Performance of Horizontally Curved Highway Bridge with Seismic Isolation

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The Concrete Convention and Exposition

SACRAMENTO STATE

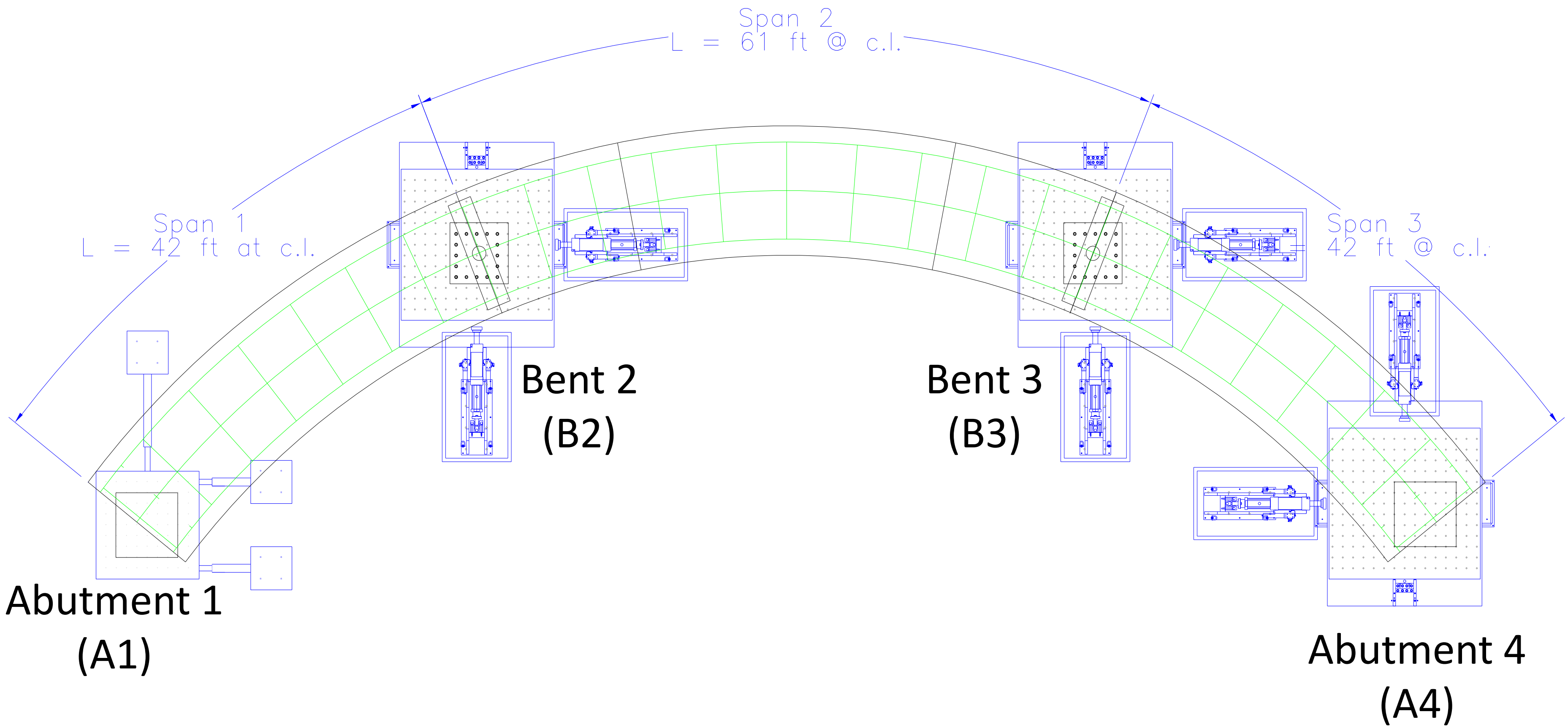
Outline

- FHWA Curved Bridge Studies at UNR
- Seismically Isolated Curved Bridge
    - Curved Bridge Response
    - Experimental Results
    - Isolator Instability
    - Conclusions

Bridge Geometry

	Prototype	Model
Total length	362.5 ft	145 ft
Span lengths	105 ft – 152.5 ft – 105 ft	42 ft – 61 ft – 42 ft
Centerline radius	200 ft	80 ft
Total width	30 ft	12 ft
Girder spacing	11.25 ft	4.5 ft
Column height	19.17 ft	7.67 ft
Column diameter	5 ft	2 ft

Curved Bridge Model Geometry



R = 80 ft at bridge c.l.

Subtended angle = 104^o (1.8 rad)


KONE
25-5T
L = 145 ft
22 ft
12 ft
Weight of model:
Total Model Weight = 167 kips
Superstructure = 107 kips
Substructure = 60 kips

Experiments

1. Conventional bridge (104^0, steel bearings, 24 inch diam. columns, sacrificial shear keys at abutments)

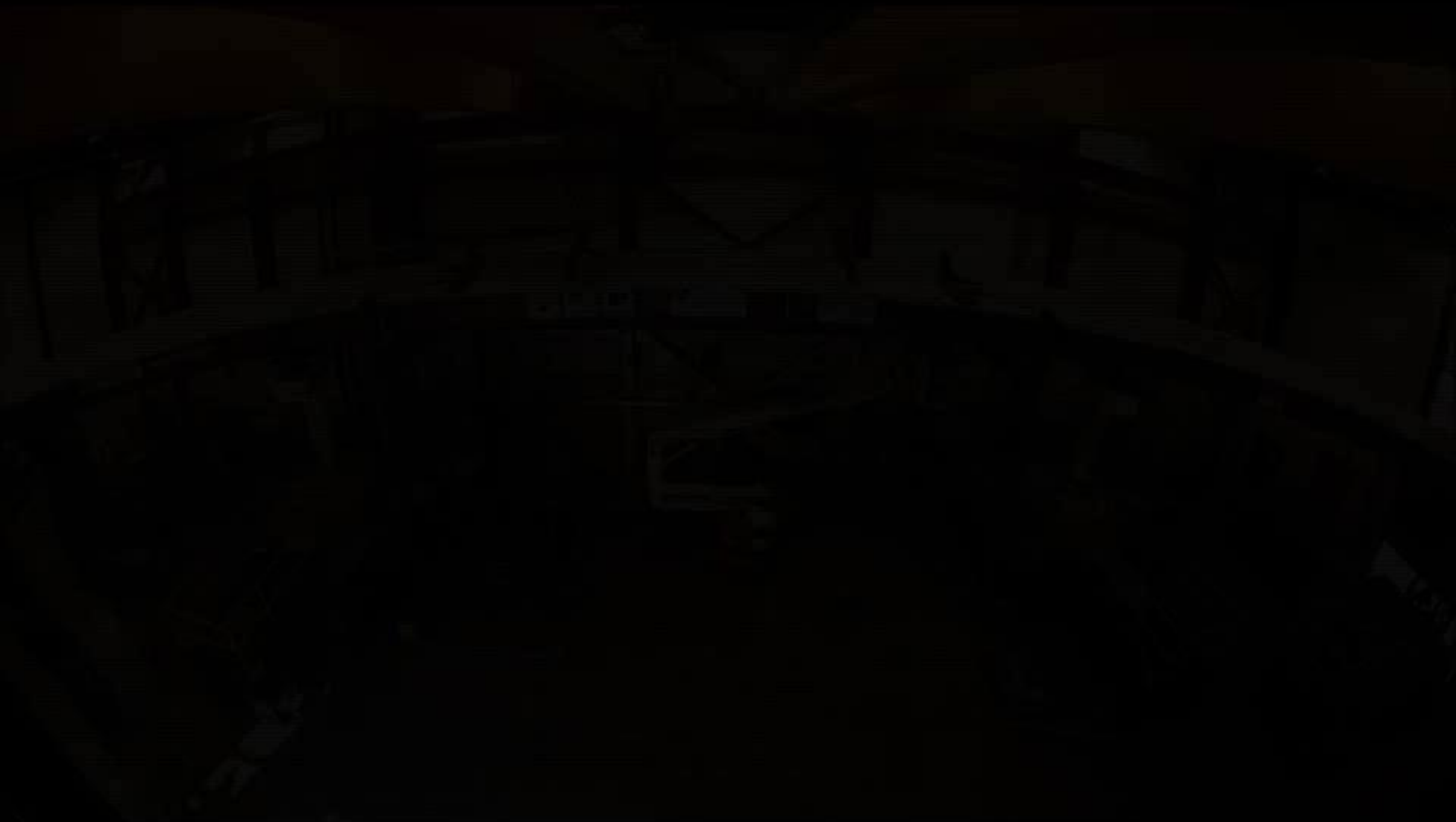
2. Conventional bridge with live load (6 trucks)

3. Fully isolated bridge with 12 LRB isolators

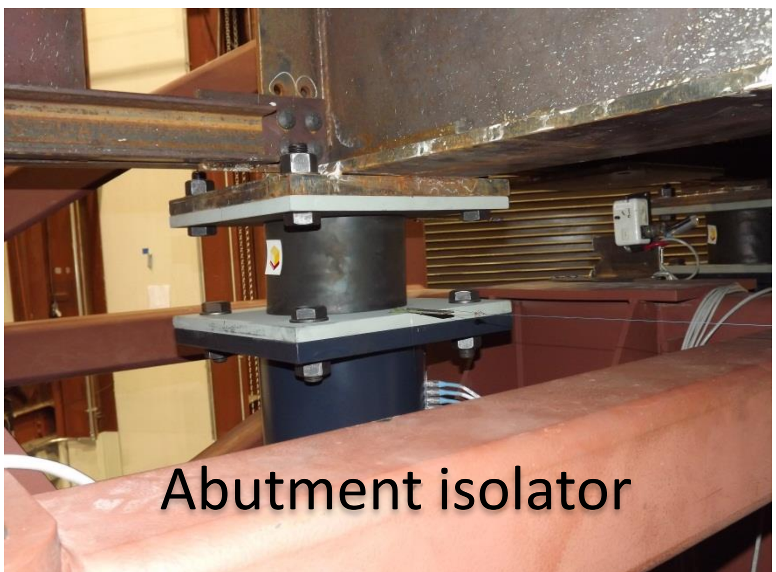
4. Hybrid isolated bridge with 6 LRB isolators and ductile cross frames

5. Abutment pounding (nonlinear backfill)

6. Rocking columns



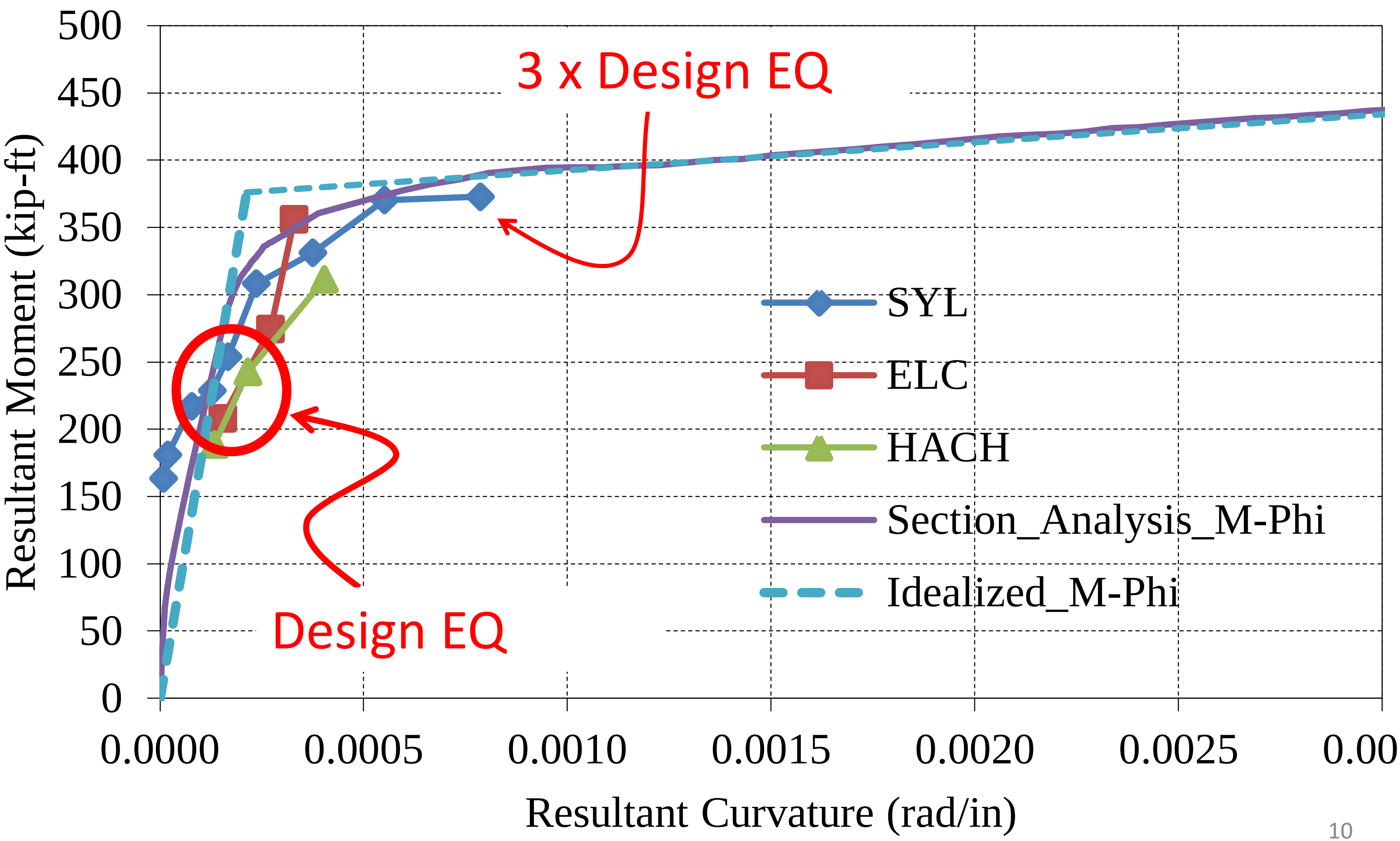
Seismic Isolators



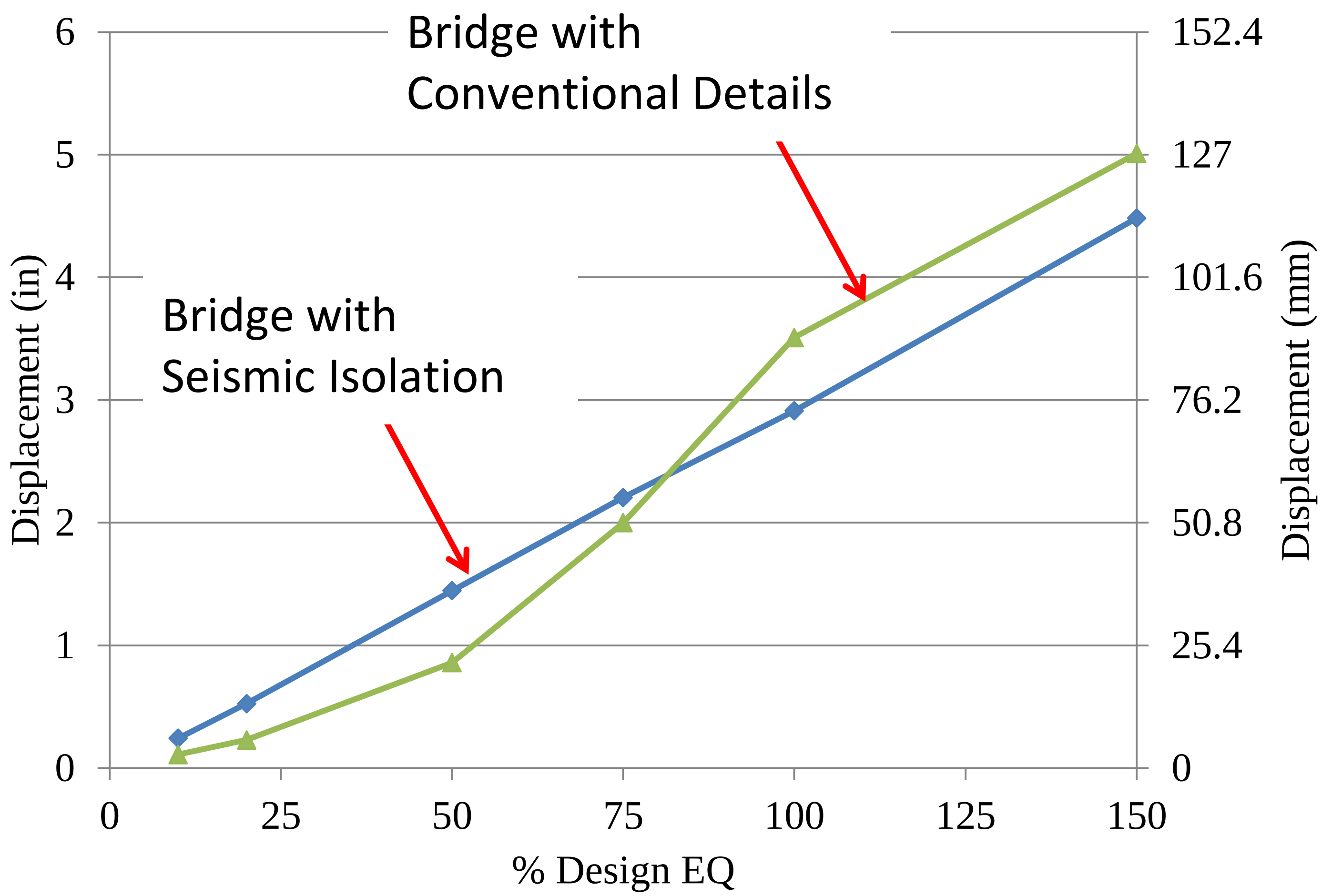
Lead Rubber Bearings

Parameters	Abutment LRB	Pier LRB
Shear modulus, G	55 psi	55 psi
Bonded diameter, B	7.5 in.	9.0 in.
Layer thickness, t_r	0.25 in.	0.25 in.
Total rubber thickness, T_r	2.75 in.	2.75 in.
Total Height, H	7.0 in.	7.0 in.
Lead core diameter, d_L	1.25 in.	1.5 in.
Stiffness, K_d	0.86 kip/in	1.24 kip/in
Characteristic strength, Q_d	1.41 kip	2.03 kip

Performance of Column in Seismically Isolated Bridge

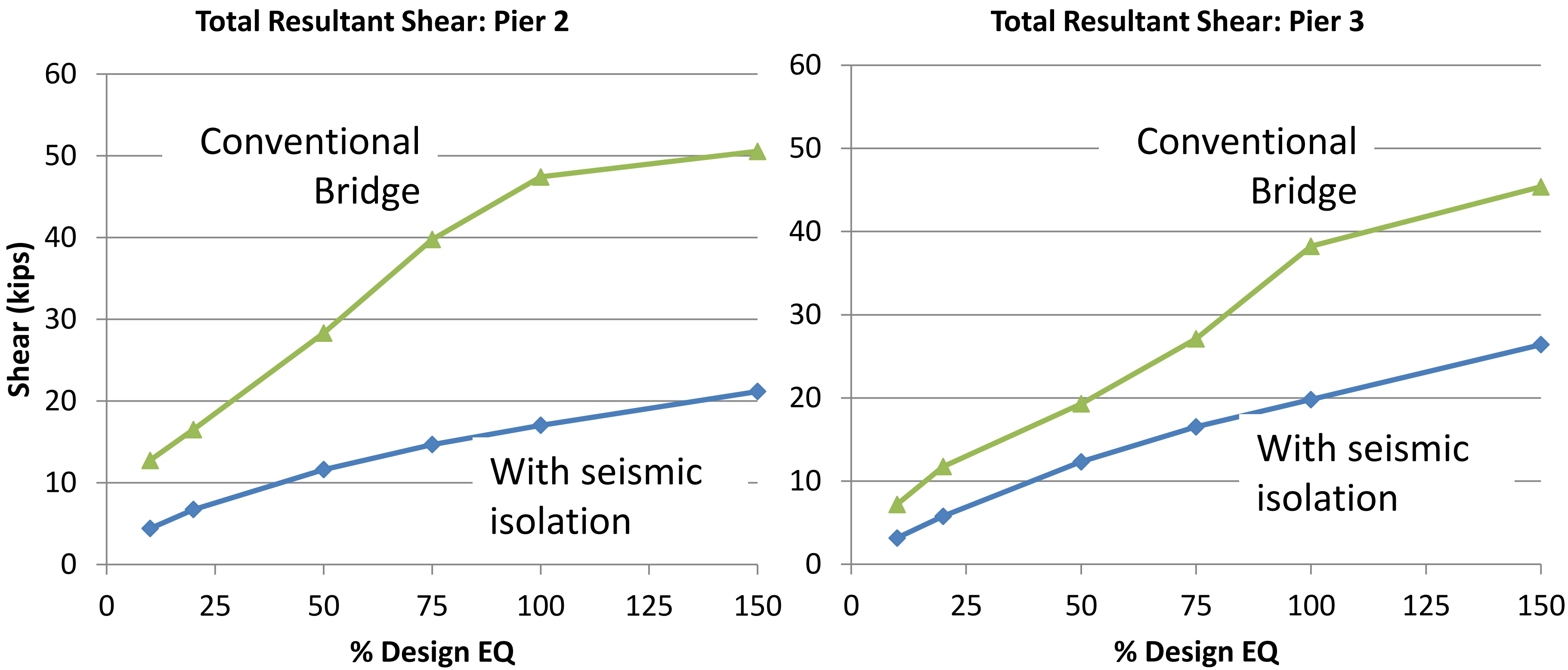


Superstructure Displacement



Due to damage in the columns, in addition to effects of in-plane torsional rotation of the curved bridge, the conventional bridge experienced higher displacement at EQ levels beyond the Design EQ.

Column Shear Forces

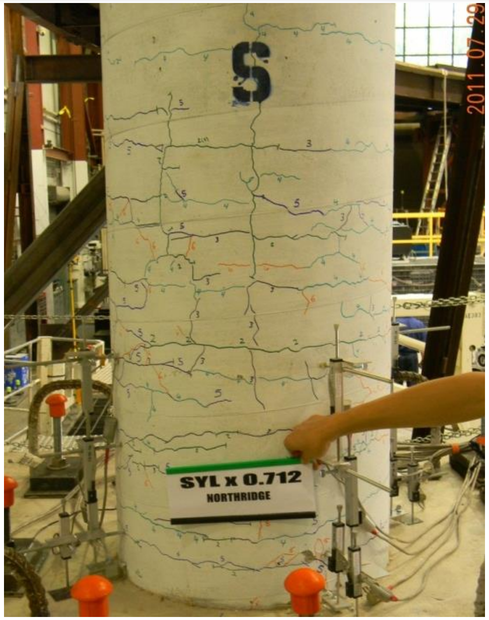


The seismic isolation reduced the column base shear by about 50% at Design EQ level.

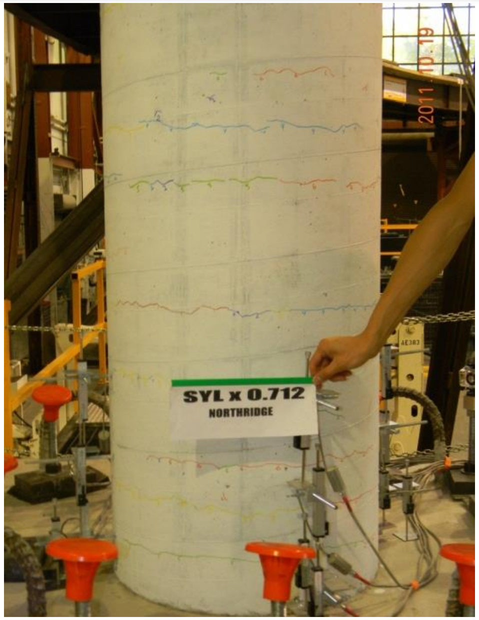
Due to bridge curvature, the supports experienced unequal base shears resulting in more damage at one support and less damage at the other. This, in turn, resulted in unequal stiffness of the columns which further increases the effect of in-plane torsional rotation.

Column Damage at 1.5 Design EQ (MCE)

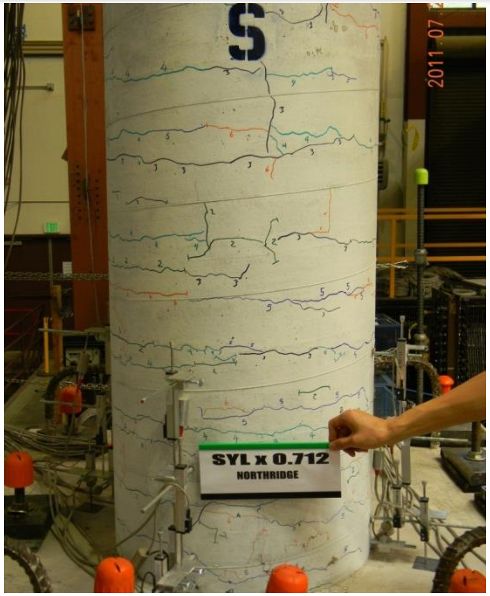
Pier 2
Bridge with
Conventional
Details



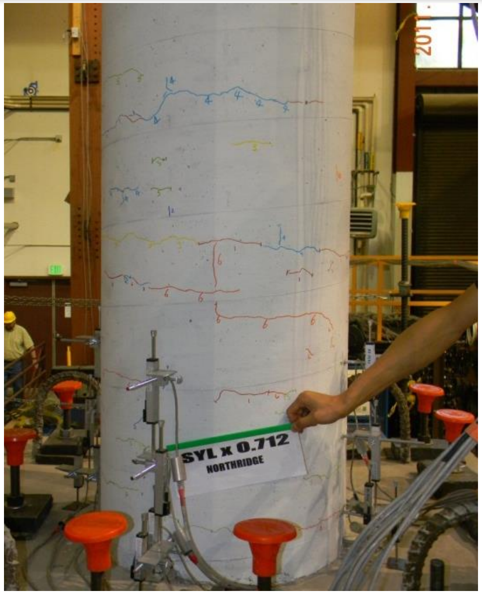
Pier 2
Bridge with
Seismic
Isolation



Pier 3
Bridge with
Conventional
Details

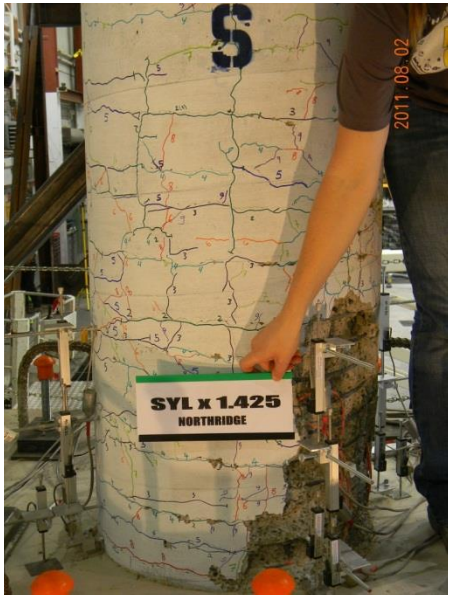


Pier 3
Bridge with
Seismic
Isolation

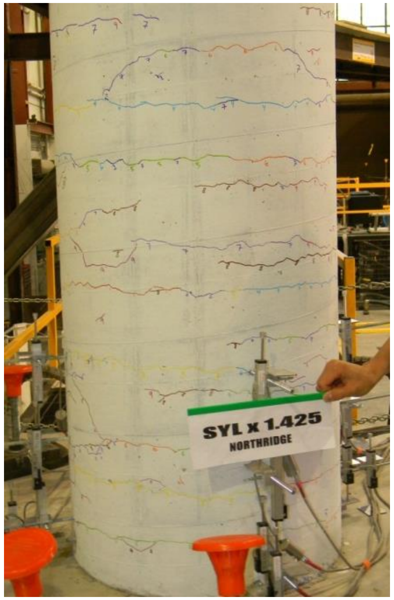


Column Damage at 3x Design EQ

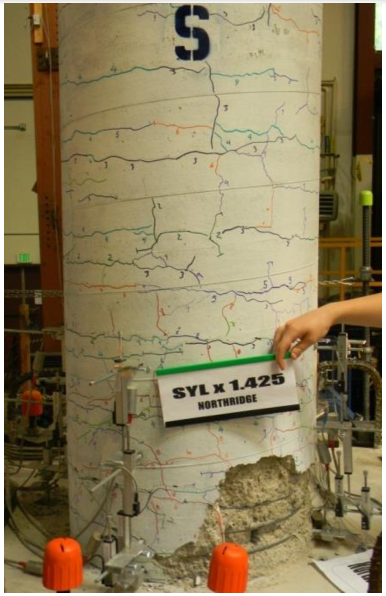
Pier 2
Bridge with
Conventional
Details



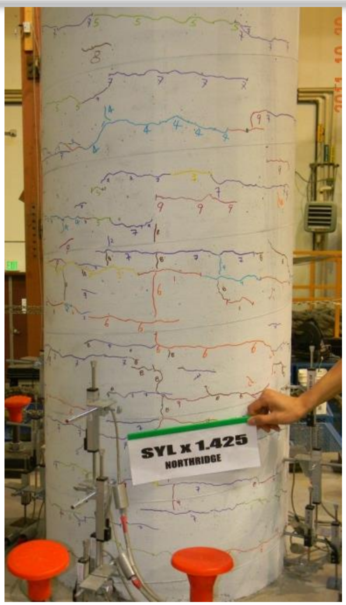
Pier 2
Bridge with
Seismic
Isolation



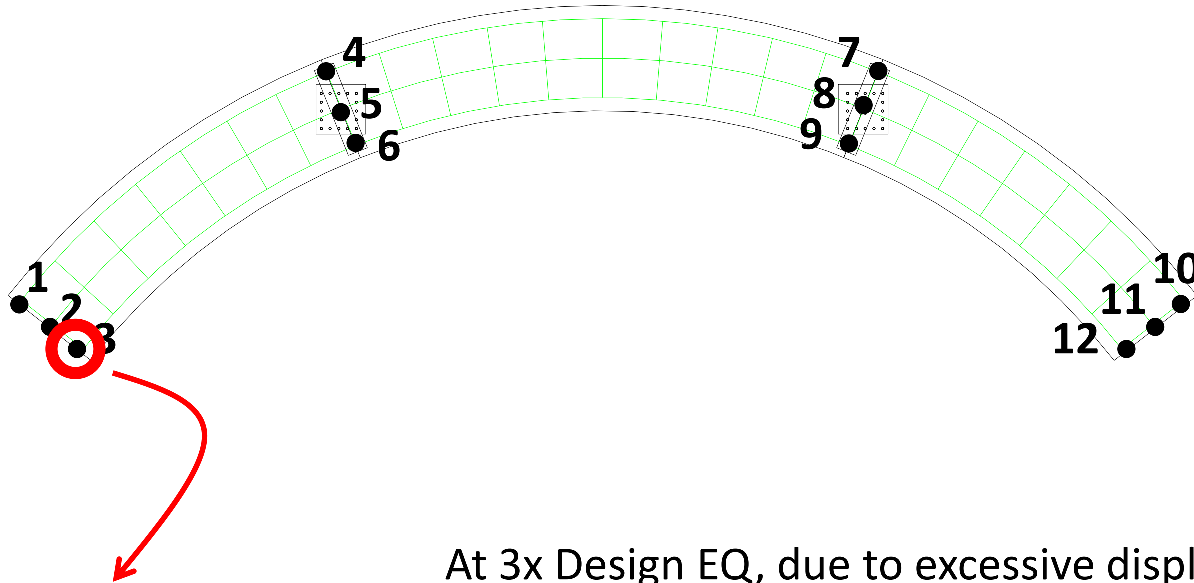
Pier 3
Bridge with
Conventional
Details



Pier 3
Bridge with
Seismic
Isolation



Isolator Deformation during instability



At 3x Design EQ, due to excessive displacements, instability occurred at the isolators at one of the abutments.

However, global instability did not occur because the isolators at other supports remained stable. This, in addition to inertial loading in the bridge, the unstable isolators were able to return to original position at the end of the excitation.

No residual displacement was observed.

Isolator Instability: 300% DE SYL

Video in Slow-Motion

Concluding Remarks

- Essentially elastic behavior of columns can be achieved in a seismically isolated bridge even at earthquake levels equal to three times the design.
- In a continuous curved bridge with multiple spans, instability of isolators at one or two supports does not lead to bridge collapse.
- Lead-rubber isolators are highly resilient seismic protective systems. Extreme deformation and instability in these isolators has minimal effect on their stiffness.

Thank You!