Damage Resistant Re-centering Bridge Columns: Evaluation by Shake Table Testing

by

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Pacific Earthquake Engineering Research Center

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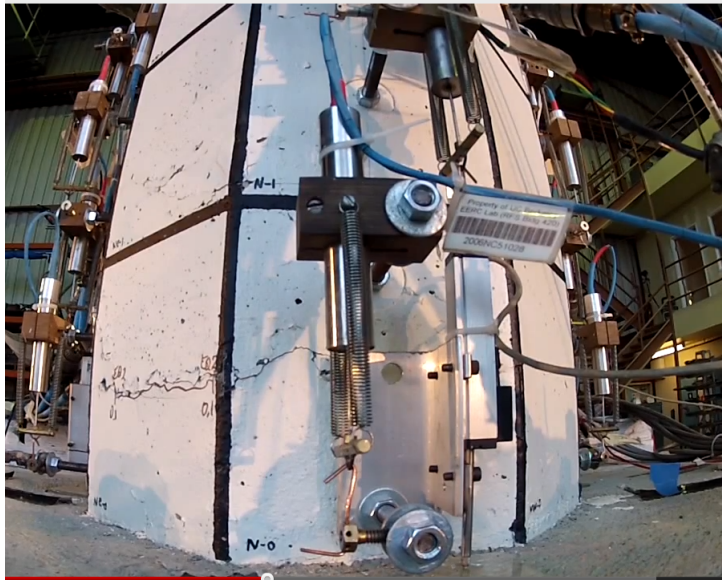
Hammad El Jisr (PEER Intern)

Program Objective

Develop resilient bridge bent systems that:

- Re-center after a design earthquake,
- Have large lateral deformation capacities,
- Display low damage levels,
- Use conventional materials as much as possible,
- Allow pre-fabrication off-site,
- Are economical to build.

Conventional column



Damage resistant re-centering column

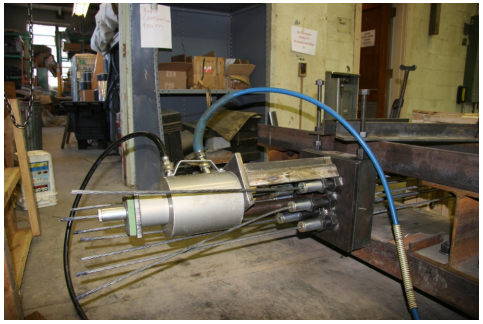
Materials

Damage resistance to be achieved using:

- Hybrid fiber reinforced concrete (HyFRC)
- Steel shells
- Stainless steel reinforcement
- Headed reinforcement

The re-centering is provided by:

- Pre-tensioning with unbonded strands
- Post-tensioning with unbonded tendons or threaded bars



Test Matrix

Conventional RC column

Testing in December

- *Benchmark, cast-in-place.*
- *Designed per Caltrans SDC v1.6*
- *A706 reinforcement*

<u>UC Berkeley</u>
Steve Mahin
Matt Schoettler
Vesna Terzic

Precast/Prestressed column

- *Precast, pre-tensioned*
- *HyFRC shell in the plastic hinge*
- *A706 reinforcement*

<u>Univ. of Washington</u>
John Stanton
Marc Eberhard
Olafur Haraldsson

HyFRC column

- *Cast-in-place, post-tensioned*
- *Precast HyFRC block at the base*
- *A706 reinforcement*
- *Rocking column*

<u>UC Berkeley</u>
Claudia Ostertag
Marios Panagiotou
Will Trono

Dual steel shell column

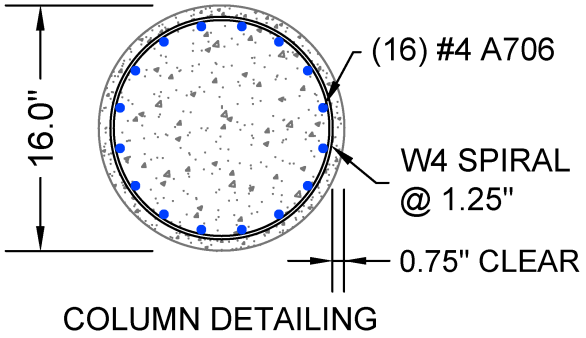
- *Precast, post-tensioned*
- *Hollow inner shell*
- *Stainless steel reinforcement*
- *Rocking column*

<u>UC San Diego</u>
José Restrepo
Gabriele Guerrini

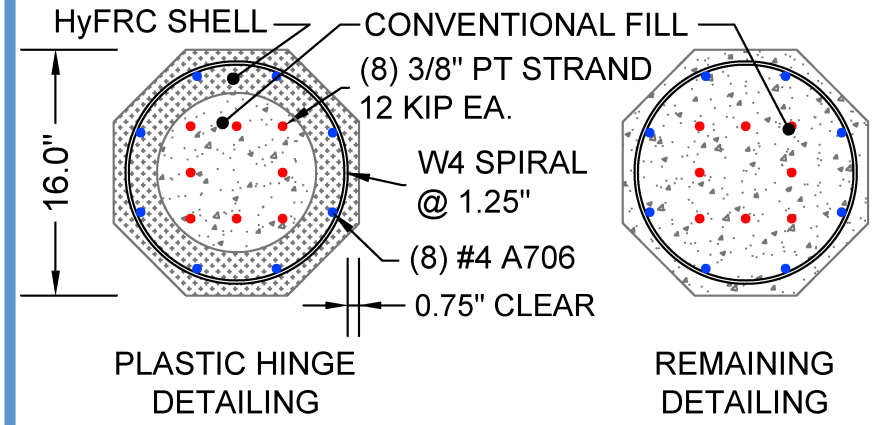
Reinforcing Details of Test Specimens

Conventional RC column

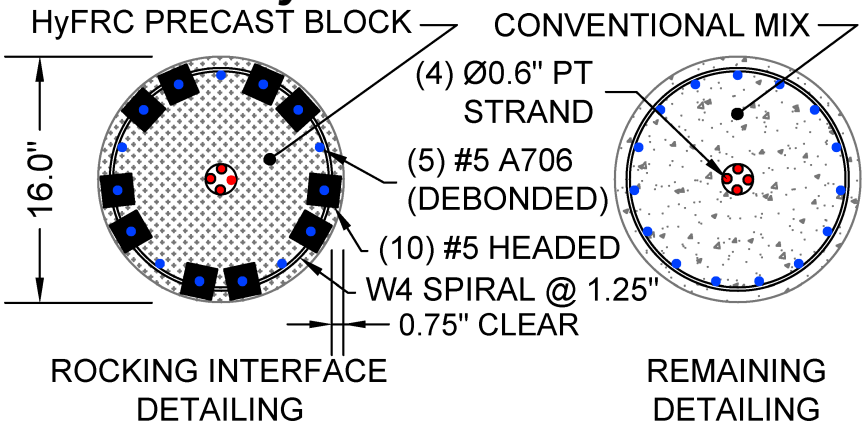
Testing in December



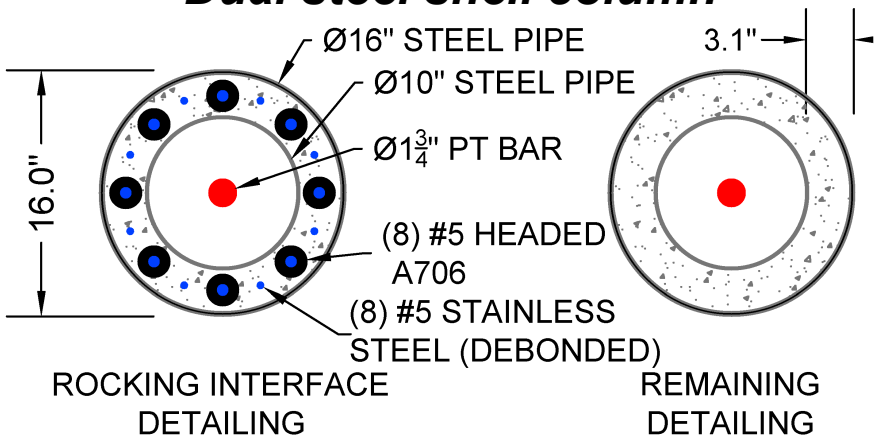
Precast/Pre-tensioned column



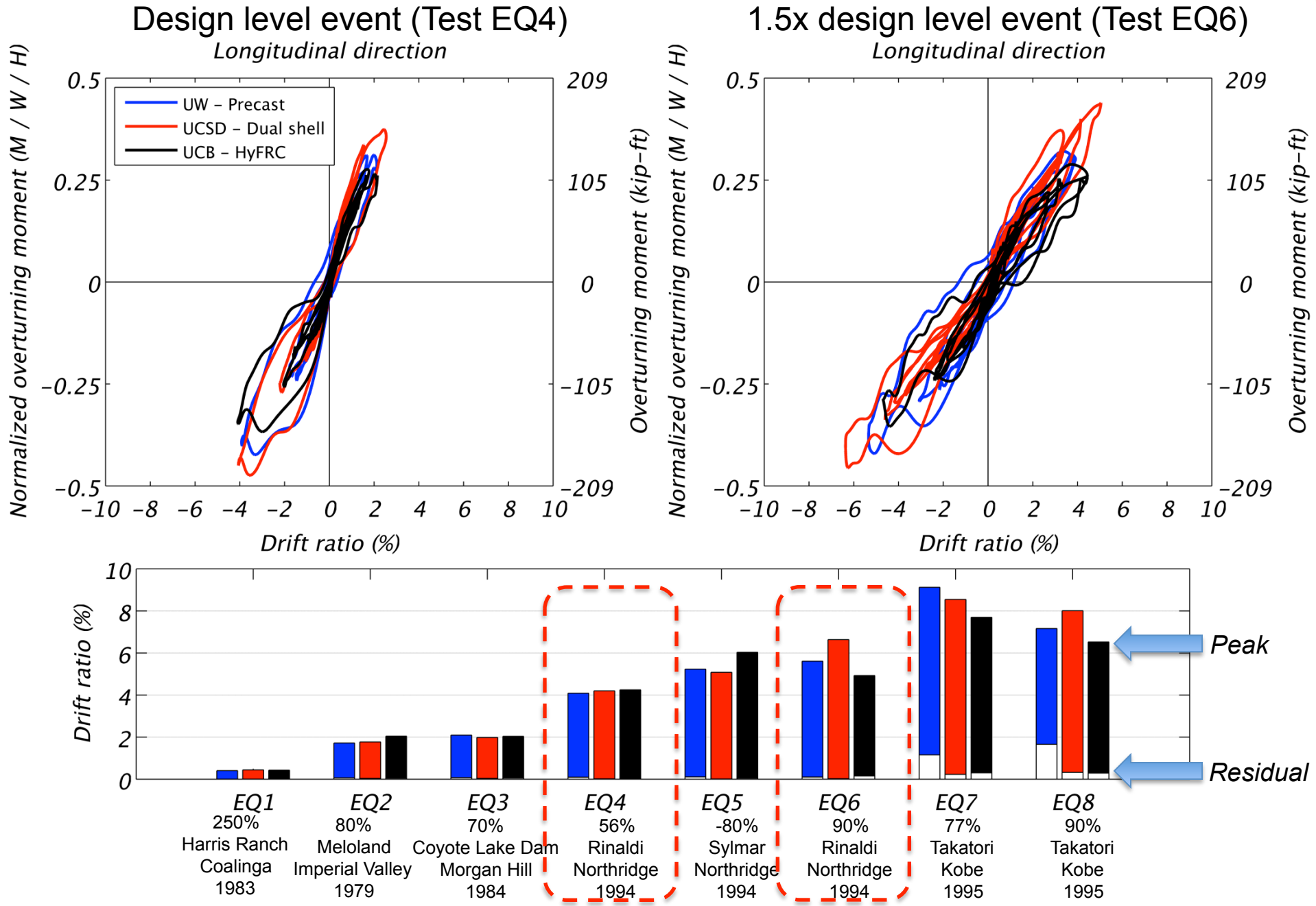
HyFRC column



Dual steel shell column



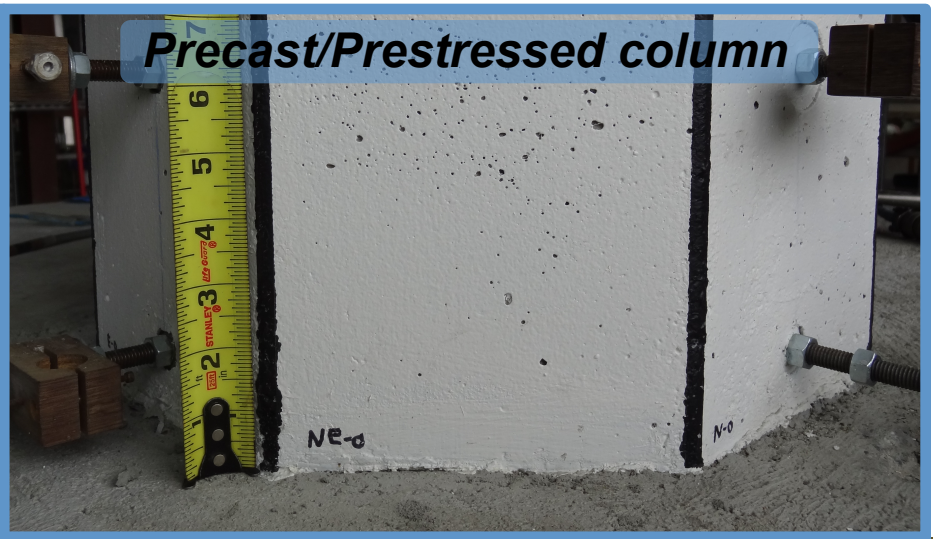
Preliminary test results

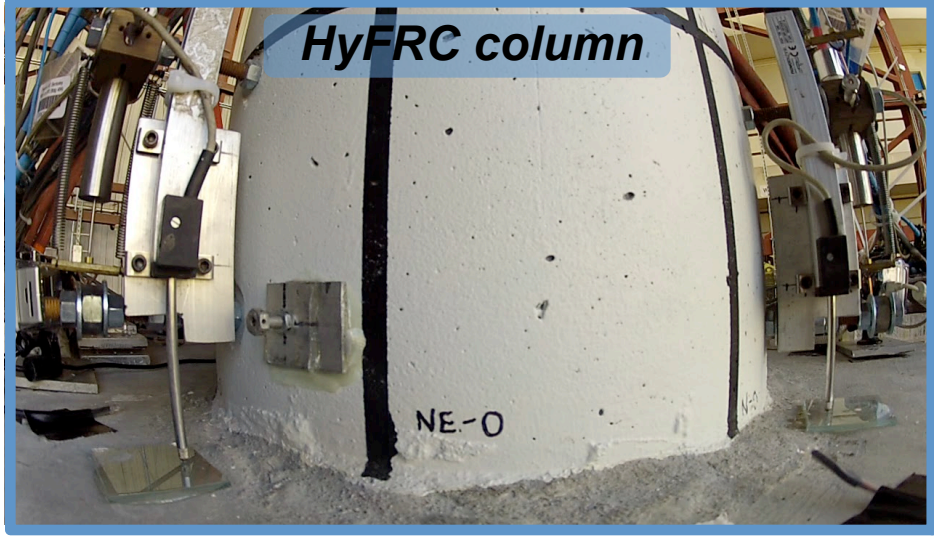


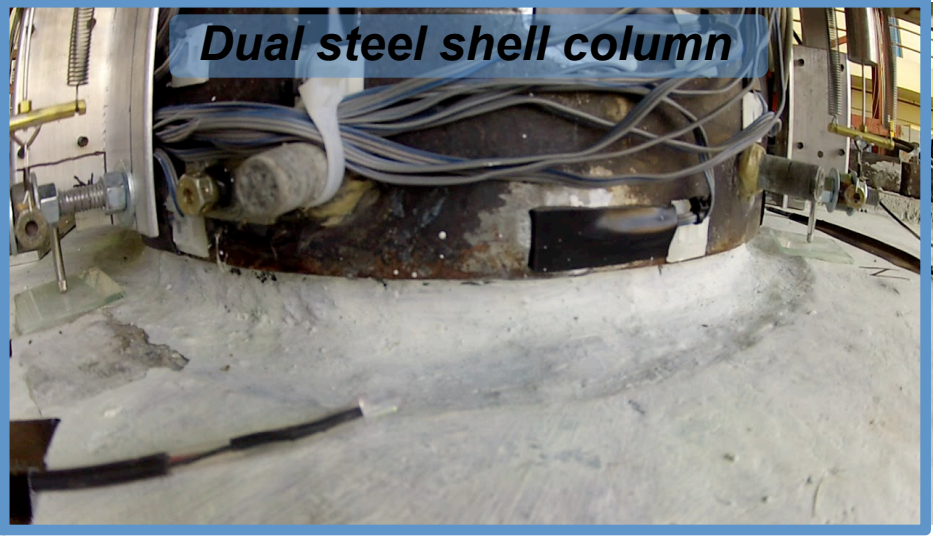
Pre-test view of the column base

Conventional RC column
and
CFRP column

Testing in December



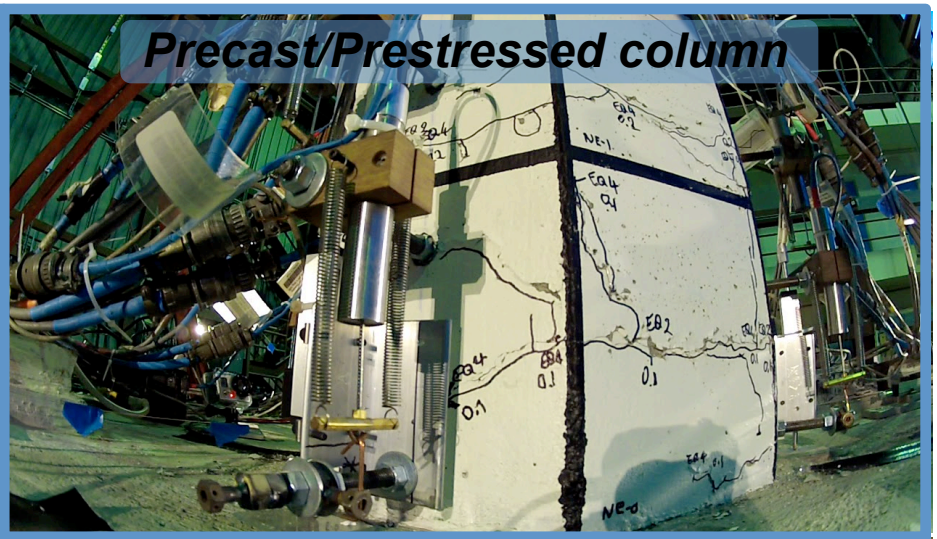


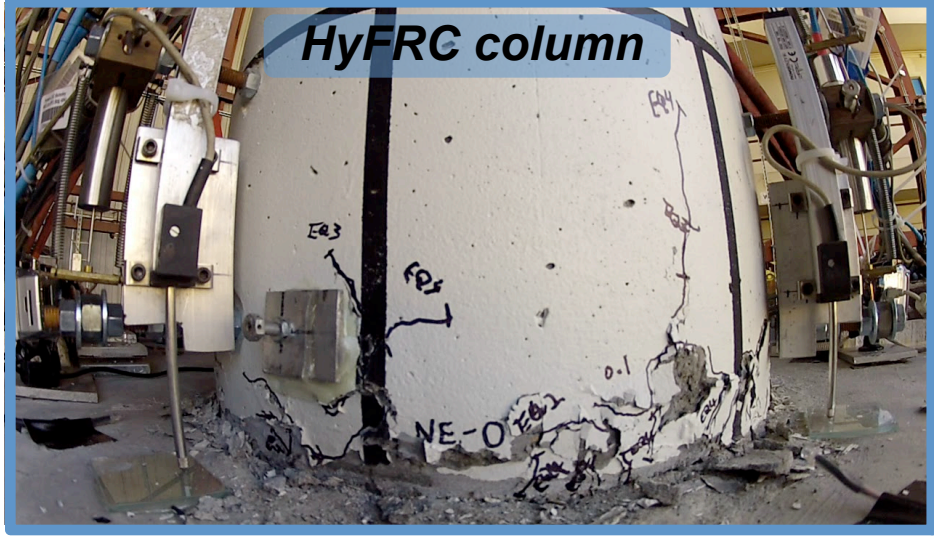


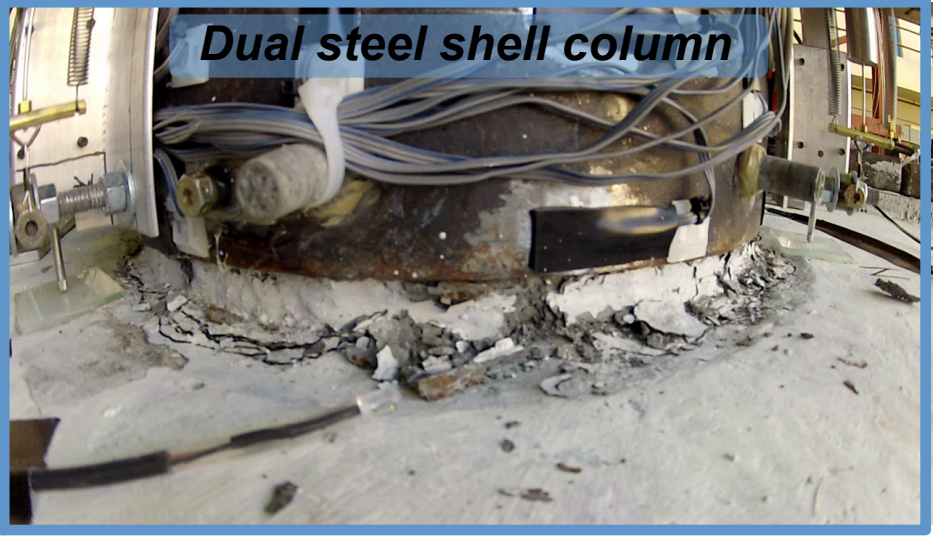
Damage: After design earthquake

Conventional RC column
and
CFRP column

Testing in December



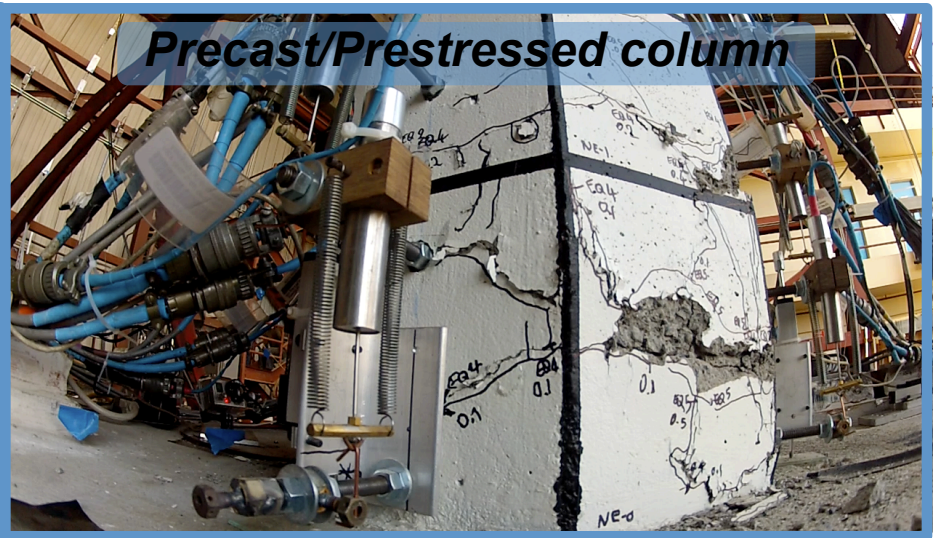


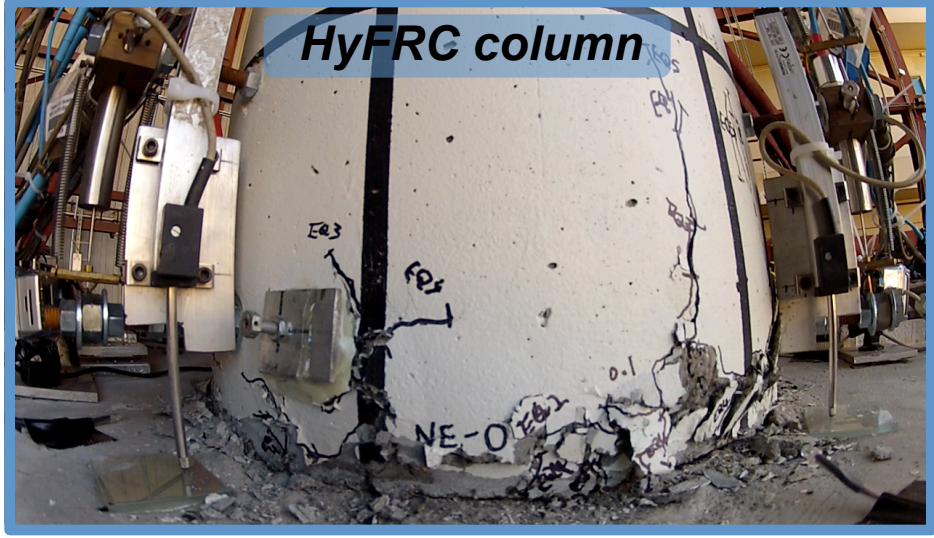


Damage: After 1.5*design earthquake

Conventional RC column
and
CFRP column

Testing in December





Summary and Conclusions - 1

- ***A family of resilient bent systems has been developed.***
- ***Shake table tests conducted to investigate seismic performance.***

Summary and Conclusions - 2

SEISMIC PERFORMANCE:

- All the columns re-centered almost perfectly after 1.5* design earthquake.
- No pre- or post-tensioning fractured.
- Some bars fractured at earthquake 7 (> *1.5* Design*)
- Damage to concrete/grout much less than in conventional columns.

EXCELLENT PERFORMANCE IN ALL THREE COLUMNS

Summary and Conclusions - 3

MATERIALS USED

- HyFRC
- Concrete
- Grout
- Pre-stressing strand
- Pre-stressing bar
- A706 rebar
- Stainless steel rebar

ONLY HyFRC IS NON-STANDARD

Summary and Conclusions - 4

CONSTRUCTION

- Some pre-fabrication in each column
- Each column used different connection methodology

CONSTRUCTION PROCEDURES NEED TO BE OPTIMIZED FOR:

- $peed
- $implicity
- $$$$$$$

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