TRANSITIONING FROM AASHTO LRFD SEISMIC SPECIFICATIONS TO THE GUIDE SPECIFICATIONS: UNDERSTANDING PERFORMANCE BASED CRITERIA IN FORCE-BASED DESIGN

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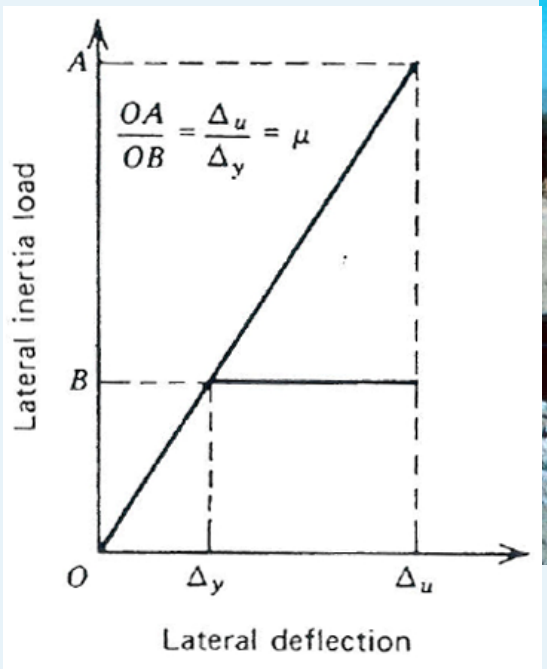
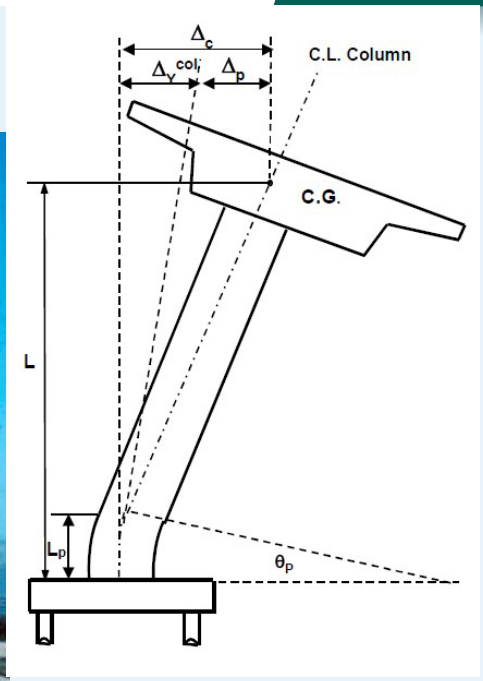




Overview

- Background
- Seismic Performance Objectives
- Force-Based Design Method
- Displacement Based Design Method
- Comparison of Methods
- Illustrative Example – HWY99 over 72nd ST
- Conclusions

Background

- **Prior to San Fernando, seismic forces were estimated using a small percentage of the dead load.**
- **A group of experts were retained and prepared ATC-6 in 1981. Recommendations were forced-based.**
- **ATC-6 was adopted as the *Guide Specifications for Seismic Design* in 1991 and later as Division 1-A.**
- **LRFD Standard Specs use basically same criteria.**

Seismic Performance Objectives

- **Moderate earthquakes should cause minimal damage**
- **Large earthquakes should not cause collapse of structure**
- **Damage should be readily detectable and accessible**

- **Source: ATC-6!! ←FORCE-BASED DESIGN CRITERIA**
- **Similar Performance Objectives are intended under the Guide Specifications**

Force-Based Design Method

- "R" ranges from 3 for single columns to 5 for multiple columns
- Plastic hinge region is designed for "Elastic Seismic Moment"/R.
- Realistic forces due to plastic hinging are developed in higher seismic zones.
- Elastic forces < Hinging forces? NO YIELDING

Force-Based Design Method (Cont.)

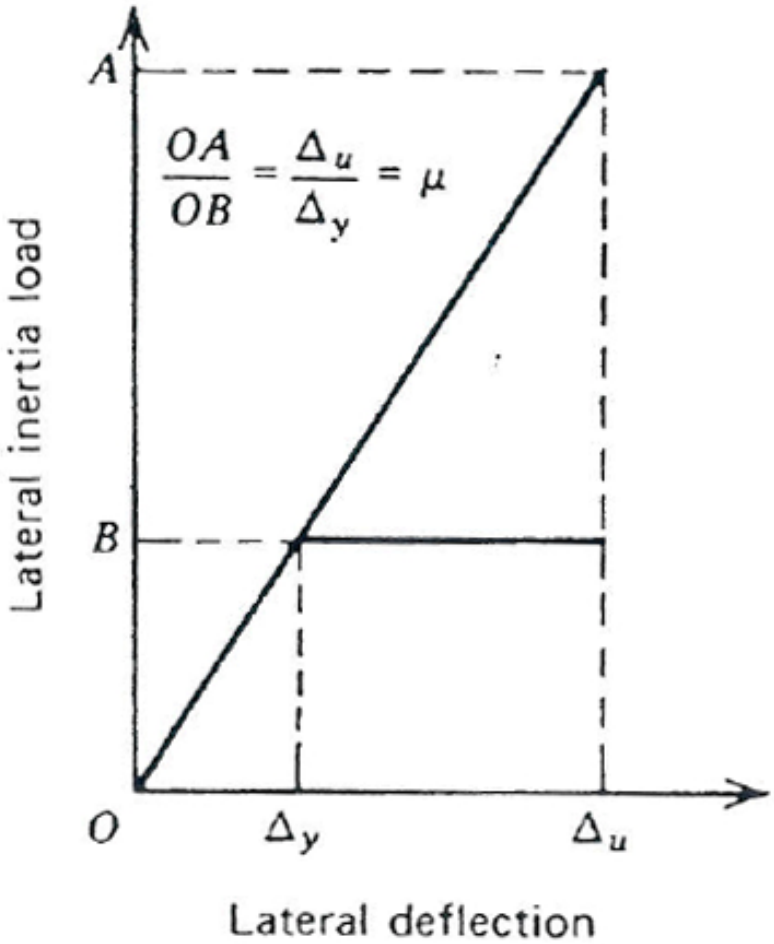
$$R = \frac{F_A}{F_B} = \frac{\Delta_A}{\Delta_B}$$

Equal Displacement

$$R = \sqrt{2\mu - 1}$$

Equal Energy

Response Modification Factor



Displacement Based Design Method

- Column capacity assessment using displacement only
- Adjacent members typically designed as capacity protected elements
- Local column ductility factor prescribed in Guide Specs to determine displacement capacity
- Elastic displacements < Column Capacity DESIGN OK!!

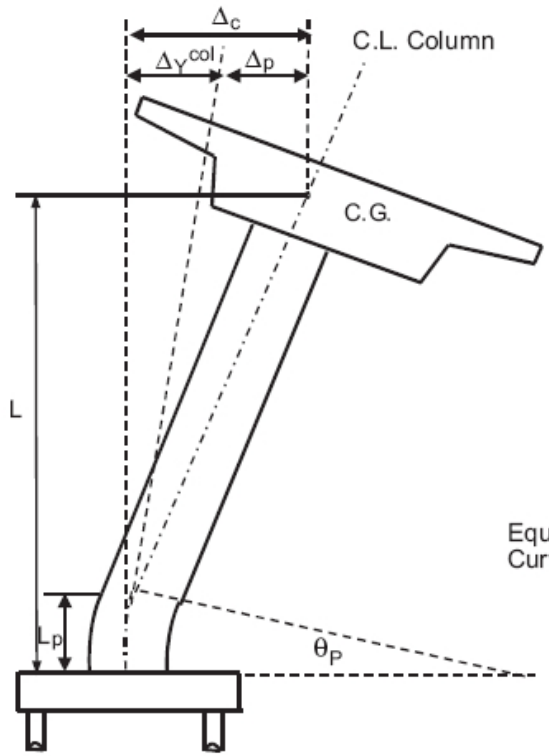
Displacement Based Design Method (Cont.)

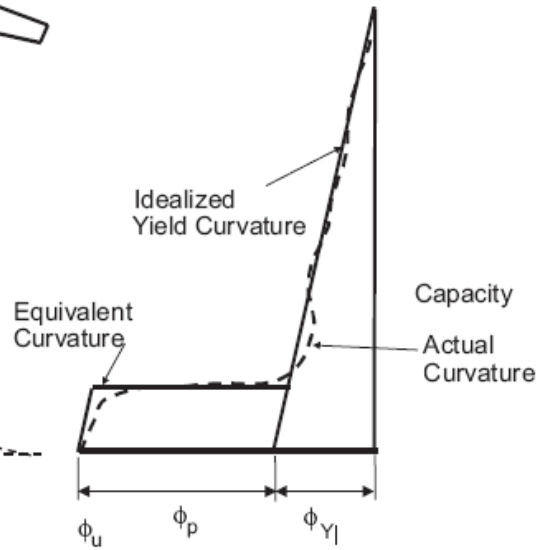
$$\Delta_Y = \phi_Y * \frac{L^2}{3}$$

Yield Displacement

$$\Delta_P = \theta_P * (L - \frac{L_P}{2})$$

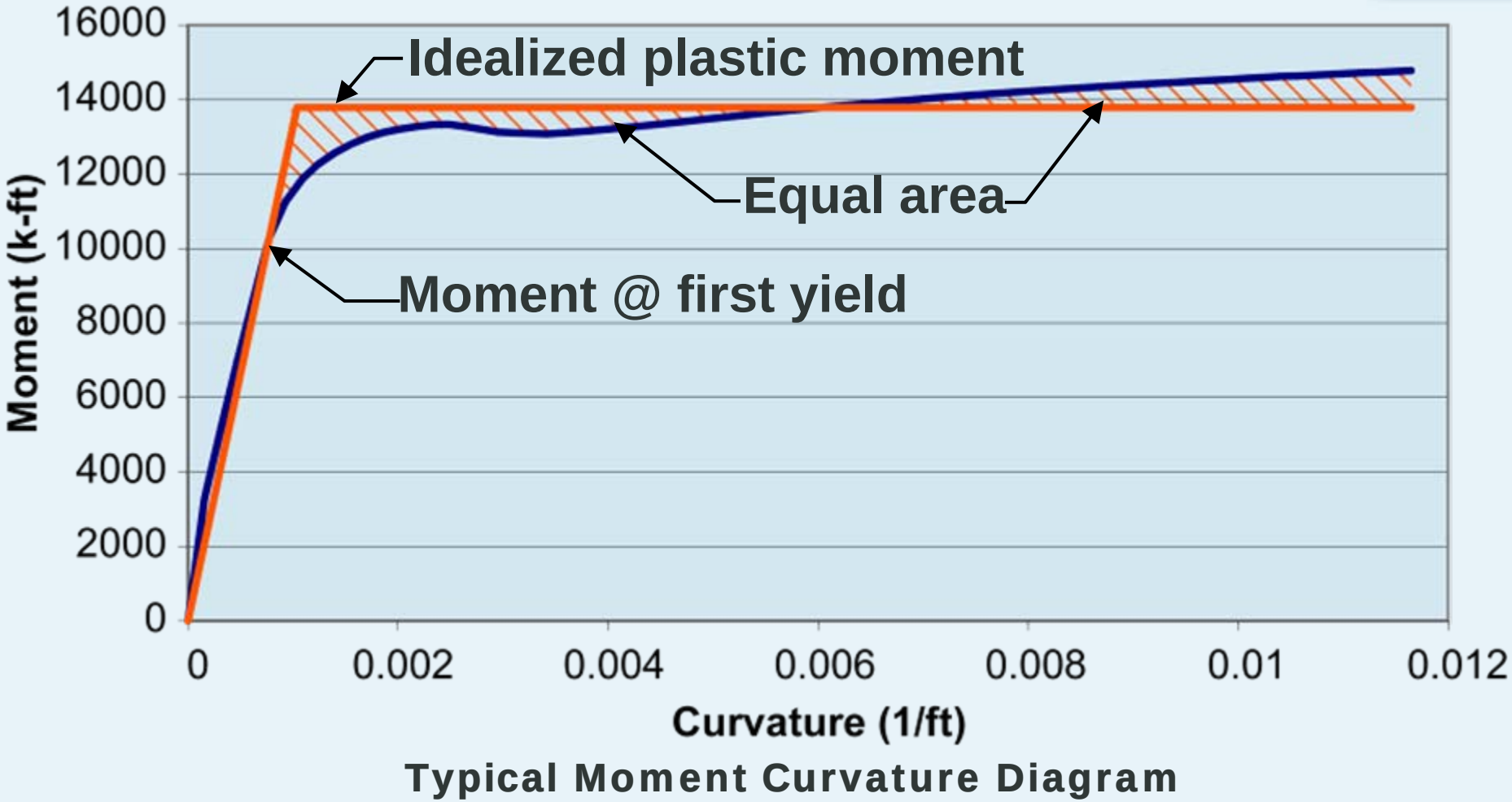
Plastic Displacement





Displacement **Curvature**

Displacement Based Design Method (Cont.)



Typical Moment Curvature Diagram

Comparison of Methods

- **Structure stiffness increase**

  FBM - Reinforcement increases. Design moment (M/R) increases due to stiffness increase

  DBM - Reinforcement not affected

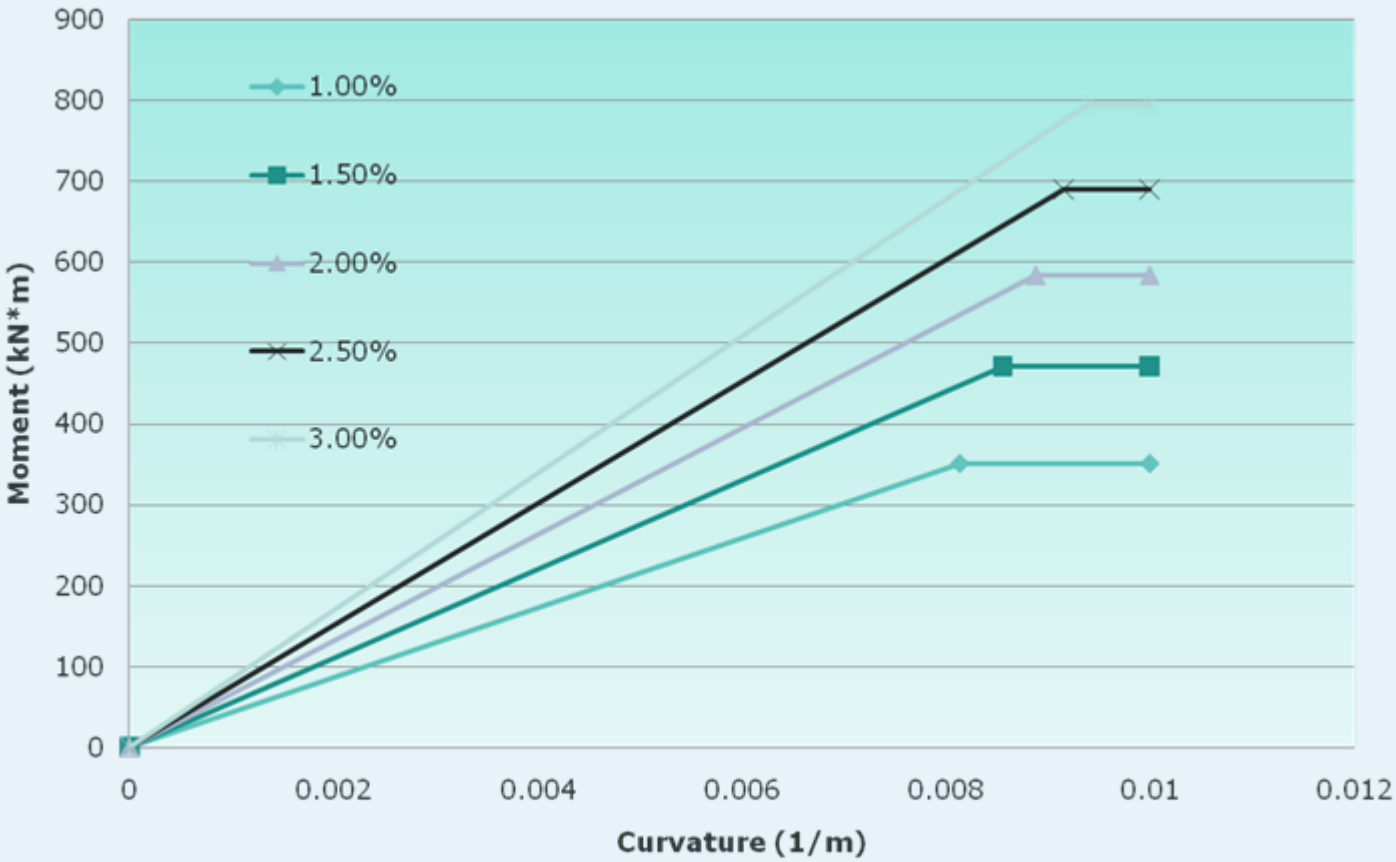
Comparison of Methods (Cont.)

- **Column steel increase**

  FBM – Column stiffness does not increase using typical assumptions. Yield displacement assumed to increase.

  DBM – Column stiffness increases. Yield displacement relatively unchanged.

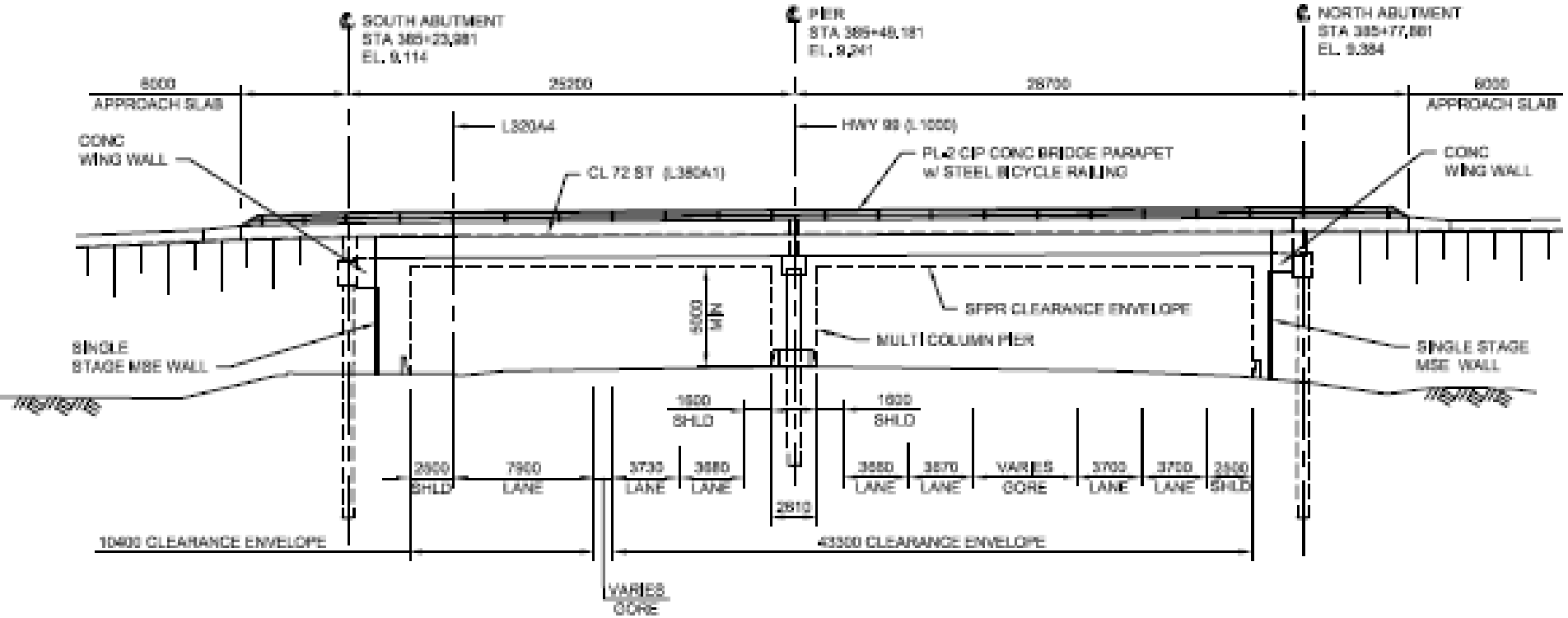
Comparison of Methods (Cont.)



610mm Diameter Column

Illustrative Example – Hwy99 over 72nd ST

- **Two span precast girder bridge in Vancouver, B.C.**



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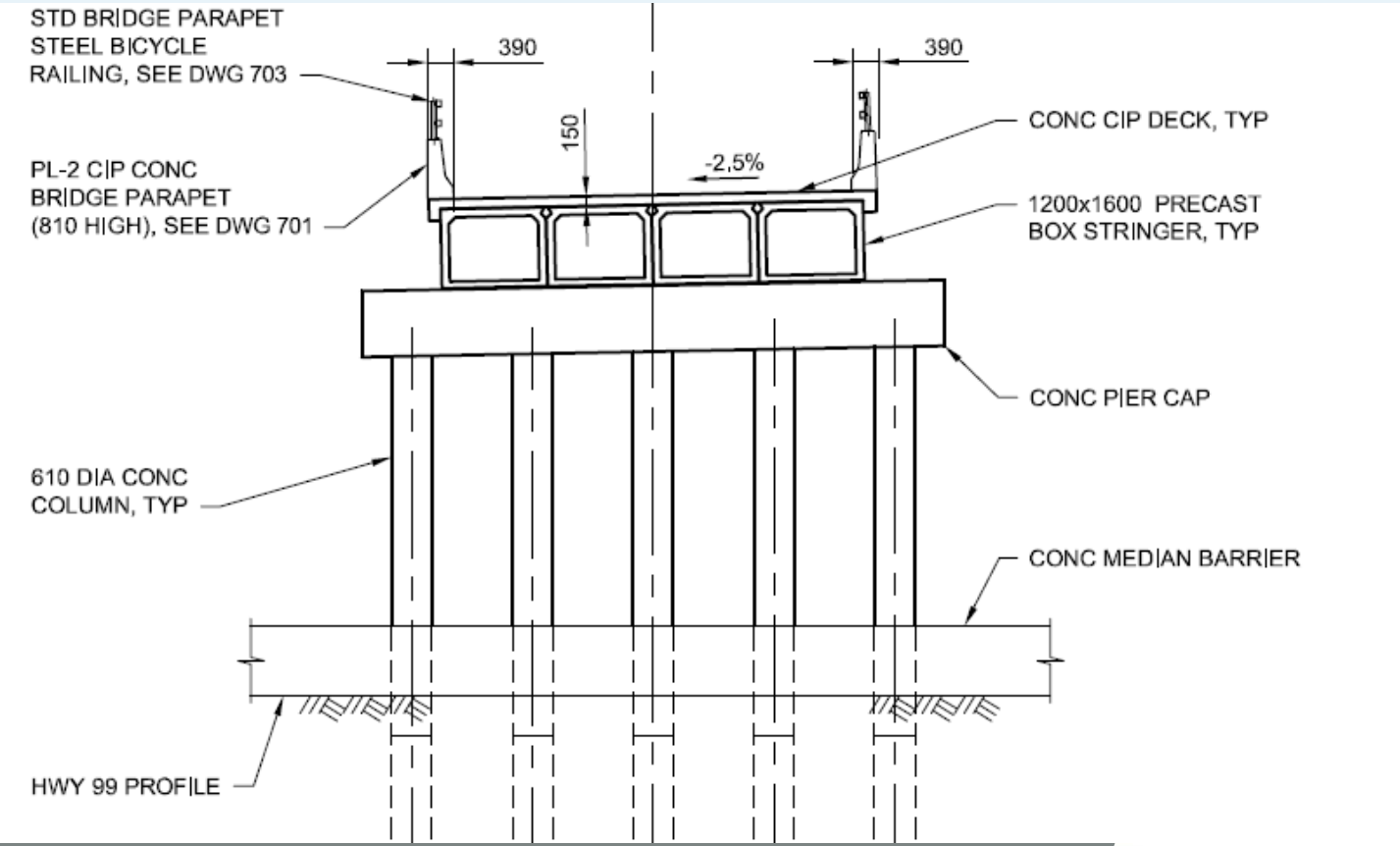
Typical Pile Bent Section

- **610 mm diameter driven pile bent**



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Column Design Criteria

- **475 yr EQ**

  Column reinforcing requirements based on the greater of

  Elastic moment / R = 5

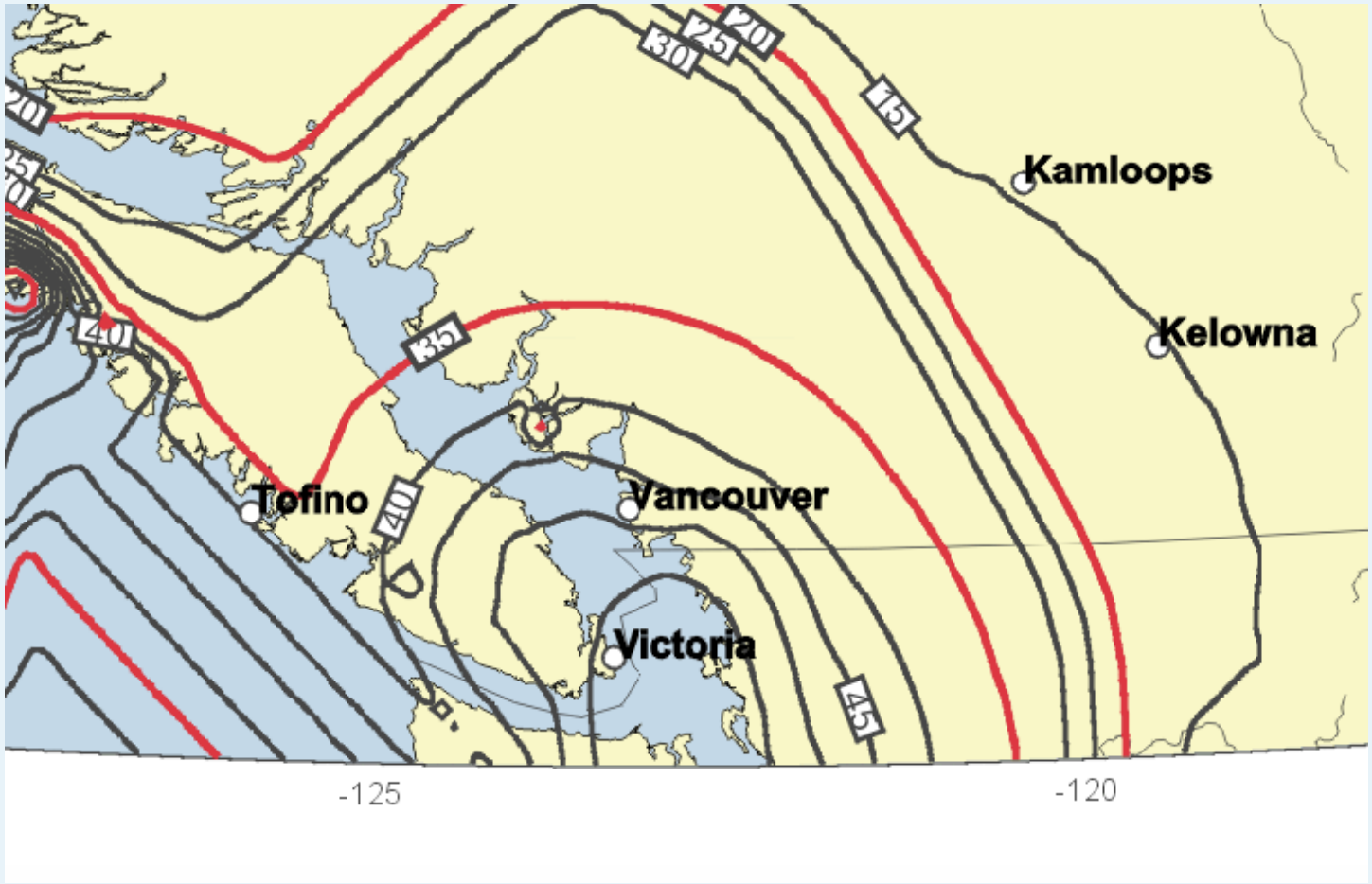
  or

$$\varepsilon_s < 0.75\varepsilon_{su} \qquad \varepsilon_c < 0.75\varepsilon_{cu}$$

- **975 yr EQ – No Collapse**

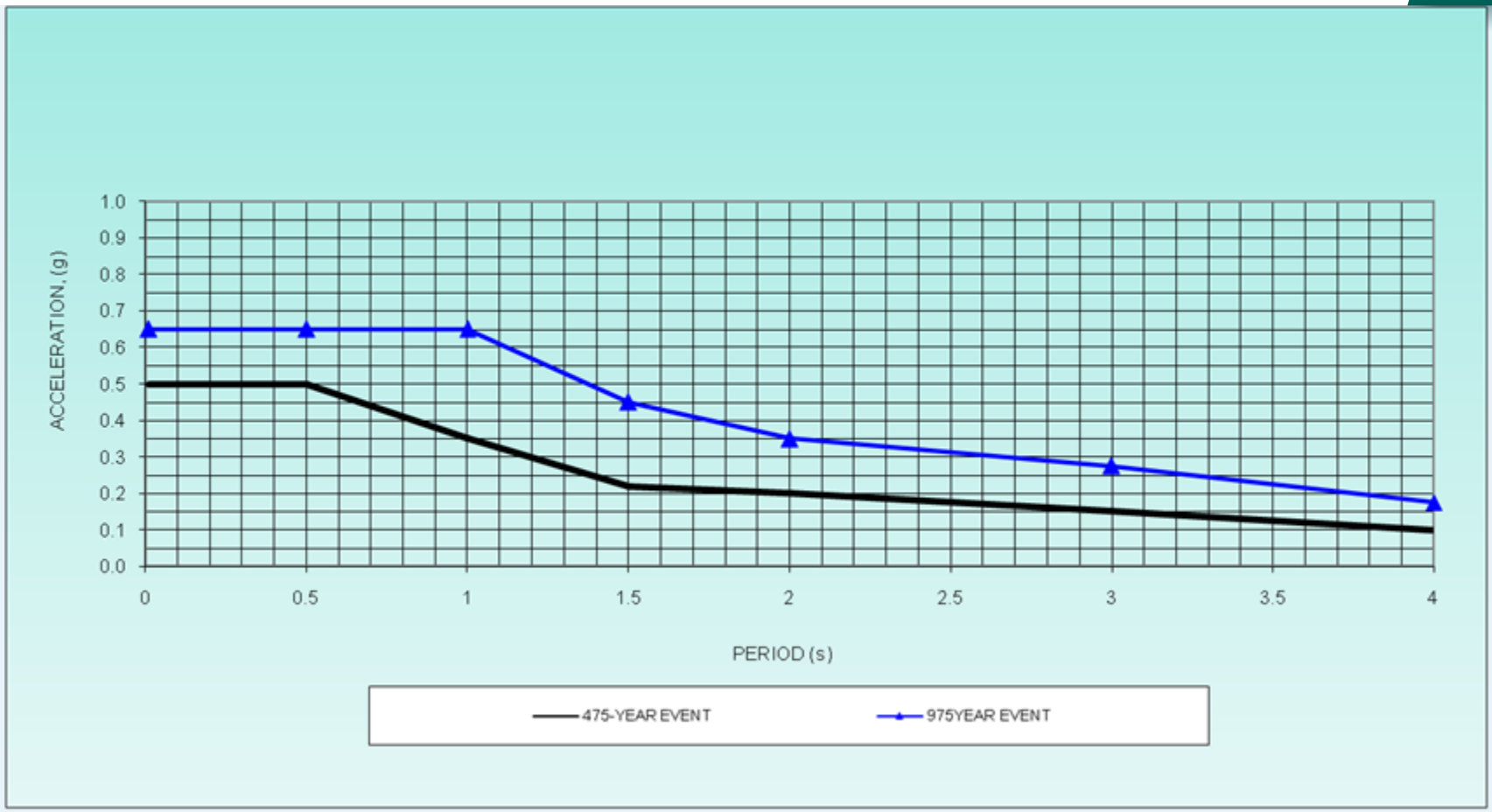
$$\varepsilon_s < \varepsilon_{su} \qquad \varepsilon_c < \varepsilon_{cu}$$

Seismicity

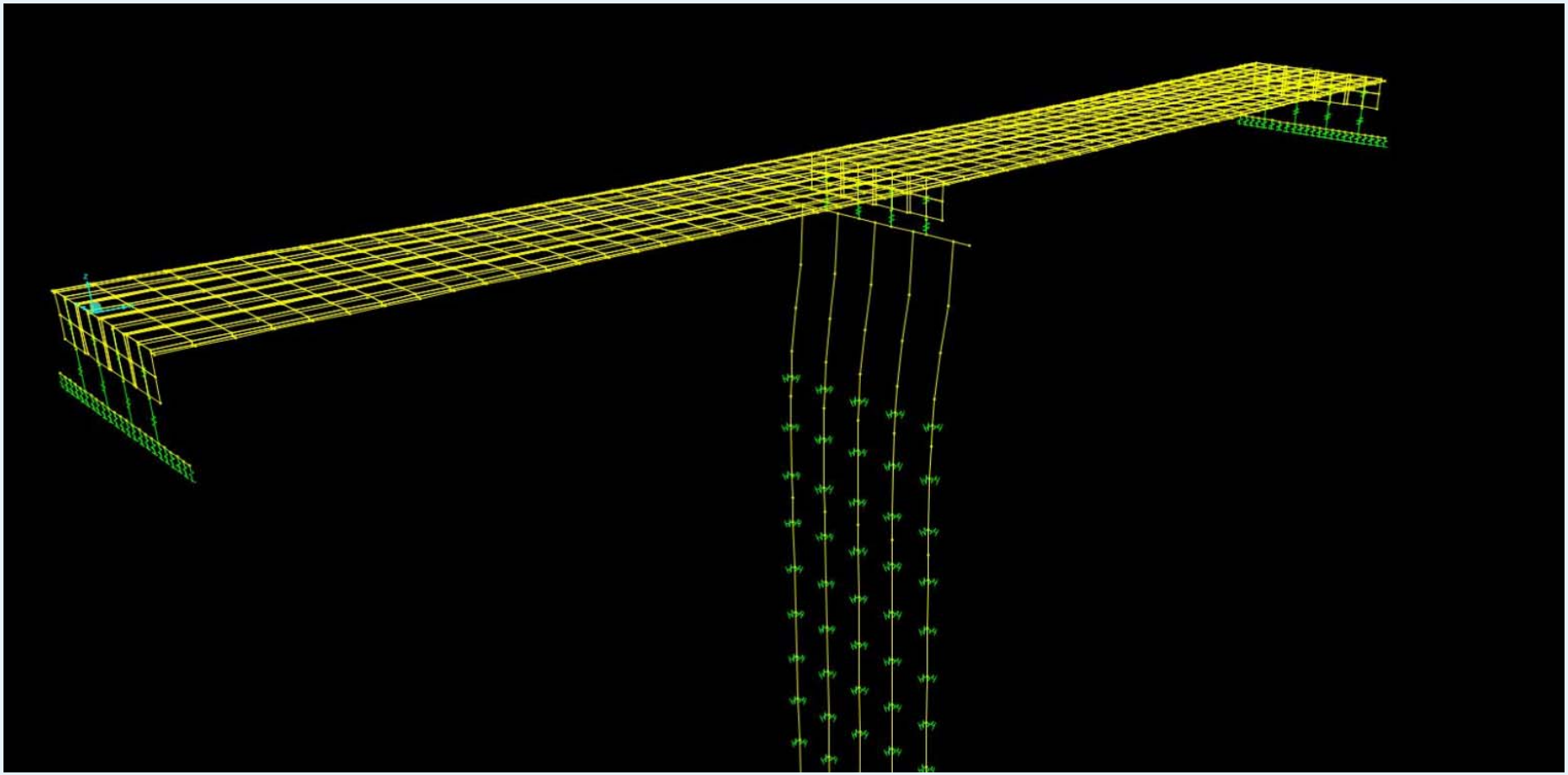


975 yr Earthquake

Design Response Spectrum

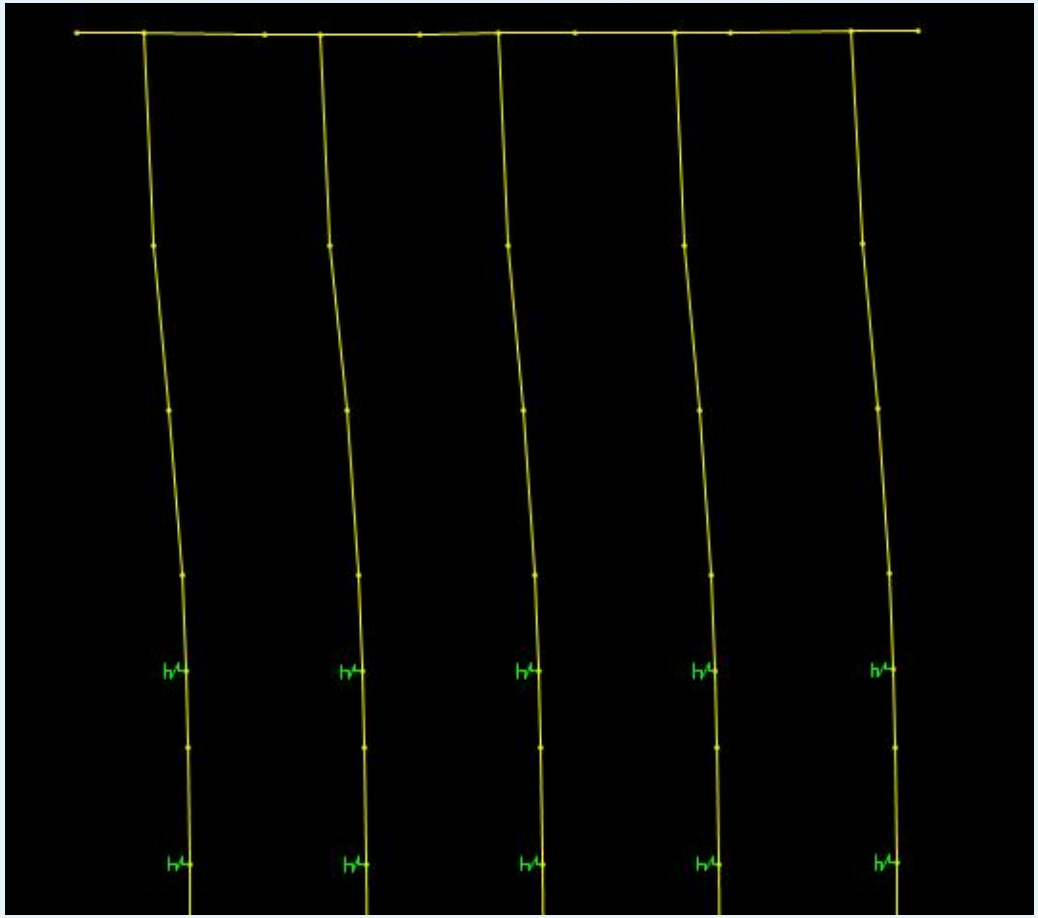


Fundamental Transverse Mode



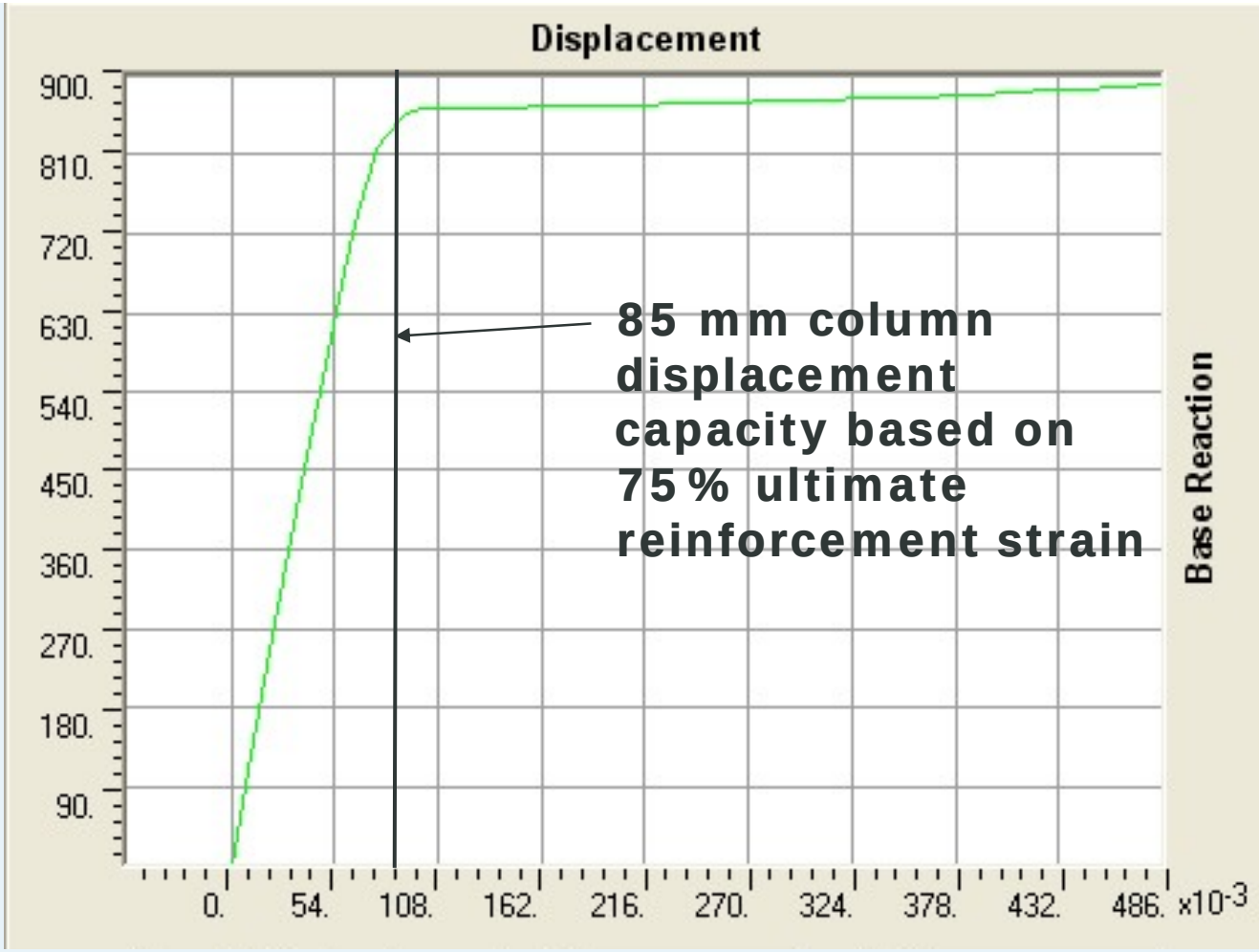
Tm = 0.39 sec

Pier Response Under Design EQ

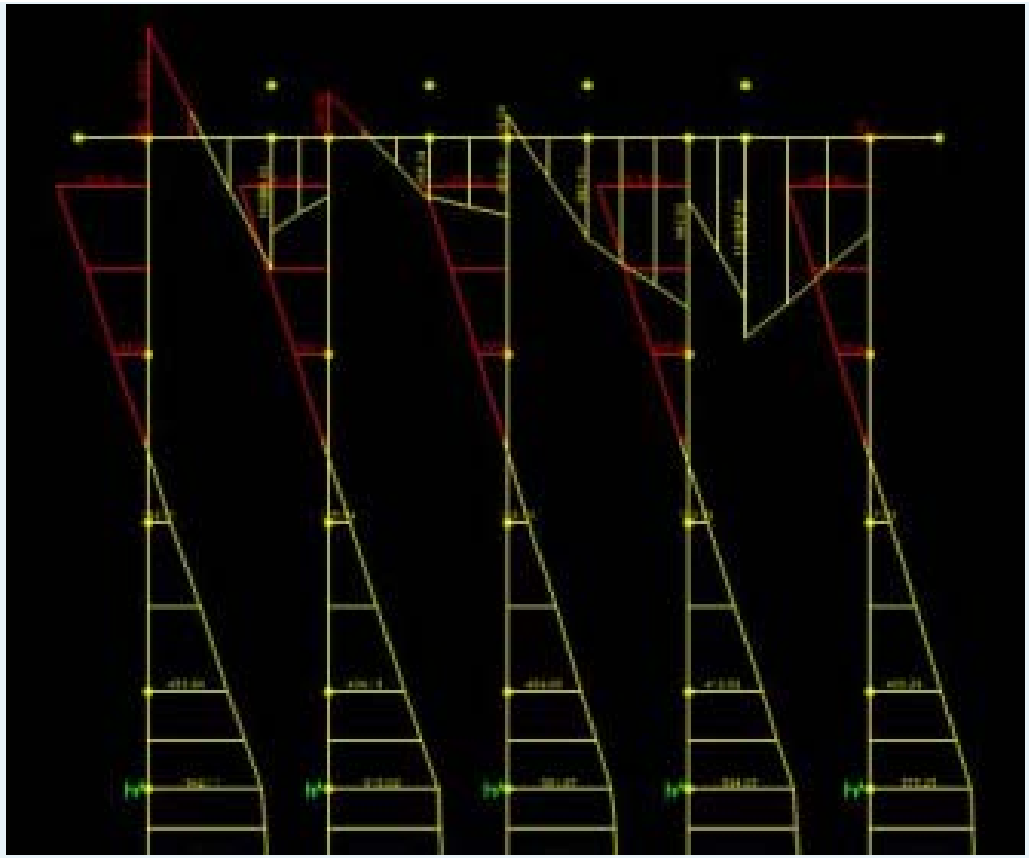


No Hinging is Expected
Maximum displacement = 28 mm

Pushover Curve



Pushover Analysis – Moment Diagram



Used for Capacity Protected Members

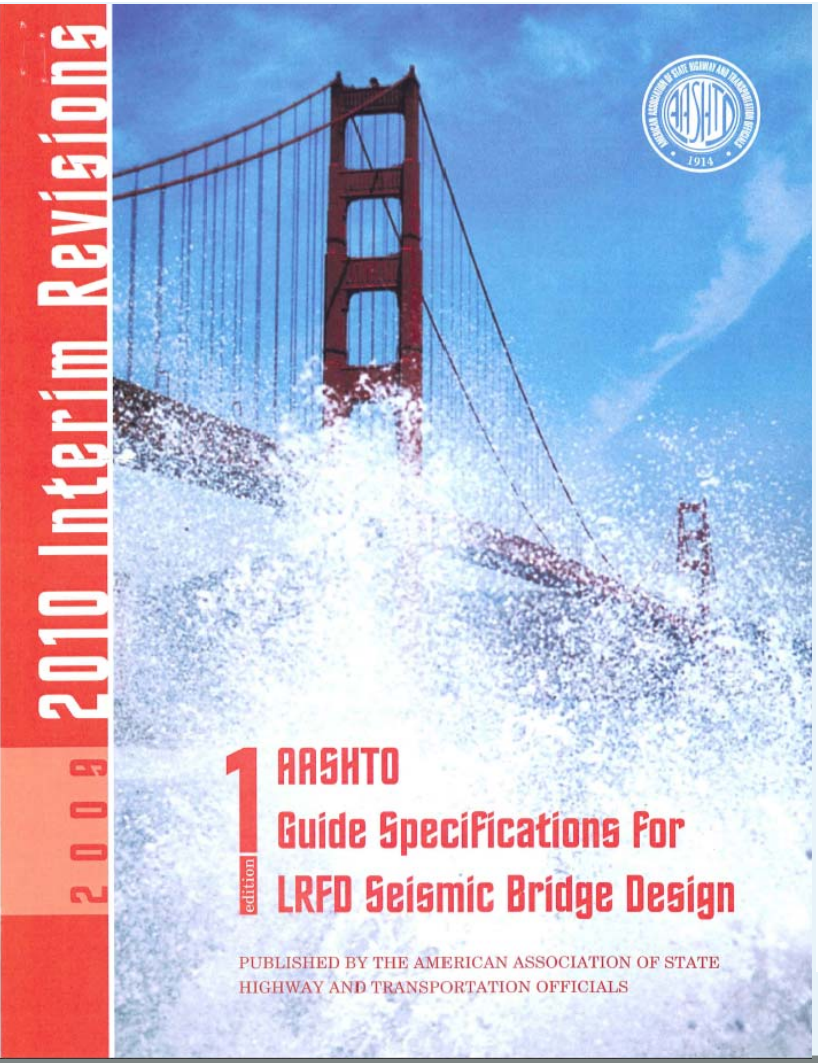
Summary of Design

- Number of piles were governed based on geotechnical capacity requirements under service loads.
- Minimum reinforcement requirements were used in the columns.
- Column hinging is not expected at the 975 yr EQ.
- Piles are capacity protected.

Conclusions

- A simplified model without explicitly modeling of the piles such as a fixed based model could be used to simplify the demand analysis.
- A simplified hand calculation could be used to show the columns have adequate displacement capacity.
- Pier cap and piles should be capacity protected although hinging is not expected.
- Displacement based method does not require significant additional effort to assess column capacity.
- Displacement based method provides a more rational approach.

Questions?


2010 Interim Revisions
2009
1
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Guide Specifications for
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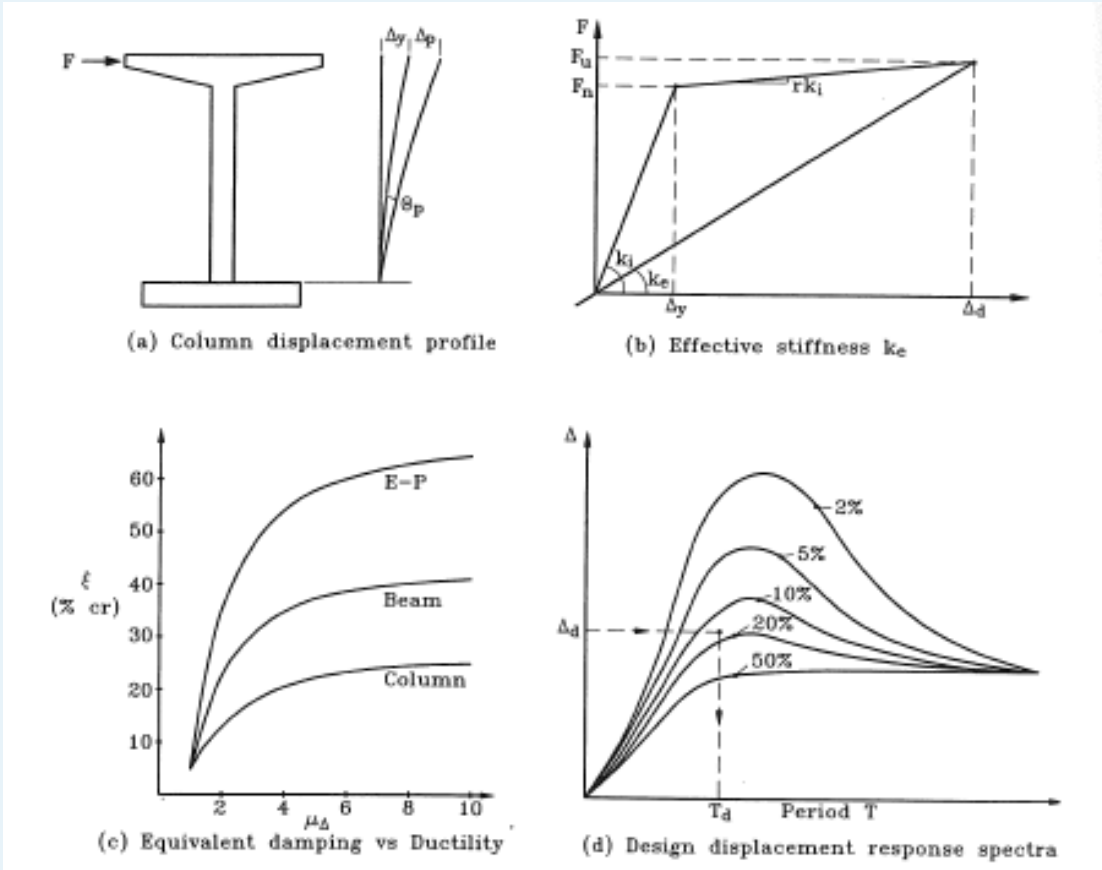
F
Δ_y Δ_p
θ_p
(a) Column displacement profile
F
F_u
F_n
rk_i
k_i
k_e
Δ_y
Δ_d
(b) Effective stiffness k_e
60
50
40
30
20
10
ξ (% cr)
E-P
Beam
Column
2
4
6
8
10
μ_Δ
(c) Equivalent damping vs Ductility
Δ
Δ_d
2%
5%
10%
20%
50%
T_d
Period T
(d) Design displacement response spectra