Effects of Different Support Modeling Assumptions on Seismic Response of Ordinary Bridges (BP222)

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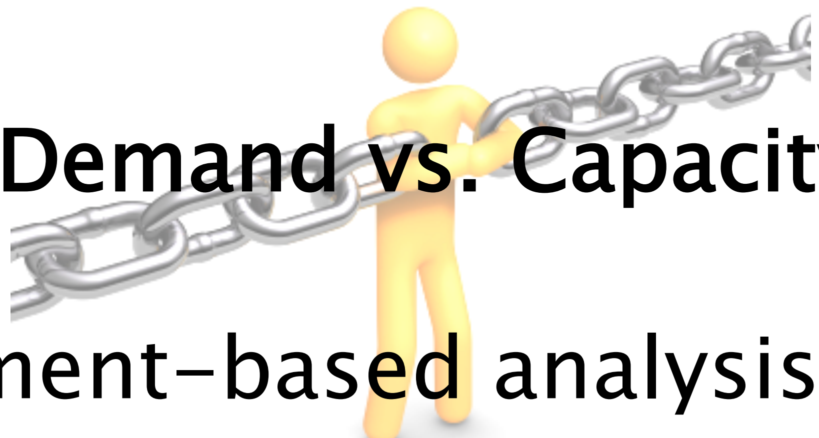
Preface

- Generally in performance-based design:



Demand vs. Capacity

- Displacement-based analysis:

Evaluating the potential damage to a structure based on <u>displacement-related quantities.</u>

- Displacement-based design:

Displacement Capacity (Δ_C)

I- Capacity Analysis (Δ_C and Δ_y)

Displacement Ductility (μ_Δ) → Δ_y

II- Demand Analysis (Δ_D)

↓

$\Delta_D \leq \Delta_C$

μ_Δ should meet required criteria

I- Capacity Analysis

Nonlinear time history analysis (the ideal approach when subjected to earthquake loadings) → difficulties in GM selection and computational process

Nonlinear static pushover analysis (a compromise between the simplification of the linear analysis and the accuracy of the nonlinear dynamic analysis)

✓ Conventional Pushover Methods:

application of an increasing, but *invariant*, lateral load pattern on the structural system.

→ Fundamental mode shape proportional

Single-mode pushover: based on one, predominant, mode shape.

Multi-modal pushover (MMP): estimates the pushover result for a number of modes.

II- Demand Analysis

- ✓ Independently Determined Demand

  AASHTO Guide Specifications for LRFD Seismic Bridge Design (2009).

  California Seismic Design Criteria SDC-2010 (Caltrans, 2010).

- ✓ Capacity-dependant Demand:

  Generally known as Capacity Spectrum Methods (CSMs): determine the performance point ($\Delta_D = \Delta_P$)

✓ AASHTO Specifications Procedure:

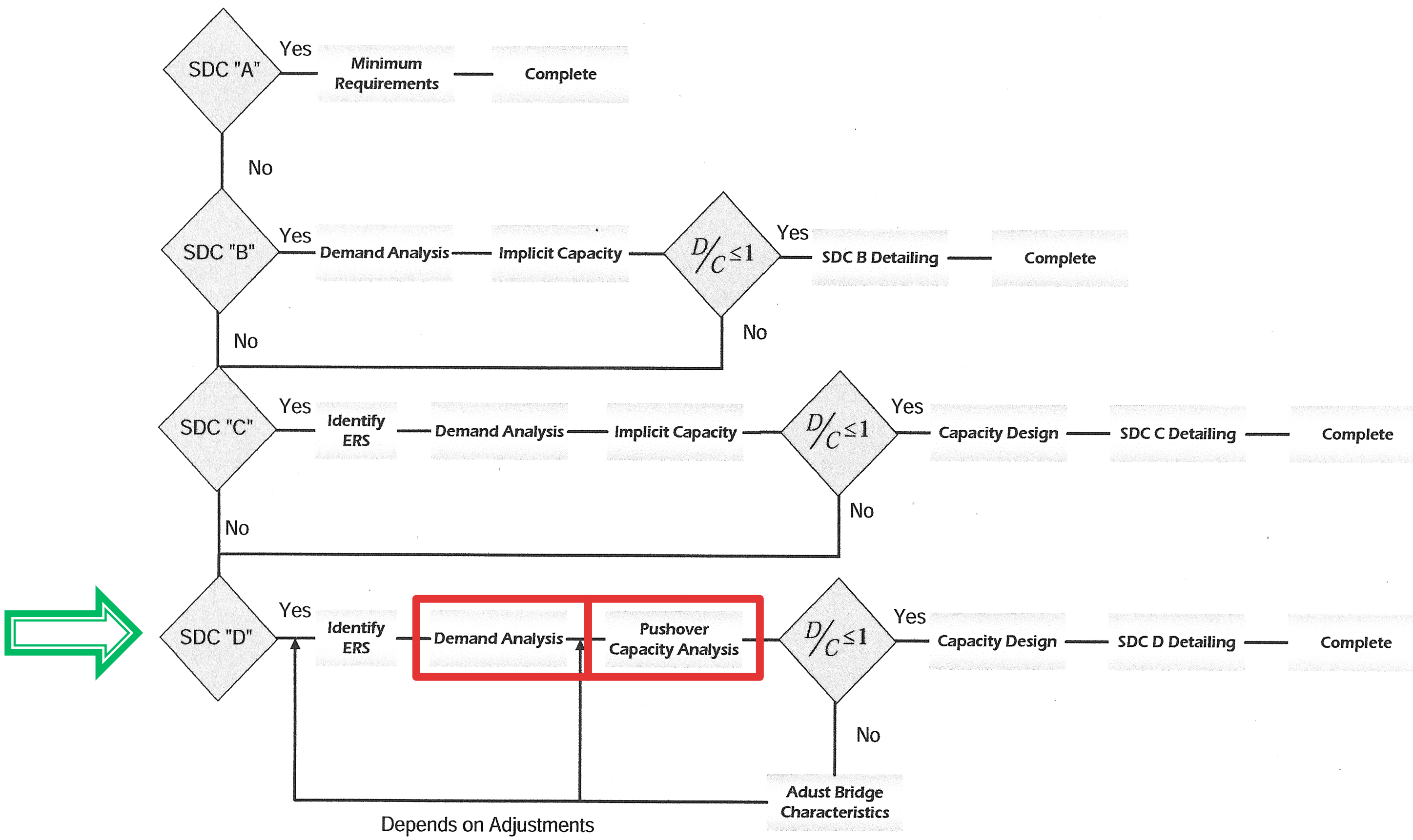
Seismic Design Categories

Table 3.5-1

$SD_1 = F_V S_1$	SDC
$SD_1 < 0.15$	A
$0.15 <= SD_1 < 0.30$	B
$0.30 <= SD_1 < 0.50$	C
$0.50 <= SD_1$	D

✓ AASHTO Specifications Procedure:

Core Flowchart



✓ AASHTO Specifications Procedure:

SDC D Demand Analysis Procedures

Table 4.2-2

Regular Bridge	Not Regular Bridge
Equivalent Static or Elastic Dynamic	Elastic Dynamic

Regularity requirements (T 4.2.3; Art. 4.2)

✓ AASHTO Specifications Procedure:

Elastic Dynamic Analysis (EDA)

- Response spectra analysis (AASHTO-USGS maps)
- Orthogonal combination (Art. 4.4)
- General considerations (Art. 5.4.3)
- Mathematical modeling (Art. 5.5)
- Effective section properties (Art. 5.6)

⇨ Seismic lateral displacement demand (Art. 4.3)

✓ AASHTO Specifications Procedure:

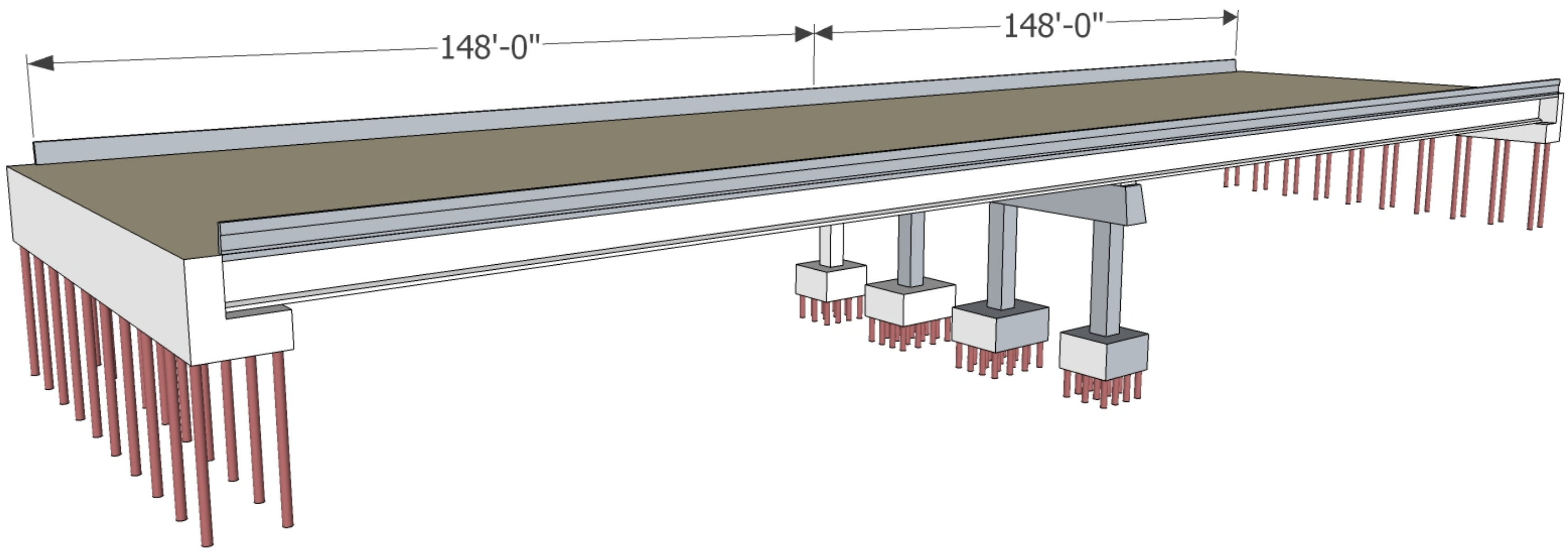
Displacement Modifications:

- Other than 5% damped; R_D (Art. 4.3.2)
- Short-period structure; R_d (Art. 4.3.3)

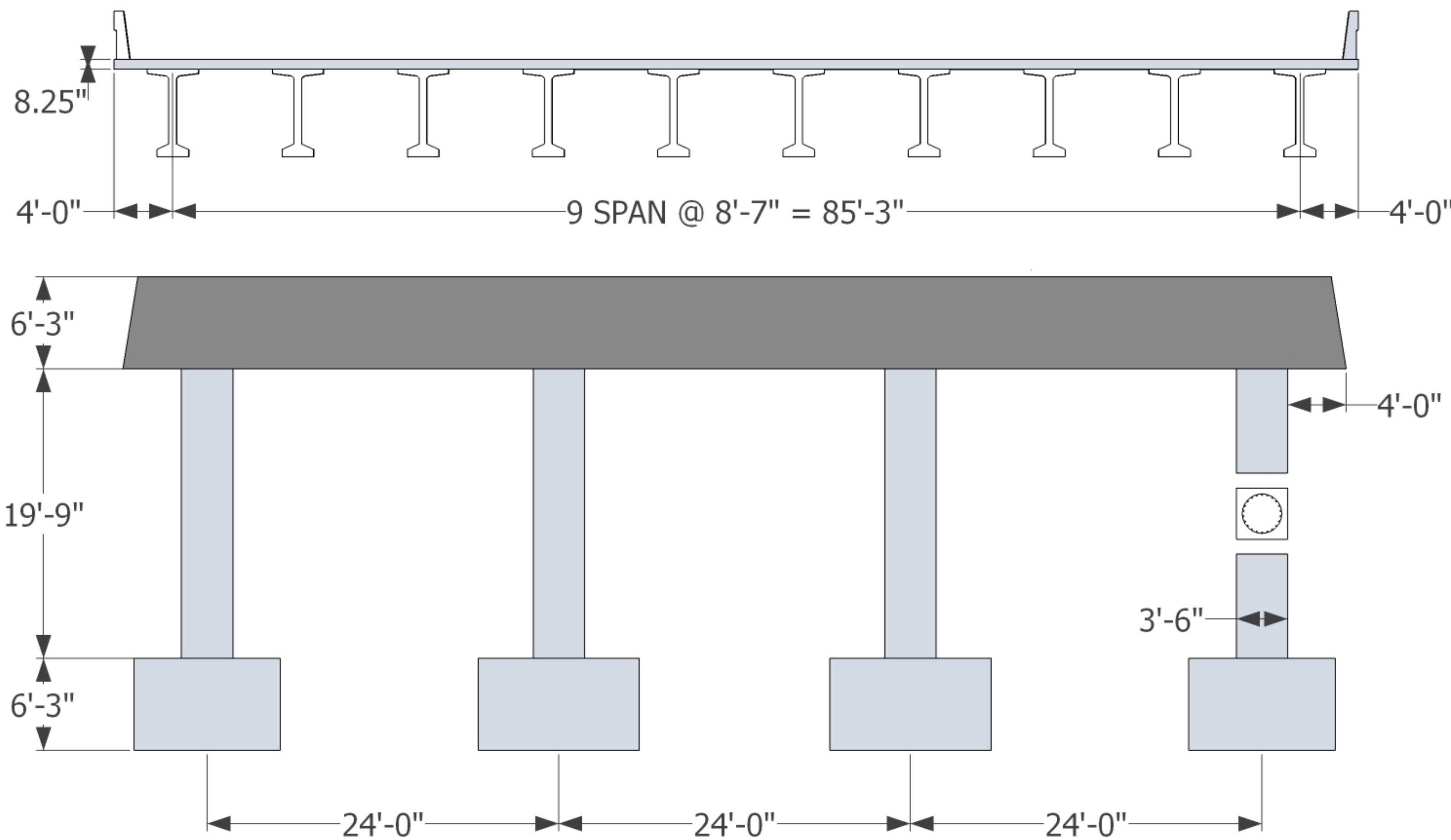
Case Study Bridges:

1. The State Route 21 over Interstate 69 Bridge (SR21-I69): two-span continuous with prestressed bulb T girders and four-column bent frame.

- SR21-I69 Bridge:



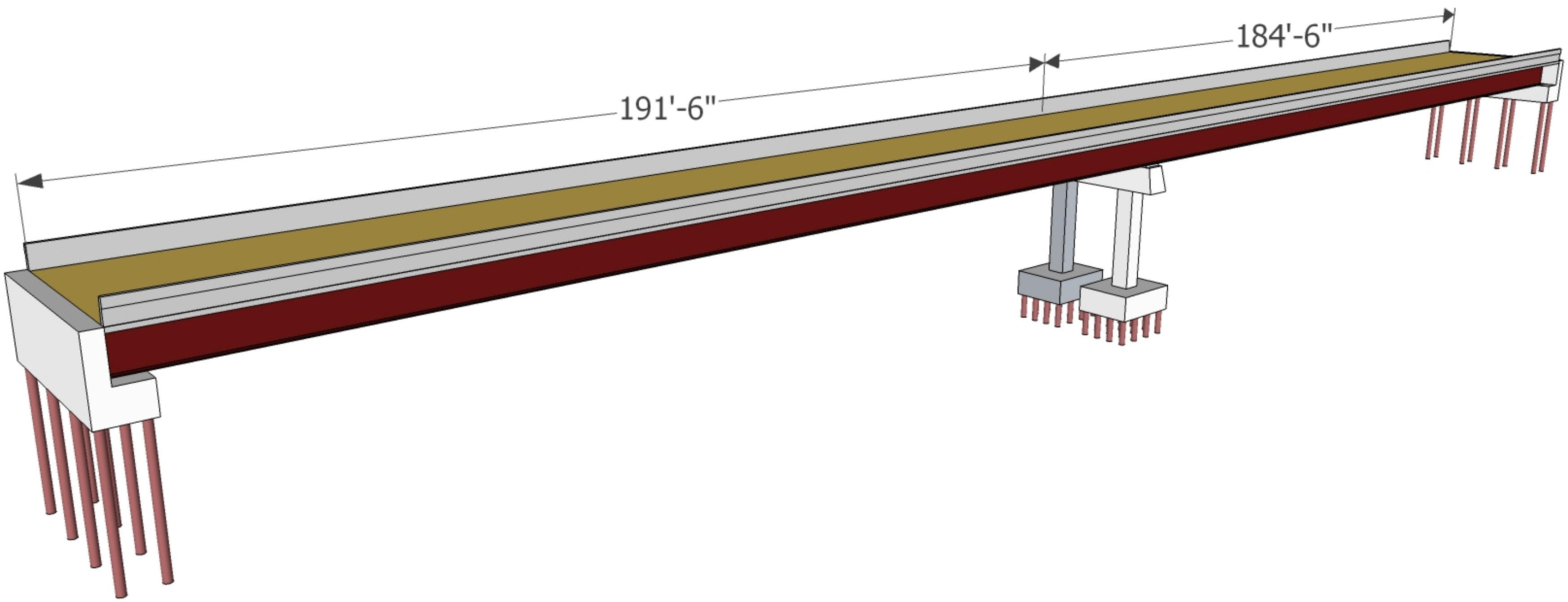
✓ SR21-I69 Bridge:



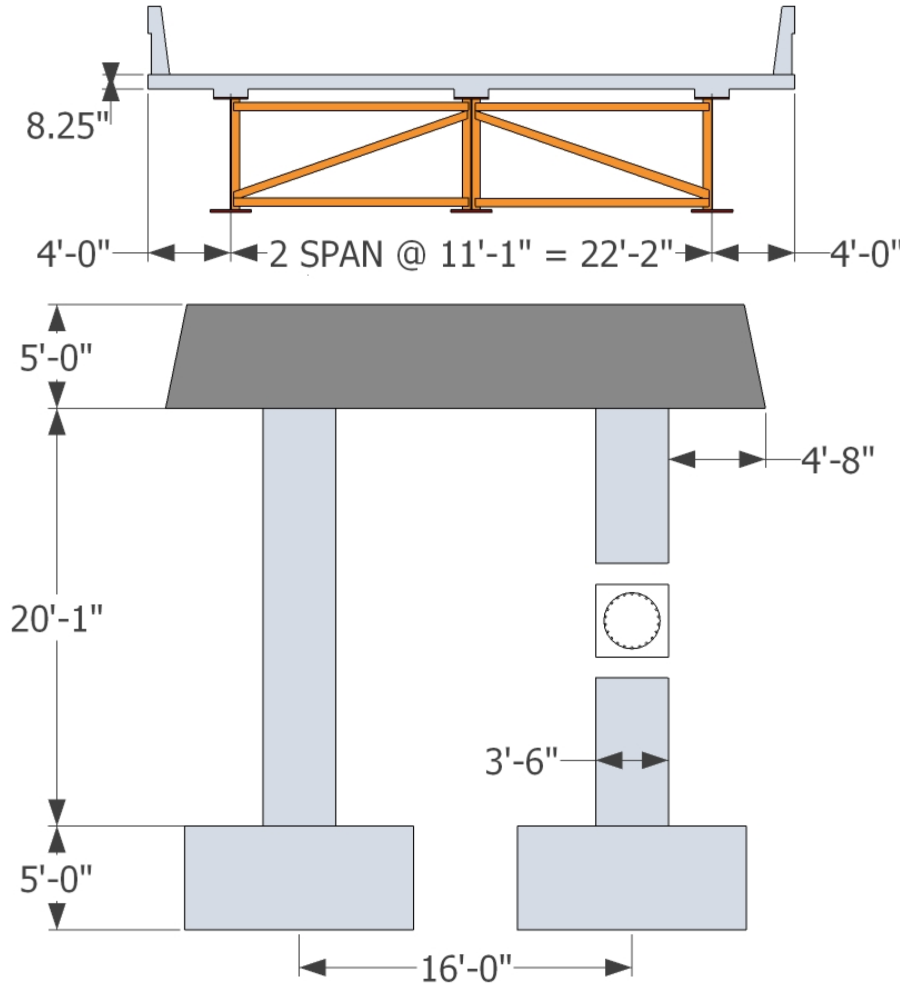
Case Study Bridges:

2. The Forrester Road over Interstate 69 Bridge (Forrester Rd-I69): two-span continuous with steel plate girders and two-column bent frame.

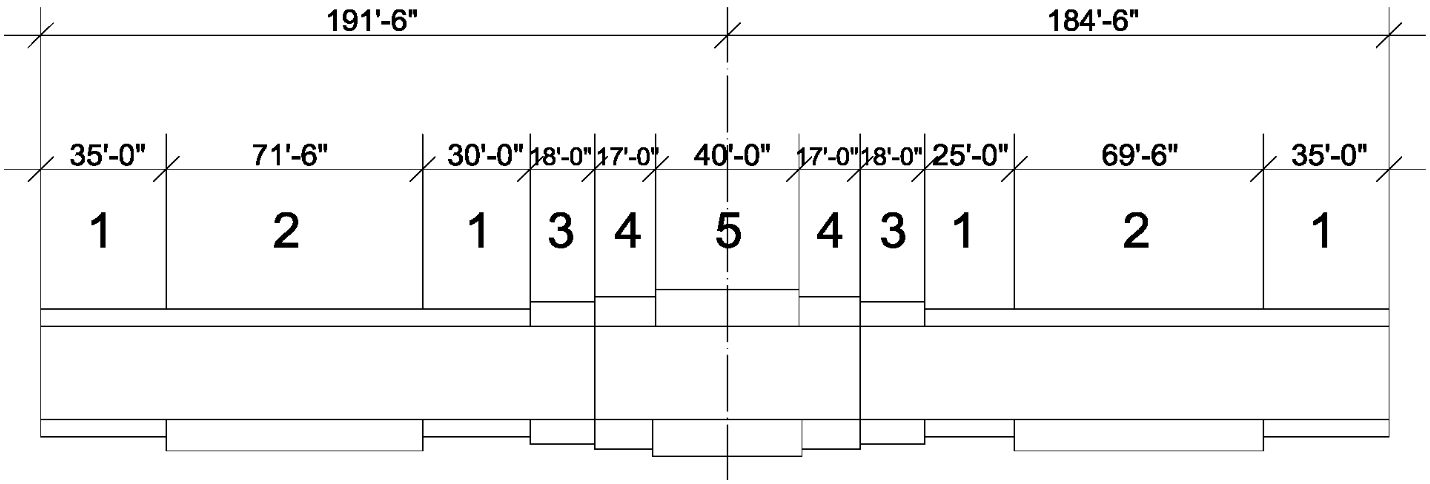
- ✓ Forrester Rd-I69 Bridge:



✓ Forrester Rd–I69 Bridge:



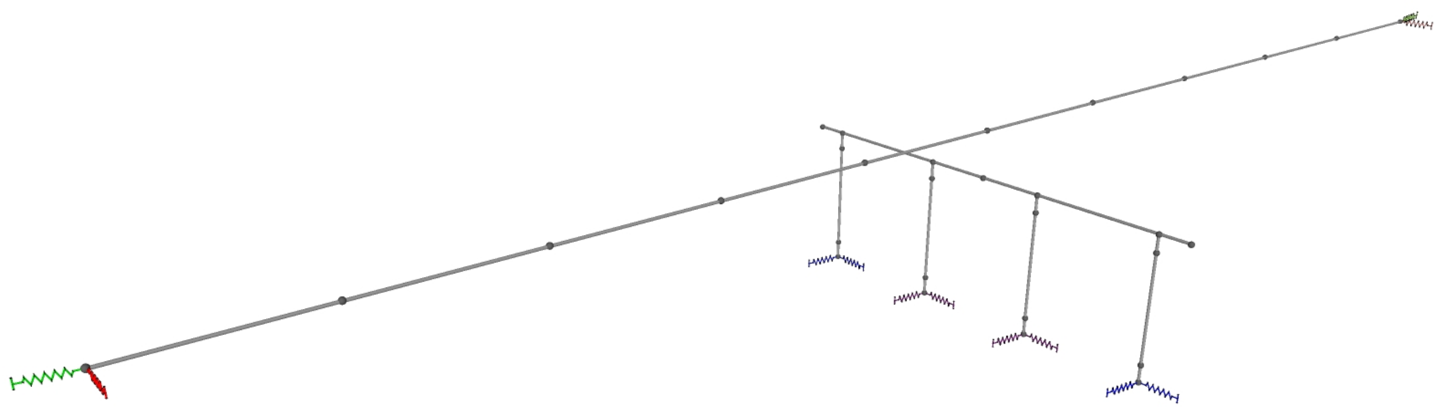
✓ Forrester Rd–I69 Bridge:



Section	Web	Top Flange	Bottom Flange
1	64 x 9/16	20 x 1-1/8	24 x 1-1/8
2	64 x 9/16	20 x 1-1/8	24 x 2-1/8
3	64 x 9/16	28 x 1-1/4	30 x 1-1/4
4	64 x 5/8	28 x 1-3/4	30 x 1-3/4
5	64 x 5/8	28 x 3-1/4	30 x 3-1/4

✓ General Modeling Properties:

–Idealized mathematical model



- General Modeling Properties:
  - The seismic behavior of both bridges was evaluated in the transverse direction only.
  - *Basic support configuration*:
    - Fixed column footings;
    - Fixed abutments for all rotations and vertical translation; and
    - Linear springs for abutments in longitudinal and transverse translations.

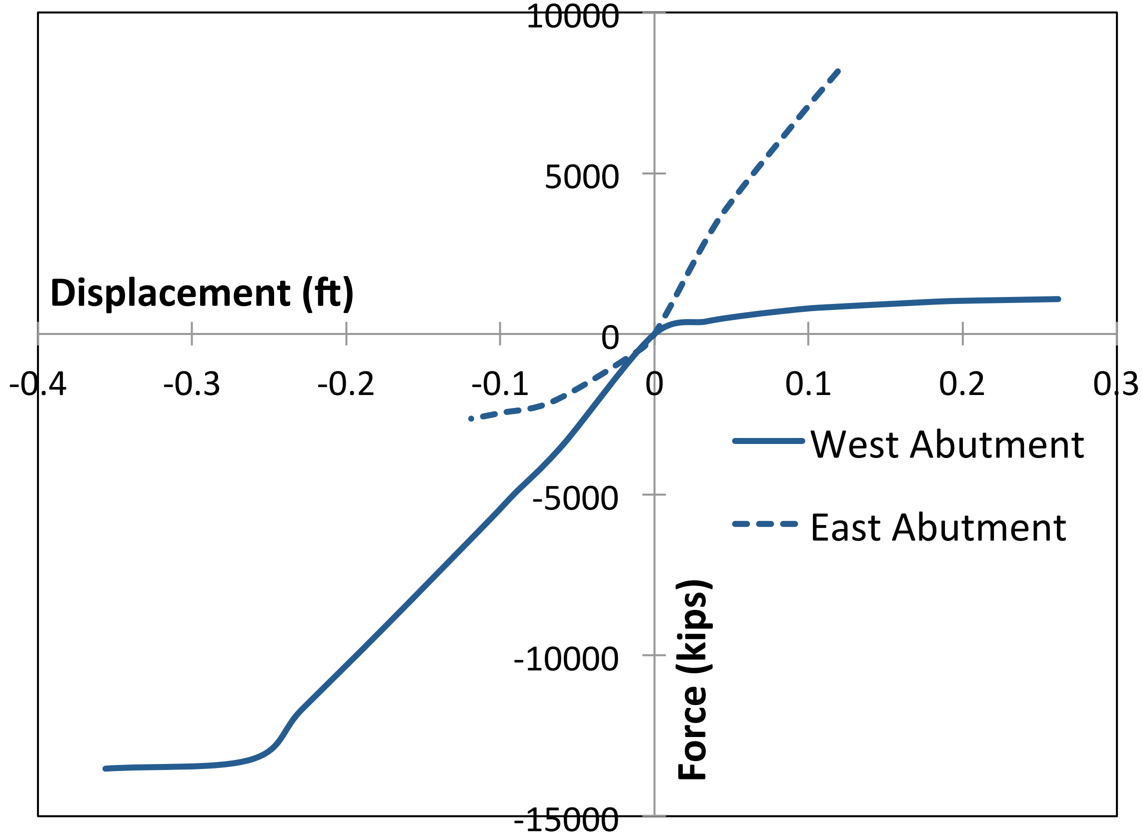
- ✓ General Modeling Properties:
  - *Nonlinear springs support configuration*:

    Fixed column footings for all rotations and vertical translation;

    Fixed abutments for all rotations and vertical translation; and

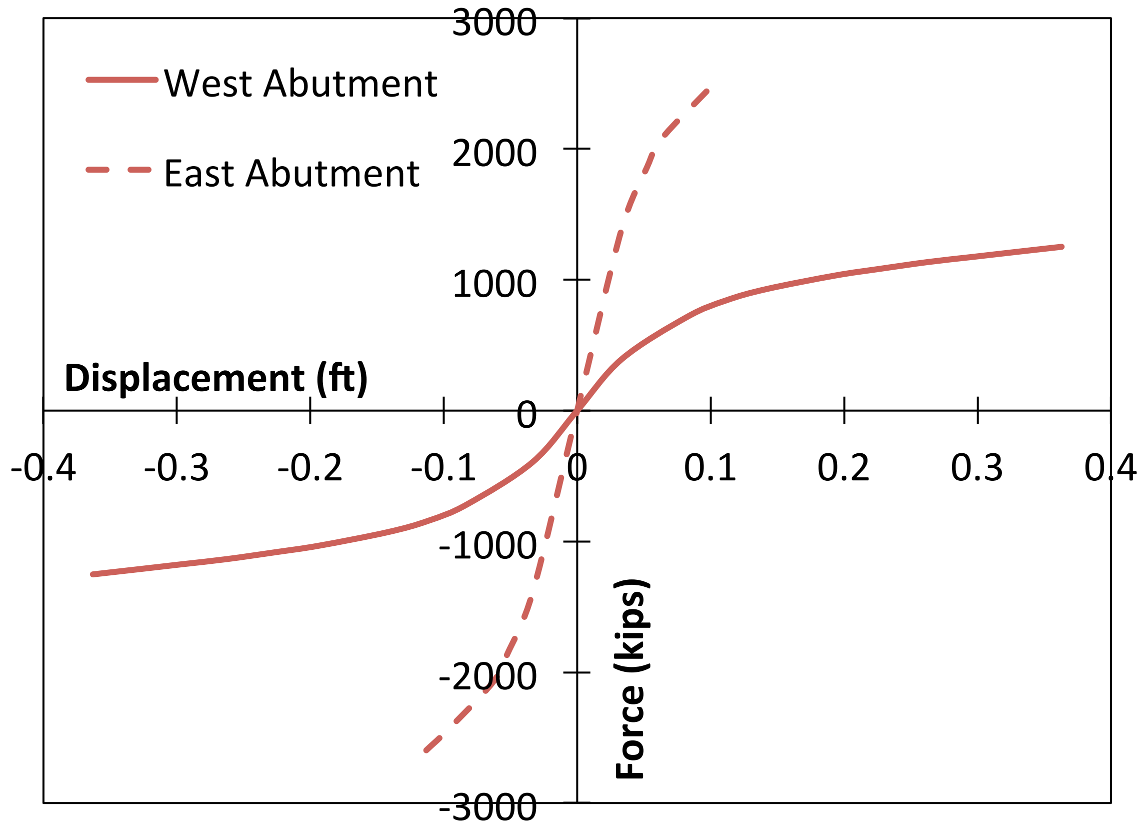
    Nonlinear springs for abutments and column footings in longitudinal and transverse translations.

✓ SR21–I69 Bridge:



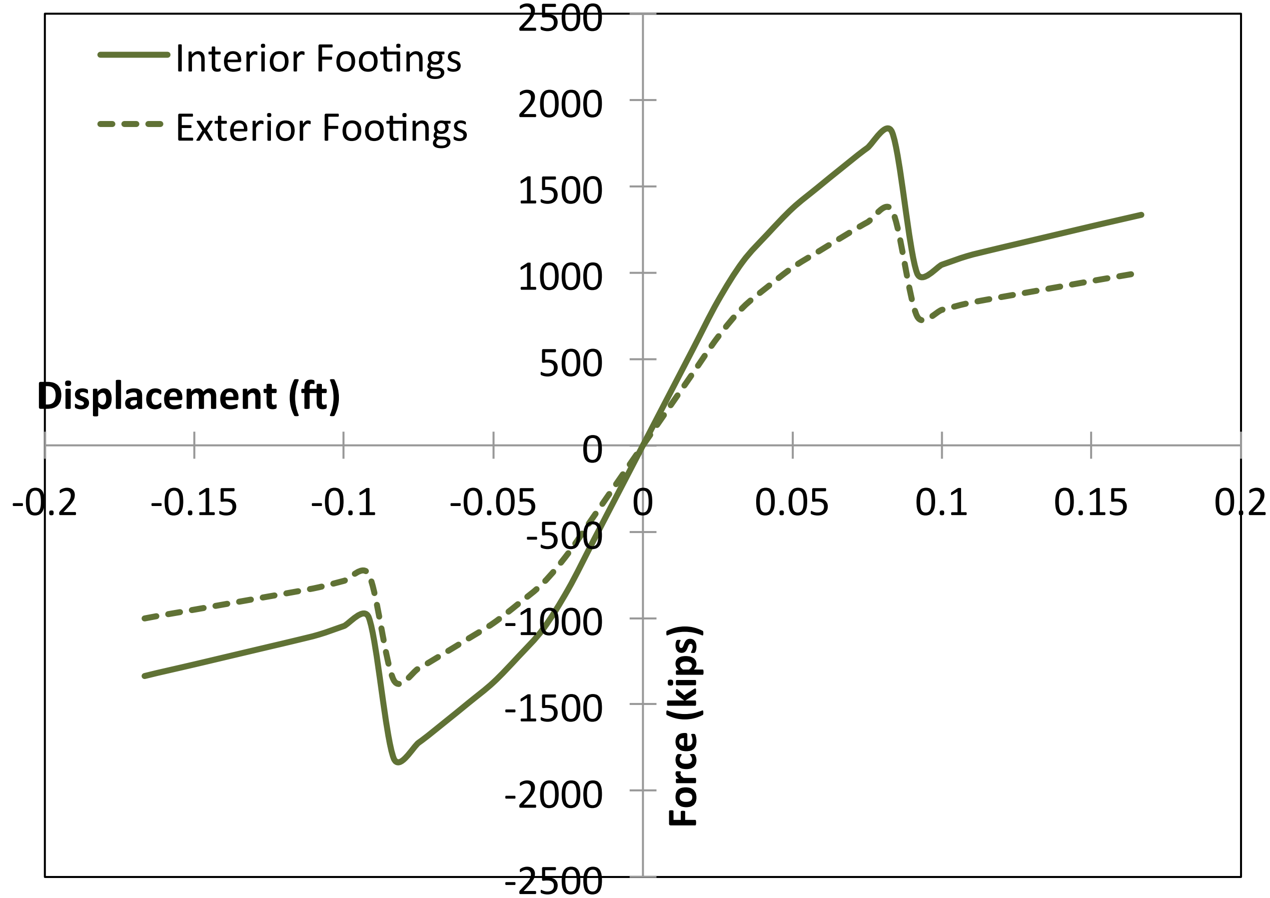
Abutments in Longitudinal Direction

✓ SR21–I69 Bridge:



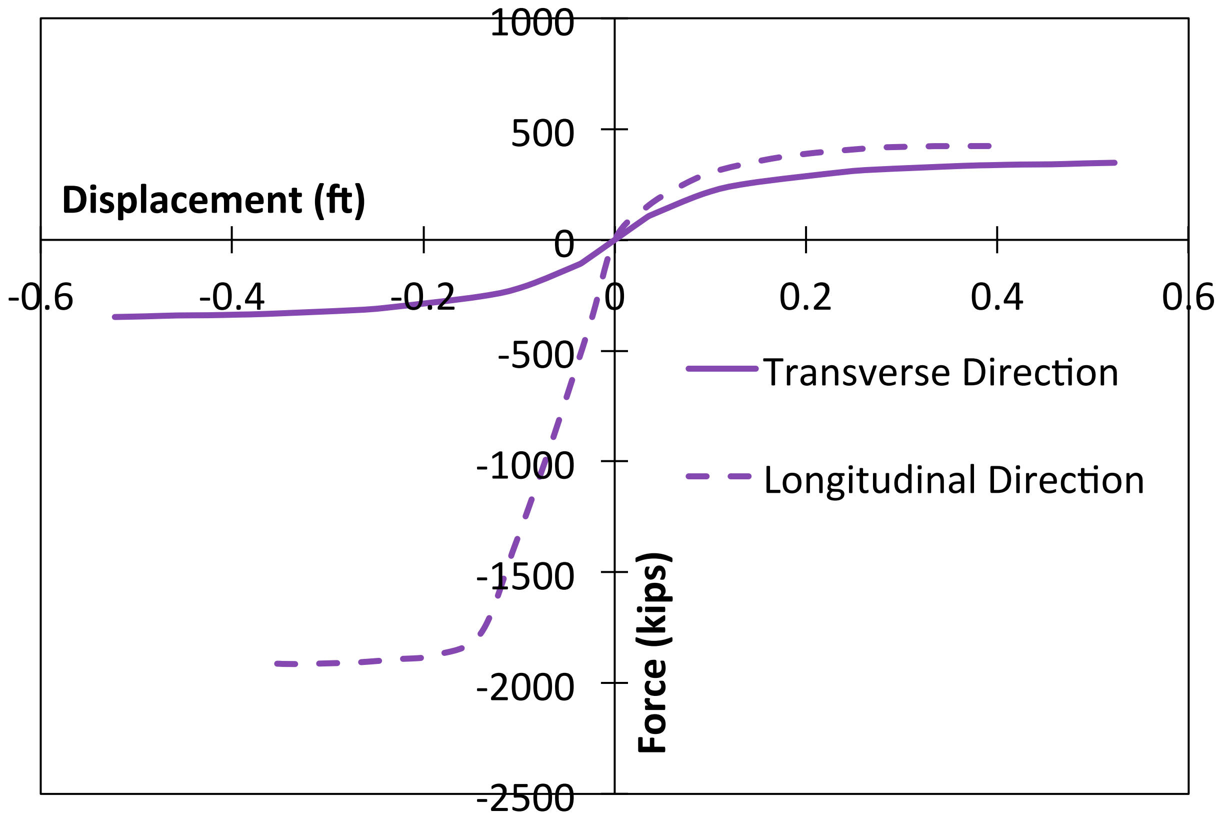
Abutments in Transverse Direction

✓ SR21-I69 Bridge:



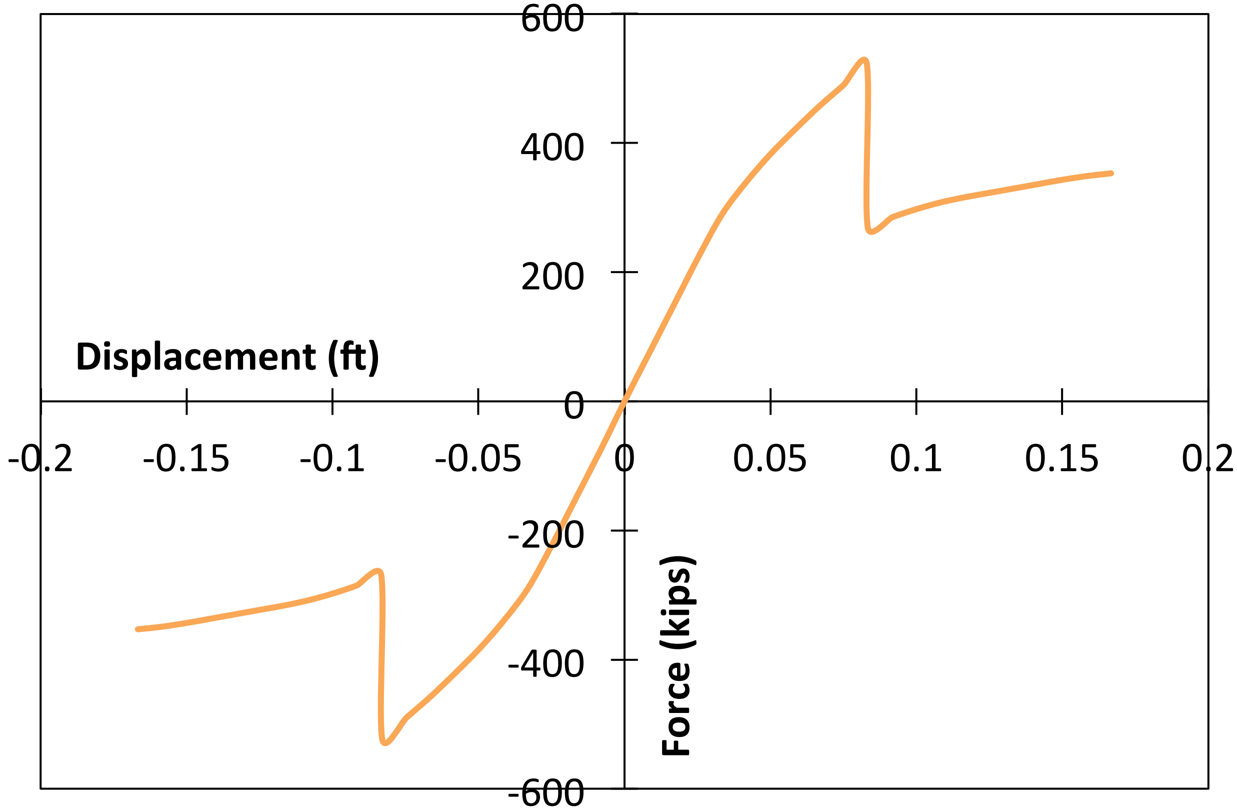
Column Footings in Both Directions

✓ Forrester Rd–I69 Bridge:



Abutments in Both Directions

Forrester Rd-I69 Bridge:

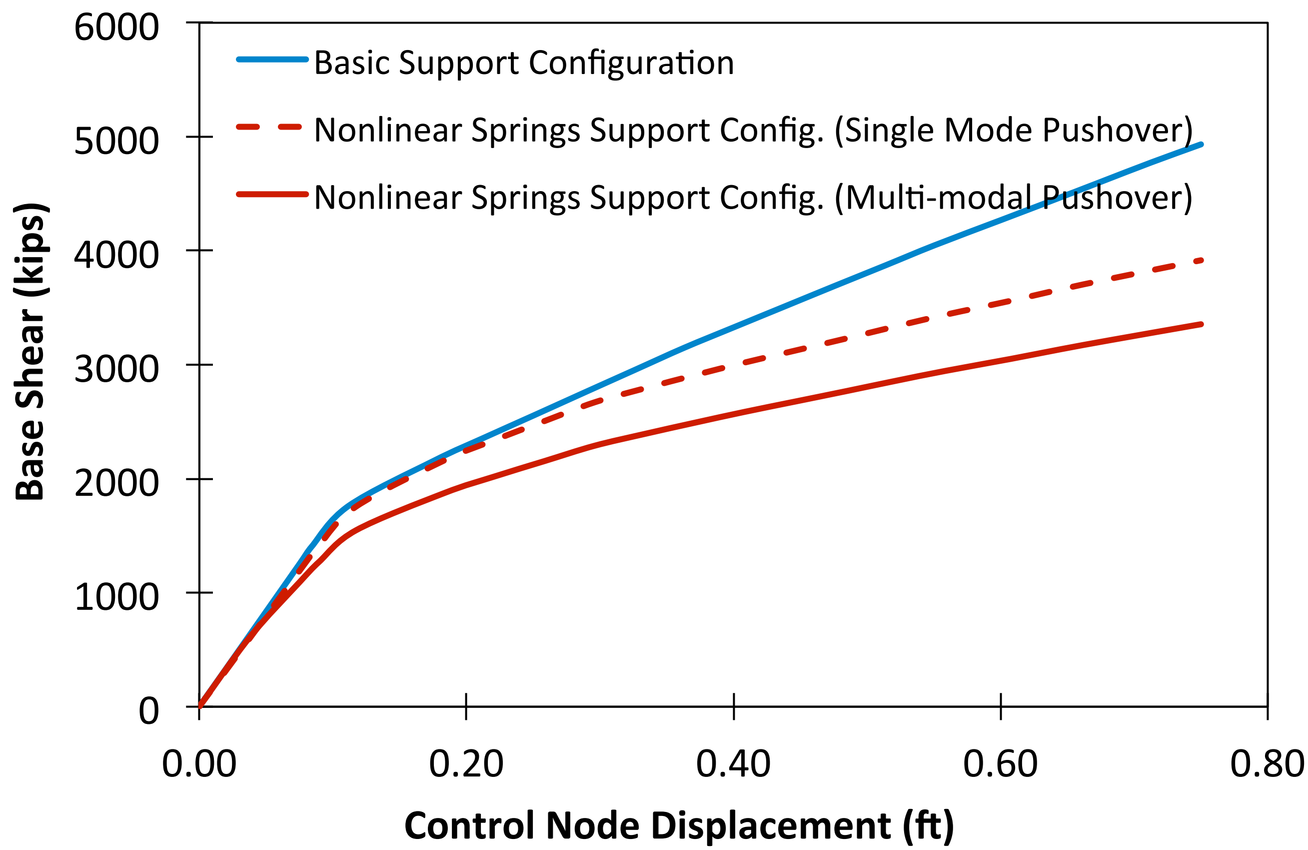


Column Footings in Both Directions

✓ Modal Analysis:

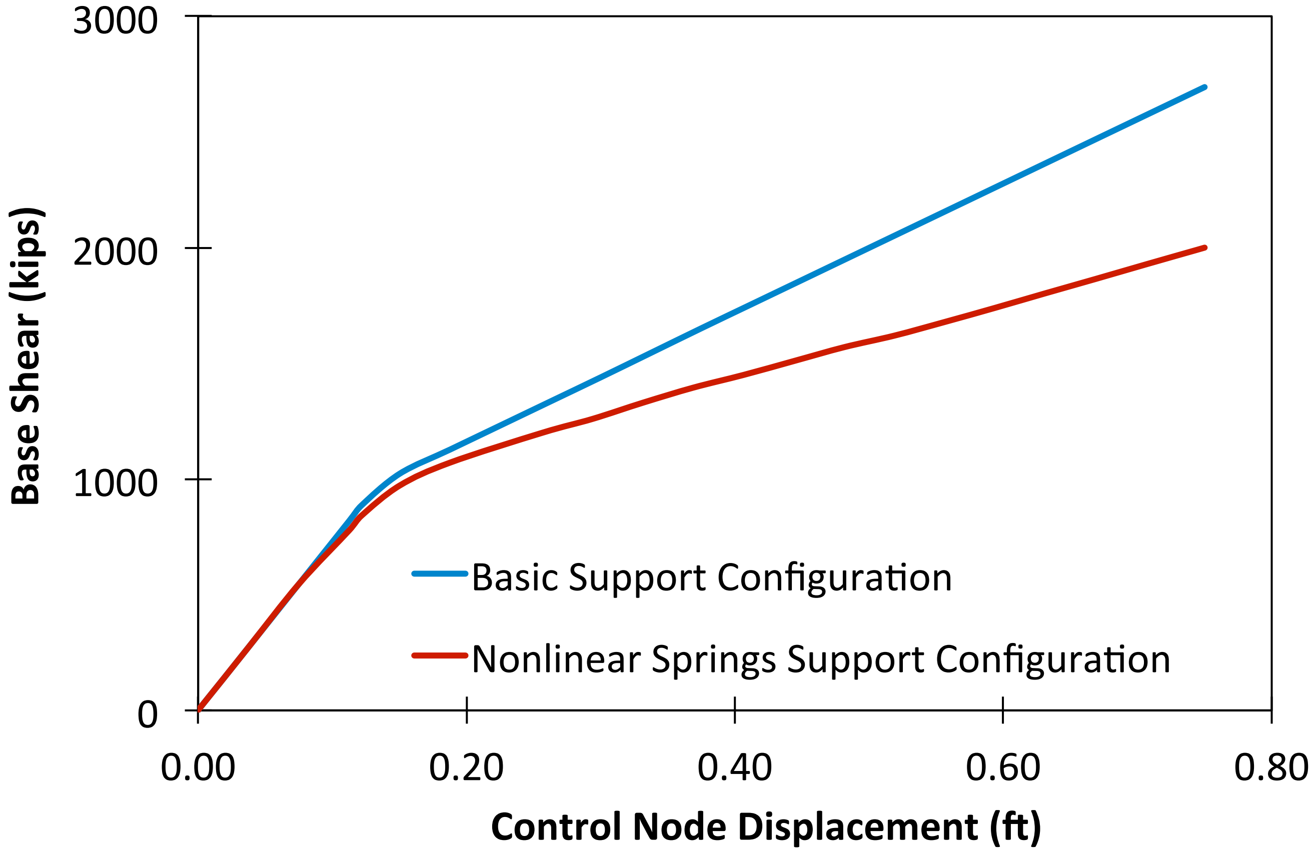
Case Study	Support Model	Mode Number	Period (sec)	Modal Participating Mass Ratio (%)
SR 21 – I 69 Bridge	Basic Support Config.	2	0.84	0.997
	Nonlinear Springs Support Config	1	0.71	0.789
		6	0.3	0.126
Forrester Rd – I69 Bridge	Basic Support Config	1	0.75	0.998
	Nonlinear Springs Support Config	1	0.61	0.961

✓ Pushover Analysis with SAP2000:



SR21-I69 Bridge

✓ Pushover Analysis with SAP2000:



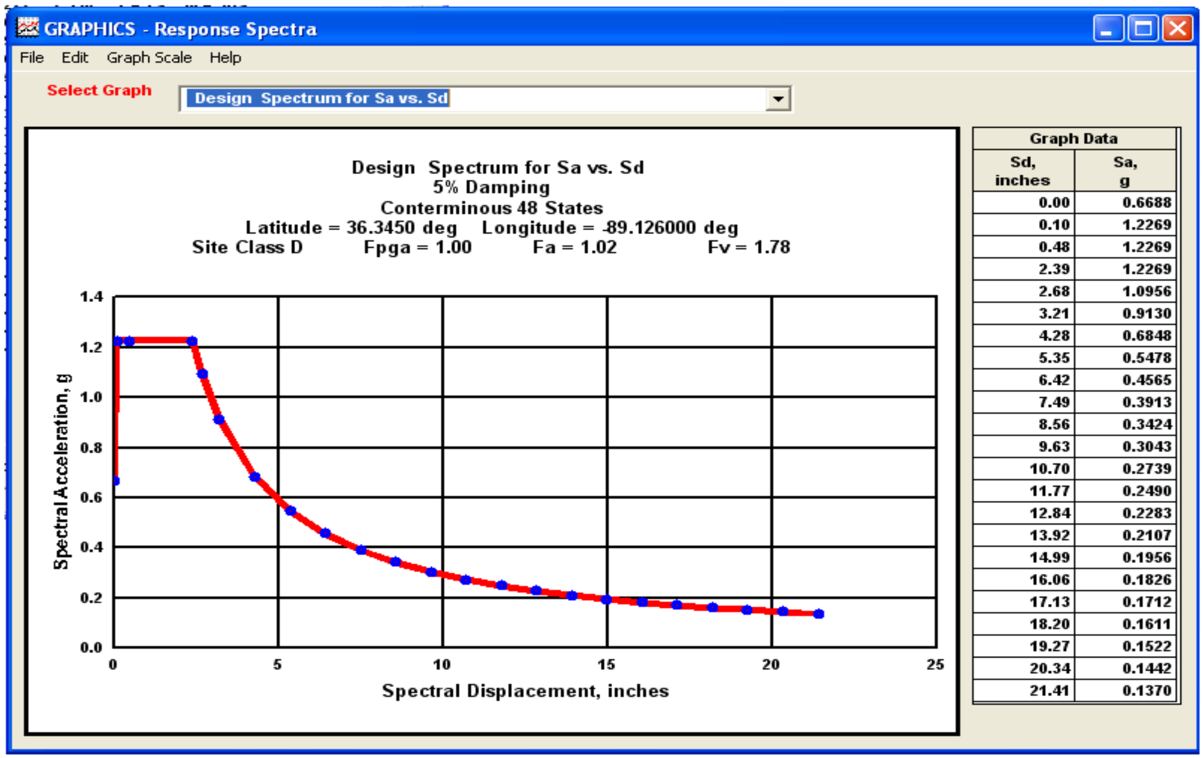
Forrester Rd–I69 Bridge

✓ Pushover Analysis with SAP2000:

	Yielding Displacement Δ_y (ft)
SR21-I69 Basic Support Model	0.115
SR21-I69 Nonlinear Springs Support Model (SMP)	0.134
SR21-I69 Nonlinear Springs Support Model (MMP)	0.125
Forrester Rd-I69 Basic Support Model	0.134
Forrester Rd-I69 Nonlinear Springs Support Model	0.148

Displacement-based Analysis Procedures:

Seismic Demand



Sd, inches	Sa, g
0.00	0.6688
0.10	1.2269
0.48	1.2269
2.39	1.2269
2.68	1.0956
3.21	0.9130
4.28	0.6848
5.35	0.5478
6.42	0.4565
7.49	0.3913
8.56	0.3424
9.63	0.3043
10.70	0.2739
11.77	0.2490
12.84	0.2283
13.92	0.2107
14.99	0.1956
16.06	0.1826
17.13	0.1712
18.20	0.1611
19.27	0.1522
20.34	0.1442
21.41	0.1370

✓ AASHTO Specifications Procedure:

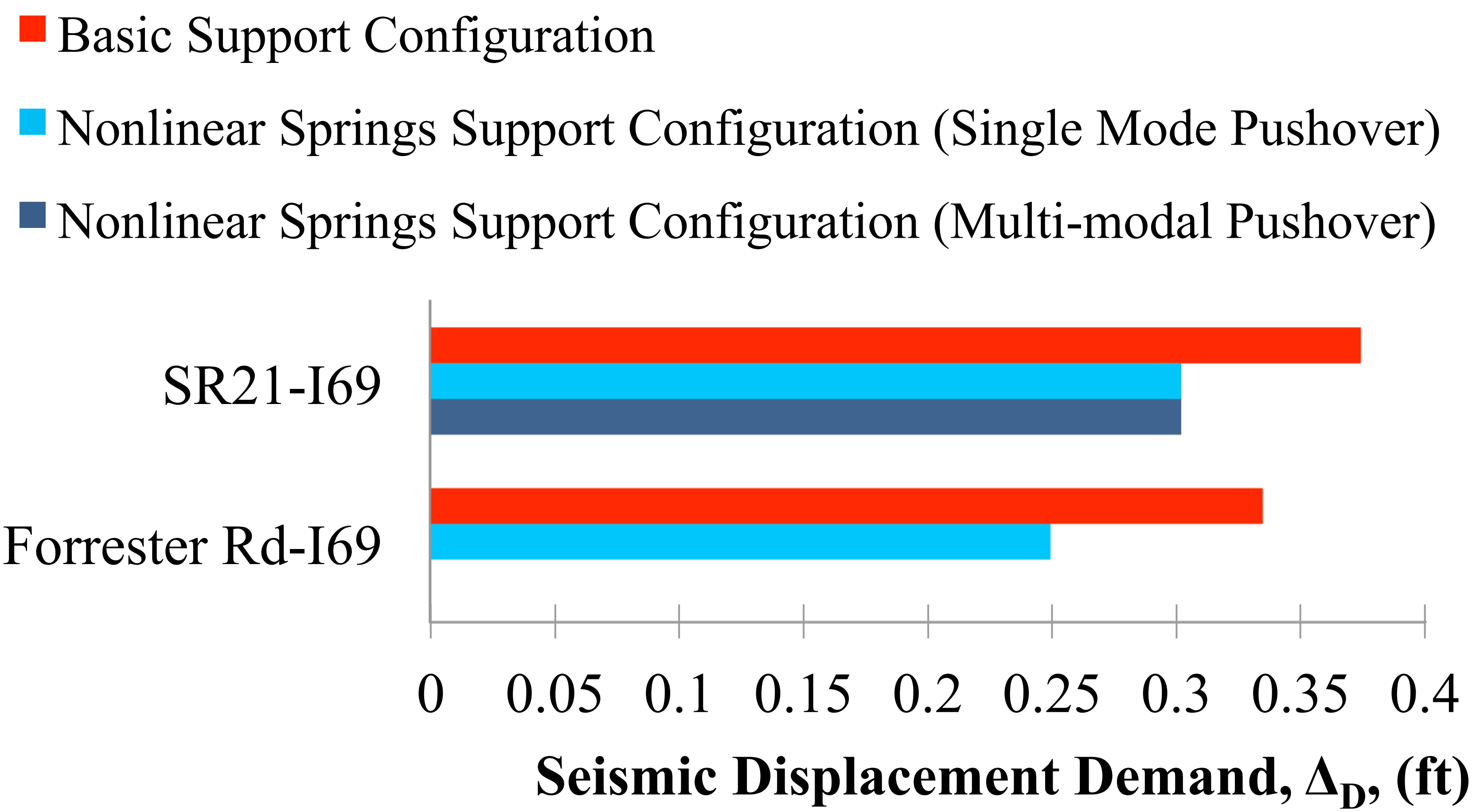
Demand analysis:

- Response spectrum method;
- Four orthogonal combinations;
- CQC modal combination; and
- Δ_D = max. transverse displacement.
- $\mu_\Delta = \Delta_D / \Delta_y$

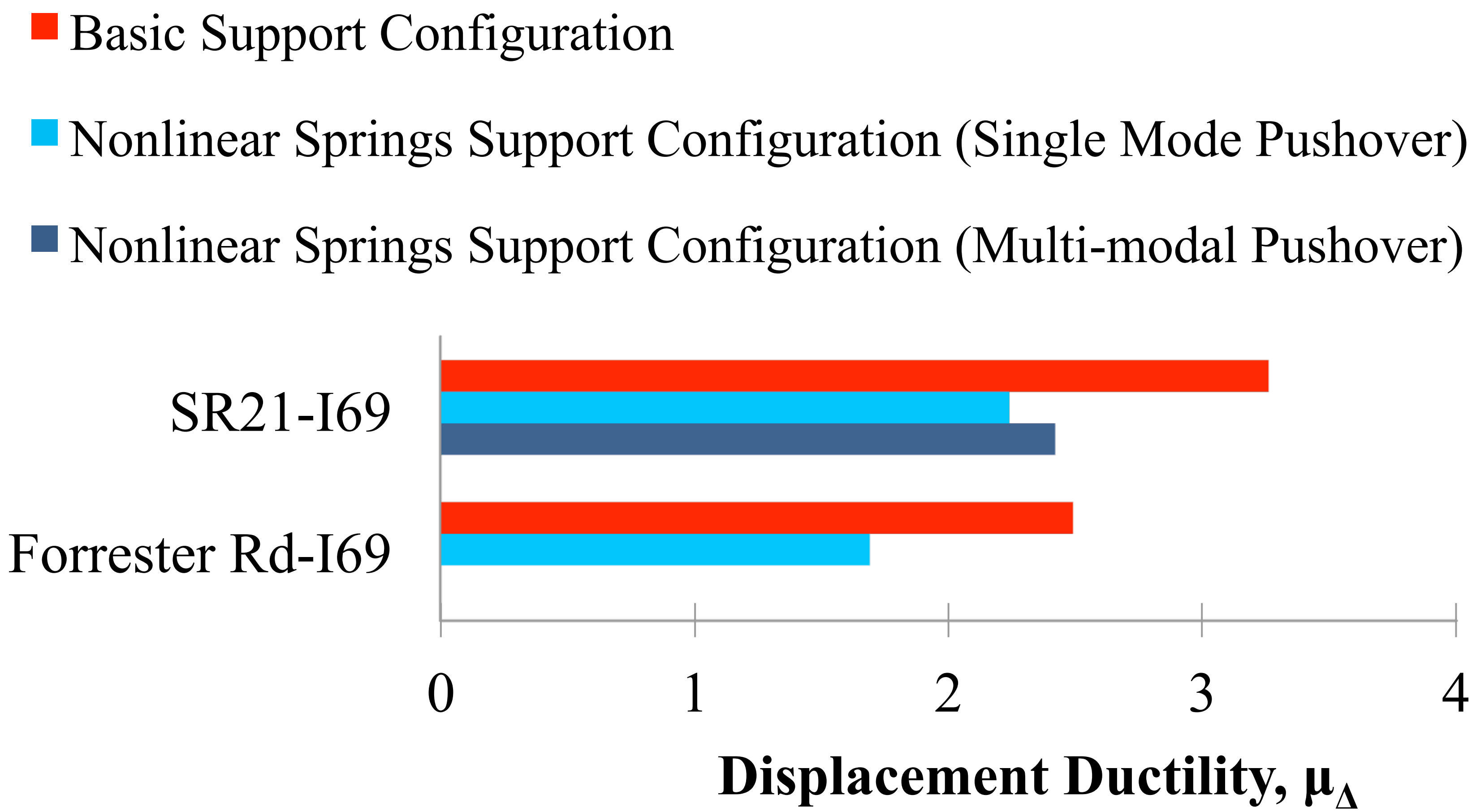
✓ AASHTO Specifications Procedure:

	Seismic Displacement Demand, Δ_D (ft)	Displacement Ductility, μ_Δ
SR21-I69 (Basic)	0.374	3.26
SR21-I69 (Non. Springs; SMP)	0.302	2.24
SR21-I69 (Non. Springs; MMP)	0.302	2.42
Forrester Rd-I69 (Basic)	0.335	2.49
Forrester Rd-I69 (Non. Springs)	0.25	1.69

Conclusions:



Conclusions:



References:

1. American Association of State Highway and Transportation Officials. (2009). *AASHTO Guide Specifications for LRFD Seismic Bridge Design* (1st Ed.). Washington, DC: AASHTO Highways Subcommittee on Bridges and Structures.
2. California Department of transportation, Caltran. (2004). *Caltrans bridge Design Specifications*. Sacramento, CA: Caltrans.
3. Chopra, A. K. (2007). *Dynamics of structures: Theory and applications to earthquake engineering*, 3rd Ed. Englewood Cliffs, NJ: Prentice-Hall.
4. SAP2000 (Version 15.1). (2011). Computers and Structures, Berkeley, CA: CSI.

Thank you for your attention!