

Seismic Performance of Reinforced Concrete C-bent Columns

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C-bent Columns

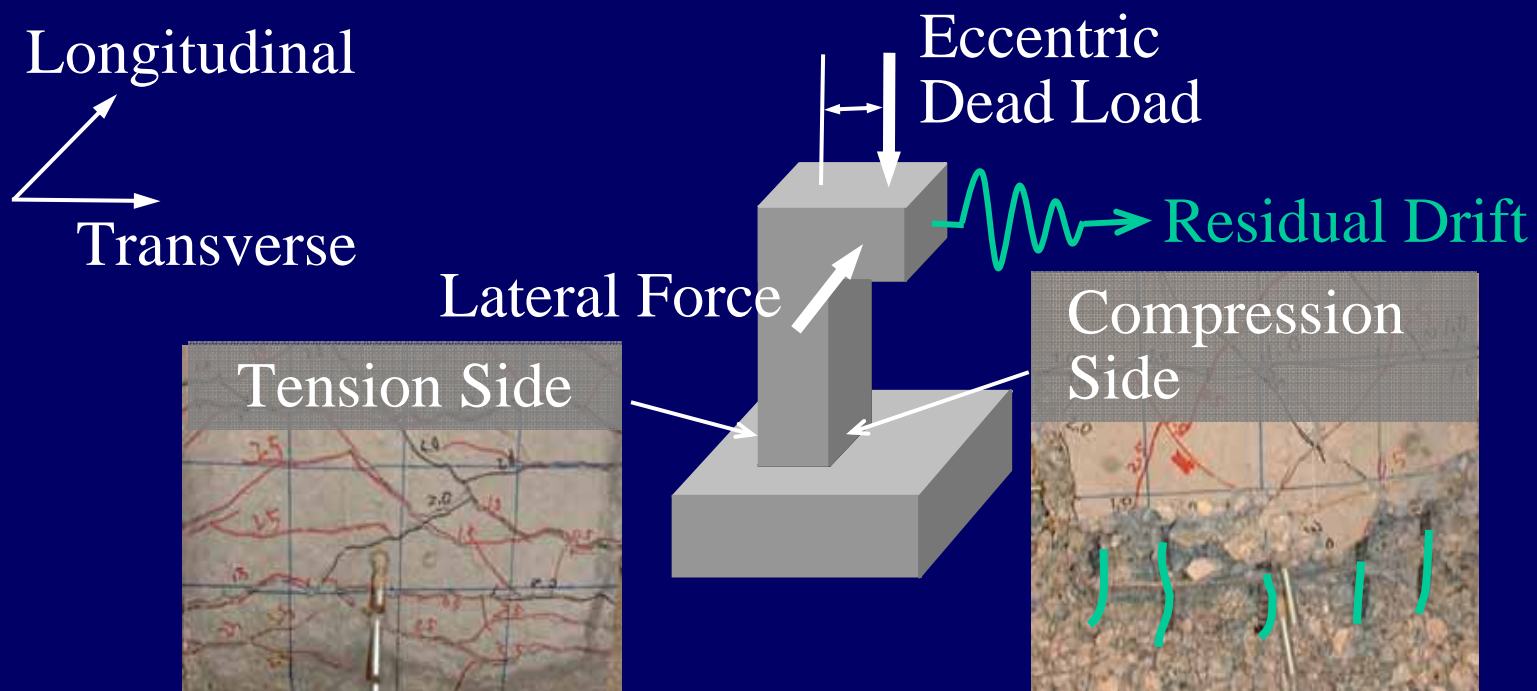
In urban area, there exist a large number of RC columns with the lateral beam being longer in one side than the other.



C-bent columns have a poor seismic performance!

Current Researches on C-bent Columns

- Cyclic loading and shake table tests in transverse direction, Kawashima and Unjoh, 1994.
- Cyclic loading tests in longitudinal direction, Tuchiya and Maekawa et al, 1999.
- Cyclic loading tests in bilateral direction, Kawasima et al, 2002



Objectives

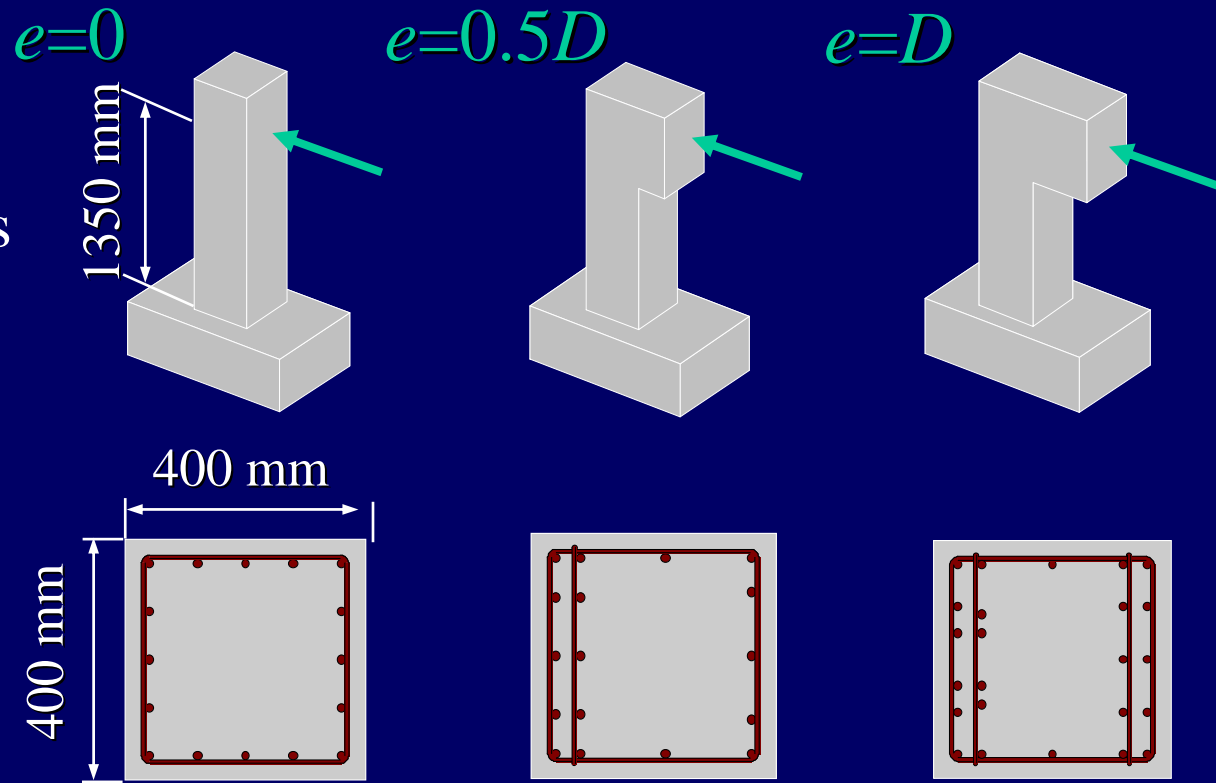
- To clarify seismic response of RC C-bent columns under bilateral excitation, a series of hybrid loading test were conducted.
- To reproduce the experimental response of RC C-bent columns, a fiber element analysis was conducted

Test Specimens

RC Columns were designed based on the current Seismic design codes.

e : Eccentricity
 D : Width of Columns

- 1350mm Effective Height
- 400mm x 400mm Square Section



Axial Reinforcements

1.27 %

1.35 %

1.9 %

Tie Reinforcements

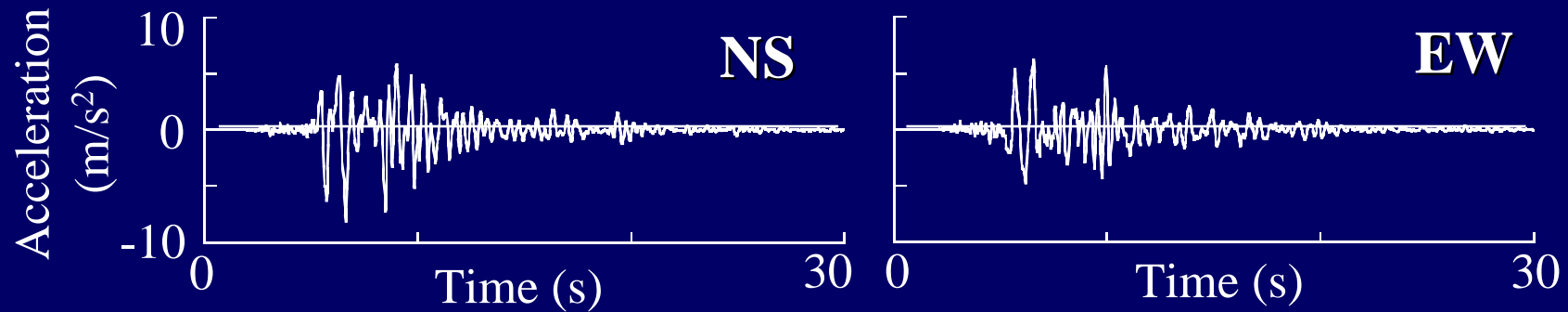
0.79 %

0.99 %

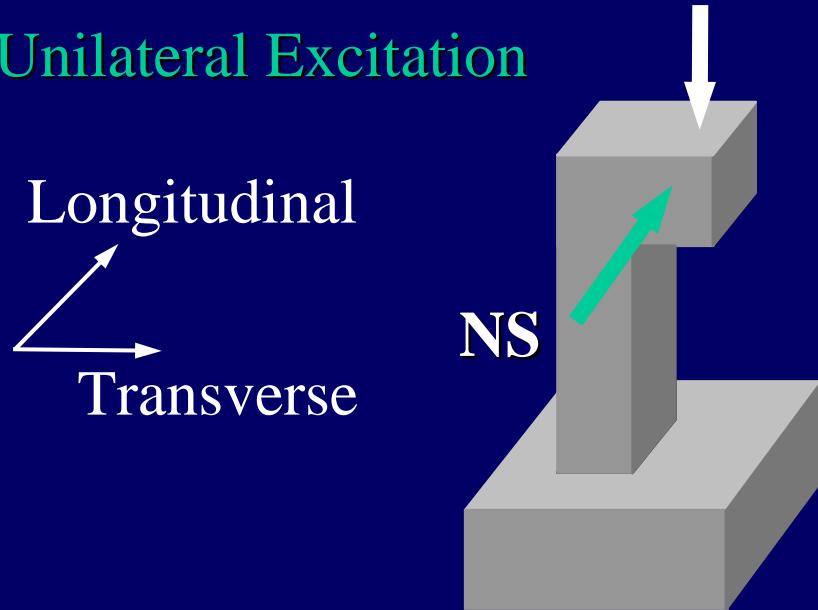
1.19 %

Hybrid Loading Test on C-bent Columns

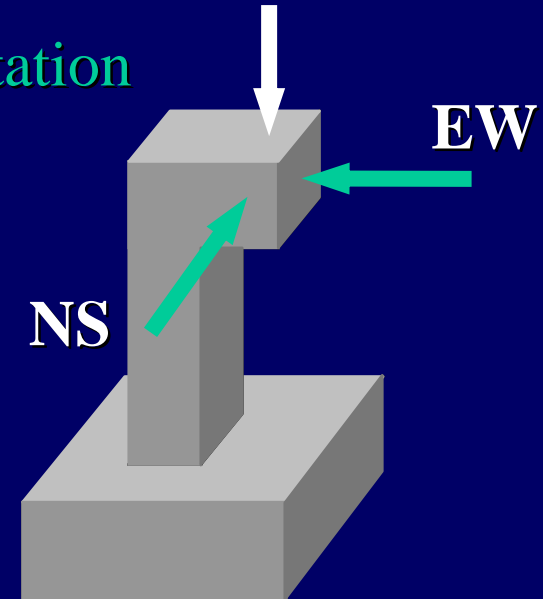
Input Ground Motion: JMA Kobe Record



Unilateral Excitation

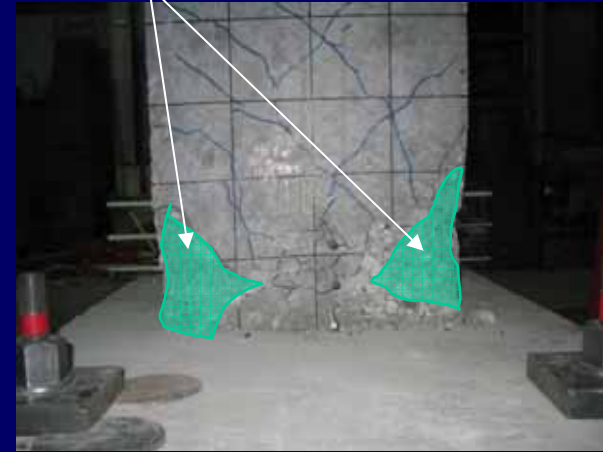
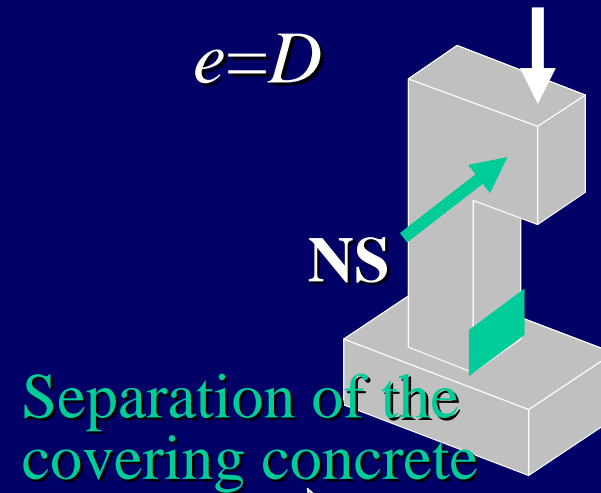
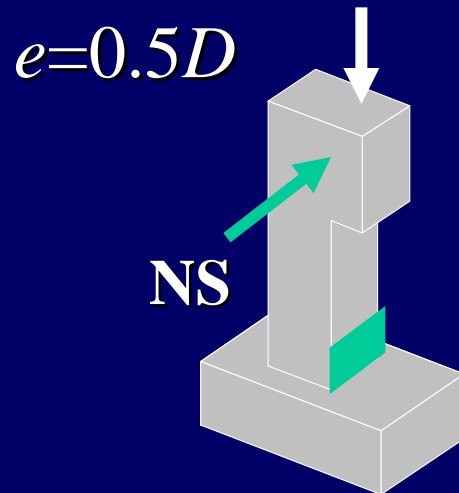
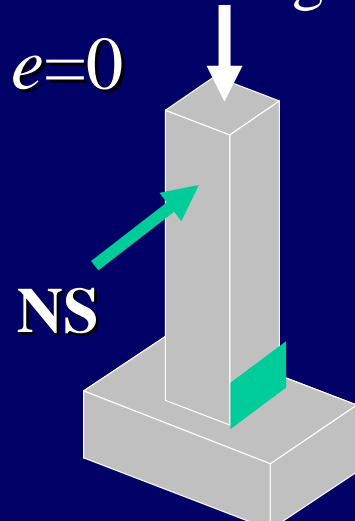


Bilateral Excitation



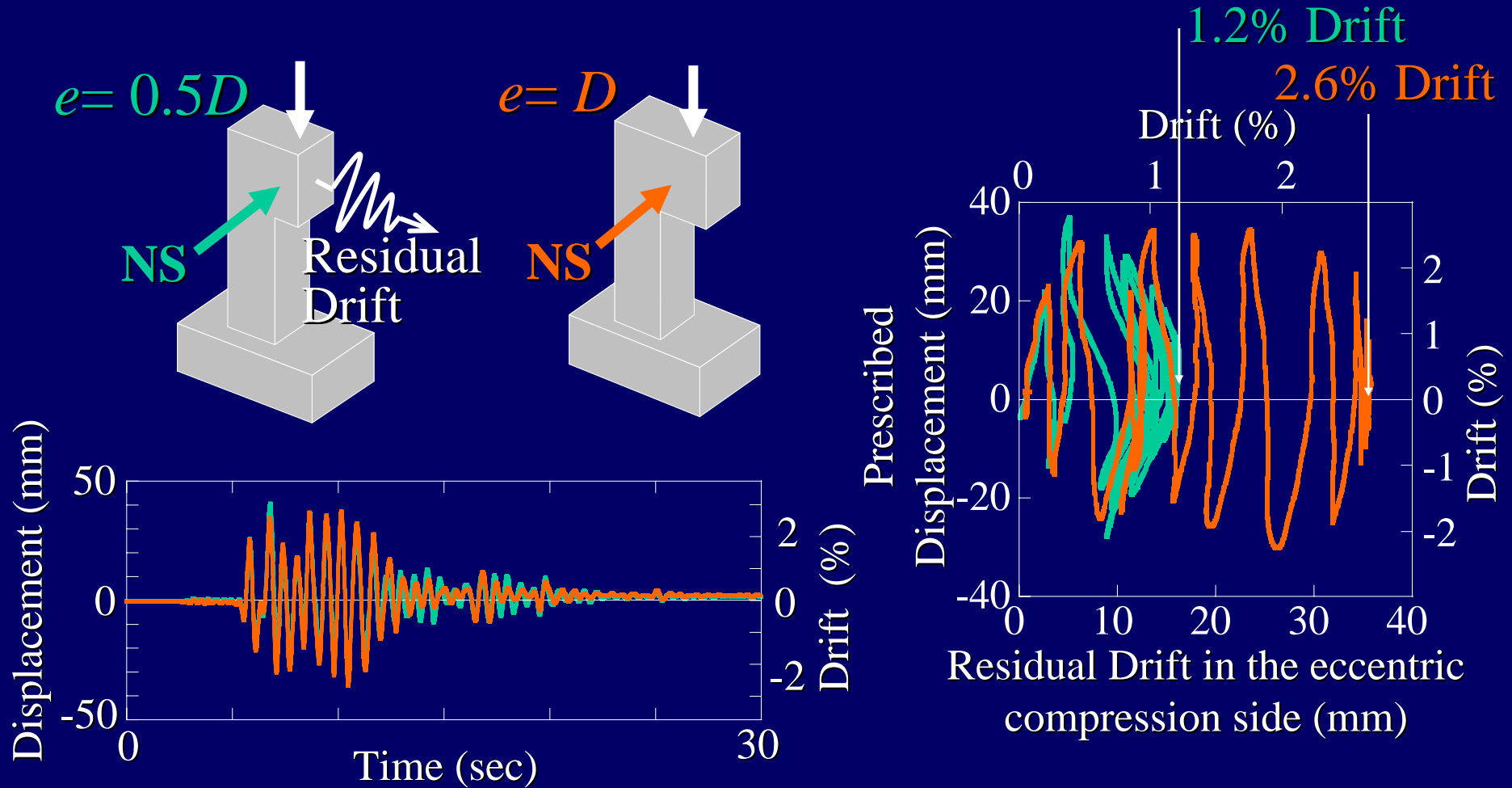
Damage after the Unilateral Excitation

Damage of columns at the eccentric completion side



The damage increases as the eccentricity increases.

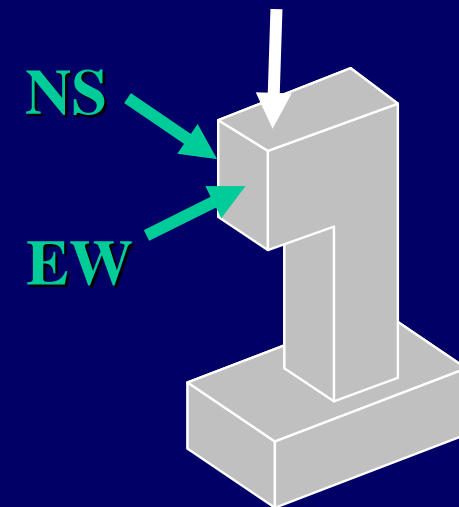
Seismic Response under the Unilateral Excitation



The residual drift increases as the eccentricity increases.

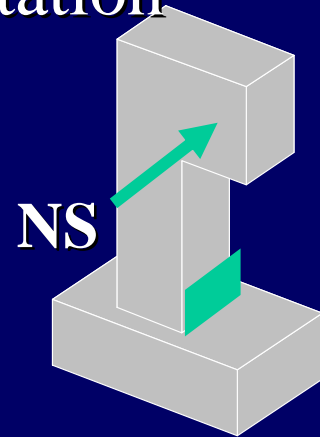
Hybrid Loading Test under the Bilateral Excitation

Residual Drift
After Loading ——— Before Loading

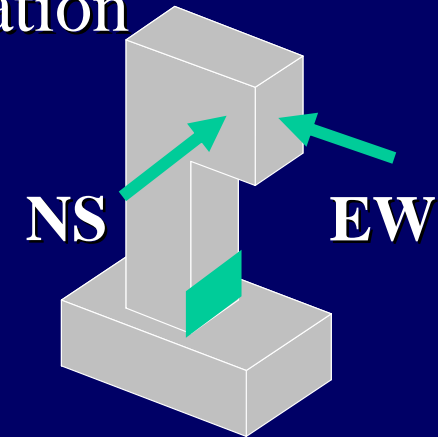


Effect of Bilateral Excitation $e=D$

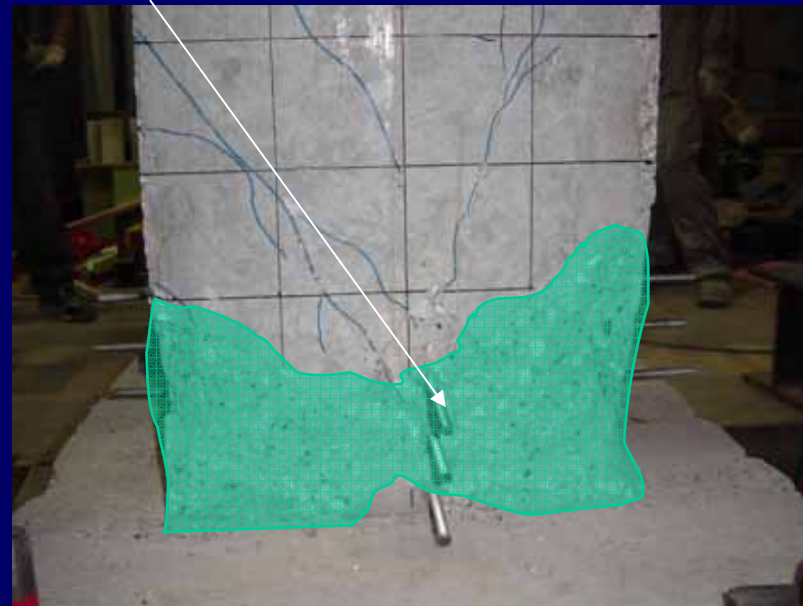
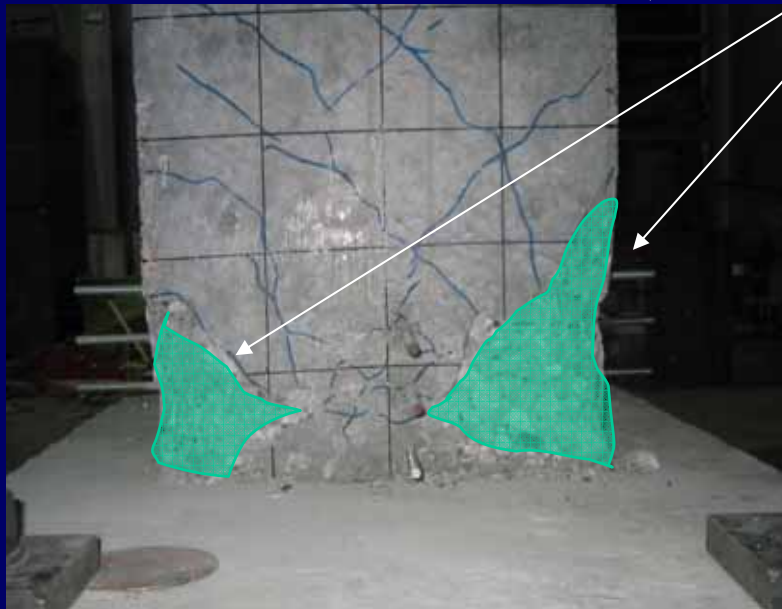
Unilateral Excitation



Bilateral Excitation

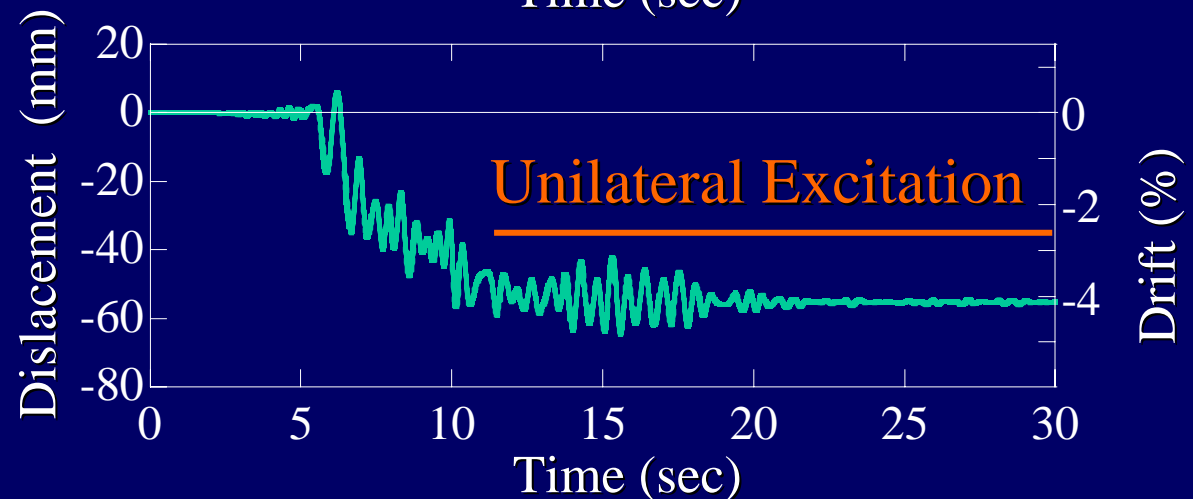
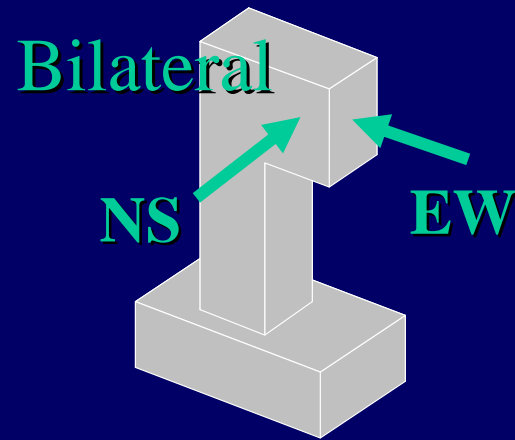
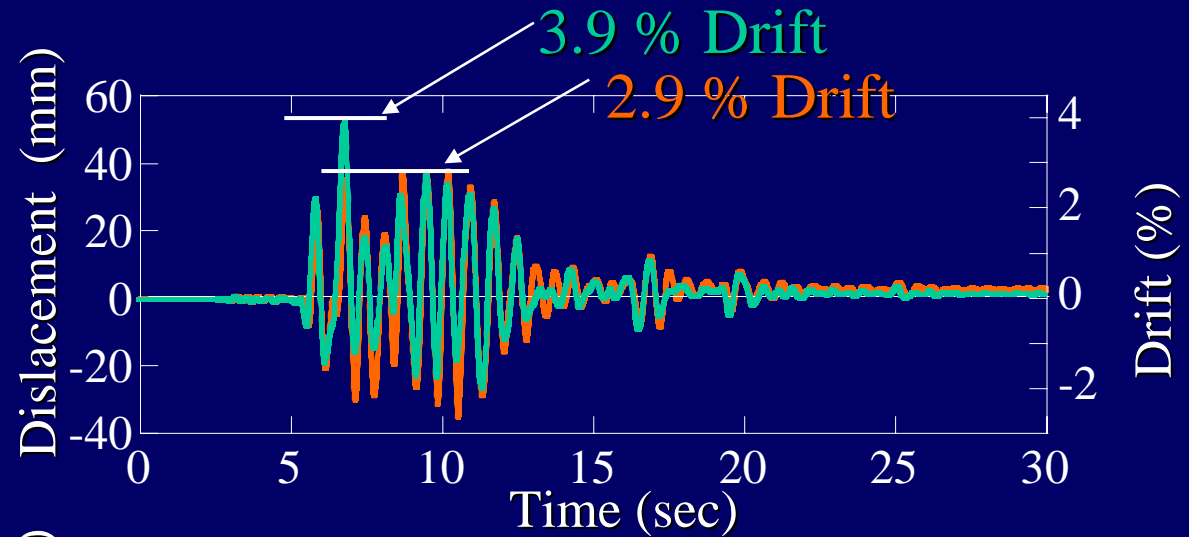


Separation of the covering concrete



Bilateral excitation results in more extensive damage

Effect of Bilateral Excitation $e=D$

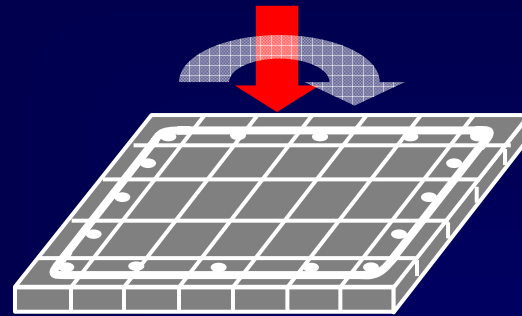
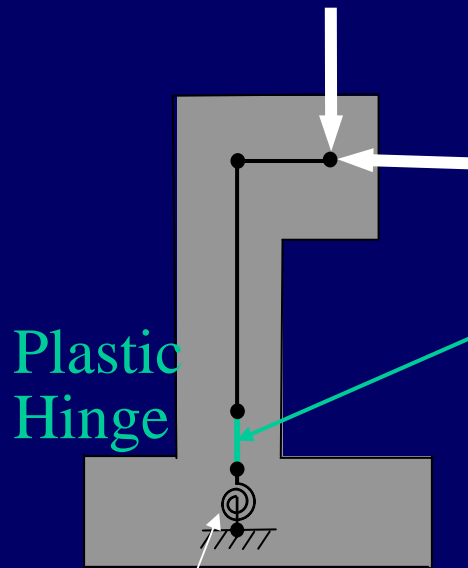


Bilateral Excitation results in larger residual drift.



Effect of bilateral excitation is important in evaluation of a residual drift

Fiber Model of the RC C-Bent Columns



Fiber Element

Torsional Stiffness

$$T = GJ \cdot \phi$$

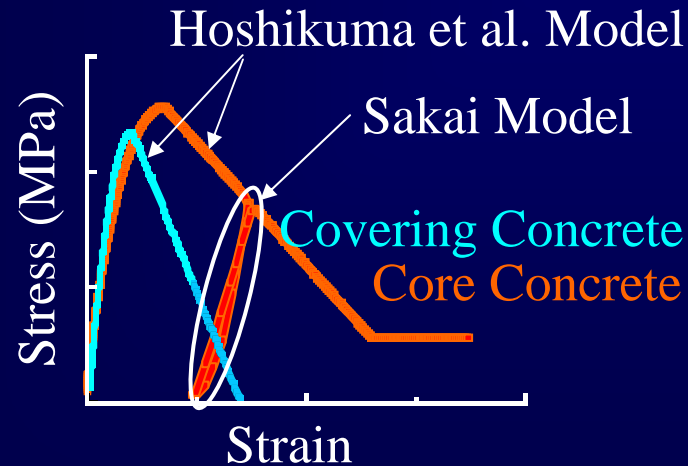
T : Torsional Moment

ϕ : Curvature

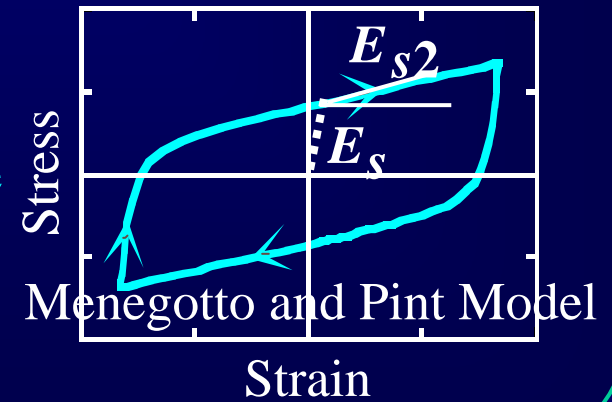
G: Shear modulus

J : Torsional moment of inertia

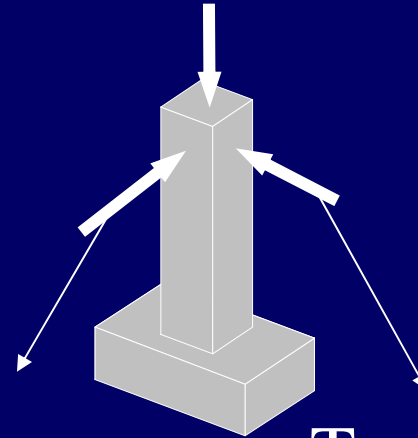
Concrete



Reinforcements



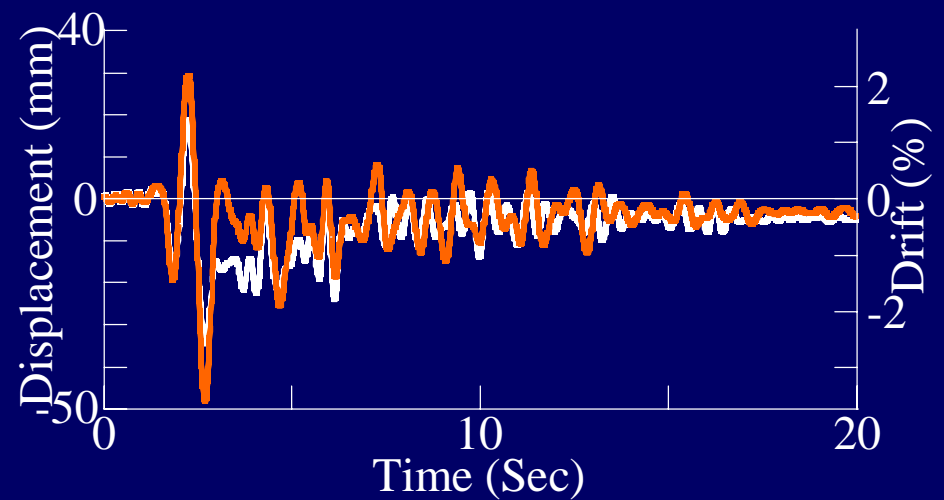
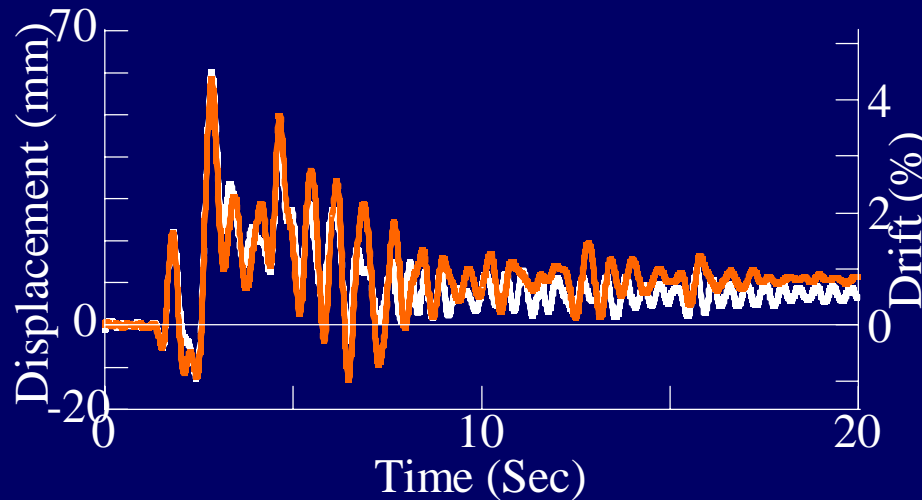
Fiber Element Analysis $e=0$



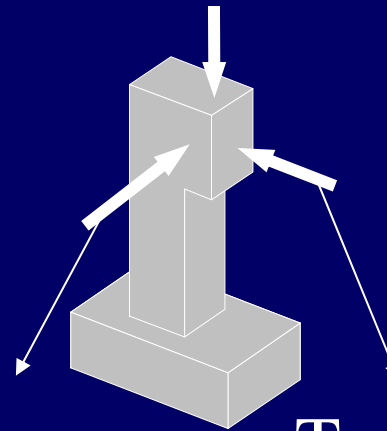
Analysis
Experiment

Longitudinal

Transverse



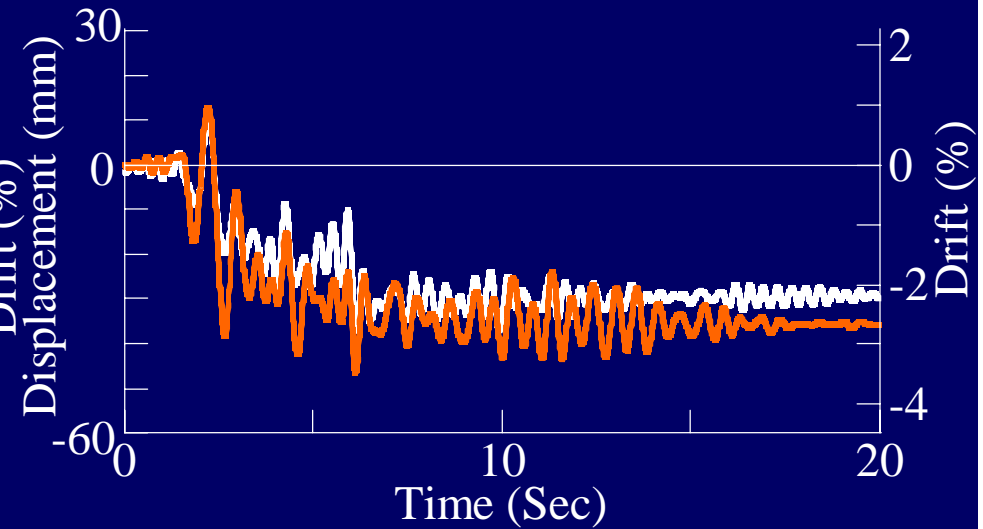
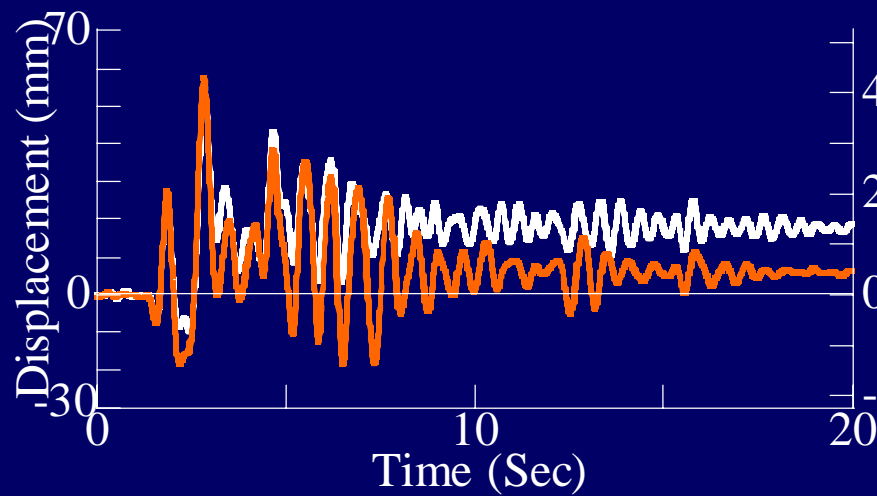
Fiber Element Analysis $e=0.5D$



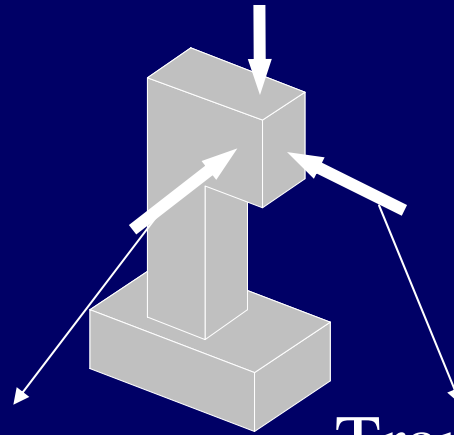
Analysis
Experiment

Longitudinal

Transverse



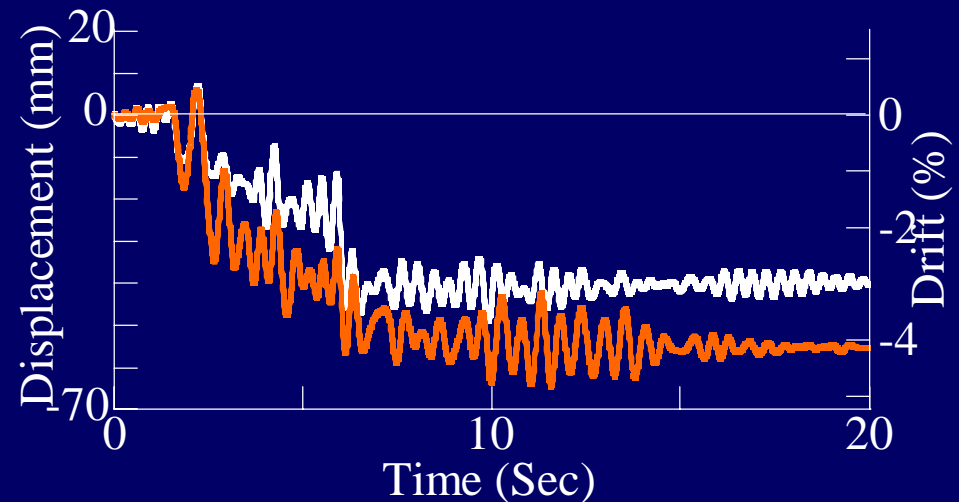
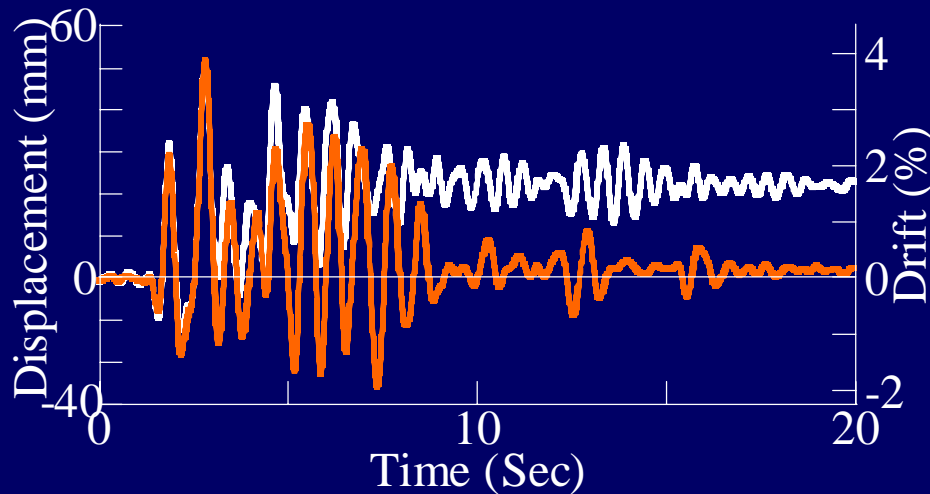
Fiber Element Analysis $e=D$



Analysis
Experiment

Longitudinal

Transverse



The analysis correlates the accumulation of residual drift in the eccentric compression side.

Conclusions

- Extensive failure occurs at the eccentric compression side under both the unilateral and the bilateral excitations. This results in a large residual displacement in the eccentric compression side.
- The failure and the residual displacement under the bilateral excitation are more extensive than those under the unilateral excitation.
- A fiber analysis correlates the accumulation of residual drift in the eccentric compression side. However, the analysis underestimates the residual drift.

Thank you for your attention