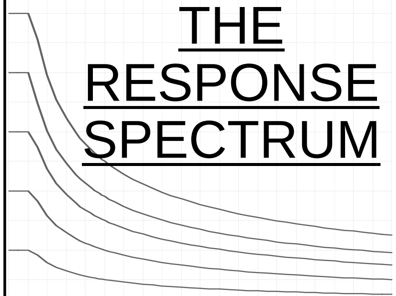
The Canadian Society for Civil Engineering, Vancouver Section

THE RESPONSE SPECTRUM



A Technical Seminar on the Development and Application of the Response Spectrum Method for Seismic Design of Structures

Response Spectrum Analyses Case Studies, Applications to Bridges

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Manager, Bridge Engineering
Associated Engineering

1-2 June 2007 Vancouver, BC

Outline

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Four Case Studies:

1. Application of RSA to bridge seismic design
2. Mission Bridge – Comparison of demands from RSA and time history analyses
3. Lake City Overpass: RSA demands and combinations
4. Knight Street Bridge retrofit – RSA and modeling

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Implications of design forces on columns

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Implications of design forces on columns

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Implications of design forces on columns

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Implications of design forces on columns
(Too much strength?)
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Implications of design forces on columns
(Too little strength, little ductility (old codes))
8

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Implications of design forces on columns

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Implications of design forces on columns

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Column proportions and curvature ductility demands

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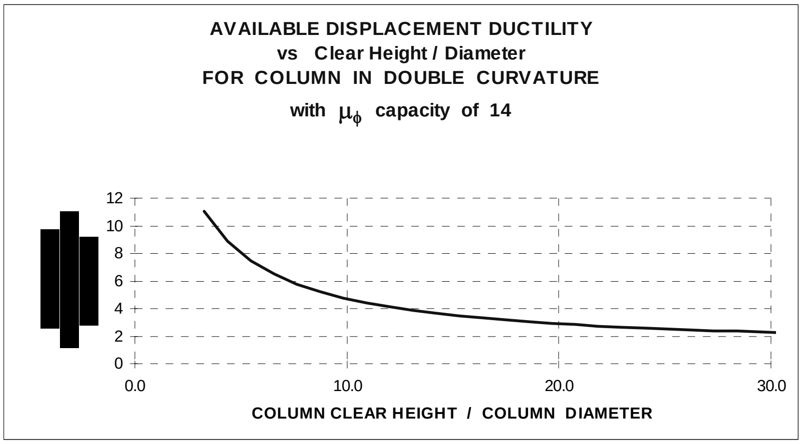

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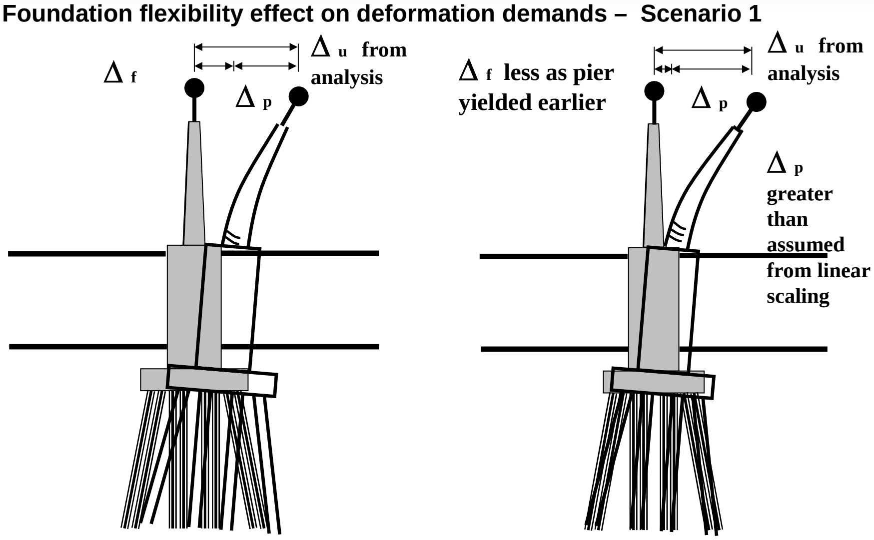
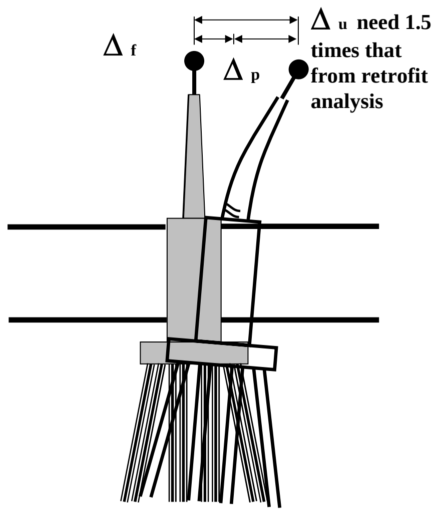
Application to Design: Displacement – based Design Issues

Foundation flexibility effect on deformation demands – Scenario 1



Foundation flexibility - Scenario 2 : Design Criteria requires 1.5 x $D_{analysis}$

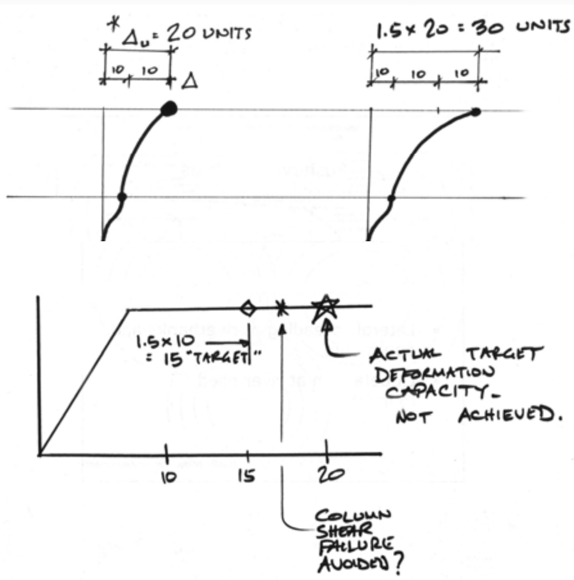


Criteria may require capacity of 150% of the ultimate displacement – not merely of the pier's mechanism displacement from pushover analysis.

If retrofit is designed to achieve a target mechanism displacement, prior to (say) a column shear failure, the criteria may not have been met.

This criteria may be very difficult to achieve if foundation flexibility contributes significantly to drifts. Consider alternative retrofit (e.g. pile hinging)

Foundation flexibility - Scenario 2 : Design Criteria requires 1.5 x $D_{analysis}$



If consider also shape of displacement spectrum & period shift from flexibility, may find little benefit to drift demands

Outline 15

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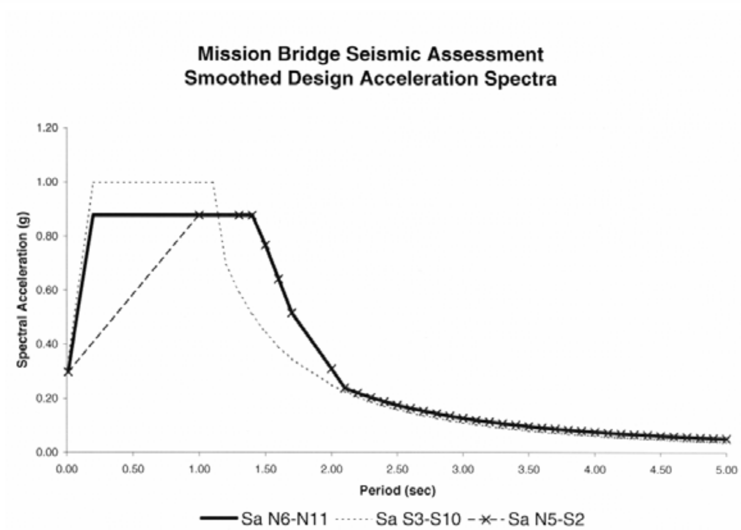
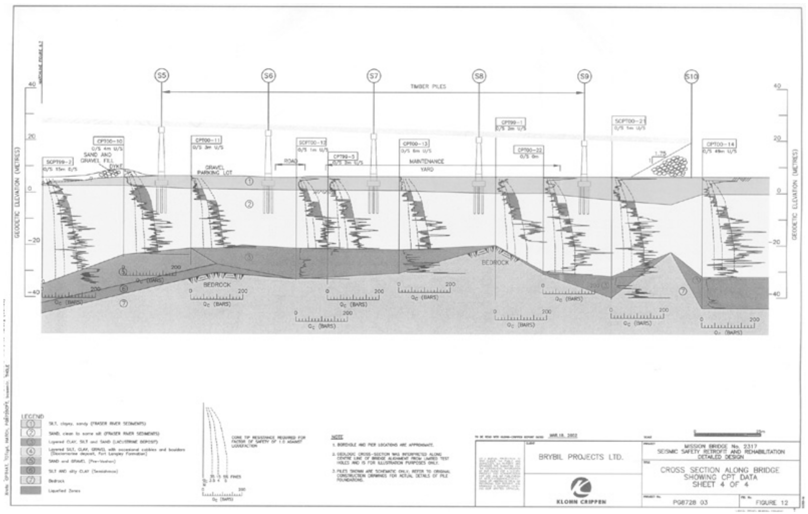
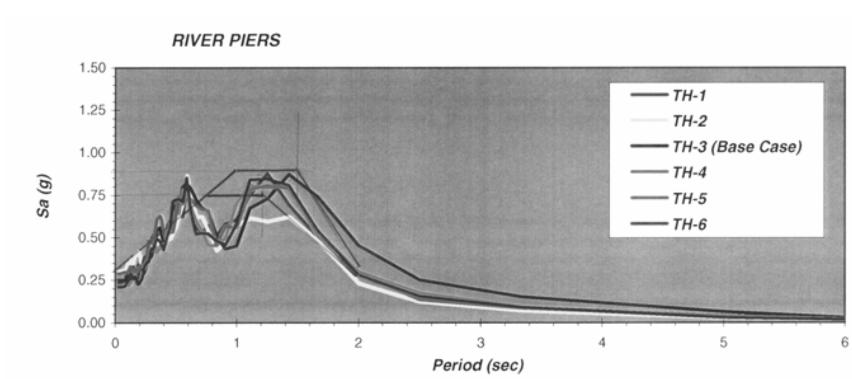
Acceleration Response Spectra



Site variation



Acceleration Response Spectra



Modeling 19

- Idealization of the real structure

- **The continuum…**

↳is replaced by discrete joints and elements

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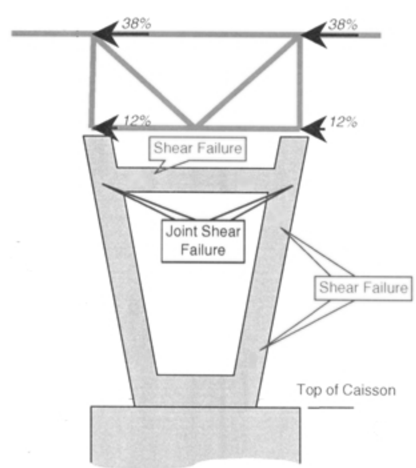
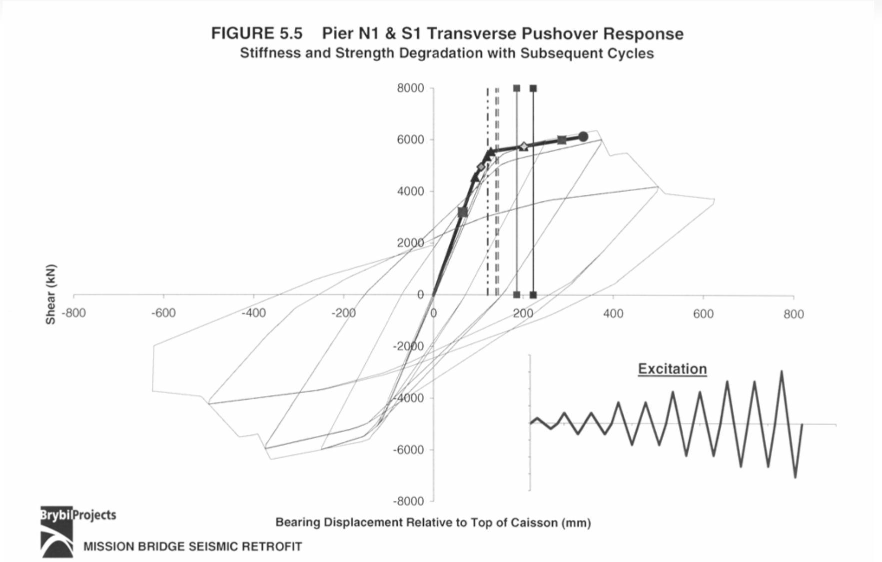
Pier modeling

- 4 SADSAP Pivot Elements per Pier



Structural Analysis – Pier Nonlinearities



Structural Analysis – Pier Nonlinearities

Oak Street & Queensborough Bridges - Two Column Bent Tests 35

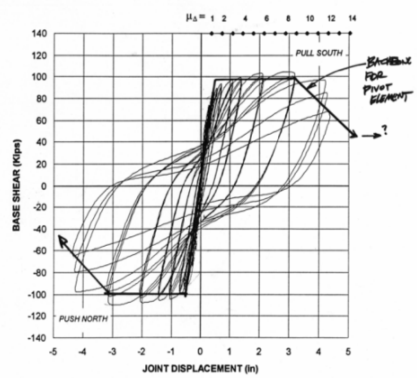


Fig. 6.4(a) Lateral Load Displacement Response for OSB4.

NOTE: 1) SADSAP DOES NOT DIRECTLY ACCOUNT FOR DEGRADATION IN SUBSEQUENT CYCLES AT SAME DEFORM'N
2) DEGRADATION WITHIN CYCLES DEPENDS ON NATURE OF RETROFIT SCHEME.

UBC Civil Engineering - Earthquake Engineering Research Facility - Technical Report 95-02 July 1995

Oak Street & Queensborough Bridges - Two Column Bent Tests 31

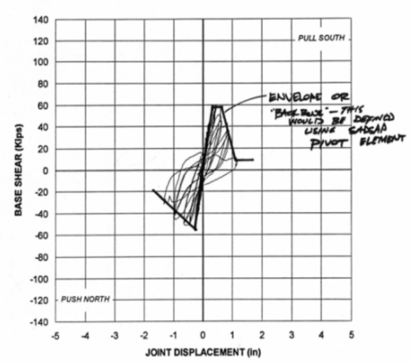


Fig. 6.1 Lateral Load Displacement Response for OSB1.

AS CONSTRUCTED – NOT RETROFIT

UBC Civil Engineering - Earthquake Engineering Research Facility - Technical Report 95-02 July 1995

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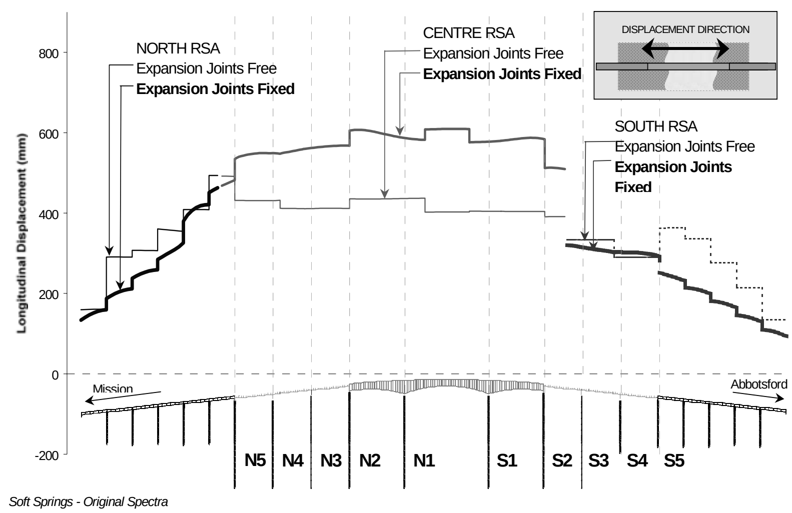
MISSION BRIDGE SEISMIC ASSESSMENT - FIGURE 7.13
Longitudinal Displacement Demands



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Structural Analysis – Model Calibration

- *Cracked Pier Stiffness Properties*
  - SAP 2000: I_e/I_g = 35%
  - SADSAP: I_e/I_g = 25%
- *Directional Effects*
  - SAP2000: SRSS combination
  - SADSAP: simultaneous inputs in orthogonal directions

SMSB VI – July 30, 2002
Mission Bridge Seismic Retrofit and Rehabilitation

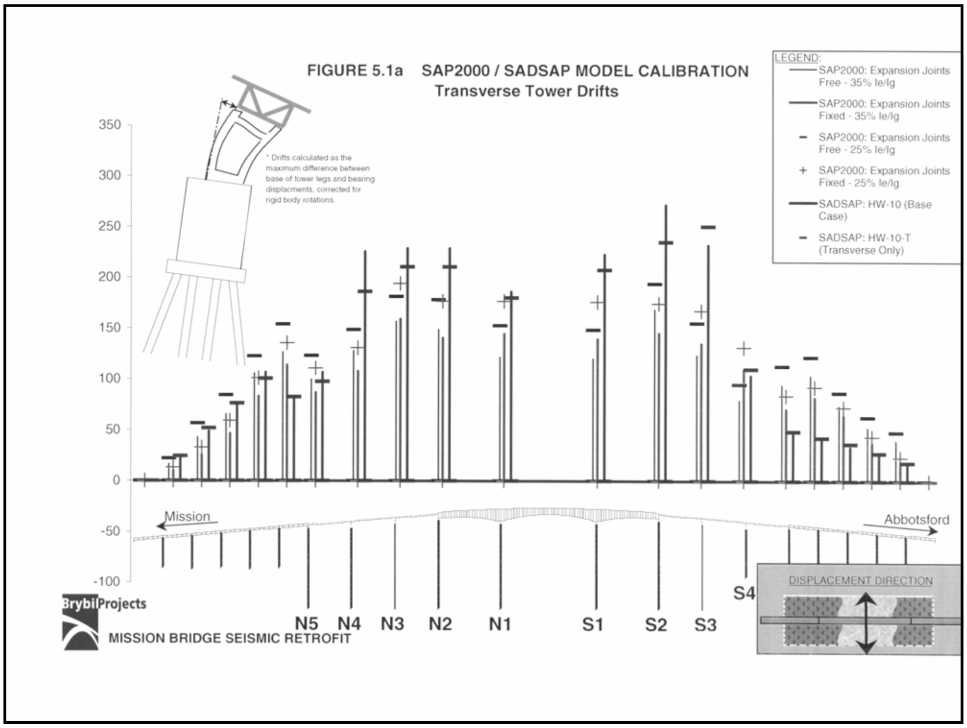
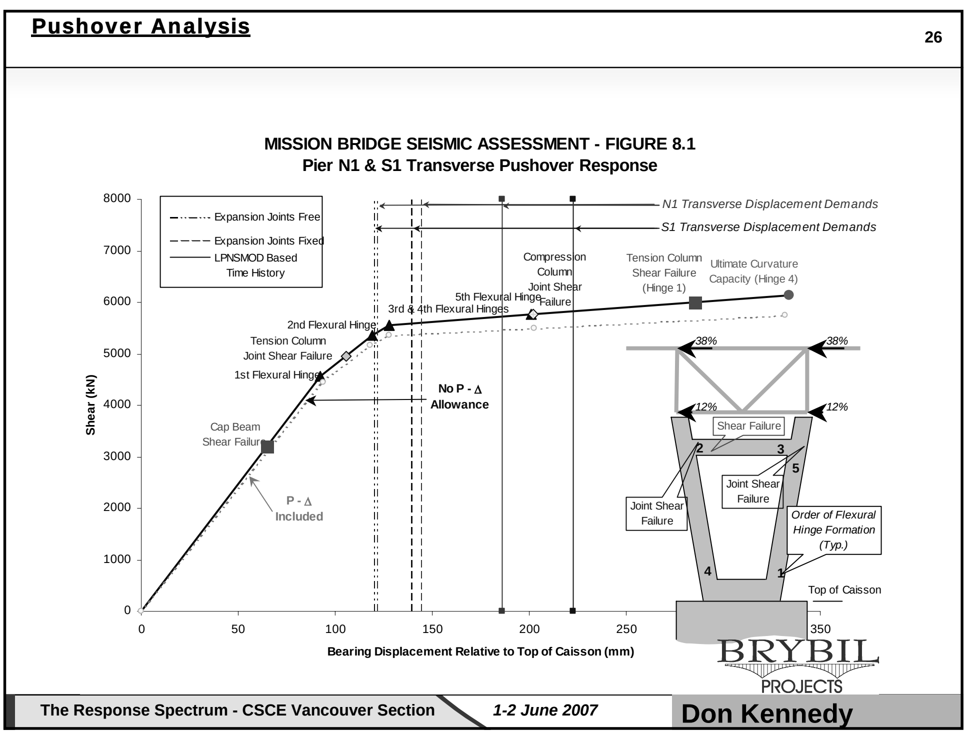


FIGURE 5.1a SAP2000 / SADSAP MODEL CALIBRATION
Transverse Tower Drifts
LEGEND:
SAP2000: Expansion Joints Free - 35% Ie/Ig
SAP2000: Expansion Joints Fixed - 35% Ie/Ig
SAP2000: Expansion Joints Free - 25% Ie/Ig
SAP2000: Expansion Joints Fixed - 25% Ie/Ig
SADSAP: HW-10 (Base Case)
SADSAP: HW-10-T (Transverse Only)
* Drifts calculated as the maximum difference between base of tower legs and bearing displacments, corrected for rigid body rotations.
350
300
250
200
150
100
50
0
-50
-100
Mission
Abbotsford
N5 N4 N3 N2 N1 S1 S2 S3 S4
DISPLACEMENT DIRECTION
BrybilProjects
MISSION BRIDGE SEISMIC RETROFIT


Pushover Analysis
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MISSION BRIDGE SEISMIC ASSESSMENT - FIGURE 8.1
Pier N1 & S1 Transverse Pushover Response
Expansion Joints Free
Expansion Joints Fixed
LPNSMOD Based Time History
N1 Transverse Displacement Demands
S1 Transverse Displacement Demands
Compression Column Joint Shear Failure
Tension Column Shear Failure (Hinge 1)
Ultimate Curvature Capacity (Hinge 4)
5th Flexural Hinge
3rd & 4th Flexural Hinges
2nd Flexural Hinge
Tension Column Joint Shear Failure
1st Flexural Hinge
No P - Δ Allowance
Cap Beam Shear Failure
P - Δ Included
38%
38%
12%
12%
Shear Failure
Joint Shear Failure
Joint Shear Failure
Order of Flexural Hinge Formation (Typ.)
Top of Caisson
Shear (kN)
8000
7000
6000
5000
4000
3000
2000
1000
0
0
50
100
150
200
250
350
Bearing Displacement Relative to Top of Caisson (mm)
BRYBIL PROJECTS
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