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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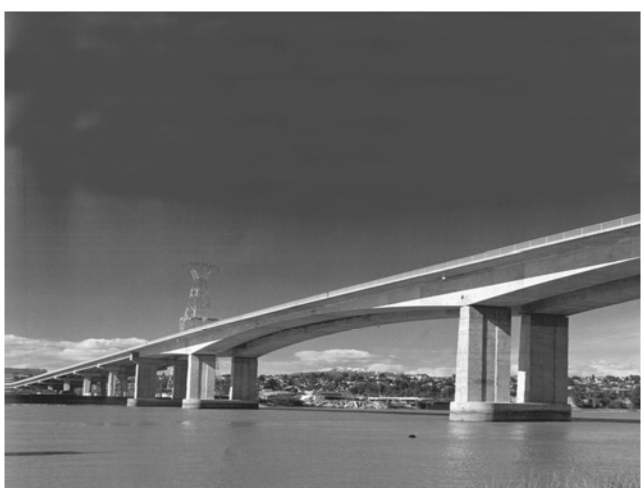

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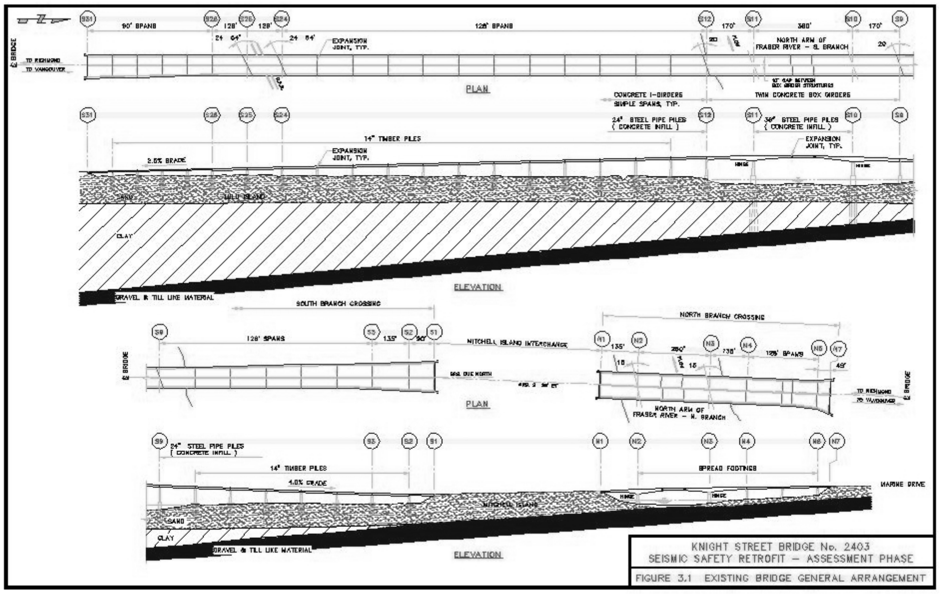

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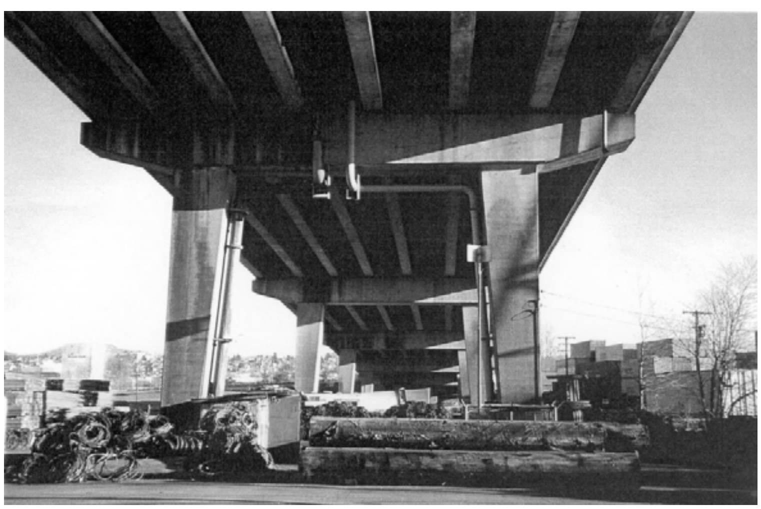

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Bridge arrangement (Knight St.)

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- Over Fraser River between Vancouver and Richmond
- Approximately 1500 m long with three distinct bridge (South Channel Crossing, North Channel Crossing, Marine Drive Overpass)
- Typically comprises of four lanes, locally flared to six with two sidewalks
- River bridges comprise simply supported concrete girder approach spans and balanced cantilever PT boxes with suspended spans over the river channels

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Performance objectives (Knight St.)

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- "Life Line Bridge" within the context of the CSA-S6-00
- Defined as Seismic Performance Zone 4 (moderate to high level of seismic risk)
- Two level assessment and retrofit design was specified as follows:
- Retrofit for 10% in 50 year event (475 year return period), it will remain functional: the bridge can be used by some traffic including the public after the event.
- Retrofit for 5% in 50 year even (1000 year return period) to at least a minimal level to increase the likelihood the bridge will not collapse. The crossing need not be passable but damage does not increase the risk of collapse

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Performance objectives (Knight St.)

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- Global model not developed. The structural systems lent themselves to segmental (sections of bridge) and local (single pier) models.
- Segmental models were used in the South River span region and for the skewed pier S24 assessment
- Several pier models were developed to determine equivalent linear properties, evaluate displacement demands, and to carry out push-over demands
- The output from the various models was used to determine elastic displacement demands and not for evaluating member forces
- Deformation demands on hinges from plastic mechanisms were determined from push-over analyses.

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Performance objectives (Knight St.)

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- The cracked-section stiffness of concrete columns is considered a function of the axial load and longitudinal rebar ratios
- The elastic cracked-stiffness for concrete sections may vary by +/- 50% or more in a frame structure during a seismic event
- The elastic cracked-stiffnesses were determined as 0.3*I_g using charts produced by Priestley et.al.
- Stiffness depends on flexural *strength*; assessing member stiffness using moment-curvature analysis is an improvement. This was investigated as a sensitivity to initial stiffness assumption (very good agreement)

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FUNDAMENTALS OF SEISMIC BRIDGE BEHAVIOR 173

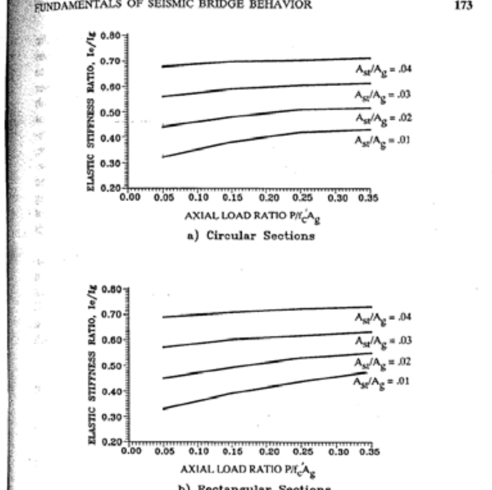

FIG. 4.9 Effective stiffness of cracked reinforced concrete sections [N4].

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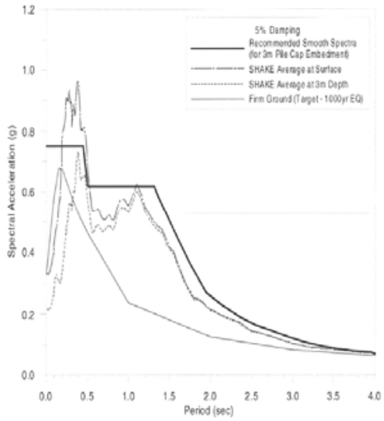

Figure 4- 8 Recommended Smooth Response Spectra at Pier S8 for 1000yr EQ

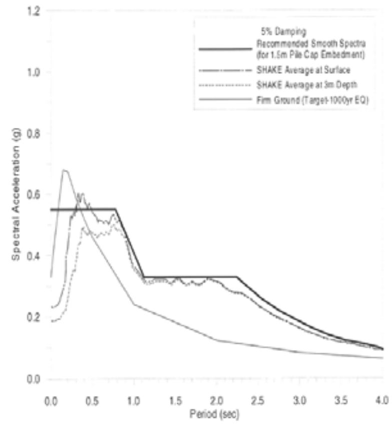

Figure 4- 10 Recommended Smooth Response Spectra at Pier S25 for 1000yr EQ

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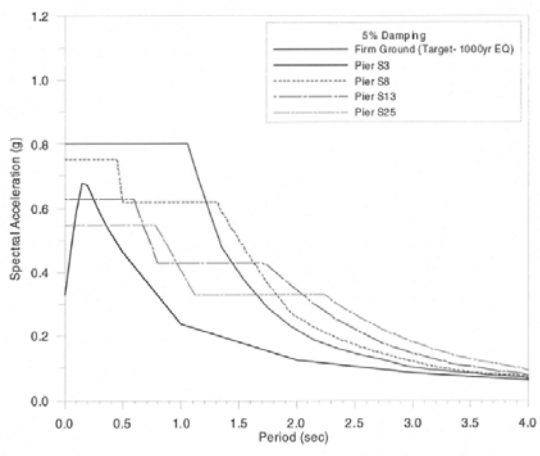

Figure 4- 11 Comparison of Recommended Smooth Response Spectra at Piers S3, S8, S13 and S25 for 1000yr EQ

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Modal combinations
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- Peak modal forces and displacements were combined using the Complete Quadratic Combination (CQC) method
- Demands from longitudinal and transverse directions were combined using SRSS combination method approach

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Knight Street Bridge – Longitudinal (T = 1.14 sec)
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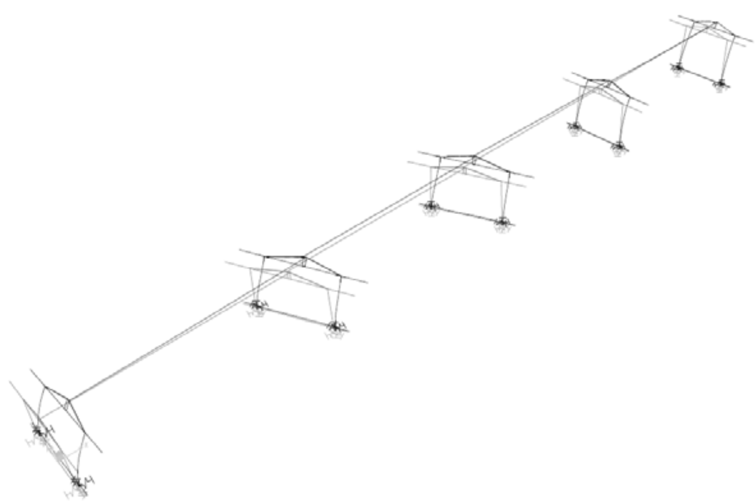

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Knight Street Bridge – Transverse (T = 0.97 sec)

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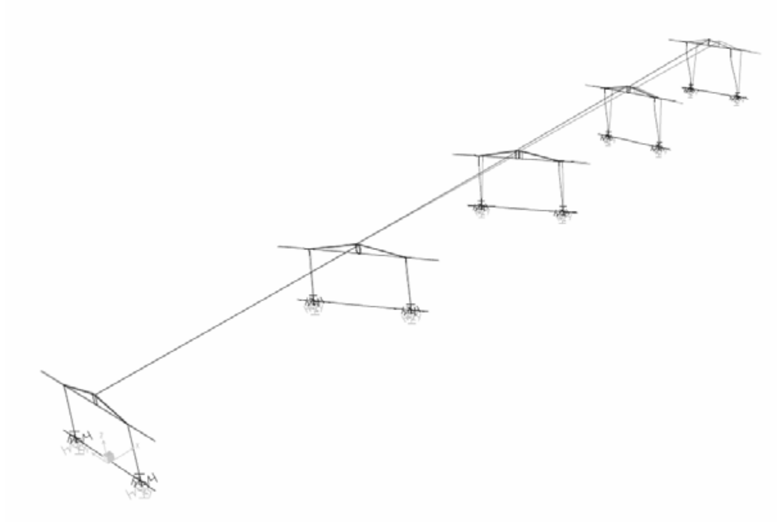

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Knight Street Bridge – Transverse (T = 0.97 sec)

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Associated Engineering

CALCULATIONS

PROJECT Knight Street Bridge Seismic Assessment — PROJ NO. 042628
DETAILS Pier S24 - Demands from Segmental Model — BY S Cook

Calculate displacement demands relative to the global bridgge axis for each response spectrum applied in the transverse and longitudinal directions using various combinmation rules.

Pier Skew θ_p 24.9 °

Soft Soil Springs *1000 year demand*

Displacement Component		Cap		Footing		Structure		Combination			
		Trans	Long	Trans	Long	Trans	Long	100/30	30/100	ABS	SRSS
Δlongit	mm	21.4	102.8	3.4	7.3	18	95.5	46.7	100.9	113.5	97.2
Δtransv	mm	68.2	50.4	10.2	4.4	58	46	71.8	63.4	104.0	74.0

Note: Trans and Long cases in table refer to response to spectra applied in the transverse and longitudinal directions of the bridge respectively.

Soft Soil Springs *475 year demand*

Displacement Component		Cap		Footing		Structure		Combination			
		Trans	Long	Trans	Long	Trans	Long	100/30	30/100	ABS	SRSS
Δx	mm	15.9	80.1	2.9	6.2	13	73.9	35.2	77.8	86.9	75.0
Δy	mm	44.4	35.7	8.4	3.5	36	32.2	45.7	43.0	68.2	48.3

Soft Soil Springs *Golders 475 year demand*

Displacement Component		Cap		Footing		Structure		Combination			
		Trans	Long	Trans	Long	Trans	Long	100/30	30/100	ABS	SRSS
Δx	mm	25.2	111.1	4.2	8.5	21	102.6	51.8	108.9	123.6	104.7
Δy	mm	82.8	55.4	12.6	5.3	70.2	50.1	85.2	71.2	120.3	86.2

Note: Trans and Long cases in table refer to response to spectra applied in the transverse and longitudinal directions of the bridge respectively.

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Knight Street Bridge – Transverse (T = 0.97 sec)

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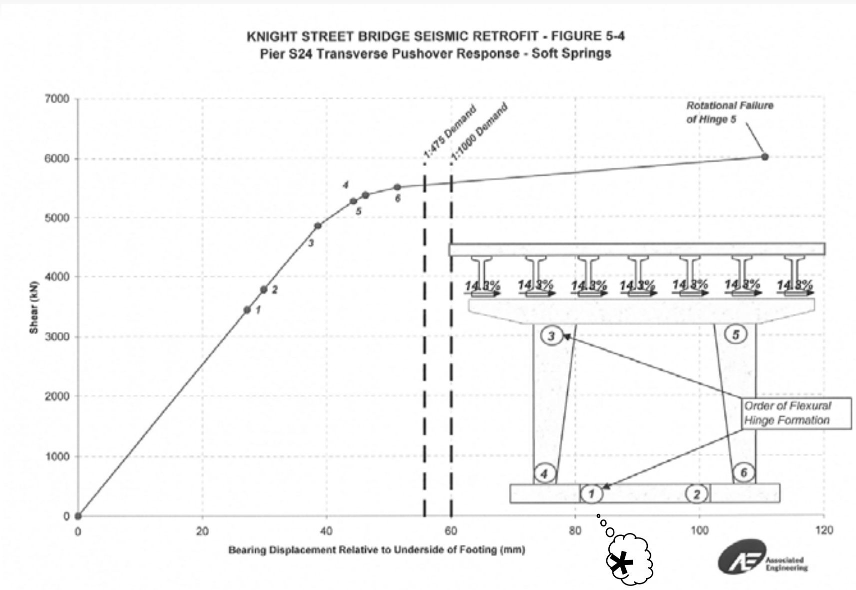

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Knight Street Bridge – Transverse (T = 0.97 sec)

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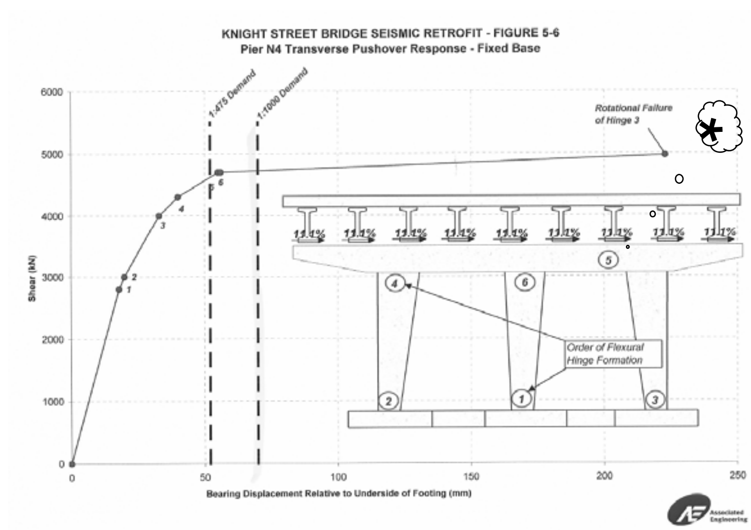

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Comparisons to earlier work

- 1997 required 'safety' retrofit for 475-year RP event; collapse of any part of the crossing
- 2005 considered a1000-year earthquake. Comparable demands are about 30% higher than the 475-year even.
- RSA using *near-surface spectra* and soil liquefaction proved to be no higher than the 475-year results in the 1997 report
- Column / beam retrofits reduced, however, joint shear retrofits were required to meet ToR
- Compared push-overs and elastic K's of piers using initial stiffness and secant stiffness methods.
- Secant stiffnesses preferred in disp't-based design
- Comparing only bent stiffness approaches on displ't demand – found excellent agreement for this bridge