Traffic Load Capacity of a Bridge Damaged in an Earthquake

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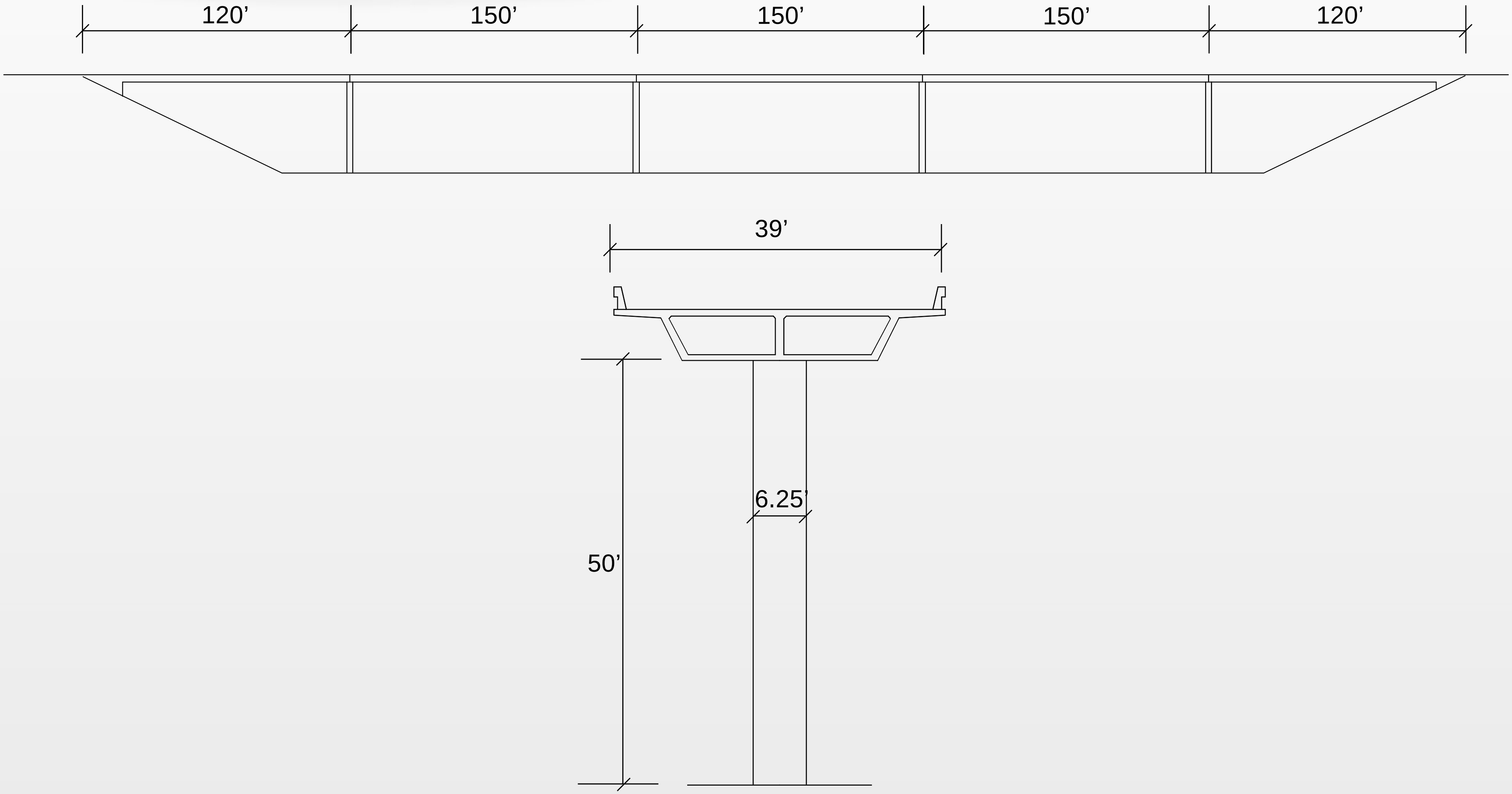
PEER

Caltrans

Introduction

Post-earthquake bridge traffic load capacity?

Prototype Bridge



Ketchum et. al., 2004

Methodology

Experimental data from quasi-static lateral test followed by axial crushing of specimen

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Axial load capacity vs. Ductility demand degradation curve

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Calibrate finite element model

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Hybrid simulation of bridge response under earthquake and a truck load followed by axial crushing of specimen

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Validate finite element model

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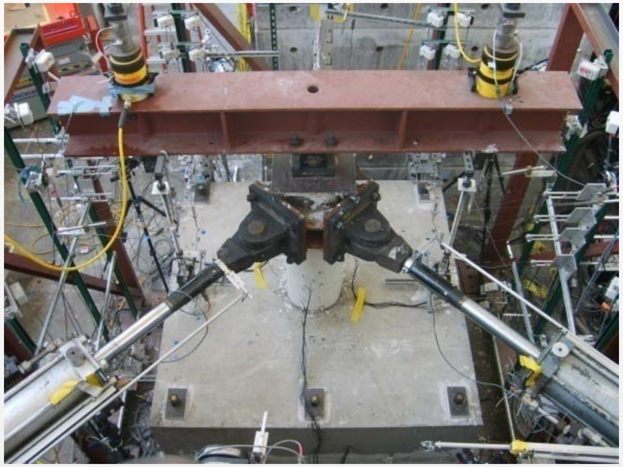
Truck load capacities for different sets of influencing parameters

Quasi-static lateral test



Axial test

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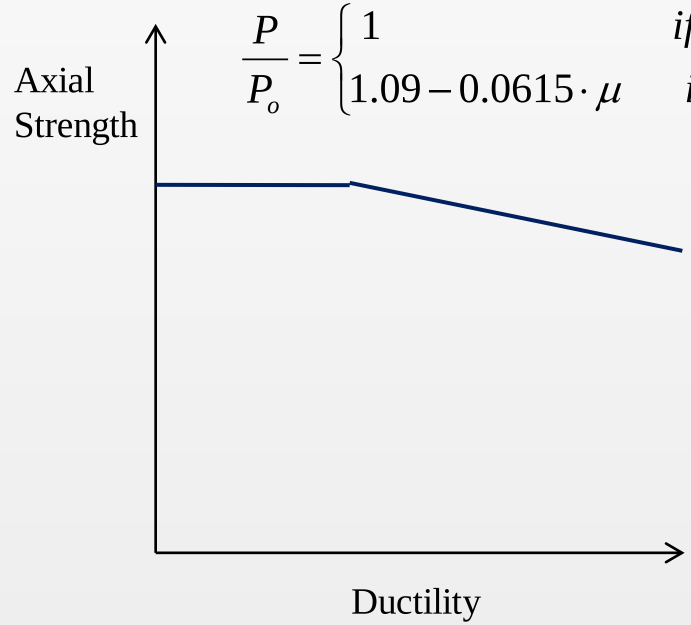
$$\frac{P}{P_o} = \begin{cases} 1 & \text{if} \quad \mu < 1.5 \\ 1.09 - 0.0615 \cdot \mu & \text{if} \quad \mu \geq 1.5 \end{cases}$$



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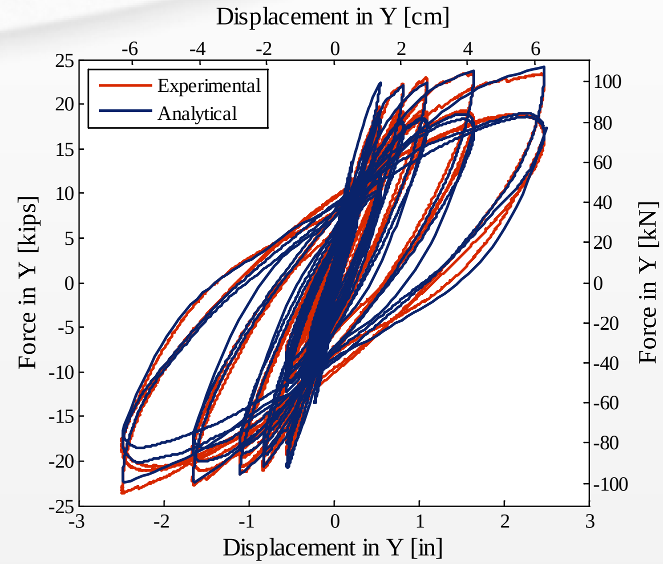

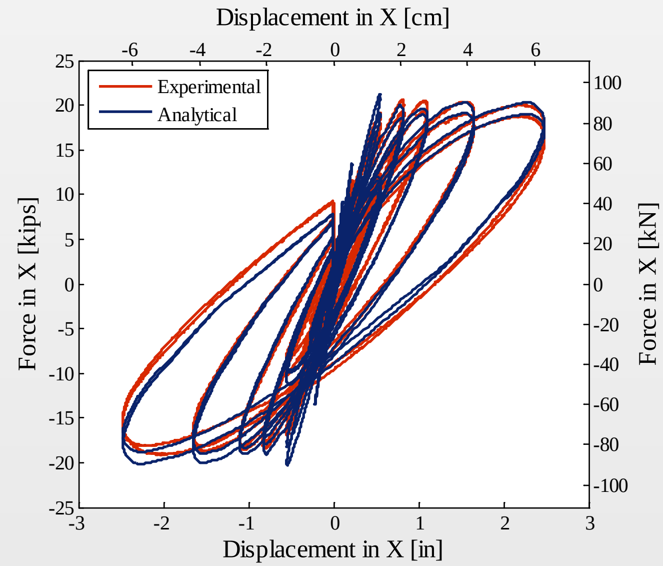

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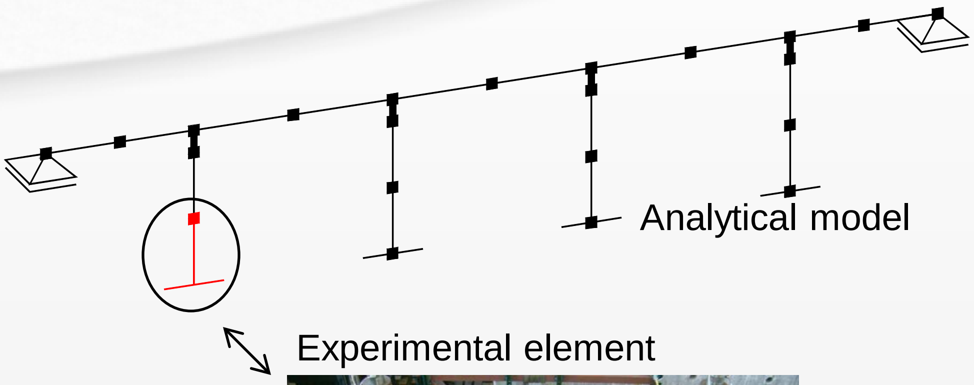

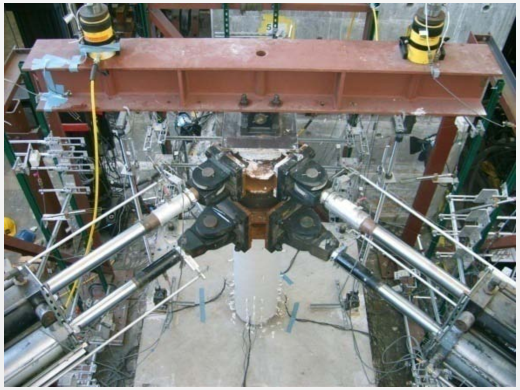

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Validate finite element model for earthquake and axial load

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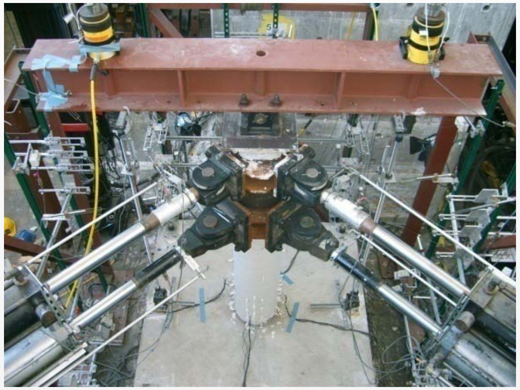
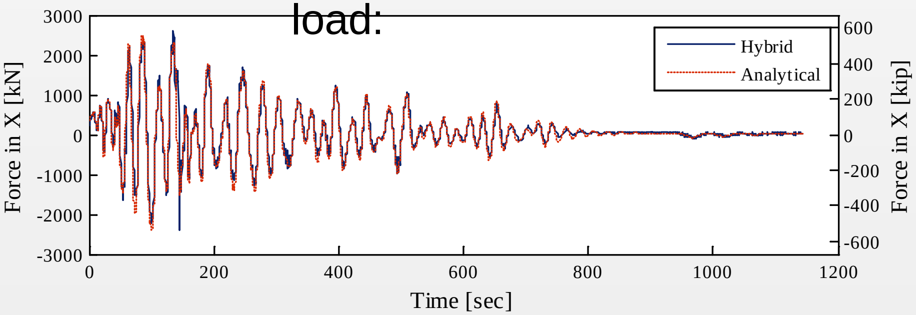
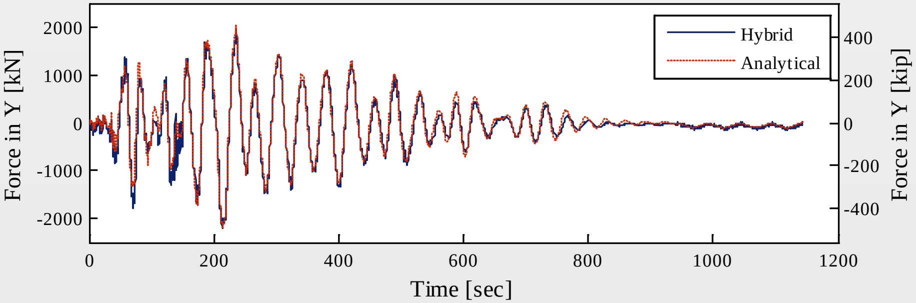


Validation of model for earthquake load:





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Hybrid simulation of bridge response under earthquake and a truck load followed by axial crushing of specimen

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Validate finite element model for earthquake and axial load

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Truck load capacities for different sets of influencing parameters

Validation of model for axial strength:

Test	Experiment [kips]	Analytical [kips]	Error [%]
MIHS	1417	1387	2.11
HIHS	1396	1397	0.07

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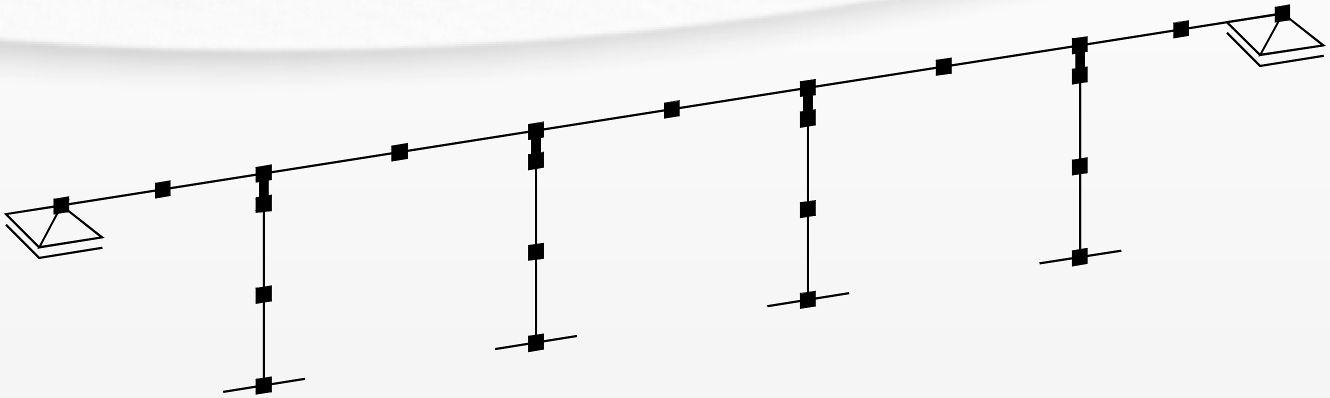
Truck load capacities for different sets of influencing parameters

Influencing parameters:

- Abutment type
- Residual drift of the bridge columns
- Position of the truck on the bridge relative to the superstructure centerline
- Ultimate strain of reinforcing bars

Analytical model of the bridge

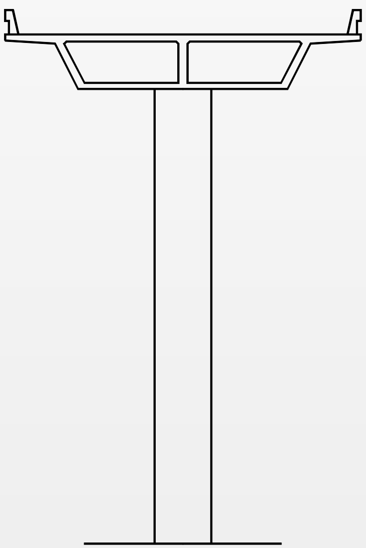


- 3D model developed in OpenSees
- Column and deck elements are modeled with force-based nonlinear beam-column elements (Steel02, Concrete01) – calibrated based on experimental data
- Two types of abutments:

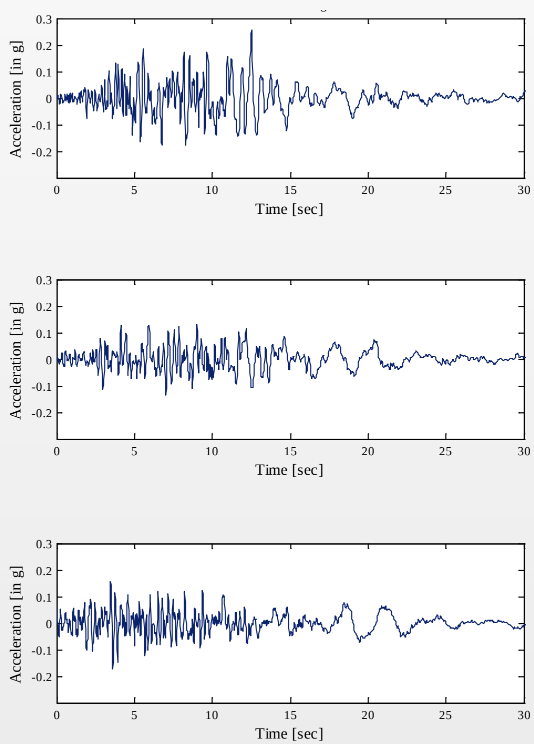
  Rx1 – roller in two directions with full torsional restraint of the deck

Loads

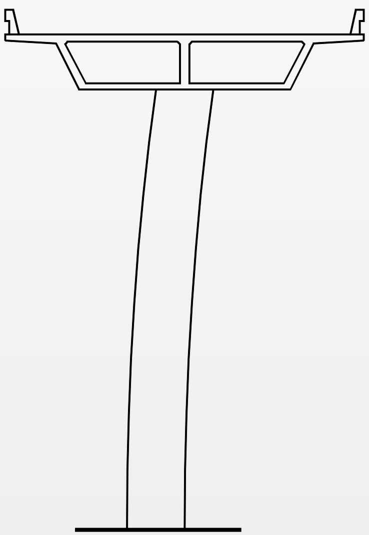
Self-weight



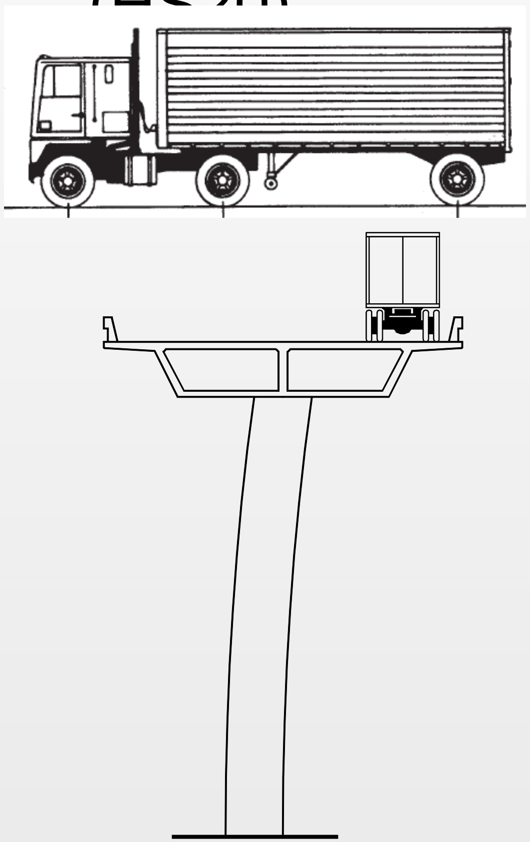
Earthquake



Residual drift



Truck load (HS20)



Ground Motions

- 8 bins, each containing 20 ground motions
- The bins distinguish by:

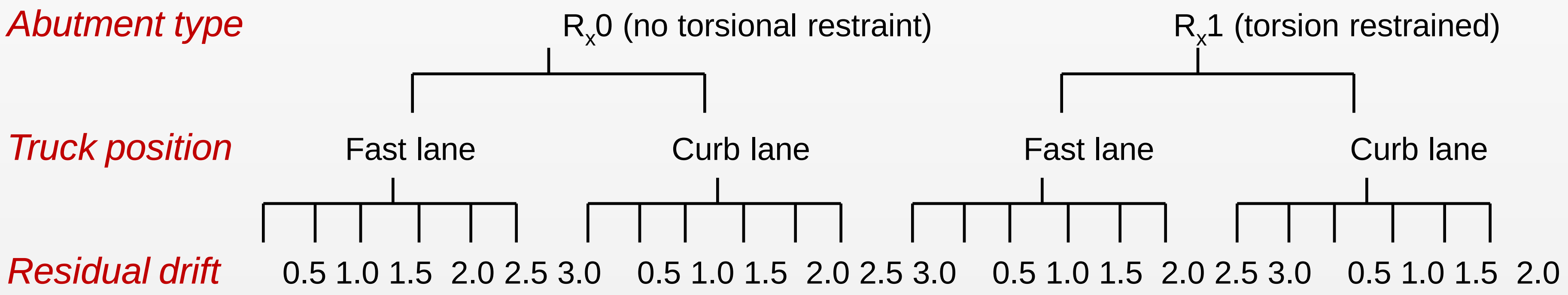
  Magnitude of the earthquake

  The distance to the fault (near or far)

  The fault type (strike-slip, reverse)

  Directivity effects

Parametric Study



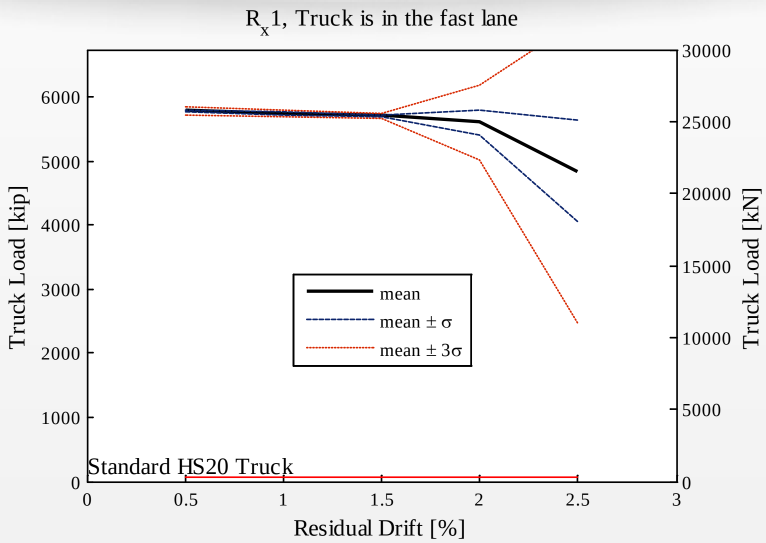
Total of 24 analyses were performed for one ground motion and

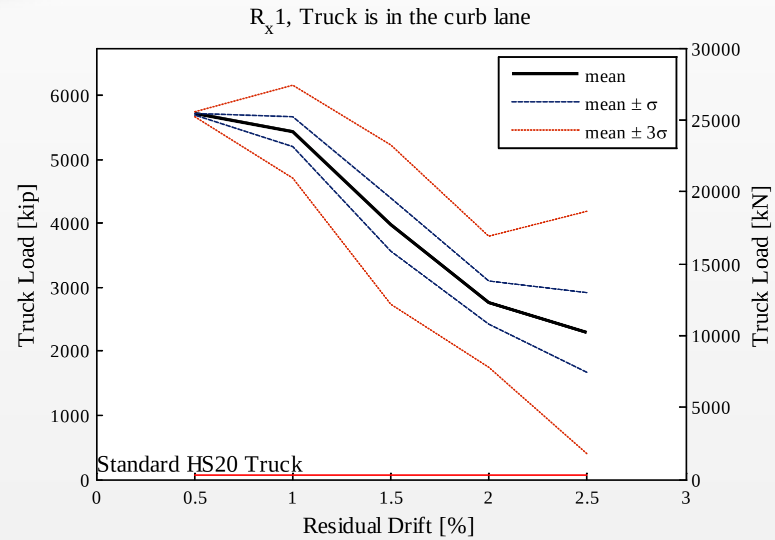
a fixed value of the ultimate strain of reinforcing bars of 6% (*Caltrans SDC*).

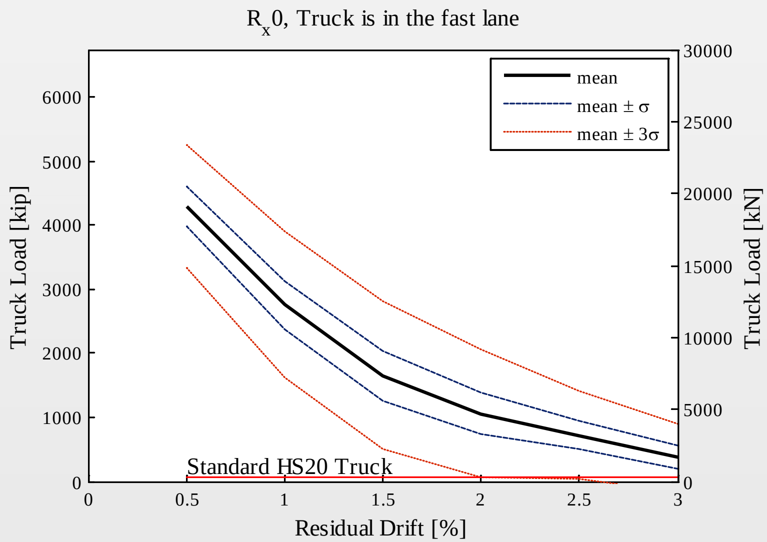
Two groups of results

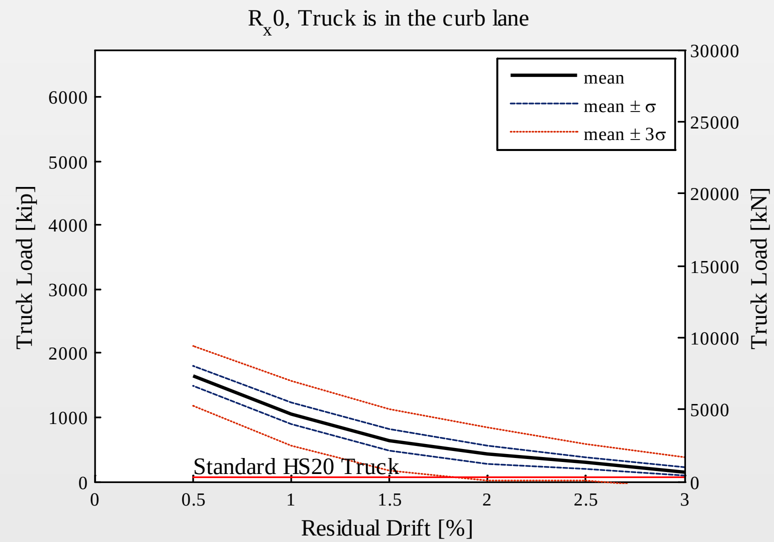
- Case 1: None of bridge columns has failed during an earthquake
- Case 2: At least one bridge columns has failed during an earthquake

Results – Case 1:
no failure of column during Eqk



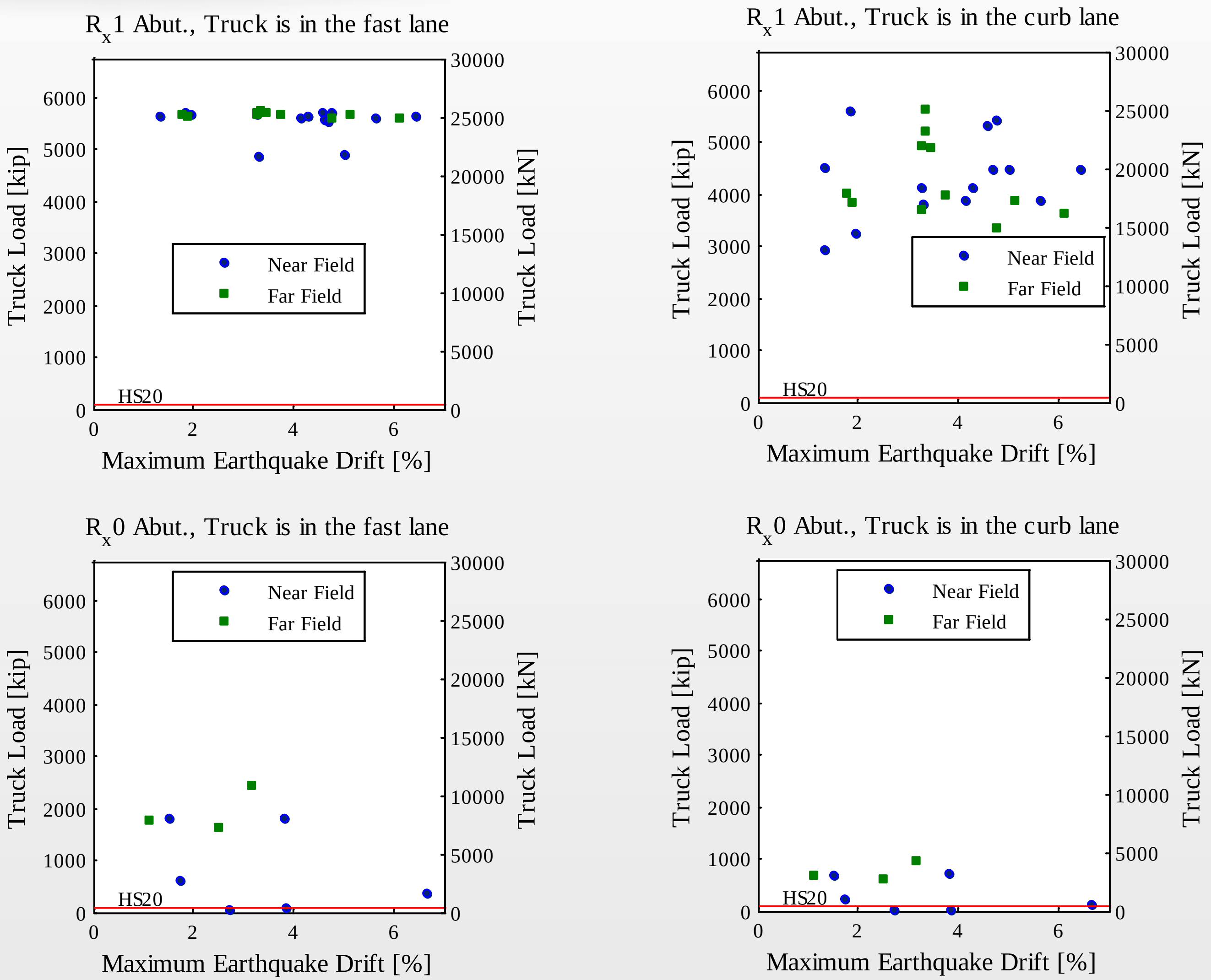






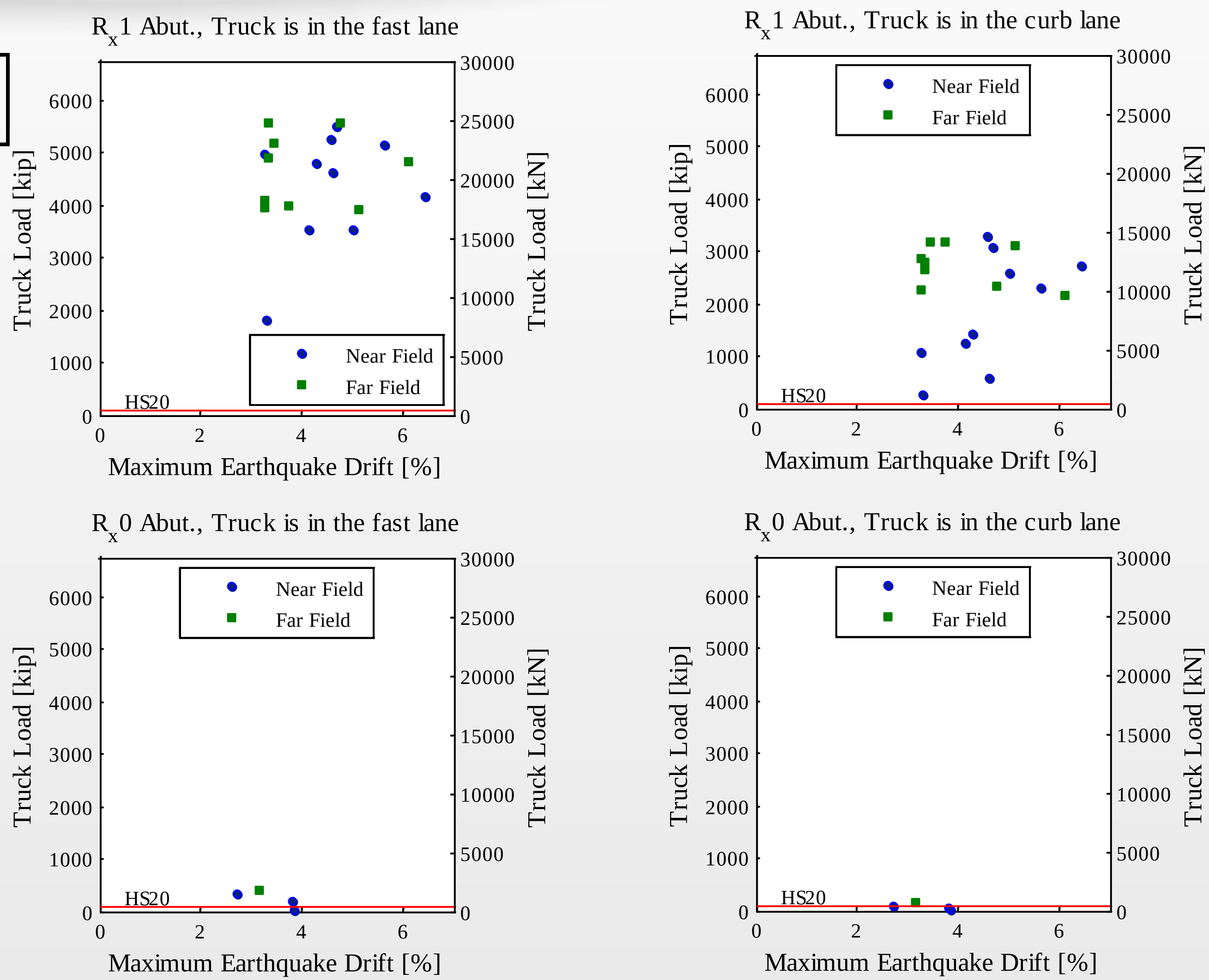
Results – Case 2: failure of column during Eqk

RD = 1%



Results – Case 2: failure of column during Eqk

RD = 2.5%



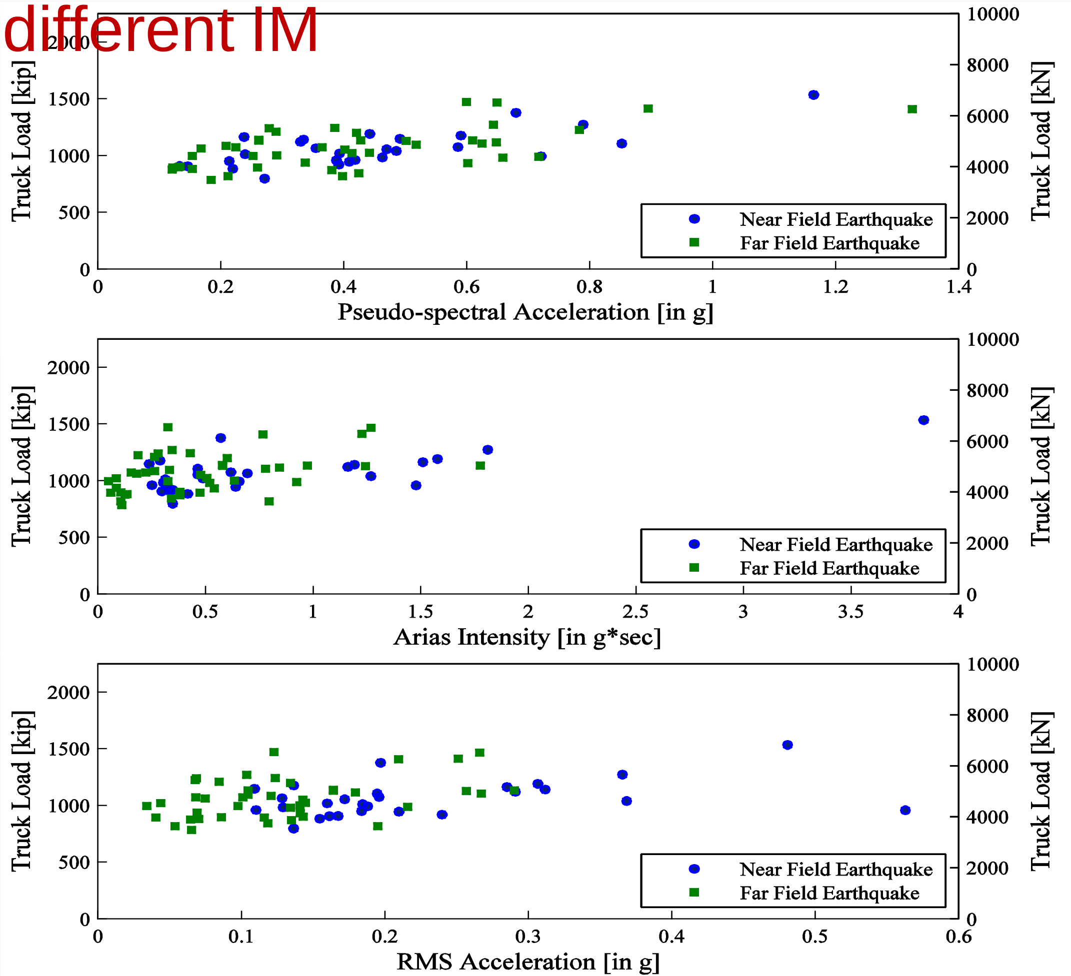
Conclusions

- Bridge safety and serviceability can be greatly enhanced by limiting residual drifts through design
- It is recommended to provide torsional restrains at the superstructure ends and to design the abutments such that this restrains are preserved following the earthquake
- It is safer to use fast lane that curb lane of the bridge roadway following the earthquake.

Questions?

Results – Case 1
no failure of column during Eqk

Truck load capacity as a function of different IM



RD = 1%
Rx1

Pushover for transverse direction