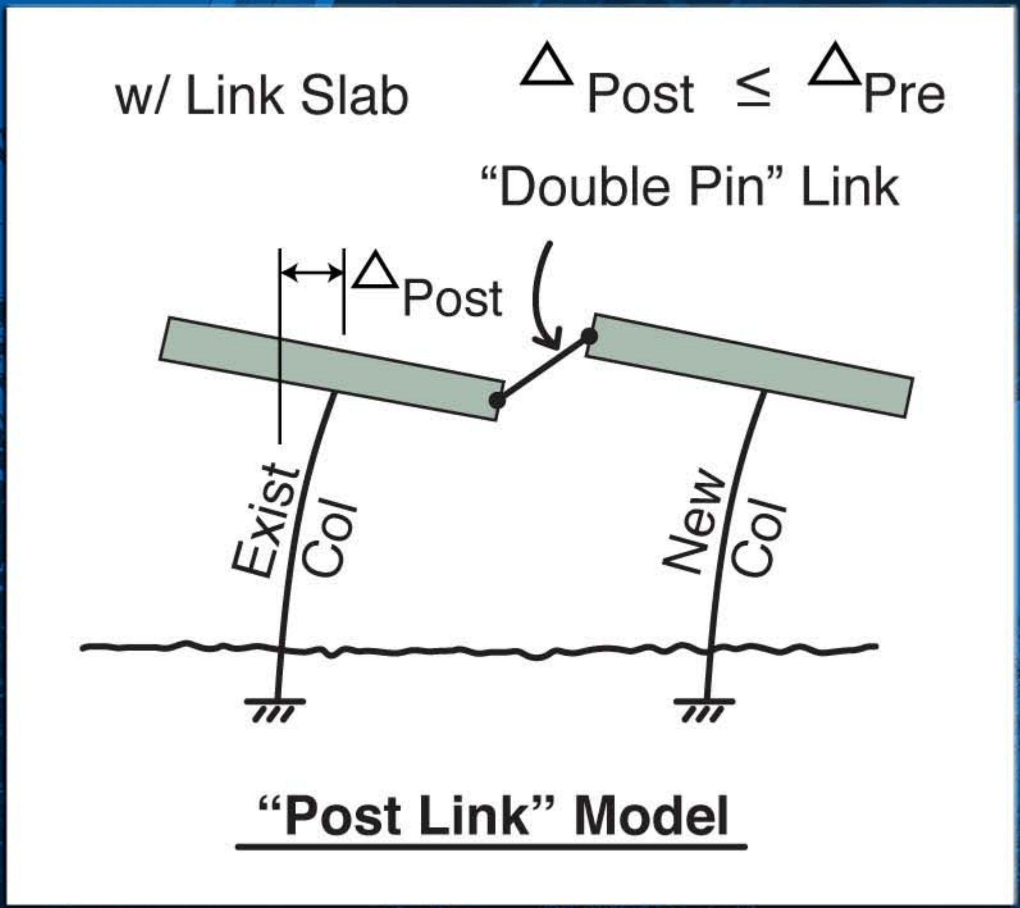
Typical Section

Existing (Pre-Widening) Bridge Pier



"Pre" Model = Pre-Widening

Post-Widening Bridge Pier



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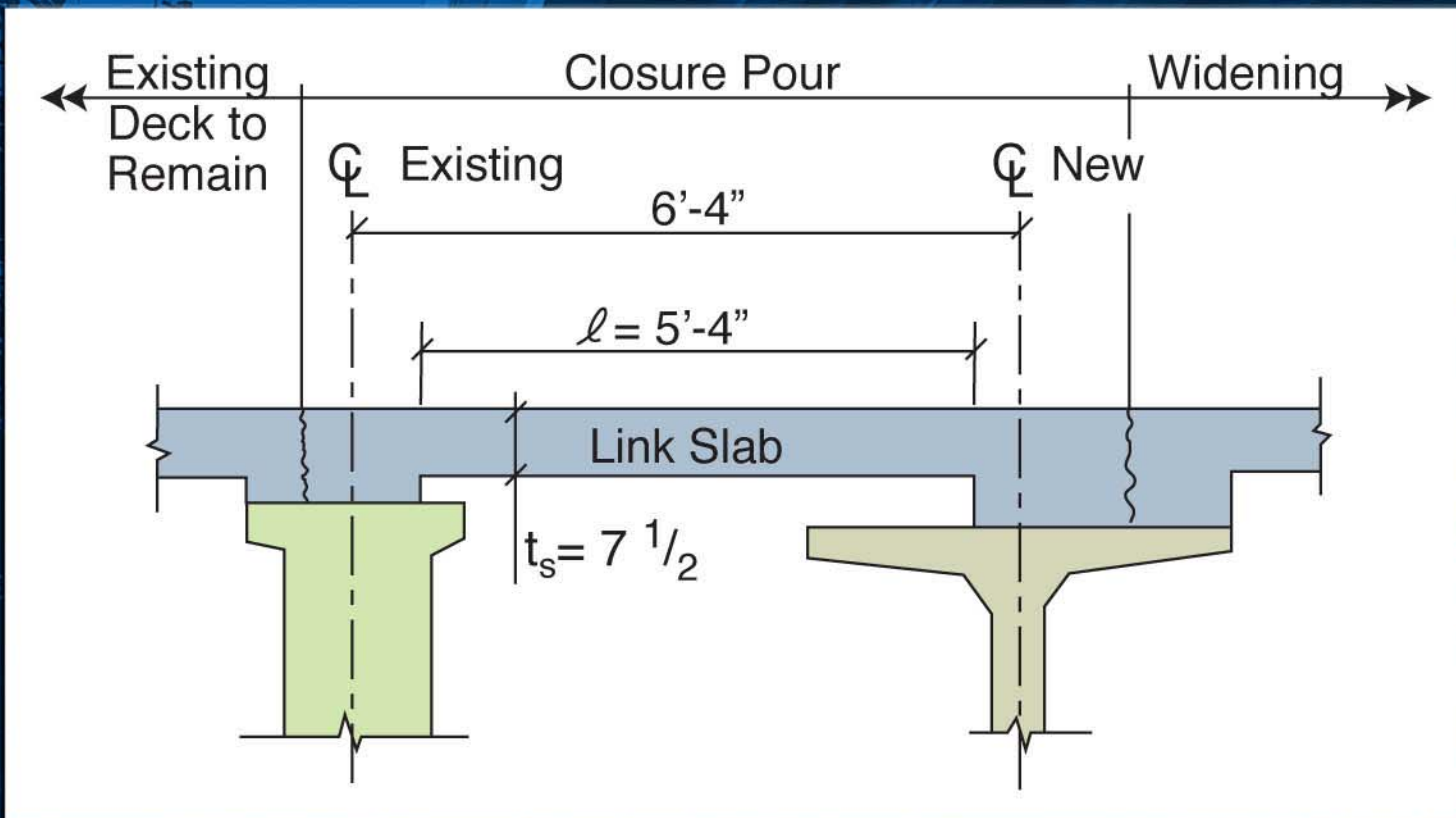
Typical Link Slab Section



Link Slab Design Objectives

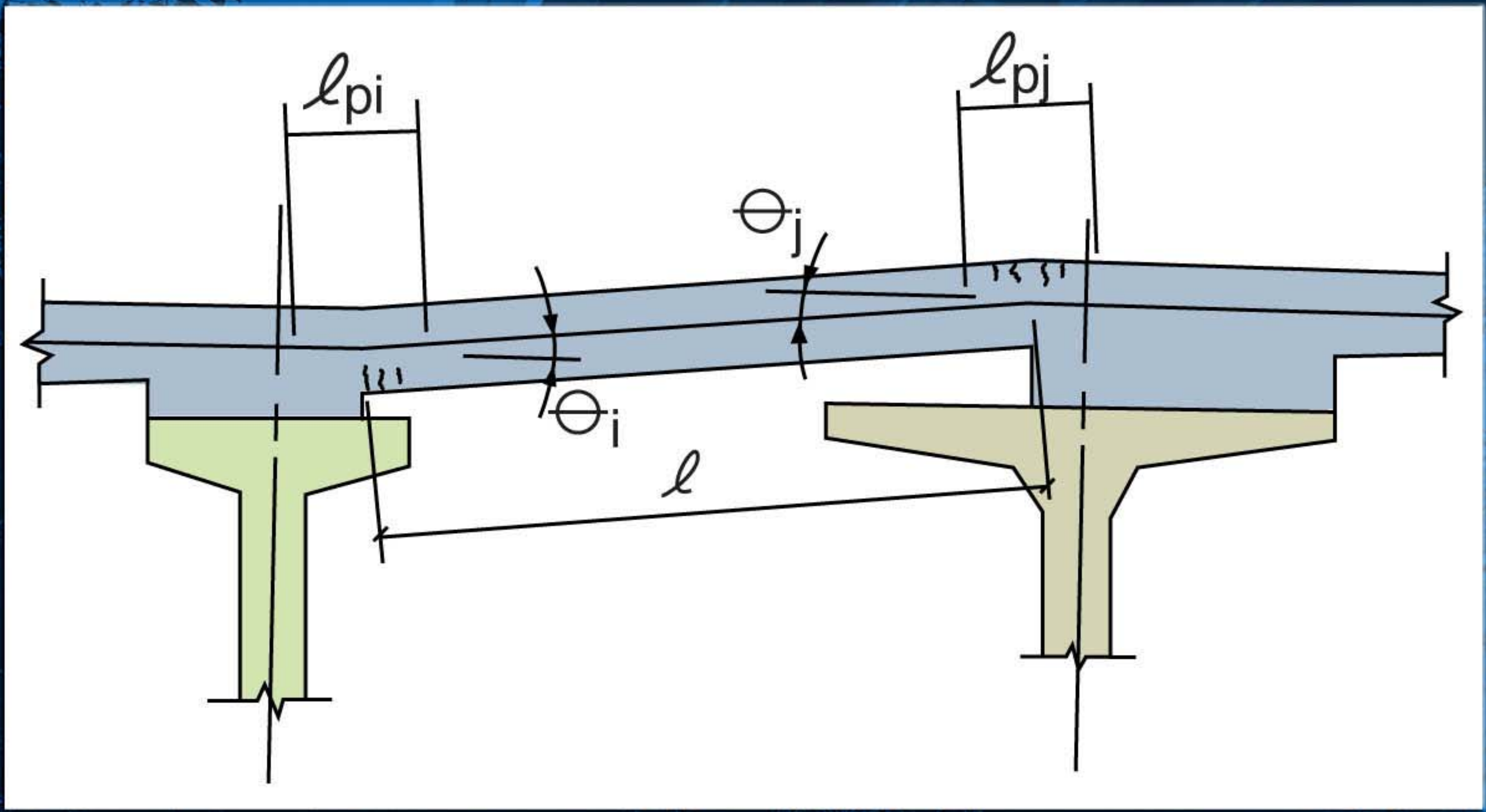
Strength Limit State:

- Strength to resist loads

Extreme Event (475-yr earthquake):

- Life Safety
- Ductility to accommodate rotations without significant loss of concrete section (spalling)
  - protect gravity load resistance
  - prevent falling debris hazard

Link Slab Hinges



Hinge Rotation

- Demand: θ_u = 0.067 radians
- Capacity: θ_n = hinge length × curvature

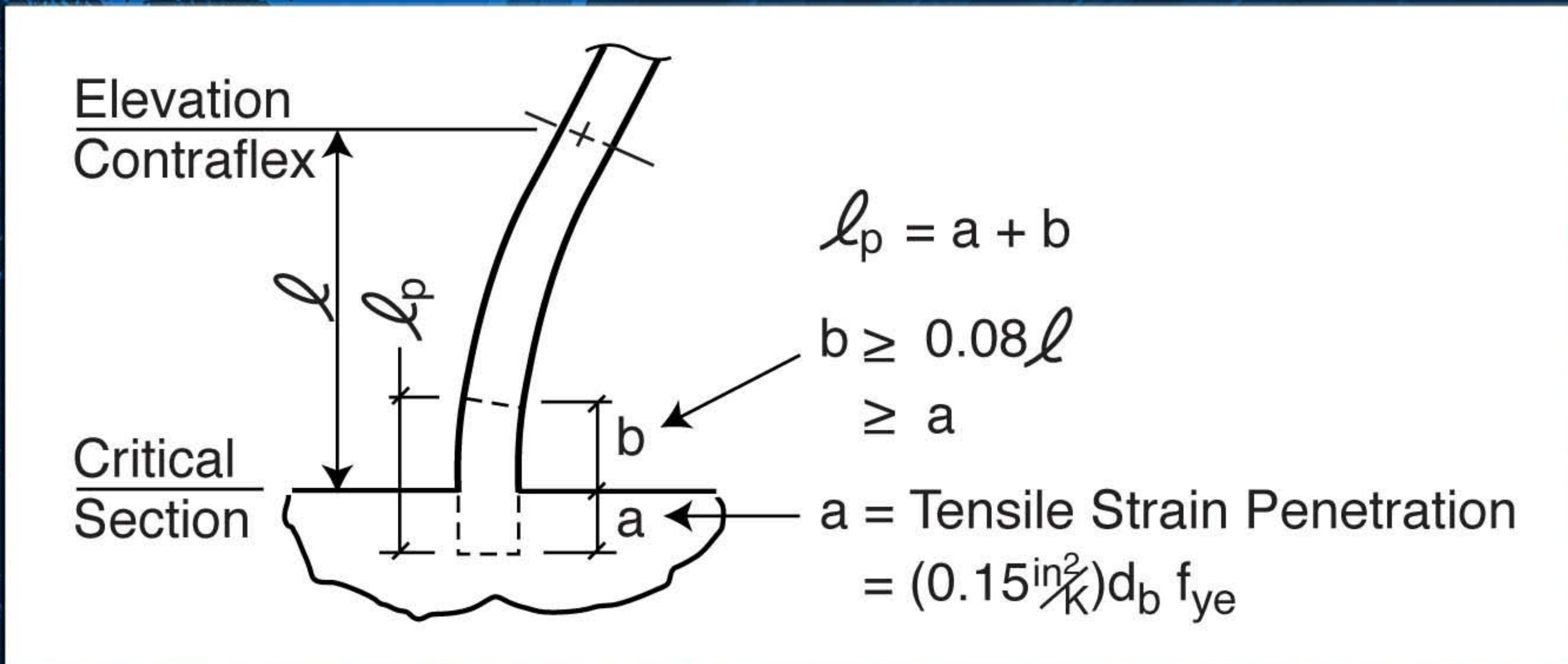
  $= \ell_p \times \varphi_n$

Hinge Length References

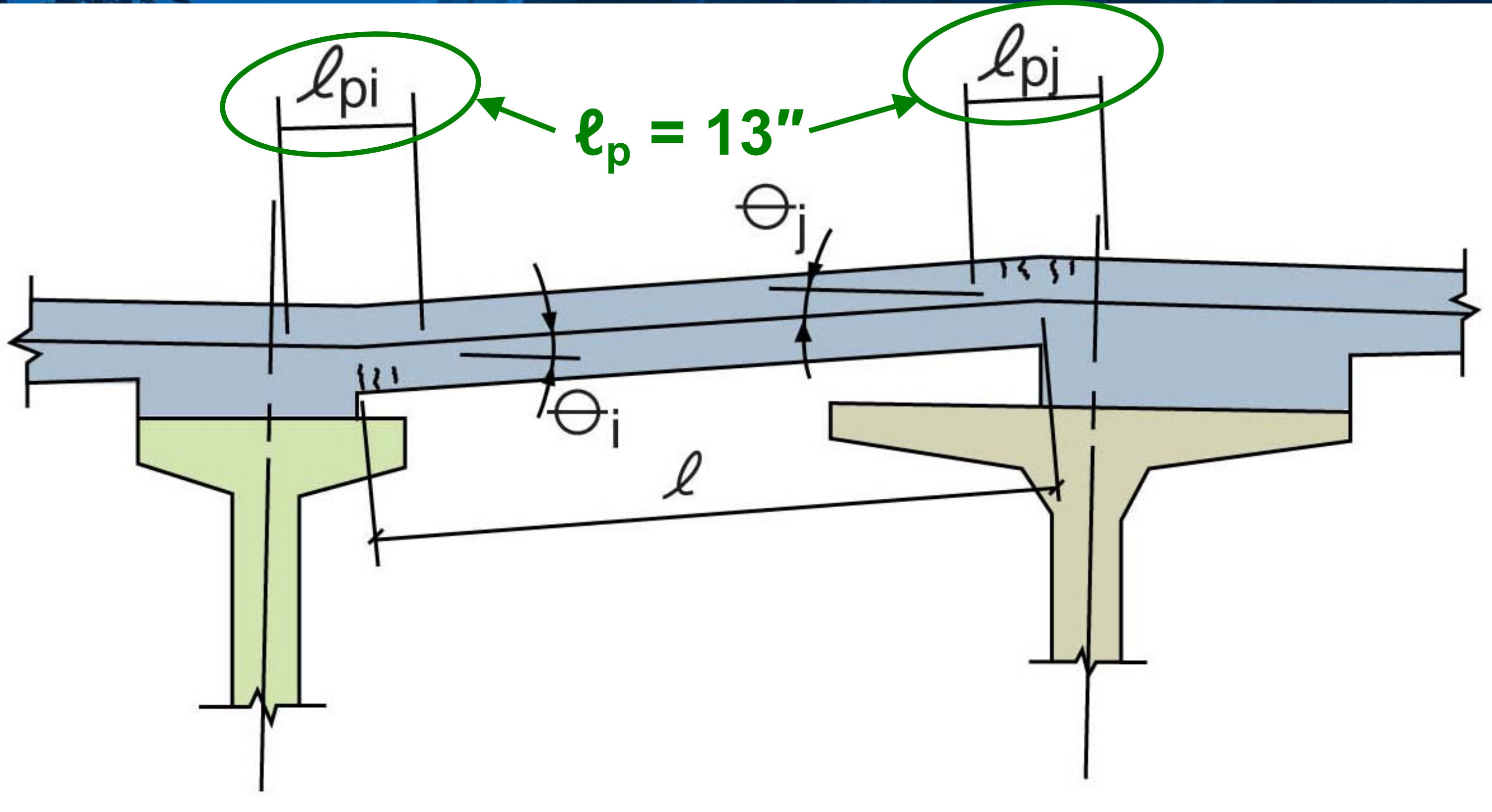
- Kennedy (1975)
- Berdette & Bernal (1978)
- Paulay & Priestley (1992)
- Priestley, Seible, & Calvi (1996) ← used

Hinge Length Model

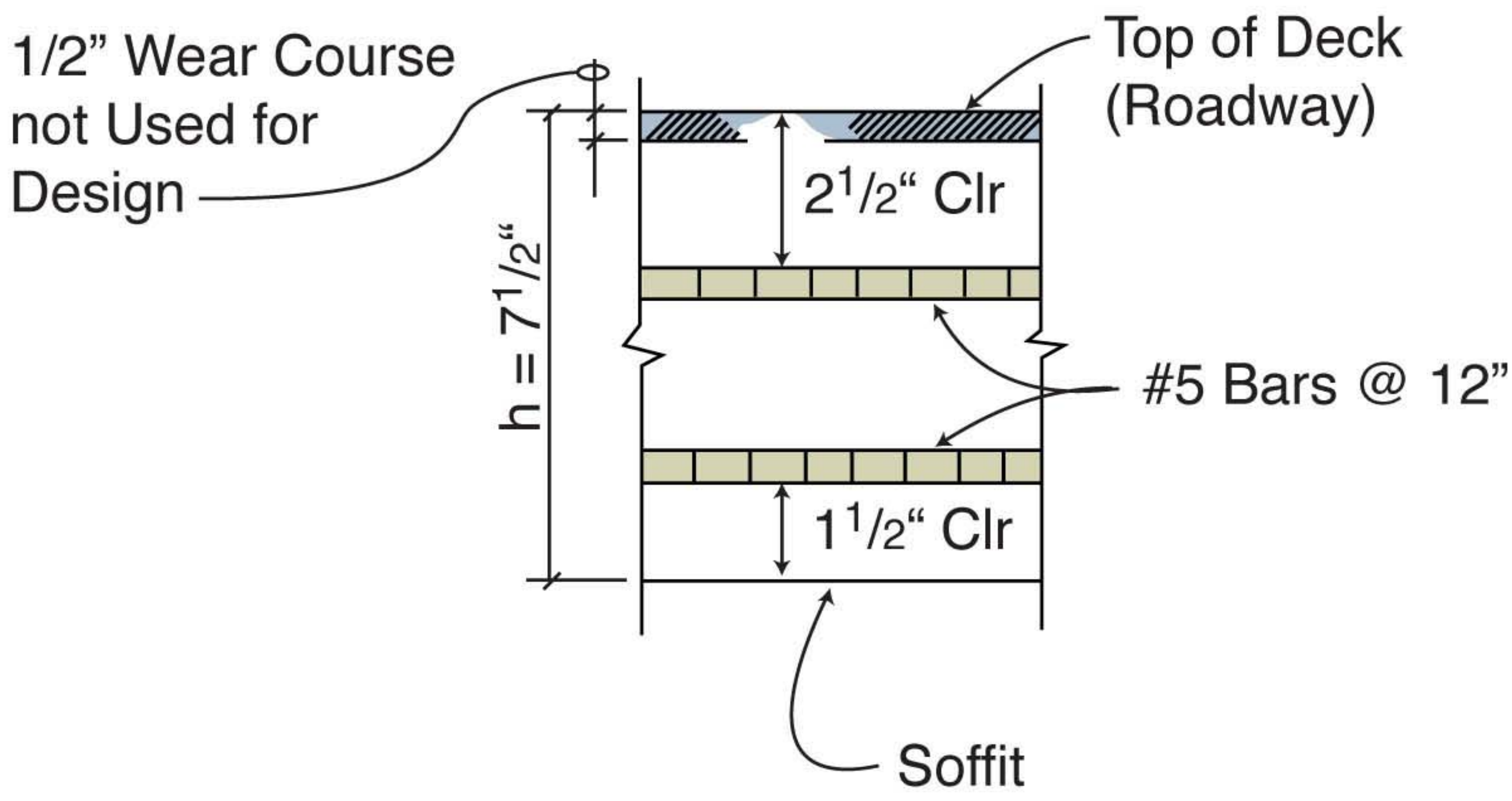
Priestley, Seible, & Calvi (1996):



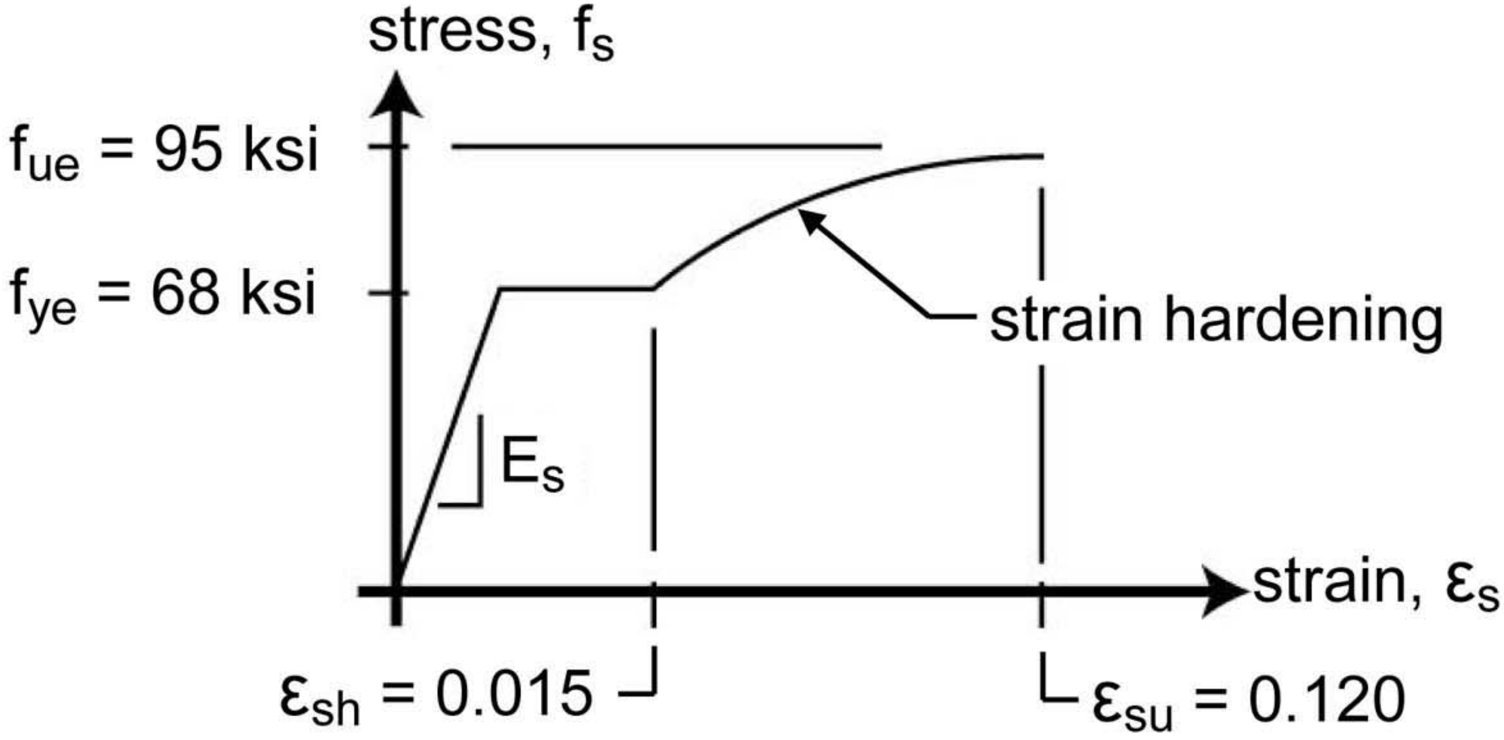
Link Slab Hinge Length



Typical Link Slab Section

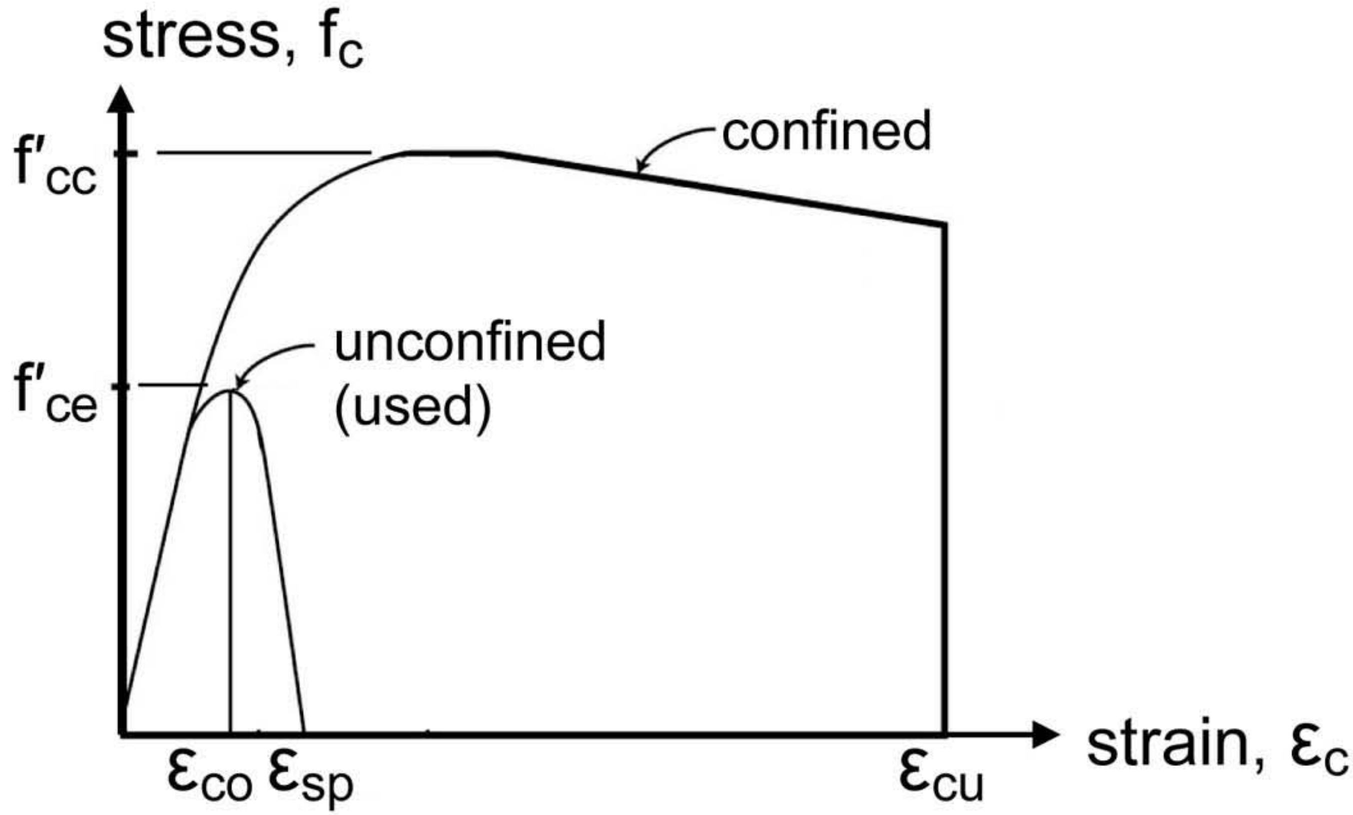


Steel Material Model



Source: Caltrans *Seismic Design Criteria* (2004)

Concrete Material Model



Source: Caltrans *Seismic Design Criteria* (2004)

Concrete Strength

- **Nominal Concrete Cylinder Strength:** $f'_c = 6$ ksi
- **Expected Cylinder Strength:** $f'_{ca} = 1.53\,f'_c = 9.2$ ksi
- **Expected Flexural Strength:** $f'_{ce} = 0.85\,f'_{ca} = 1.3\,f'_c = 7.8$ ksi

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Concrete Strength

- Nominal Concrete Cylinder Strength: $f'_c = 6$ ksi
- Expected Cylinder Strength: $f'_{ca} = 1.53\ f'_c$
  $= 9.2$ ksi
- Expected Flexural Strength: $f'_{ce} = 0.85\ f'_{ca}$
  $= 1.3\ f'_c$
  $= 7.8$ ksi
- Estimating Flexural Overstrength: $f'_{ce} = 1.3\ f'_c$
  – recommended by Caltrans *Sesimic Design Criteria* (2004)

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Concrete Strain

- Spalling Strain – observed [1]: ε_{sp} = 0.005 – 0.010
- Model Strains [2]: spalling: ε_{sp} = 0.005

  peak stress: ε_{c0} = 0.002

[1] Priestley, Seible, & Calvi (1996)

[2] Caltrans (2004) *Sesimic Design Criteria*.

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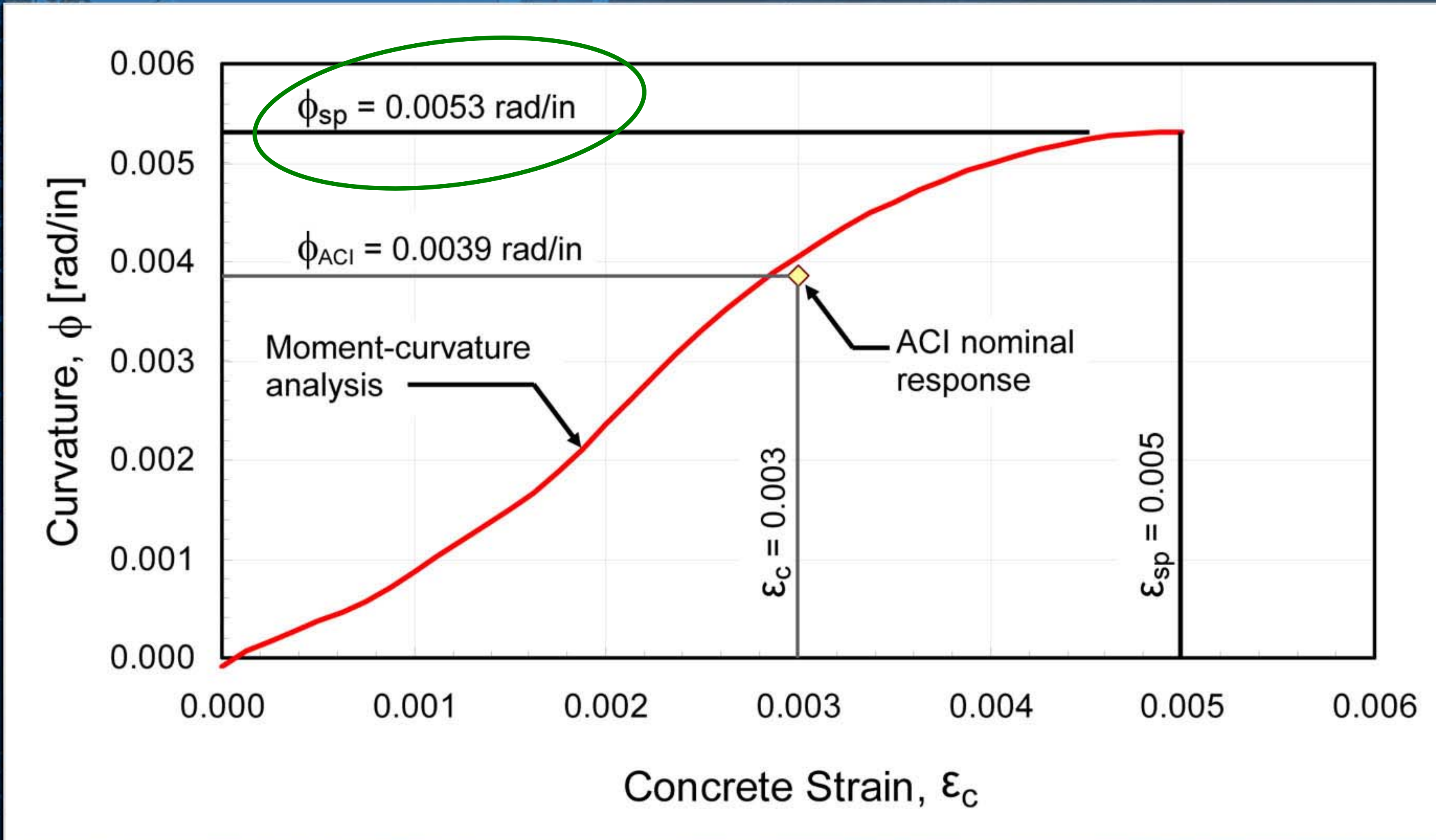
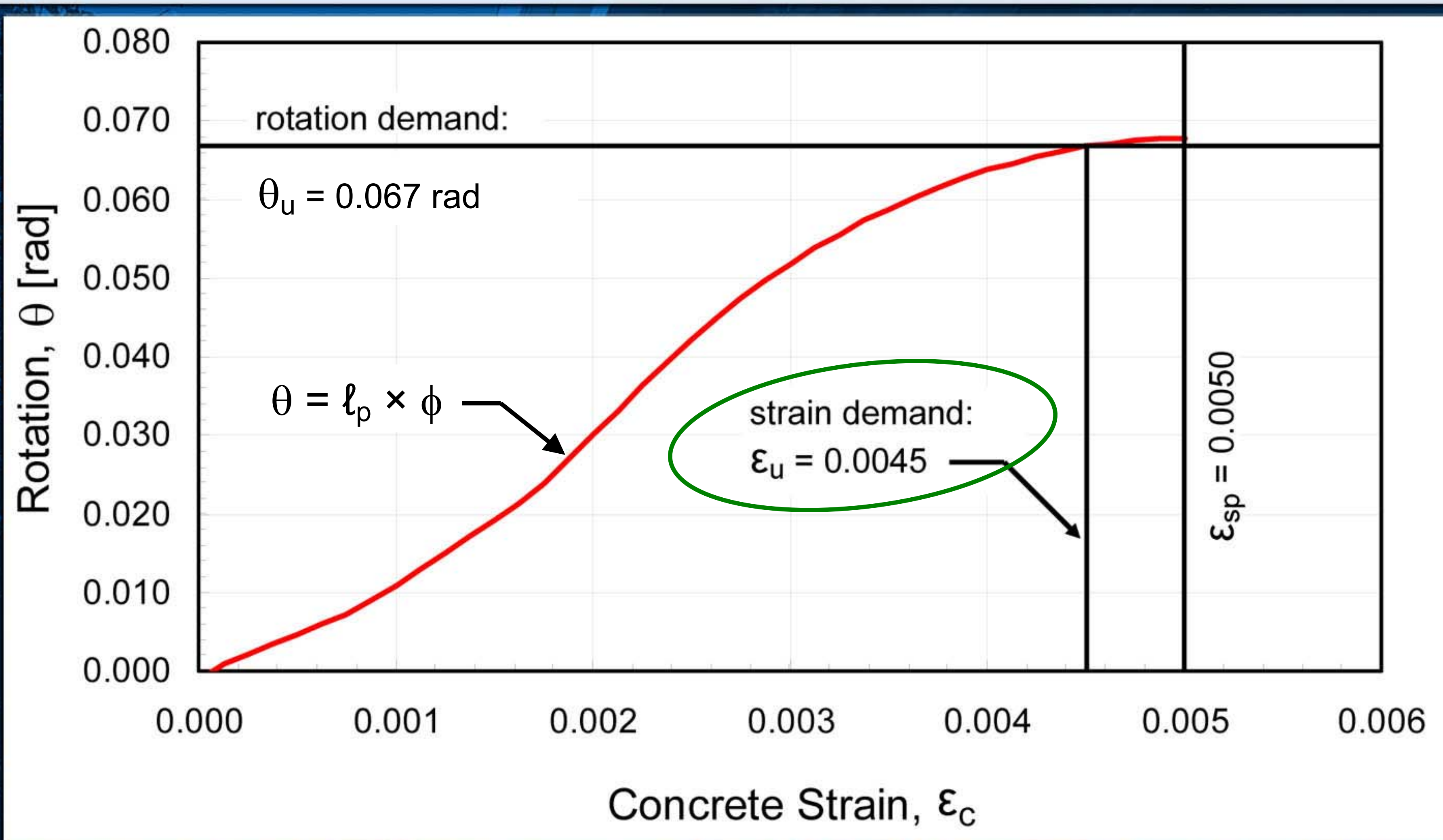
Curvature vs. Strain



Rotation vs. Strain



Concrete Strain

- **Spalling Strain[1]:** $\varepsilon_{sp} = 0.005$
- **No-Spall Design Criteria[2]:** $\varepsilon_c \leq 0.004$
- **Project Strain Demand:** $\varepsilon_u = 0.0045$

1 Caltrans (2004) *Sesimic Design Criteria*.

2 Ferrito et al. (1999) *Seismic Criteria for California Marine Oil Terminals*. Design Criteria for Serviceability Limit State (72-yr earthquake).

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Concrete Strain

- Spalling Strain [1]: $\varepsilon_{sp} = 0.005$
- No-Spall Design Criteria [2]: $\varepsilon_c \leq 0.004$
- Project Strain Demand: $\varepsilon_u = 0.0045$
- Acceptable strain for Life Safety at Extreme Event (475-yr) Limit State

1 Caltrans (2004) *Sesimic Design Criteria*.

2 Ferrito et al. (1999) *Seismic Criteria for California Marine Oil Terminals*. Design Criteria for Serviceability Limit State (72-yr earthquake).

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