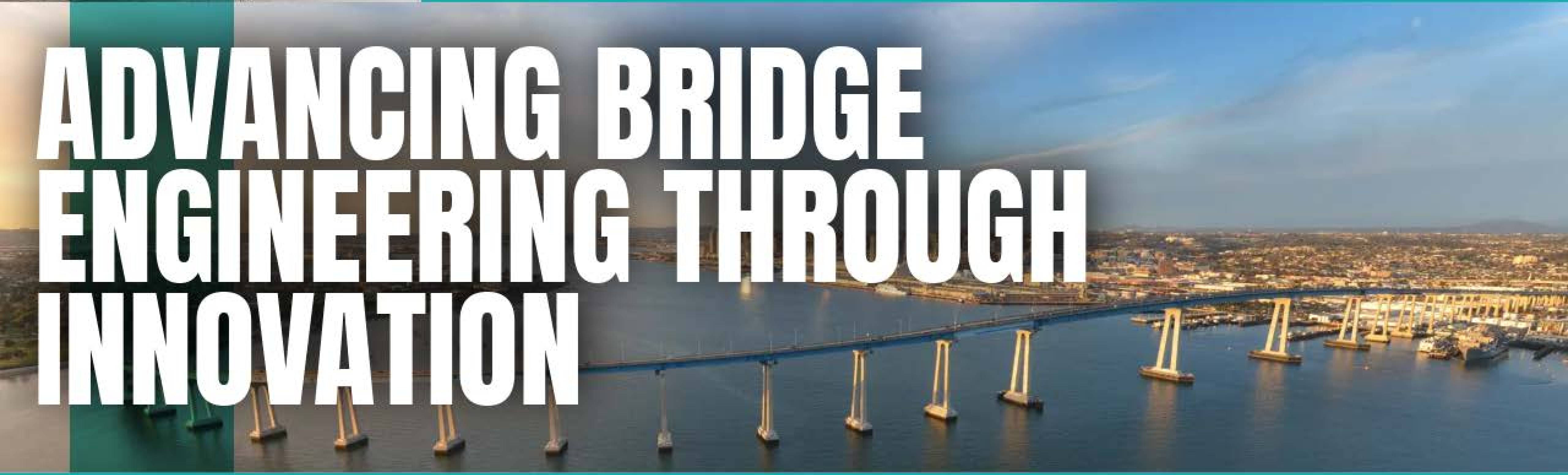
CALIFORNIA BRIDGE ENGINEERS SEMINAR



ADVANCING BRIDGE ENGINEERING THROUGH INNOVATION

CABES 2026

Presentation 3 - Evaluation of Buckling-Restrained Braces for Seismic Retrofit of Canyon Creek Bridge

Evaluation of Buckling-Restrained Braces for Seismic Retrofit of Canyon Creek Bridge

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Branch Chief, Complex Bridge Design

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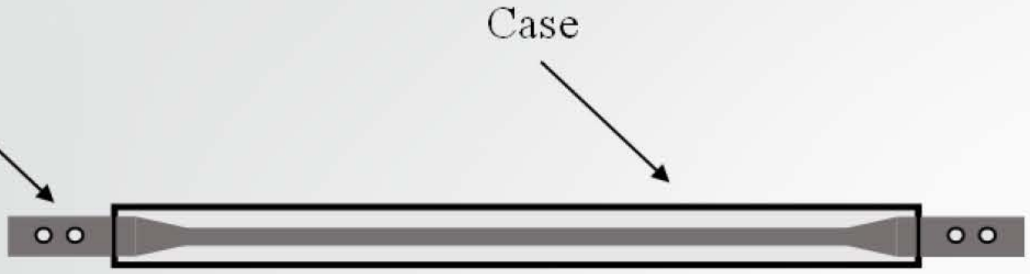
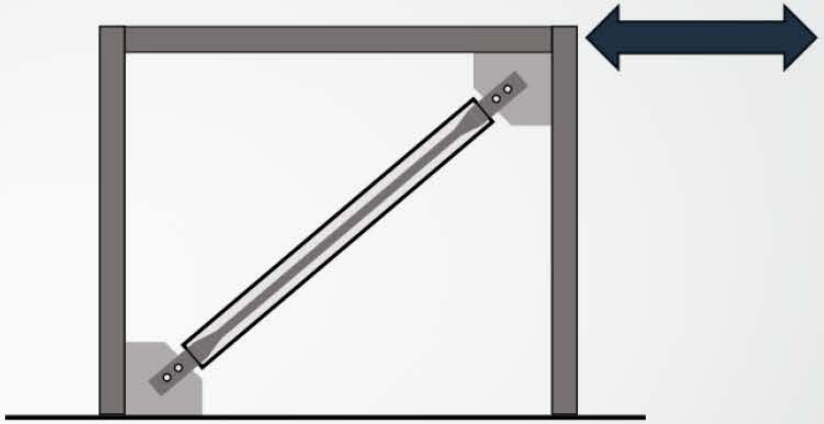
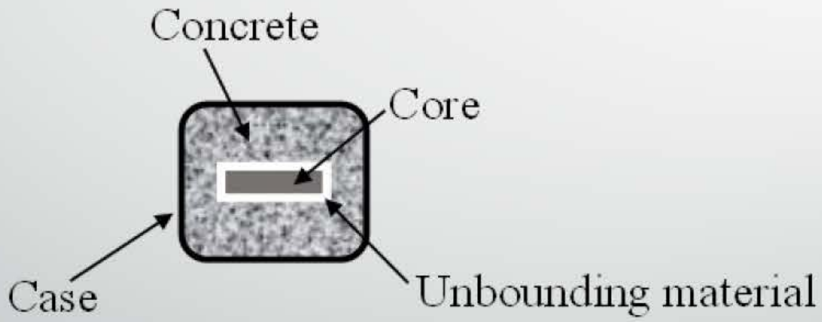
Buckling Restrained Brace



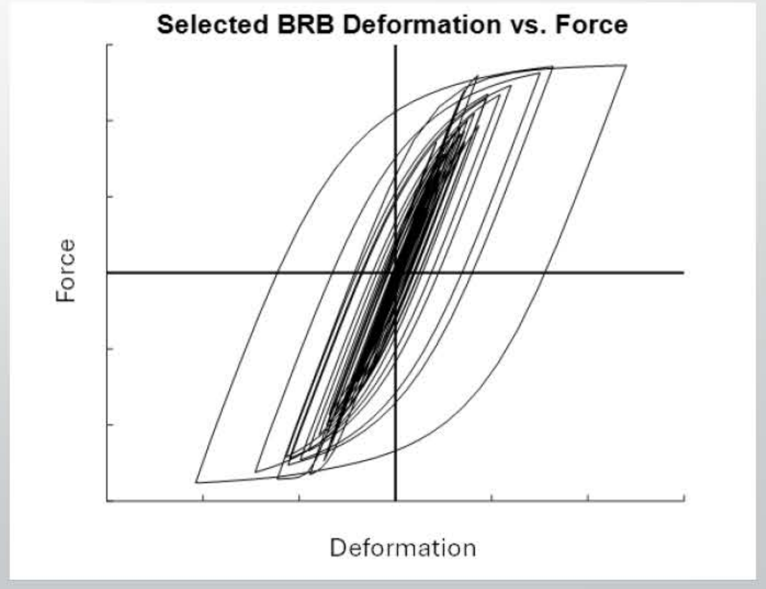
(a) BRB Parts



(c) BRB in frame



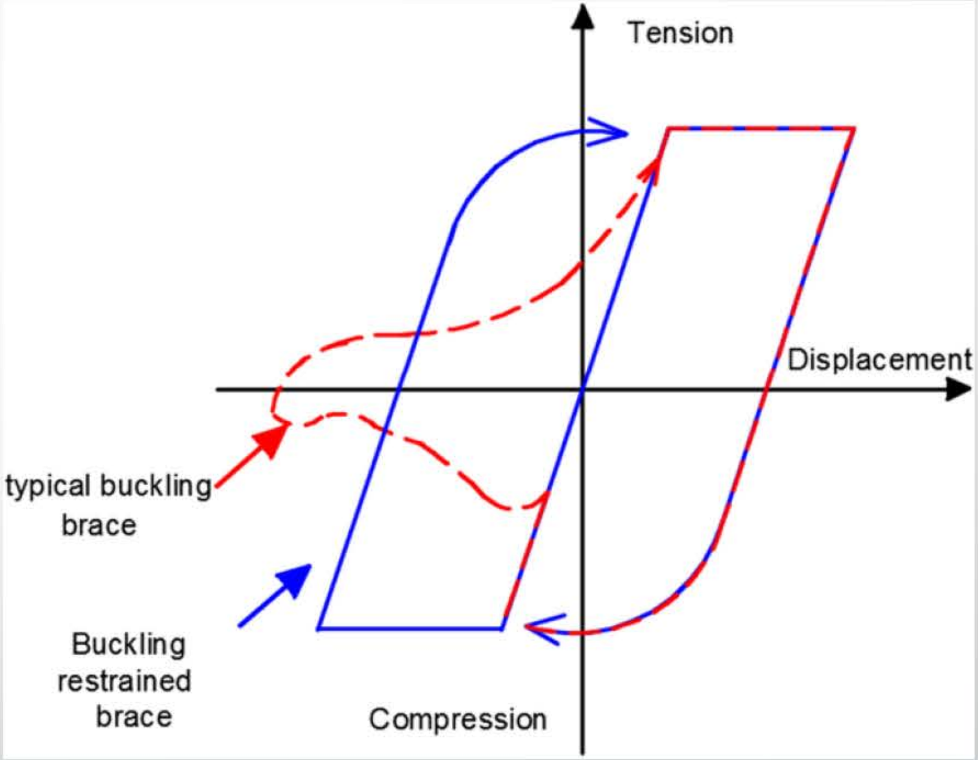
(b) BRB cross-section



(d) Hysteretic Behavior

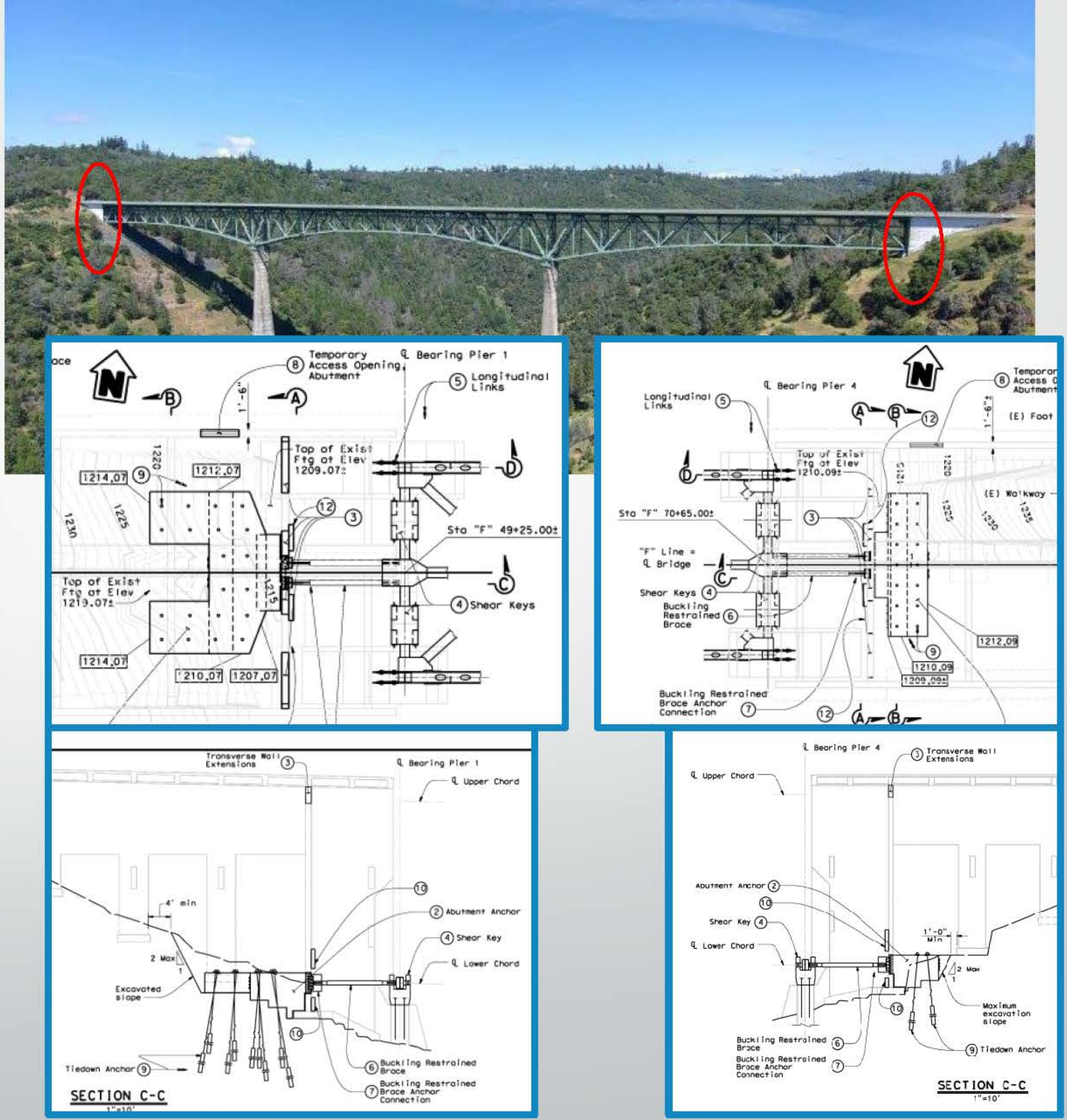
Buckling Restrained Brace

- Nearly symmetric and stable hysteretic behavior.
- Capable of significant amounts of accumulated cyclic ductility before failure.
- Easy installation.



BRBs on Bridges

- **Foresthill Road Bridge – Seismic Retrofit**
  - Longitudinal anchor plates exceed capacity in seismic analyses, risking truss unseating.
  - Strengthening anchors increases force demands on the truss.
  - BRBs provide ductile restraint while limiting force transfer to the superstructure.



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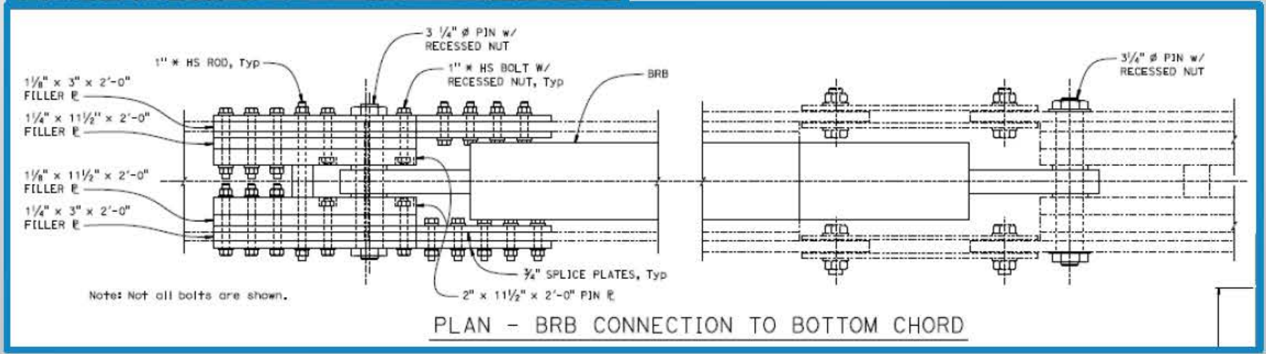
BRBs on Bridges

- **Vincent Thomas Bridge – Seismic Retrofit**
  - Viscous dampers lost effectiveness due to leakage.
  - Increased seismic response and excessive bridge movement.
  - BRBs provide longitudinal restraint and seismic displacement control.



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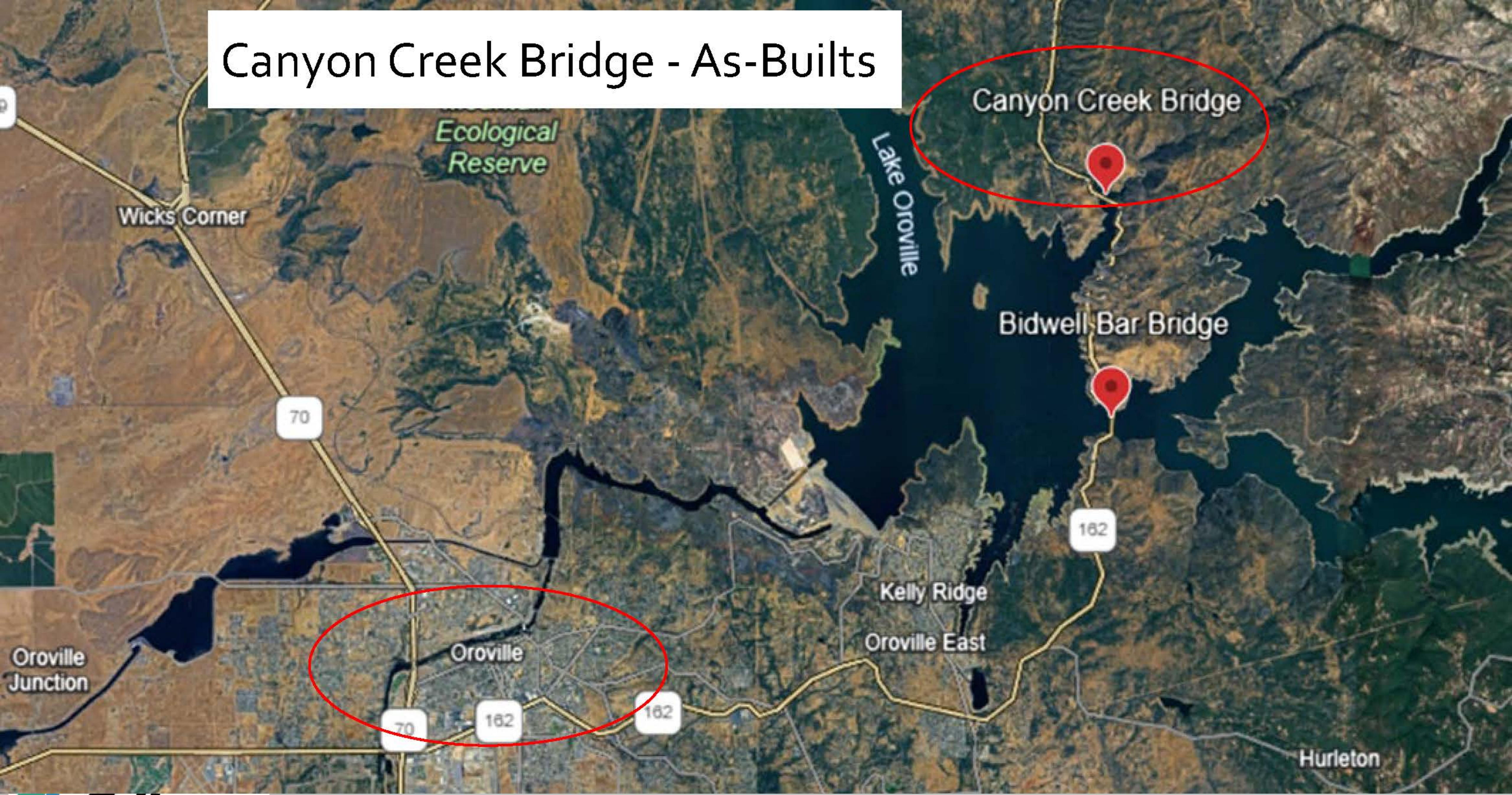
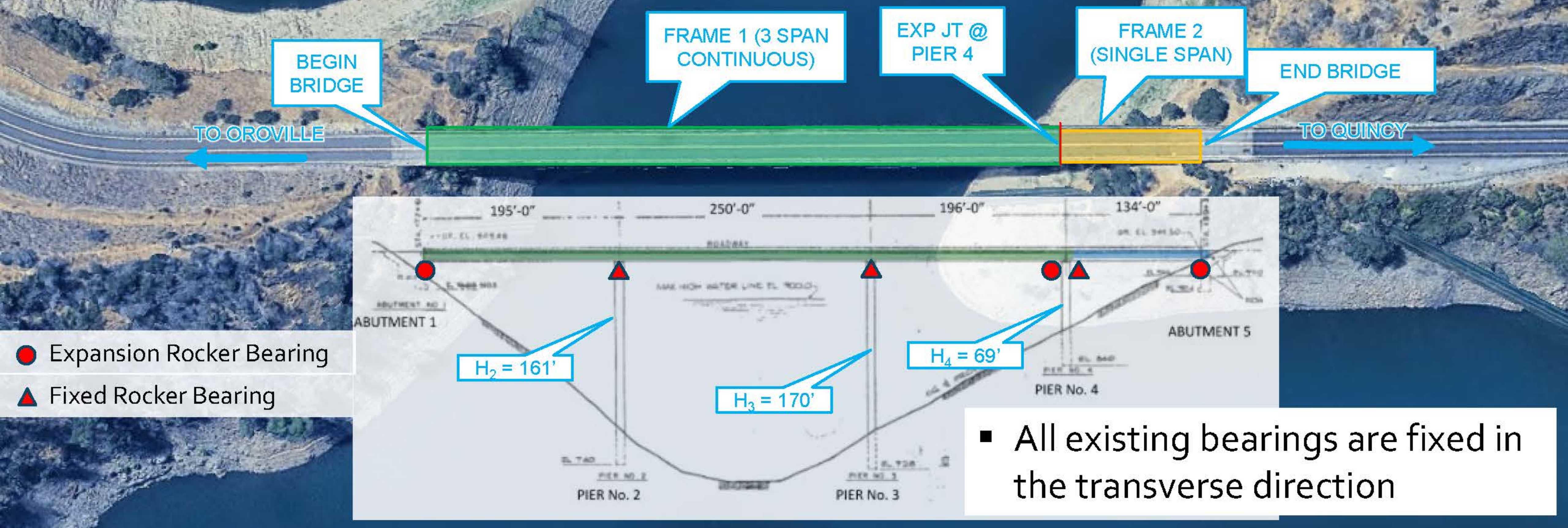
Canyon Creek Bridge - As-Builts



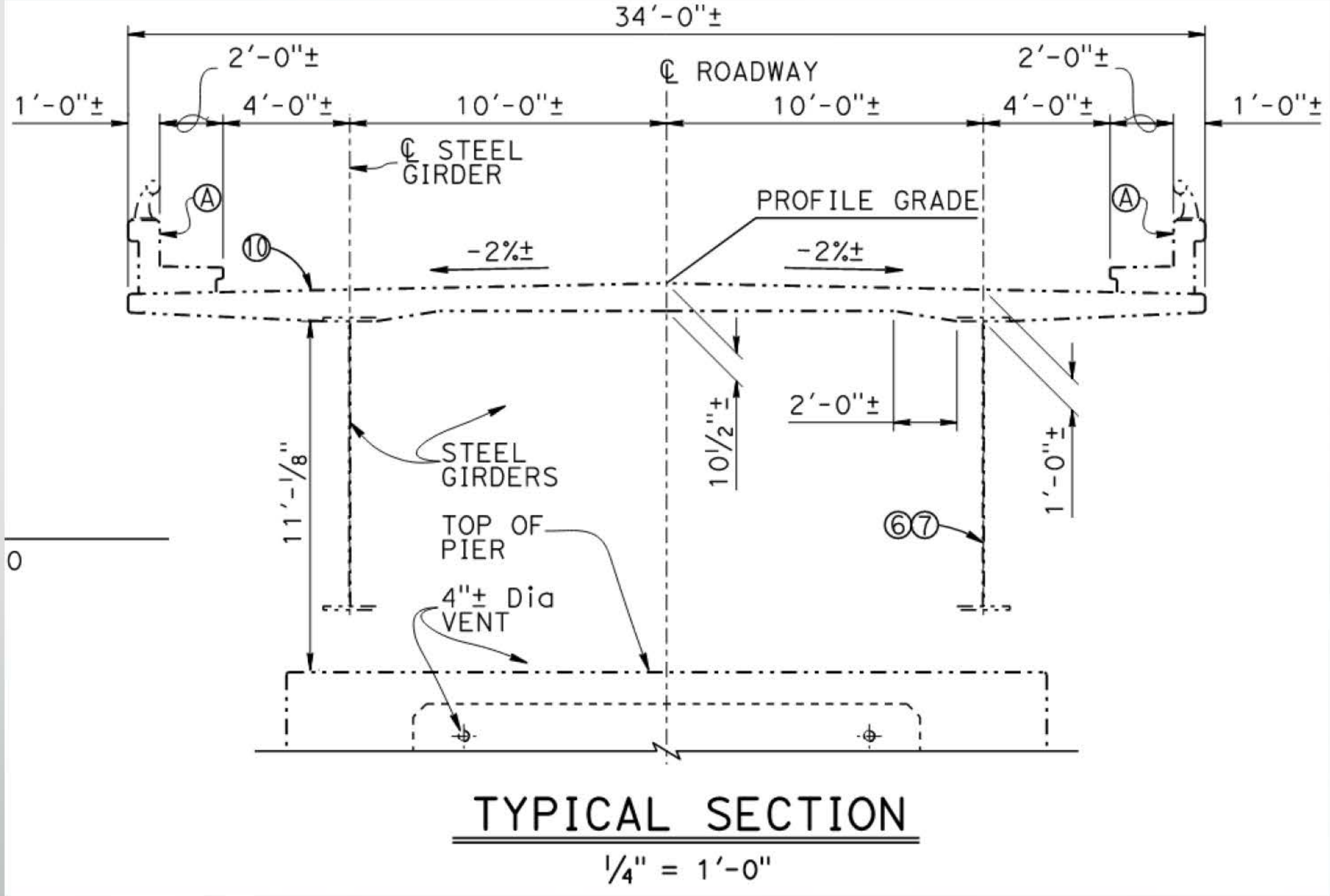
Canyon Creek Bridge - As-Builts

- Built in 1967 by Department of Water Resources (DWR)
- 780′ Long, 4-Span Bridge
- Seat Abutments
- Hollow Pier Walls & Solid Caissons



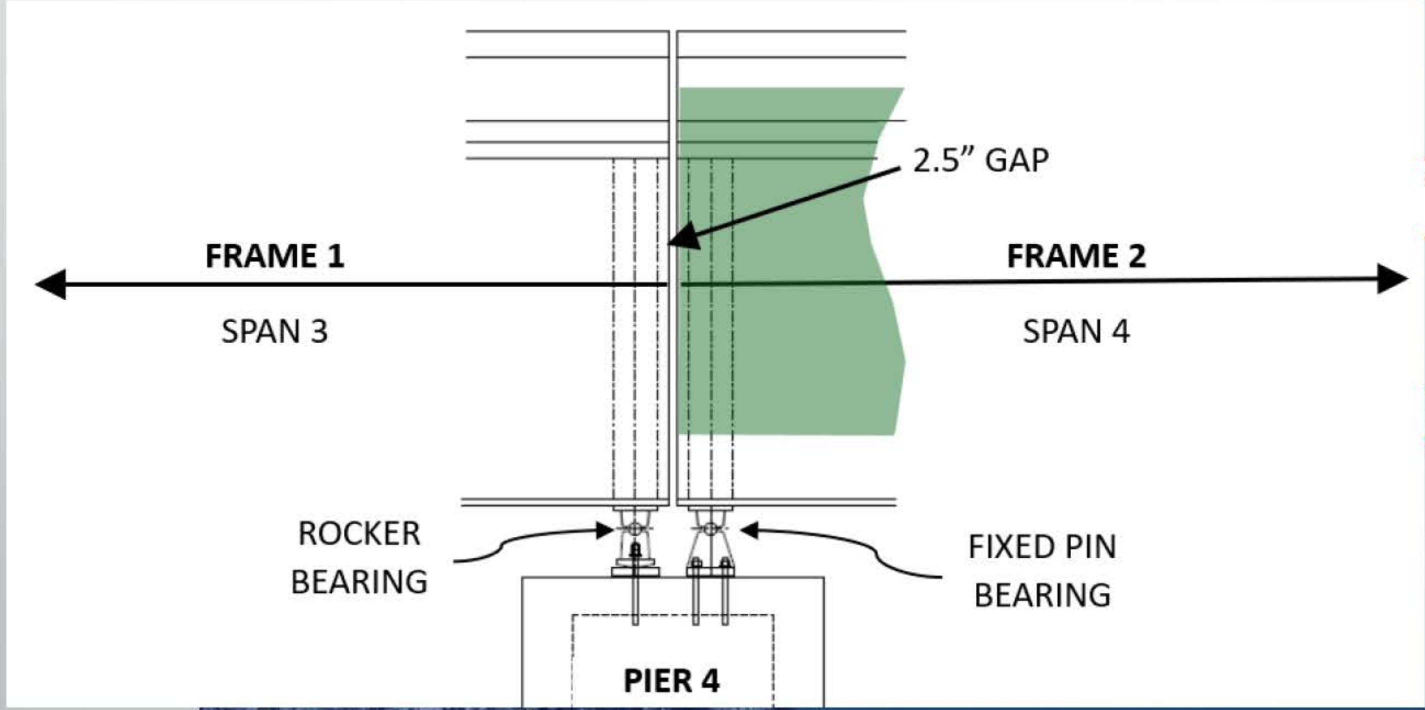
- All existing bearings are fixed in the transverse direction

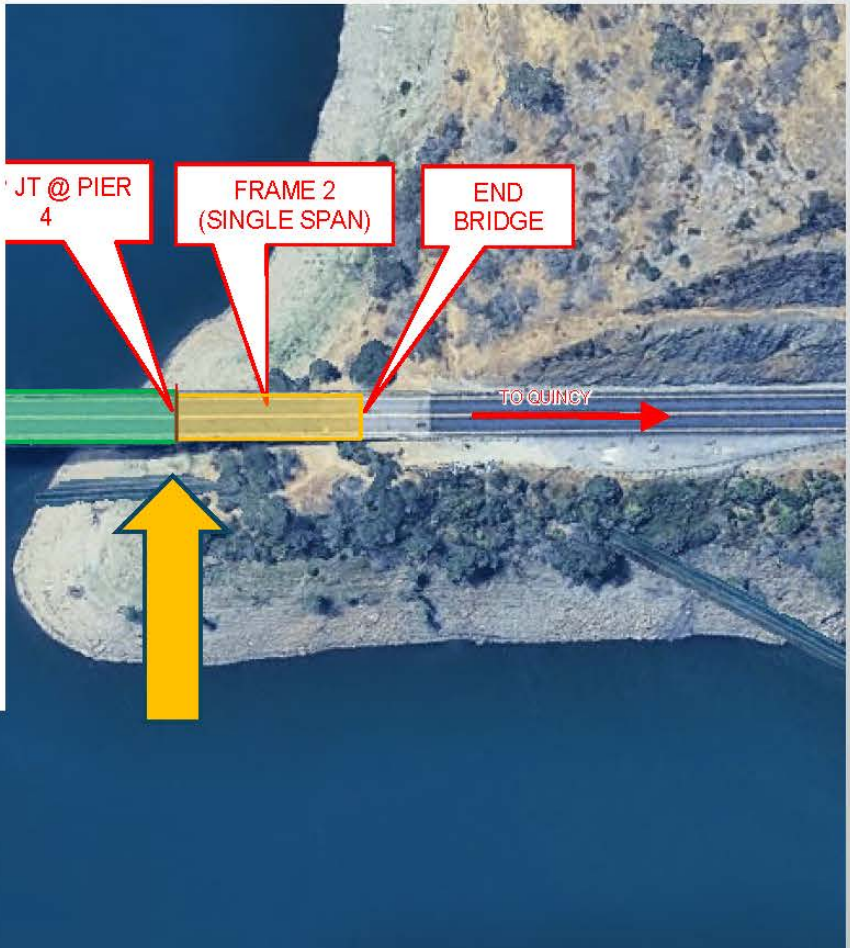
Canyon Creek Bridge - As-Builts



Canyon Creek Bridge – Expansion Joint

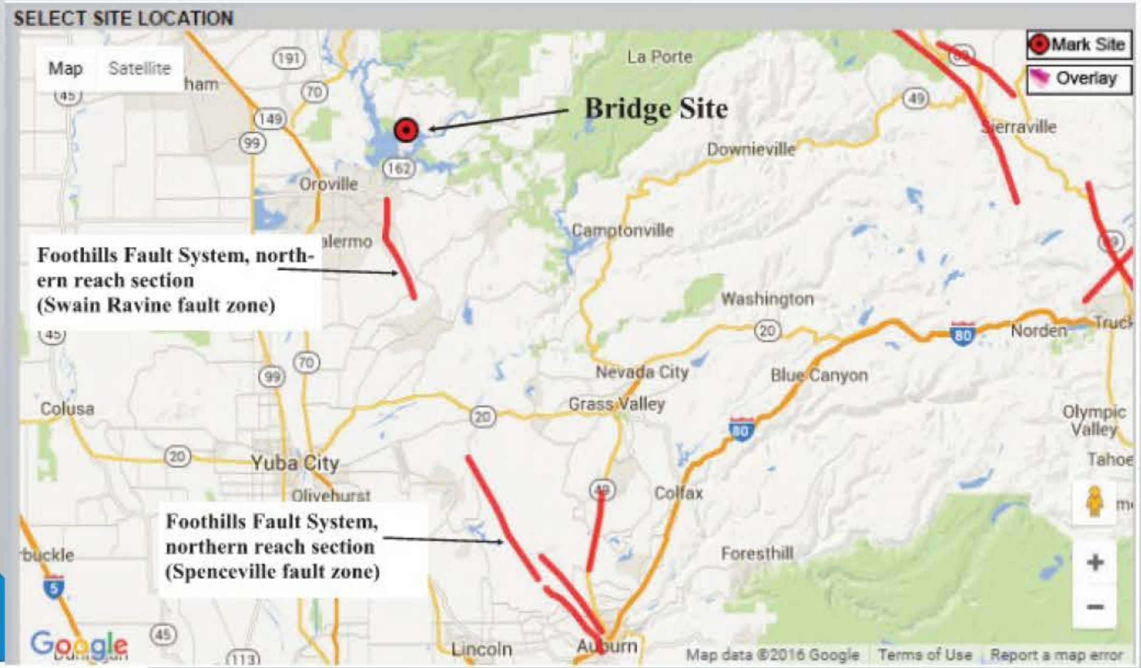
- 2.5" Gap between Frame 1 and Frame 2
- Expansion Rocker & Fixed Rocker Bearing

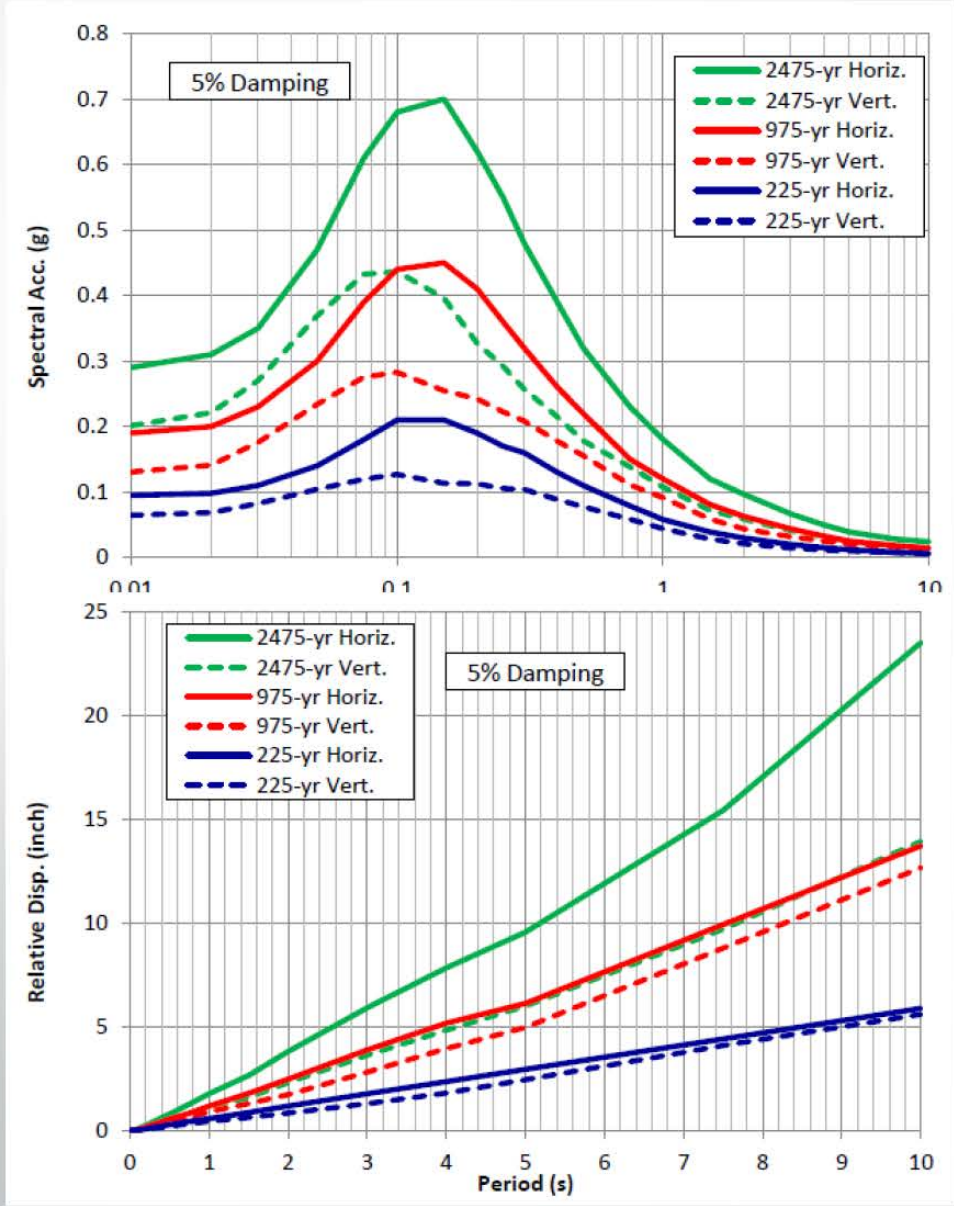




Canyon Creek Bridge – Seismic Hazard

- Site Classification: Vs30 = 1,100 m/s
- PGA (975-year): 0.19g
- ARS peak acceleration: 0.45g @ T = 0.15s
- T = 1.16s Longitudinal
- T = 1.85s Transverse





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Canyon Creek Bridge – Ground Motions

Earth Mechanics, Inc.
Geotechnical & Earthquake Engineering

Table 1. Target acceleration response spectra

Period (sec)	5% Damped Spectral Acceleration (g)					
	225-yr		975-yr		2475-yr	
	Horizontal	Vertical	Horizontal	Vertical	Horizontal	Vertical
0.01	0.095	0.065	0.190	0.131	0.290	0.201
0.02	0.098	0.068	0.200	0.141	0.310	0.221
0.03	0.110	0.083	0.230	0.176	0.350	0.270
0.05	0.140	0.104	0.300	0.234	0.470	0.369
0.075	0.180	0.120	0.390	0.275	0.610	0.432
0.1	0.210	0.127	0.440	0.283	0.680	0.437
0.15	0.210	0.113	0.450	0.255	0.700	0.396
0.2	0.190	0.112	0.410	0.242	0.620	0.327
0.25	0.170	0.106	0.360	0.222	0.550	0.292
0.3	0.160	0.104	0.320	0.209	0.480	0.257
0.4	0.130	0.089	0.260	0.178	0.390	0.215
0.5	0.110	0.078	0.220	0.156	0.320	0.178
0.75	0.079	0.058	0.150	0.111	0.230	0.138
1	0.058	0.044	0.120	0.091	0.180	0.108
1.5	0.039	0.028	0.081	0.059	0.120	0.072
2	0.030	0.021	0.063	0.044	0.097	0.059
3	0.020	0.015	0.044	0.032	0.067	0.041
4	0.015	0.011	0.033	0.025	0.050	0.031
5	0.012	0.010	0.025	0.020	0.039	0.024
7.5	0.008	0.007	0.018	0.016	0.028	0.018
10	0.006	0.006	0.014	0.013	0.024	0.014

Table 2. Ground motion sets

Set Number(s)	Earthquake Event	Year	Station (NGA #)	Mag.	Dist. (km)	Time Step (sec)	# Steps
225-1 975-1 2475-1	Landers	1992	Obregon Park (870)	7.3	152	0.02	3500
225-2	Chi-Chi, Taiwan	1999	KAU043 (1372)	7.6	172	0.01	8200
225-3 975-2 2475-2	Denali, Alaska	2002	TAPS Pump Station #12 (2116)	7.9	165	0.01	10458
225-4 975-3 2475-3	Chuetsu-oki	2007	Joetsu Ogataku (4848)	6.8	18	0.01	6000
225-5 975-4 2475-4	Tohoku	2011	Utsunomiya (4001181)	9.1	100	0.01	16000
975-5 2475-5	Tohoku	2011	Hikawa (4001191)	9.1	153	0.01	16000
225-6 975-6 2475-6	Iquique	2014	PB03 (6001377)	8.2	202	0.01	14608
225-7 975-7 2475-7	Maule, Chile	2010	ROBL (6001801)	8.8	142	0.01	16000

Notes:

1. Set number format: X-Y where X is the return period and Y is the set number within that return period.
2. Time step and number of steps are after modifications to the original records.

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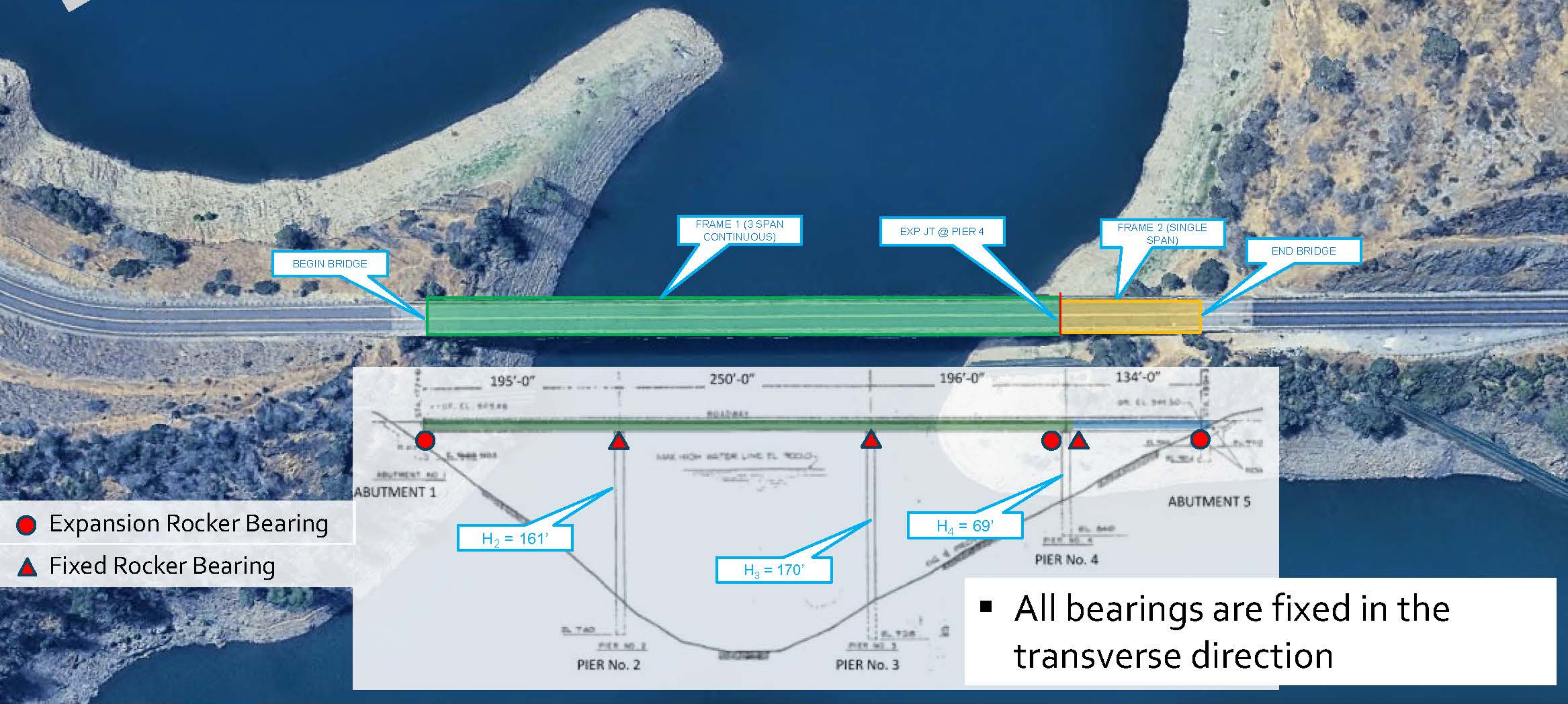
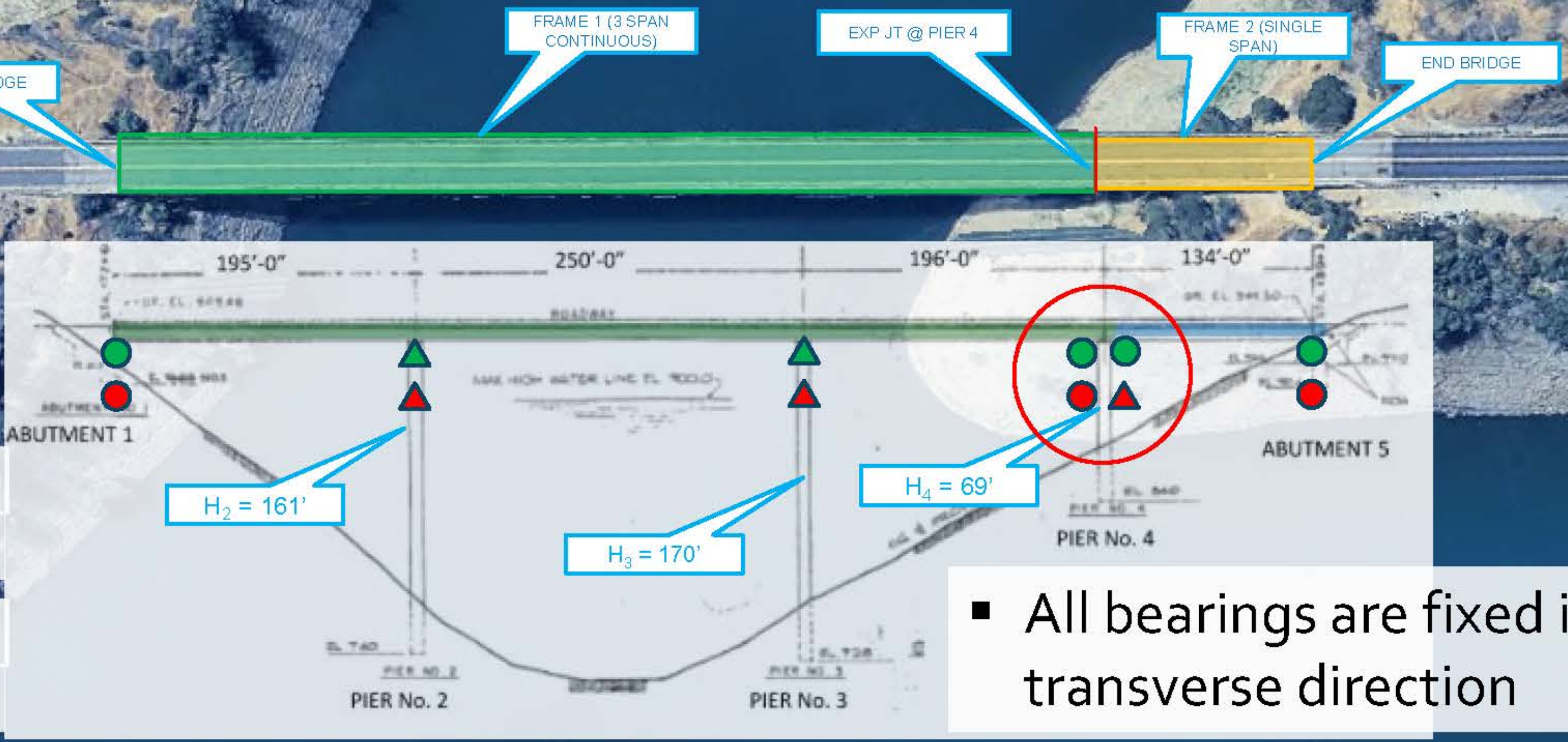
Canyon Creek Bridge – Seismic Retrofit



- All bearings are fixed in the transverse direction

Canyon Creek Bridge – Seismic Retrofit

- Replace Rocker Bearings with Spherical Bearings
- Connect Frames 1 &2

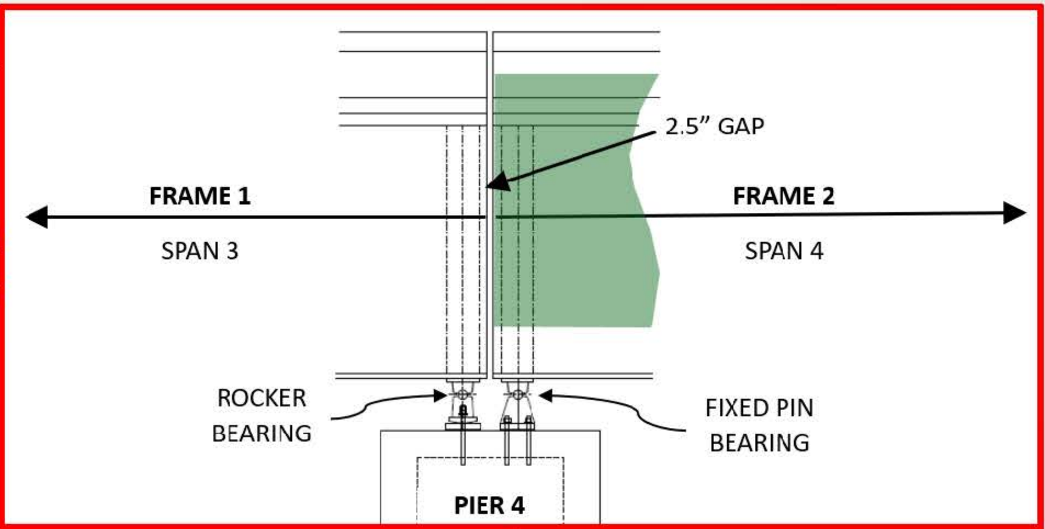


- Sliding Spherical Bearing
- Fixed Spherical Bearing
- Expansion Rocker Bearing
- Fixed Rocker Bearing

- All bearings are fixed in the transverse direction

Canyon Creek Bridge – Design ar

- Nonlinear Time History Analysis (NTHA)- E
  - Pier 4 Gap



Hazard	Relative Dis (in)
225-yr	2.25
975-yr	>2.5

Connect Frame 1 & Fr

Gap Displacement (Red= Closed)
225 yr

GM	Right Displacement (in)	Left Displacement (in)
S1-225	3.04 -2.51	3.01 -2.51
S2-225	3.03 -2.51	3.07 -2.50
S3-225	2.17 -1.91	2.19 -1.97
S4-225	0.90 -1.78	0.89 -1.77
S5-225	2.55 -2.50	2.57 -2.50
S6-225	1.86 -2.05	1.86 -2.05
S7-225	2.18 -2.25	2.19 -2.26

Gap Displacement (Red= Closed)
975yr

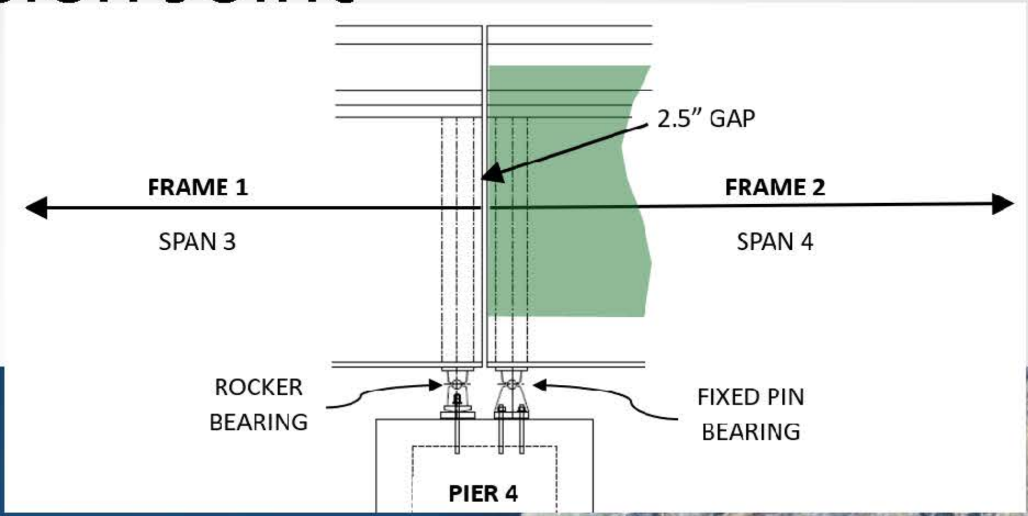
GM	Right Displacement (in)	Left Displacement (in)
S1-975	3.05 -2.52	3.02 -2.52
S2-975	3.54 -2.51	3.59 -2.51
S3-975	2.09 -2.51	2.14 -2.50
S4-975	2.79 -2.50	2.77 -2.51
S5-975	2.52 -2.51	2.51 -2.51
S6-975	2.91 -2.50	2.91 -2.50
S7-975	2.63 -2.50	2.65 -2.50

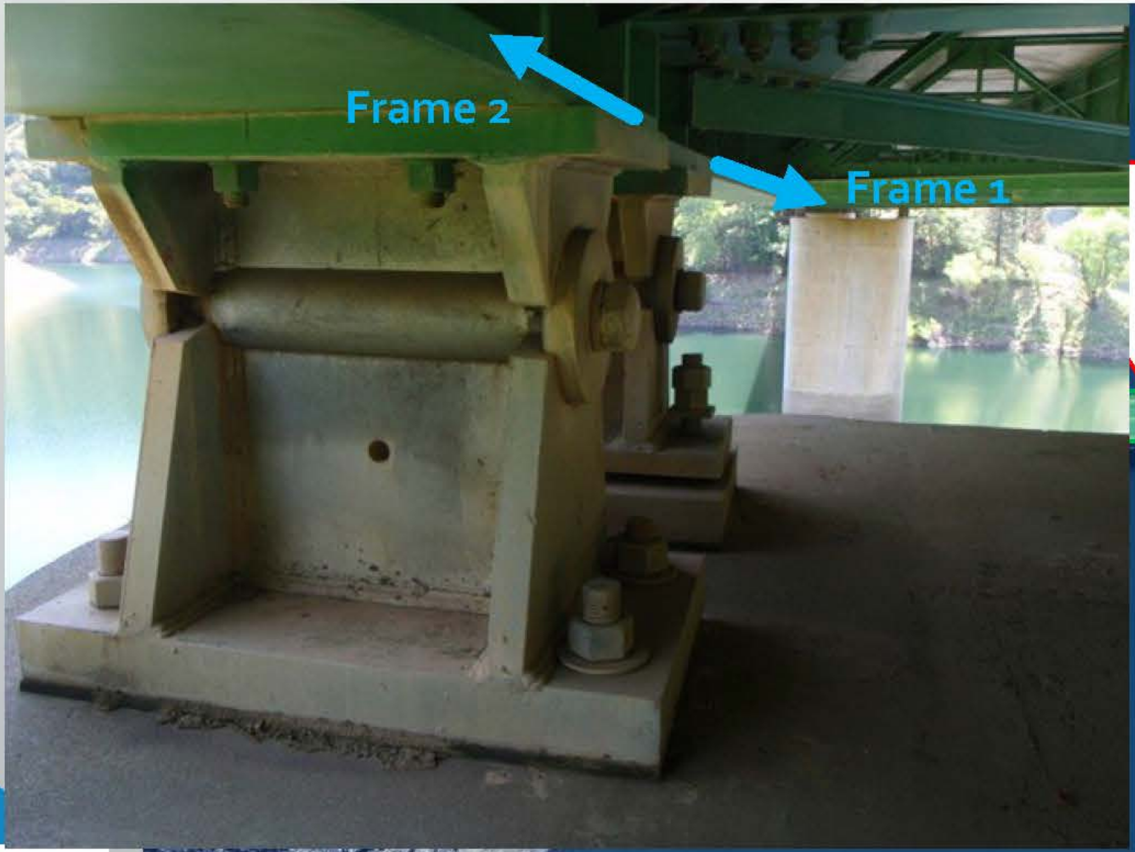
Canyon Creek Bridge – Seismic Retrofit

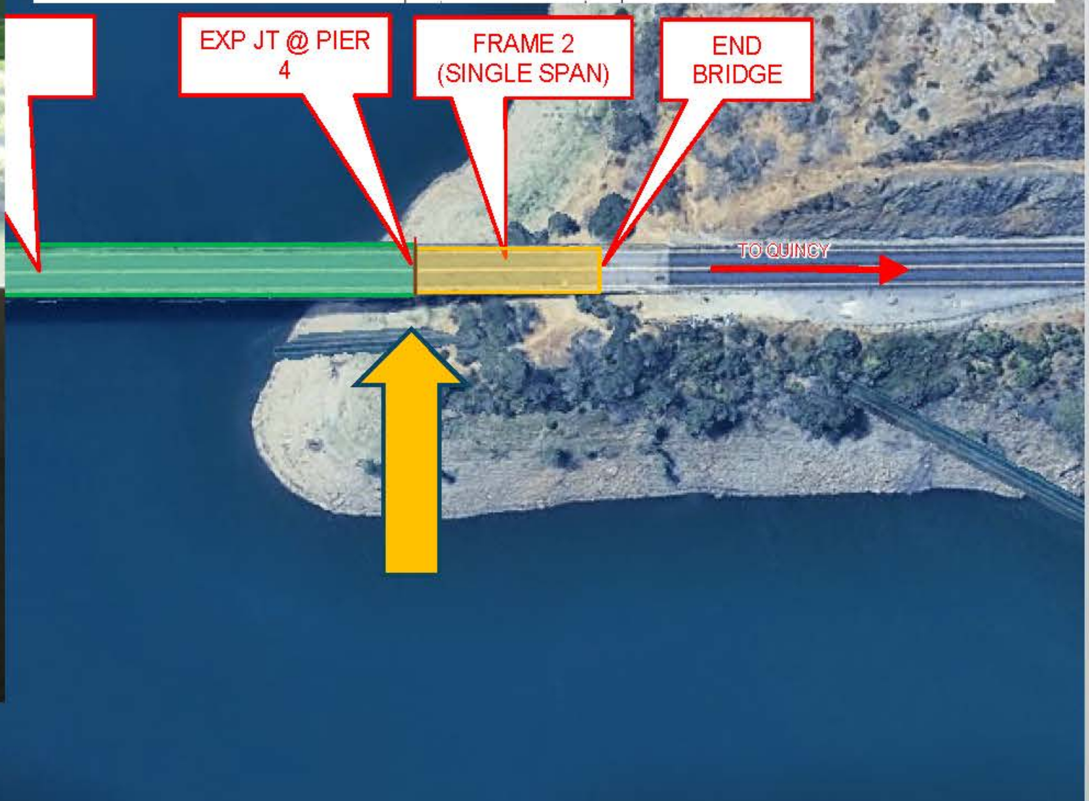
- Two Options to Connect Frames 1 & 2
  - Web Splice Plate
  - Buckling Restrained Braces (Evaluation)

Canyon Creek Bridge – Expansion Joint

- 2.5″ Gap between Frame 1 and Frame 2
- Expansion Rocker & Fixed Rocker Bearing







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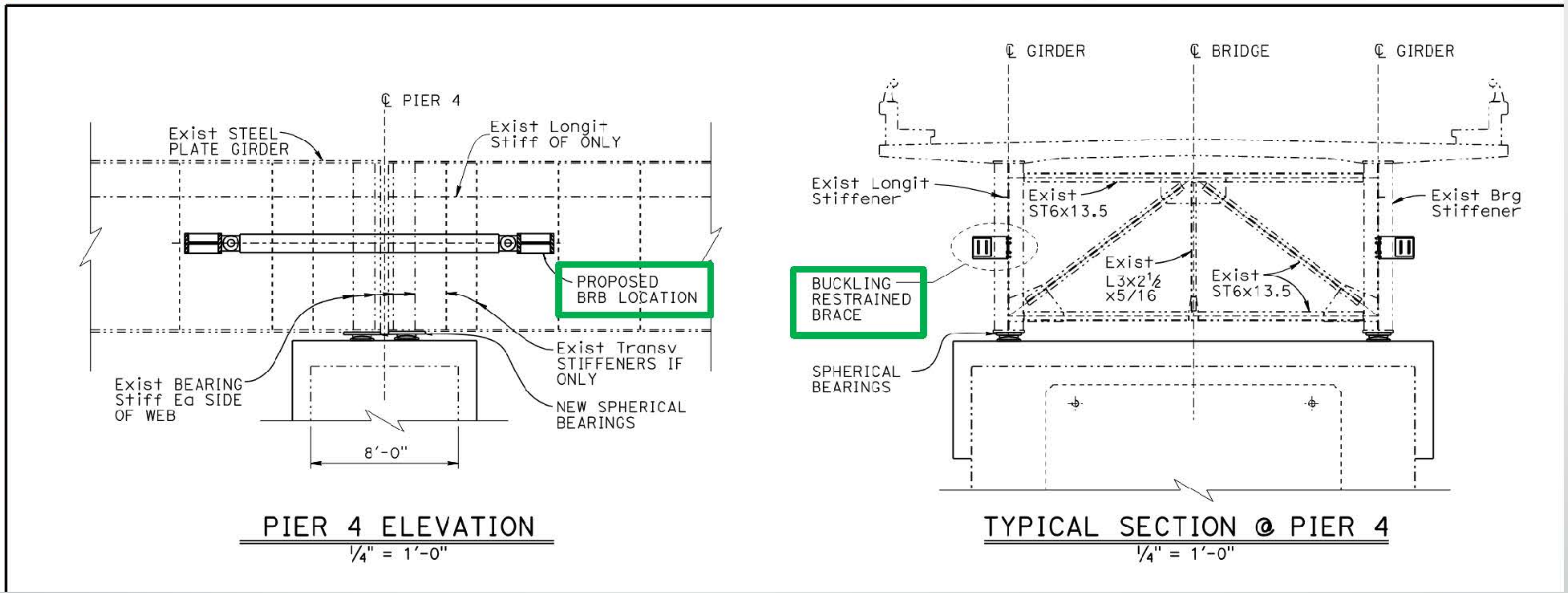
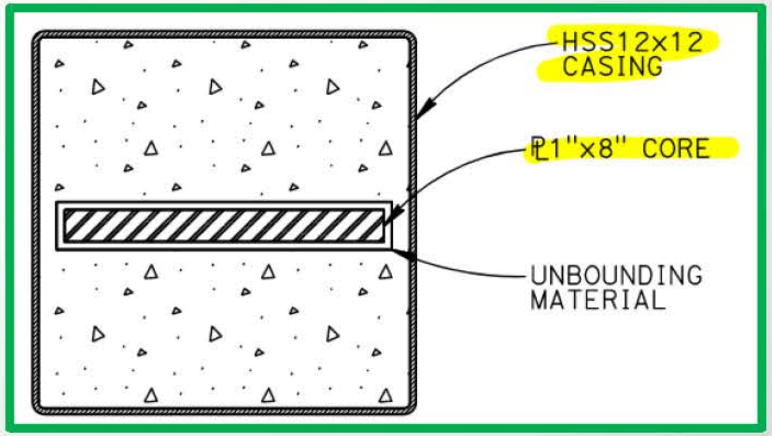
Canyon Creek Bridge – Design and Analysis



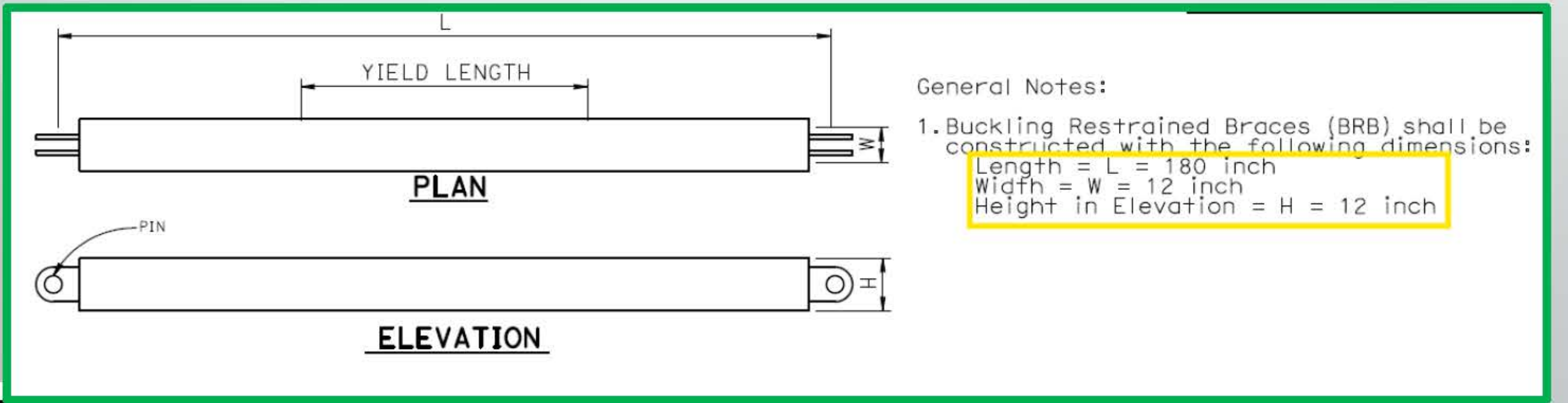
Add BRB to control the Longitudinal Displacement

Canyon Creek Bridge – Design and Analysis

- NTHA – BRB Parametric Design
  - Range of BRB Core Areas Considered/Modeled.
  - New Bearings assigned
  - Selected BRBs:
    - Remain elastic under 225-yr event
    - Yield under 975-yr event
    - Gap Displacement <2.5"



Selected BRB Cross-Section



Selected BRB

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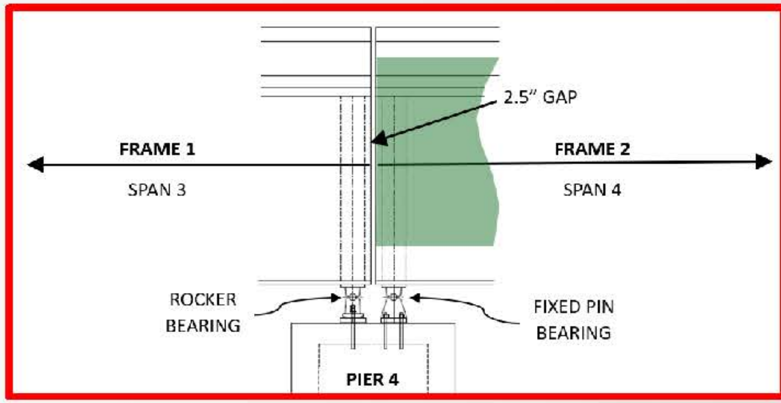
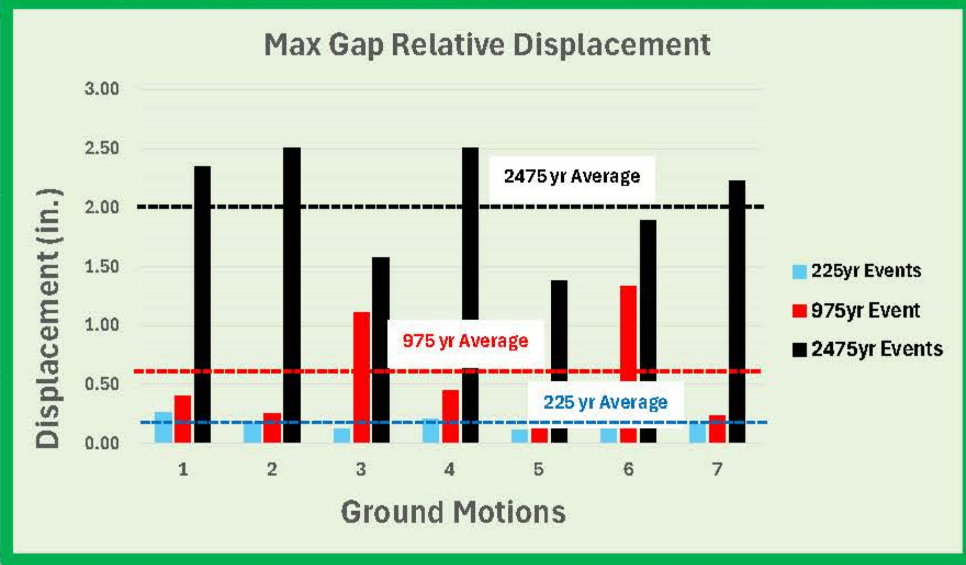
Canyon Creek Bridge – Design and Analysis

- NTHA- **Retrofitted Bridge**
  - Pier 4 Gap



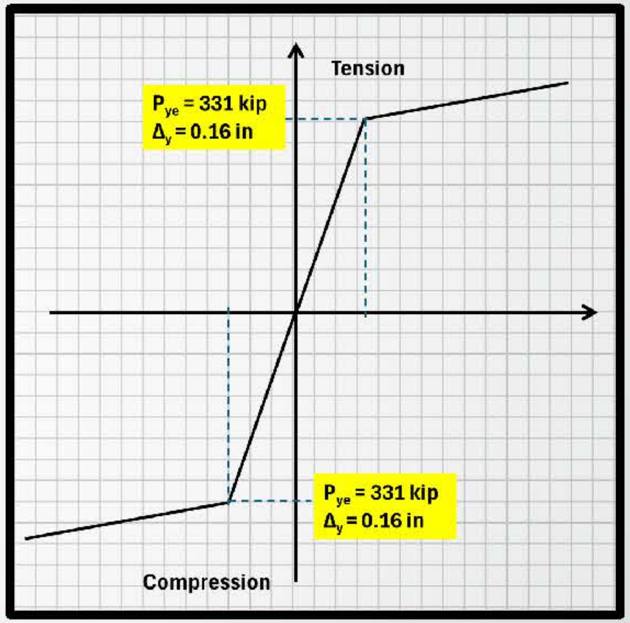
Hazard	Existing Relative Disp. (in)	Retrofit Relative Disp. (in)	Available Gap (in.)
225-yr	**2.25**	**0.17**	2.5
975- yr	**>2.5**	**0.6**	2.5
2475-yr	**>2.5**	**2.06**	2.5

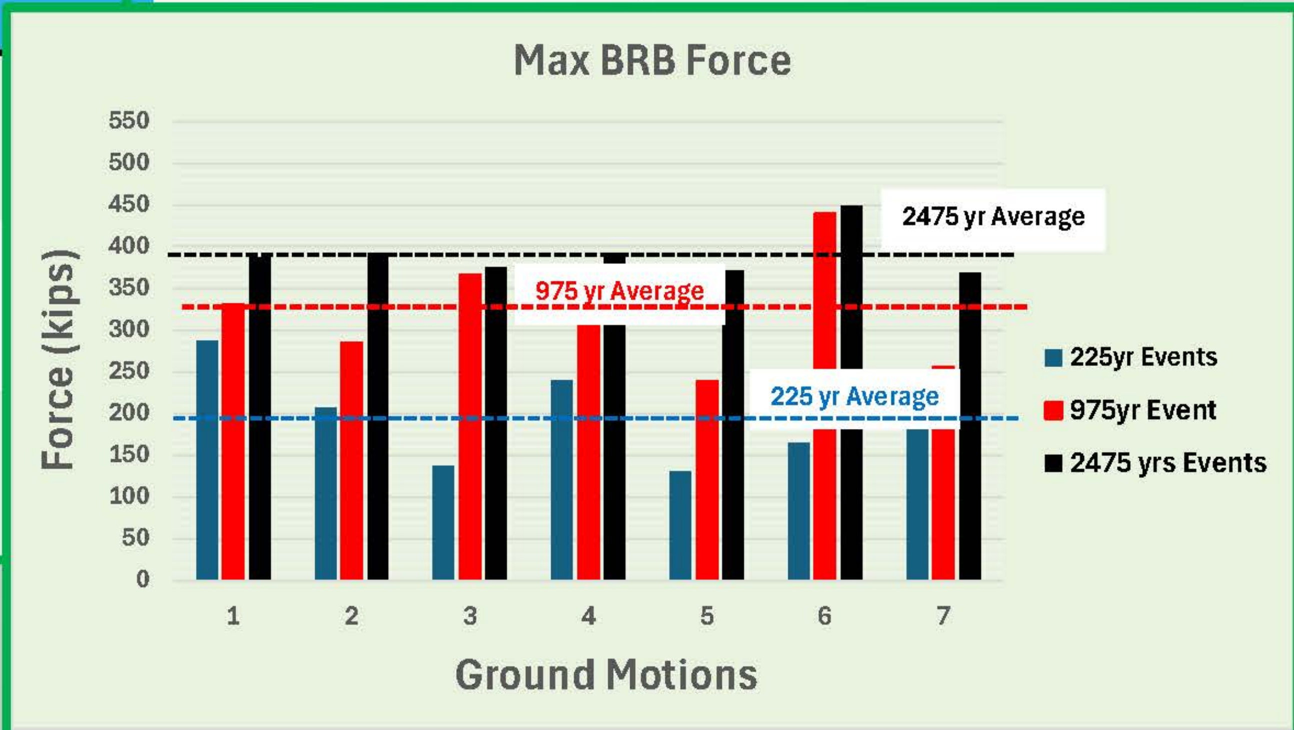


Canyon Creek Bridge – Design and Analysis

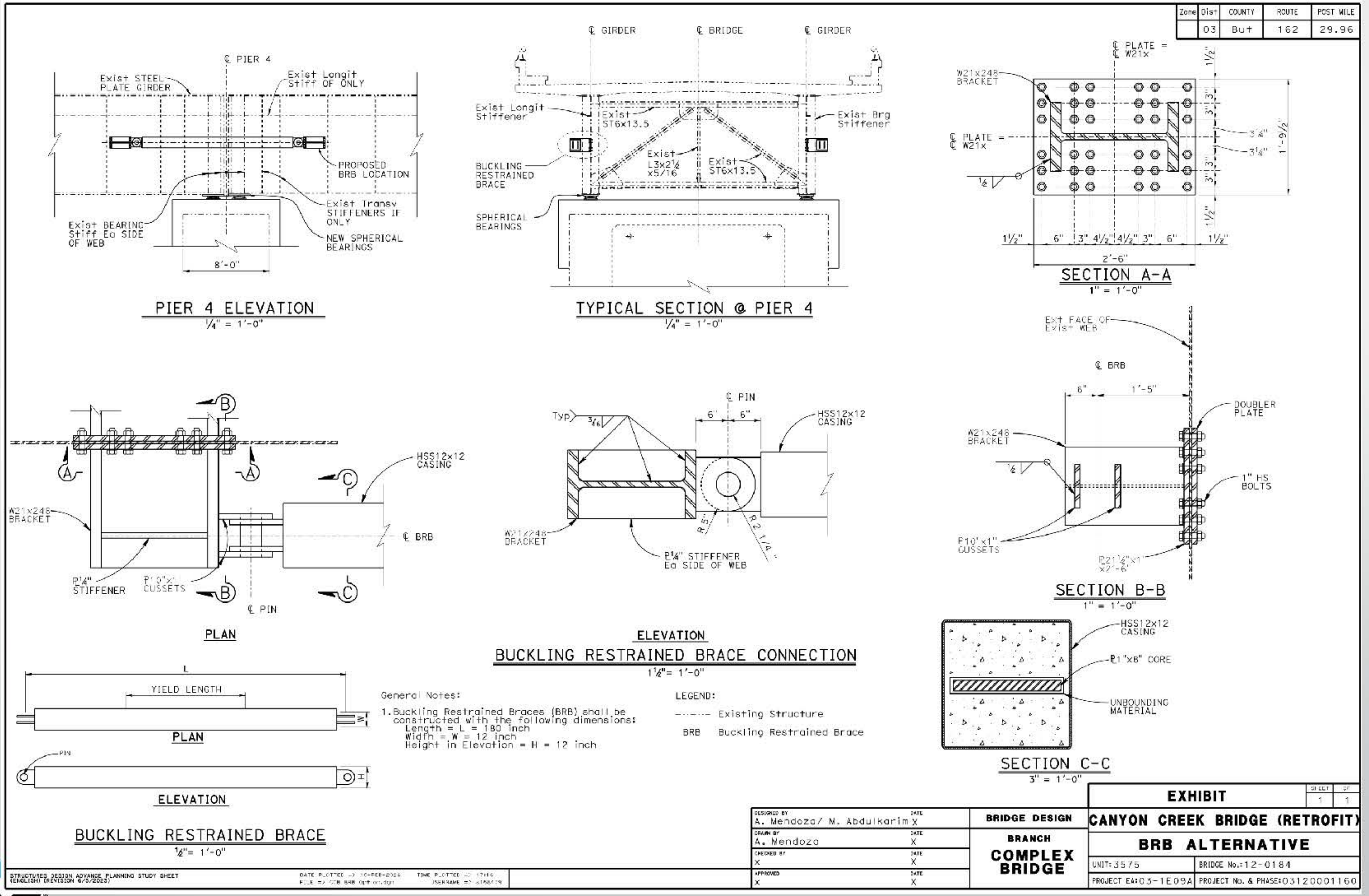
- NTHA- **Retrofitted Bridge**
  - Pier 4 Gap
  - Force in BRB

Hazard	BRB Force (kips)
225-yr	**193**
975-yr	**322**
2475-yr	**390**





Canyon Creek Bridge – BRB Retrofit Alternative



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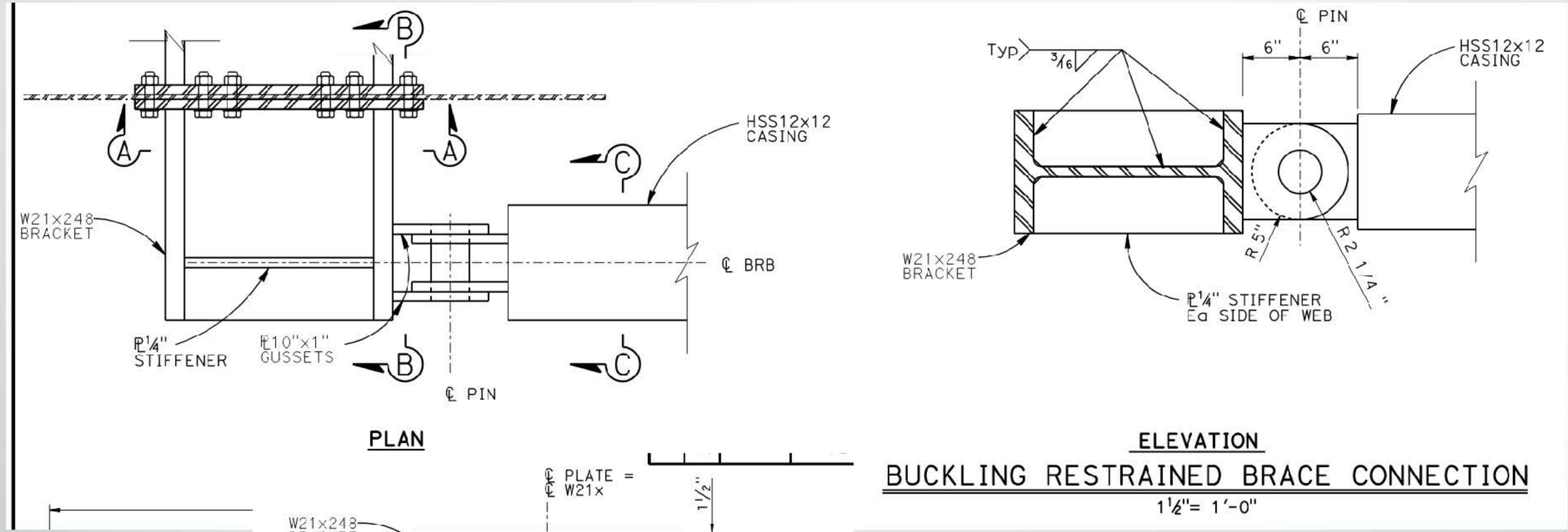
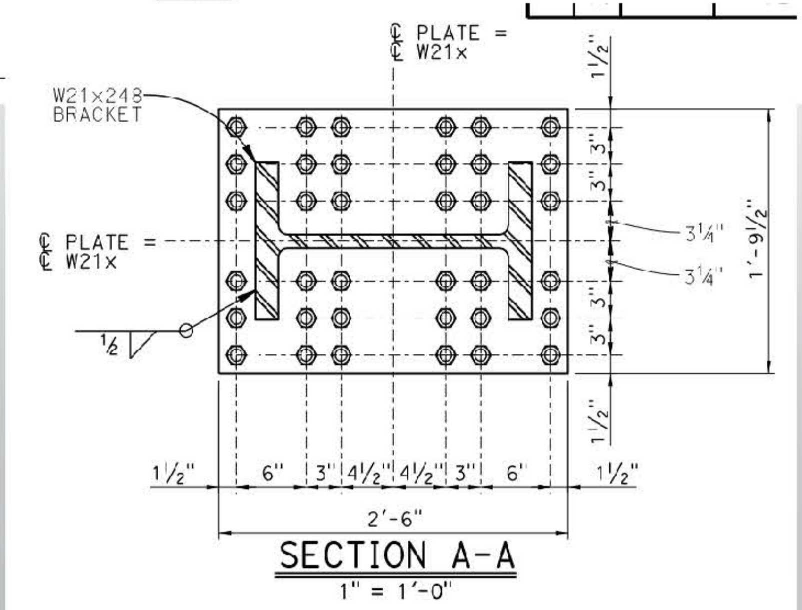
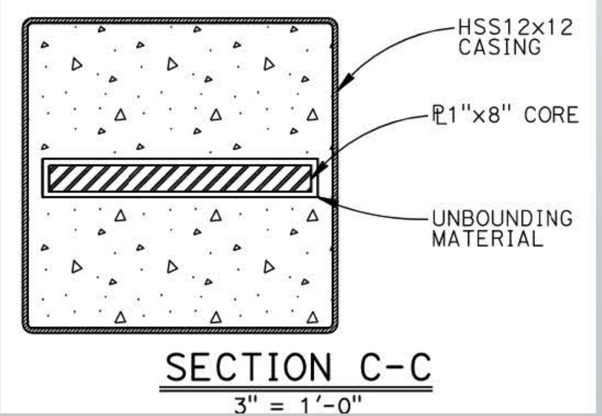
Canyon Creek Bridge – BRB Retrofit Alternative







Canyon Creek Bridge – BRB Retrofit Alternative

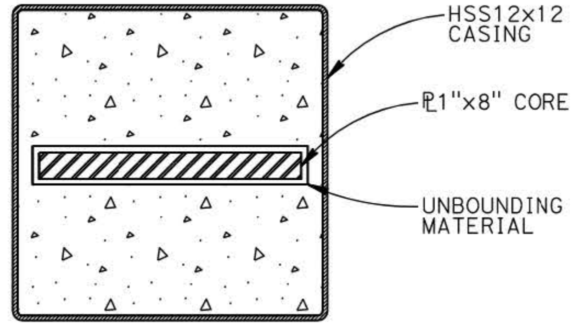
- Caltrans *Seismic Design Specifications for Steel Bridges*
- Caltrans *Bridge Design Practice (Ch. 20.2)*
- AISC 341 - *Seismic Provisions*

of a ductile component greater than its idealized plastic strength. The overstrength factor, Ω shall be determined by the project-specific criteria. Based on research recommendations, the following overstrength factors, Ω, may be used:

For shear in I-shaped links	$\Omega = 1.75$
For shear in box-shaped links	$\Omega = 1.50$
For buckling-restrained braces	$\Omega = 1.00$
For all other cases	$\Omega = 1.20$

$$T_a = \omega_T F_{yesc} A_{sc}$$

$$P_a = \omega_C F_{yesc} A_{sc}$$



SECTION C-C
3" = 1'-0"

Canyon Creek Bridge – Conclusion

- BRB retrofit effectively controls longitudinal displacement
- Relative displacement demand remains below the available 2.5" gap under all hazard levels.
- No impact or unseating risk observed in nonlinear time history analyses.
- Selected BRBs perform as intended:
  - Elastic under 225-year event
  - Yield under 975-year event

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Thank you

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