Caltrans Seismic Assessment of Bridge Inventory

Performance of Skewed Bridges

PEER

The 1994 Northridge Earthquake:
Impacts, Outcomes, Next Steps

January 16-17, 2014
northridge20.org

NORTHRIDGE 20
SYMPOSIUM

Acknowledgments



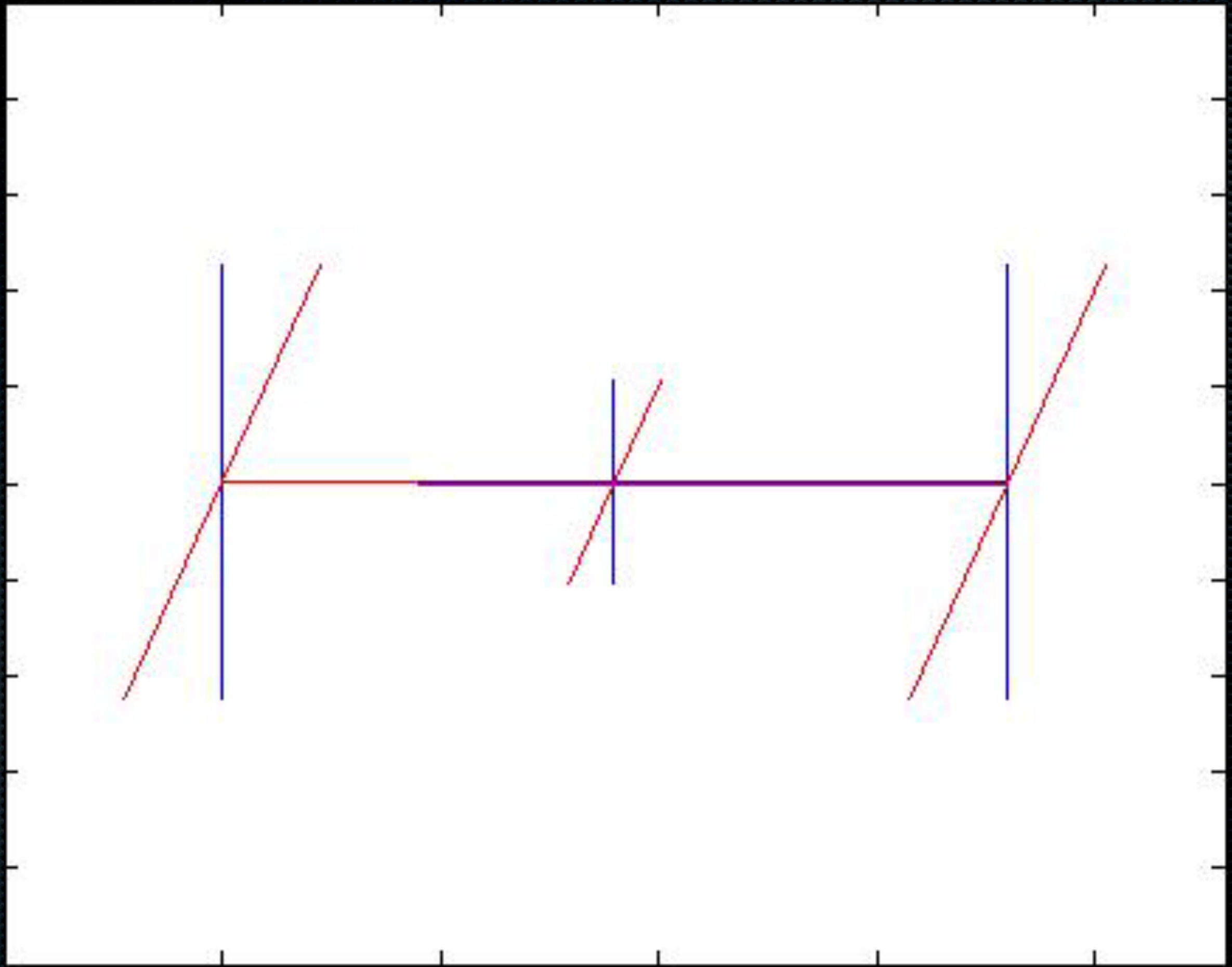






Caltrans

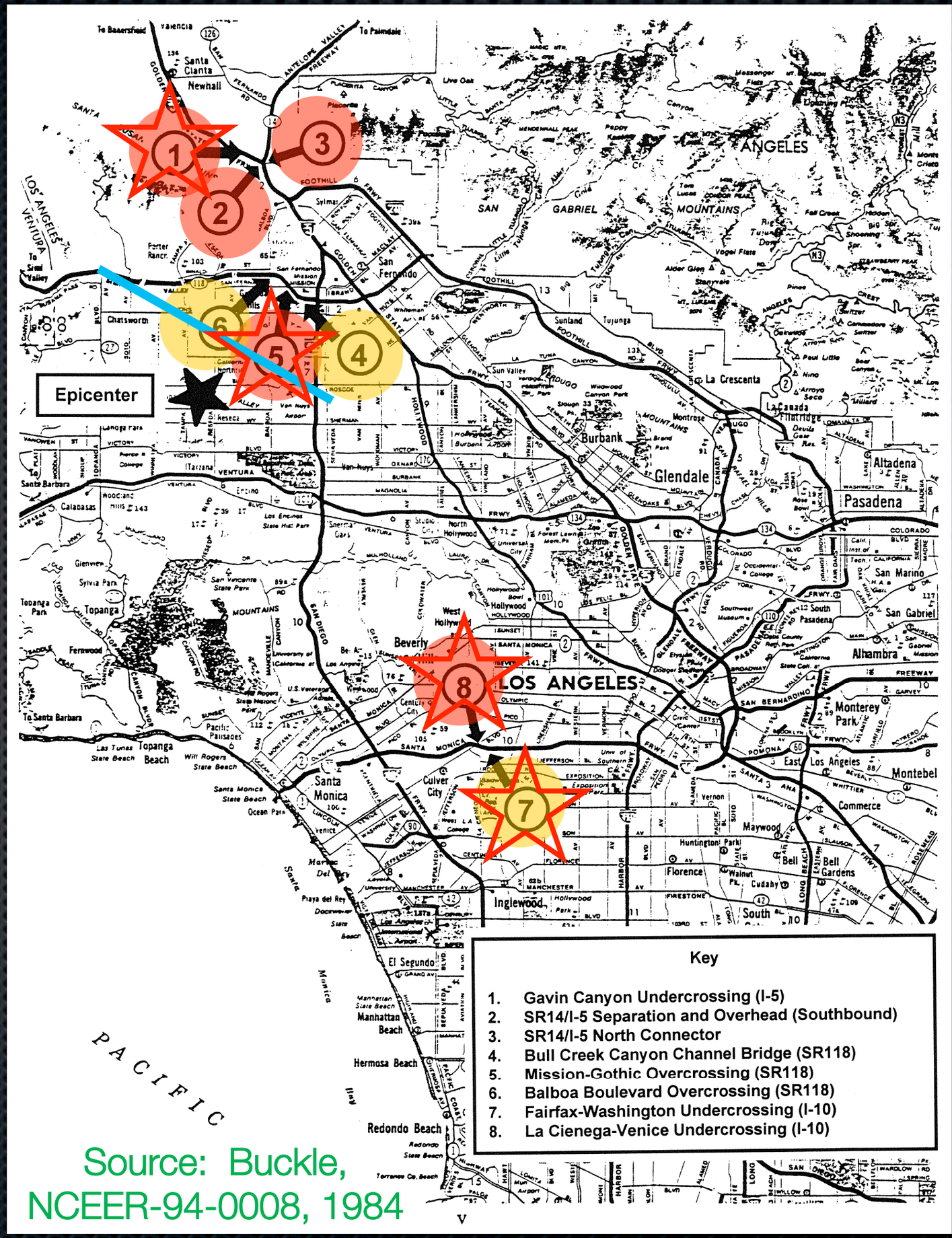
PEER



Northridge

Source: NISEE

Name	Number	Replacement Cost	Date opened
Gavin Canyon UC	1	$23,627,000	17 May 1994
Butte Canyon Bridge	Not listed	6,765,000	18 may 1994
La Cienega-Venice Sep.	Not listed	4,023,000	11 April 1994
La Cienega-Venice to Fairfax-Washington	8	34,584,000	11 April 1994
South Connector OC	Not listed	8,100,000	4 Nov 1994
North Connector OC	3	6,500,000	4 Nov 1994
Separation and Overhead Structures F and G	2	24,403,000	8 July 1994
Mission-Gothic UC*	5	15,433,000	13 May 1994
Bull Creek Canyon Channel UC	4	10,757,000	20 Nov 1994



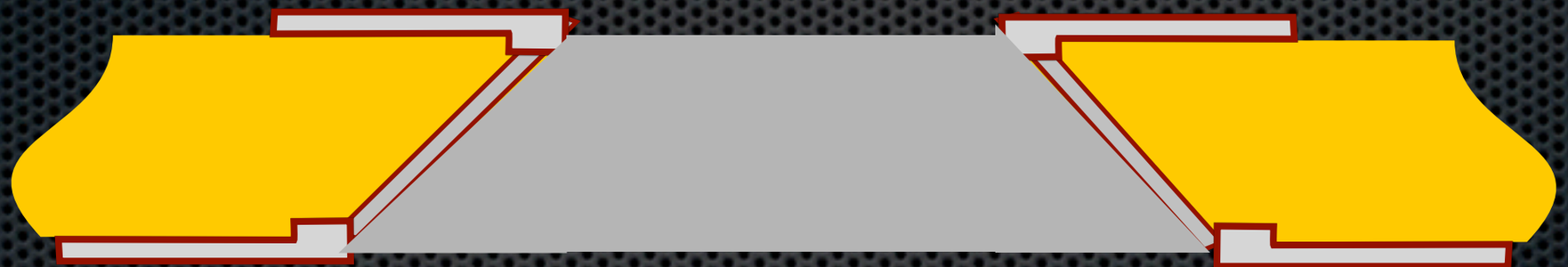
Source: Buckle, NCEER-94-0008, 1984

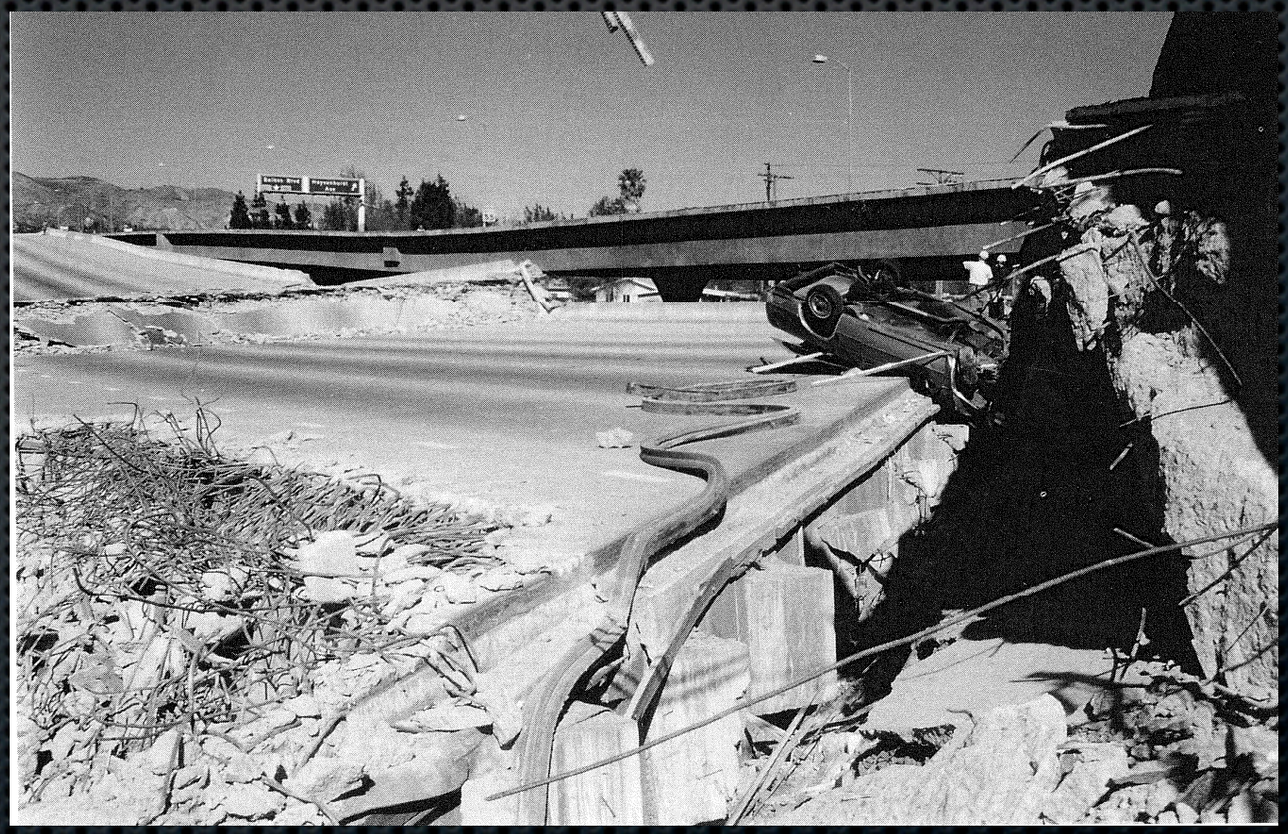
Northridge and Skewed Bridges

Source: Aschheim, NISEE,1994

Northridge and Skewed Bridges

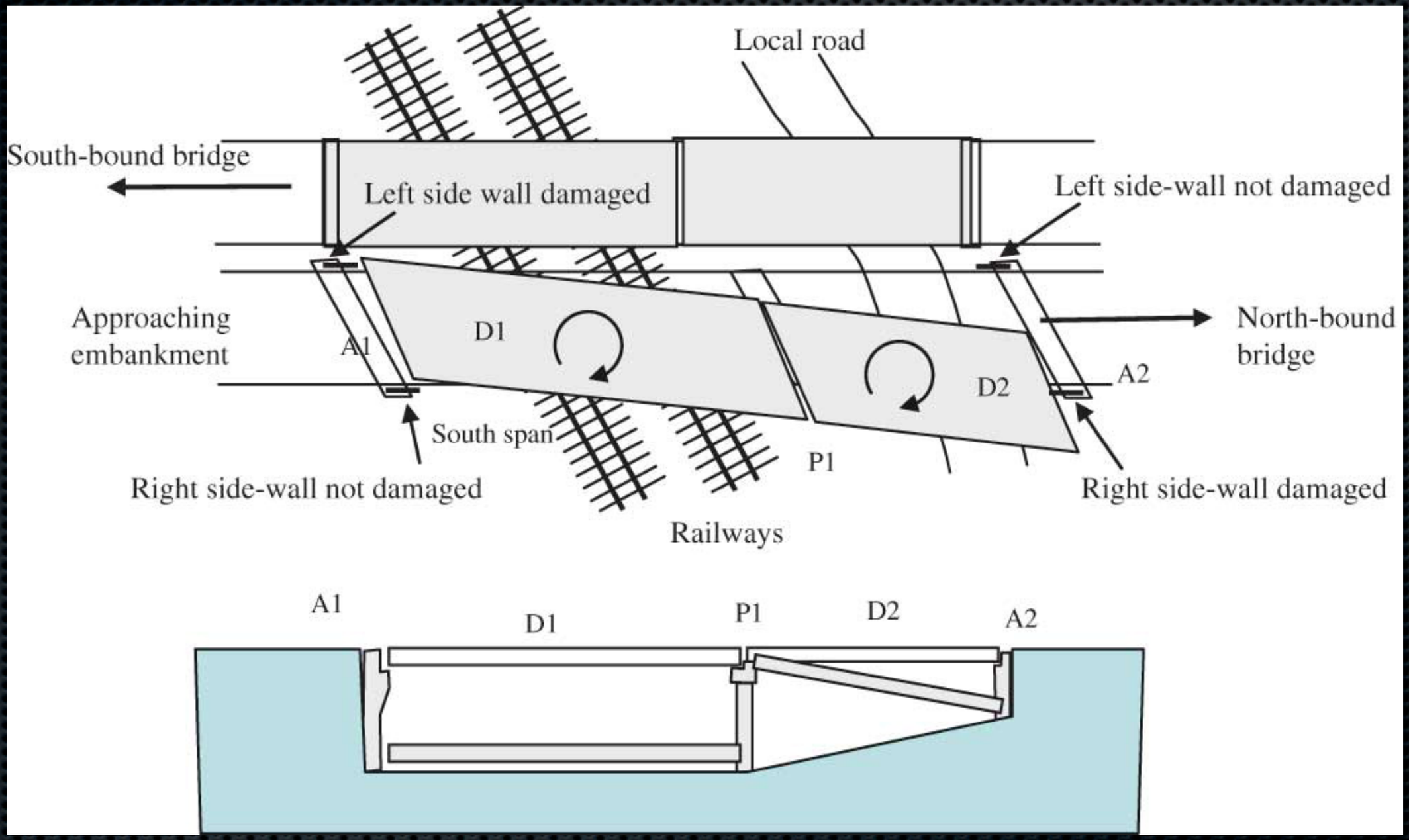
Mission-Gothic Overcrossing
45° skew angle





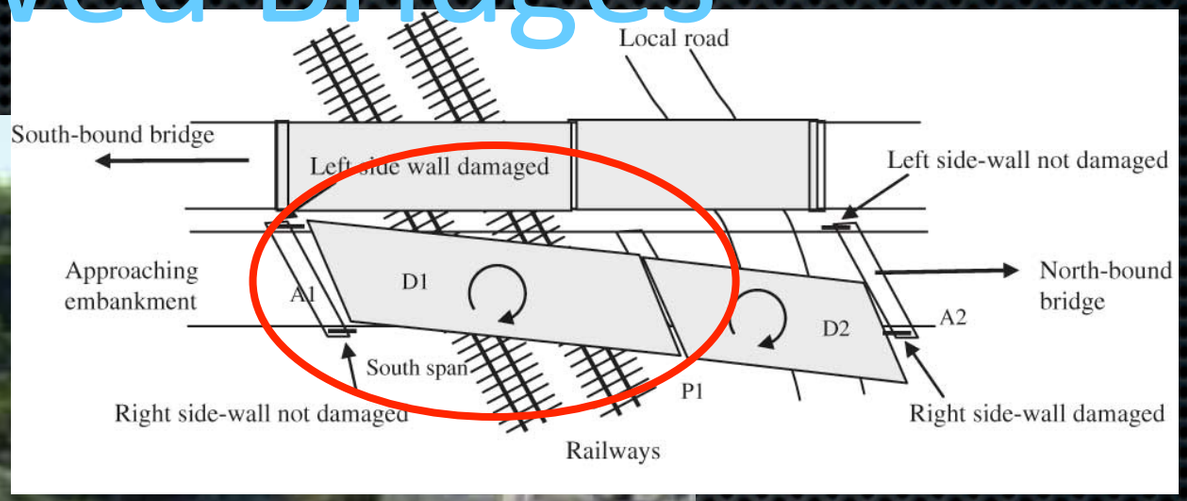
Source: Buckle, NCEER-94-0008, 1984

Recent EQs & Skewed Bridges



Hospital Overpass Bridge (Maule 2010 Chile Eq.; source, Kawashima et al., J EQ Eng., 2011)

Recent EQs & Skewed Bridges



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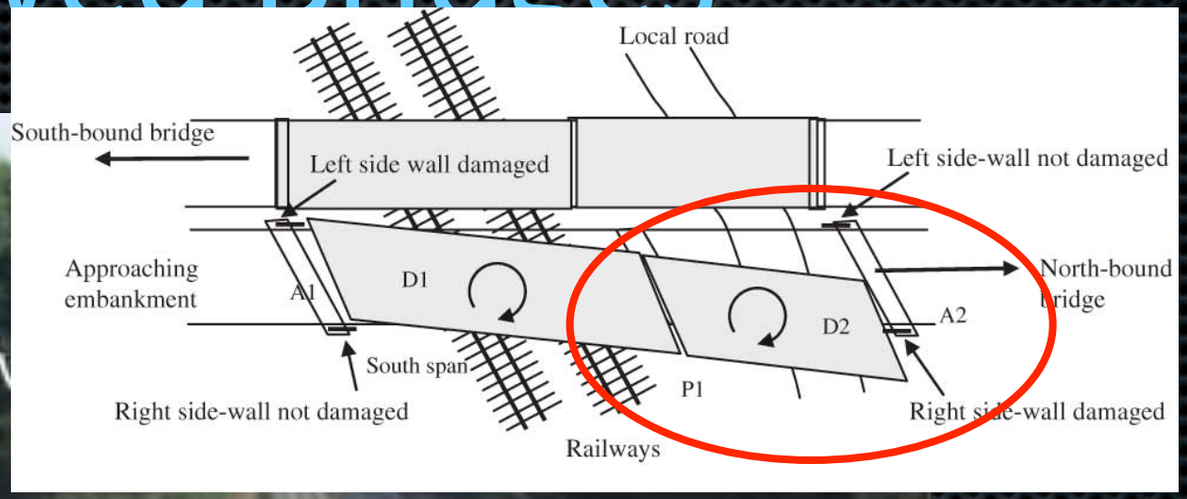
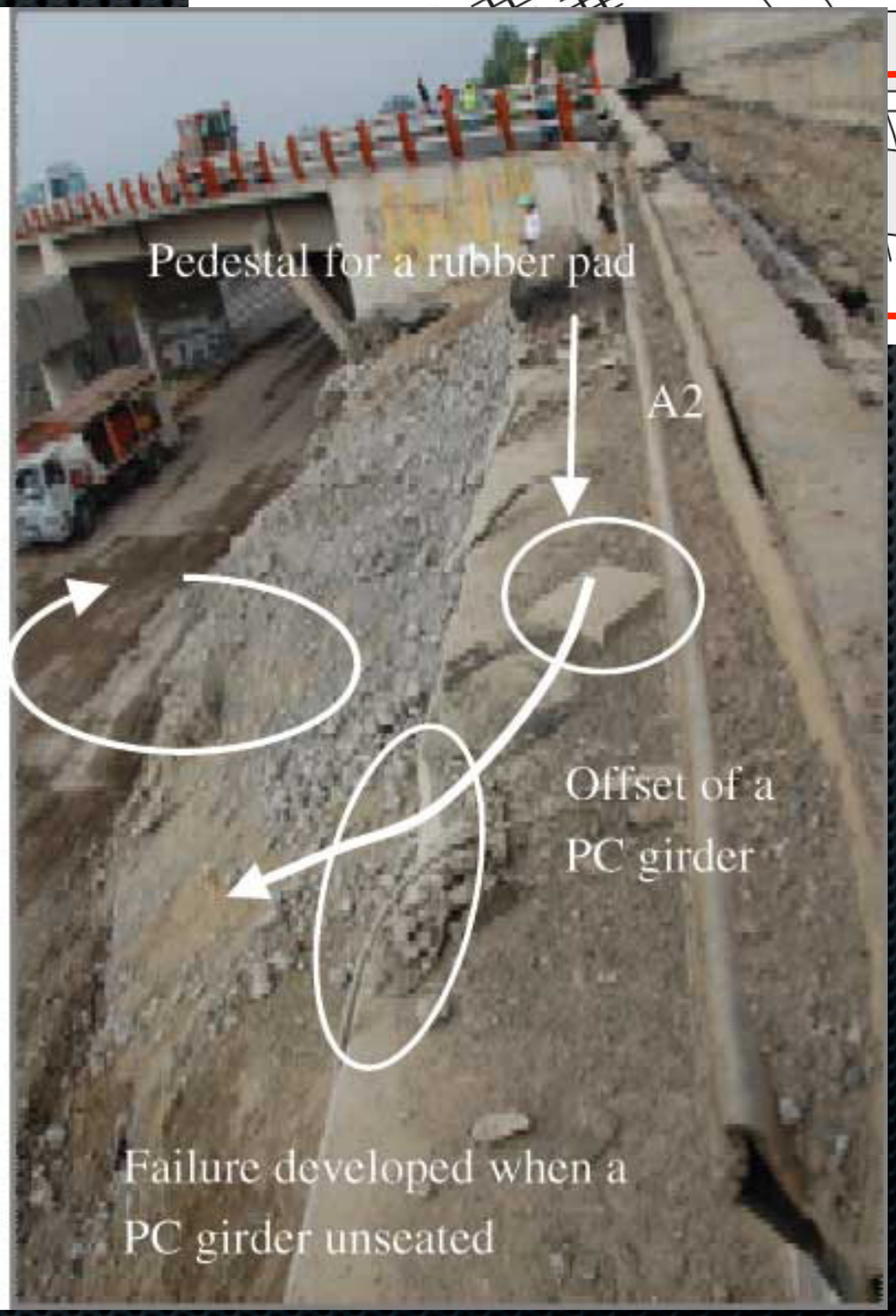


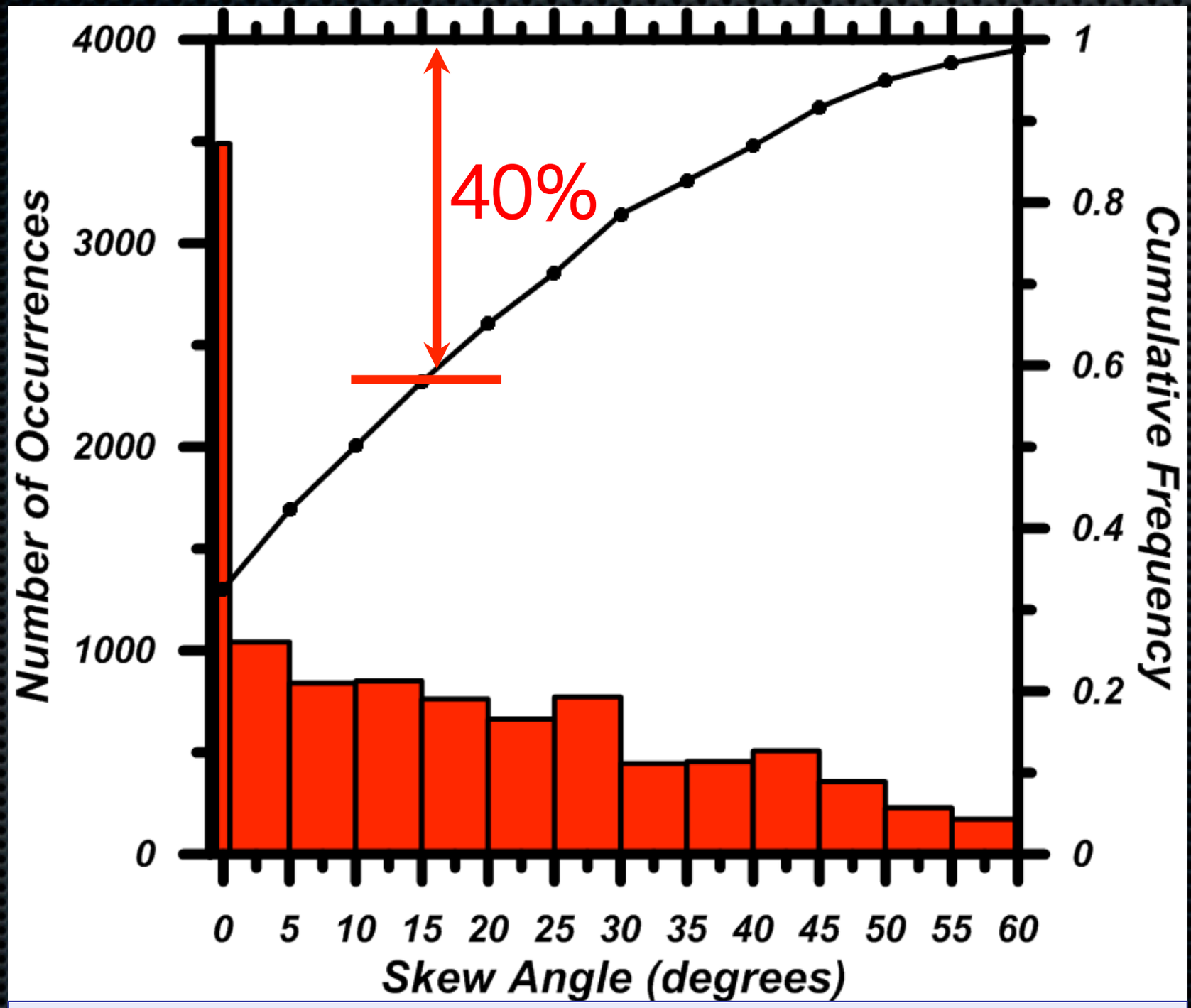
Hospital Overpass Bridge (Maule 2010 Chile Eq.; source, Kawashima et al., J EQ Eng., 2011)

Recent EQs & Skewed Bridges



Hospital Overpass Bridge (Maule 2010 Chile Eq.; source, Kawashima et al., J EQ Eng., 2011)

Skew happens

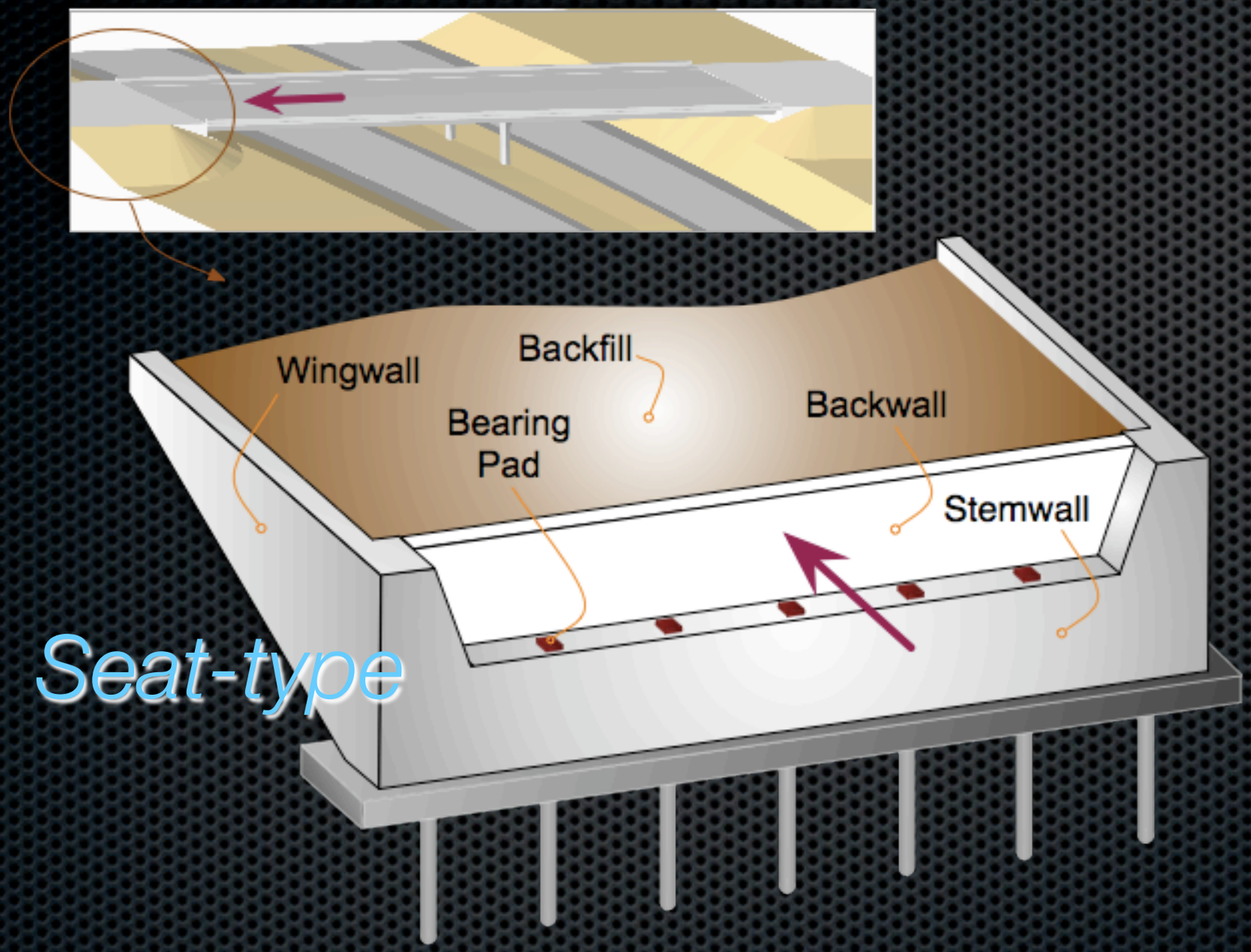


(source, FHWA National Bridge Inventory database, 2002)

Nonskewed Abutments

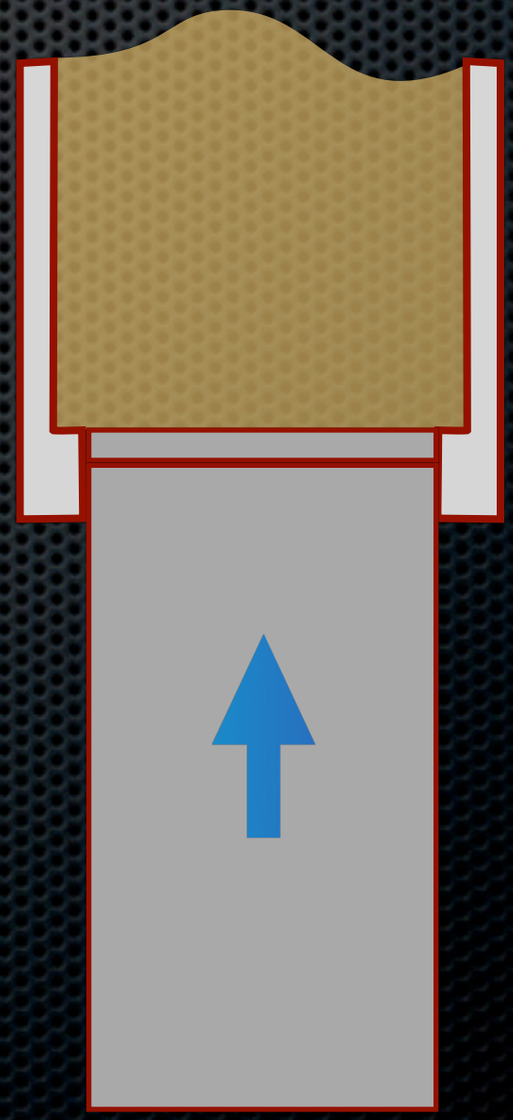
Las Mercedes Rt. 5 Overcrossing (Maule 2010 Chile Eq.; source, Buckle et al., EQ Spectra, 2012)

Current State of Practice



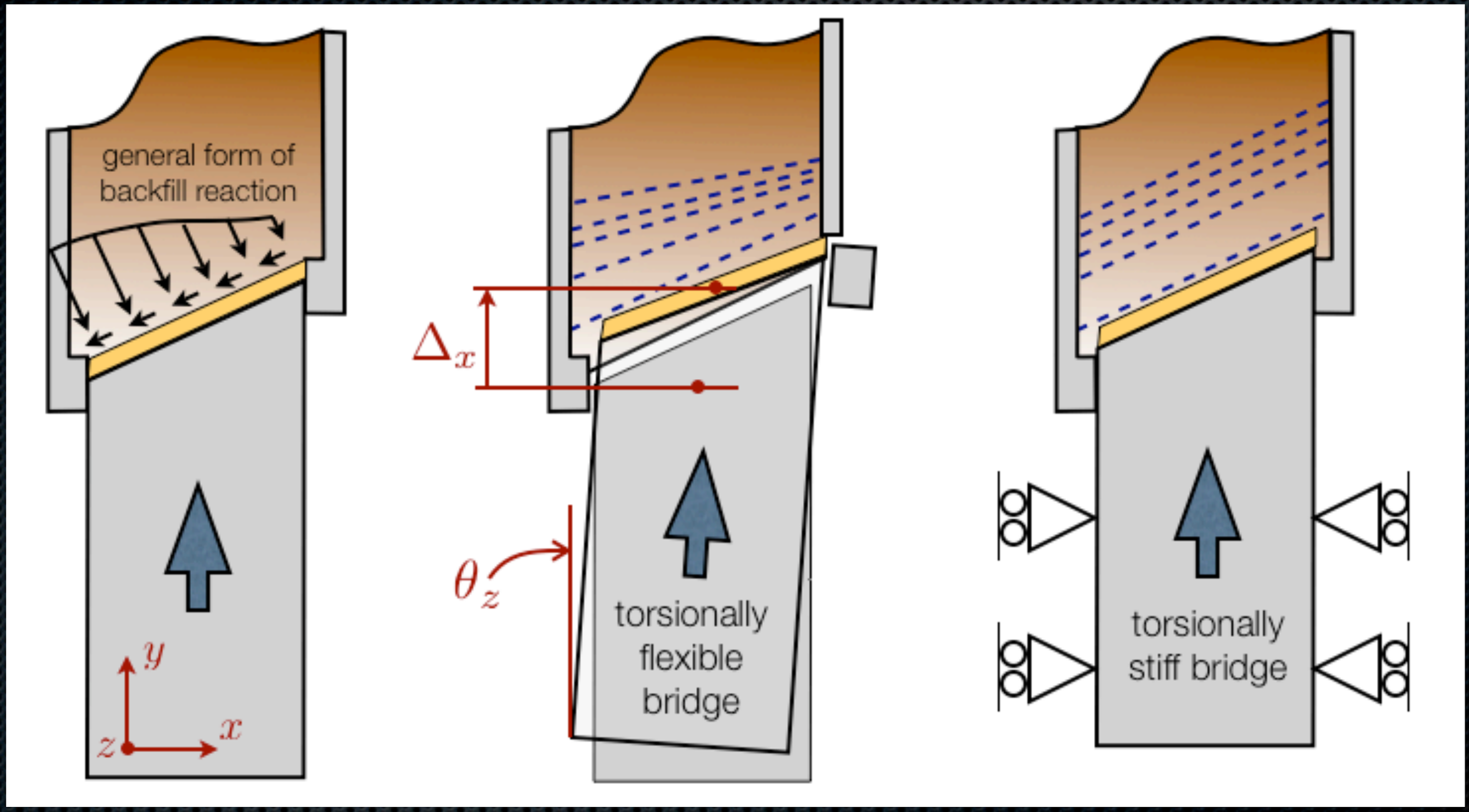
Seat-type

plan view



Skew Bridge Challenges

Skew-angled Abutments



Research Goals

Model skew abutment (component)

Model ordinary bridges (system)

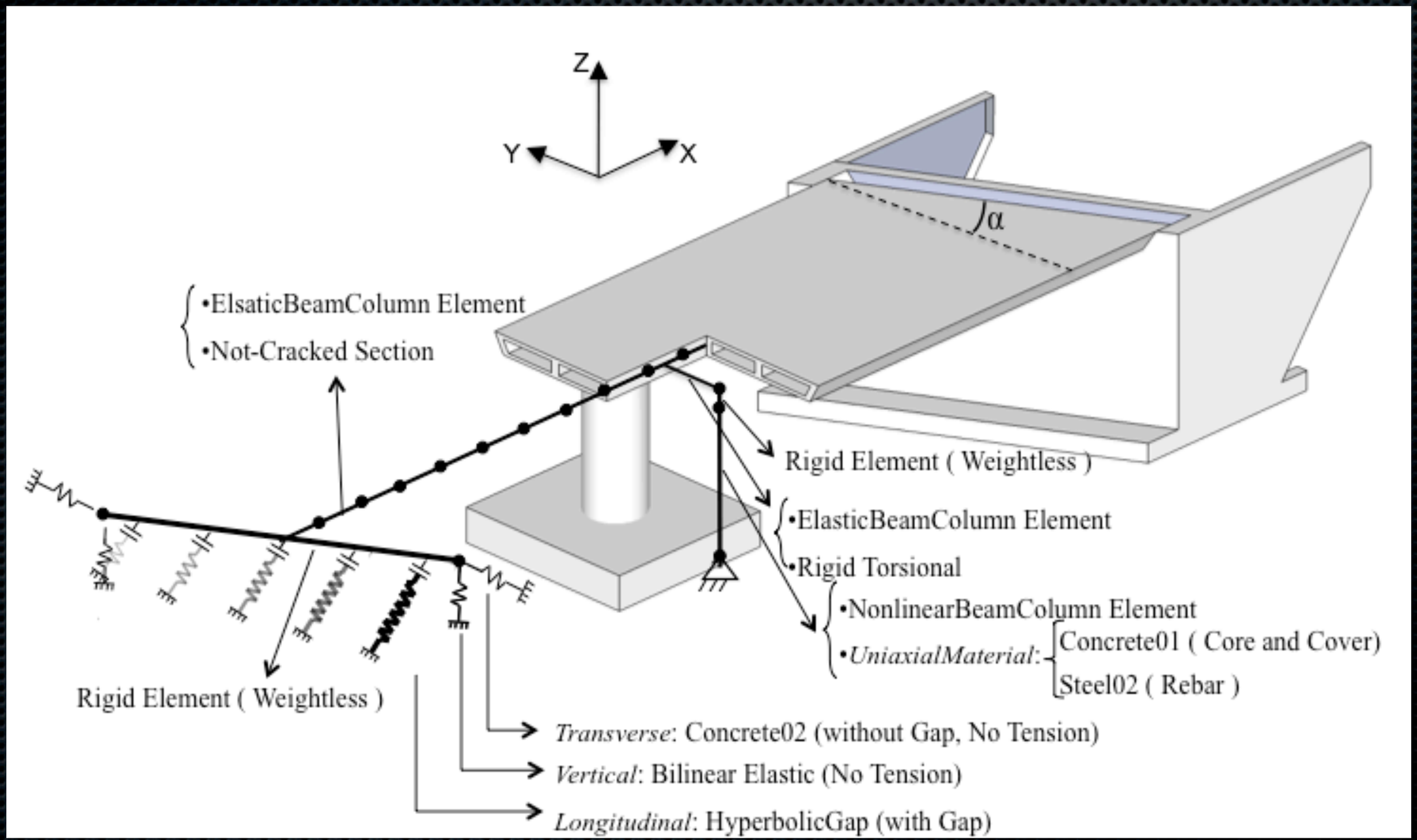
Quantify ordinary bridge response.

Ground motion characteristics (directionality, pulse, duration)

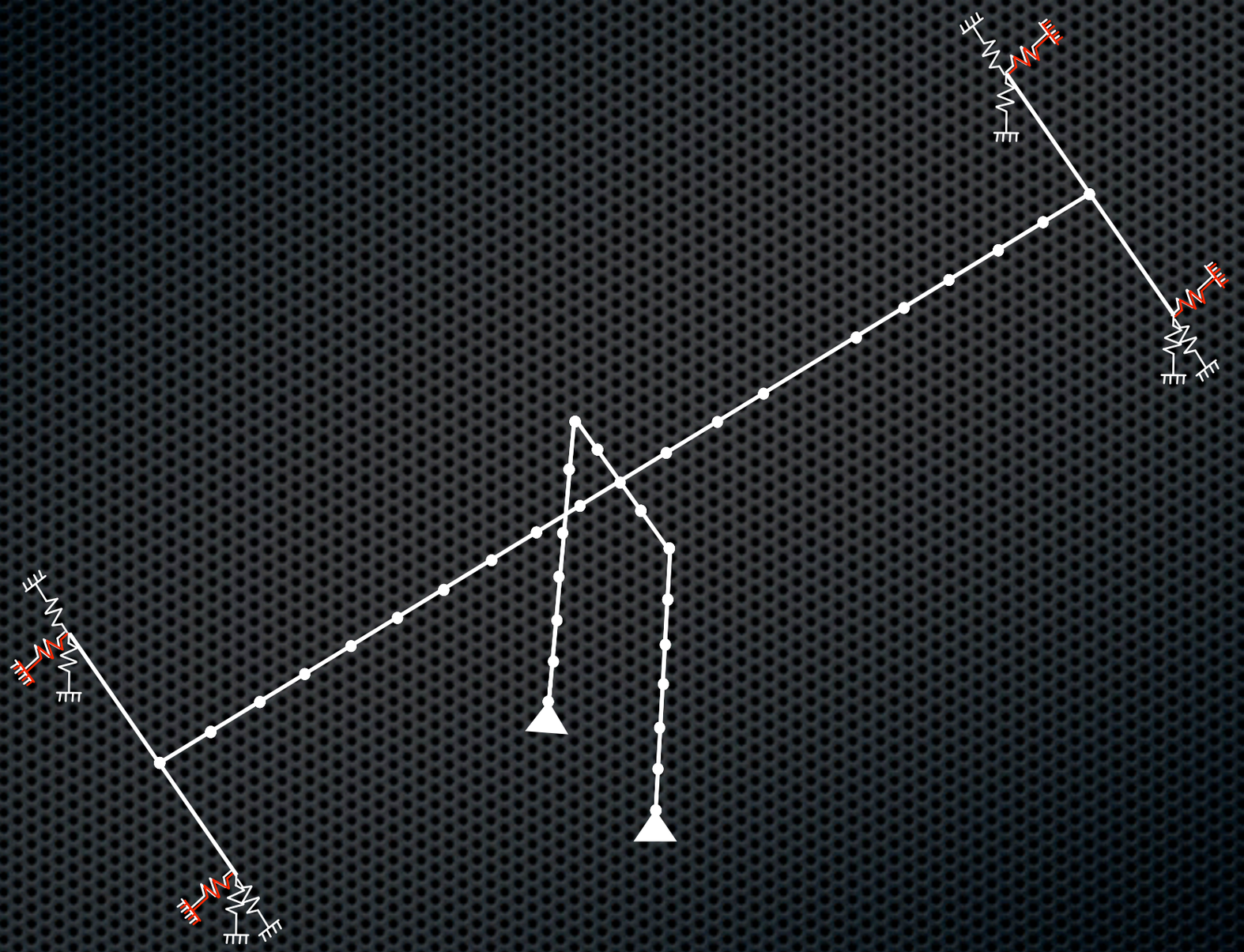
Engineering application.

$$\lambda(DV) = \int\int\int G(DV \mid DM) \cdot dG(DM \mid EDP) \cdot dG(EDP \mid IM) \cdot d\lambda(IM)$$

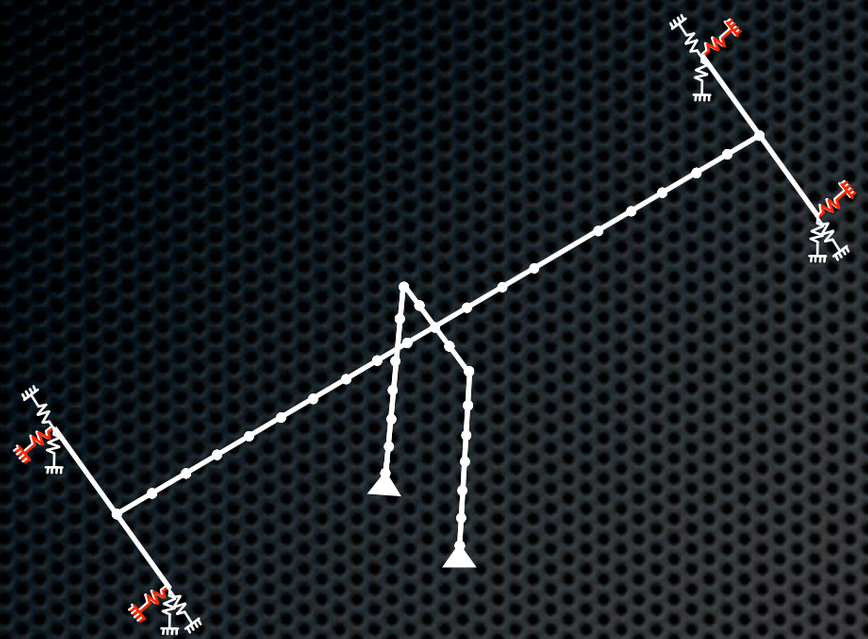
Anatomy of Bridge Model



Anatomy of Bridge Model



Anatomy of Bridge Model



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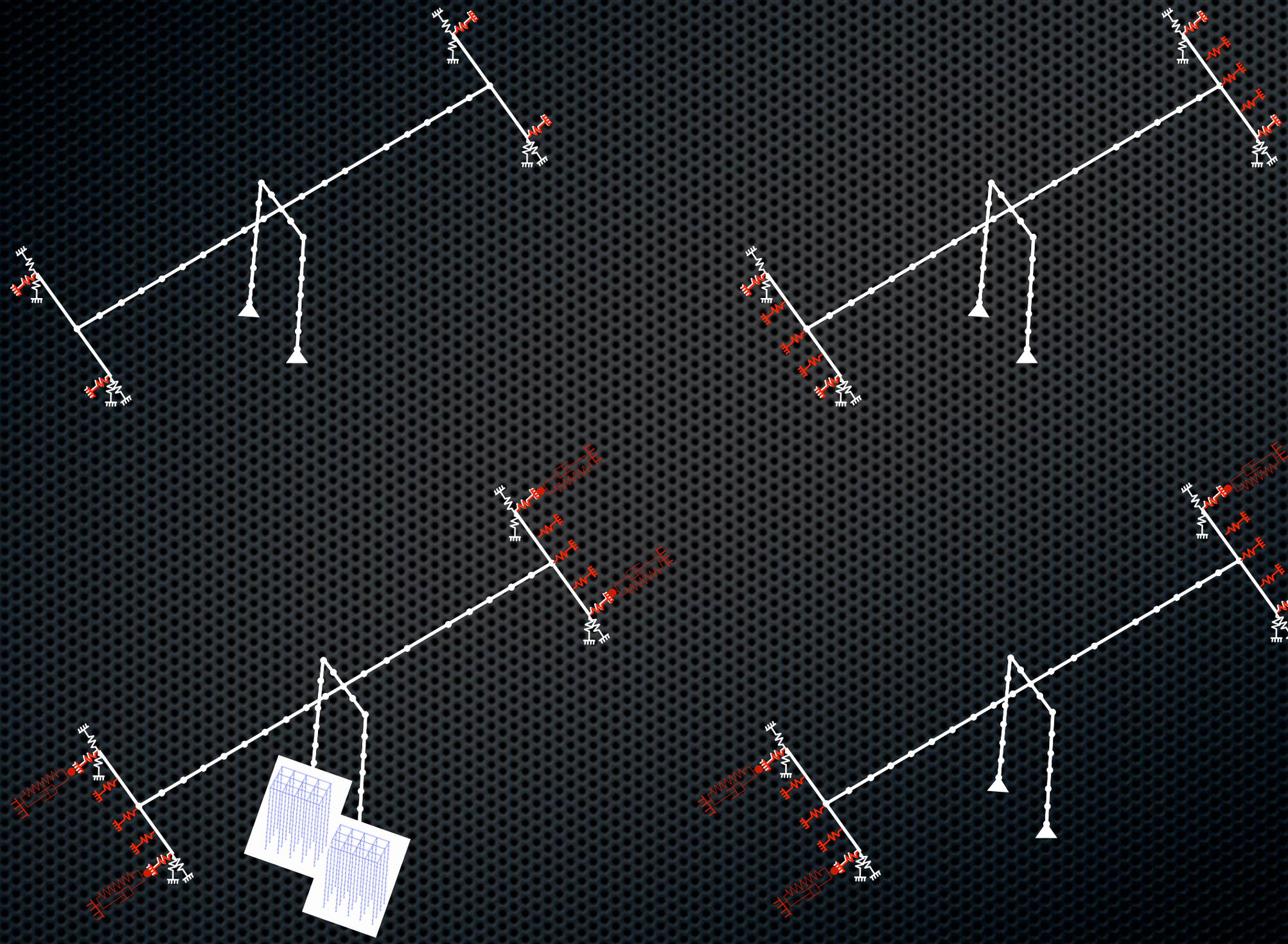
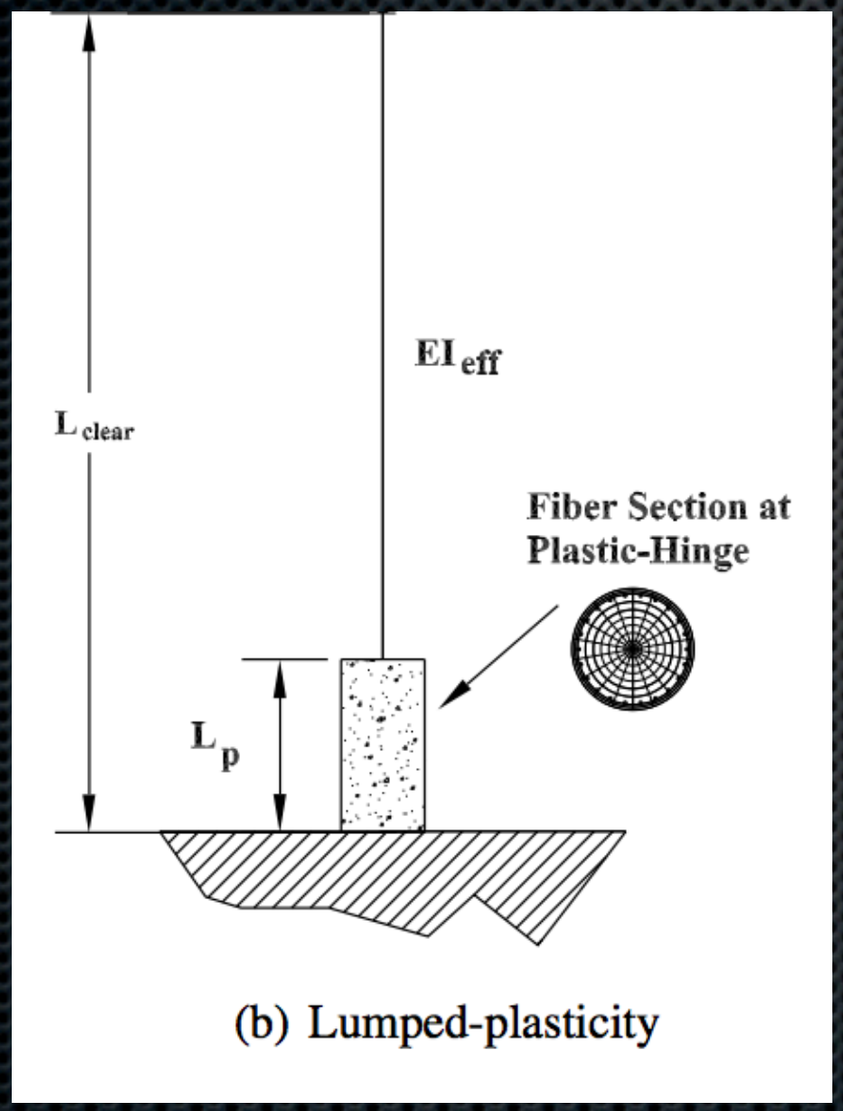


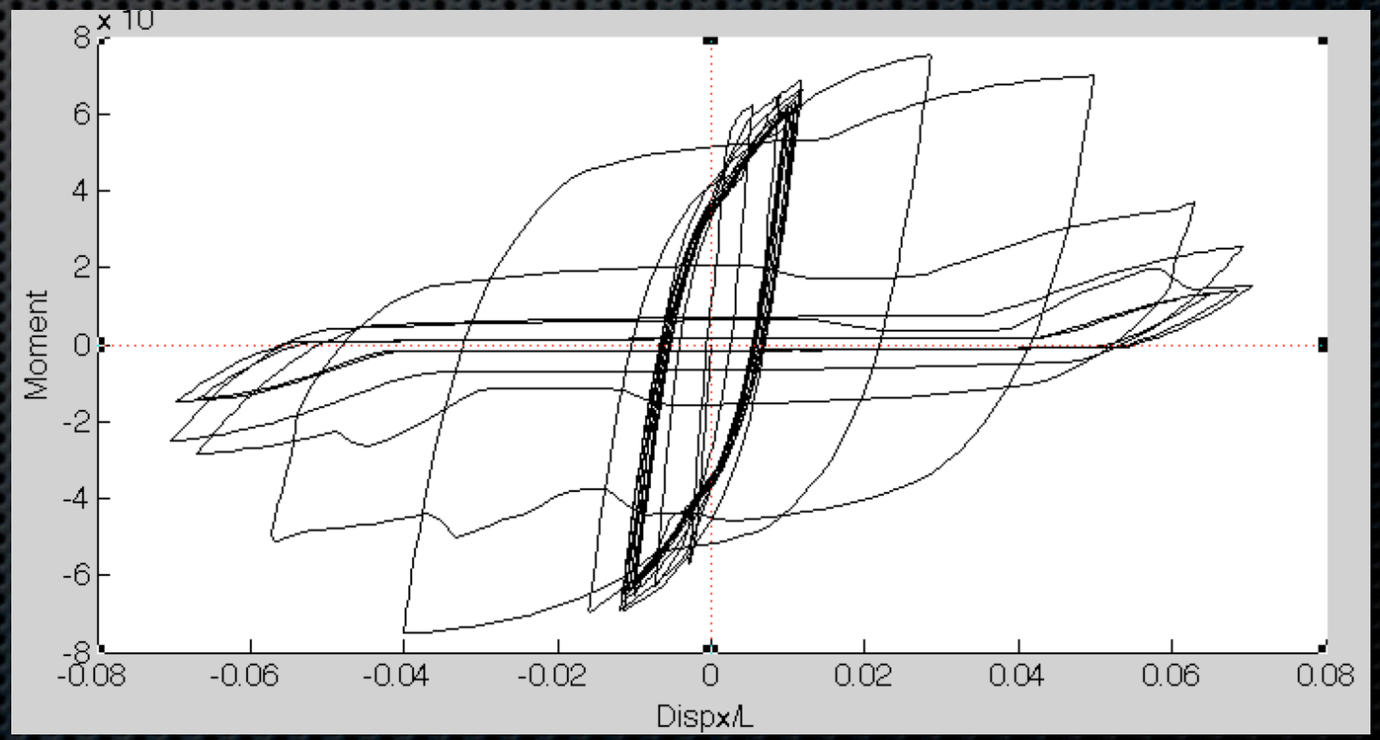
Column Modeling

Lumped- Plasticity

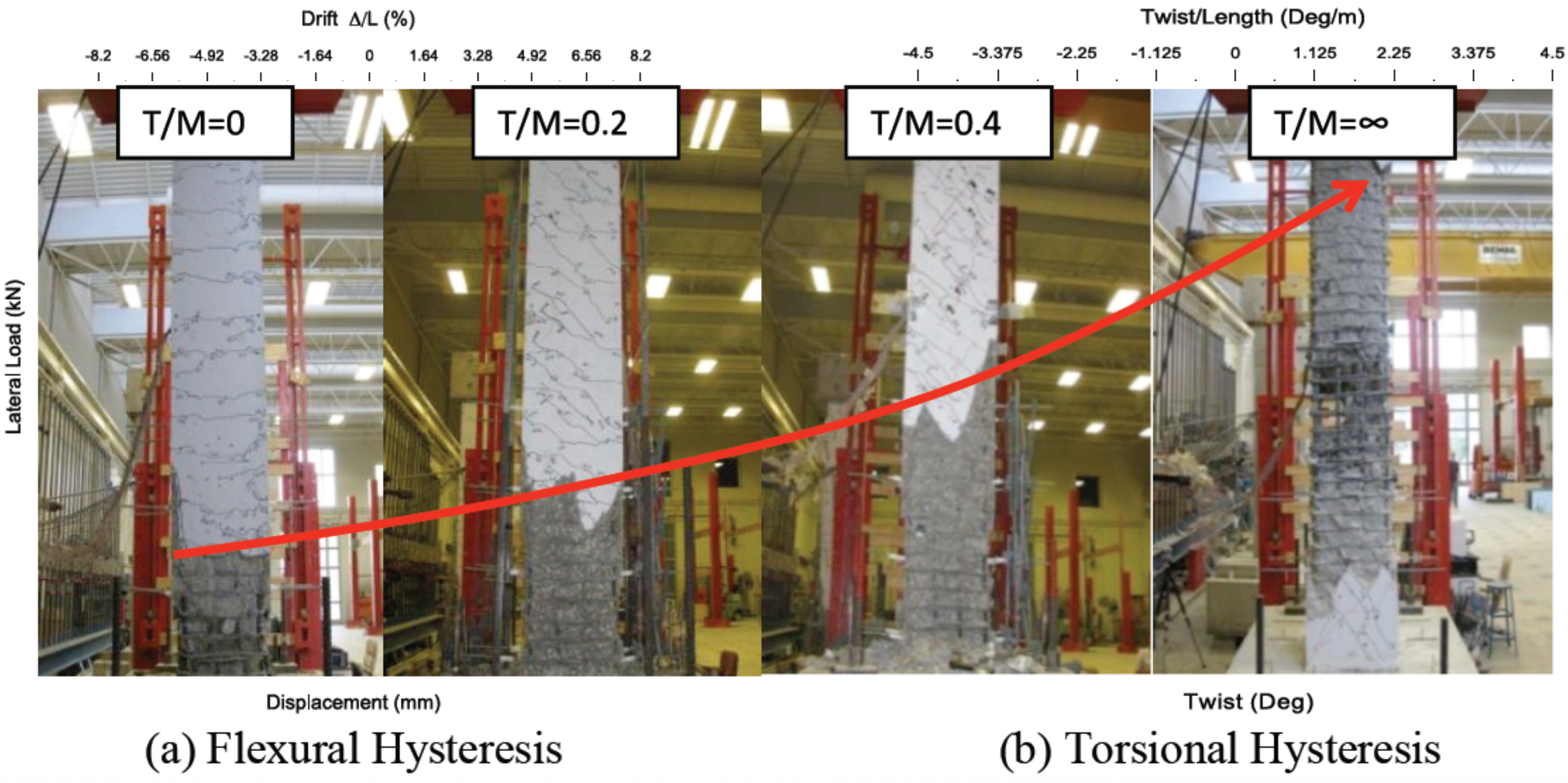


(b) Lumped-plasticity

- ✓Beam with hinges
- ✓Reinforcing steel
- ✓Concrete 01 with stuff in cracks



Column Modeling

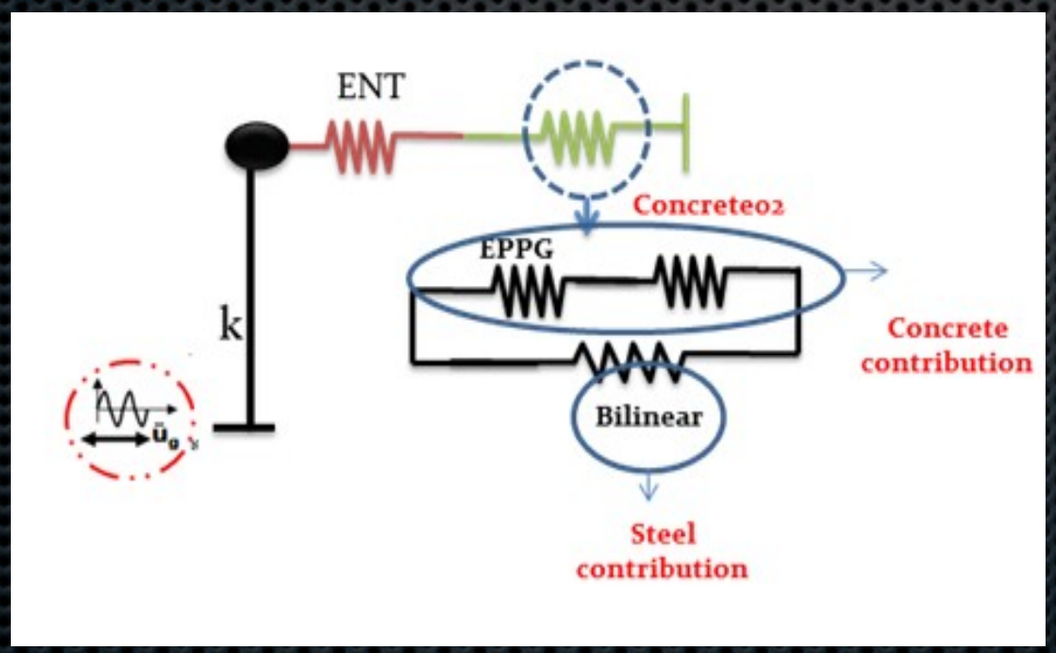


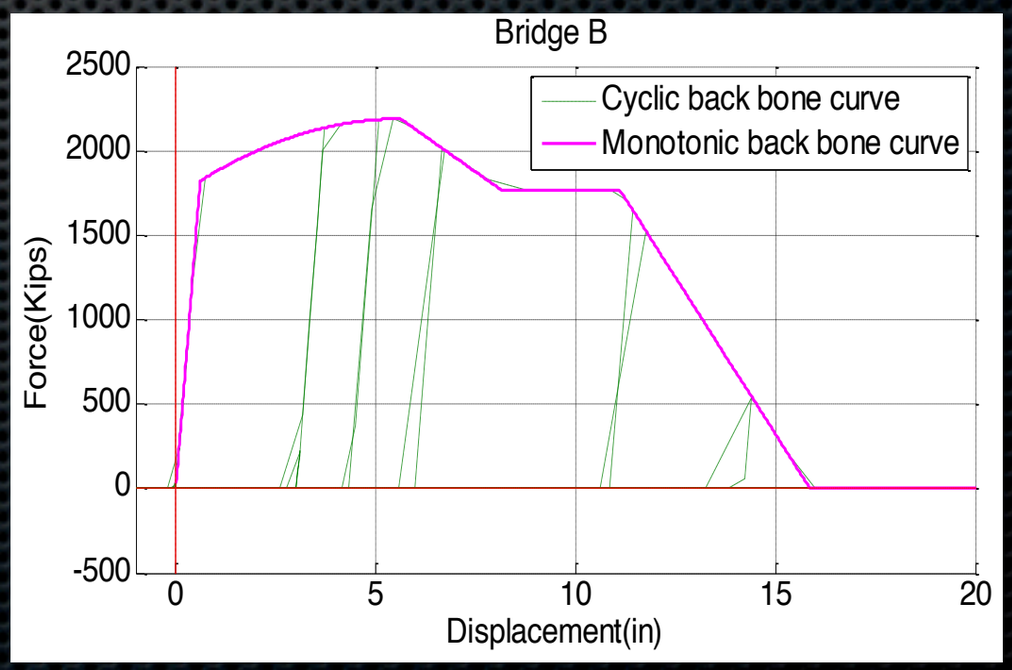
(a) Flexural Hysteresis

(b) Torsional Hysteresis

Source: Li & Belarbi

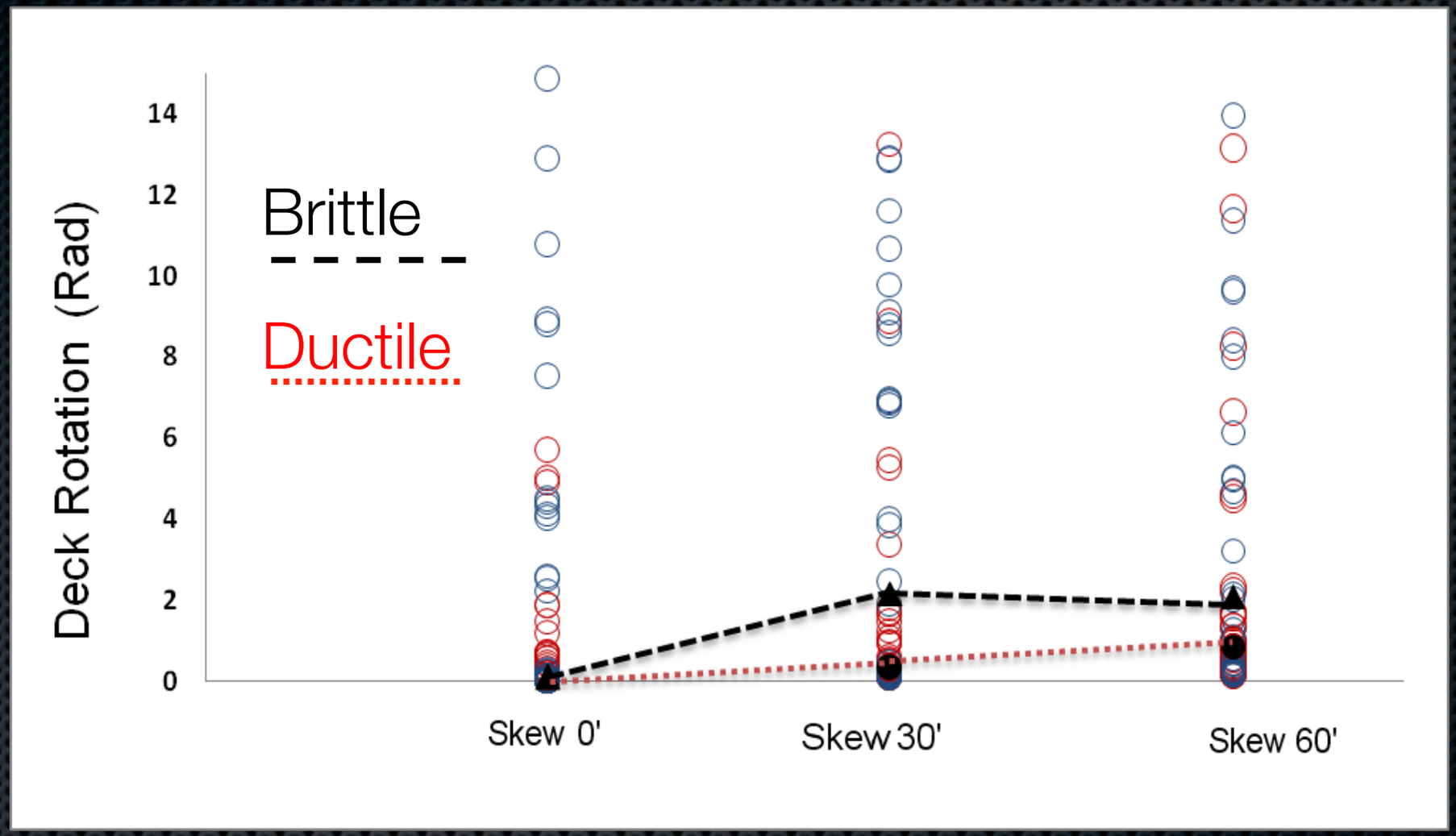
Shear Key Modeling





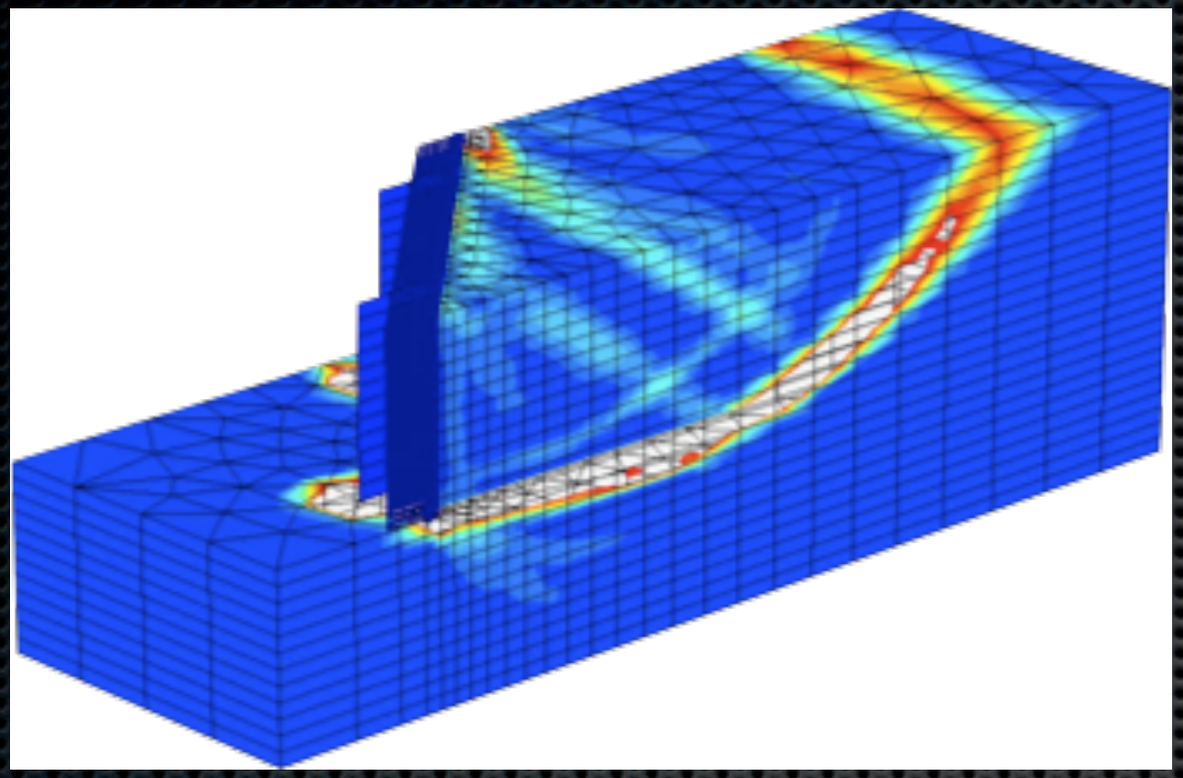
Source: Megally et. al.

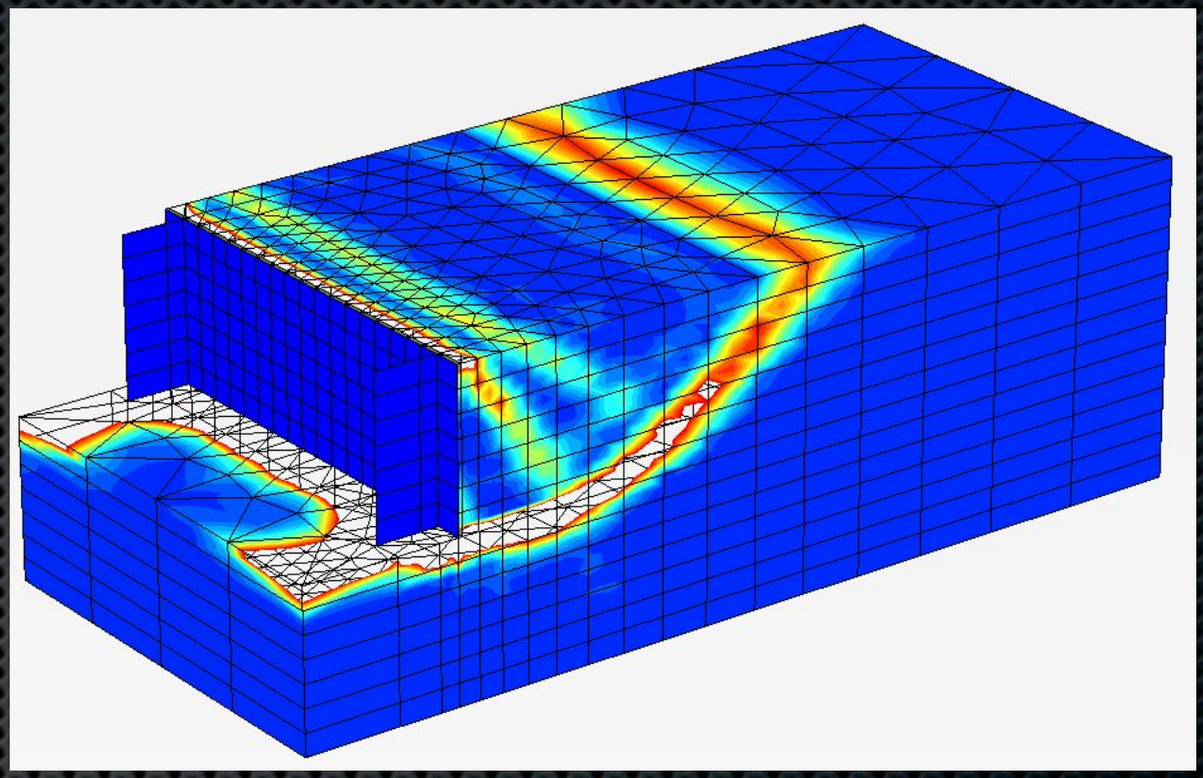
Shear Key Modeling

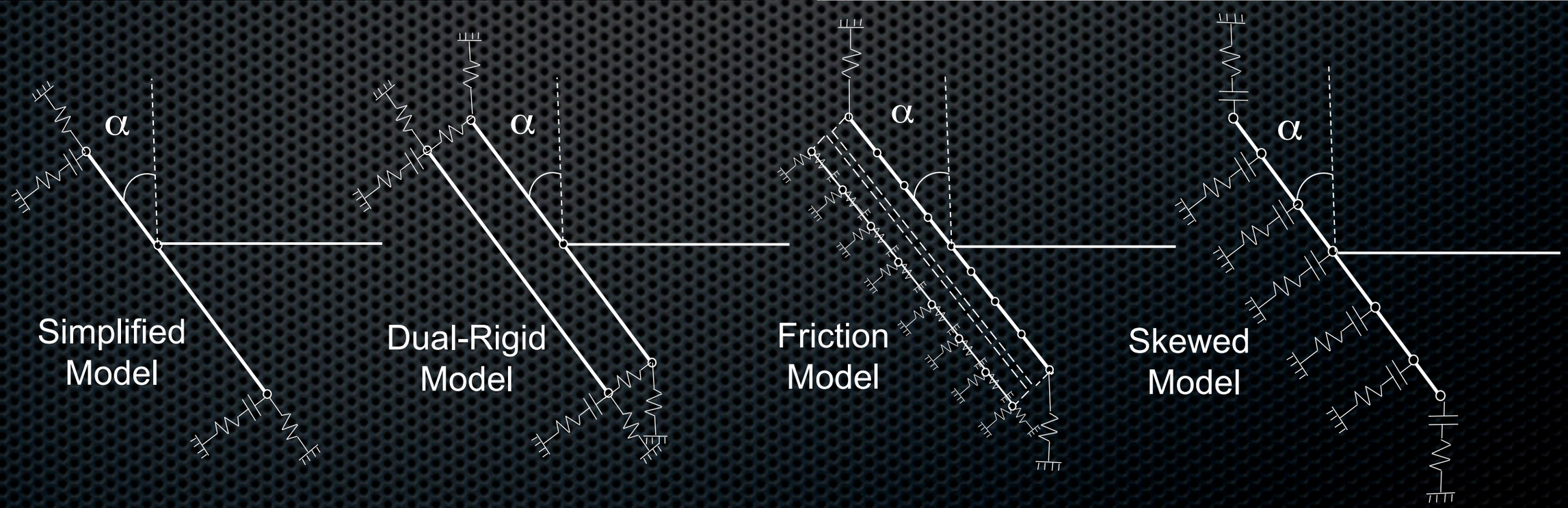


Effect of shear key modeling techniques on deck rotation for single column two span bridge.

Abutment Modeling



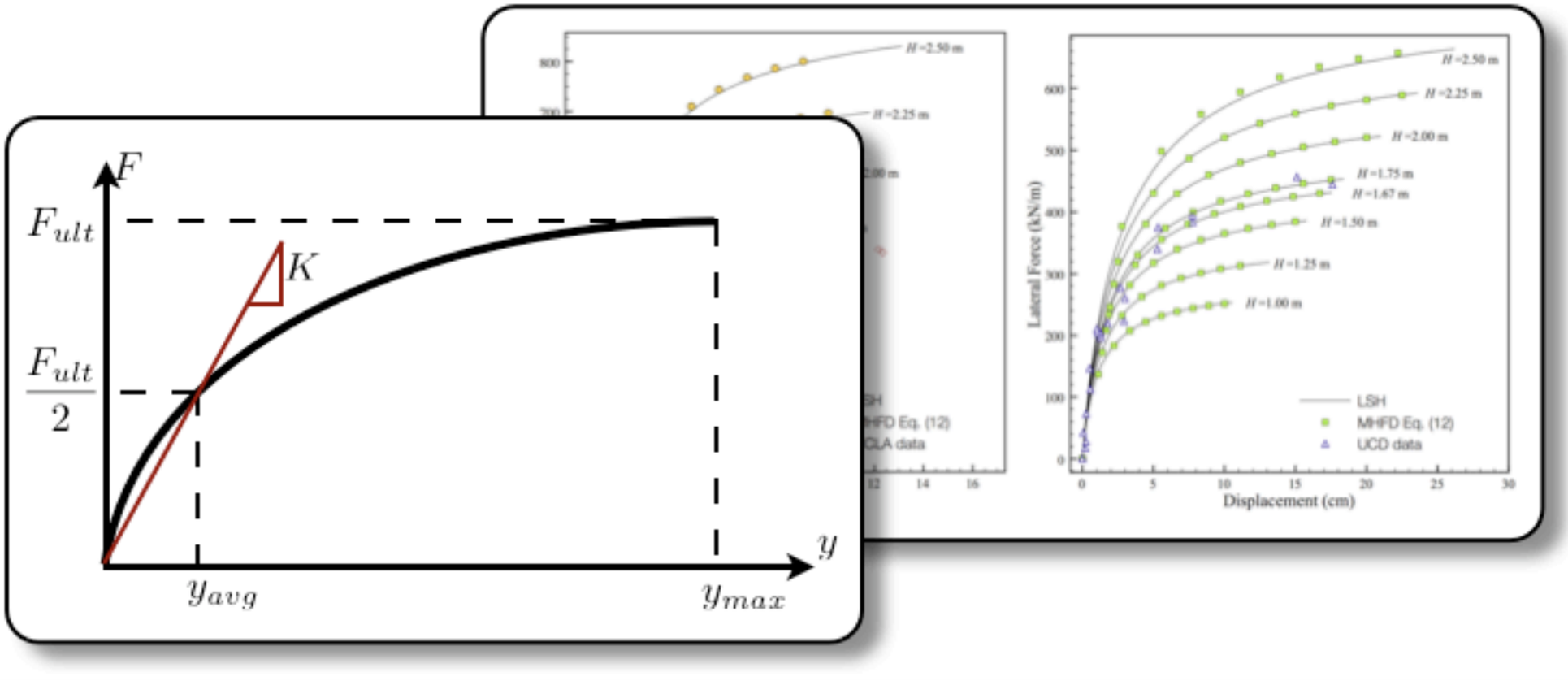




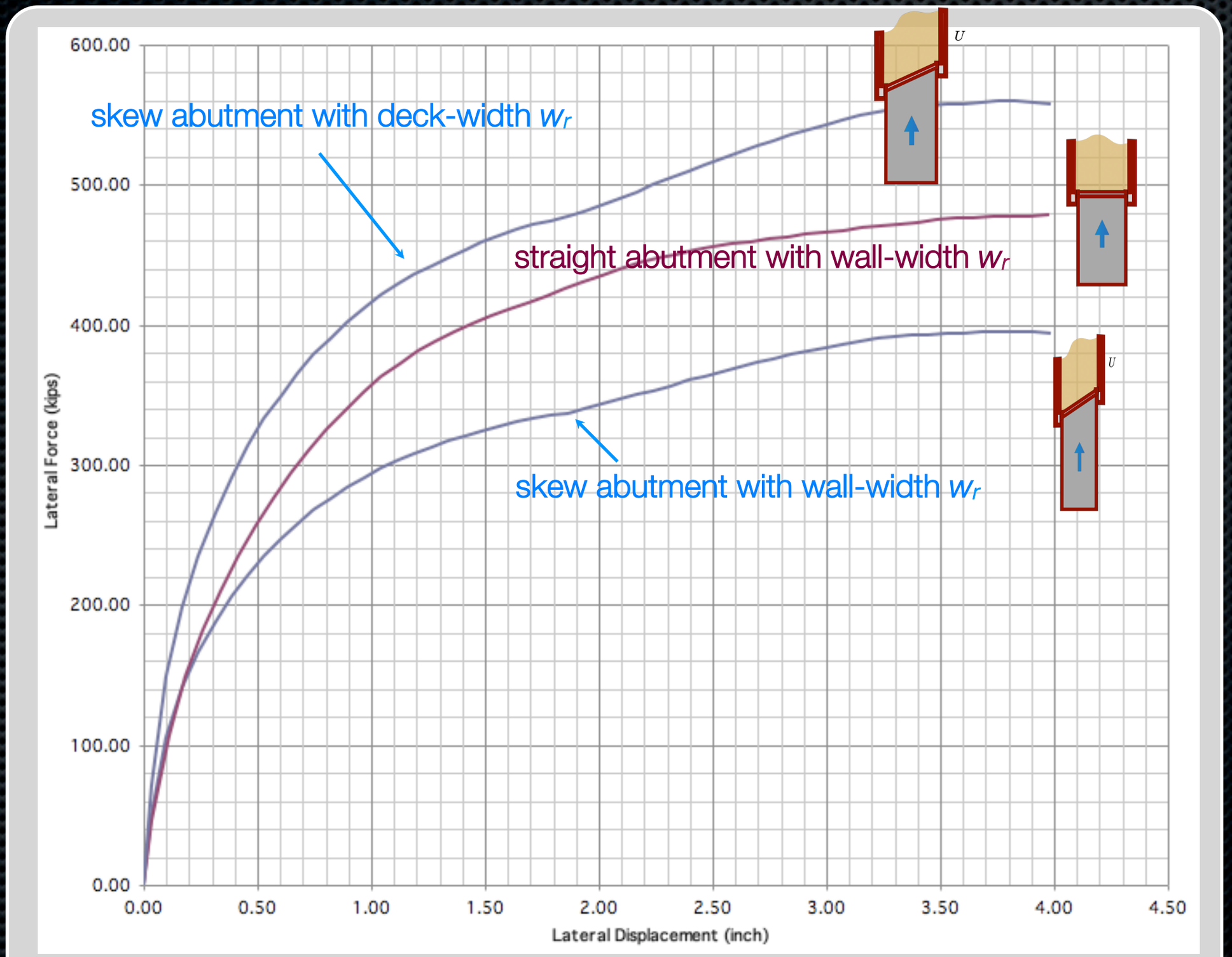
Abutment Modeling

Generalized Hyperbolic Force-Displacement (GHFD) Model Straight Abutments

- Backwall height-dependence is explicitly modeled
- Model parameters are physical soil properties

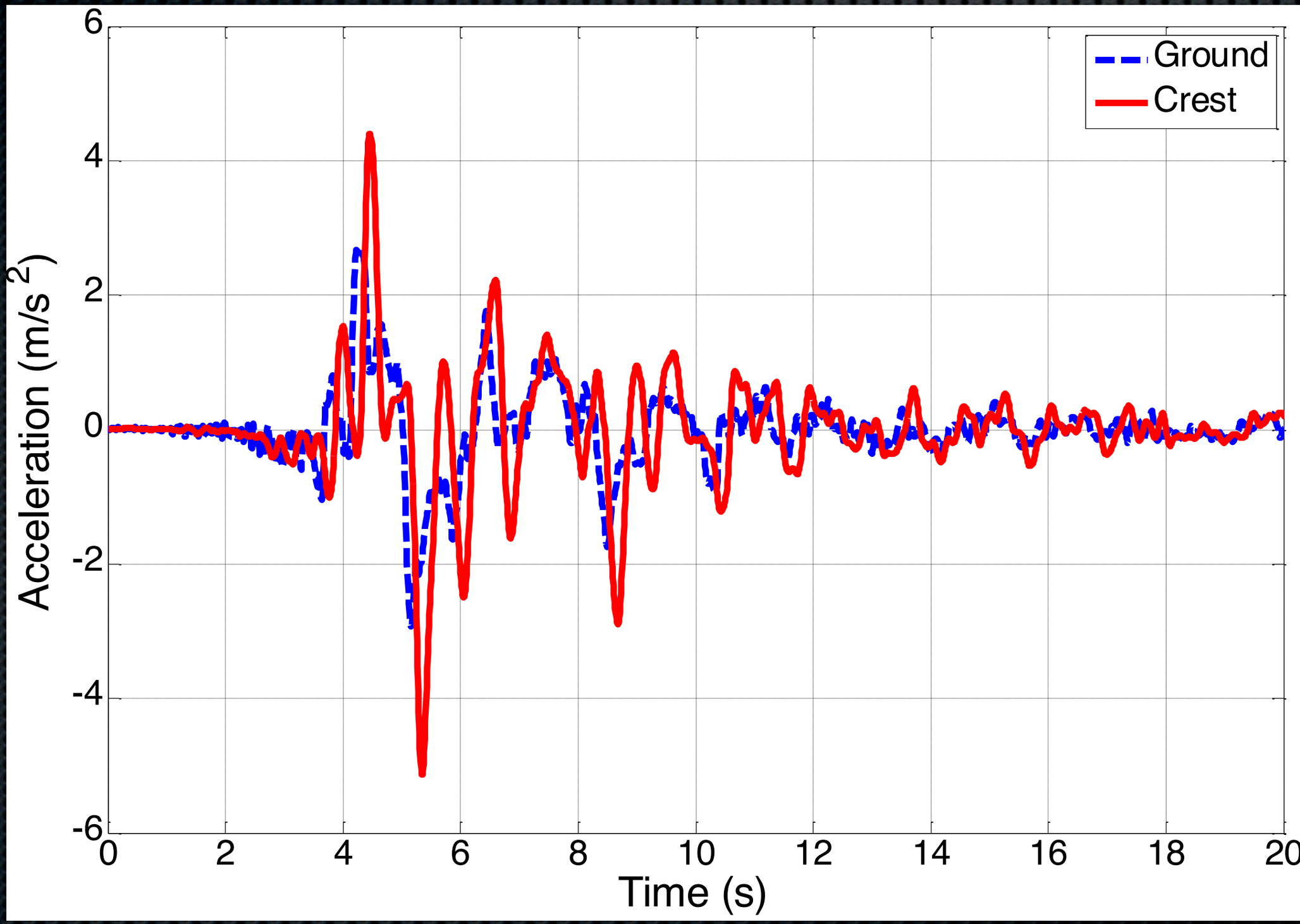


Abutment Modeling



Nonuniform Excitation

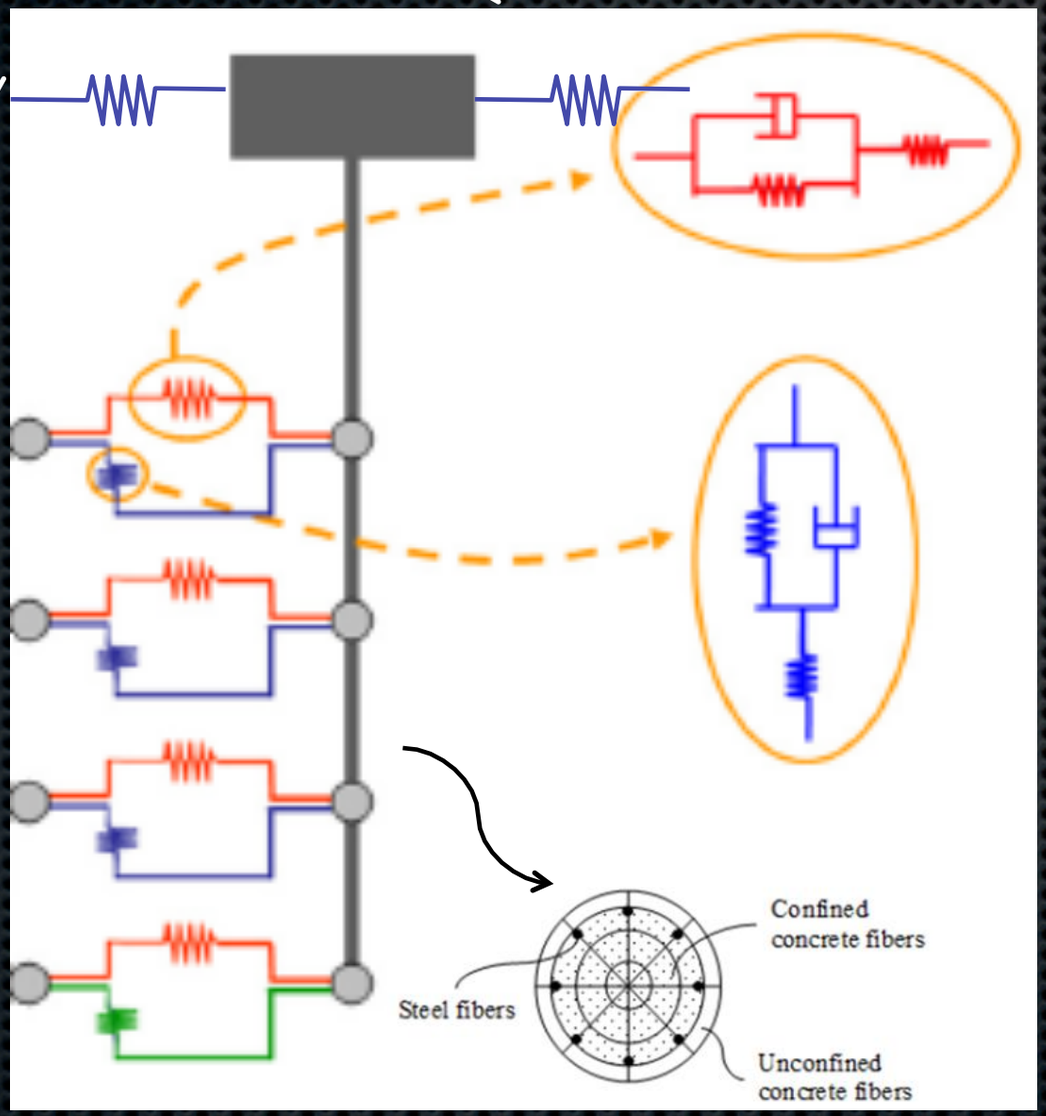
Meloland Road Overcrossing subjected to
1979 Imperial Valley earthquake (Zhang & Makris (2002))



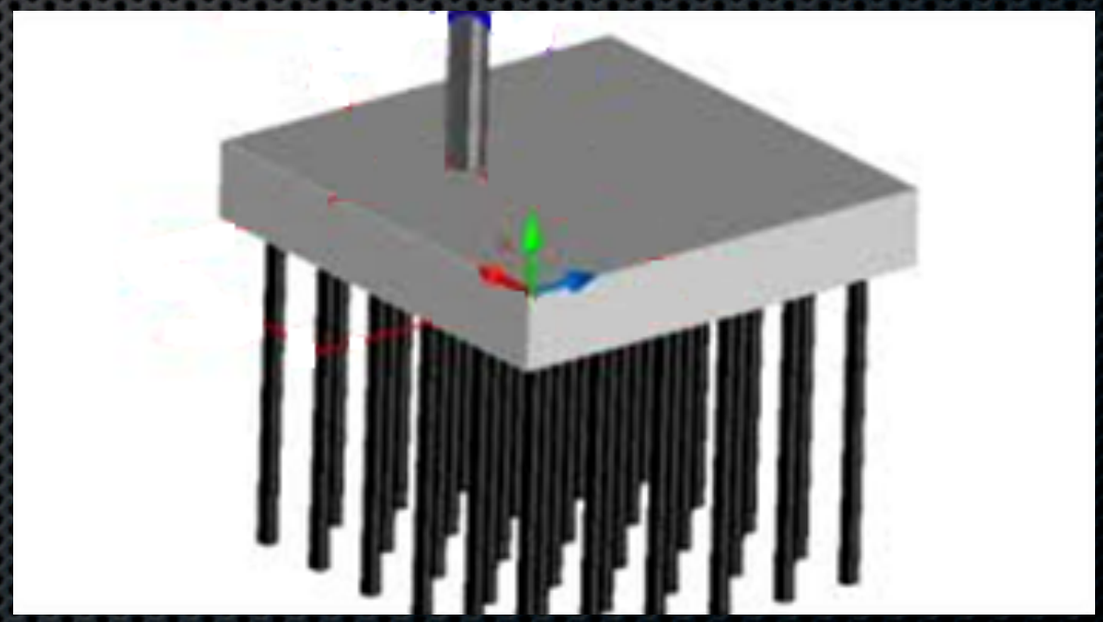
Nonuniform Excitation

HyperbolicGapMaterial

ShellMITC4 element



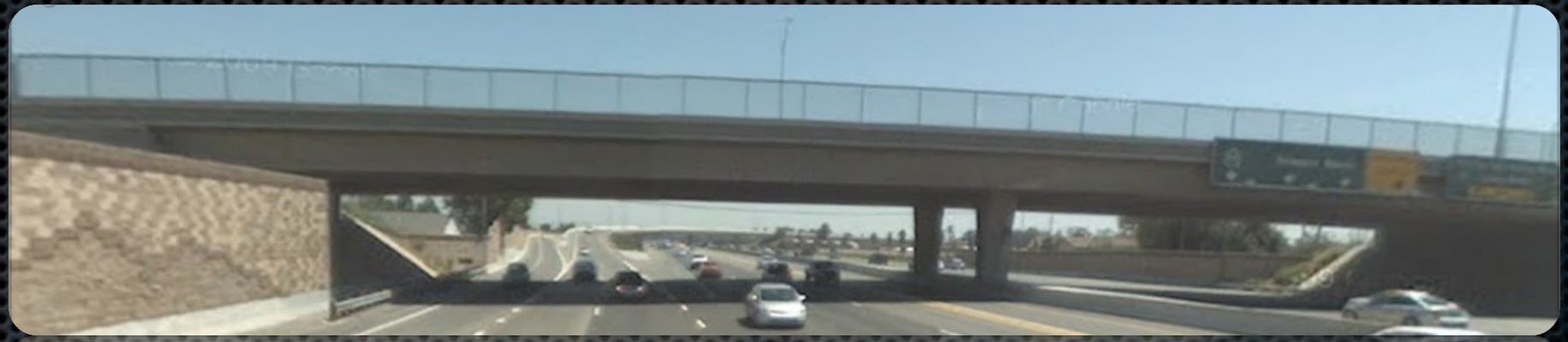
Pile Group Effects



The Bridge Matrix

The Jack Tone Road On-Ramp Overcrossing

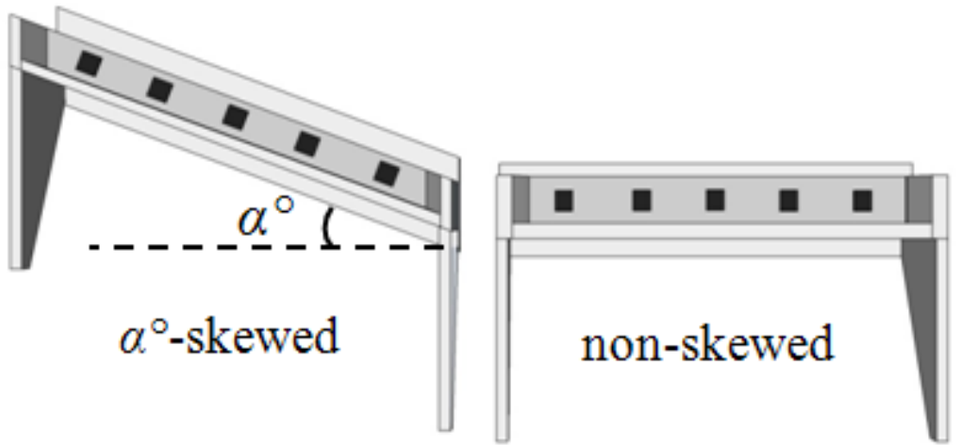
The La Veta Avenue Overcrossing



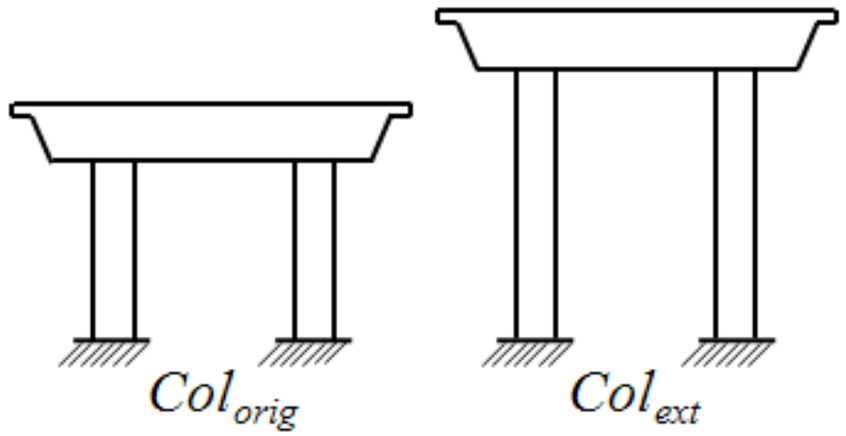
The Jack Tone Road Overhead

The Bridge Matrix

Abutment skew angle
- 0°
- 15°
- 30°
- 45°
- 60°



Column-bent height
- ➢Original height (Col_{orig})
- ➢Extended height ($Col_{ext} = 1.5 \times Col_{orig}$)



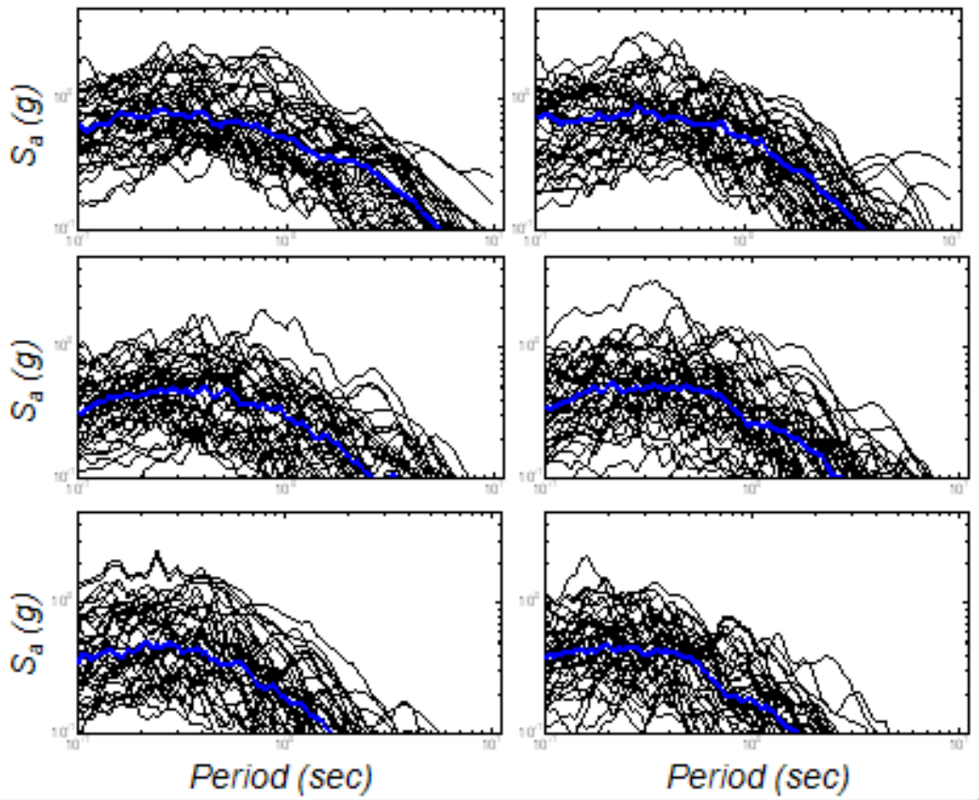
Span arrangement
- ➢Symmetric
- ➢Asymmetric

Bridges	Symmetric	Asymmetric
"Bridge A"	L_A L_A	$1.2L_A/1.1$ $L_A/1.1$
"Bridge B"	L_B L_B	$1.2L_B/1.1$ $L_B/1.1$
"Bridge C"	$1.1L_C$ L_C $1.1L_C$	$1.2L_C$ L_C L_C

The Bridge Matrix

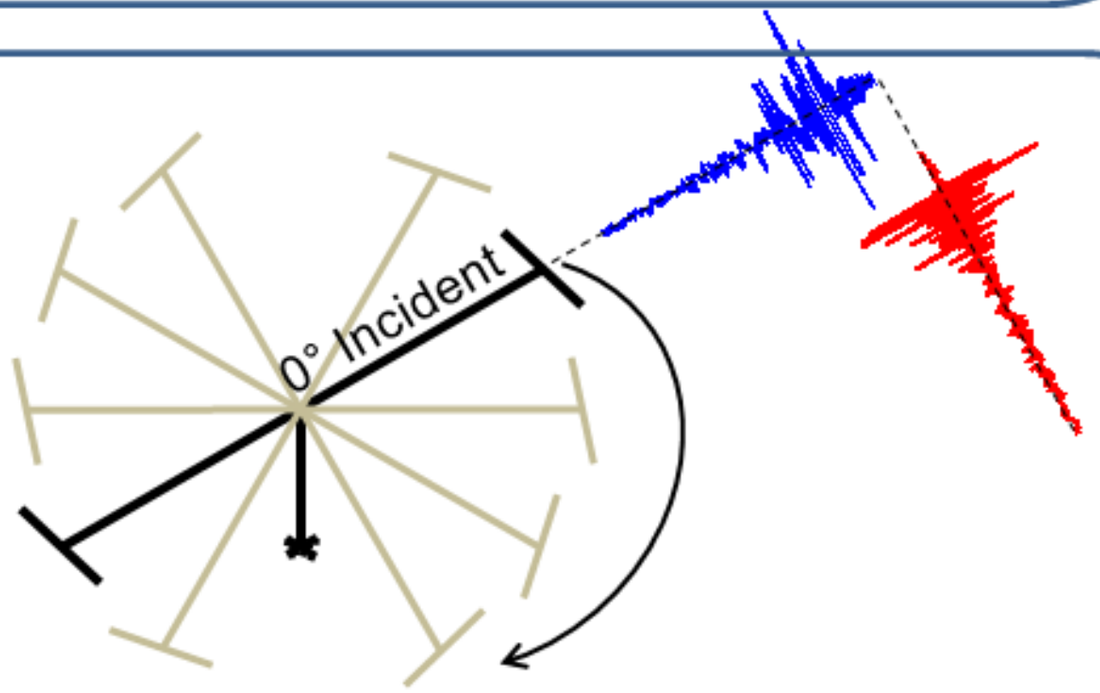
Ground Motion Type

- ➢Pulse-like
- ➢Soil-site
- ➢Rock-site

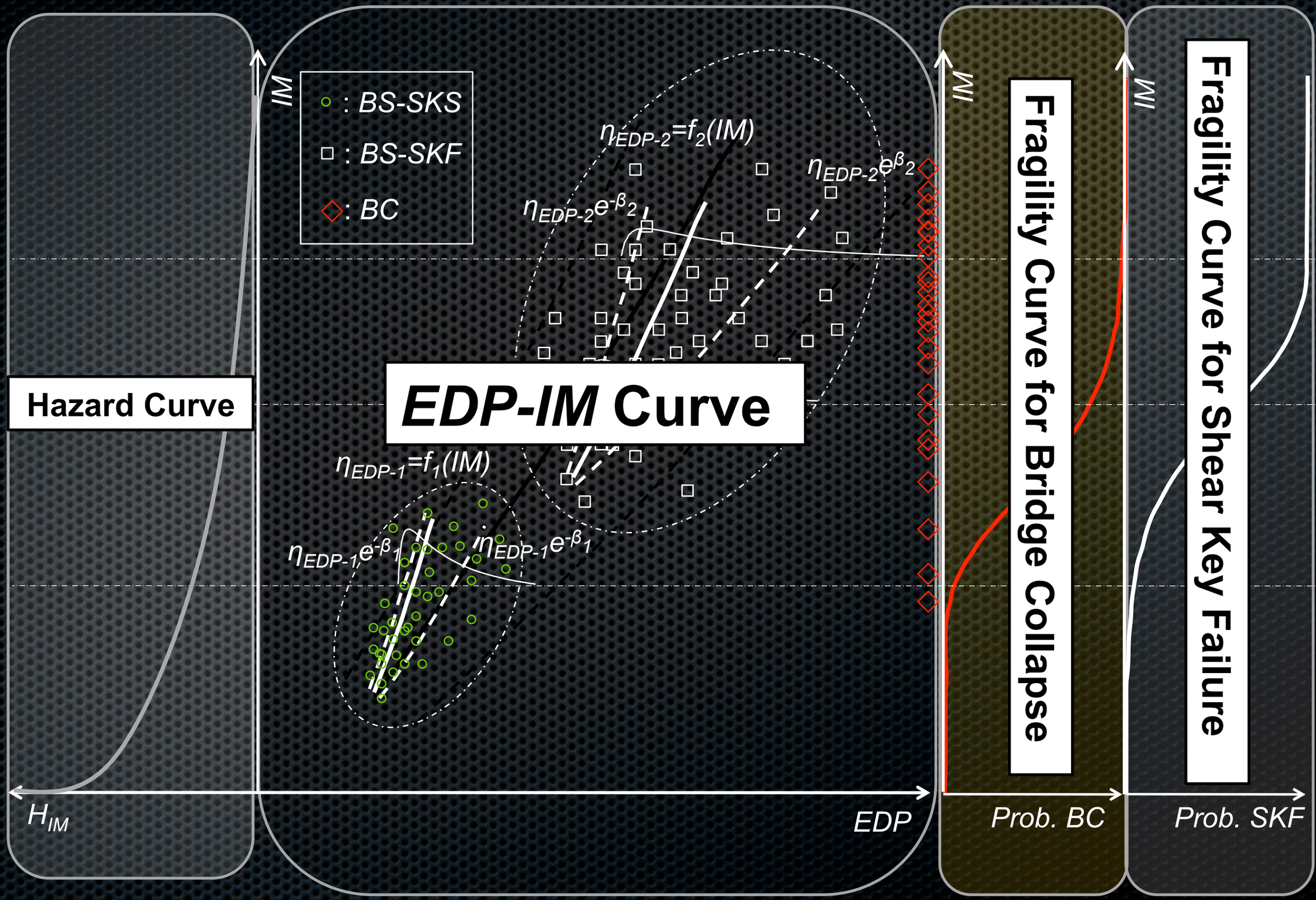


Incidence Angle

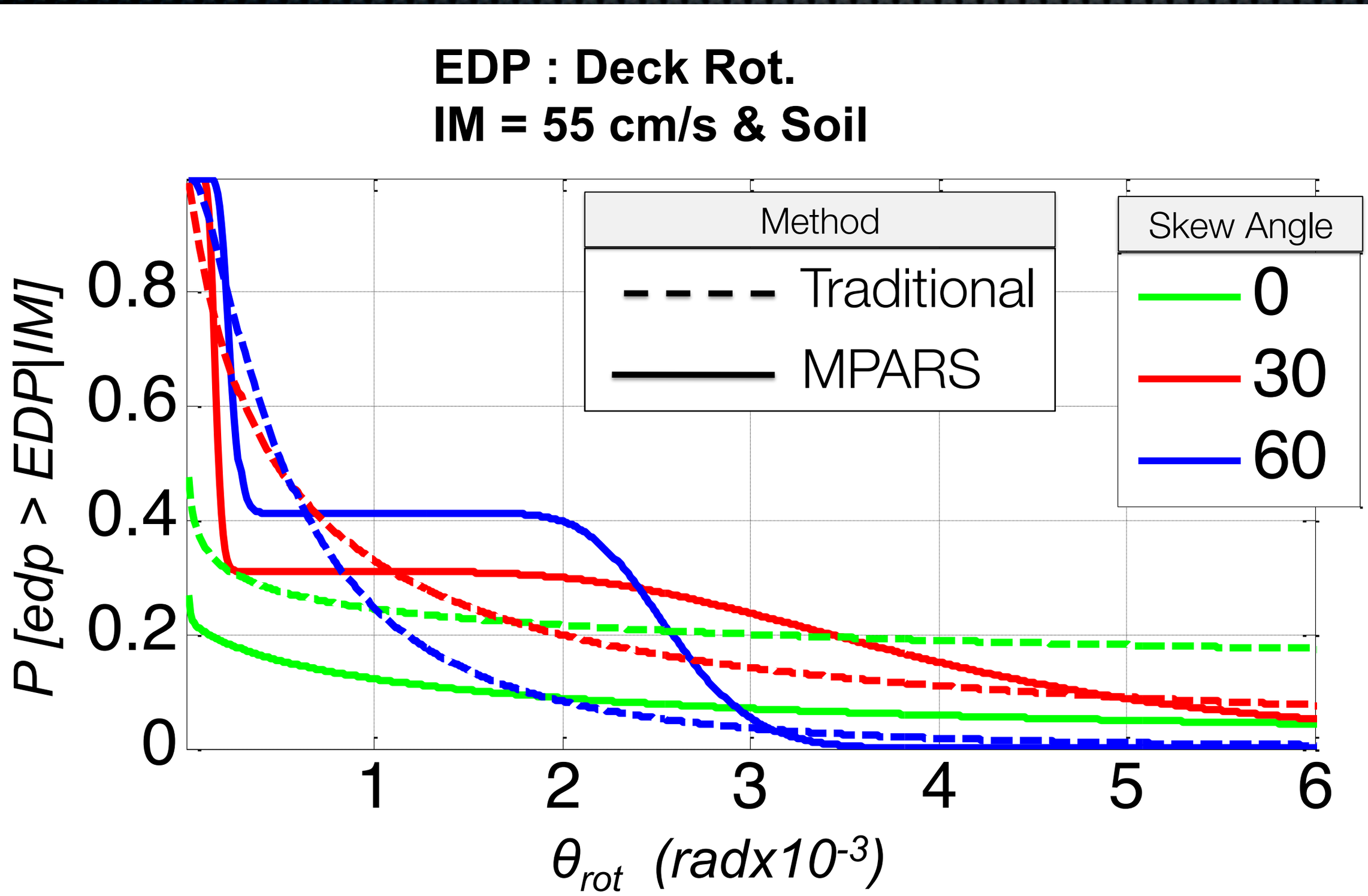
- 0°
- 30°
- 60°
- 90°
- 120°
- 150°



Multi-phase IM-EDP



Deck Rotation – Bridge A



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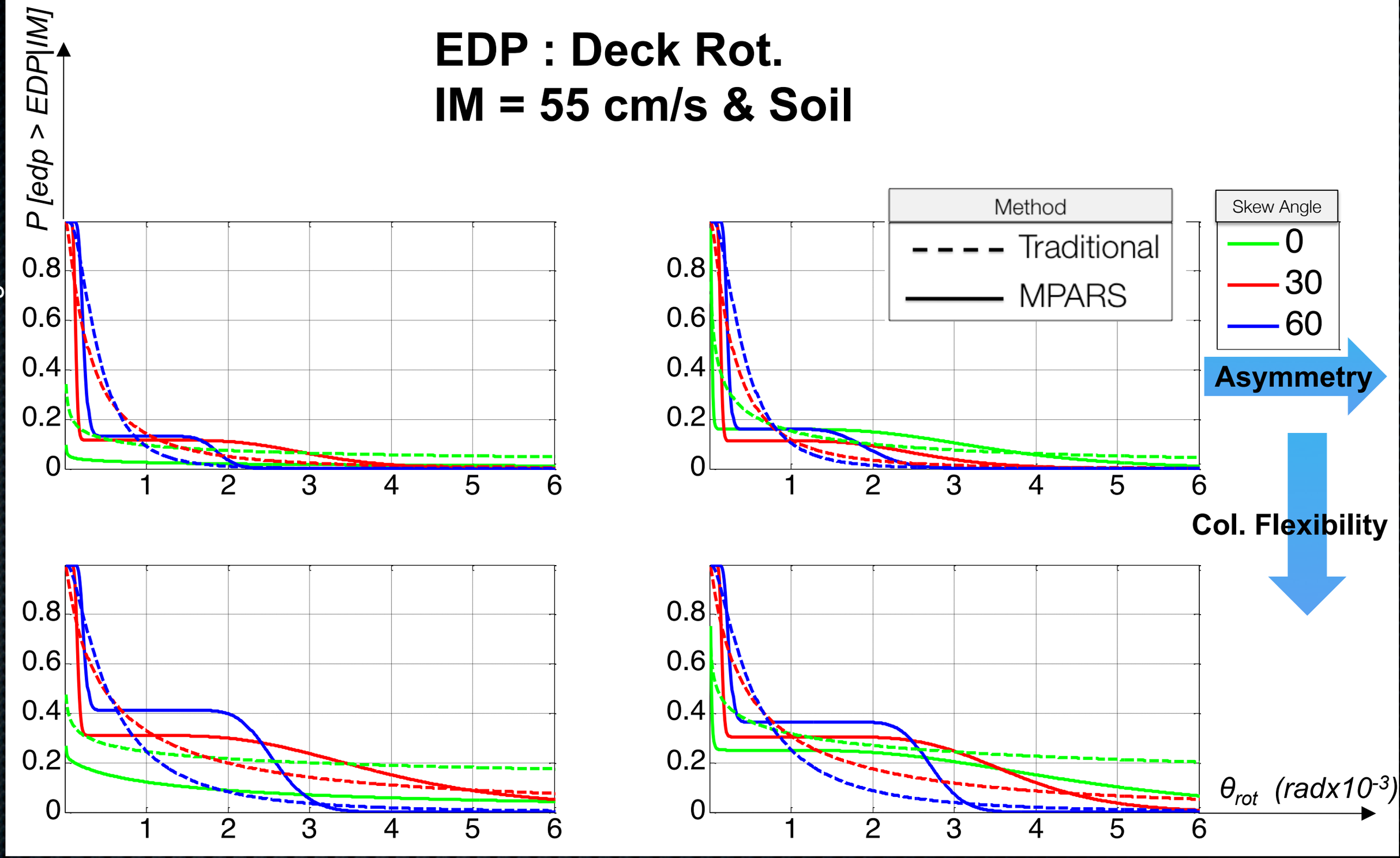
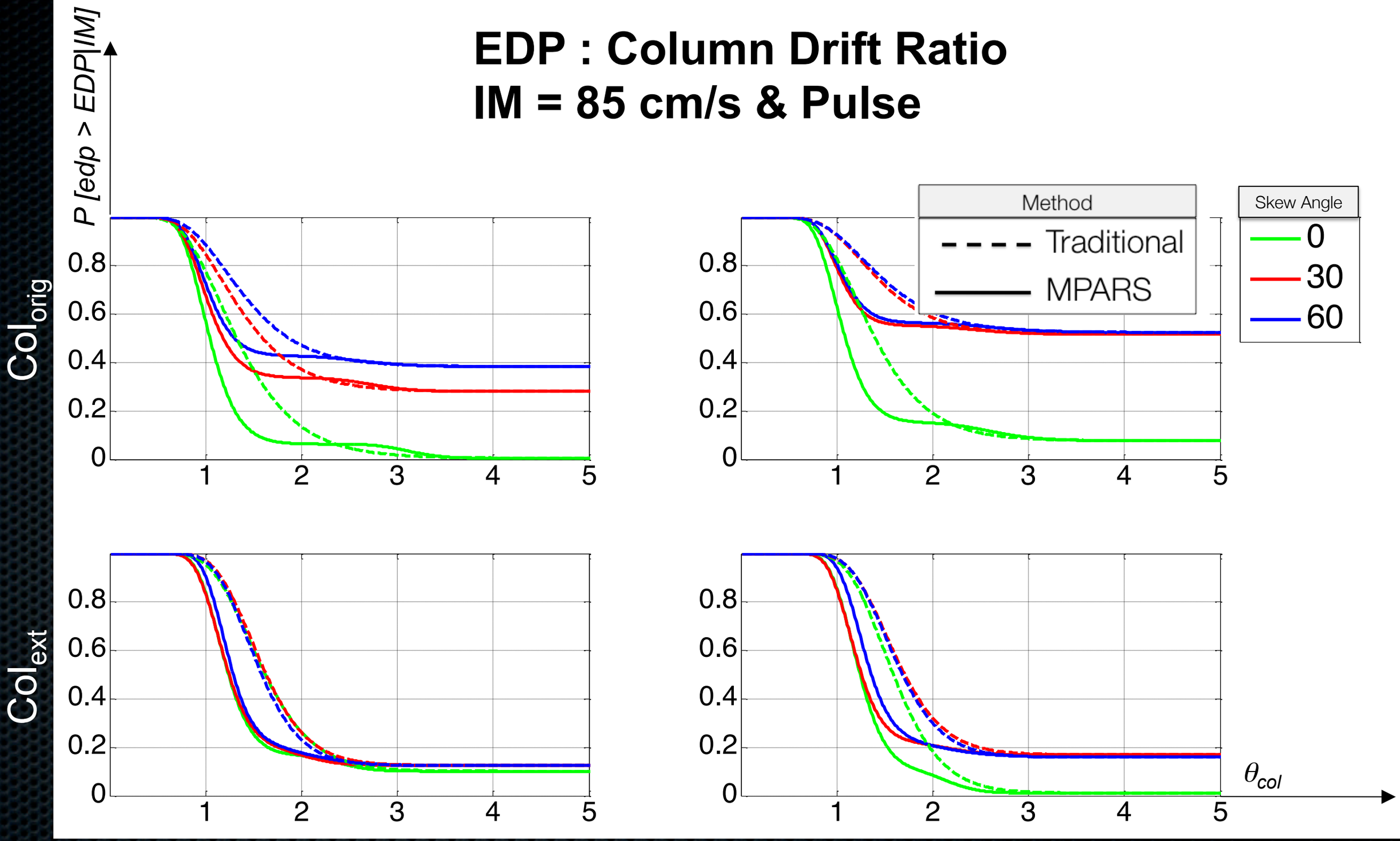
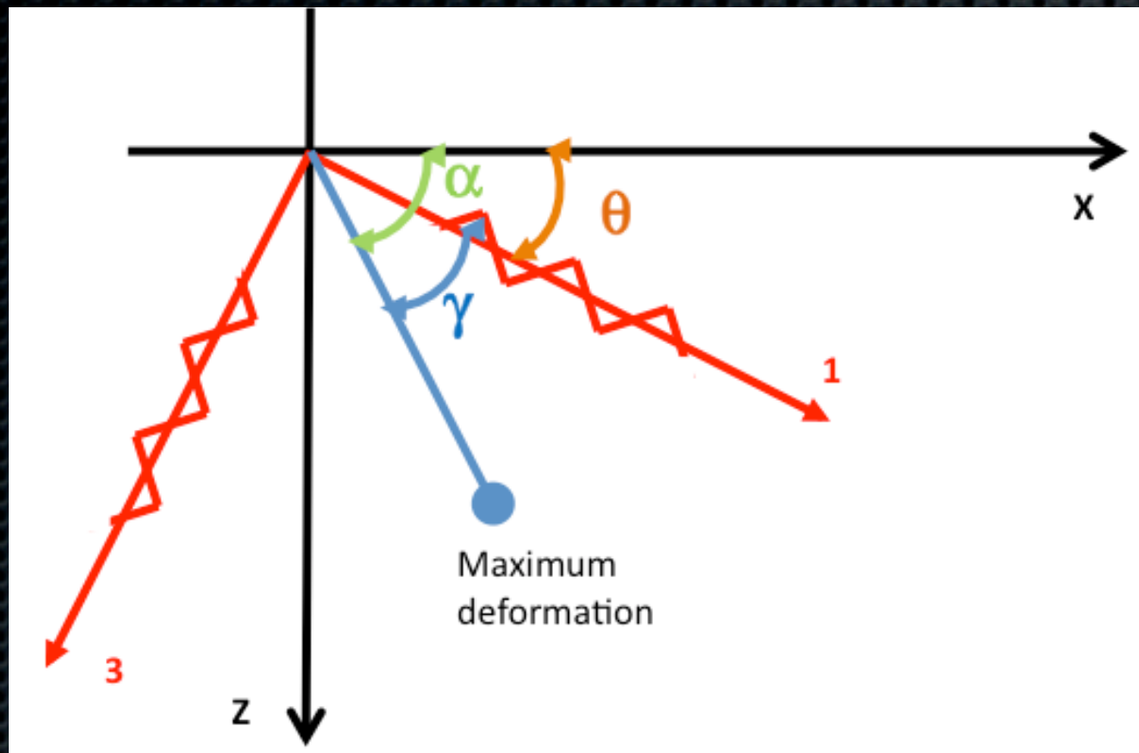


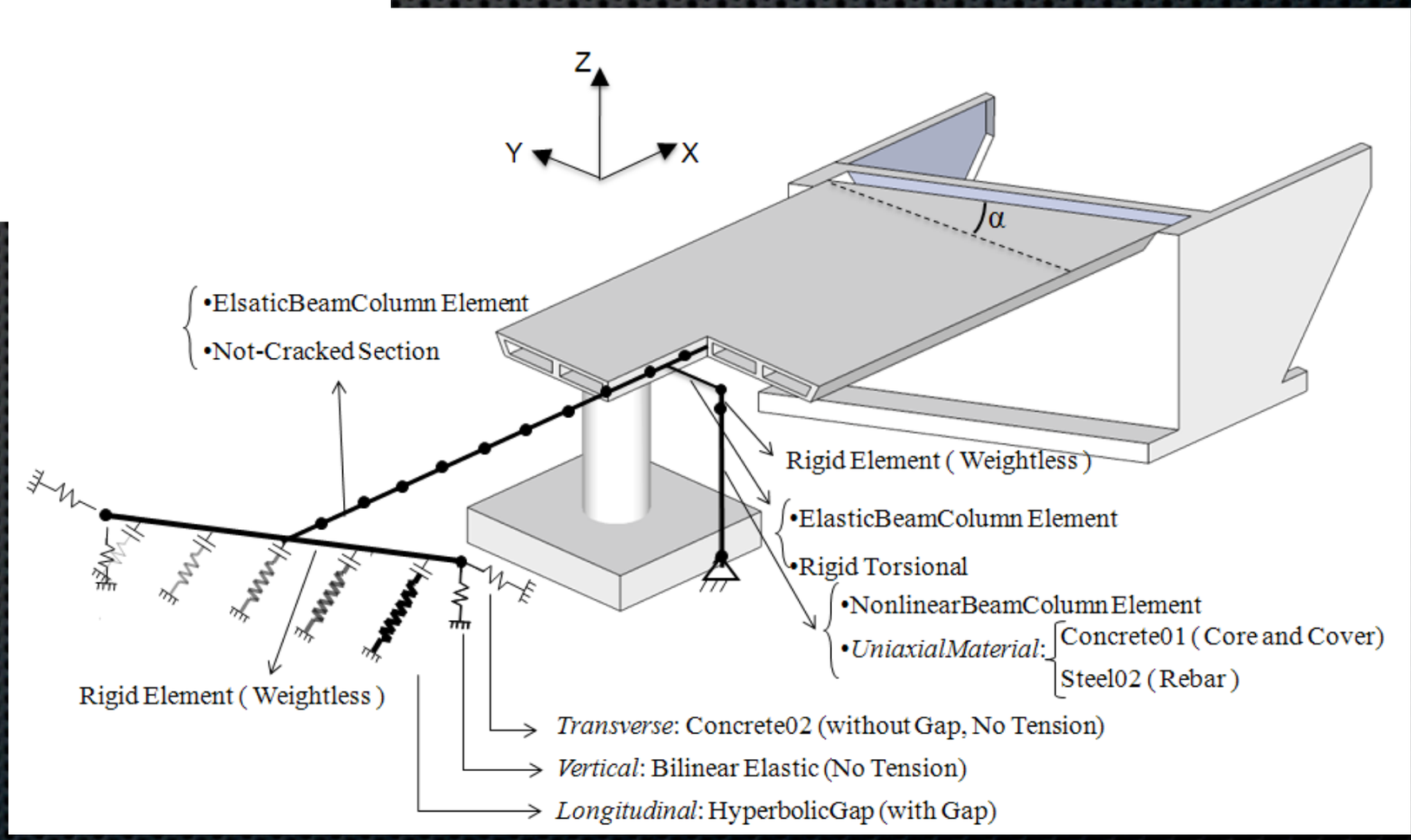
Col. Drift Ratio – Bridge A

EDP : Column Drift Ratio
IM = 85 cm/s & Pulse



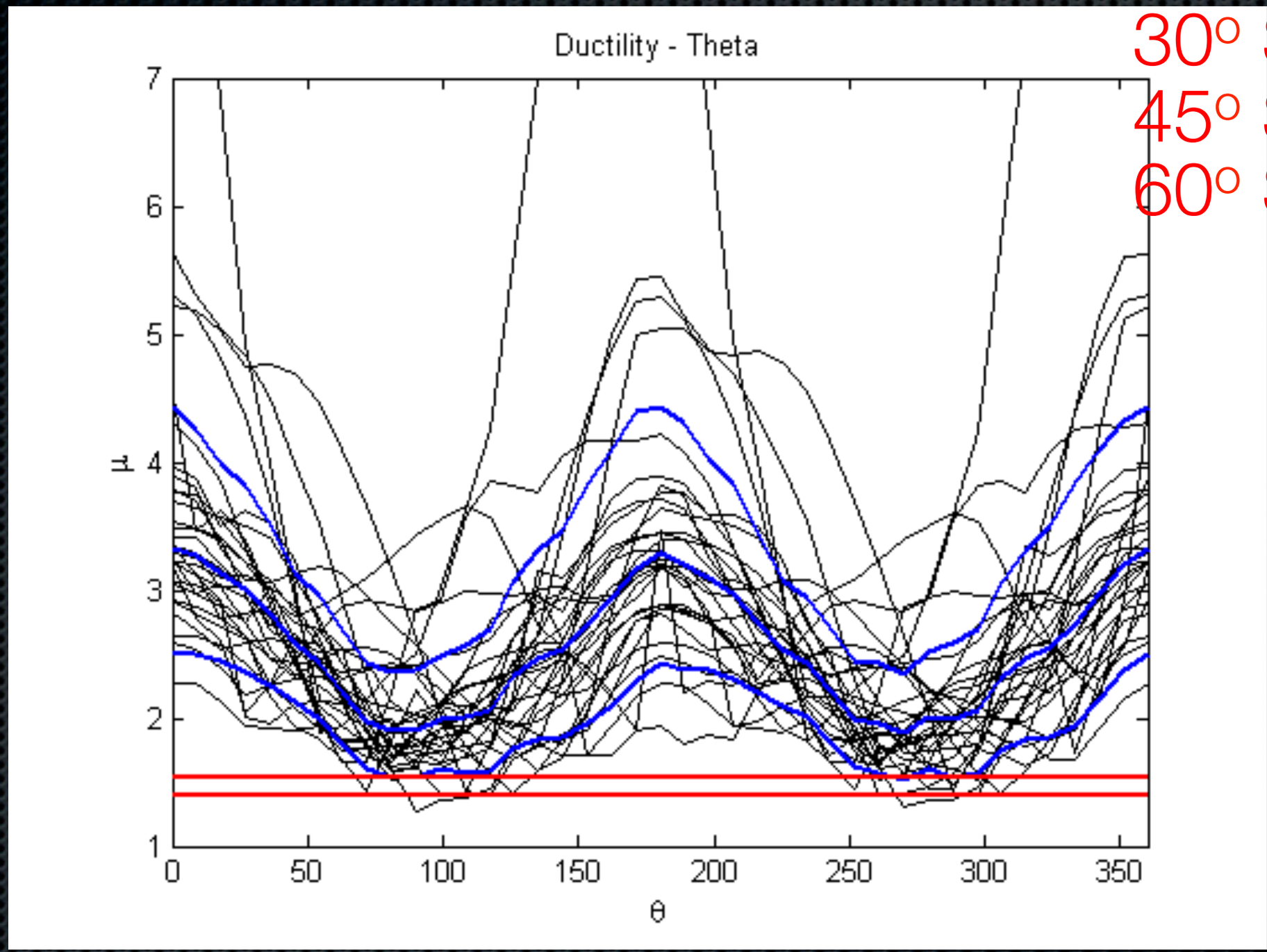
GM Directionality Effect





GM Directionality Effect

15° Skew
30° Skew
45° Skew
60° Skew



Column Ductility

Ground Motion Incidence Angle

Future Research Directions

1. Extension of the study to other type of bridge configurations
   - Abutments (e.g., monolithic),
   - Geometry (e.g., curved deck),
   - New Technologies (e.g., self-centering columns)
2. Define rigorous structural damage measures and collapse indicators
3. Performance assessment at the network level
4. Enhancement in component and ground motion modeling

Thank You