

US-Japan Young Researchers Symposium on
Natural NSF, US, Japan Disaster Mitigation, 2005

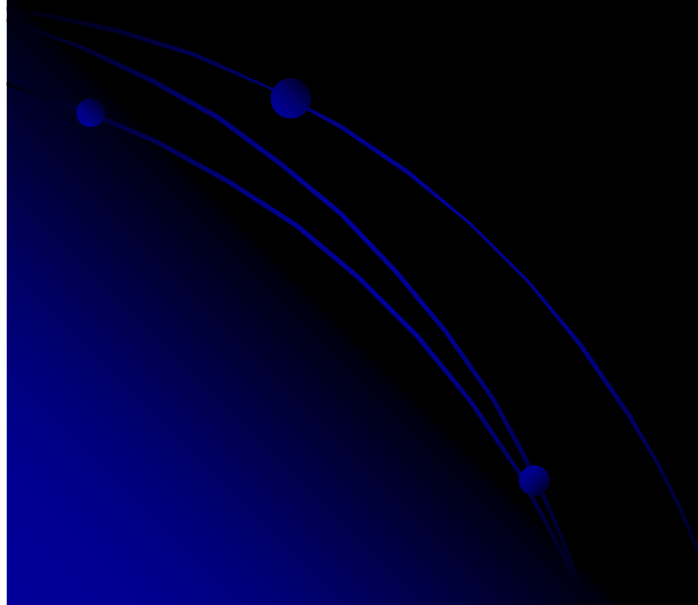
Torsional Response of Bridges

Paiboon Tirasit

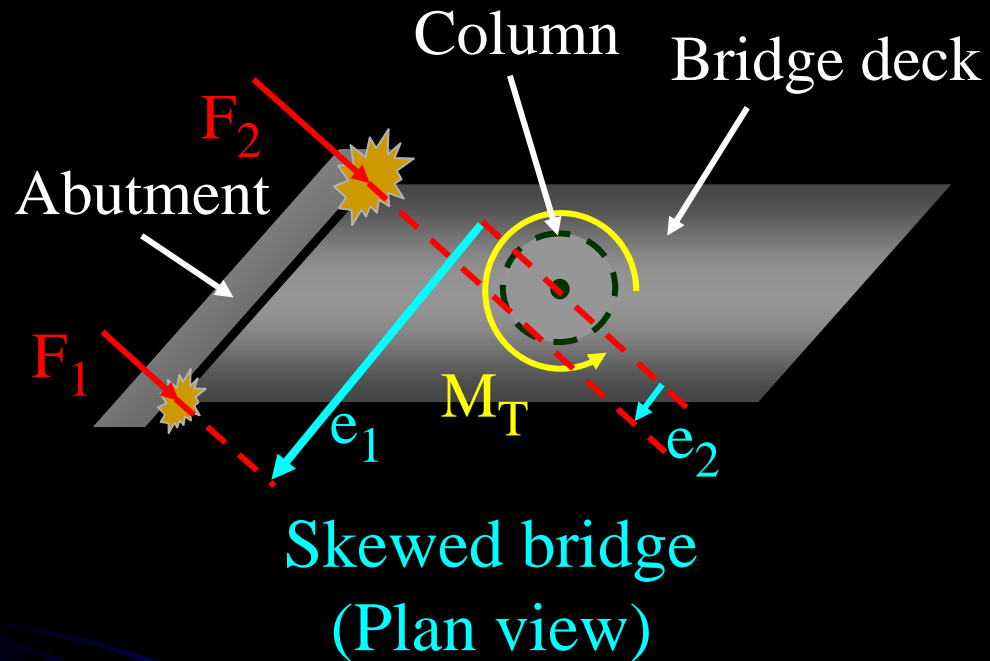
Department of Civil Engineering

Tokyo Institute of Technology

June 11th, 2005



Inplane Rotation of Skewed Bridge Deck



Skewed bridge deck possibly rotates during an earthquake due to the collision with the abutments or adjacent span.

This probably causes **seismic torsional moment coupled with other internal forces in skewed bridge piers.**

Statement of Problems

Past Experimental researches indicate that **the flexural strength, stiffness and ductility** of a RC member deteriorate when it is subjected to combined bending and torsional loading.

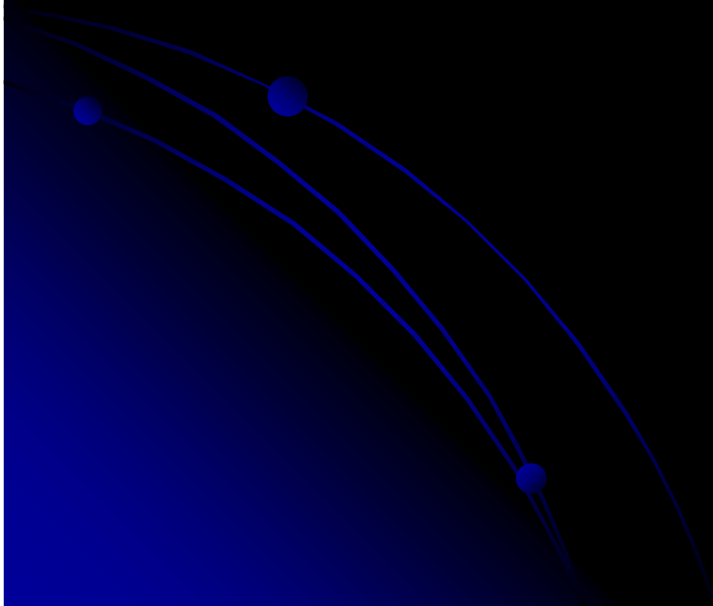


The capacities of RC piers in skewed bridges may decrease because of the existence of torsion during an earthquake.

The damage pattern of RC piers may change.

The required nonlinear torsional hysteretic model for RC piers in seismic analysis of bridges has not been available.

Seismic Analysis of Skewed Bridges

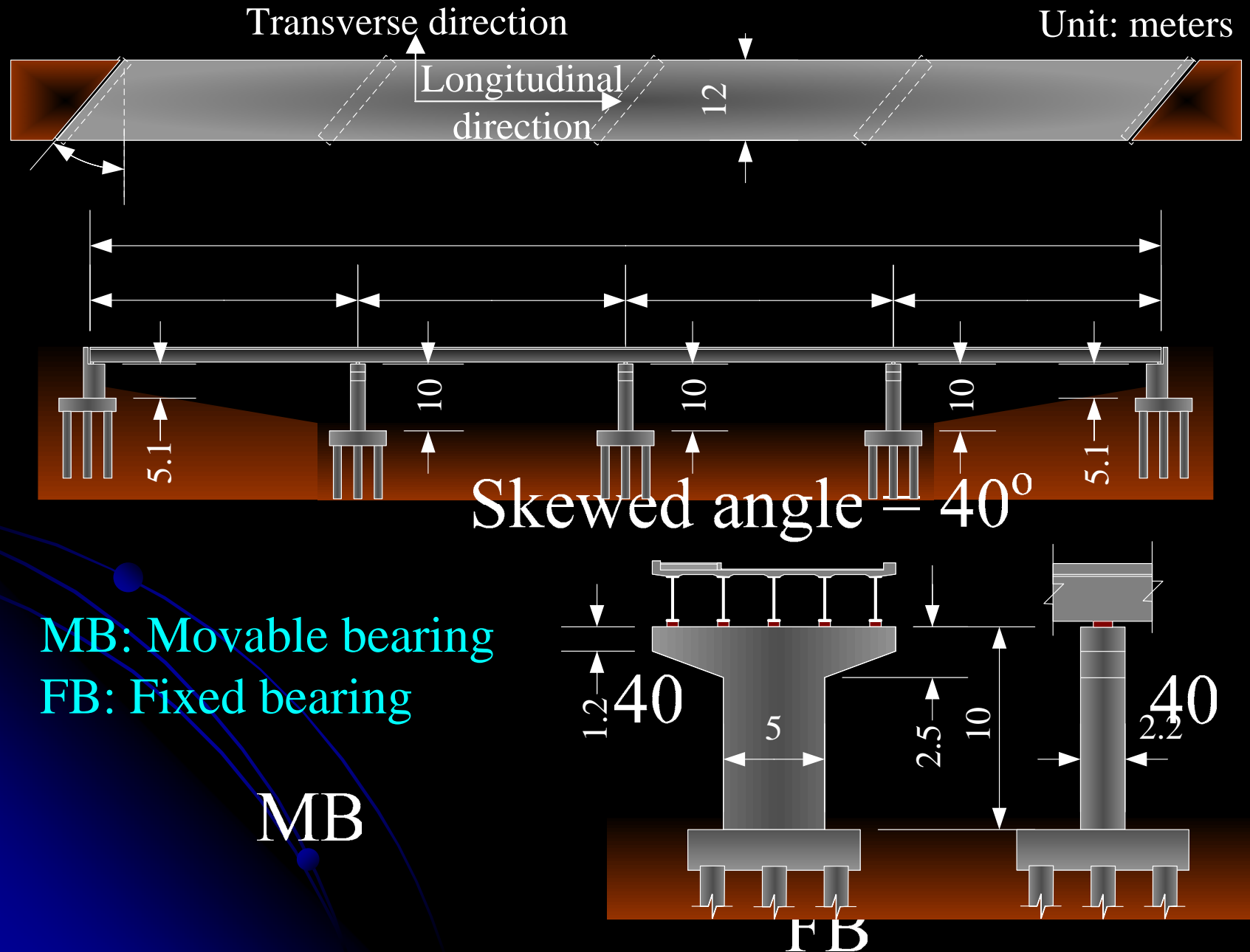


Objective of Analysis

Clarify the seismic torsion response of piers in skewed bridges under the following factors

- Skewed angles
- Pounding
- Steel bearing characteristics
- Locking of steel bearing after failure

Representative Bridge

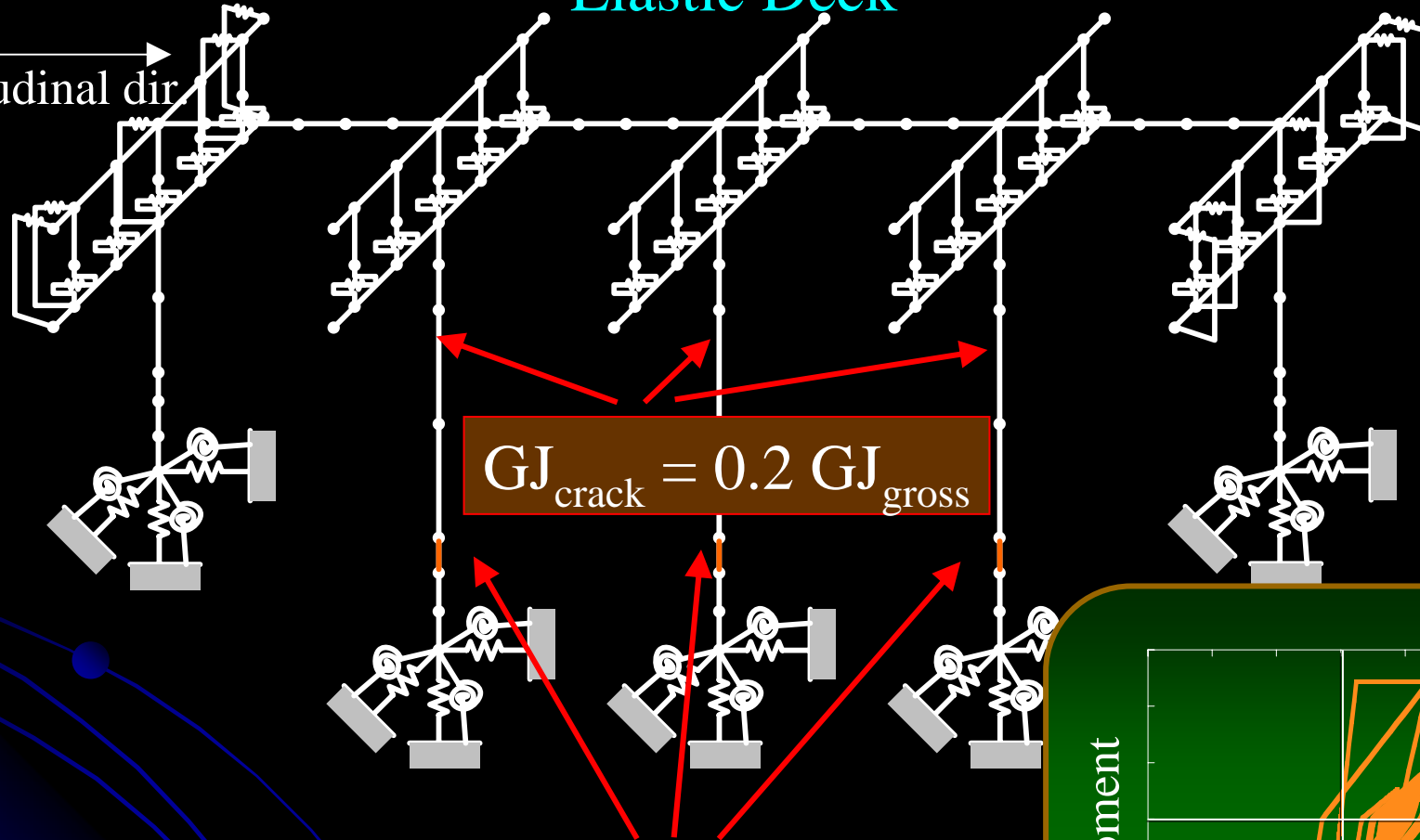


Finite Element Modeling

Transverse dir.

Longitudinal dir.

Elastic Deck

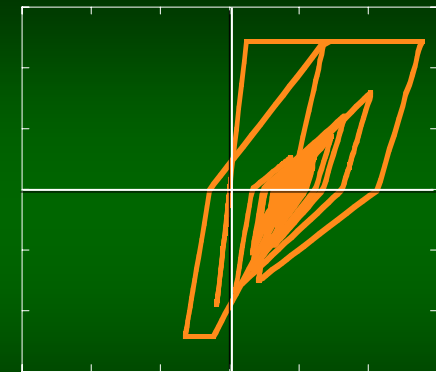


$$GJ_{\text{crack}} = 0.2 GJ_{\text{gross}}$$

Takeda model for the moment-curvature relationship about the weak axis in the plastic hinge region

Moment

Curvature

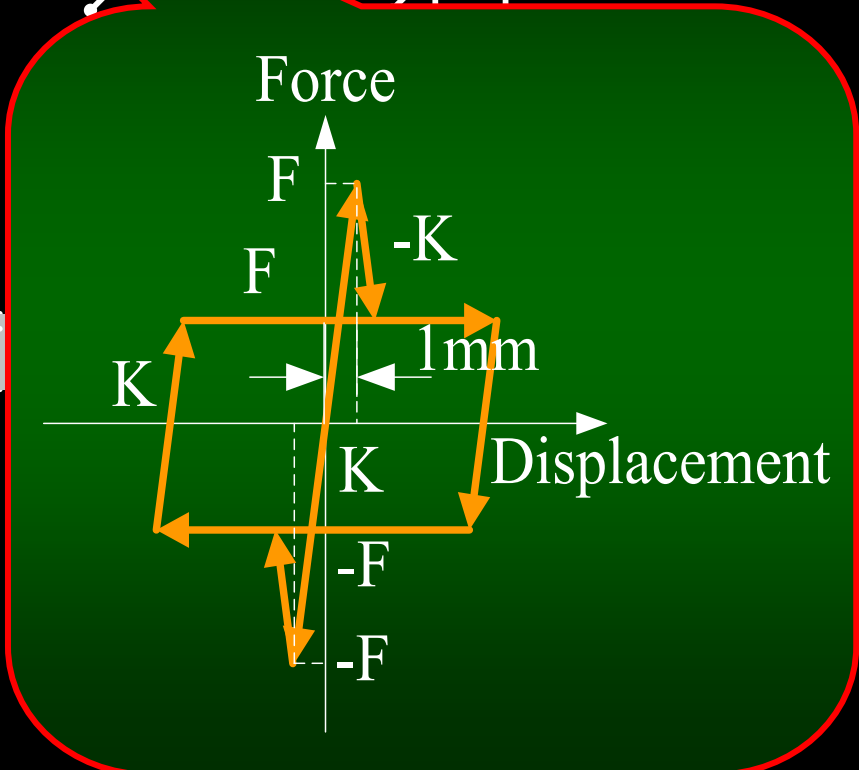
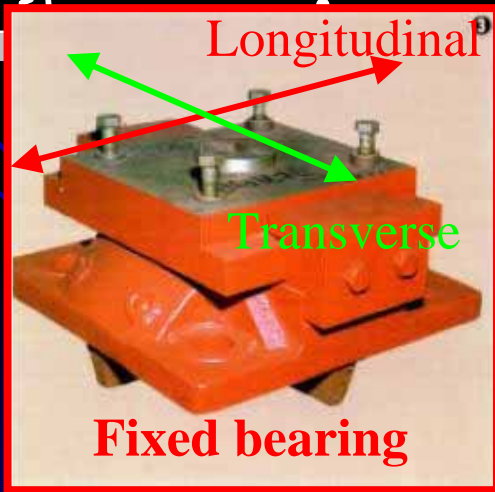
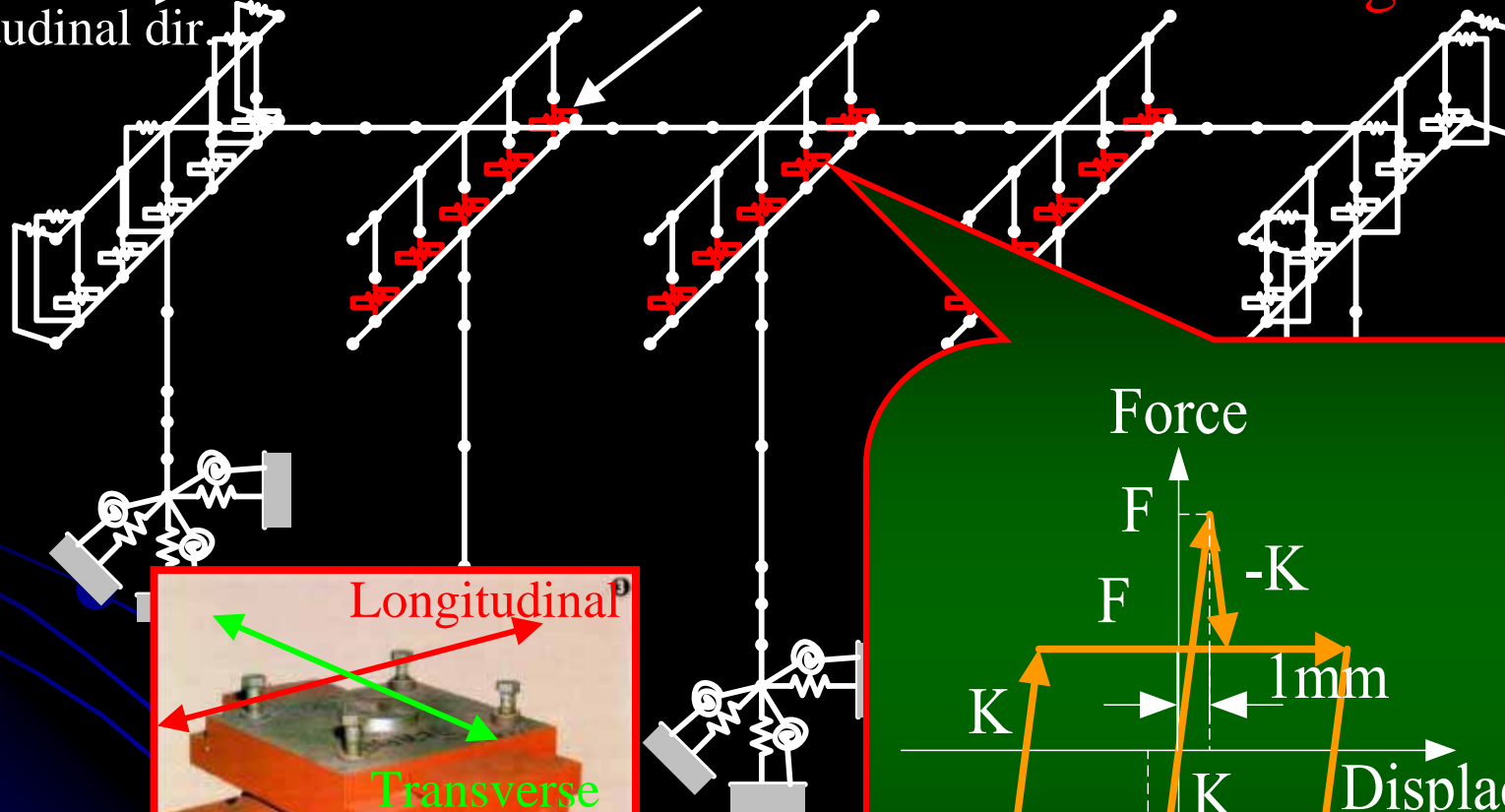


Idealization of Fixed Bearings

Transverse dir.

Longitudinal dir.

Longitudinal and transverse directions of fixed bearings

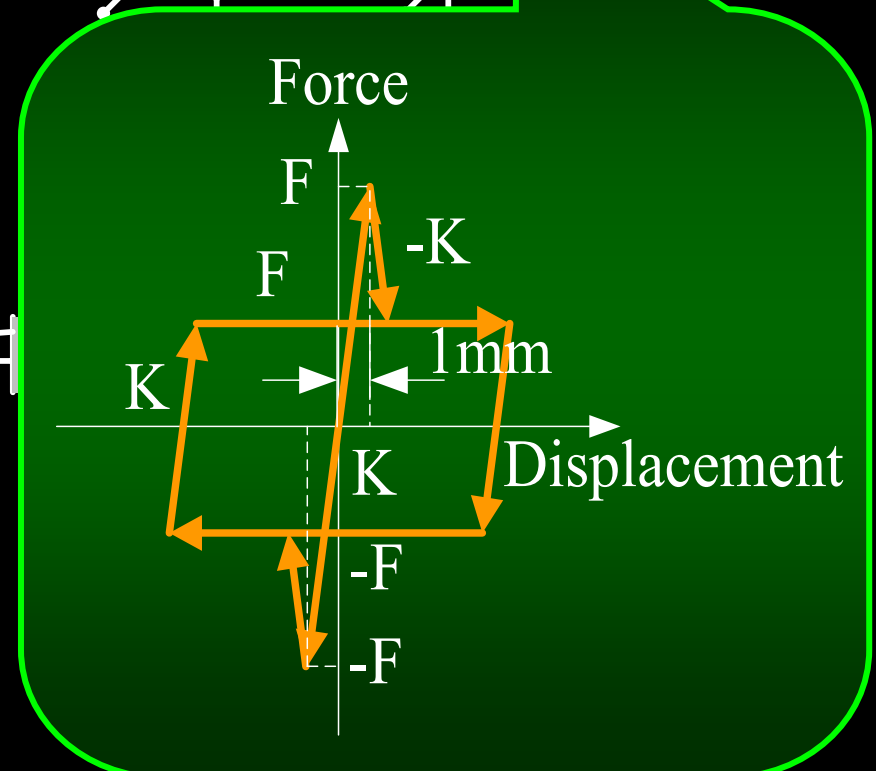
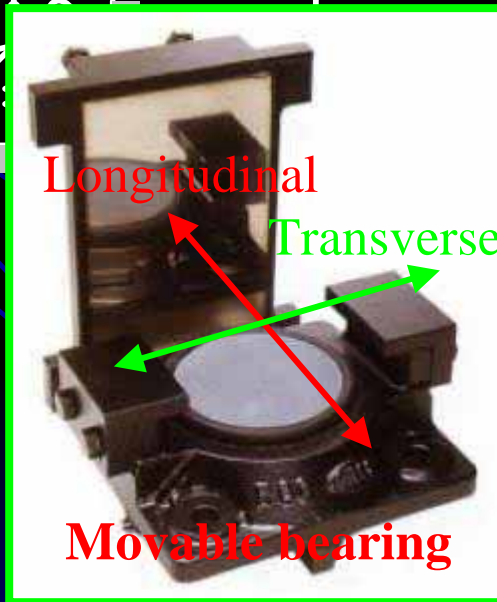
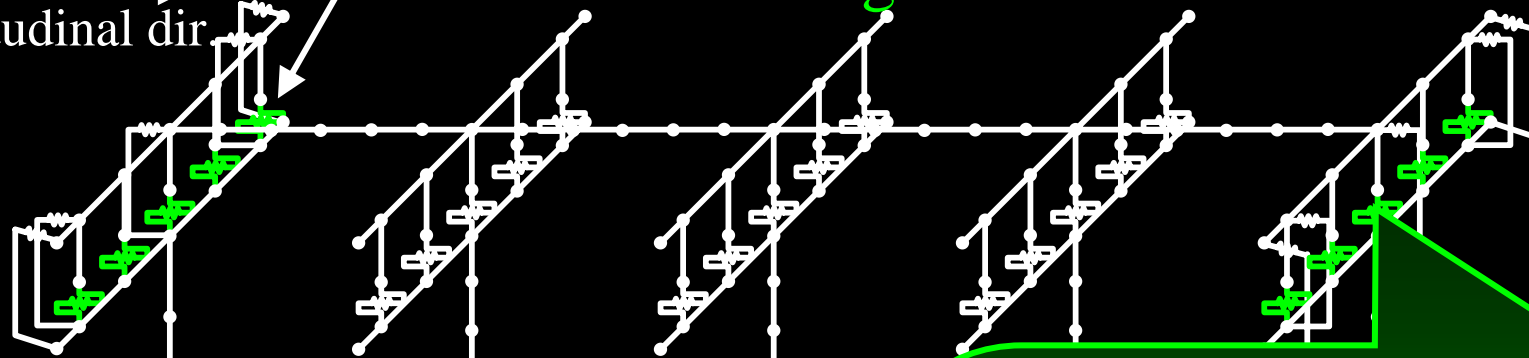


Idealization of Movable Bearing

Transverse dir.

Longitudinal dir.

Transverse direction
of movable bearings

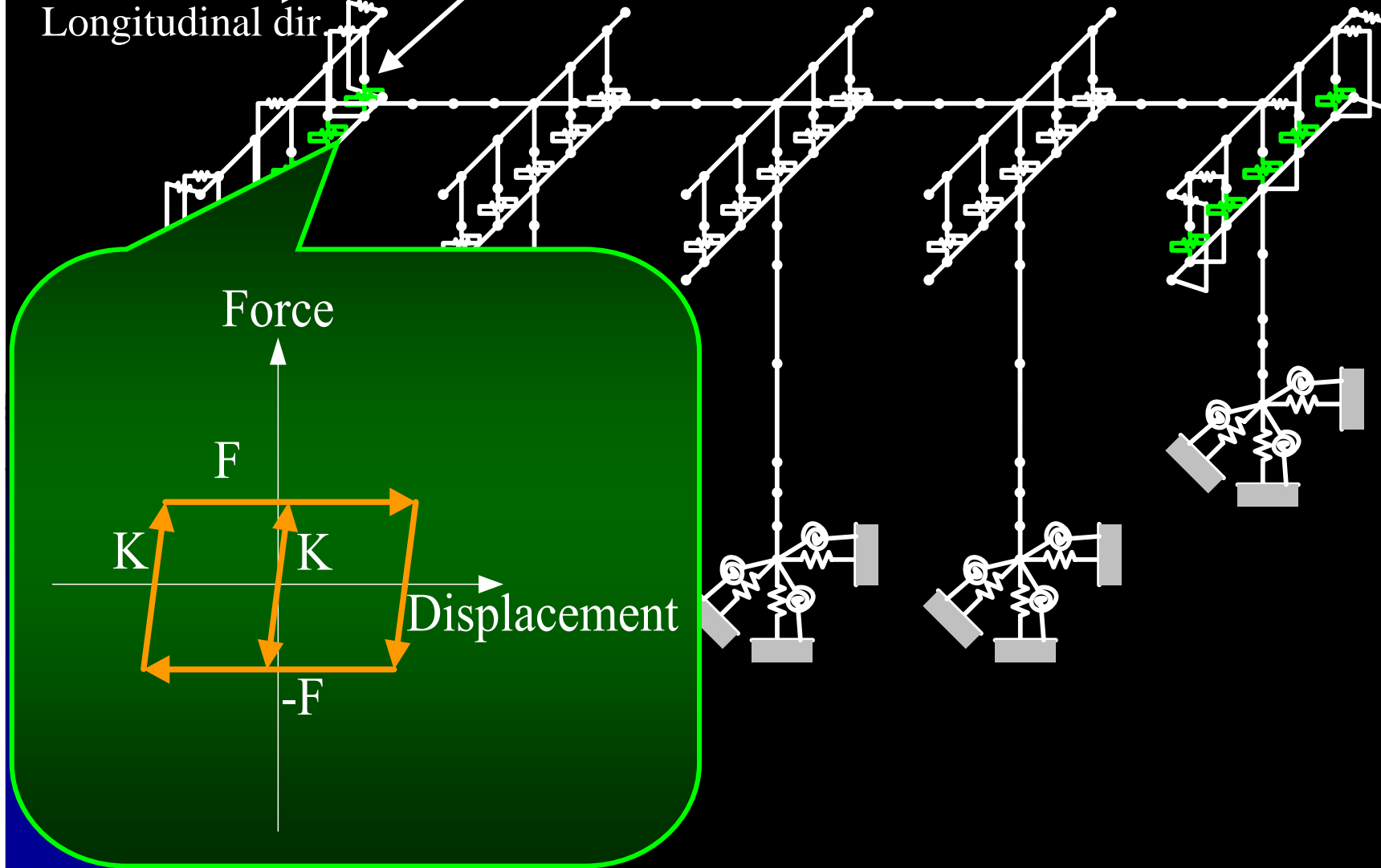


Idealization of Movable Bearing

Transverse dir.

Longitudinal dir.

Longitudinal direction of movable bearing

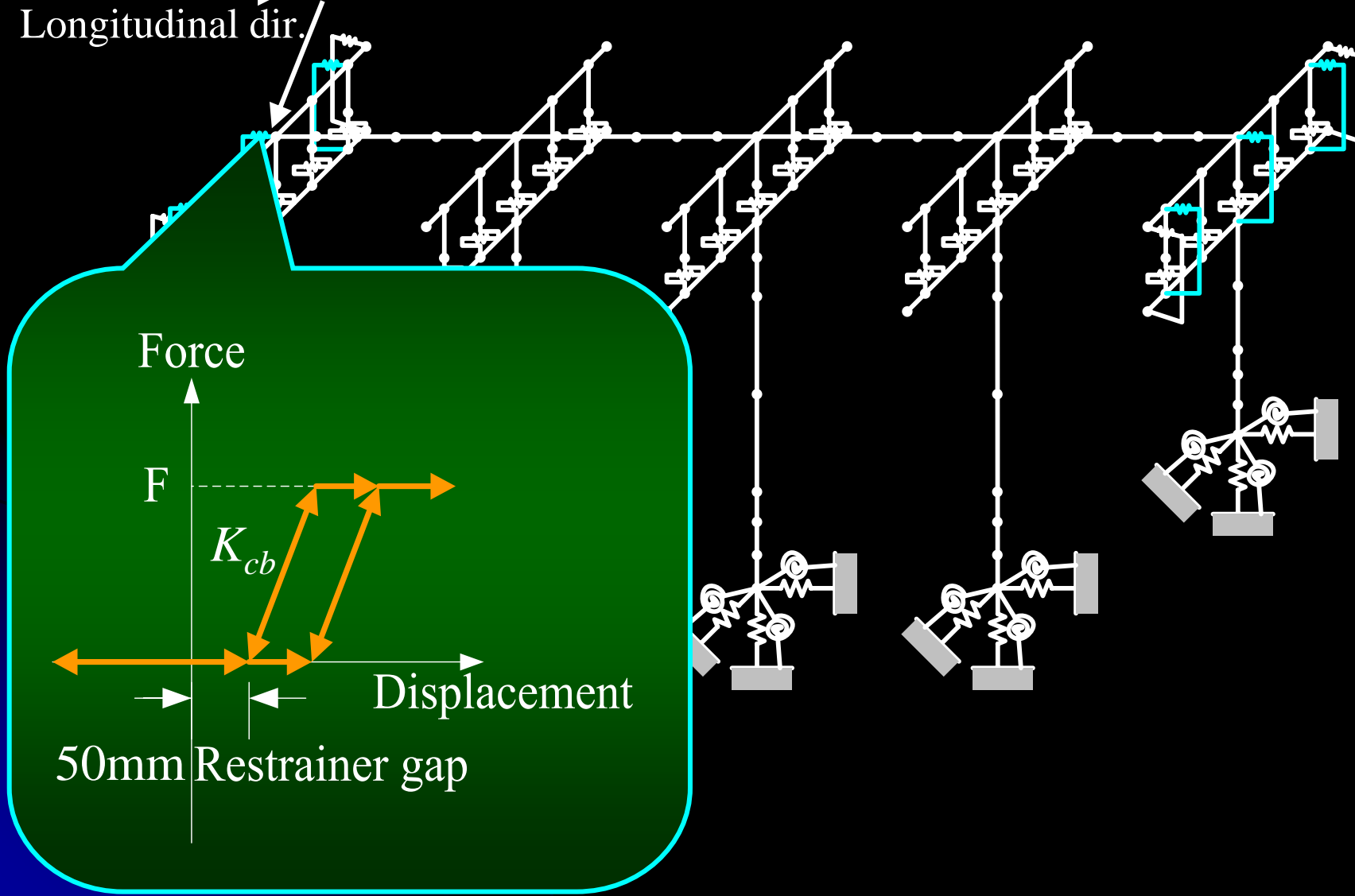


Idealization of Restrainers

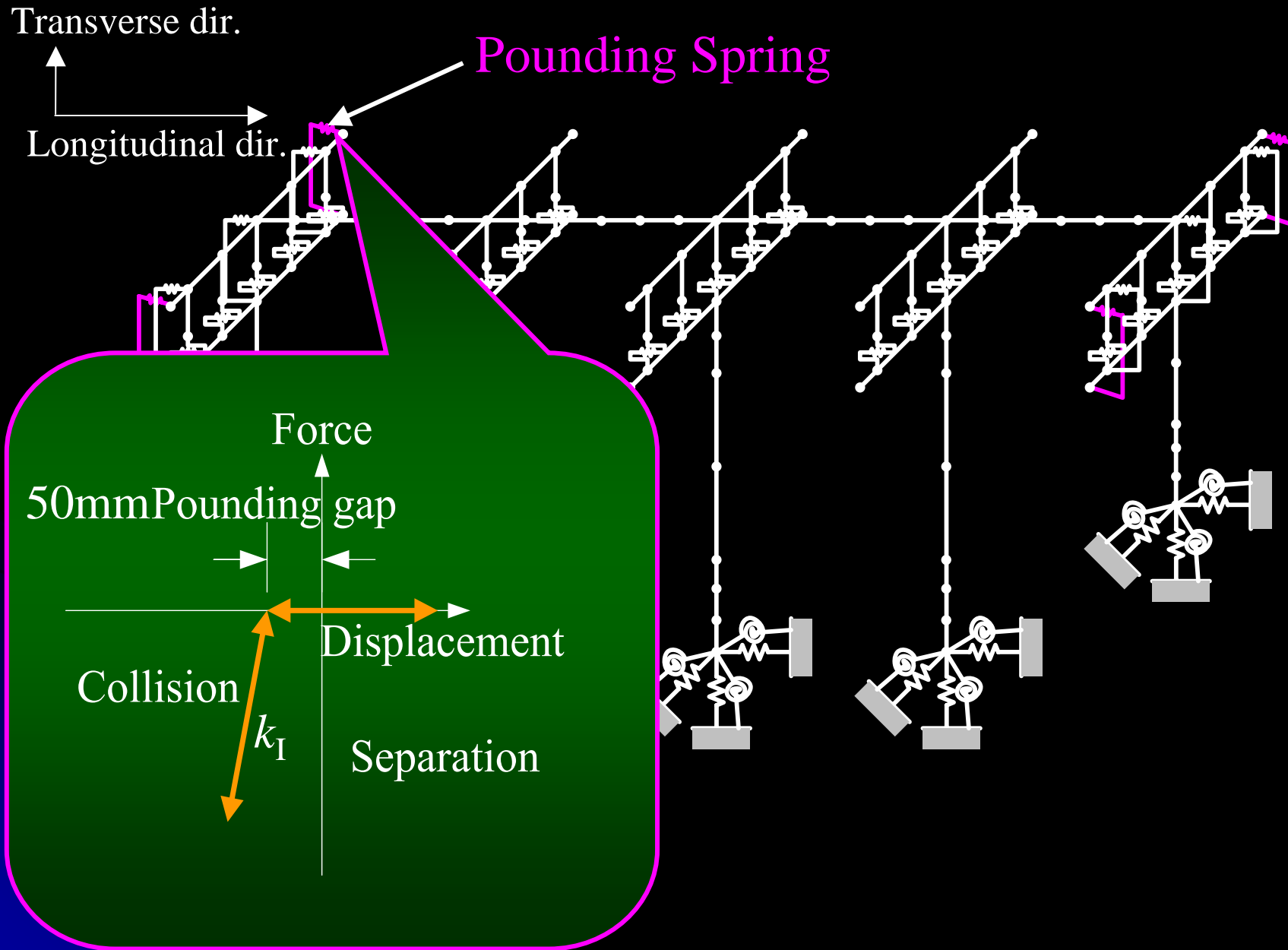
Transverse dir.

Longitudinal dir.

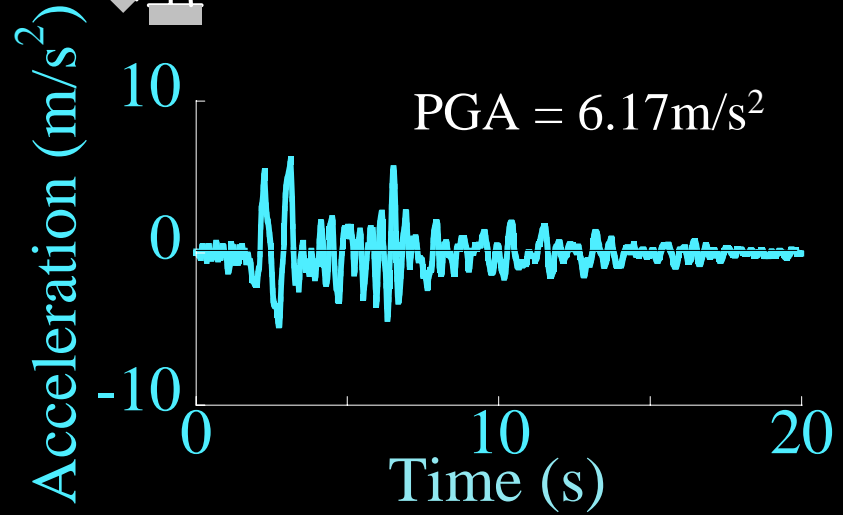
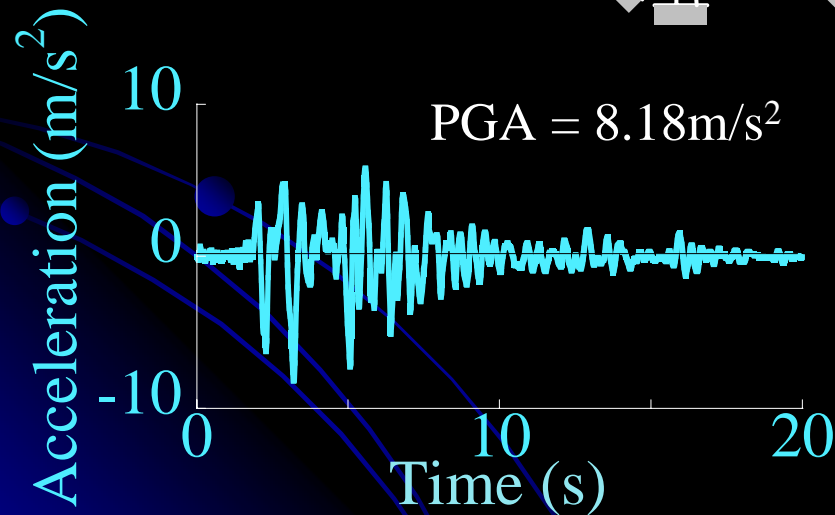
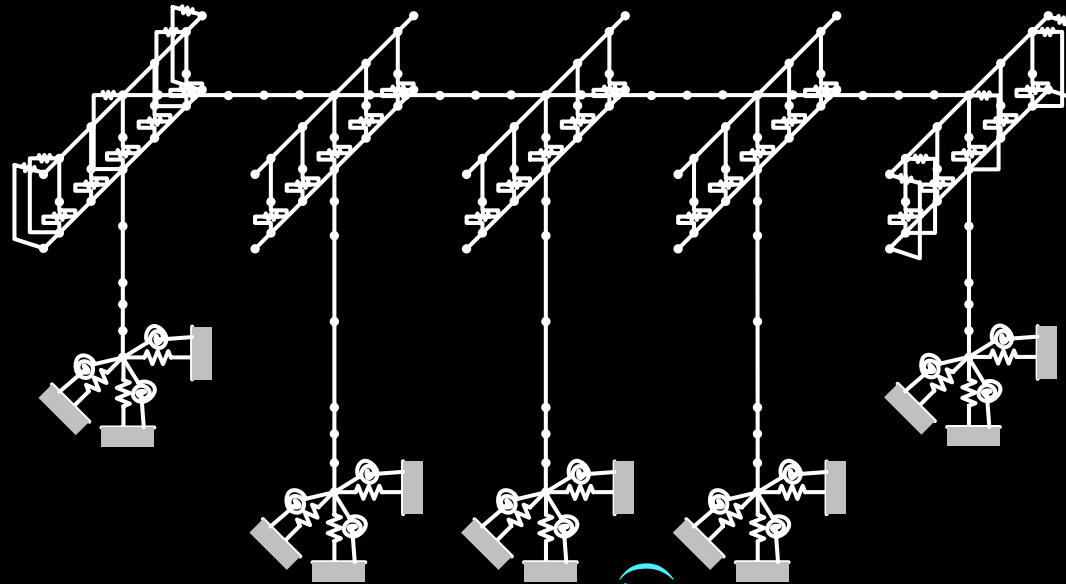
Cable restrainer



Pounding Mechanism



Time History Analysis

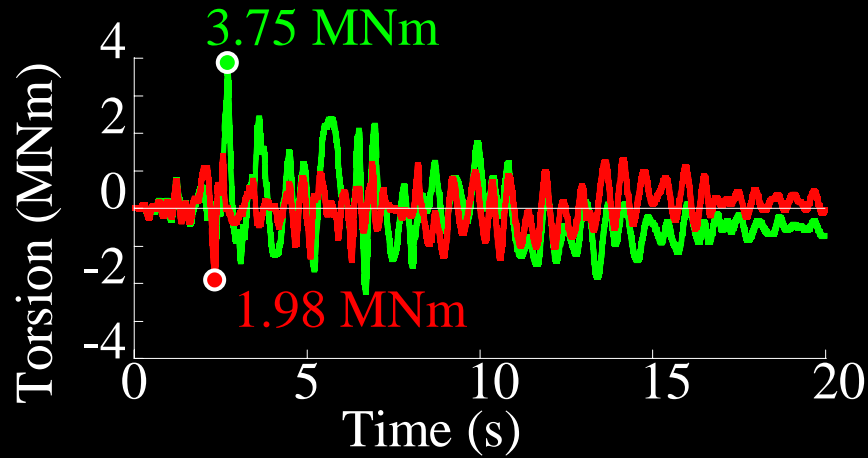


JMA Kobe NS  Long. dir.

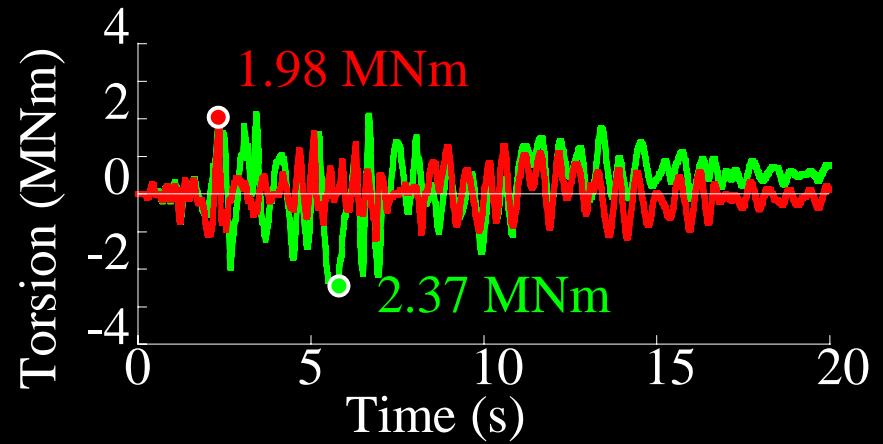
JMA Kobe EW  Transv. dir.

Effect of Skewed Angle

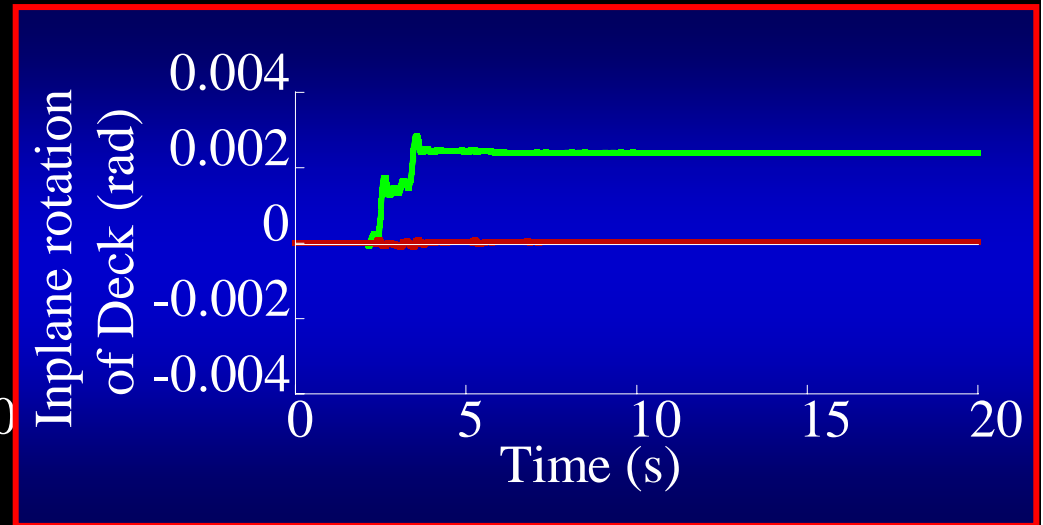
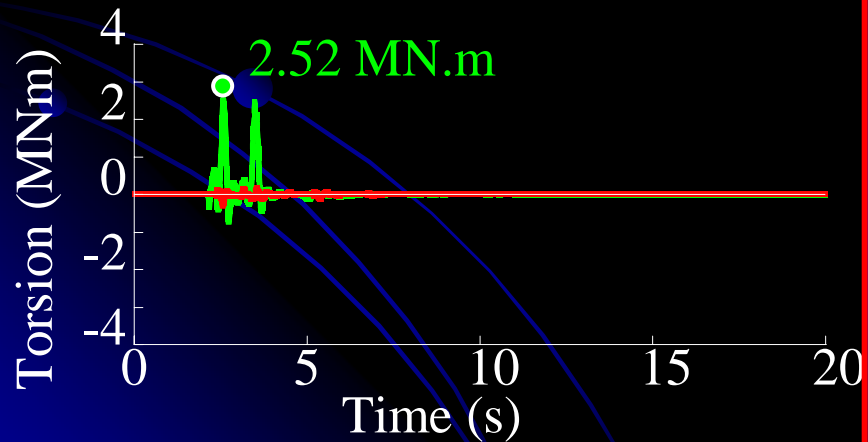
Pier P1



Pier P3



Pier P2



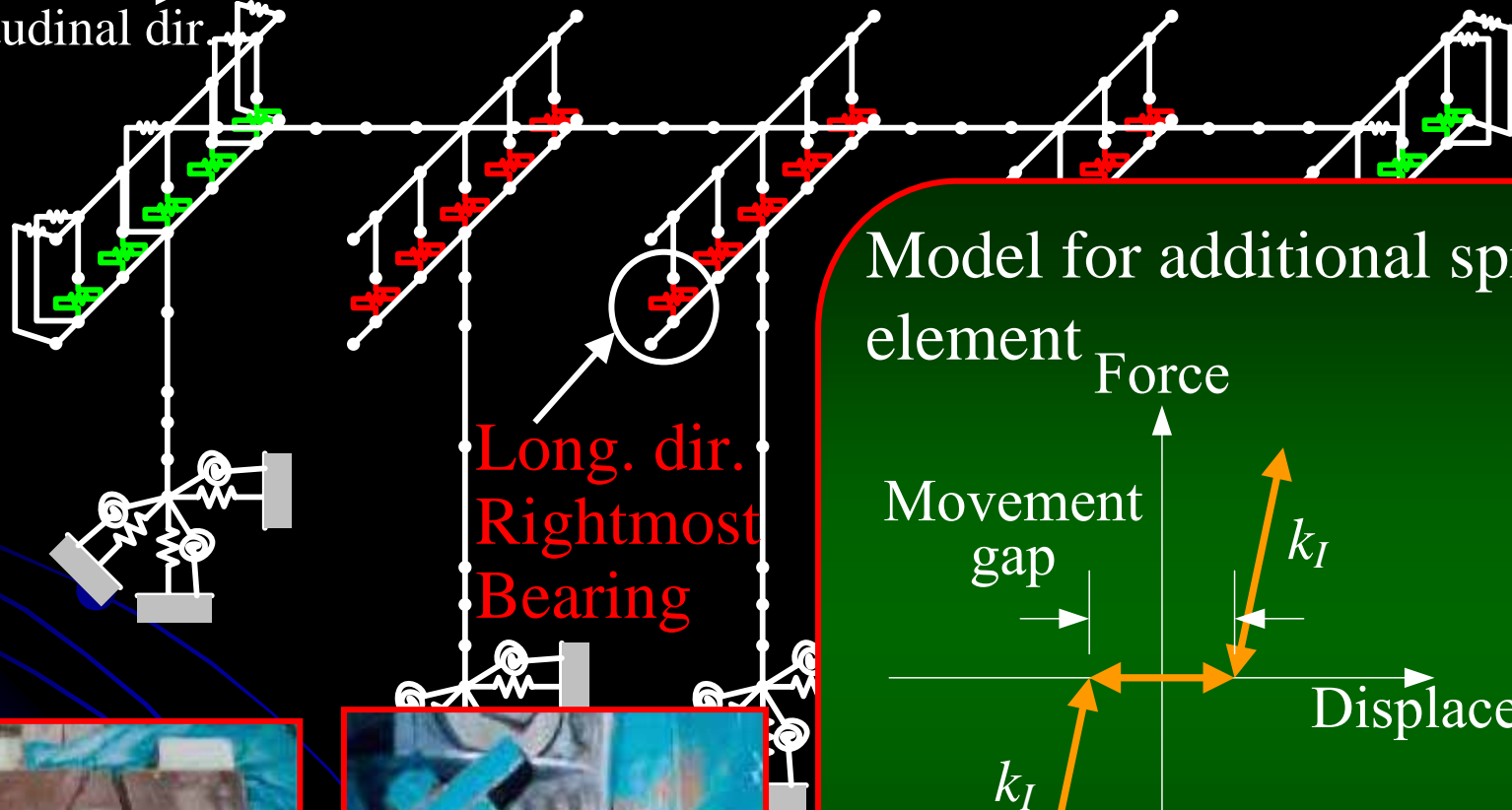
— 40° skew

— No skew

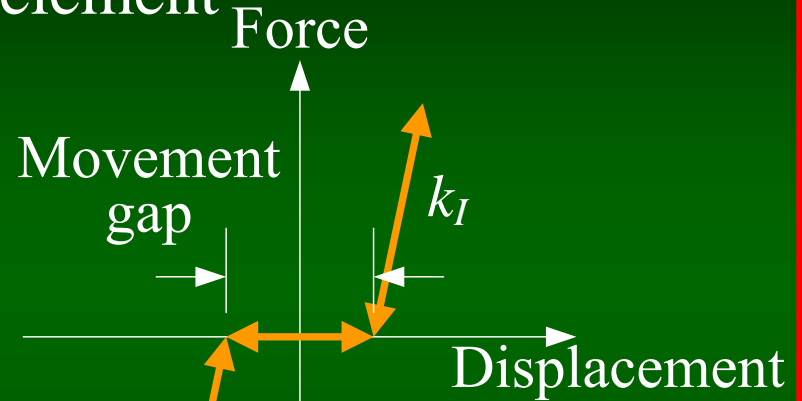
Idealization of Bearing Locking After Failure

Transverse dir.

Longitudinal dir.



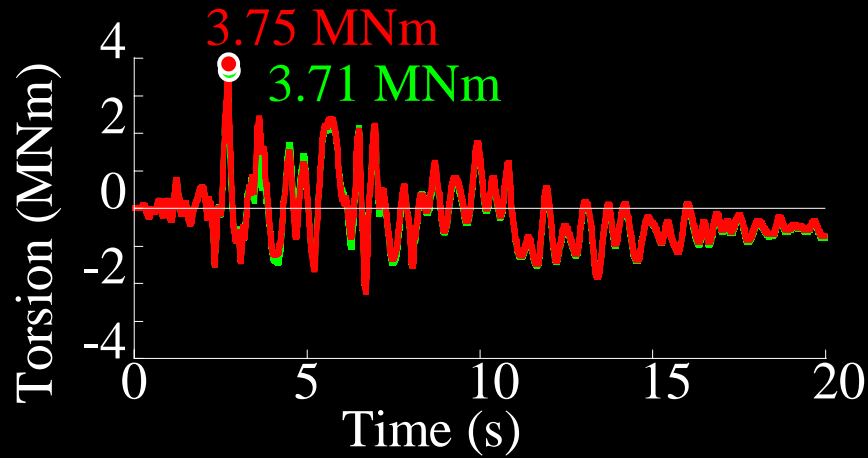
Model for additional spring element



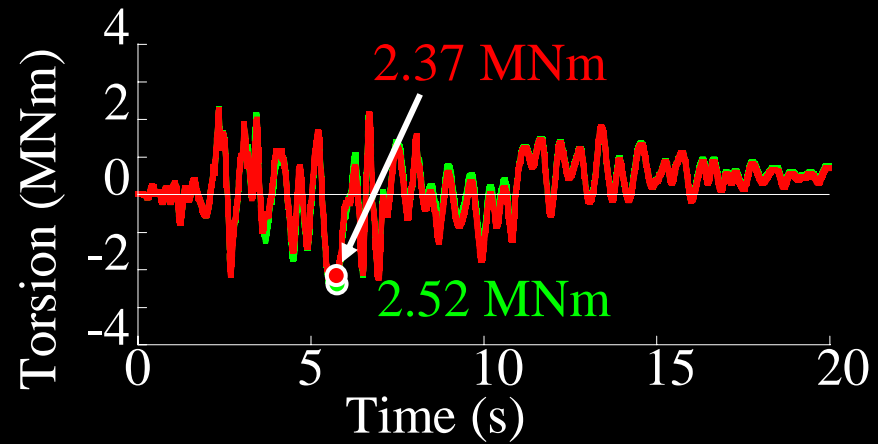
Movement gap = 20 mm

Effect of Bearing Locking

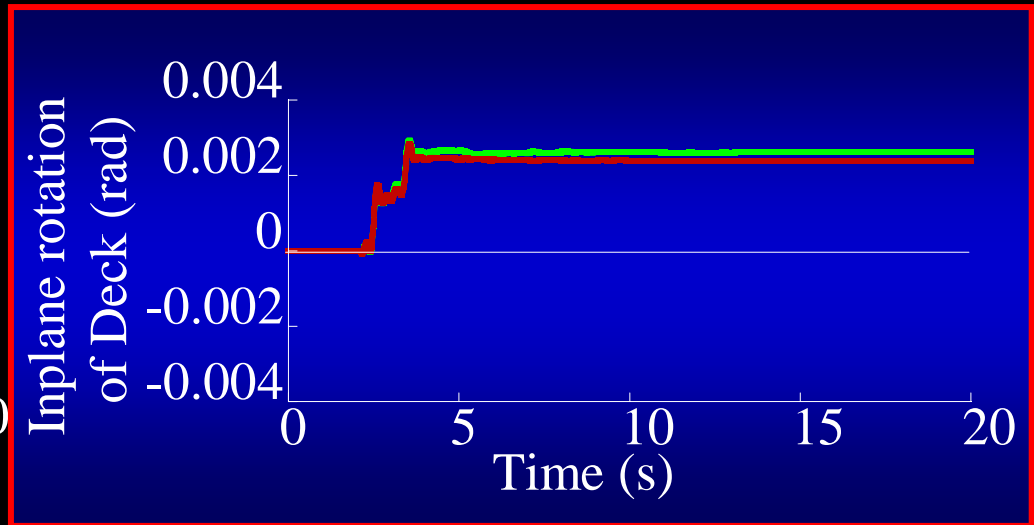
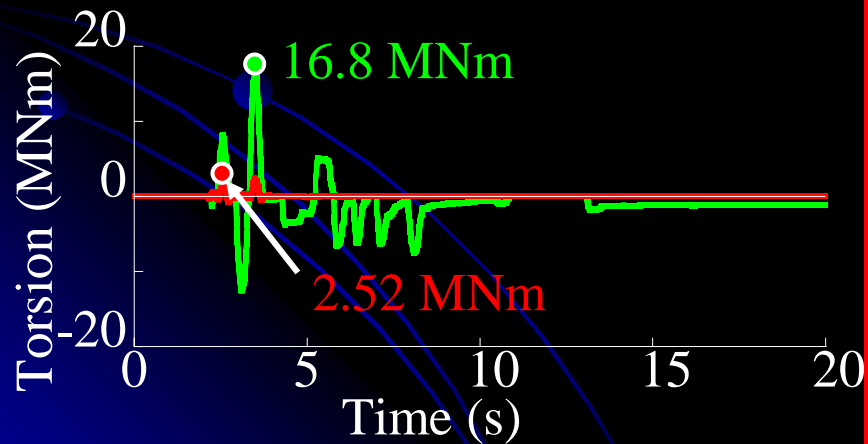
Pier P1



Pier P3



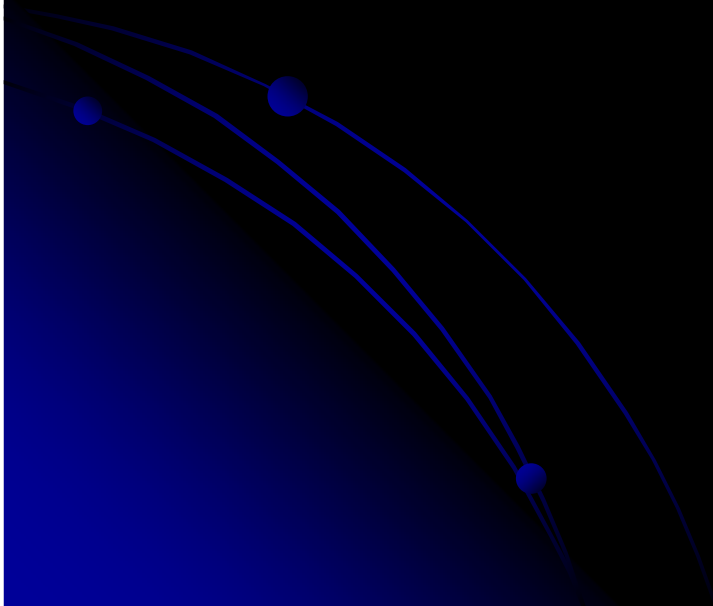
Pier P2



— With locking at rightmost bearing (20 mm movement gap)

— Without bearing locking

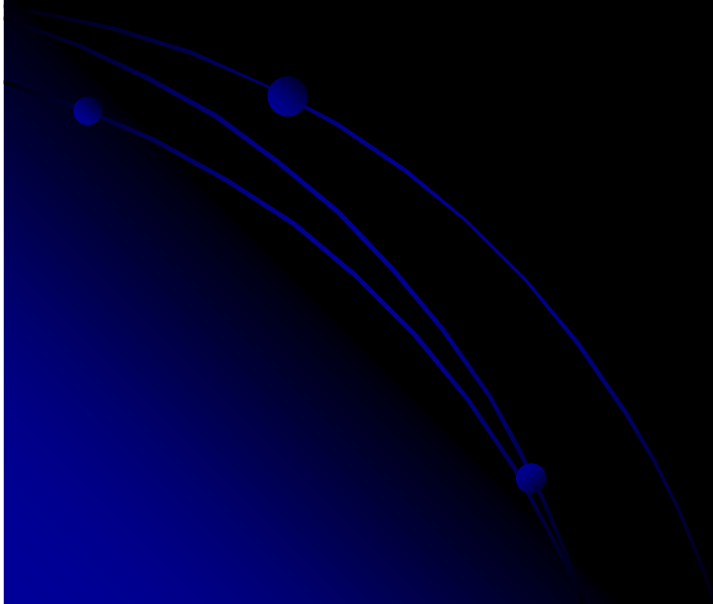
Combined Cyclic Bending-Torsional Loading Test on RC Columns



Objectives

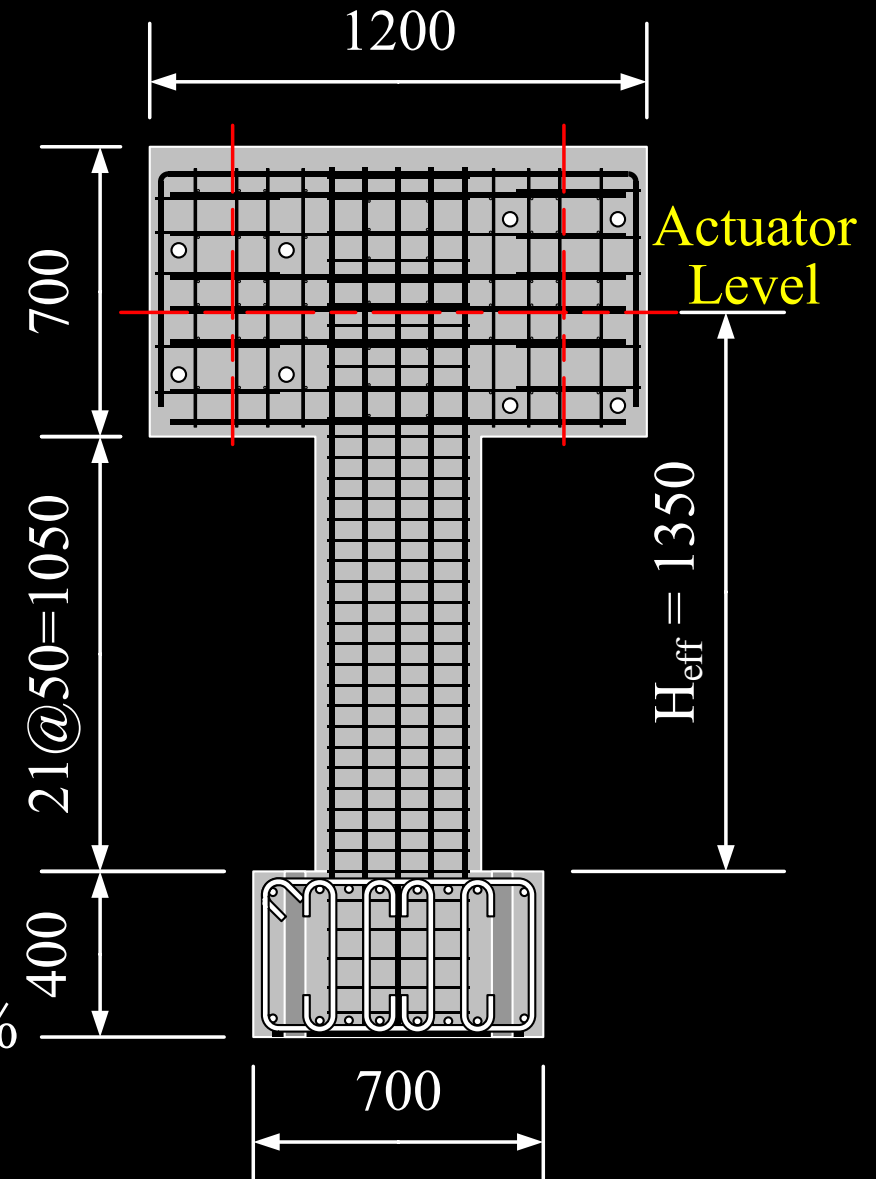
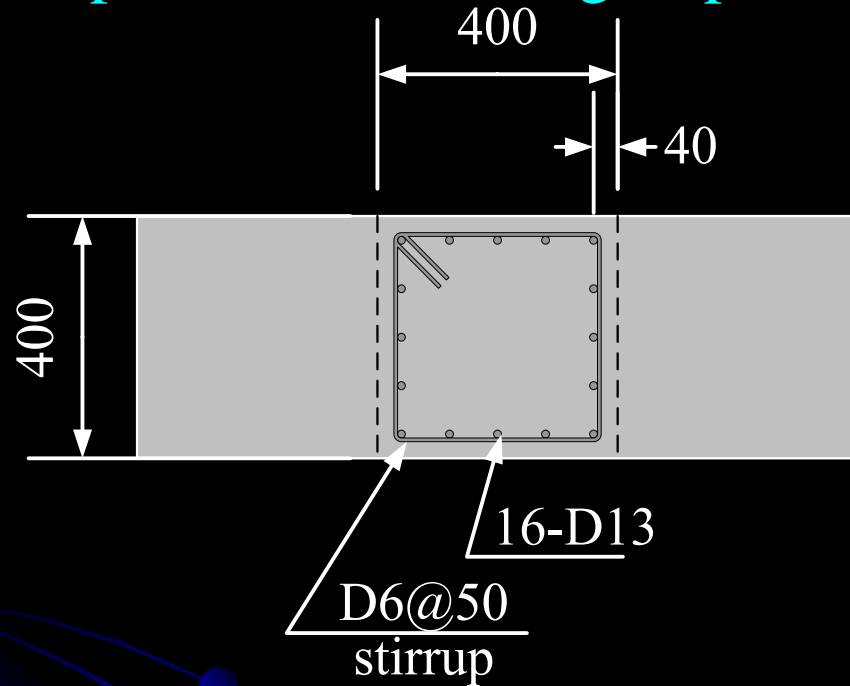
Clarify the stiffness, strength and ductility of RC columns under combined cyclic bending-torsional loading.

Formulate an empirical model of nonlinear torsional hysteresis of a RC column.



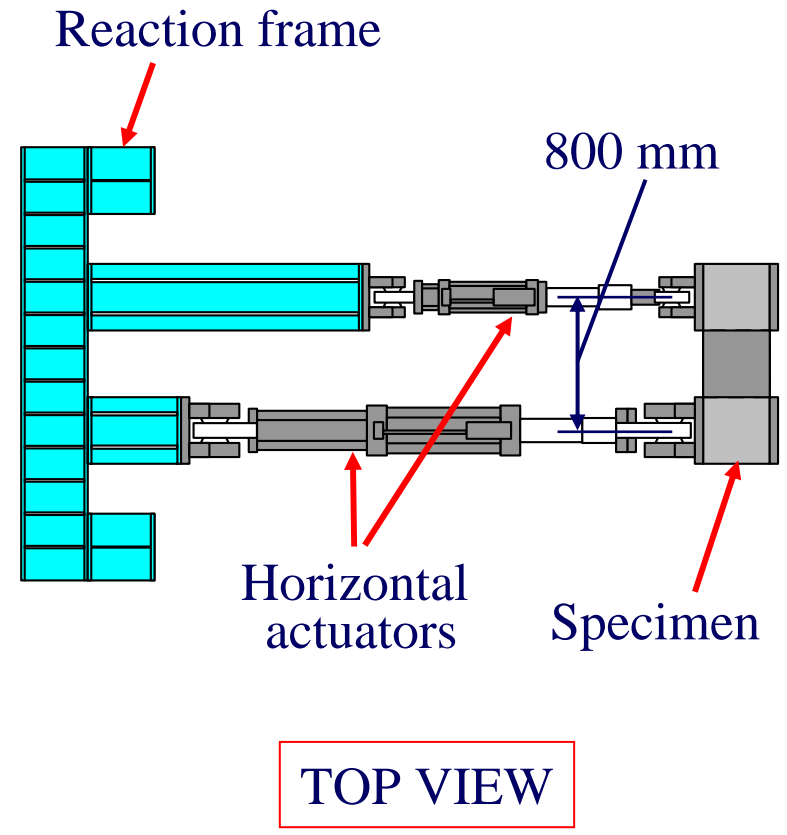
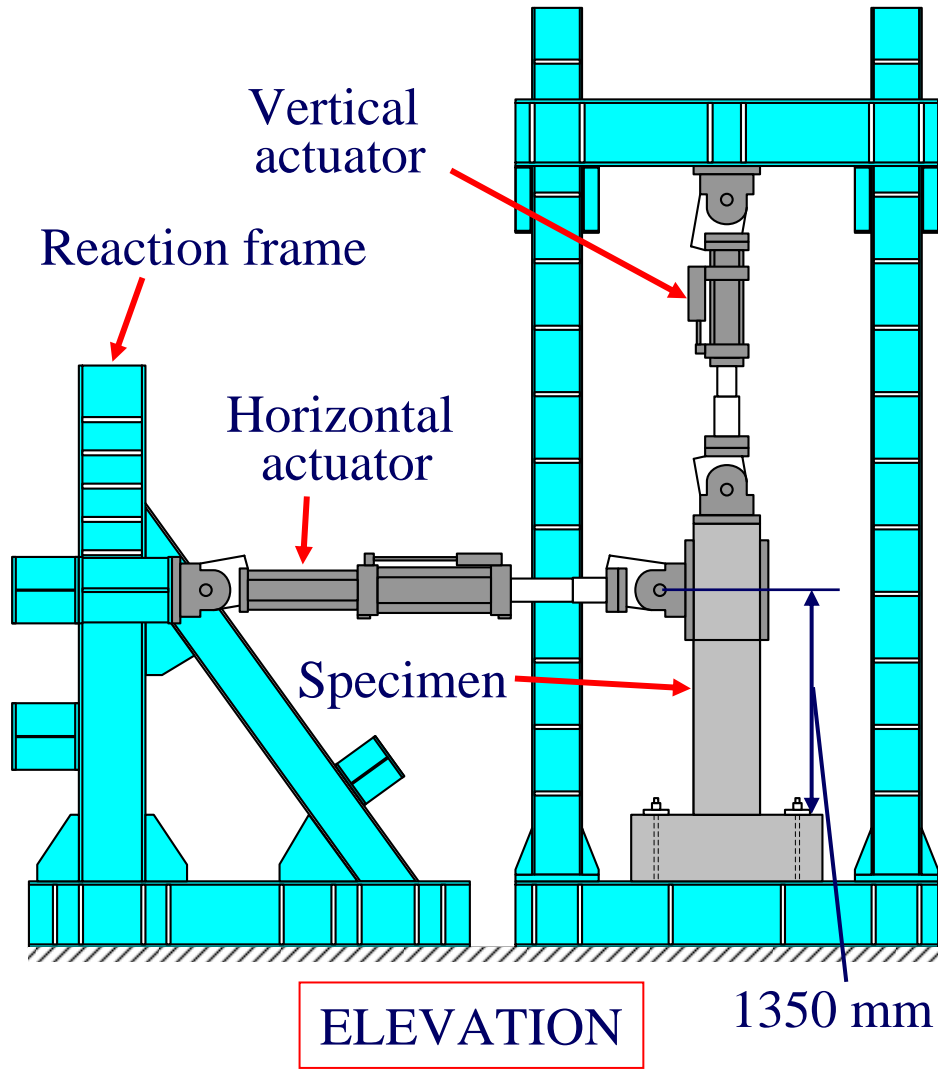
Columnar Specimen

Japanese 1996 Design Specification for Highway Bridges

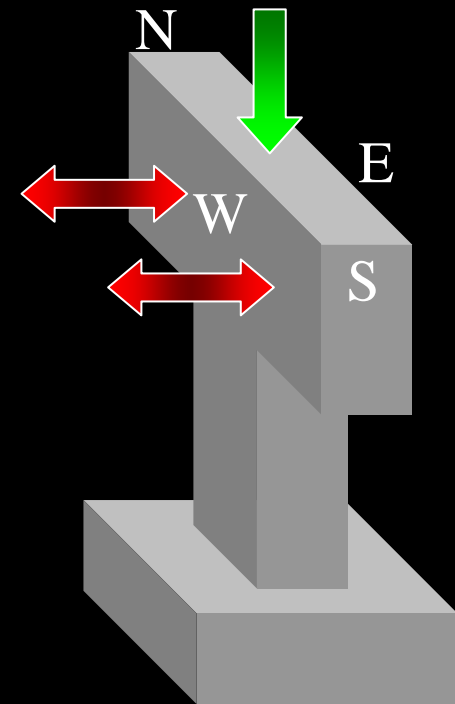


- Material property
 - Concrete : $f'_c = 30$ MPa
 - Steel bar : SD295A
 - $f_y = 295$ MPa
- Long. reinforcement ratio = 1.27%
- Tie volumetric ratio = 0.79%

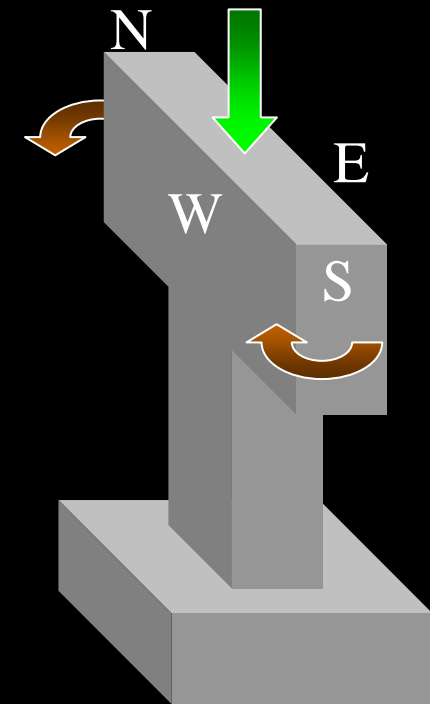
Experimental Setup



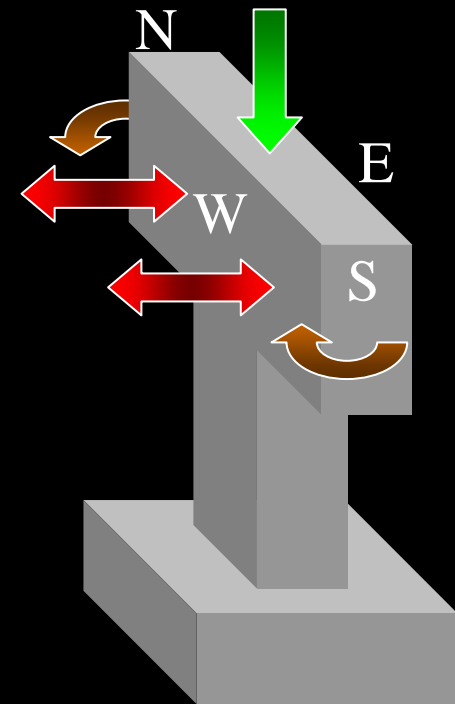
Pure Cyclic Bending under Axial Force



Pure Cyclic Torsion under Axial Force

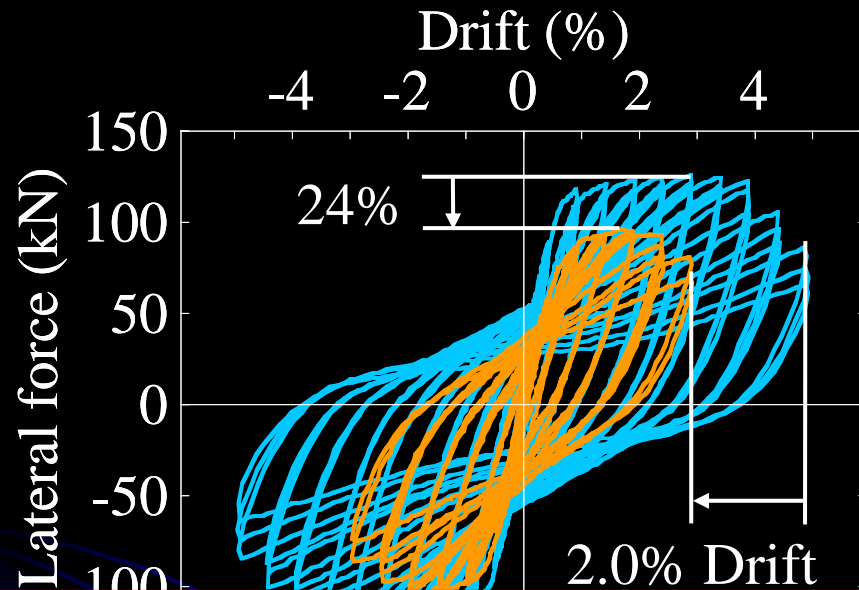


Combined Bending and Torsion under Axial Force Rotation-drift ratio $(\theta/\Delta) = 2$

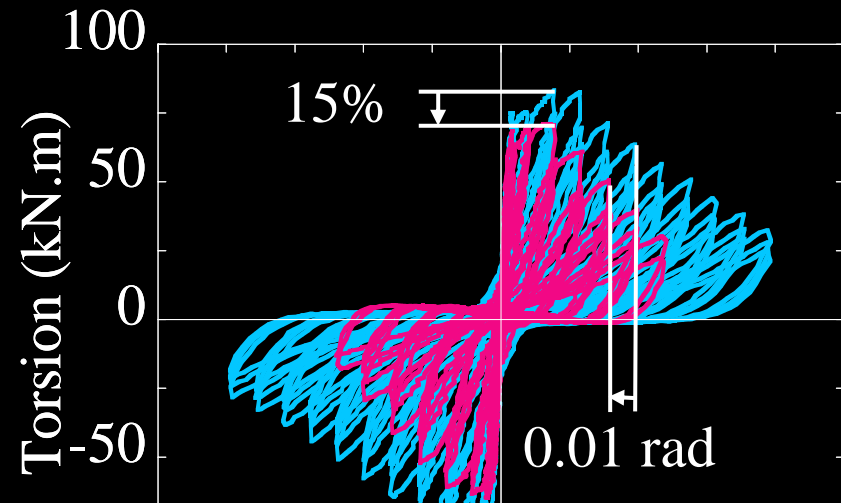


Comparison of Column Hystereses

Flexural Hysteresis



Torsional Hysteresis



Ultimate displacement or rotation : Displacement or rotation where the lateral force or torsion decreases to 80% of the capacity

Displacement (mm)

Rotation (rad)

- Pure cyclic bending
- Combined cyclic bending and torsion ($\theta/\Delta = 2$)

- Pure cyclic torsion
- Combined cyclic bending and torsion ($\theta/\Delta = 2$)

Current Conclusions

Pounding between deck and abutments can result in inplane deck rotation and seismic torsion of the columns in skewed bridge during a significant earthquake.

Locking of bearing after damage can extensively increase the seismic torsion of piers in skewed bridges

The flexural capacity and the ultimate displacement of column reduce as the torsion increases. On the other hand, the increase of bending moment results in the deterioration of torsional capacity and the ultimate rotation.

Damage of column tends to shift upward from the plastic hinge zone as the rotation-drift ratio increases.

**Thank you very much
for your attention**

