CABES

CALIFORNIA BRIDGE ENGINEERS SEMINAR

ADVANCING BRIDGE ENGINEERING THROUGH INNOVATION

Caltrans

Slide 1

CABES 2026

DES
DIVISION OF ENGINEERING SERVICES

Isolation Bearings Applications for Rail & HWY Bridges

By:

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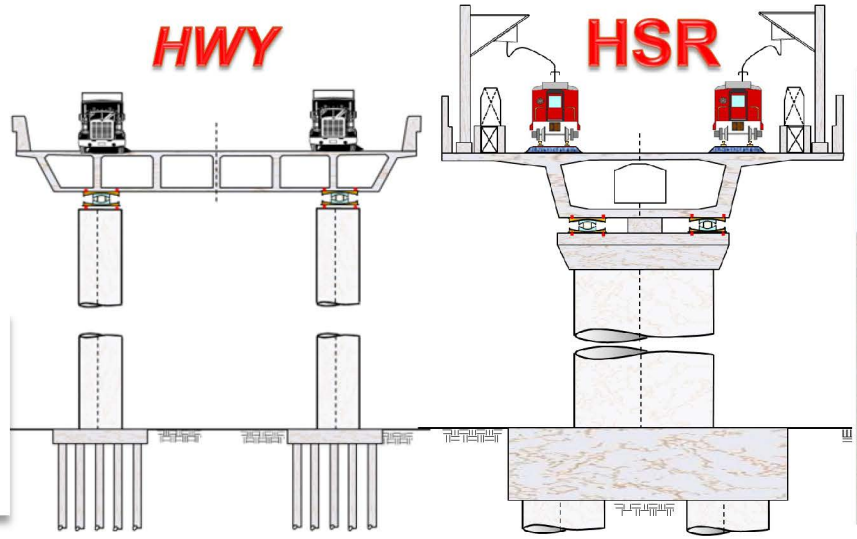
SEISMIC ISOLATIONS, RAIL BRIDGES VS. HWY BRIDGES

RAIL BRIDGES:

- Larger Foundation
- Large Columns
- Deeper Superstructure
- *Isolation locked (OBE)*

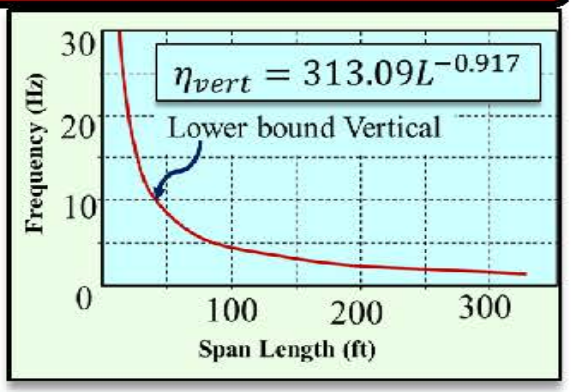


Highway- Isolation protects the BRIDGE

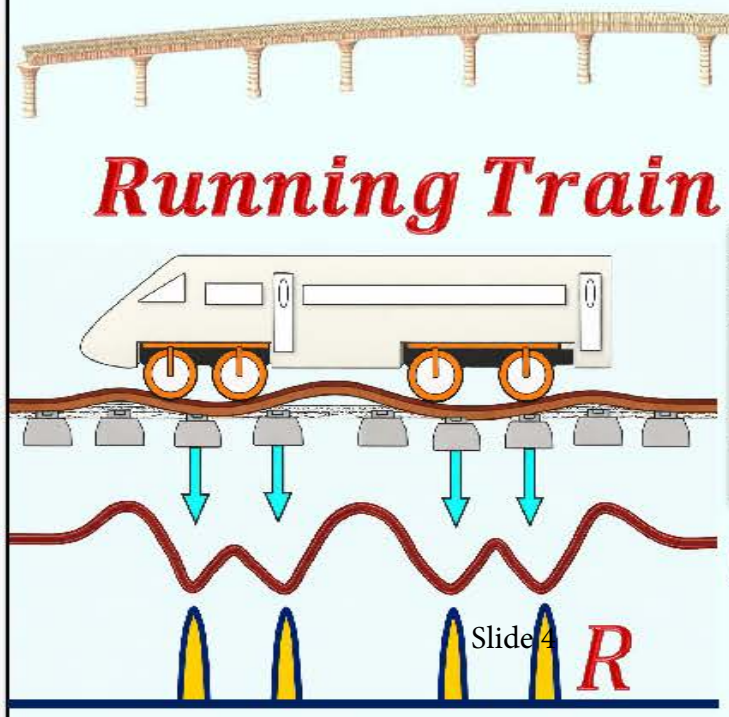
Rail- Isolation protects the Train and Track Alignment

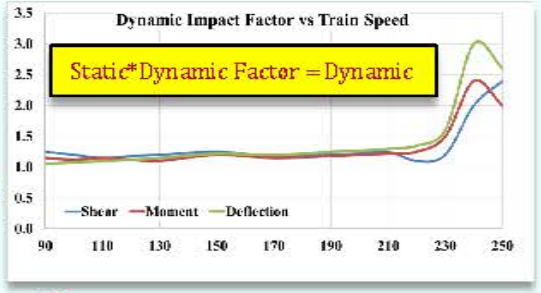
Loading Demands Between Rail and Highway Bridges

- High Fatigue; Repetitive High Axle Loading
- Dynamic Impact Factor, **Function of Speed and Span Length**
- Vehicle –Track–Structure Interaction Effects (VTRI)



Resonance: Train Passing Frequency ≈ Bridge Natural Frequency





Bridge Response

$$f_{Bridge} = \frac{1}{2\pi}\sqrt{\frac{K}{m}}$$

$$f_{Train} = \frac{V}{S}$$

DESIGN EARTHQUAKES

CSDC		HSR		AREMA Limit States	
SEE	975 yrs	MCE	975 yrs	SURVIVABILITY	2254 years
FEE	225 yrs	OBE	50 yrs	ULTIMATE	310 years
CE	PSDC	CE	100 yrs	SERVICEABILITY	95 years

- **HWY bridges-** Designed not to collapse during the rare big earthquake
- **Rail bridges-** Designed not to derail during the smaller earthquake

Governing Design Philosophy & Performance Requirements

Rail Bridges Governed by:

- Serviceability
- Displacement-Based performance criteria (OBE Level)
- Immediate Serviceability and Derailment Prevention

HWY Bridges Governed by:

- Primarily by strength, ductility,
- Collapse-prevention criteria at the (SEE)
- Life Safety and Collapse Prevention

Serviceability & Rail-Structure Interaction

- **Track Serviceability Analysis**
  - Includes L.L. & OBE

- **Rail-Structure Interaction**
  - Includes L.L., T_D & OBE

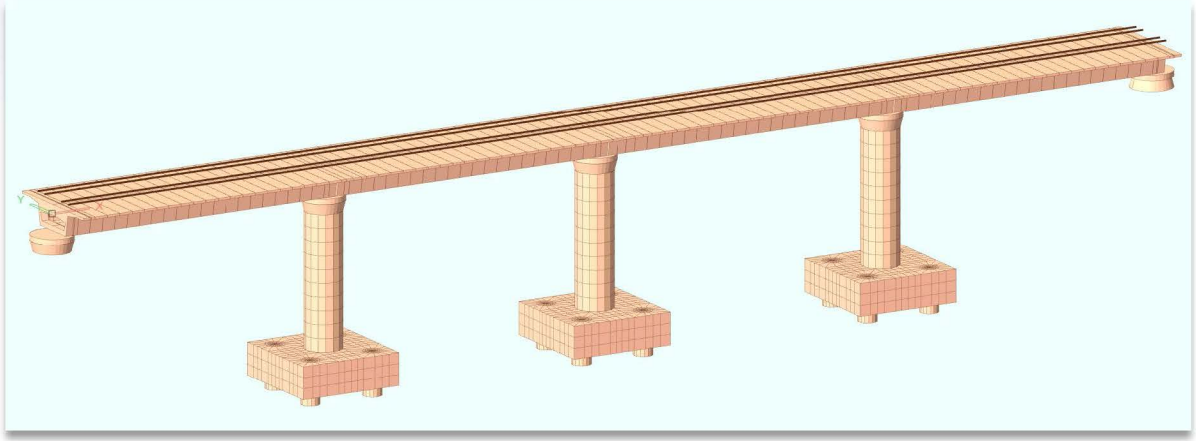
LL –LIVE LOAD

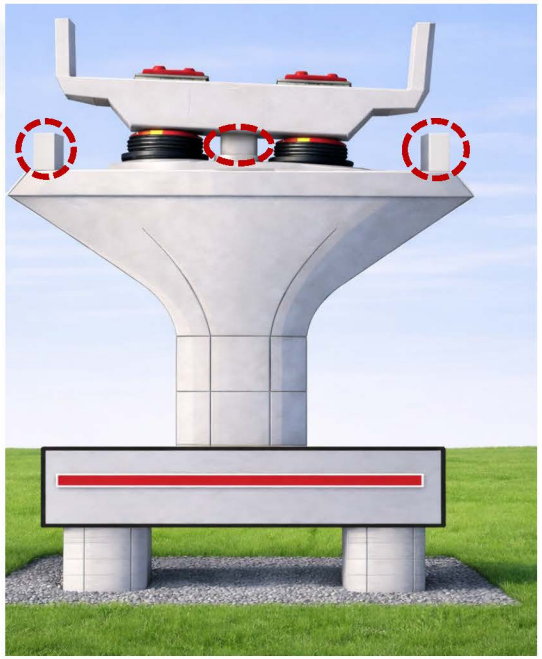
TD –TEMPERATUTRE

SEISMIC DESIGN & ANALYSIS (OBE)

Sacrificial Locked Fuses:

- Track Serviceability (OBE)





RAIL BRIDGES:
Bridge to protect the Restrainer (Rail)

HWY BRIDGES:
Restrainer to protect the bridge

- Track-Structure Interaction (OBE)
- Strength 5 Analysis (OBE)

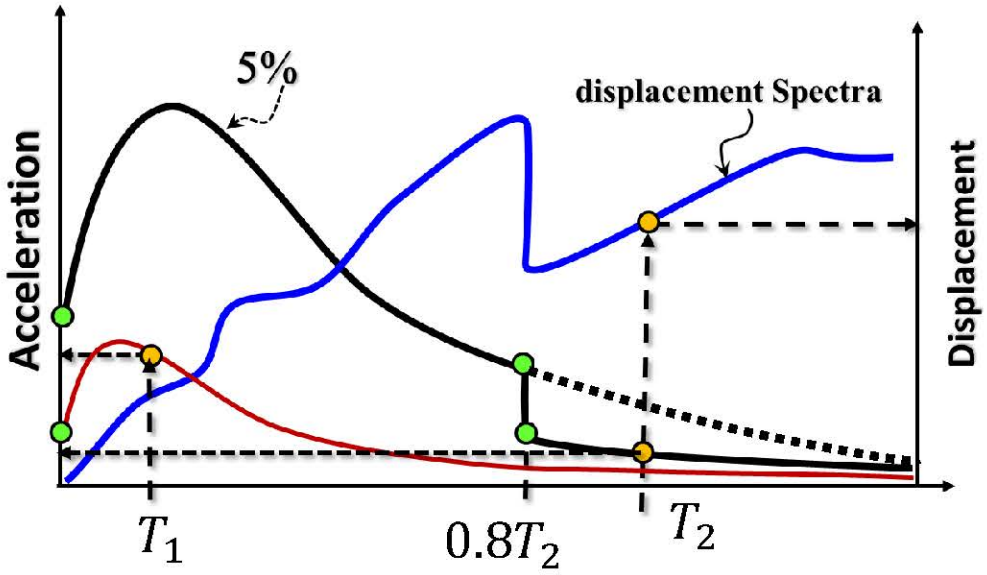
SEISMIC DESIGN & ANALYSIS (OBE)

- **Sacrificial Locked Fuses:**

SEISMIC ISOLATION FOR RAIL BRIDGES

➢ Strength 5 Design (Locked):

- ➢DL + One Braking Train + OBE
  - ❖Governs Column Size/Strength, & Isolation Strategy



$T_1 - T_{OBE}$ -*Without Isolation*

$T_2 - T_{MCE}$ -*With Isolation*

➢ Extreme 3 Design (unlocked):

- ➢DL + MCE
  - ❖ Capacity Protected Foundations

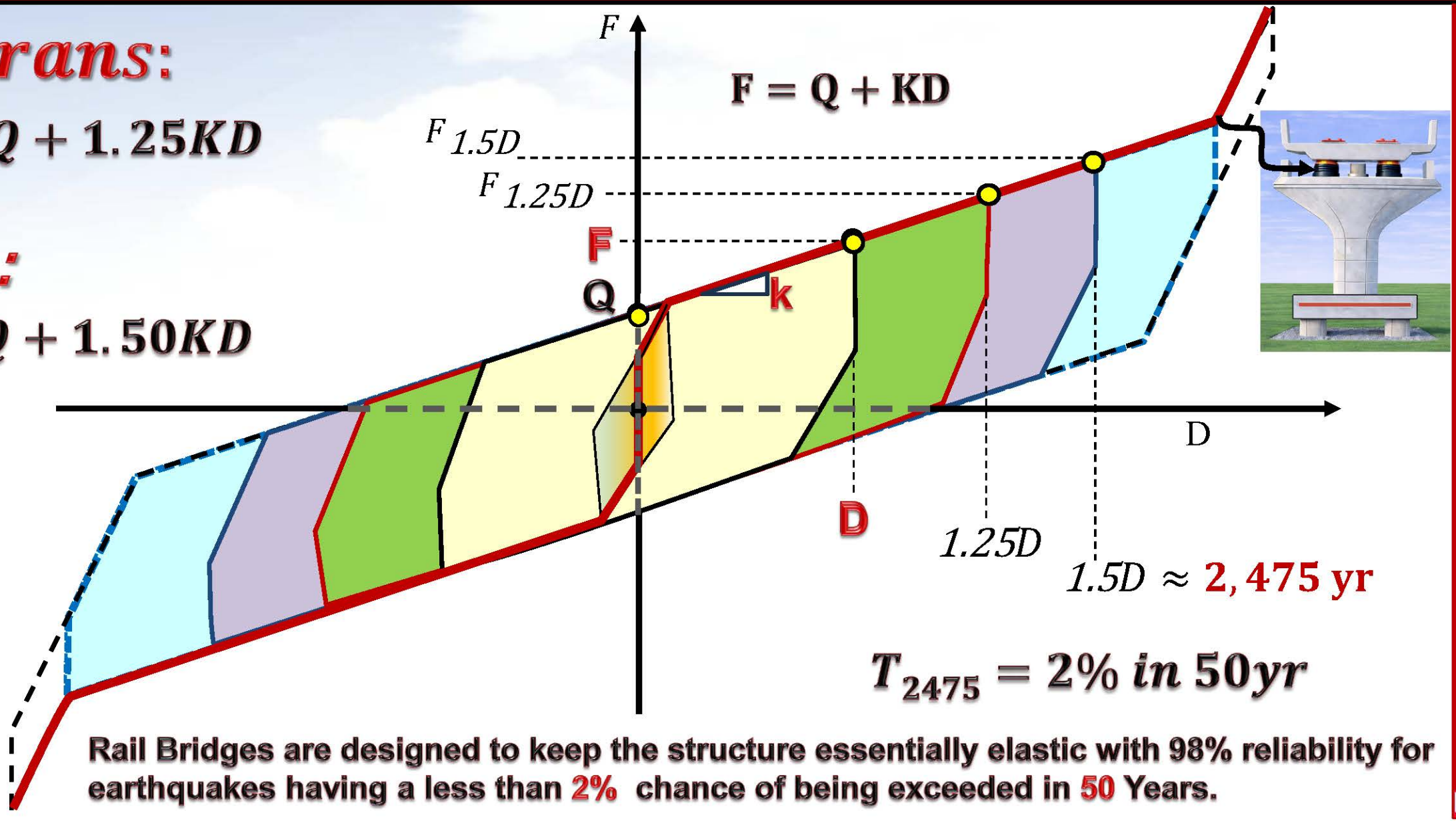
ISOLATION BEARINGS FOR RAIL AND HIGHWAY BRIDGES

Caltrans:

$$F_{CT} = Q + 1.25KD$$

Rail:

$$F_{RL} = Q + 1.50KD$$



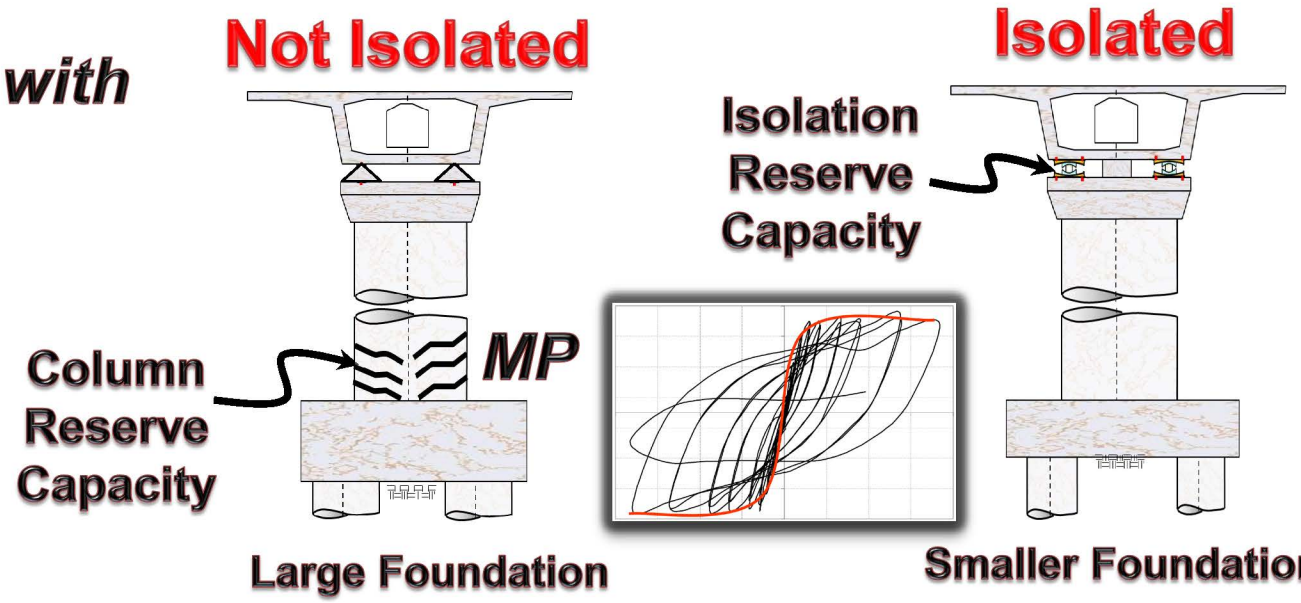
$$T_{2475} = 2\% \; in \; 50yr$$

Rail Bridges are designed to keep the structure essentially elastic with 98% reliability for earthquakes having a less than 2% chance of being exceeded in 50 Years.

SEISMIC DESIGN & ANALYSIS (MCE)

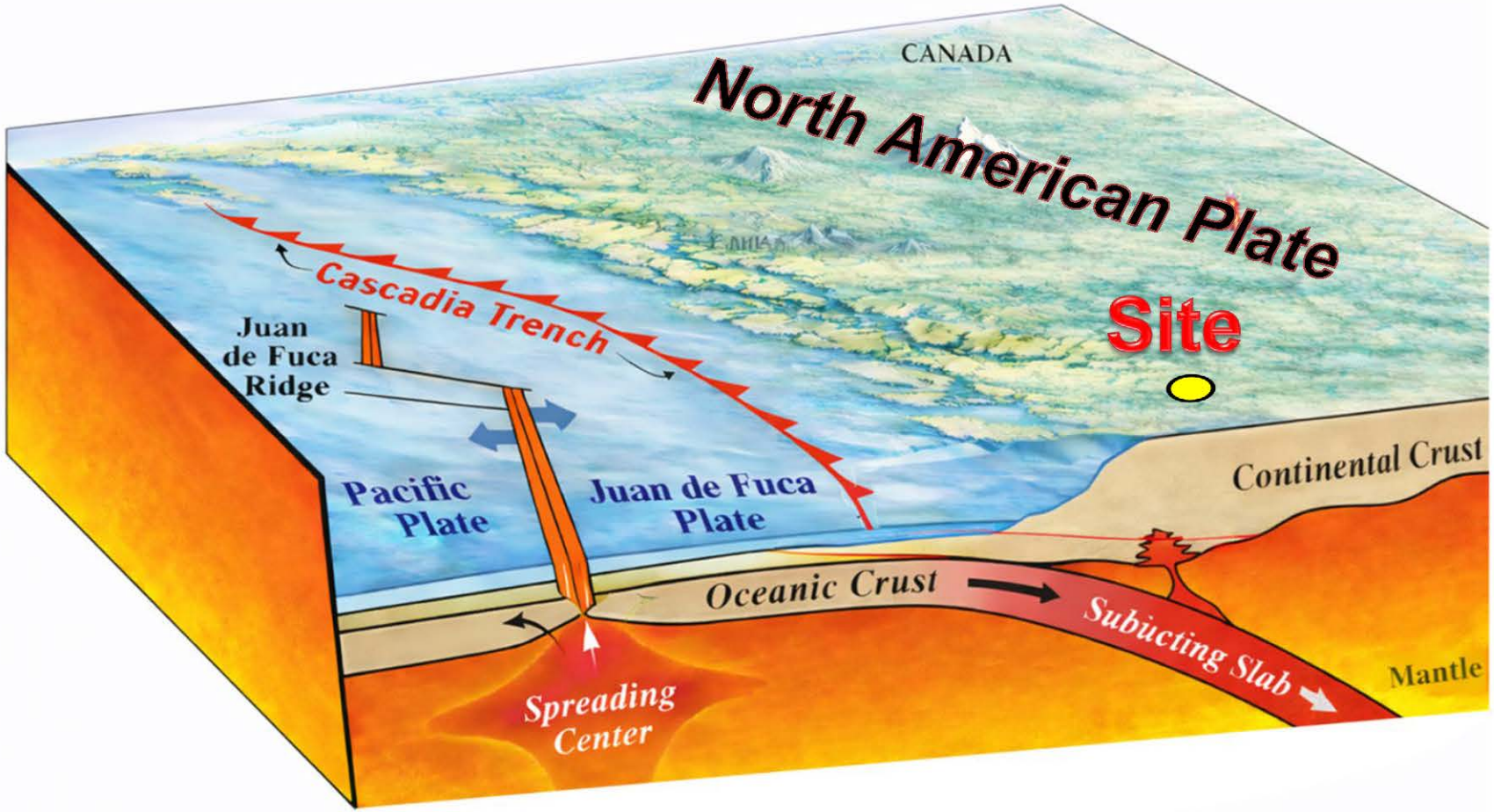
Extreme 3 Isolation Design:

- Estimate Displacement Demands; D
- *Design Isolation Capacity For 1.5D (MCE+)*
- *Perform Pushover Using MCE+ Force*
- *Substructure: "Essentially Elastic with limited force not MP*

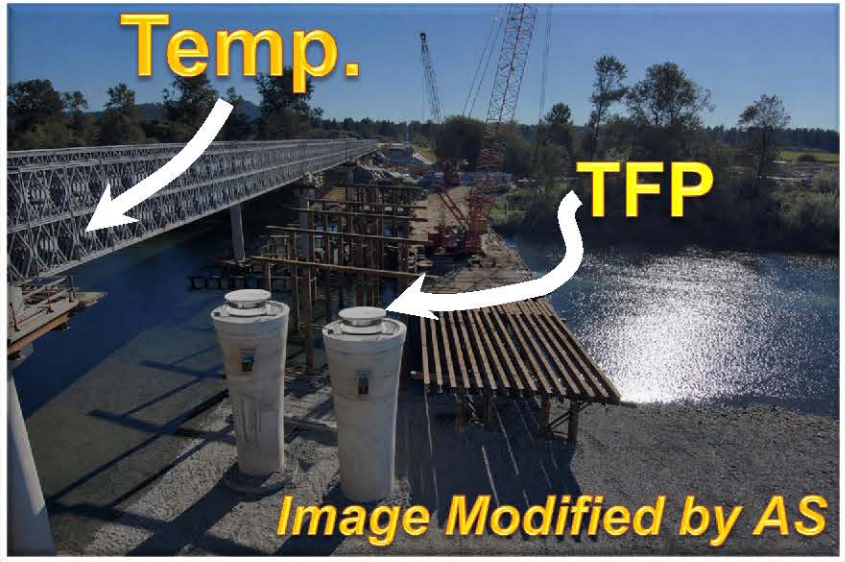


DR. FINE REPLACE PROJECT SEISMIC ISOLATION

➢ Seismic Source: Cascadia Subduction Zone

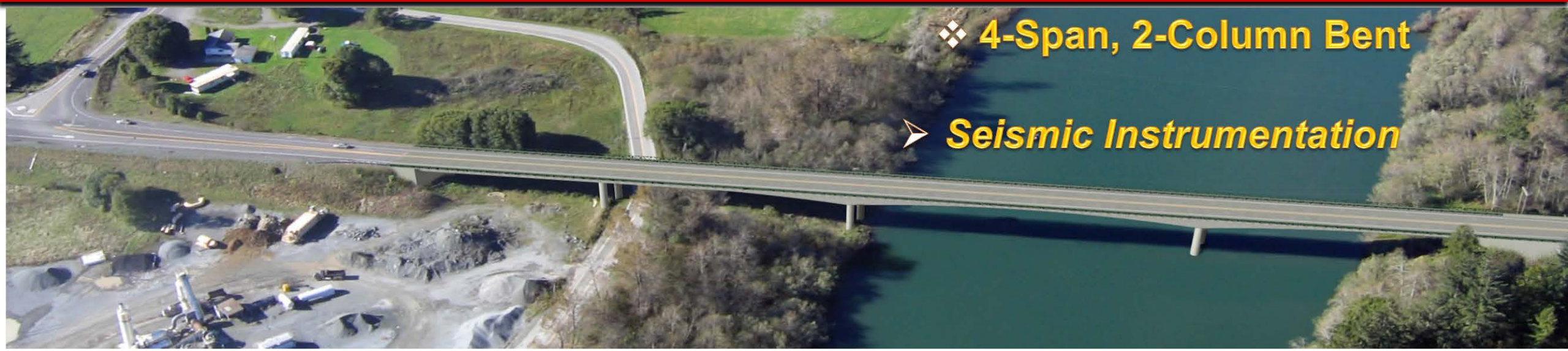


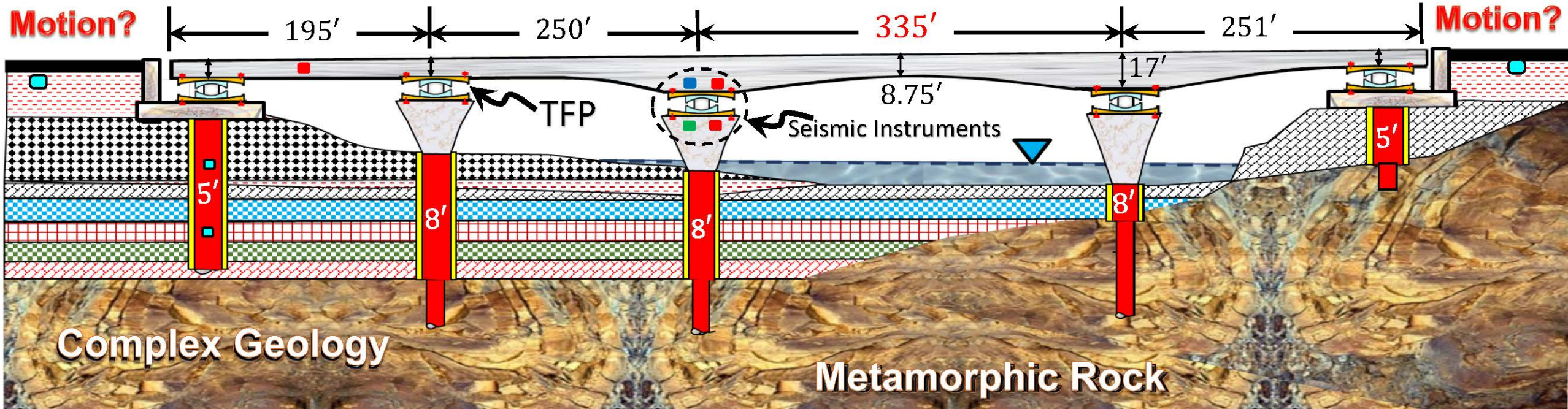
DR FINE REPLACEMENT PROJECT



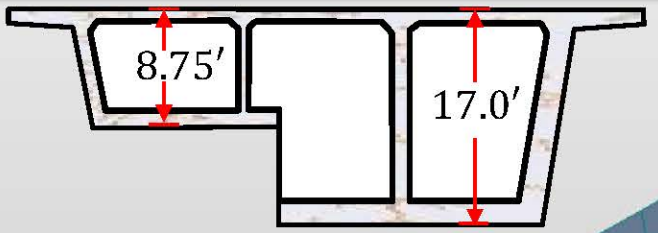
- Due to Number of Deficiencies Peer Review (2007) Recommended Replacement

BRIDGE DESCRIPTION & SUBSURFACE GEOLOGY

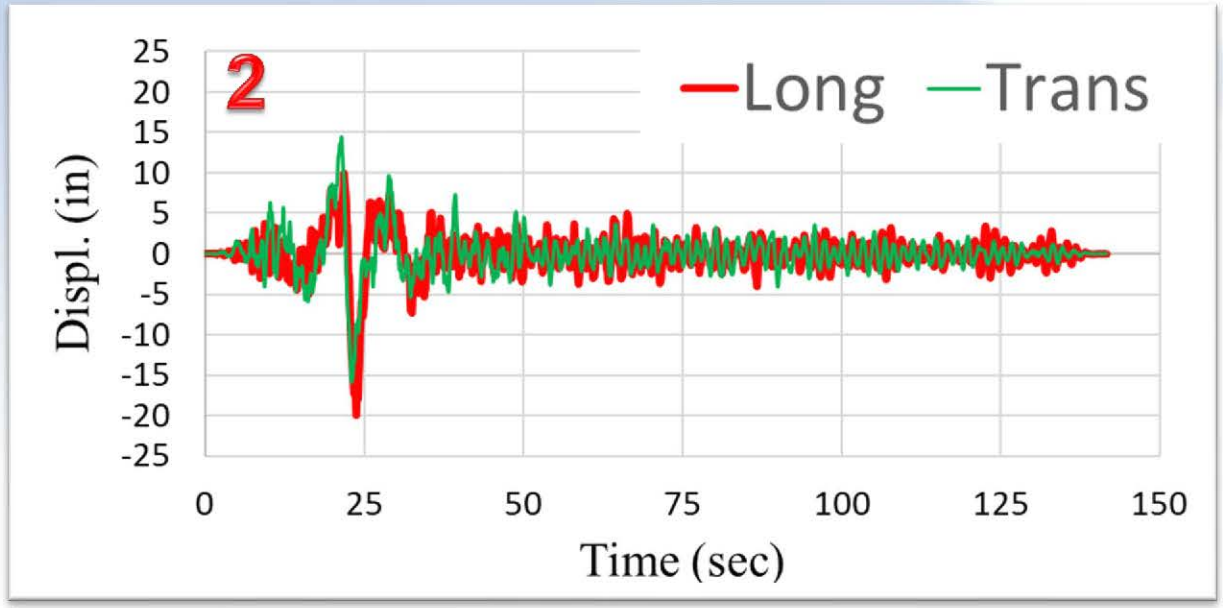


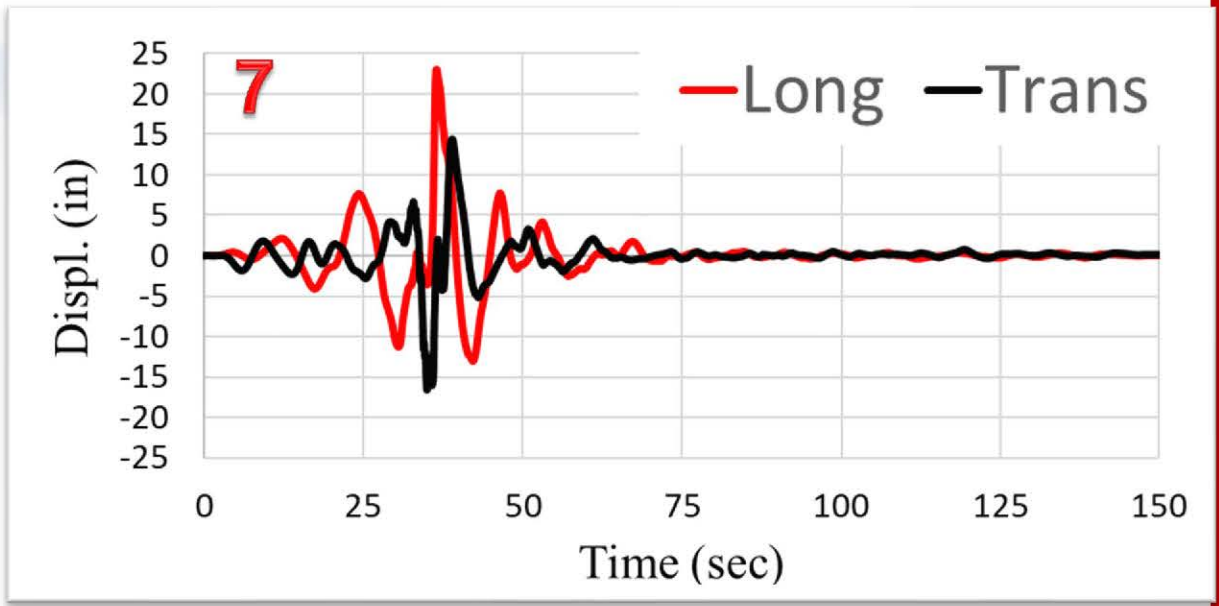


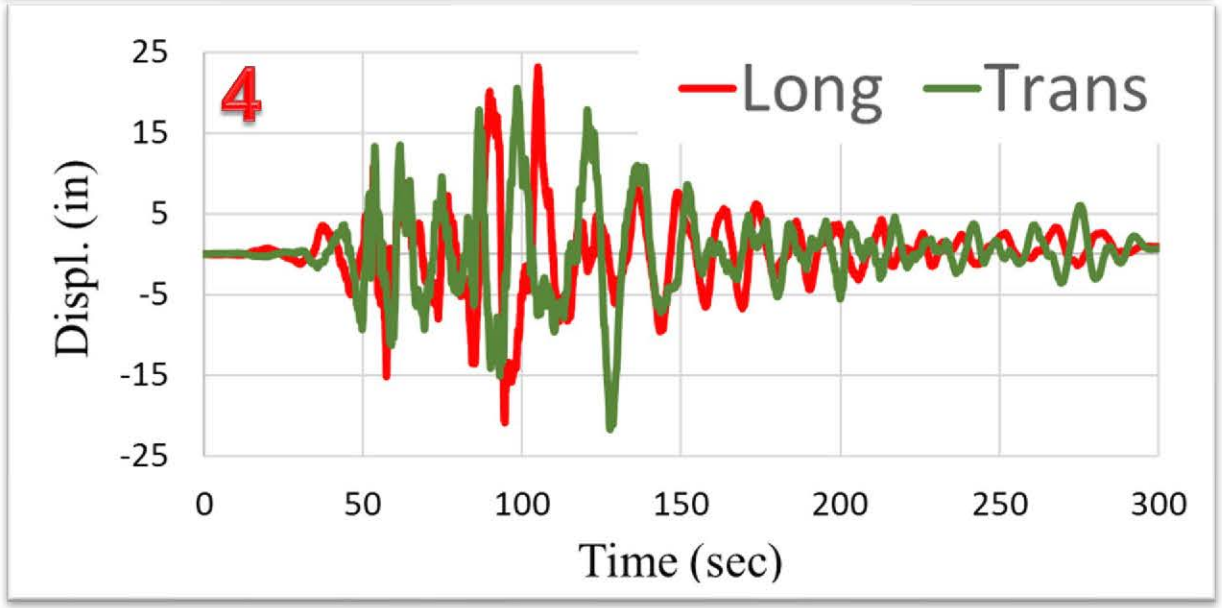
FULL 3D FEM SEISMIC DESIGN MODEL

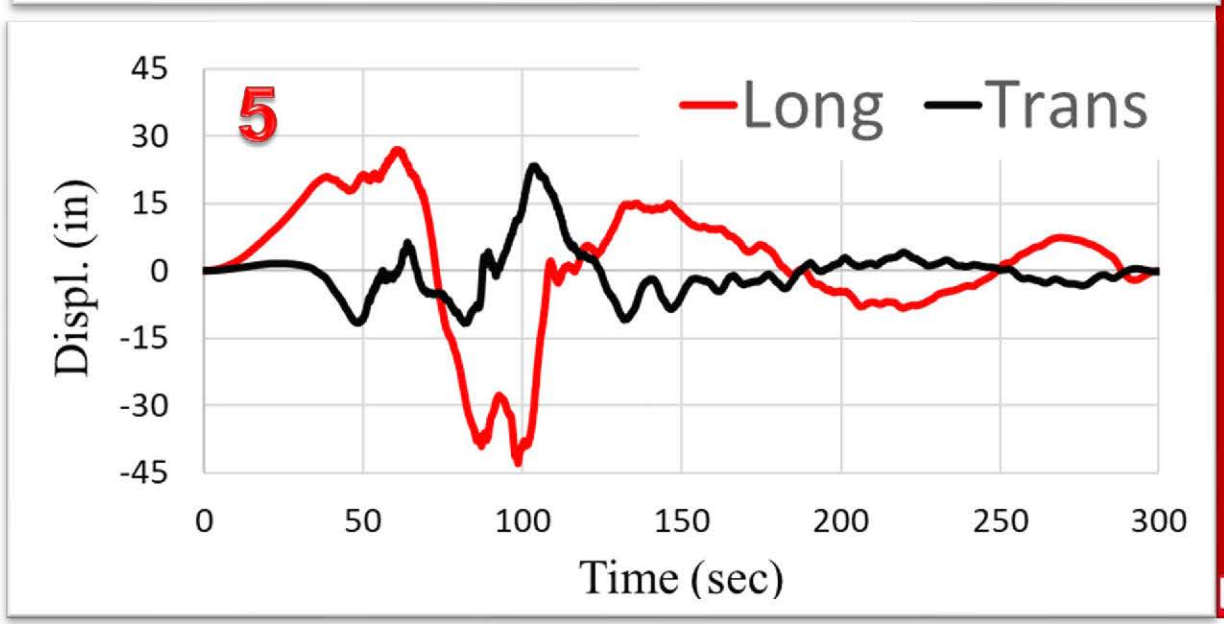


CHARACTERISTICS OF TIME HISTORIES

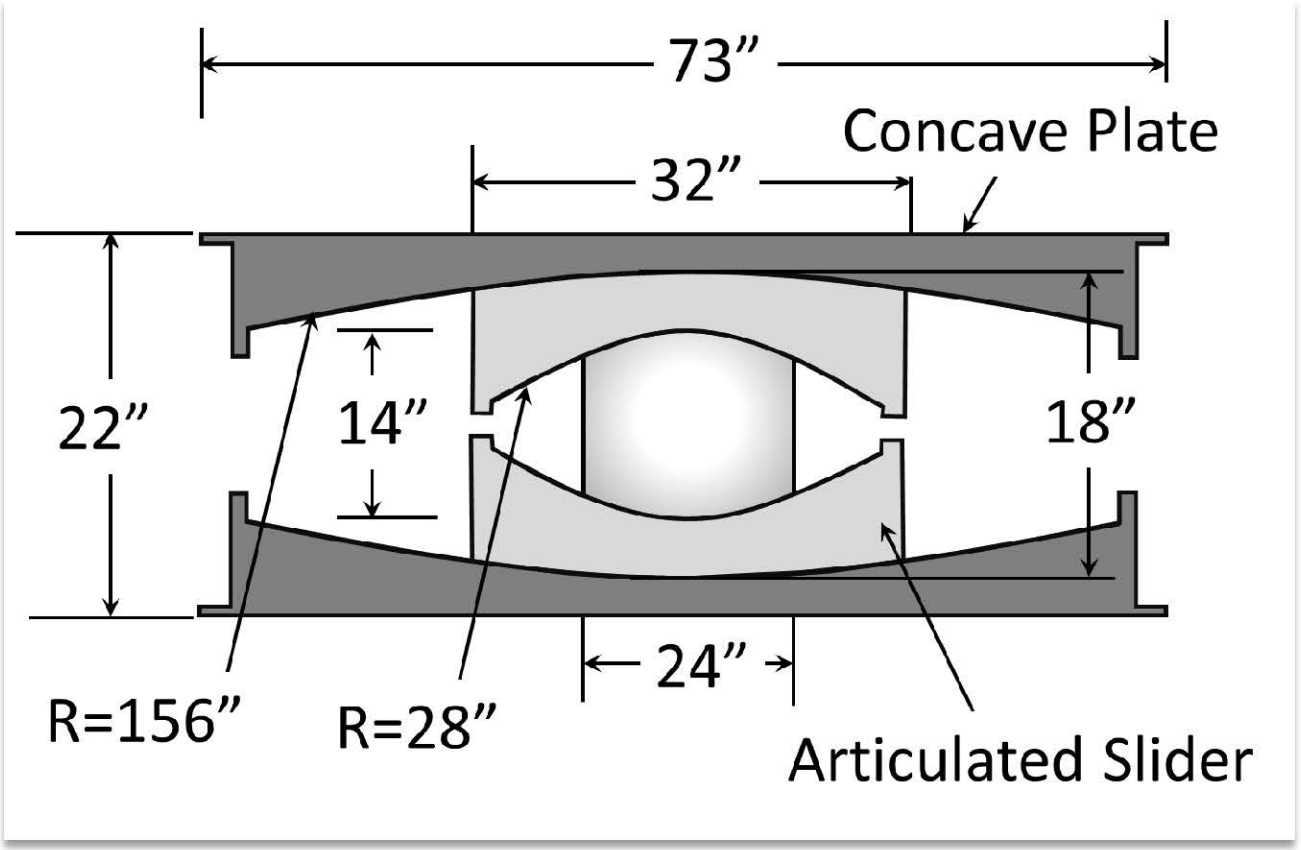




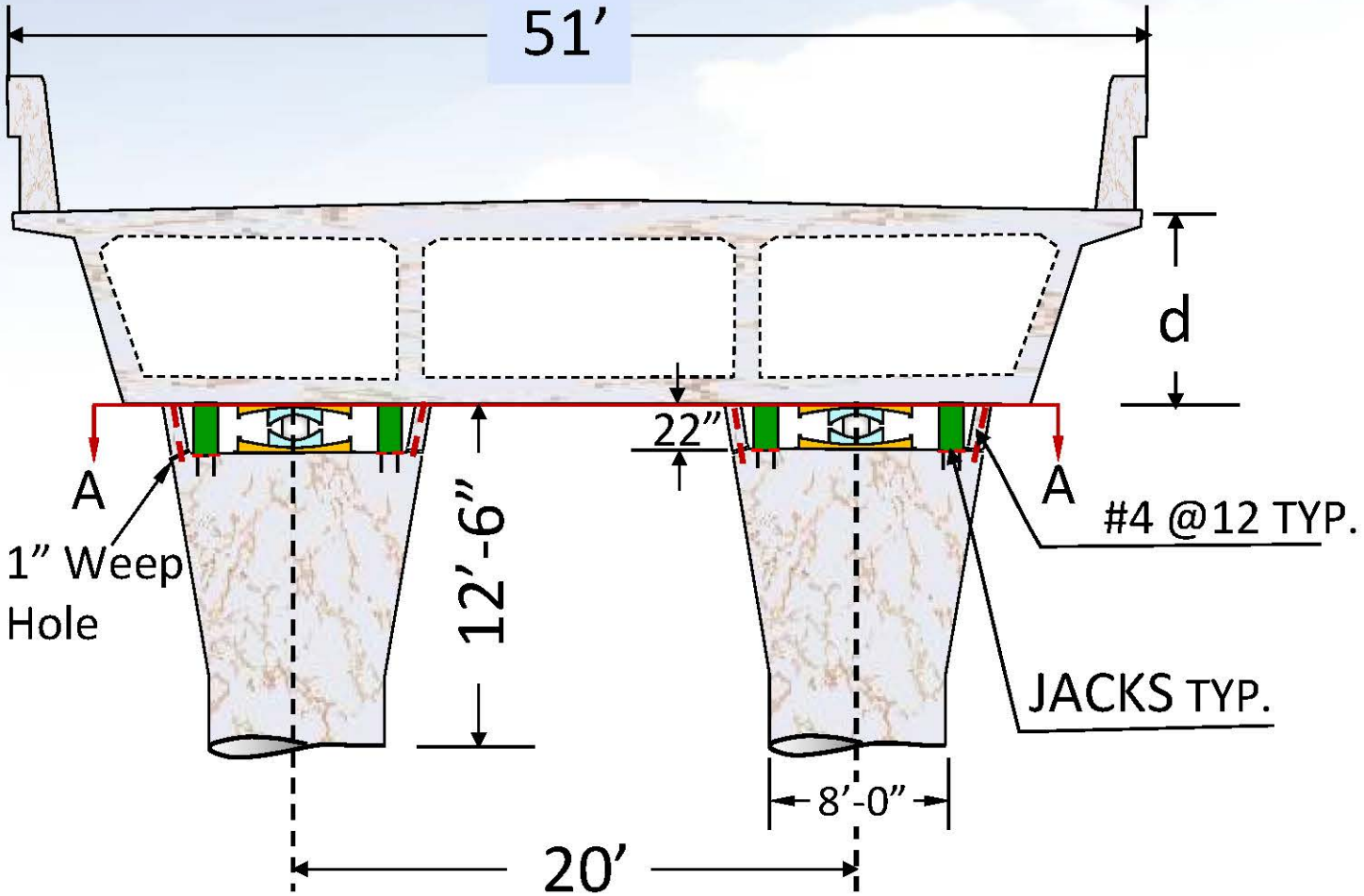




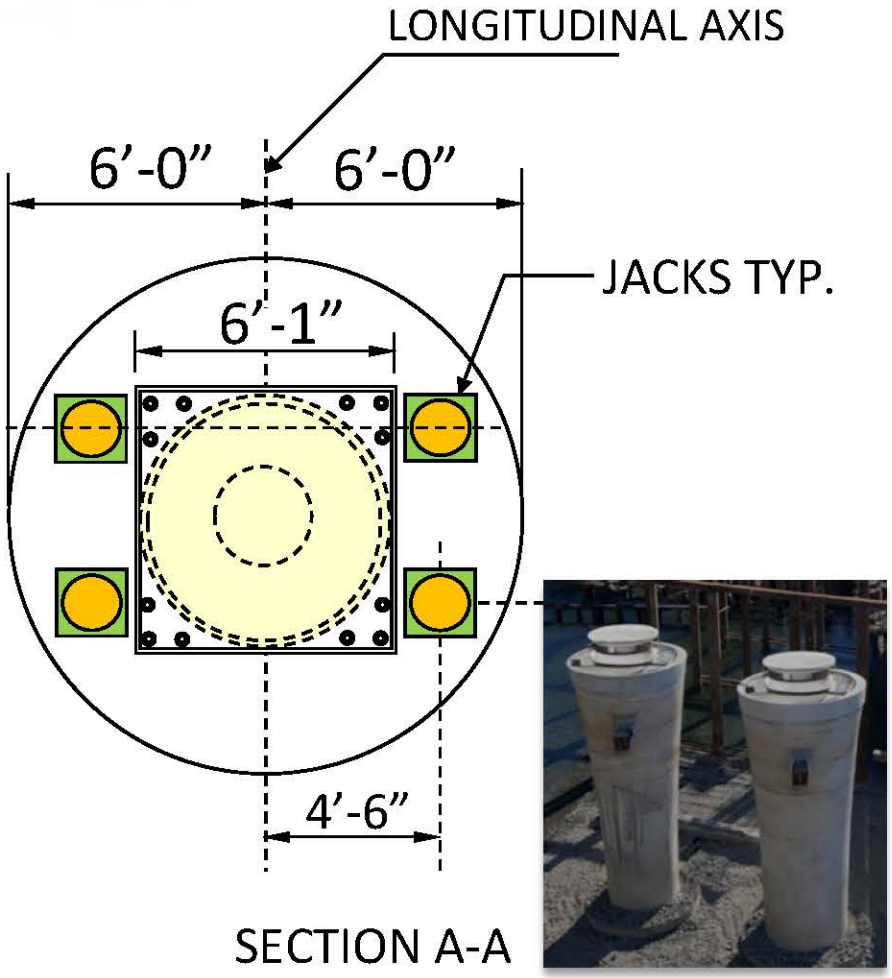
TYPICAL BENTS ISOLATION BEARINGS



FLARED COLUMNS & TFP BEARING DETAILS

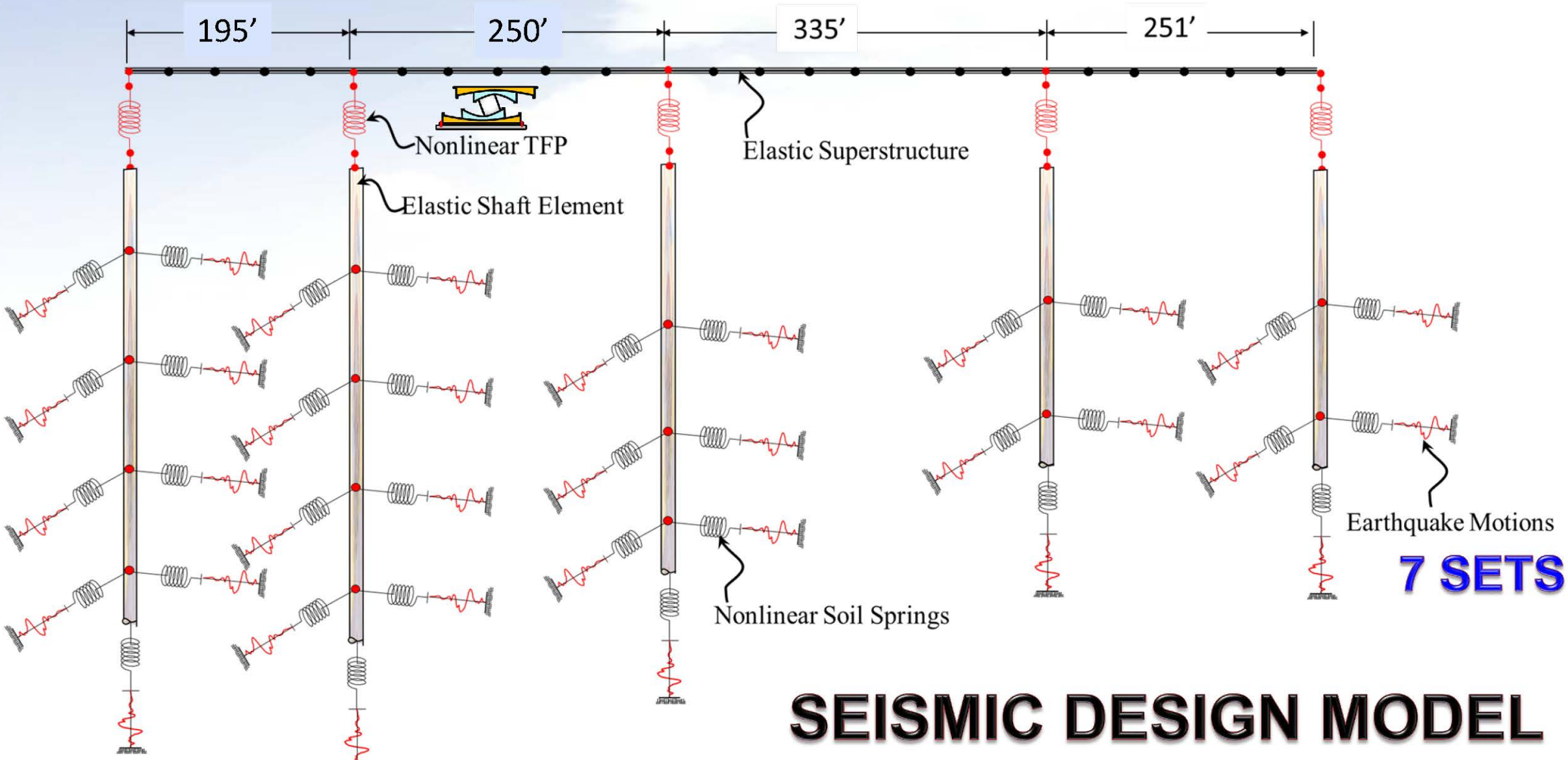


TYP. FLARED COLUMNS BEARING ELEVATION



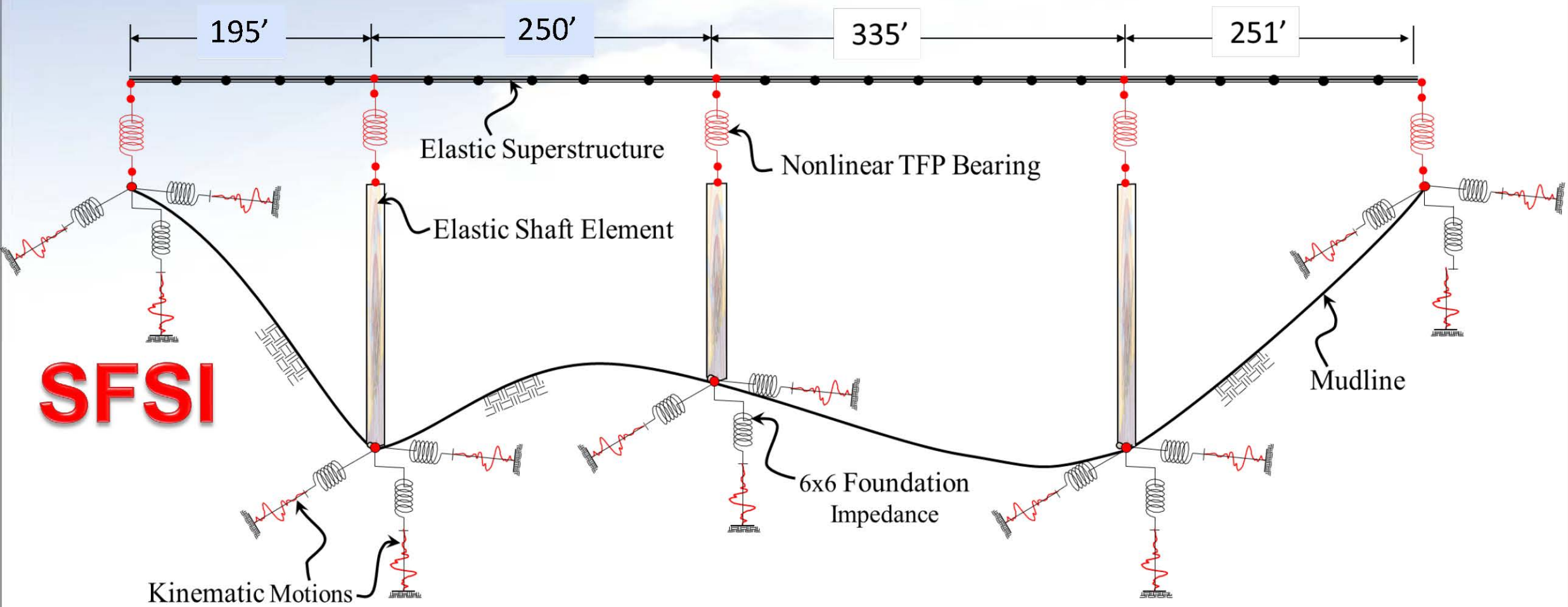
TOP OF THE TYP. FLARED COLUMN

GLOBAL NONLINEAR DIRECT MODEL



SEISMIC DESIGN MODEL

GLOBAL NONLINEAR SUBSTRUCTURE MODEL



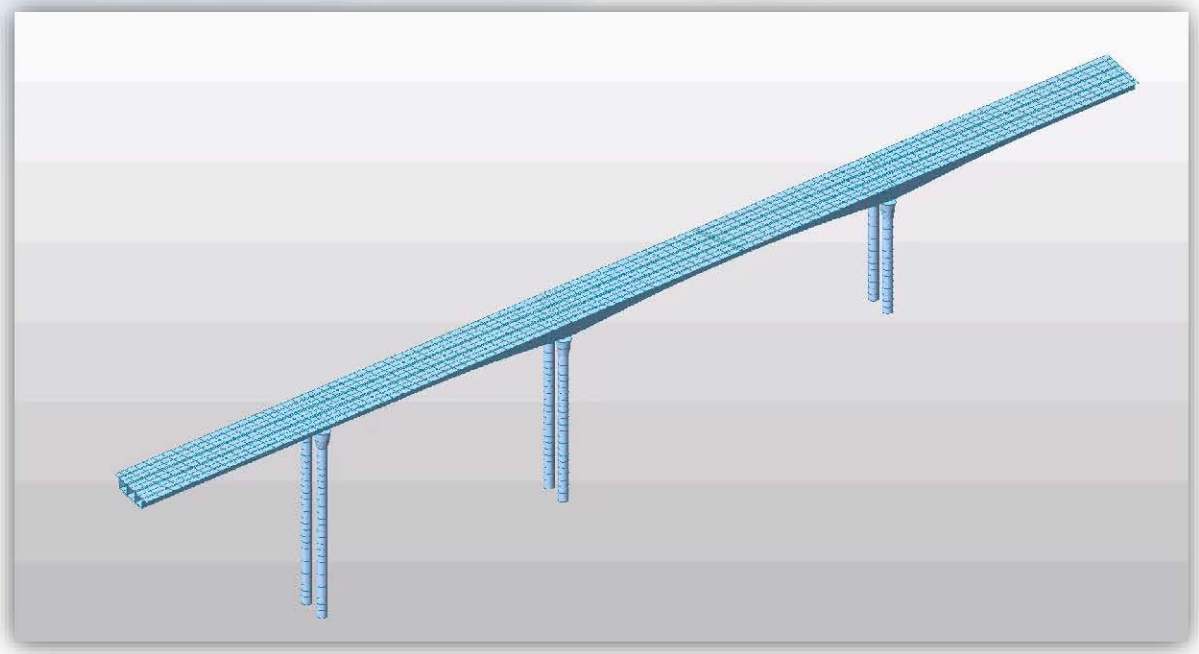
SFSI

7 SETS

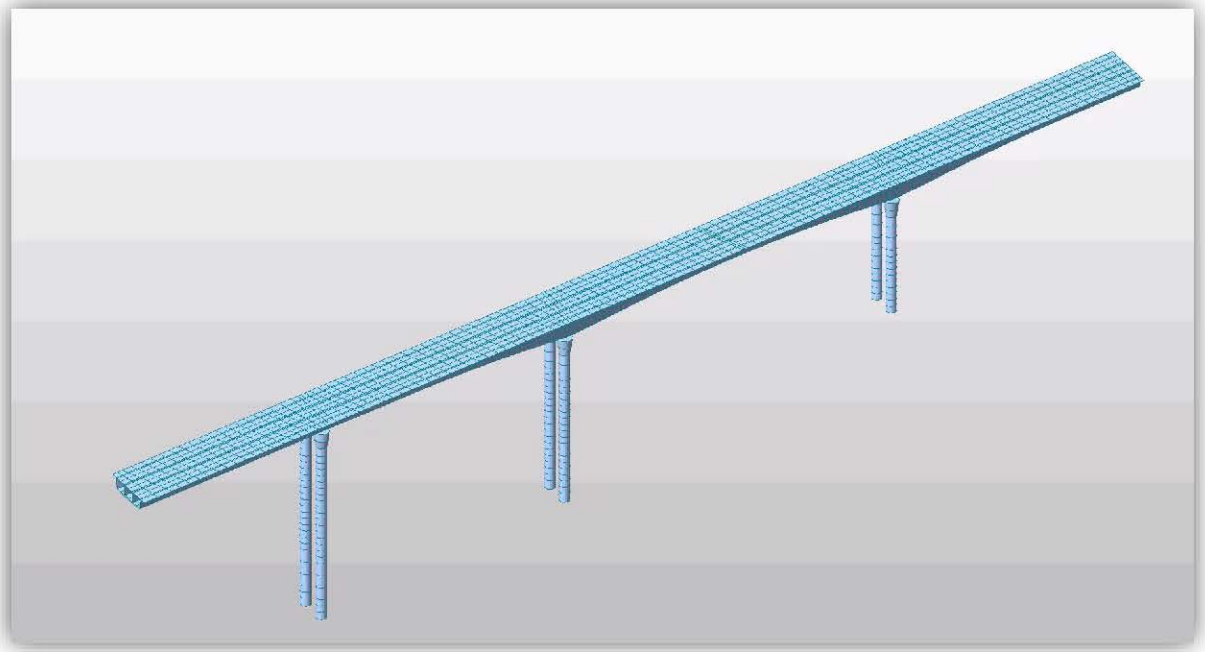
SEISMIC CHECK MODEL

MODE SHAPES OF DIRECT MODEL

TRANSVERSE

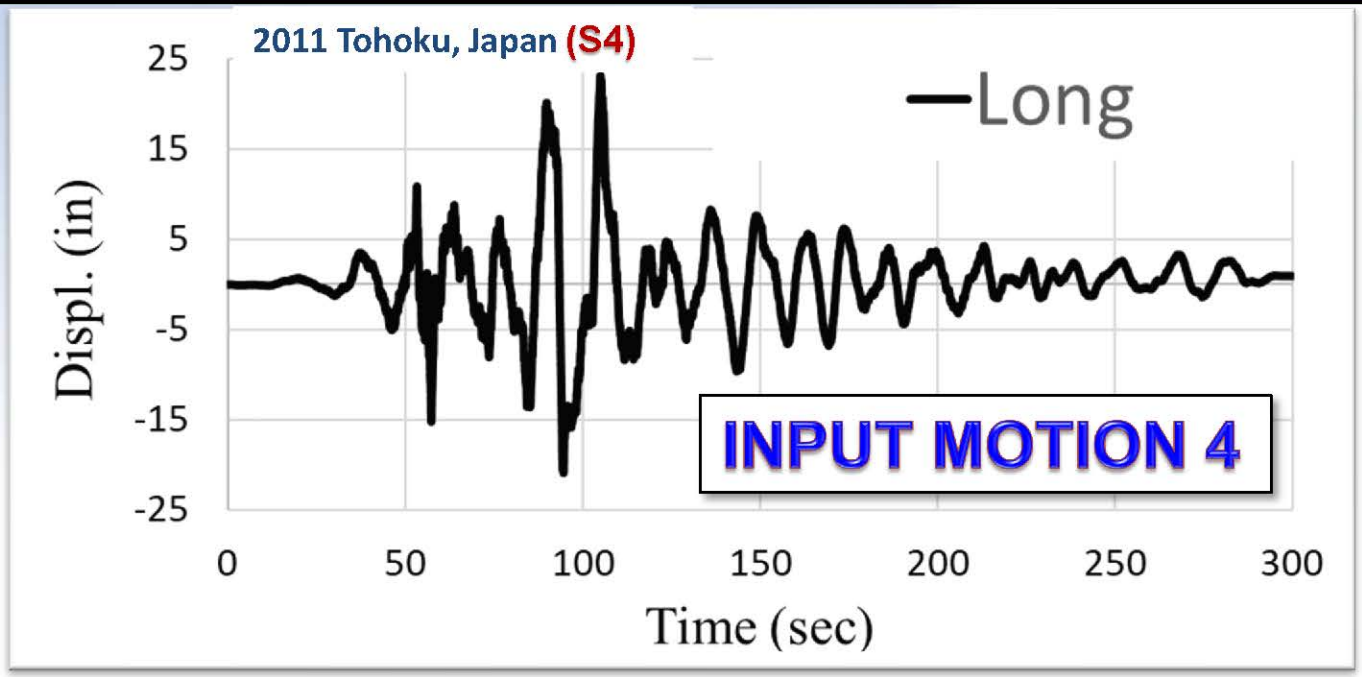


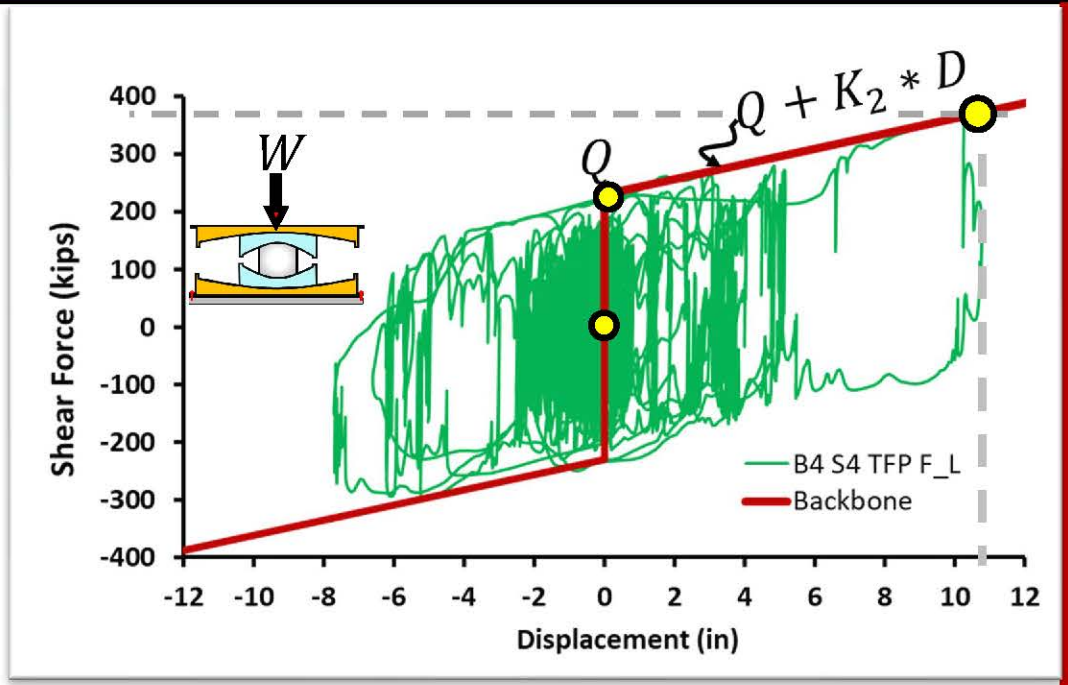
LONGITUDINAL



SEISMIC DESIGN USING DIRECT MODEL

TFP HYSTERETIC BEHAVIOR



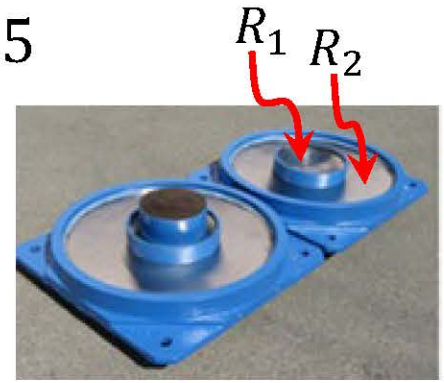


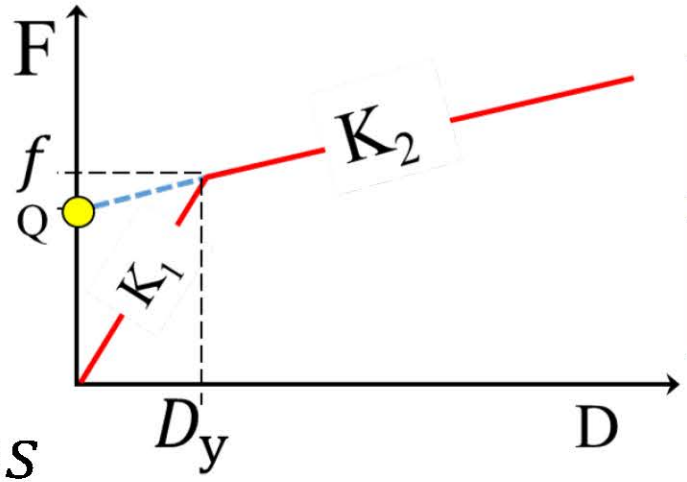
$W \approx 4000\ kips$ $f^* \approx 0.0575$

$$Q = f^* * W$$

$Q \approx 230\ kips$

$K_2 \approx 13\ kips/in$



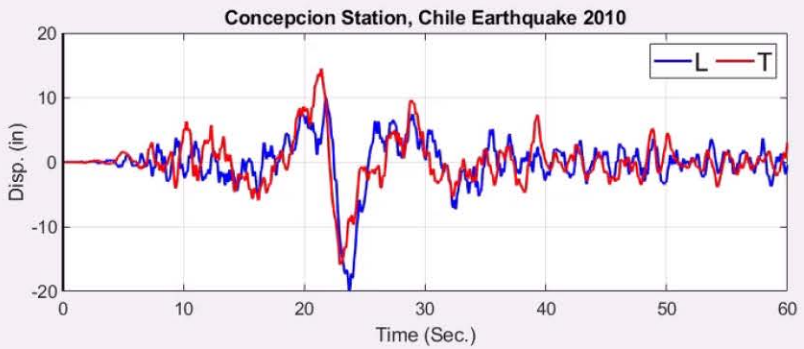


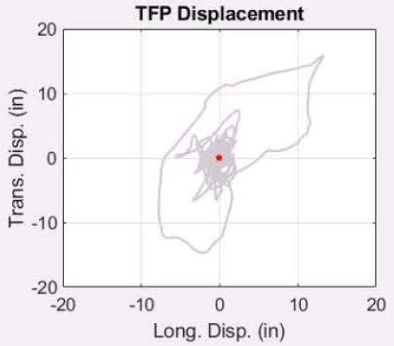
$$K_1 = \frac{W}{R_1}$$

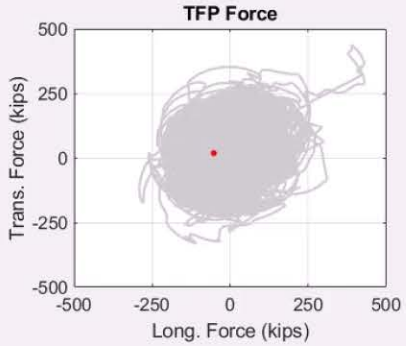
$$K_2 = \frac{W}{R_2}$$

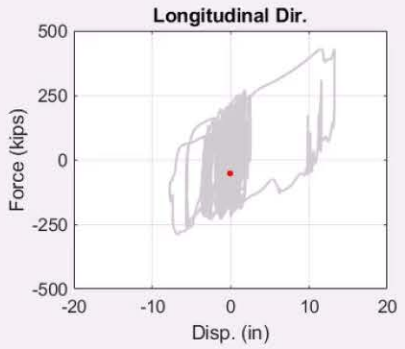
$$F_D = Q + K_2 * D = 230 + 13 * 11 = \mathbf{373}\ kips$$

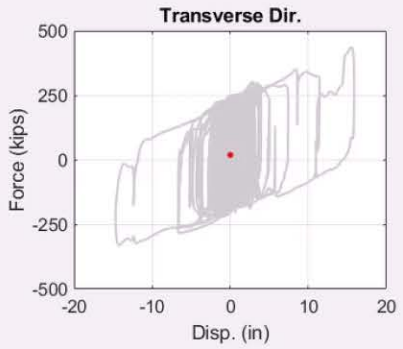
TFP ORBITAL RESPONSE & HYSTERETIC BEHAVIOR

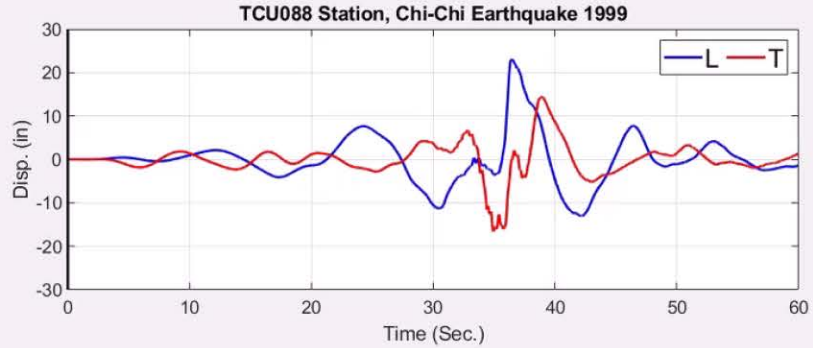


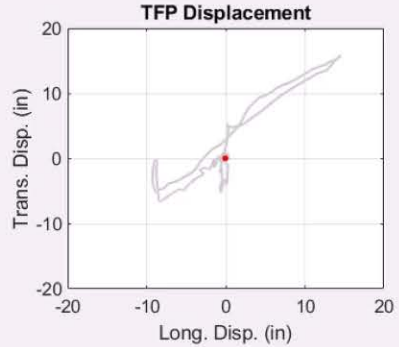


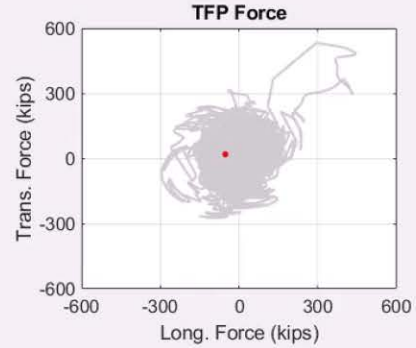


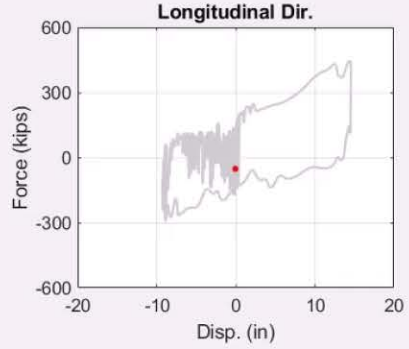


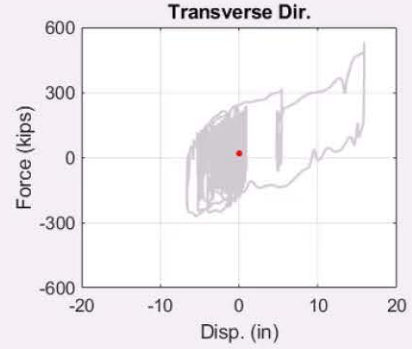




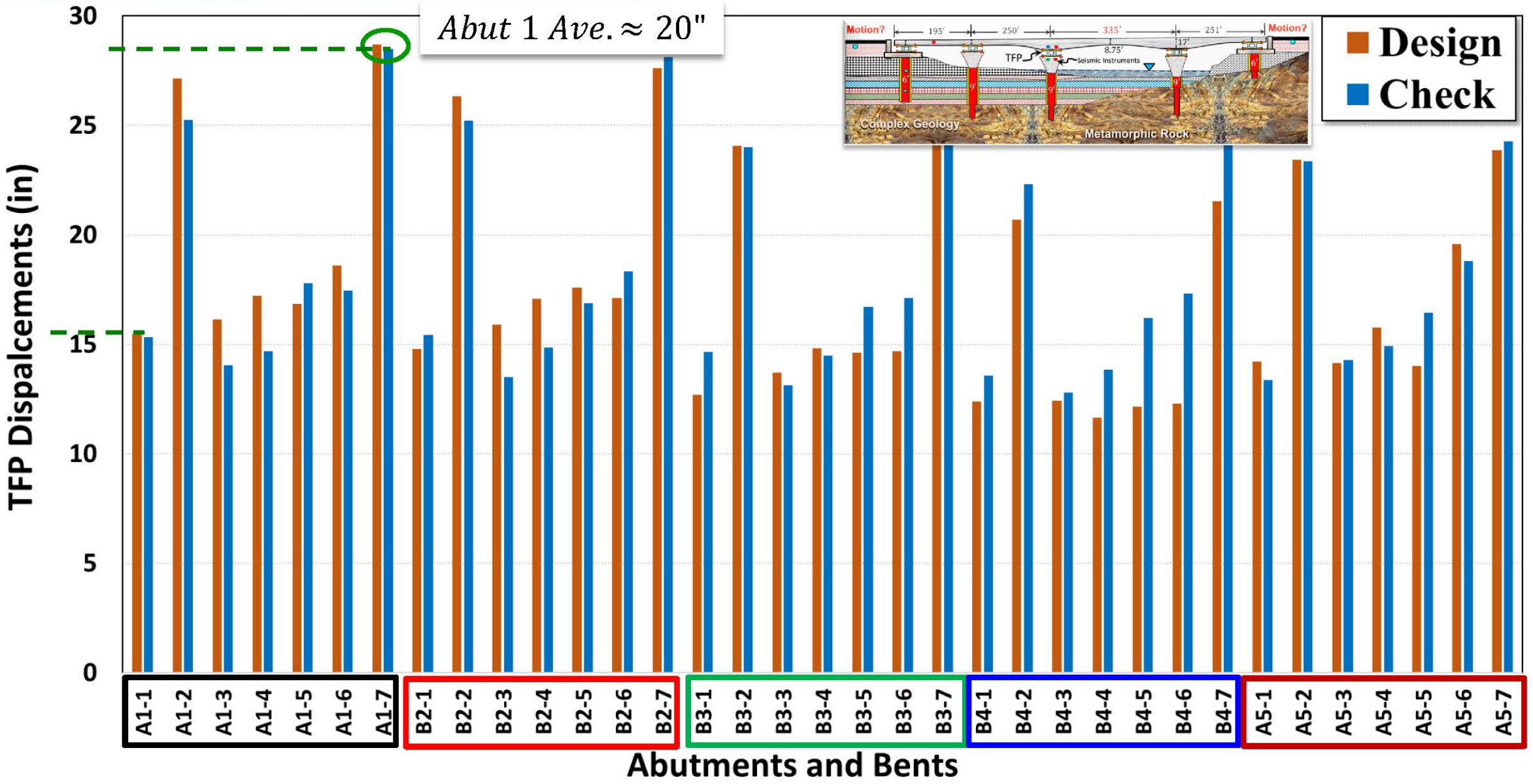




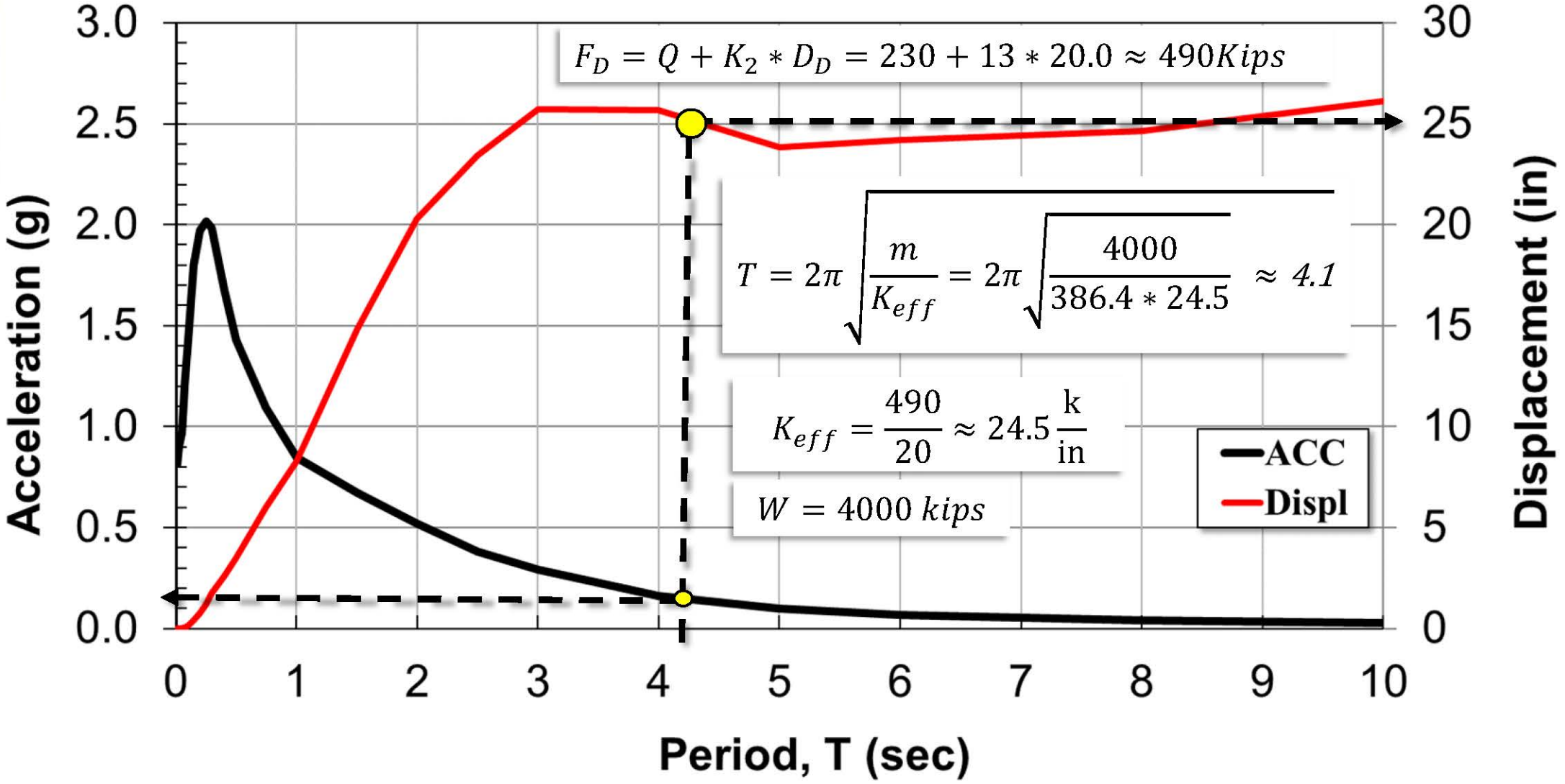




TFP MAXIMUM DISPLACEMENTS

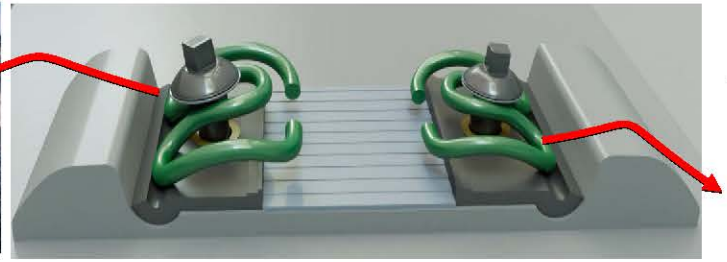


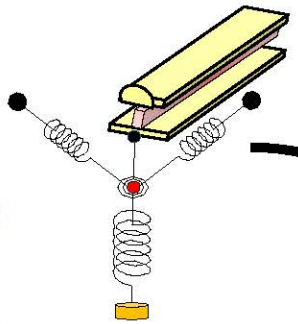
SEISMIC HAZARD TARGET SPECTRA

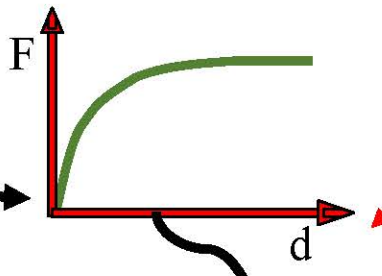


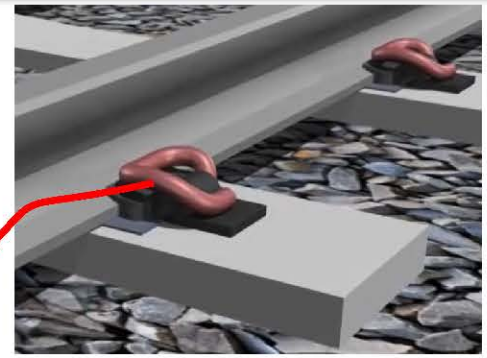
SEISMIC FOUNDATION-BRIDGE-RAIL-TRAIN-INTERACTION

Ground → Foundation → Pier →Isolation → Deck → Slab → Fastener → Rail → Wheel → Vehicle Body

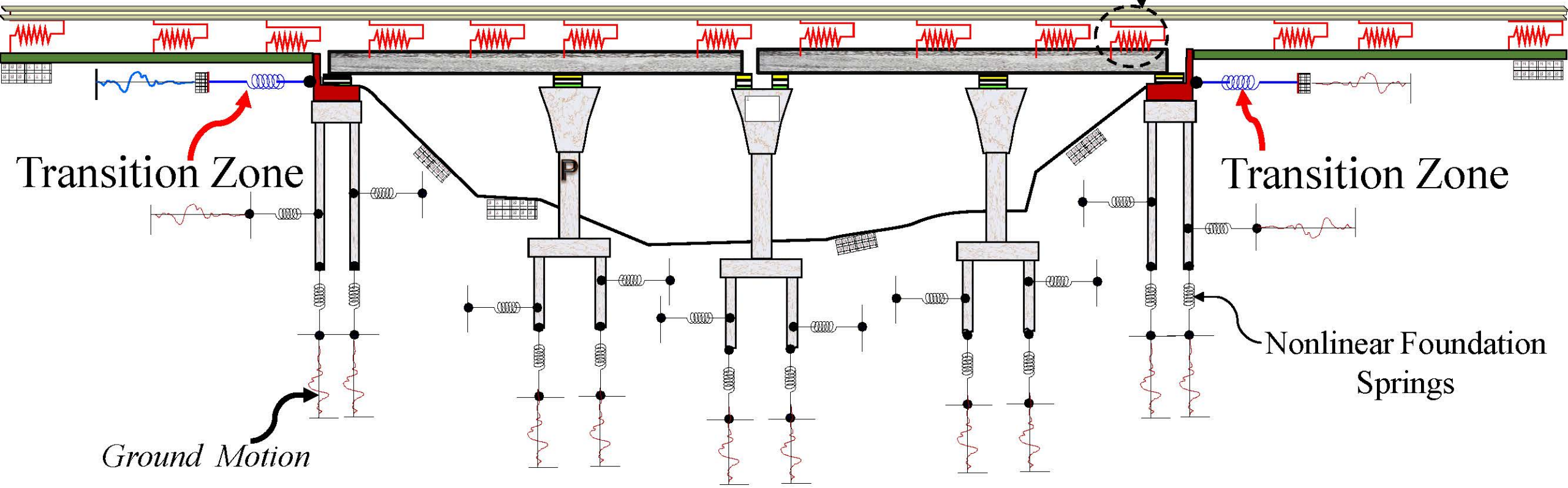




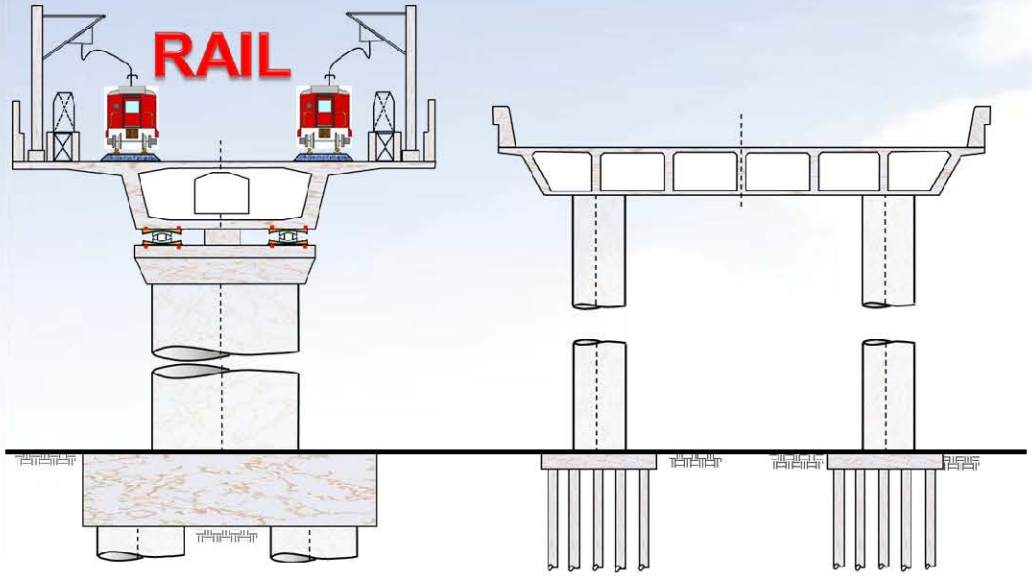


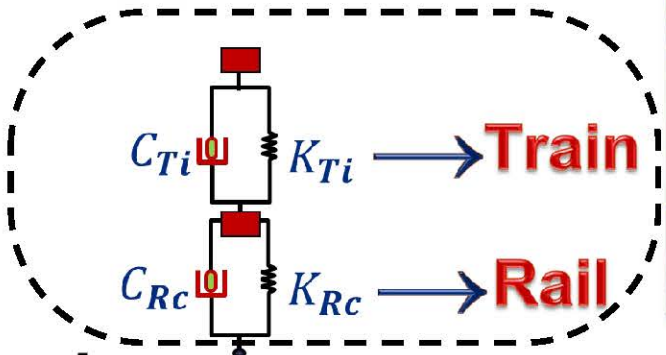


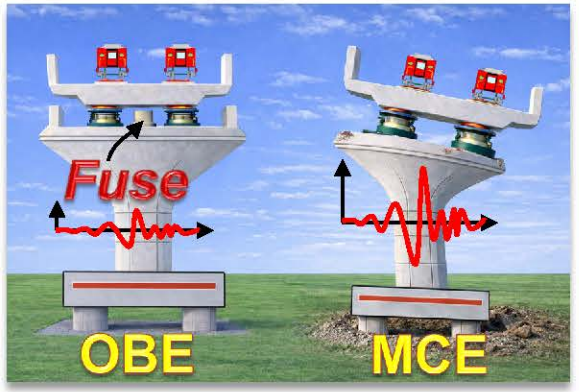
Rail- A continuous Beam on Discrete Nonlinear Springs

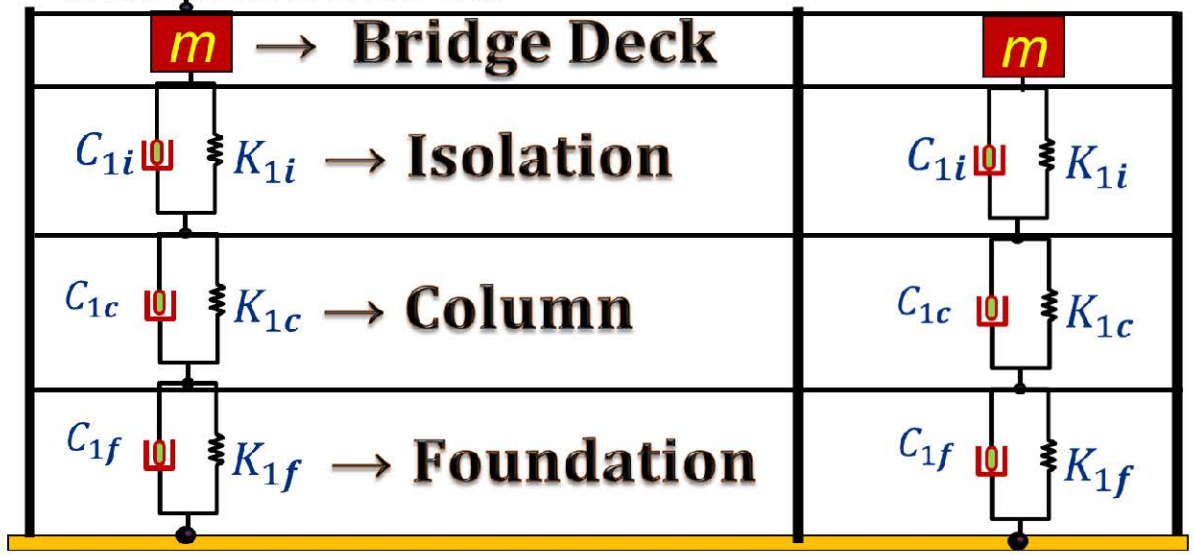


SEISMIC ISOLATION MODELS FOR RAIL BRIDGES





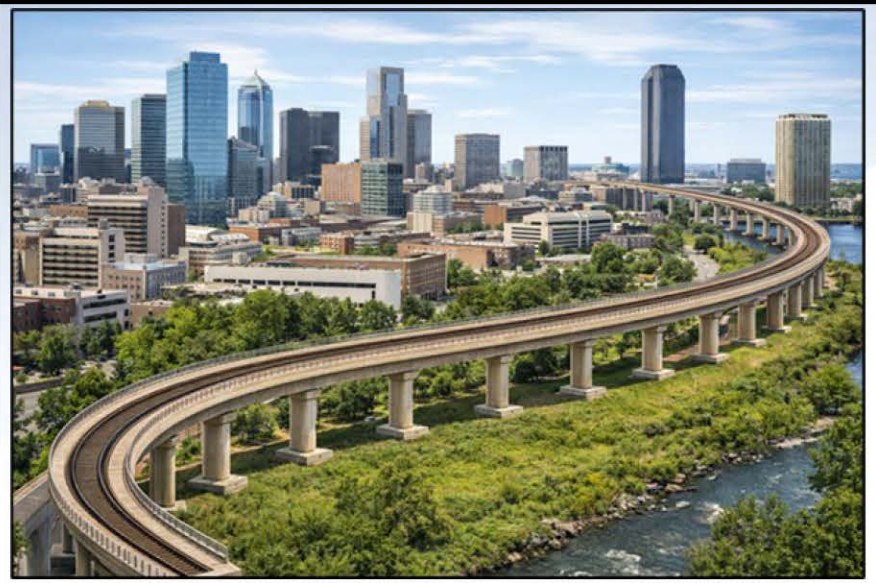




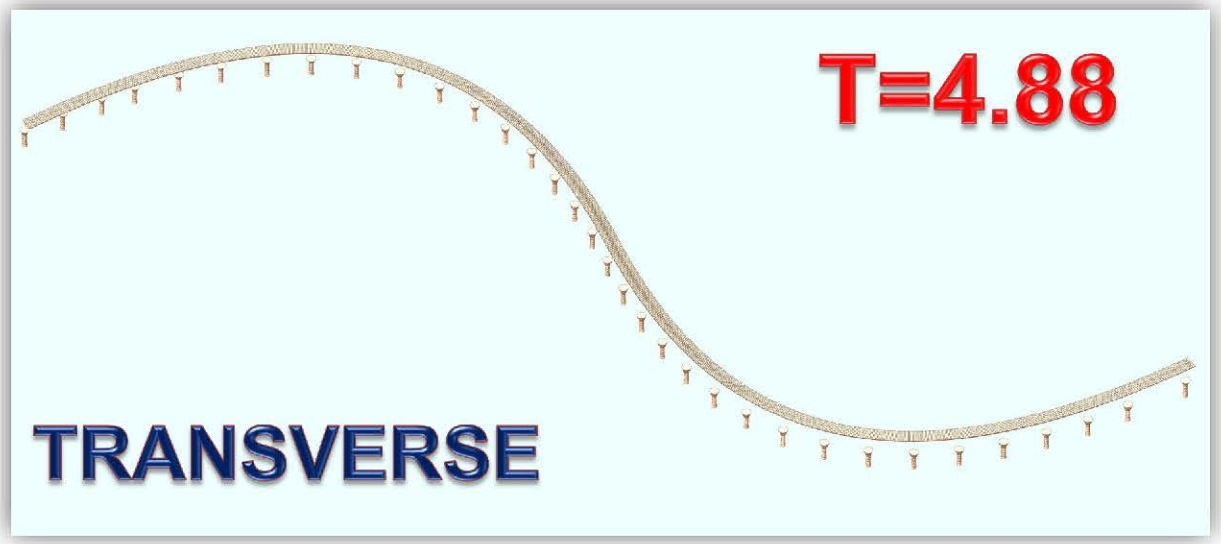
Rail Bridge

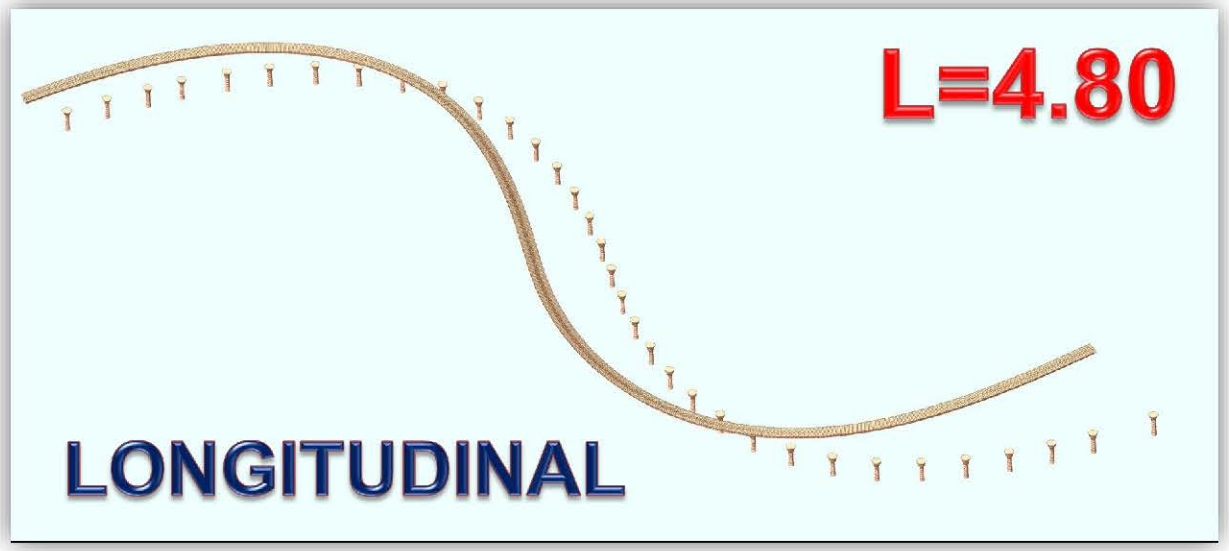
HWY Bridge

RAIL BRIDGE LAYOUT MODE SHAPES

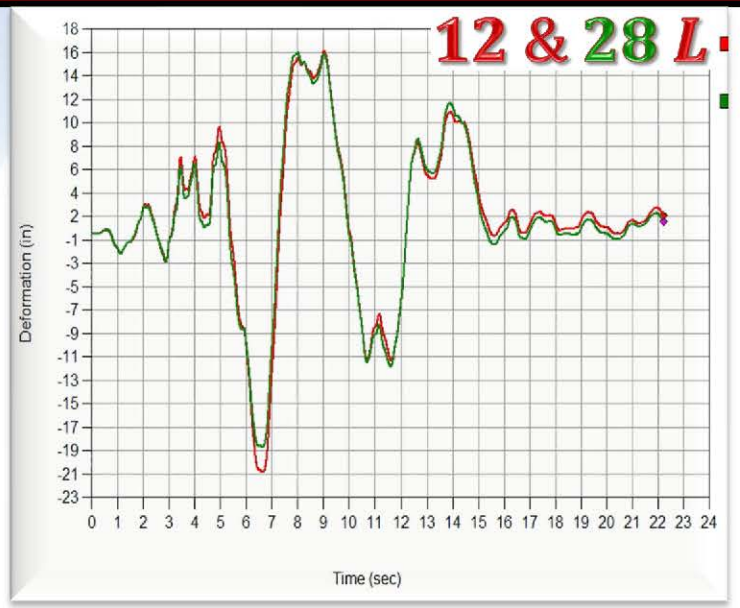


L=3822’ R=812’

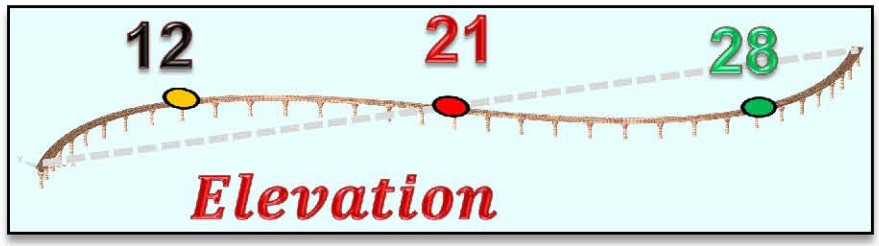


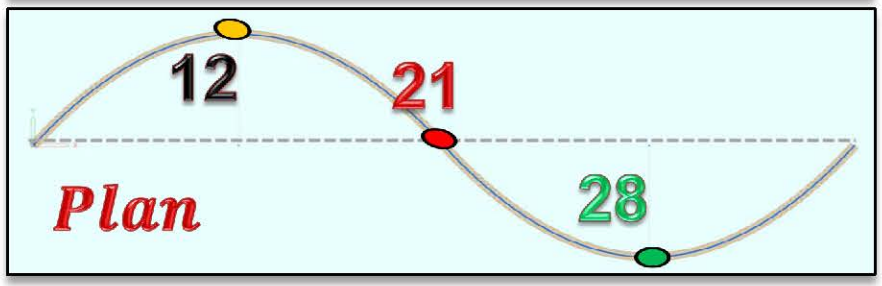


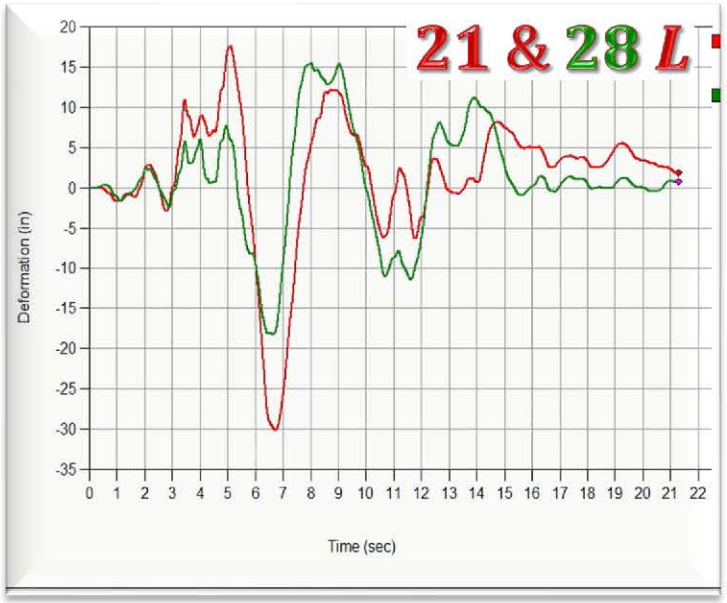
SEISMIC ISOLATION RESPONSES

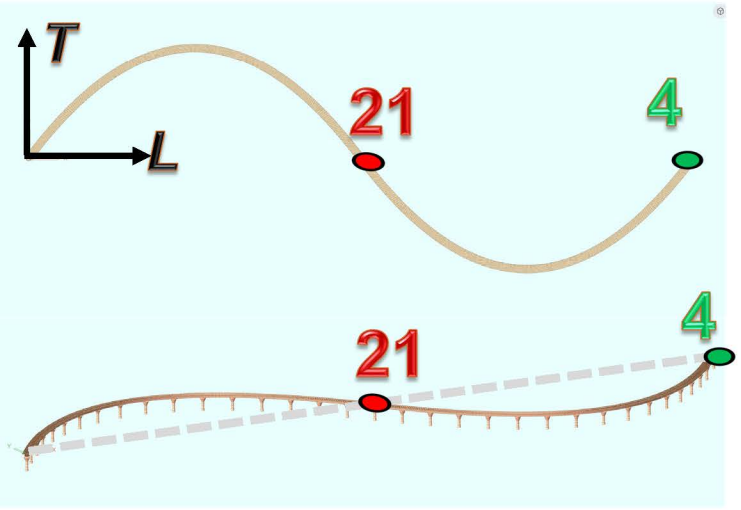


Motion #6

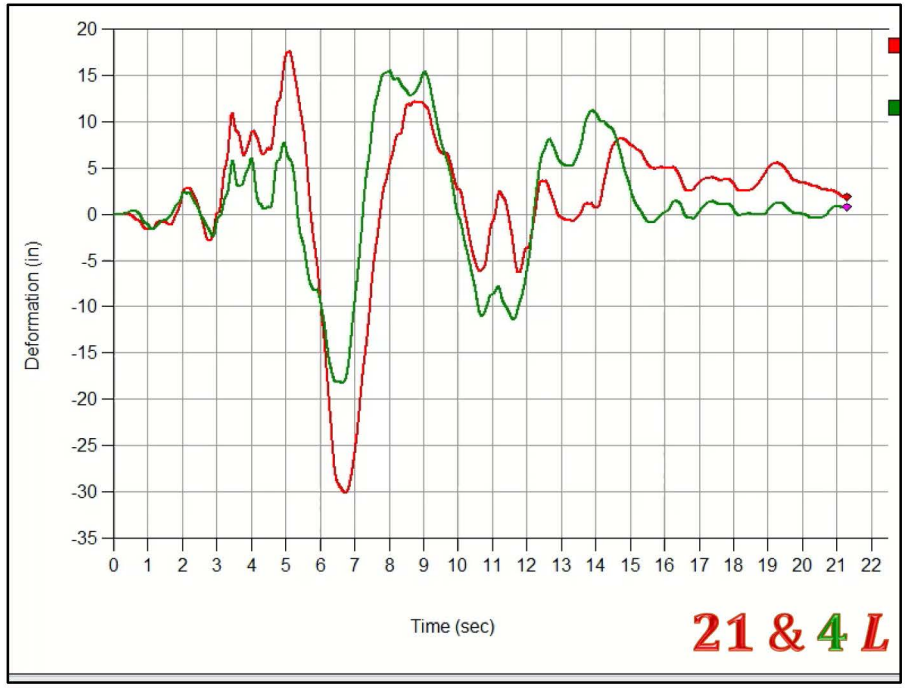


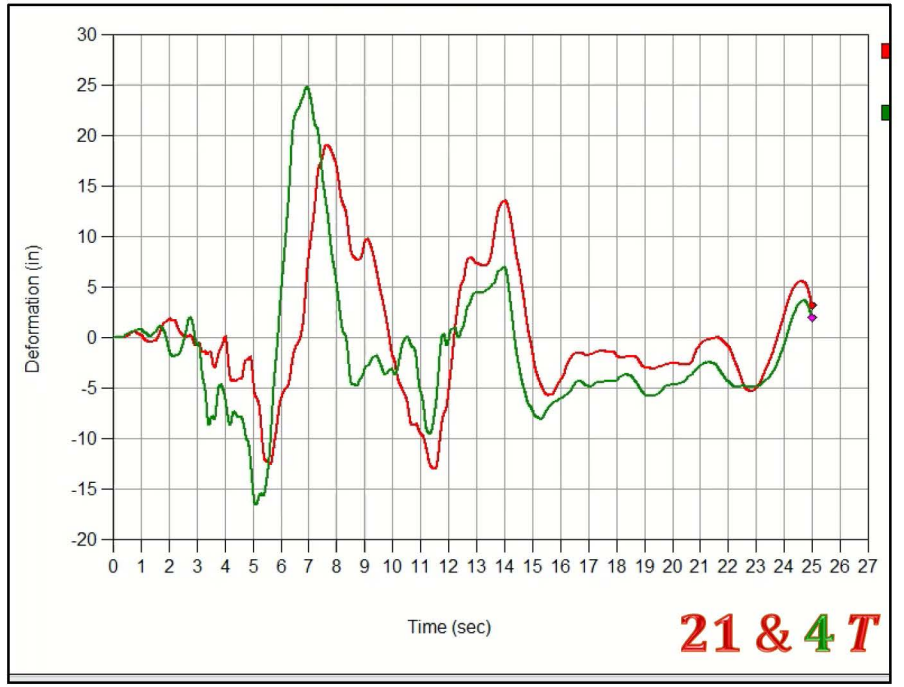


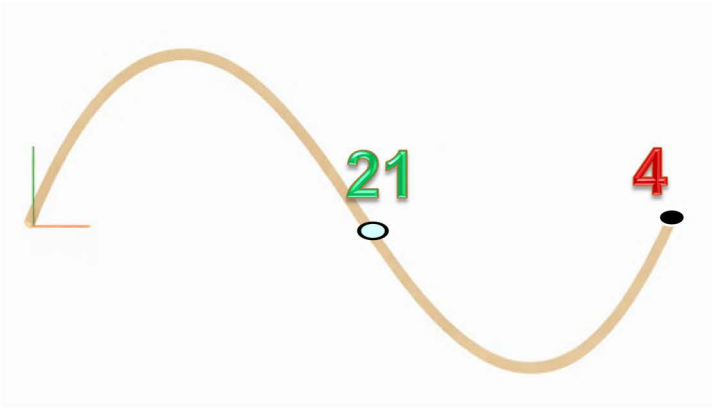




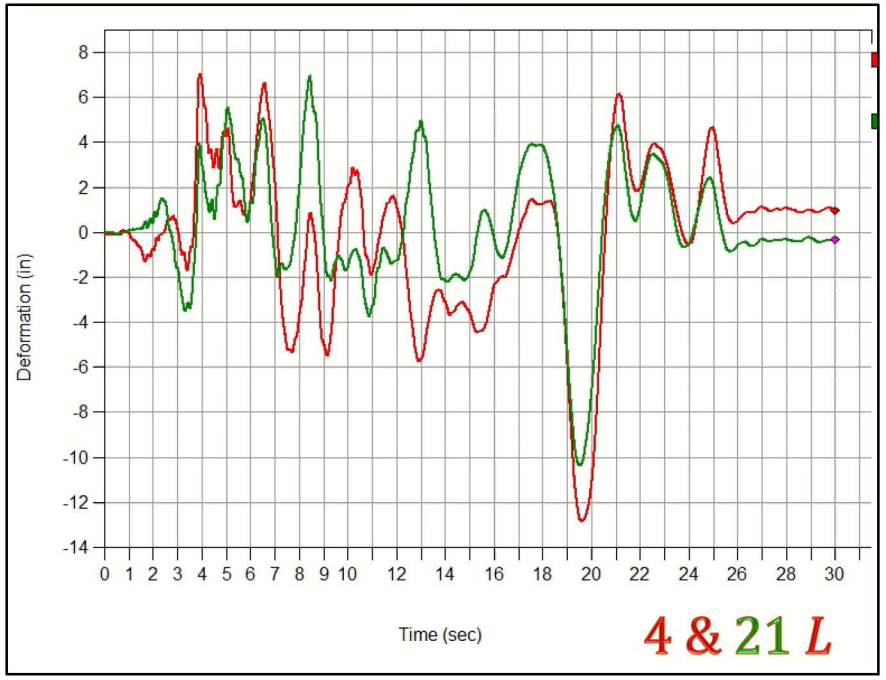
Motion #6

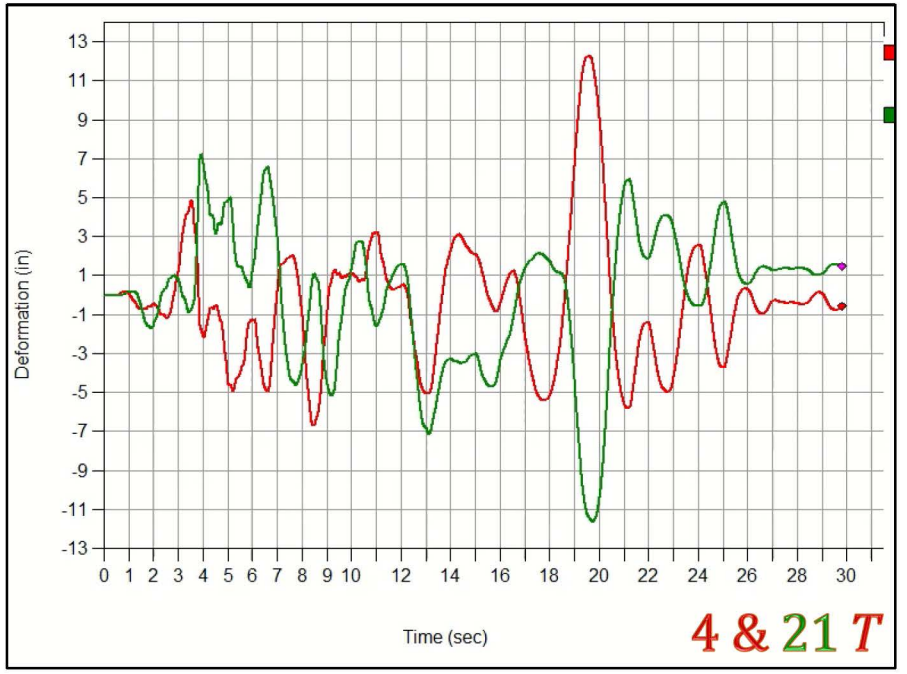




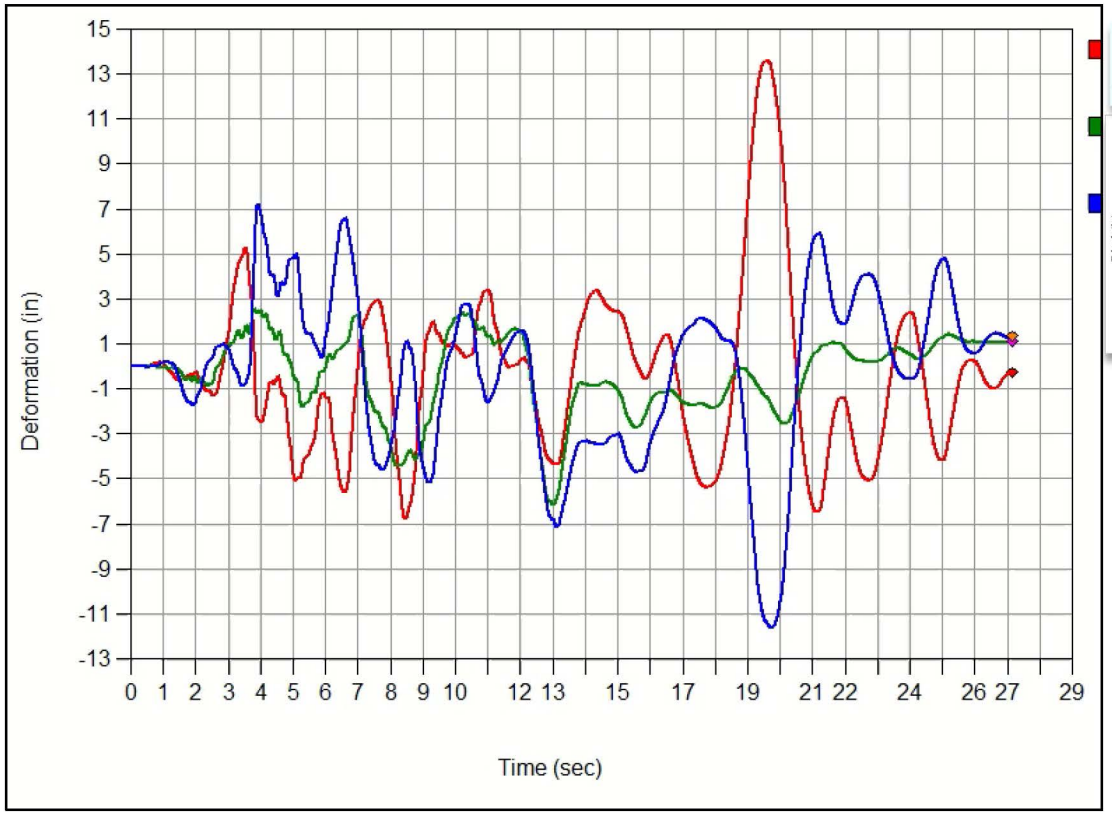


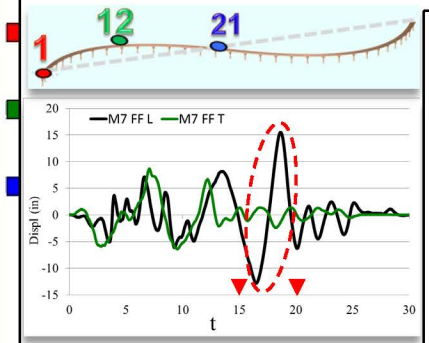
Motion 7

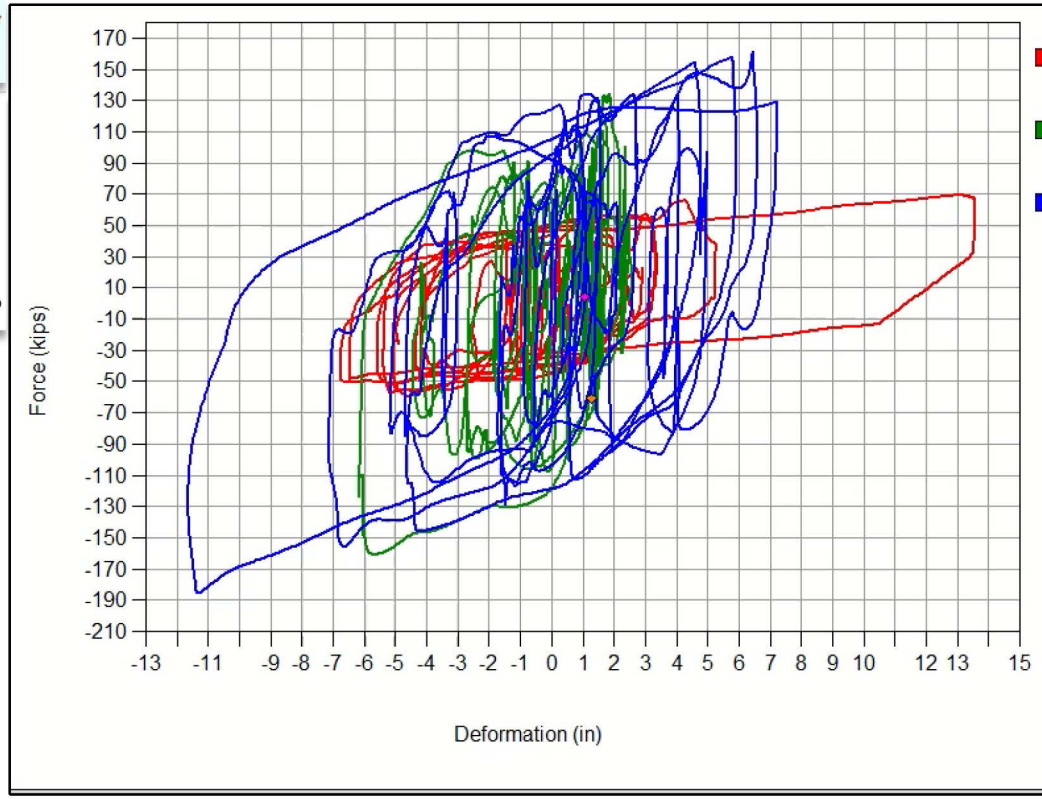


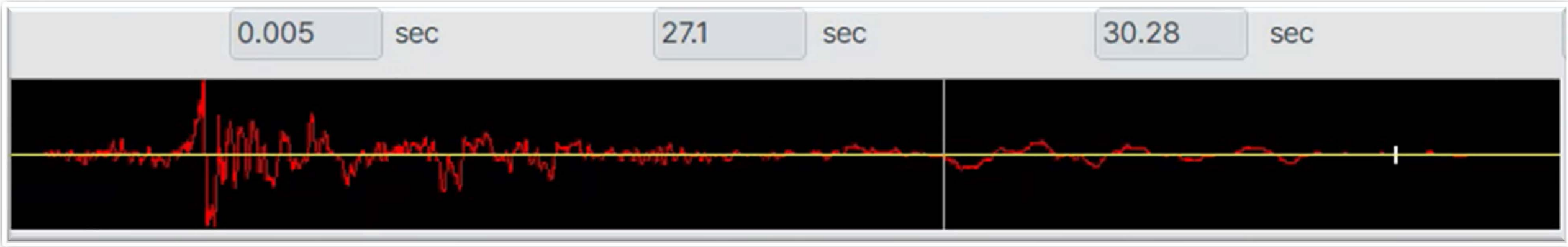


Motion 7 Trans Local Coordinates



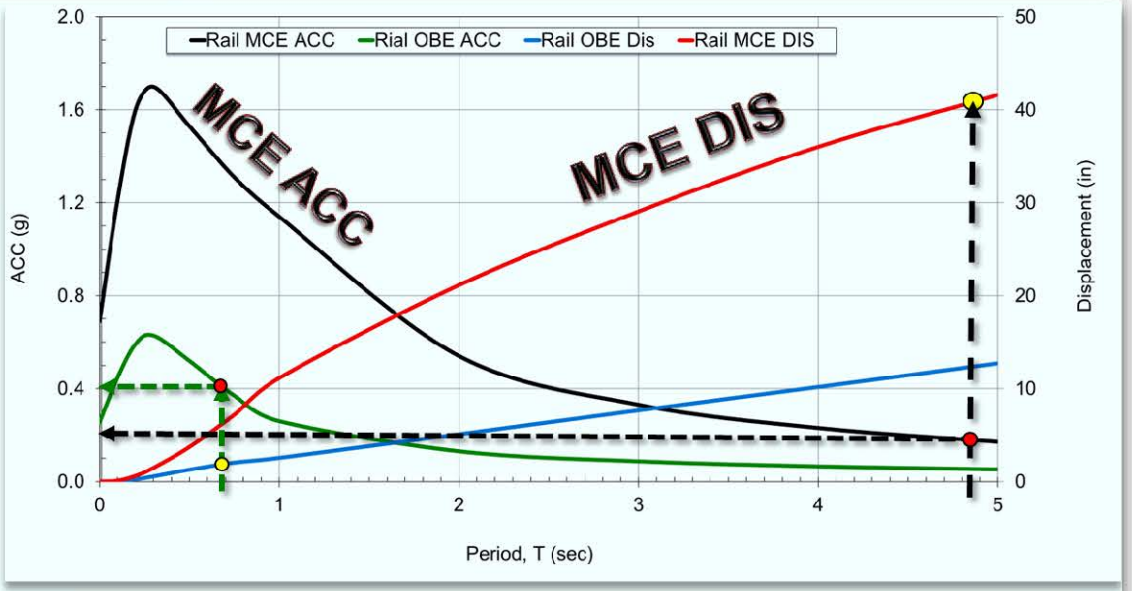






OBE, MCE SEISMIC HAZARD TARGET SPECTRA

MOTION #6



$$d = \sqrt{30^2 + 25^2} = 39 \; in \; from \; TH$$

SUMMARY

Rail Bridges:

- OBE Controls
- Displacement - Serviceability- Governs
- Isolation Shall Limit Displacement at Low Shaking
- Isolation ⟹ Provides Capacity Protection (MCE)

Highway Bridges:

- MCE Controls
- Strength and Ductility-Governs
- Isolation ⟹ Force Reduction & Provides Capacity Protection