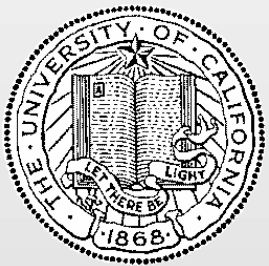# Traffic Load Capacity of a Bridge Damaged in an Earthquake

Vesna Terzic, Bozidar Stojadinovic

University of California

Berkeley
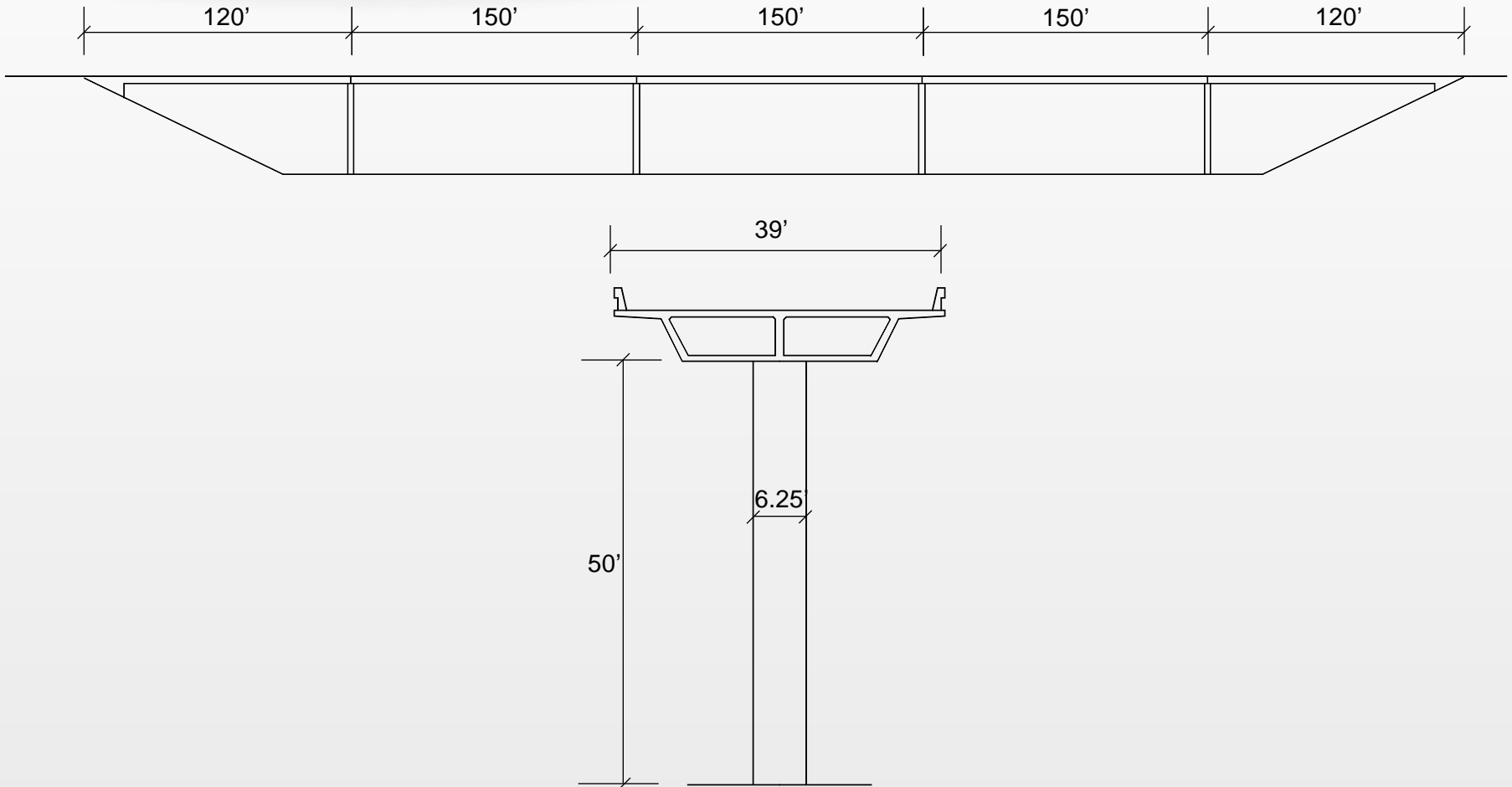
PEER

Introduction

Post-earthquake bridge traffic load capacity?

Prototype Bridge

Ketchum et. al., 2004

Methodology

Quasi-static lateral test

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

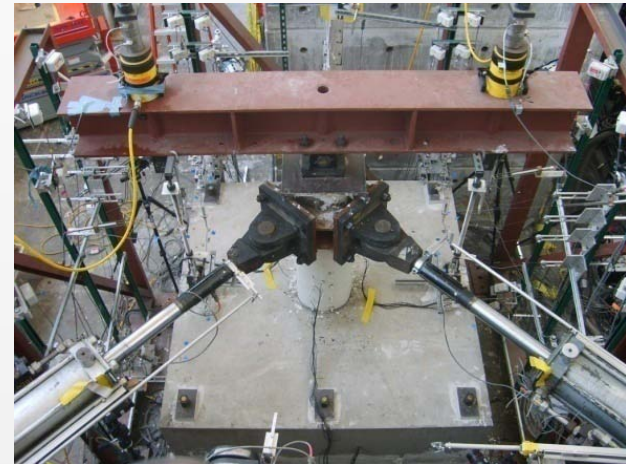Axial load capacity vs. Ductility demand degradation curve

Calibrate finite element model

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

Validate finite element model

Truck load capacities for different sets of influencing parameters

Axial test

Methodology

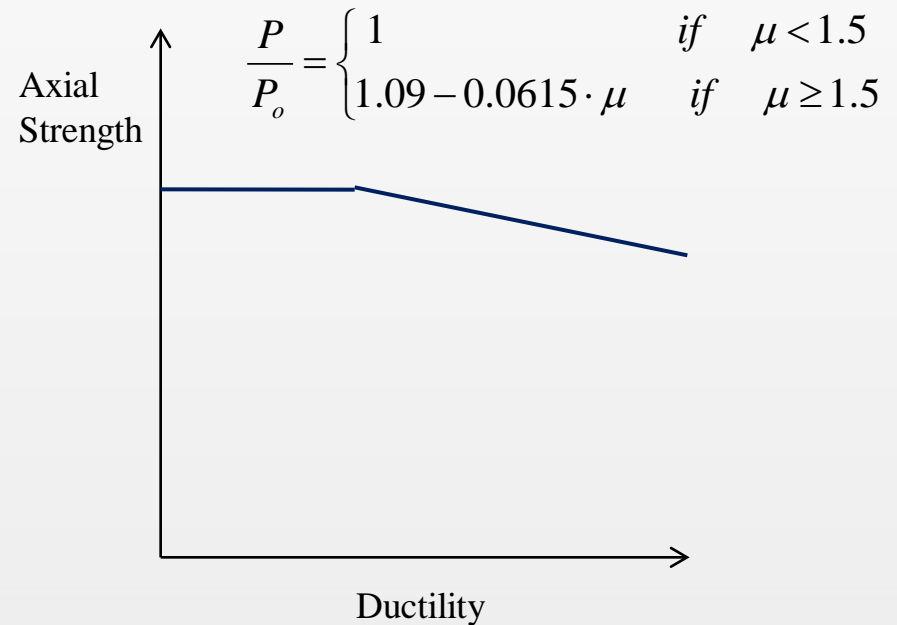Experimental data from quasi-static lateral test followed by axial crushing of specimen

Axial load capacity vs. Ductility demand degradation curve
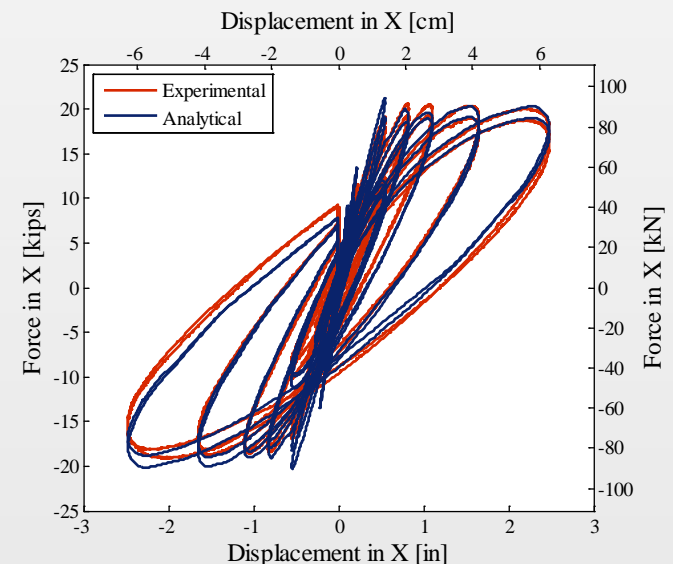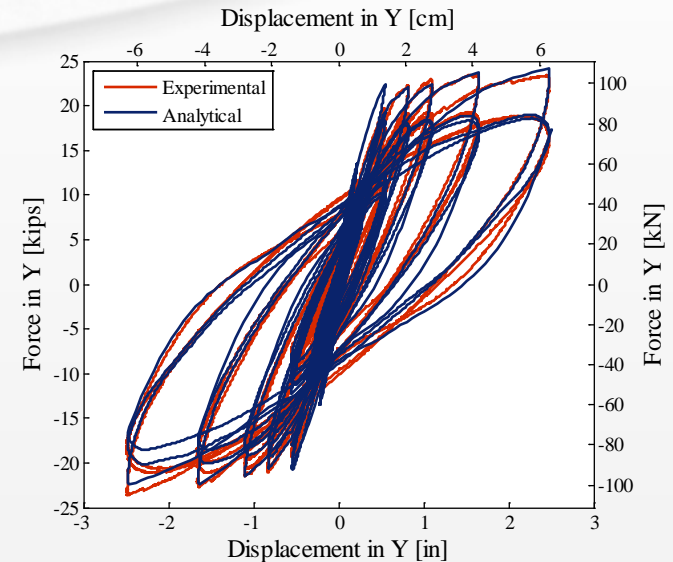
Calibrate finite element model

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

Validate finite element model

Truck load capacities for different sets of influencing parameters

Axial Strength

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

Ductility

Methodology

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

Axial load capacity vs. Ductility demand degradation curve
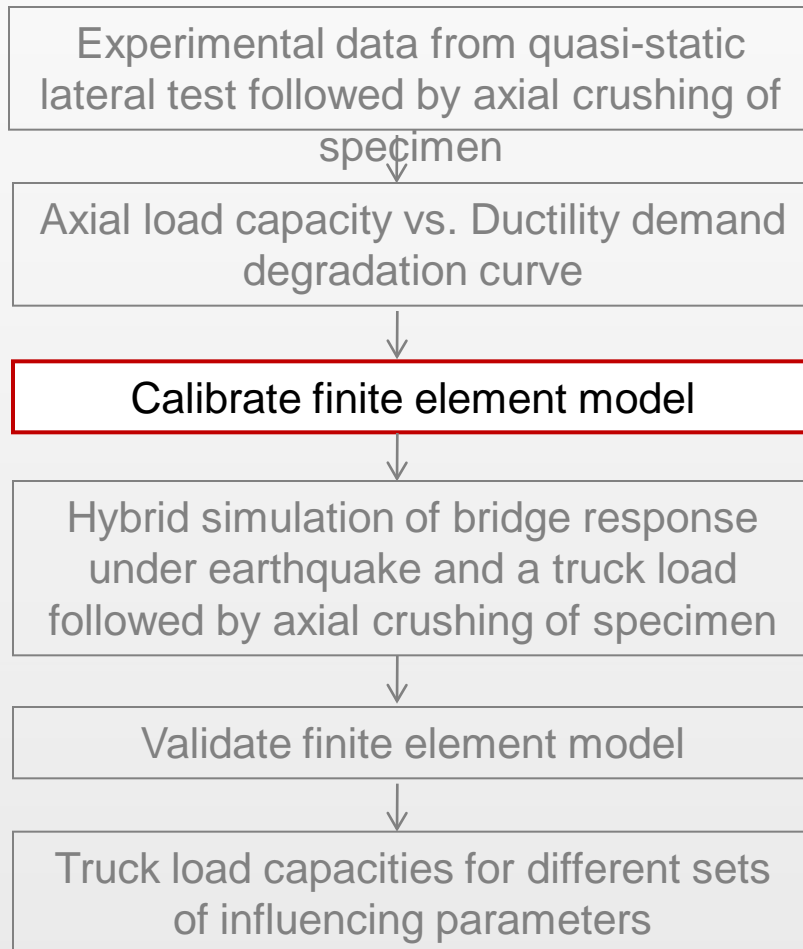
Calibrate finite element model

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

Validate finite element model

Truck load capacities for different sets of influencing parameters

Methodology

Analytical model

Experimental element

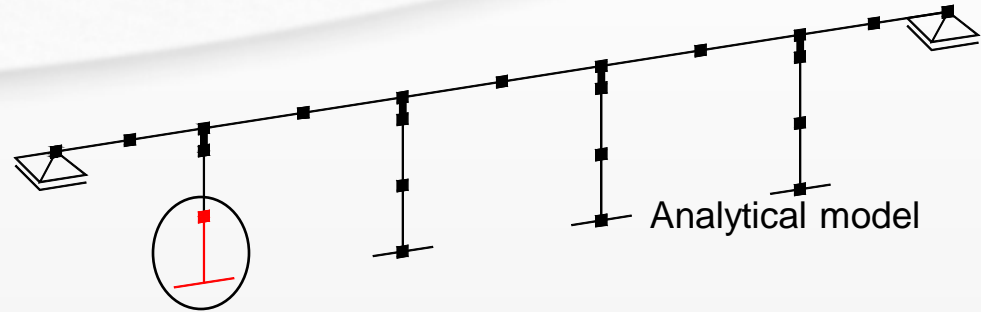Experimental data from quasi-static lateral test followed by axial crushing of specimen

Axial load capacity vs. Ductility demand degradation curve
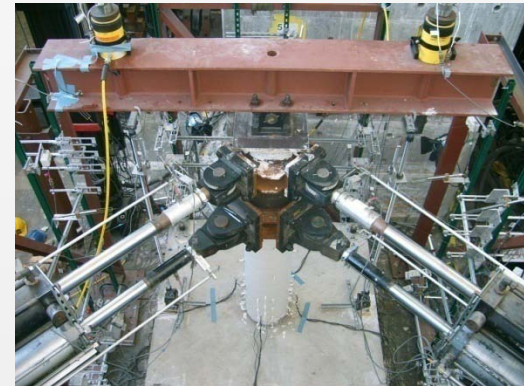
Calibrate finite element model

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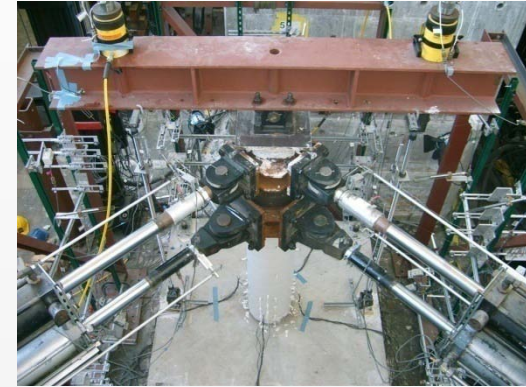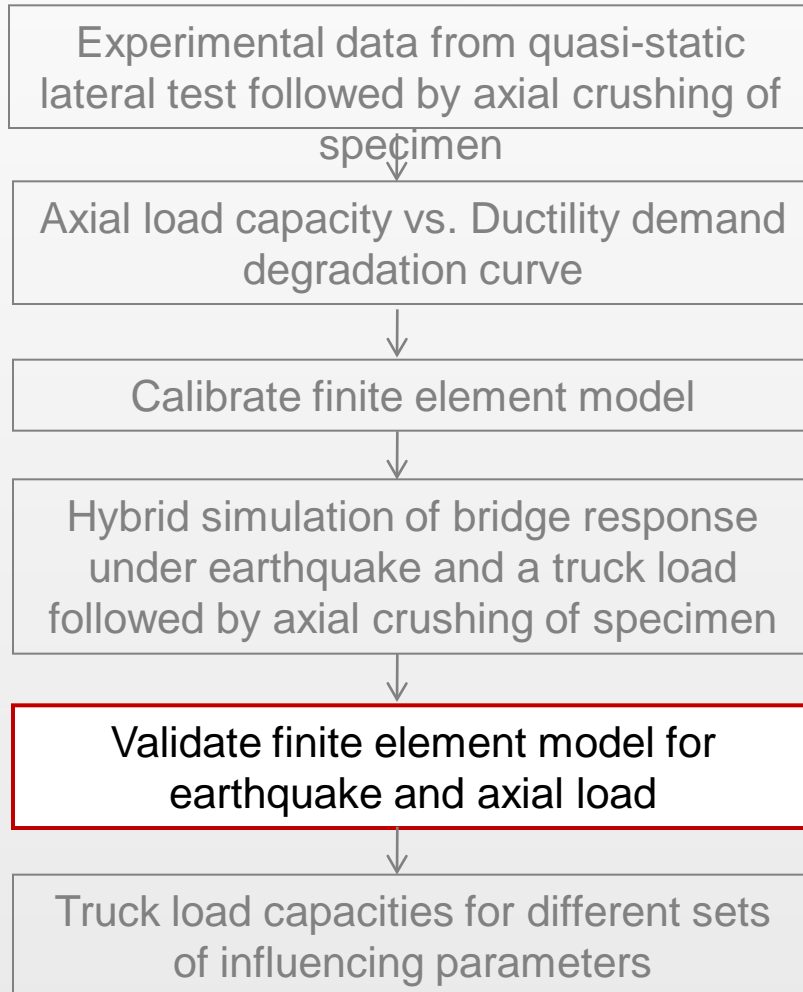
Validate finite element model

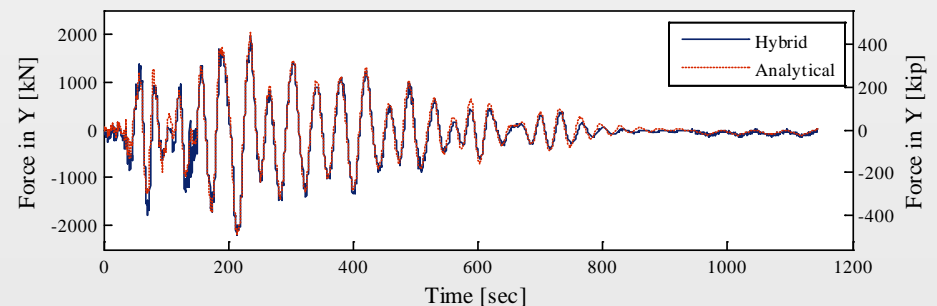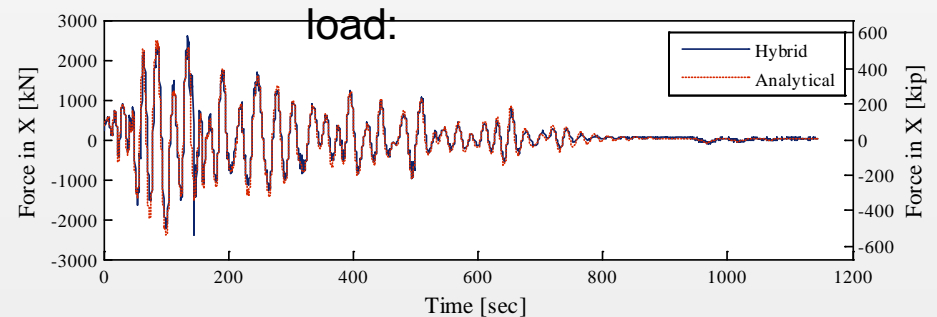Truck load capacities for different sets of influencing parameters

Methodology

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

↓

Axial load capacity vs. Ductility demand degradation curve

↓

Calibrate finite element model

↓

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

↓

Validate finite element model for earthquake and axial load

↓

Truck load capacities for different sets of influencing parameters

Validation of model for earthquake load:

Methodology

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

Axial load capacity vs. Ductility demand degradation curve

Calibrate finite element model

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

Validate finite element model for earthquake and axial load

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

Methodology

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

↓

Axial load capacity vs. Ductility demand degradation curve

↓

Calibrate finite element model

↓

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

↓

Validate finite element model

↓

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
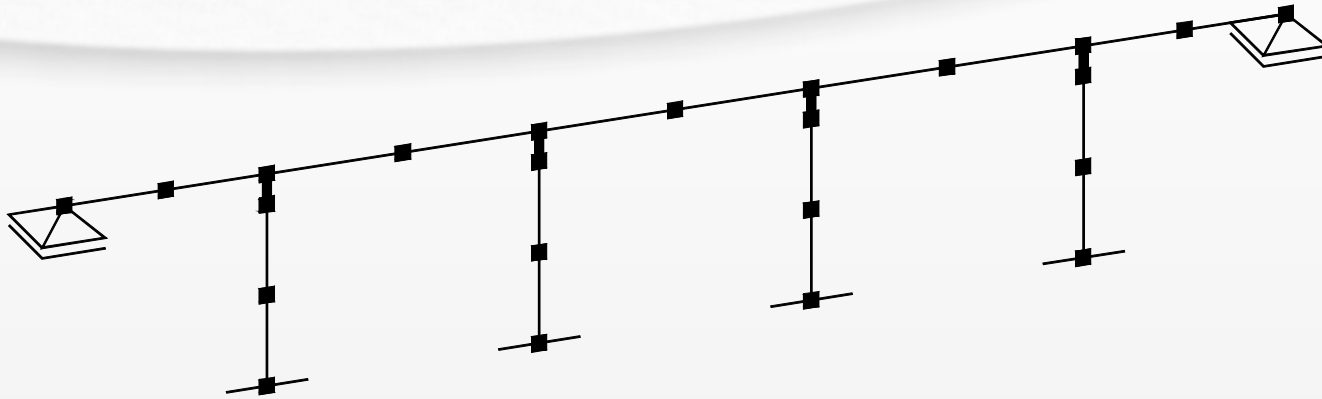
- 3D model developed in OpenSees

- 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
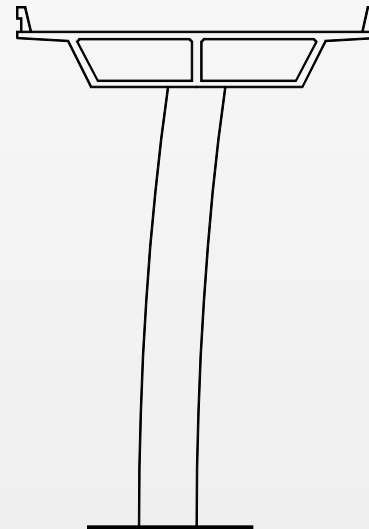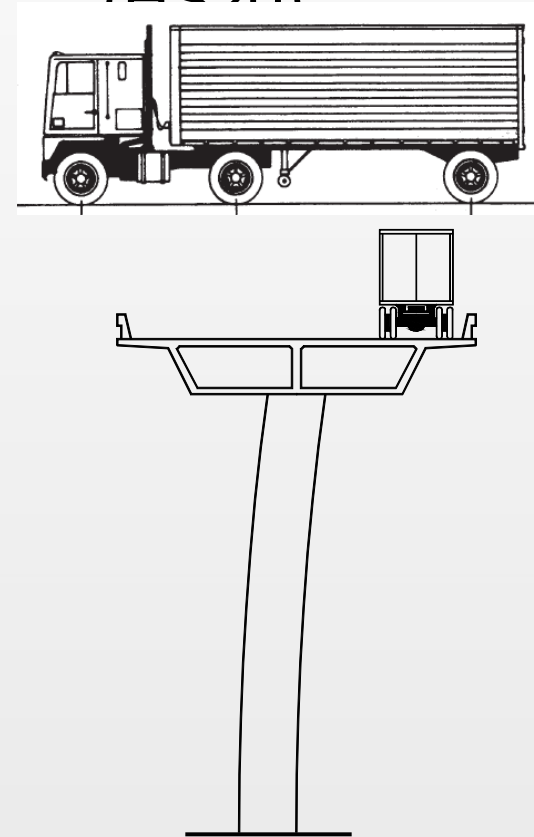
Loads

Self-weight   **Earthquake**   **Residual drift**   **Truck load (HS20)**
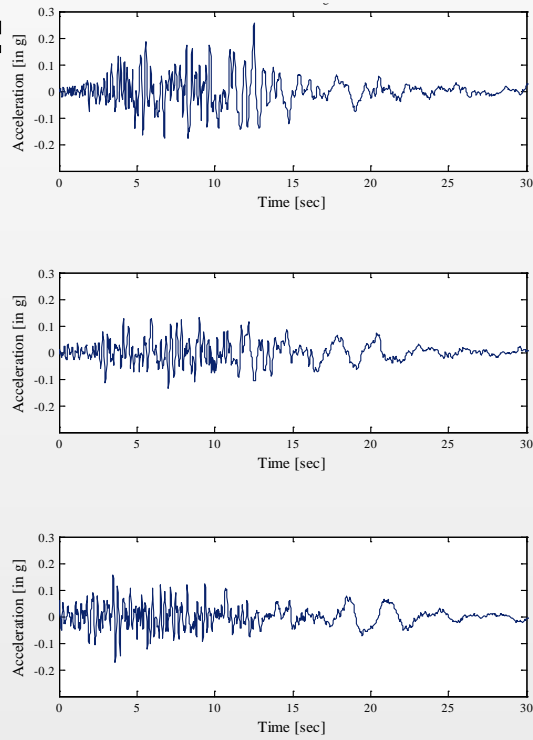
Ground Motions

- 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

Abutment type	R_x0 (no torsional restraint)		R_x1 (torsion restrained)

Truck position   Fast lane   Curb lane   Fast lane   Curb lane

Residual drift   0.5 1.0 1.5 2.0 2.5 3.0   0.5 1.0 1.5 2.0 2.5 3.0   0.5 1.0 1.5 2.0 2.5 3.0   0.5 1.0 1.5 2.0
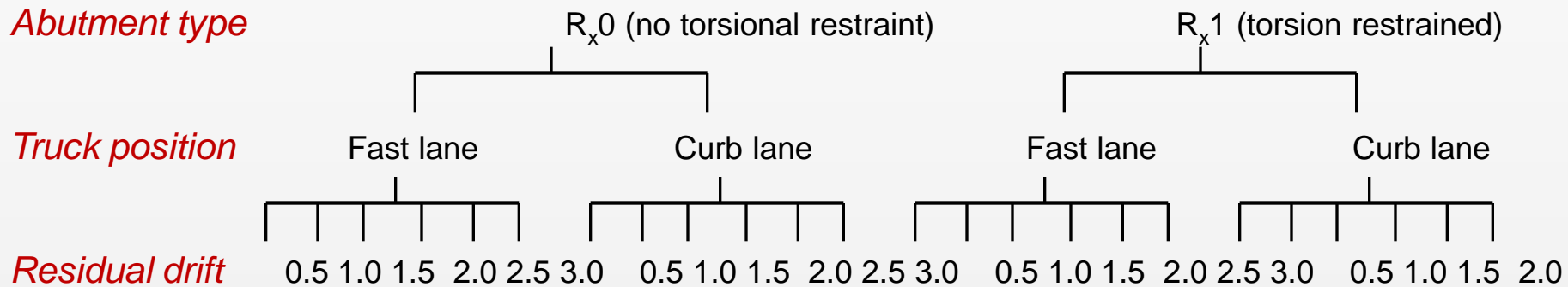
Total of 24 analyses were performed for one ground motion and

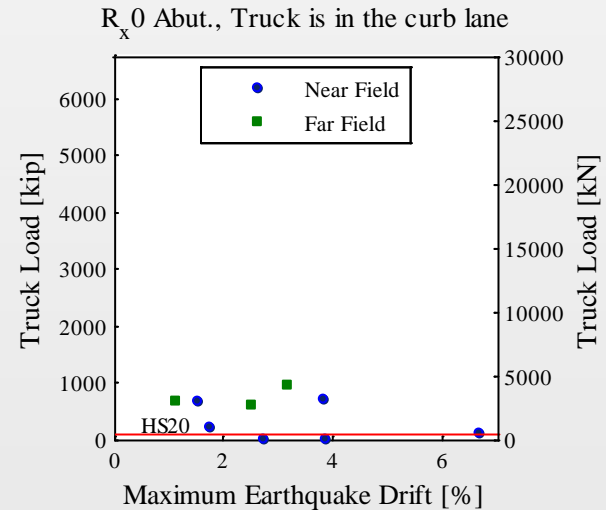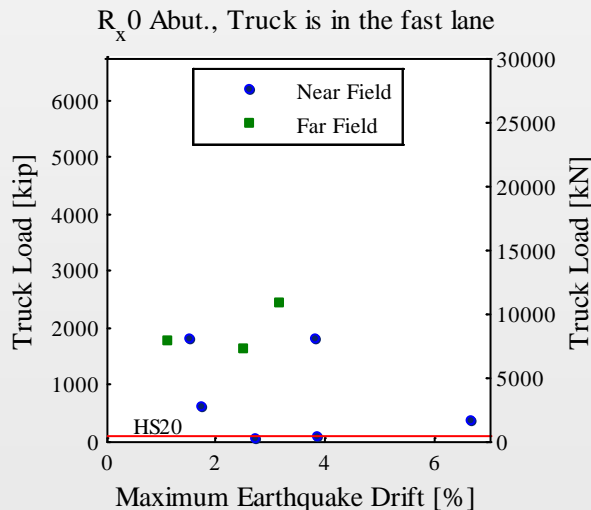a fixed value of the ultimate strain of reinforcing bars of 6% (*Caltrans SDC*).
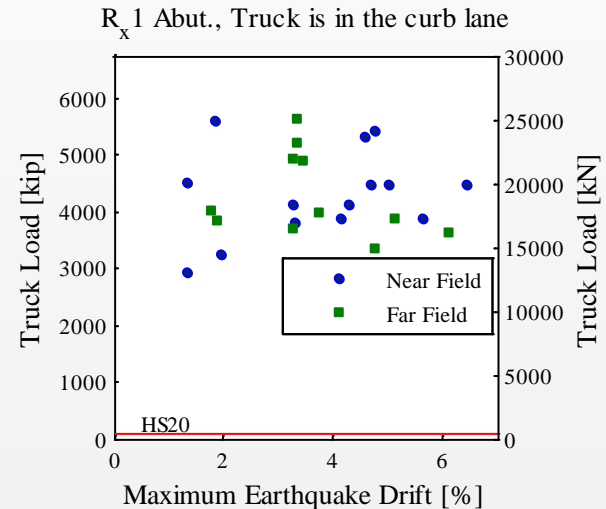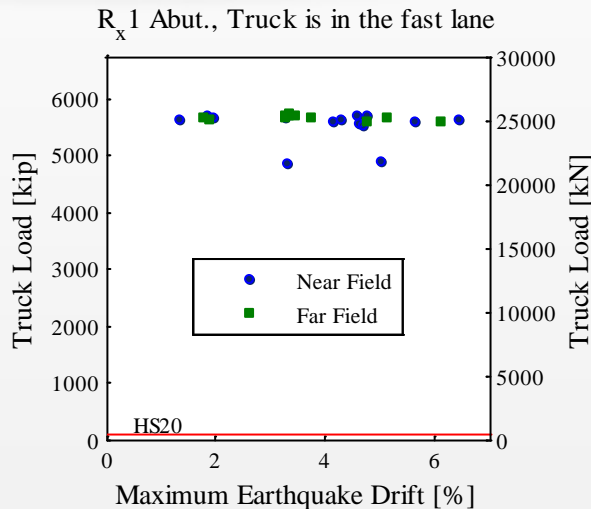
Two groups of results

- 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:
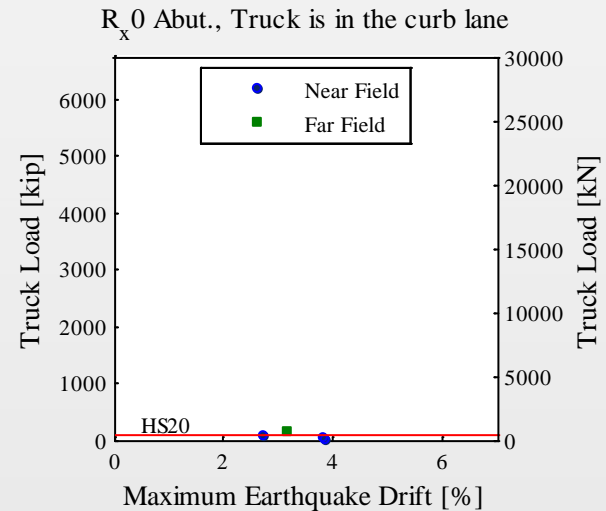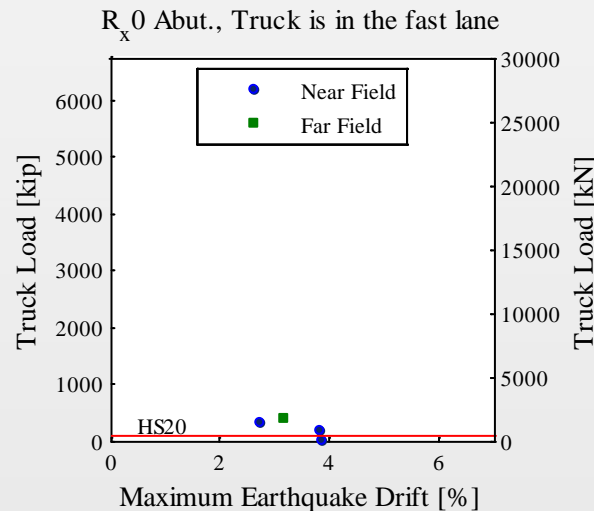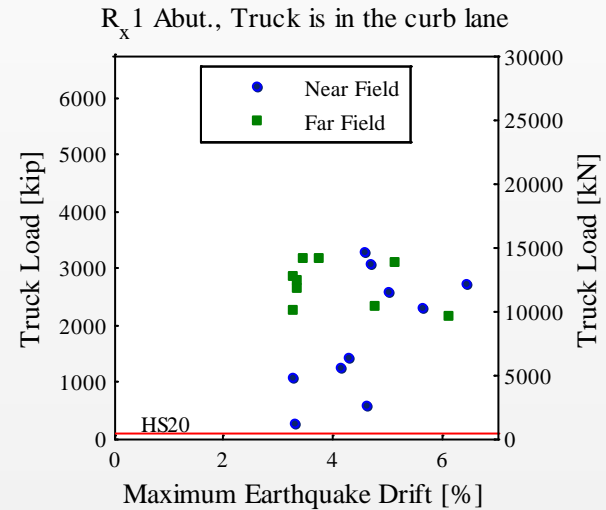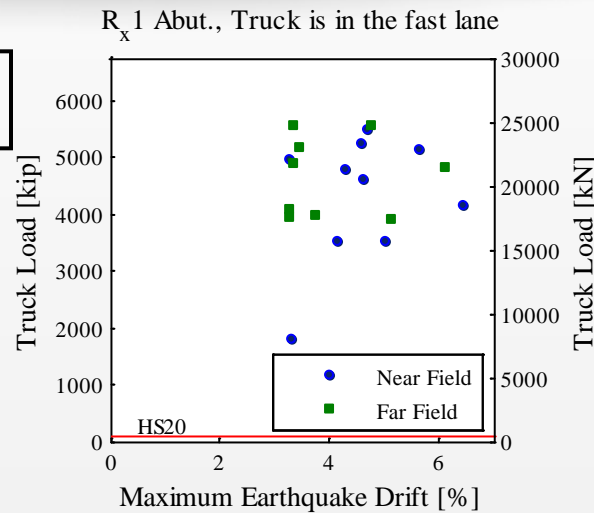# no failure of column during Eqk
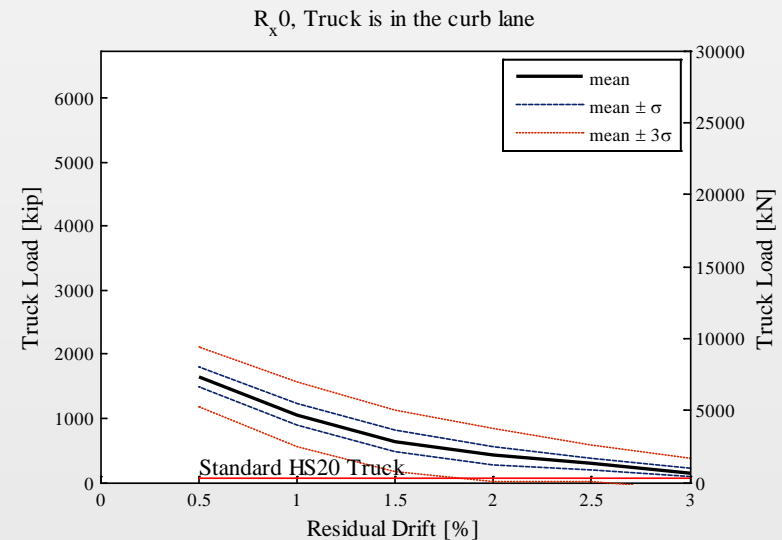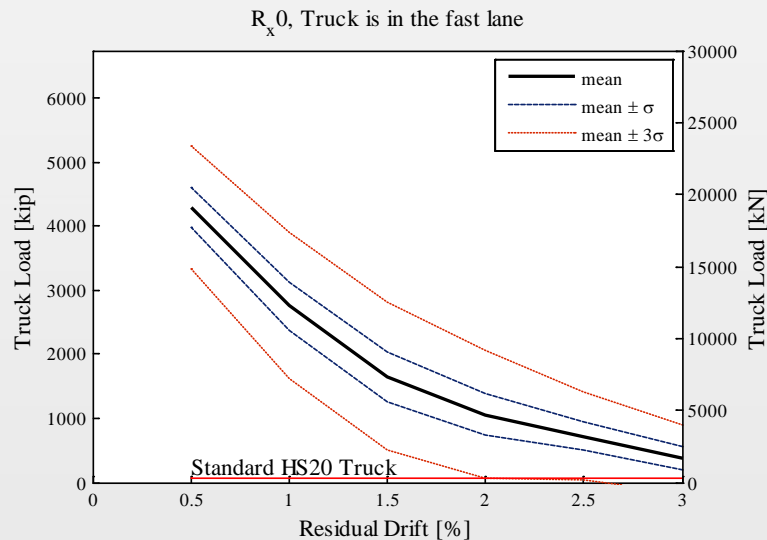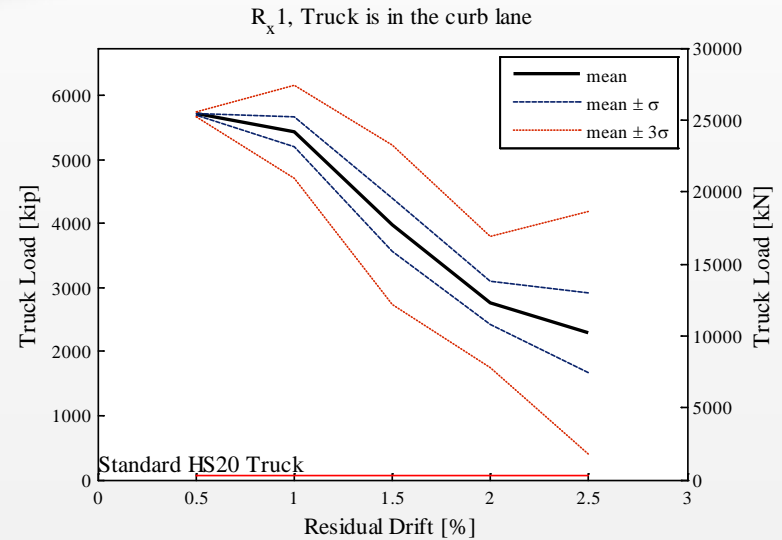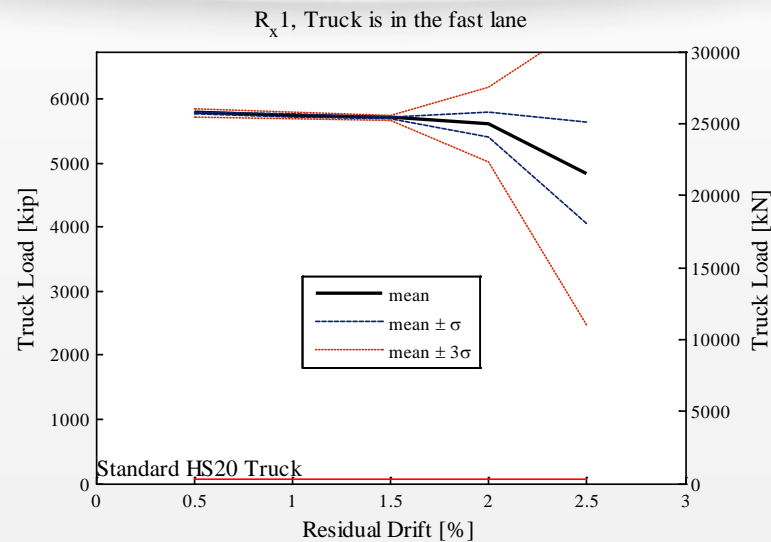
Results – Case 2: failure of column during Eqk

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.
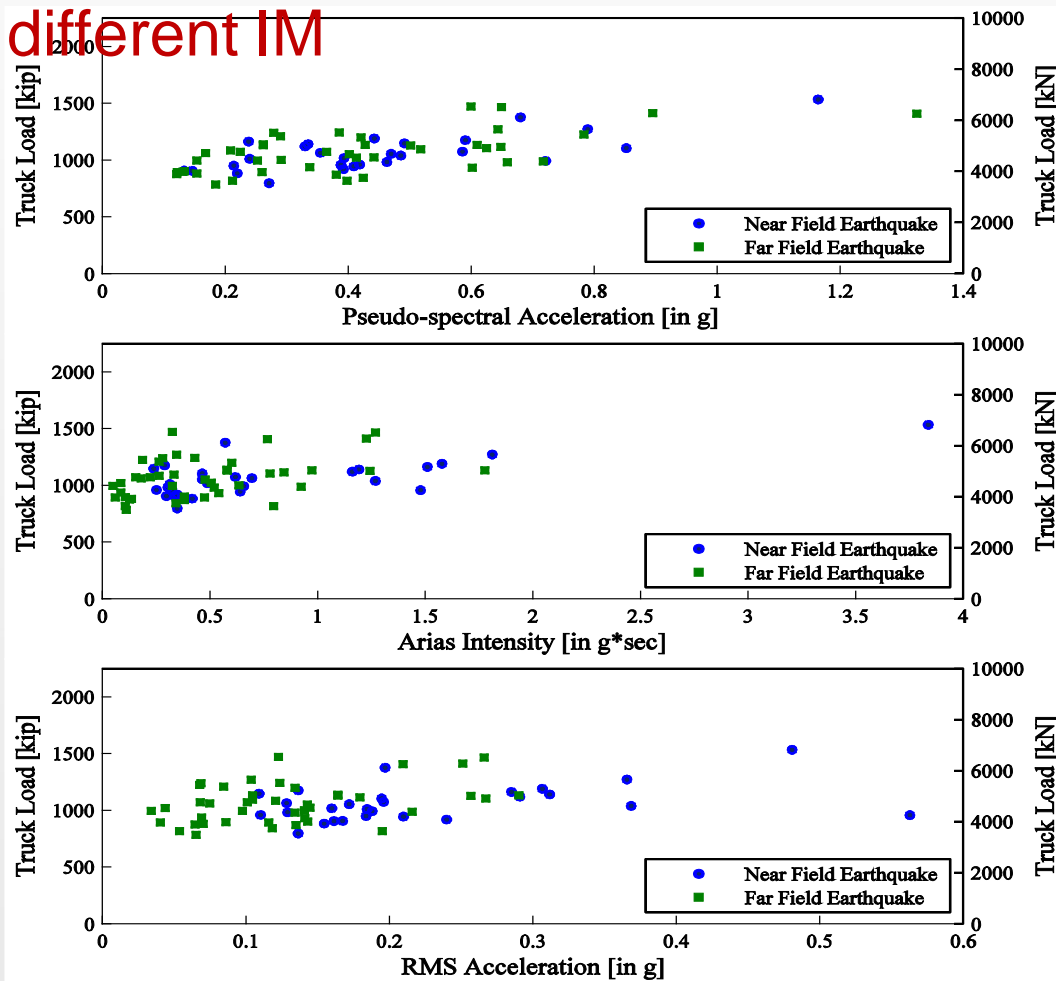
Questions?

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