Accelerated Bridge Construction Research at UNR- Seismic Performance of Bridge Columns and Systems

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Caltrans

NEVADA DOT

University of Nevada, Reno

NEES

NSF

Accelerated Bridge Construction (ABC)

- **Big Picture Problem**
  - Increasing Number of Deficient Bridge Structures
  - High Dependence on Surface Infrastructure
  - Increased City Densities and Driver Populous
- **Technology-Ready Solution: ABC**
  - Collection of Design and Construction Methods
  - Numerous Associated Benefits
  - The Use of Prefabricated Bridge Systems is Paramount
- **Challenges**
  - Contractor Learning Curve
  - Prefabricated Systems Can Pose Design Challenges

ABC Advantages

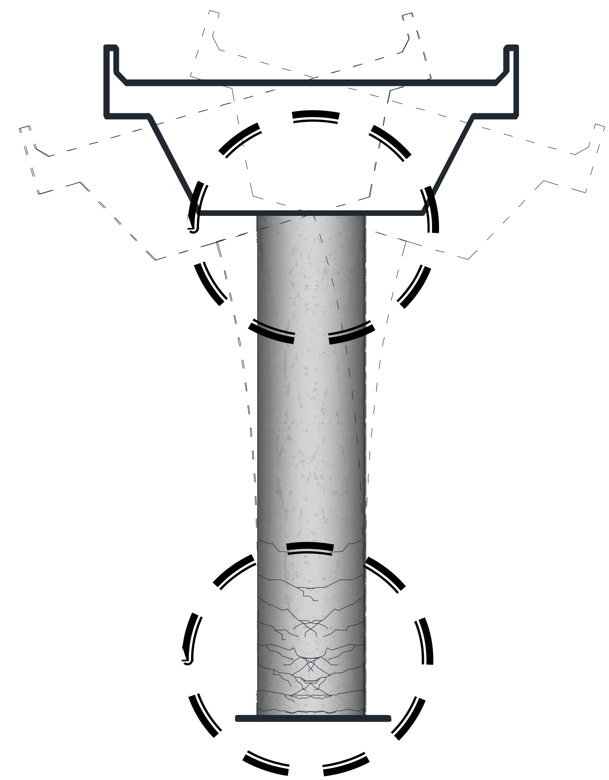
- Fabricated in a controlled environment
- Improved quality and durability
- Reduced traffic disruption
- Improved work zone safety
- Simple construction
- Fast assembly
- Low residual displacement (when post-tensioned)

Challenges for ABC in Seismic Zones

- Columns in Conventional Bridges
  - Support Superstructure
  - Dissipate Energy
  - Expected to Undergo Damage

- Design and Detailing of Connections is Critical

- Lack of Data Has Resulted in Limited use of ABC in Seismic Zones

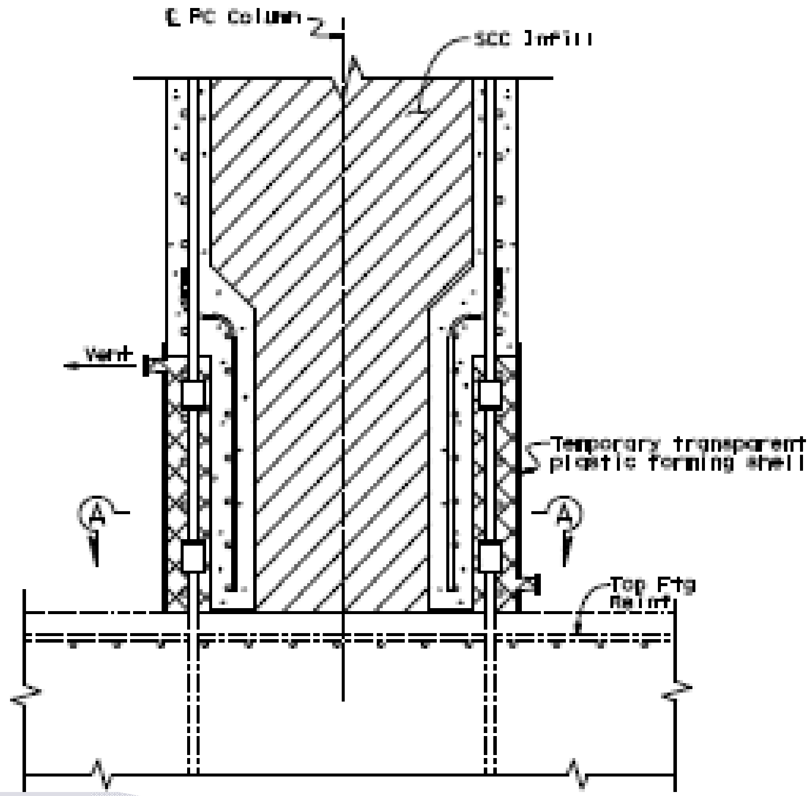


4 Research Topics

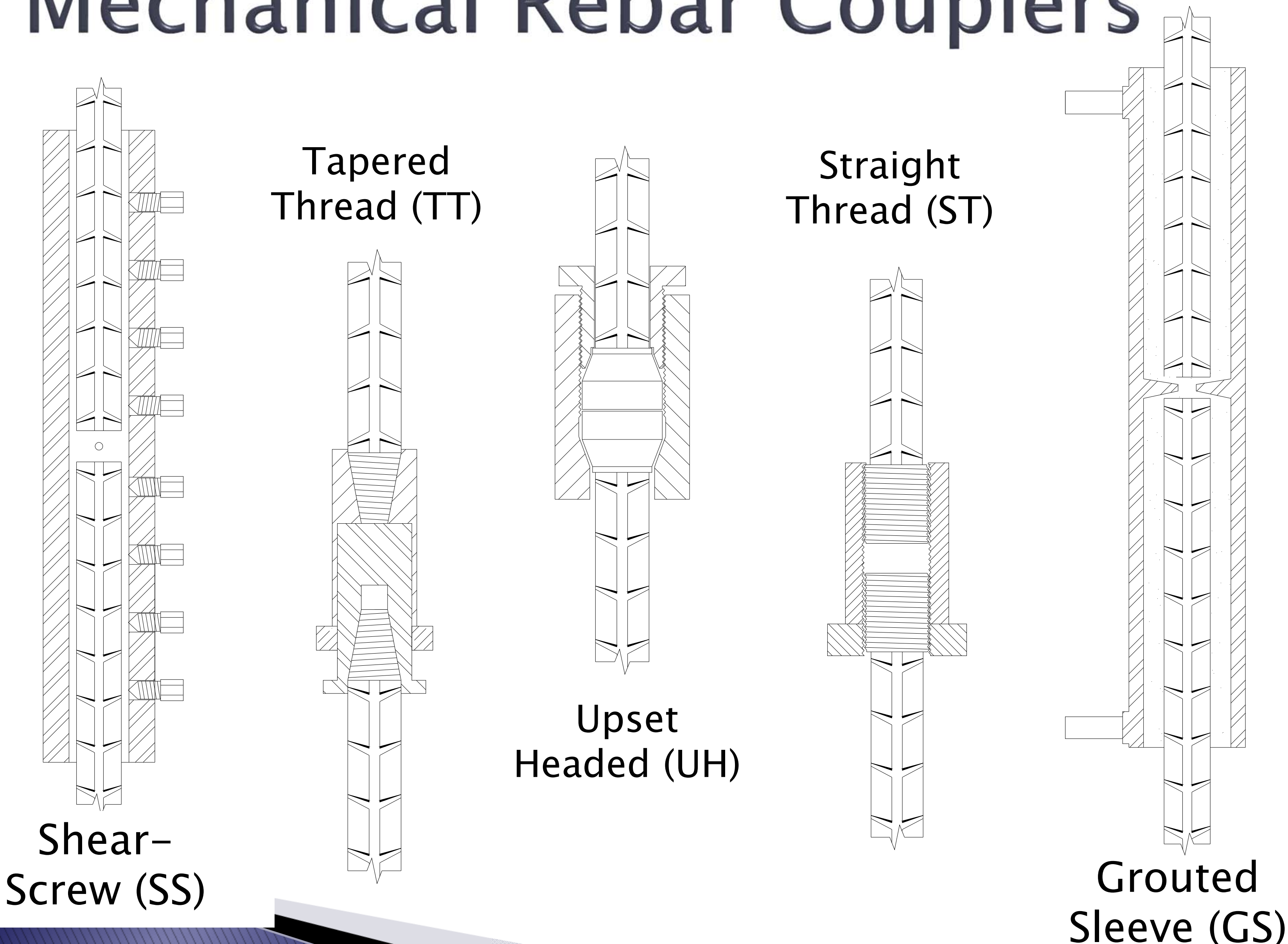
1. Emulative Precast Column Footing Connections
2. Innovation in Column Connections for ABC
3. ABC Bridge Systems
4. ABC Design for Disassembly (DFD)

Emulative Precast Column Footing Connections

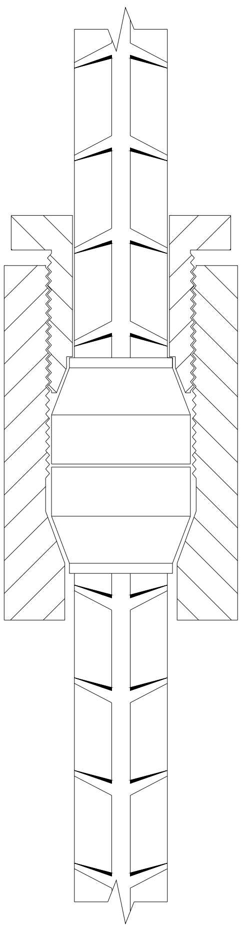
- **Objective:** Study seismic response of rigid connections between precast columns and footings



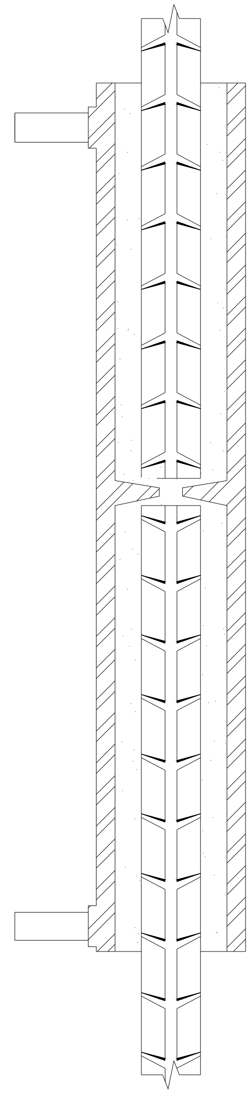
Mechanical Rebar Couplers



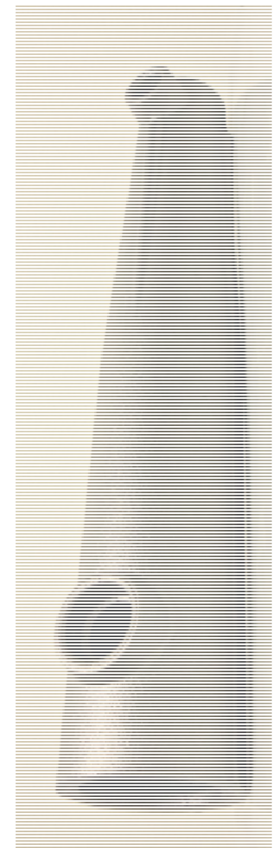
Mechanical Rebar Couplers



Upset Headed (UH)
Ultimate coupler



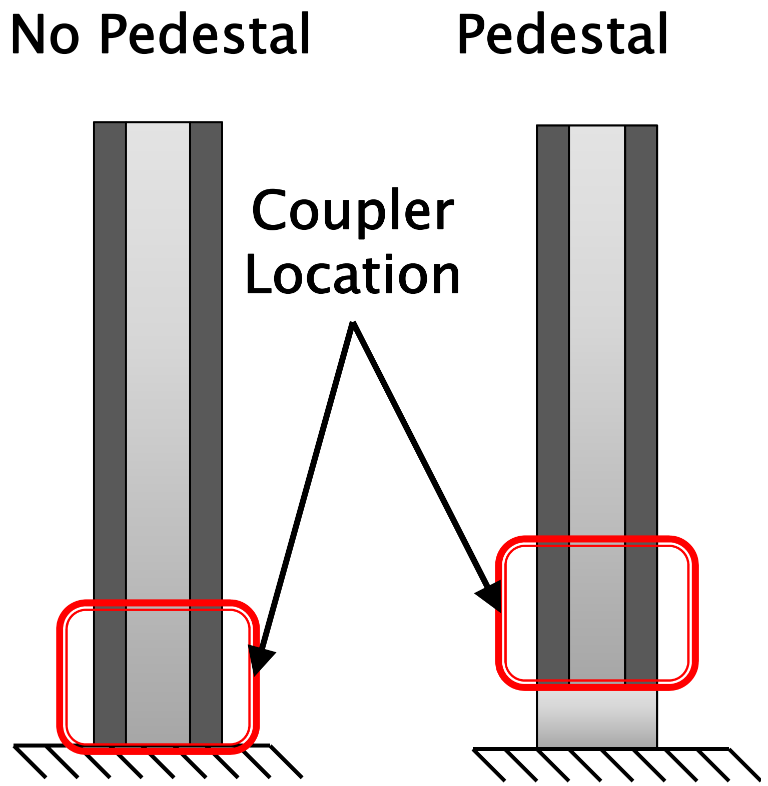
Service Coupler



Grouted
Sleeve (GS)

5 Half-Scale Column Models

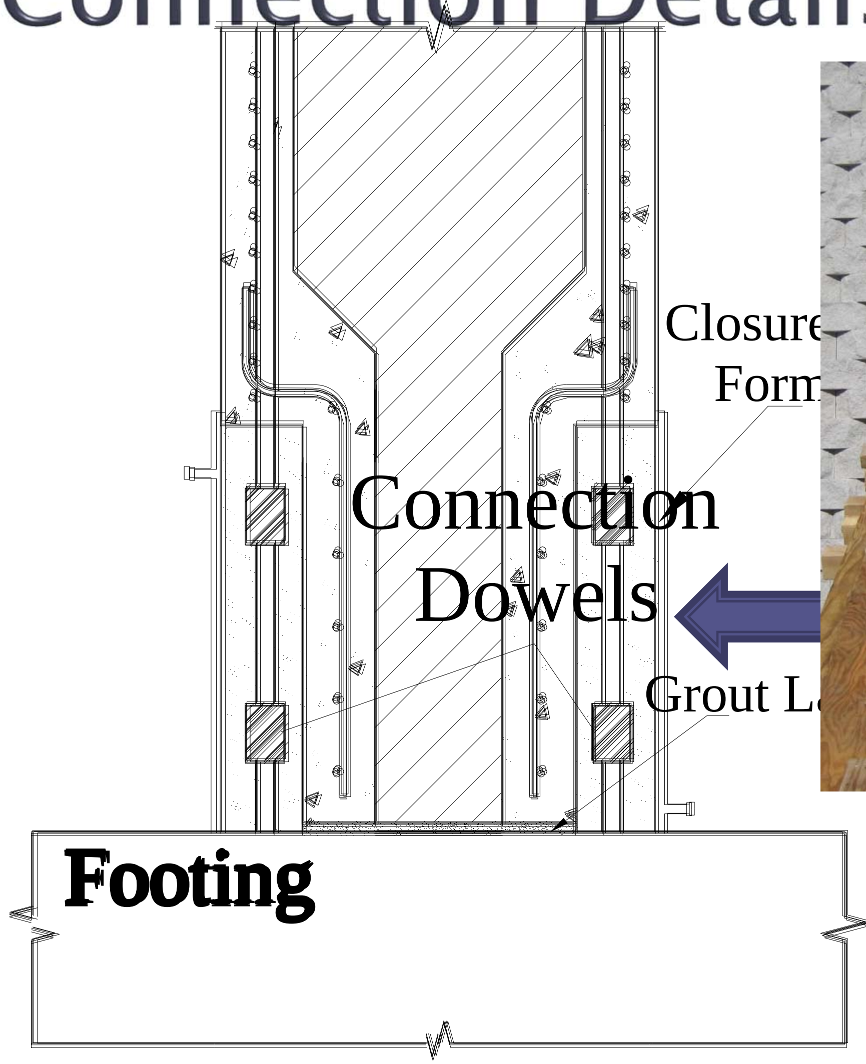
- Caltrans Seismic Design Criteria (Disp. Ductility ≥ 5)
- Design Details
  - 9ft Tall; 2ft Diameter
  - 11 #8 Longitudinal Steel (1.9%)
  - #3 Spiral @ 2in Pitch (1%)
  - Axial Load = 226kip ($0.1f'_c A_g$)
- Precast Hollow Shell Design
- Filled with SCC
- Use of Precast Pedestal

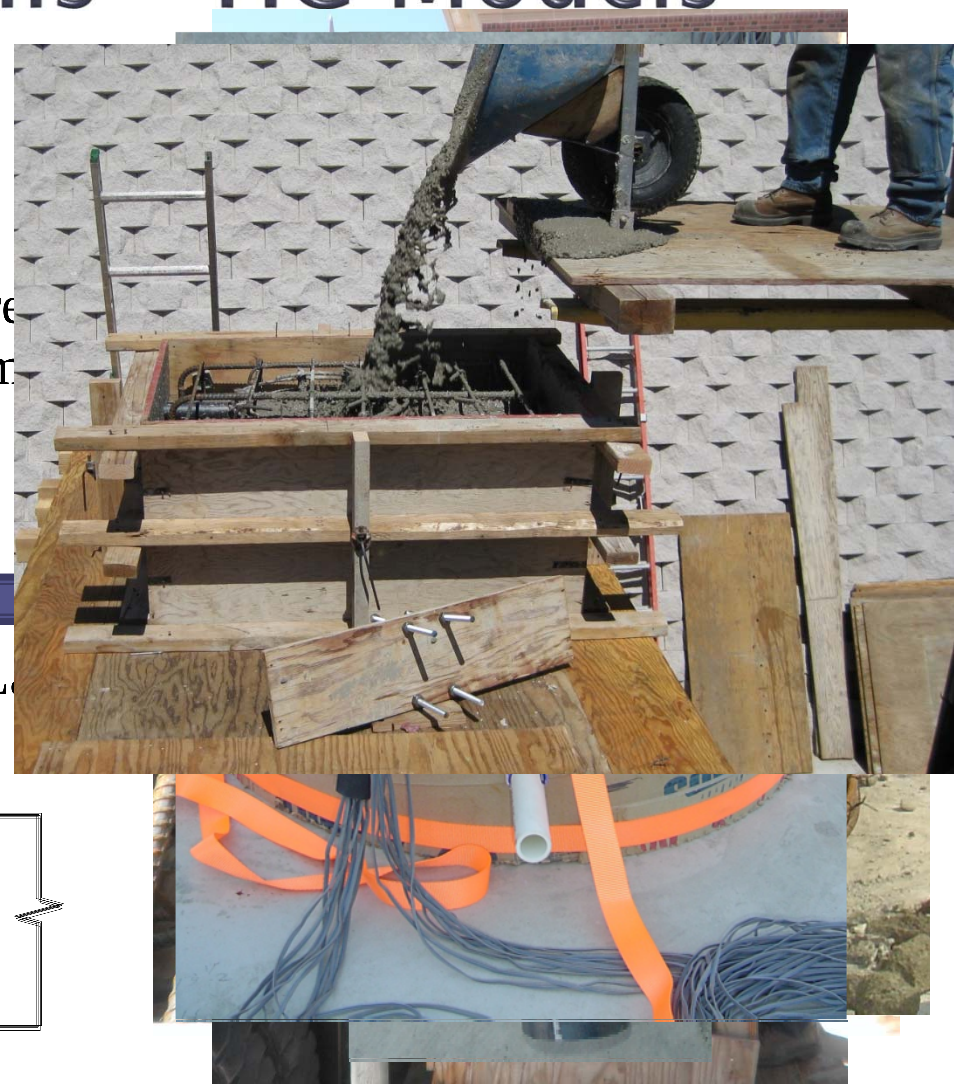


Column Models

1. CIP : Cast-in-place benchmark
2. HCNP: Headed bar coupler; no pedestal
3. HCPP: Headed bar coupler; precast pedestal
4. GCNP: Grouted coupler; no pedestal
5. GCPP: Grouted coupler; precast pedestal

Connection Details – HC Models





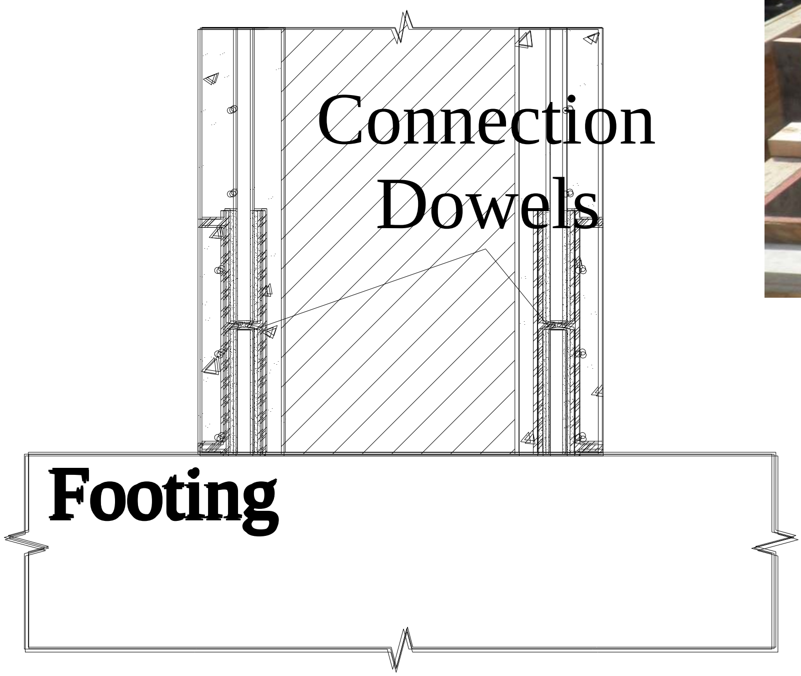
HRC Couplers

Custom Built Length

Close up

Fillers

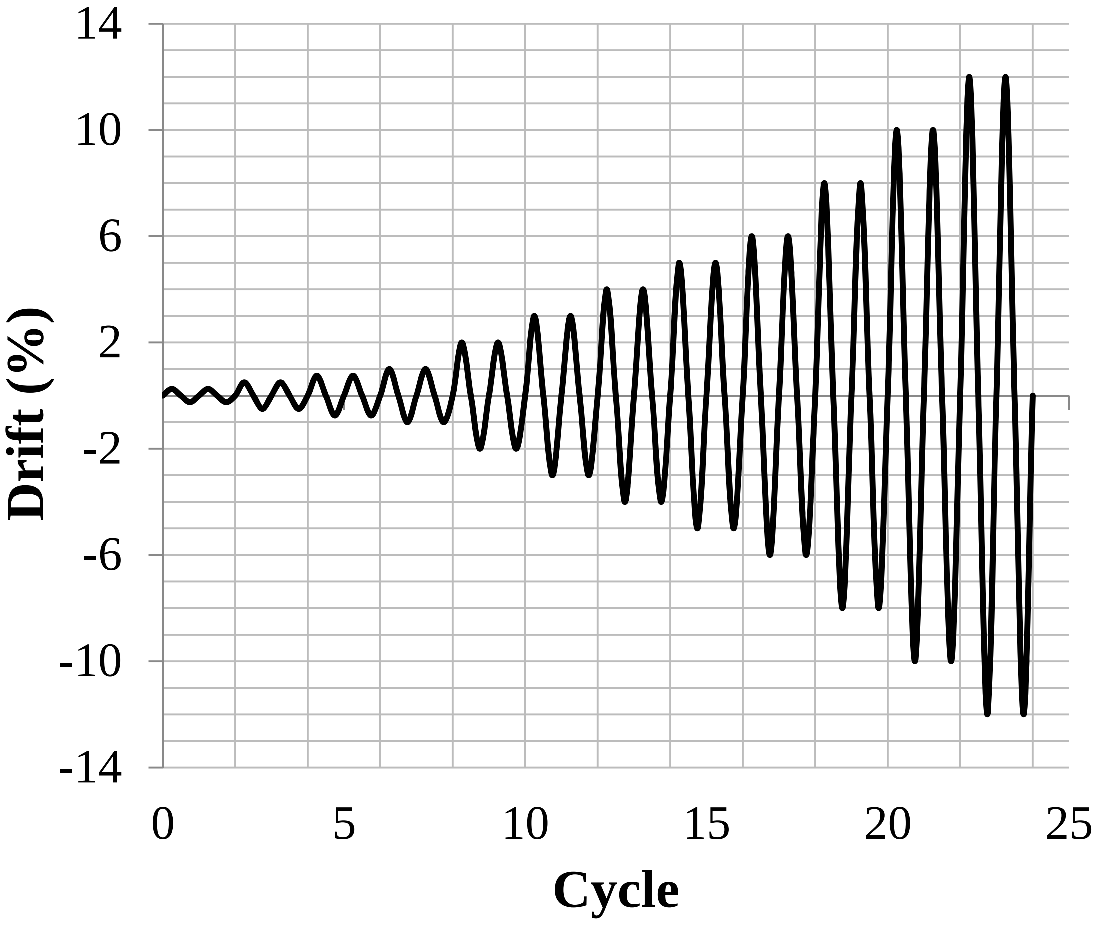
Connection Details – GC Models



Columns with Pedestal

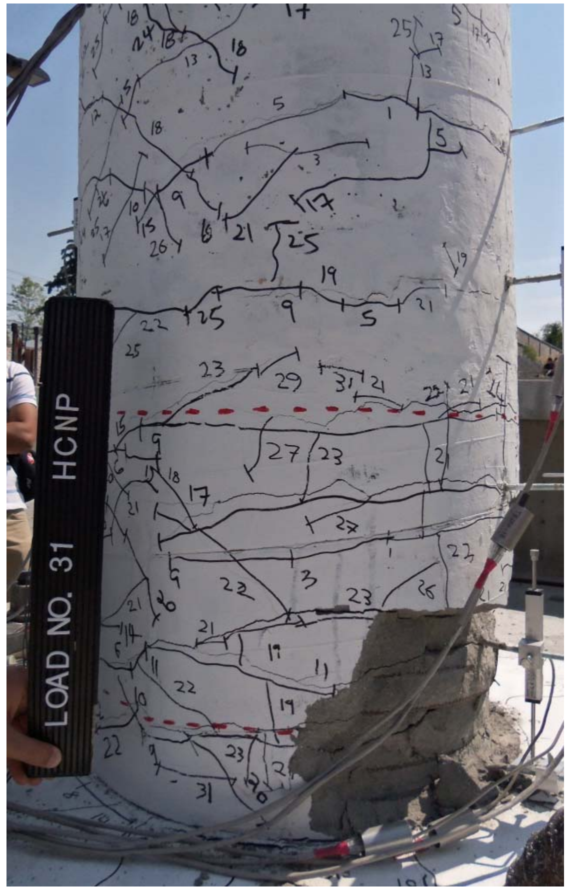
Testing

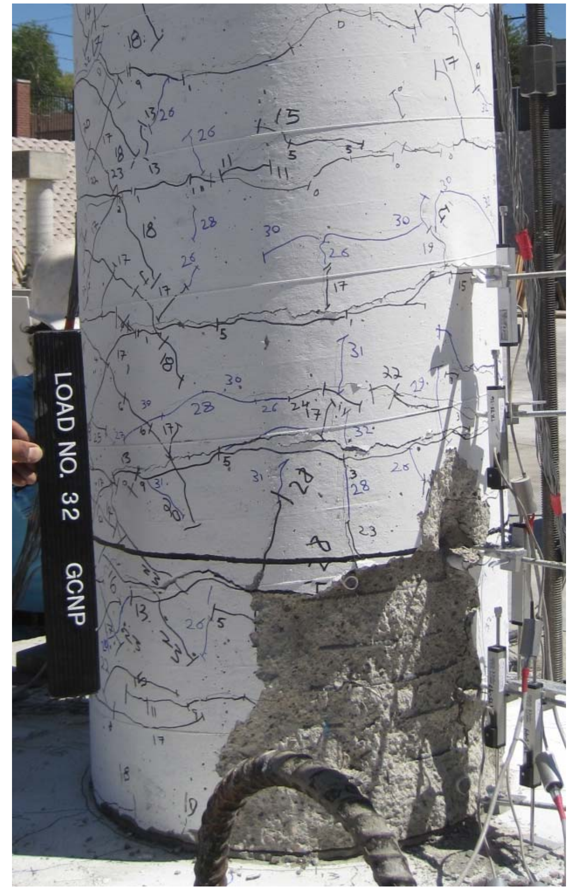

HC PP
Caltrans
University of Nevada, Reno


Drift (%)
Cycle
14
10
6
2
-2
-6
-10
-14
0
5
10
15
20
25

5% Drift – Push Cycle 2

CIP	HCNP	GCNP

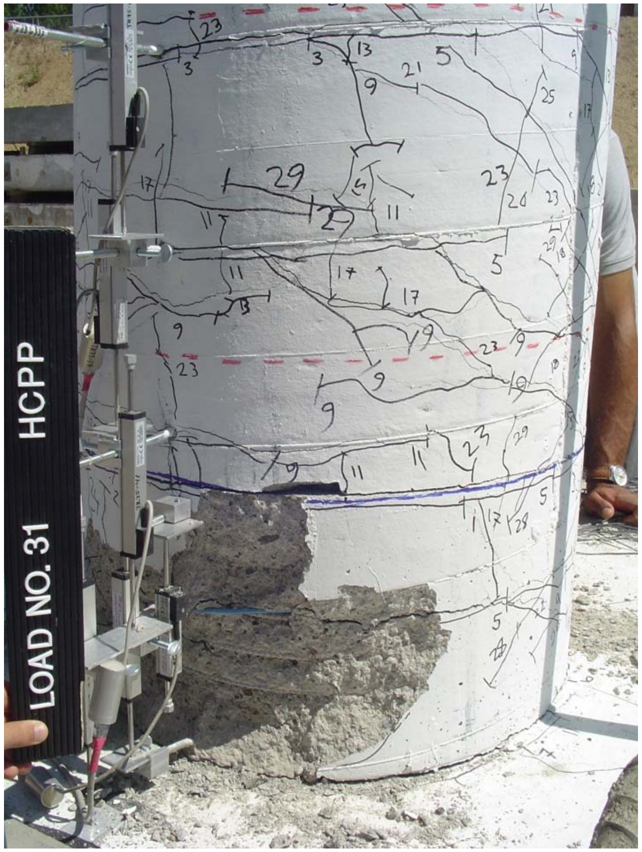




CIP	HCNP	GCNP
$\mu_D = 3.6$	$\mu_D = 3.2$	$\mu_D = 3.7$
F = 65.9 kip	F = 67.8 kip	F = 70.4 kip

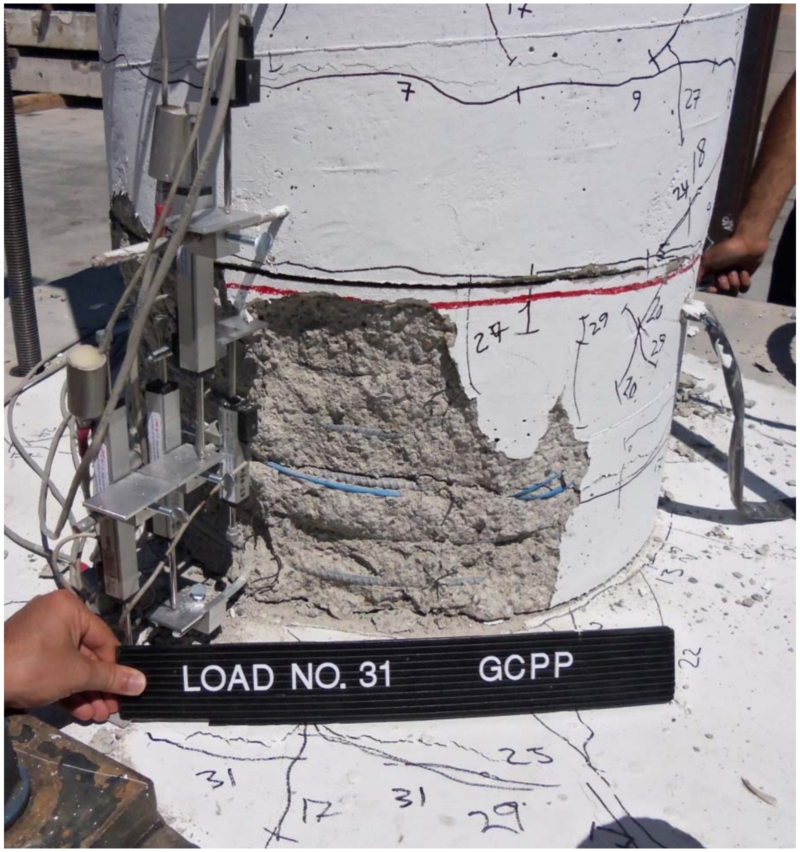
5% Drift – Push Cycle 2

HCPP



$\mu_D = 3.3$
F = 66.5 kip

GCPP



$\mu_D = 3.7$
F = 67.9 kip

"Cigar Moment!"

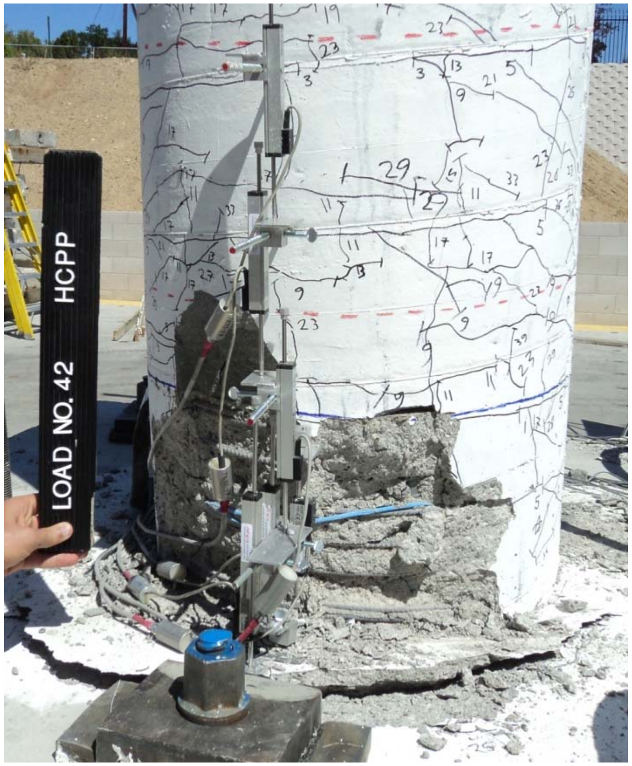
Observations –Damage at Failure

CIP
(2nd Cycle
10% Drift)

HCNP
(2nd Cycle
10% Drift)

GCNP
(2nd Cycle
6% Drift)

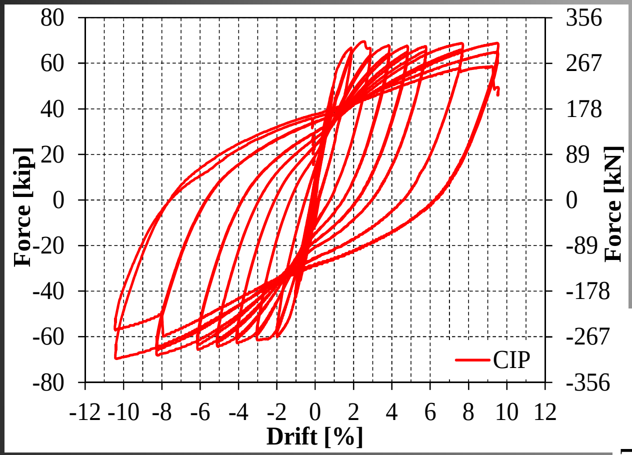
Observations –Damage at Failure

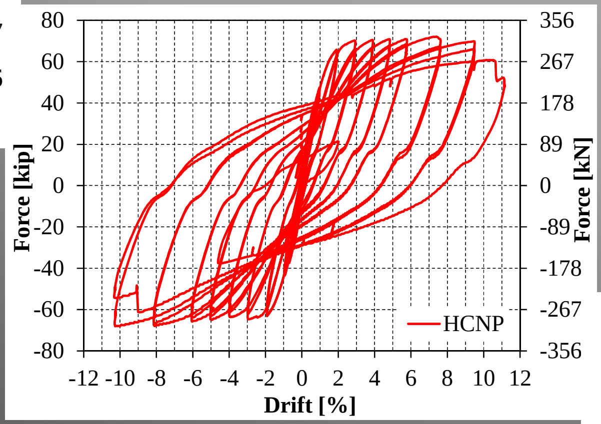


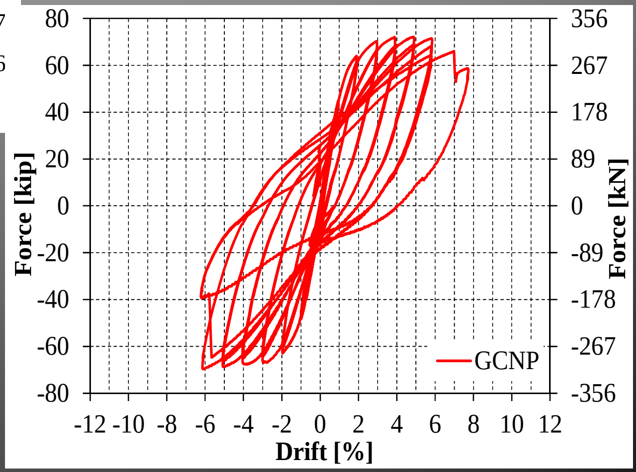
HCPP
(10% Drift)

GCPP
(6% Drift)

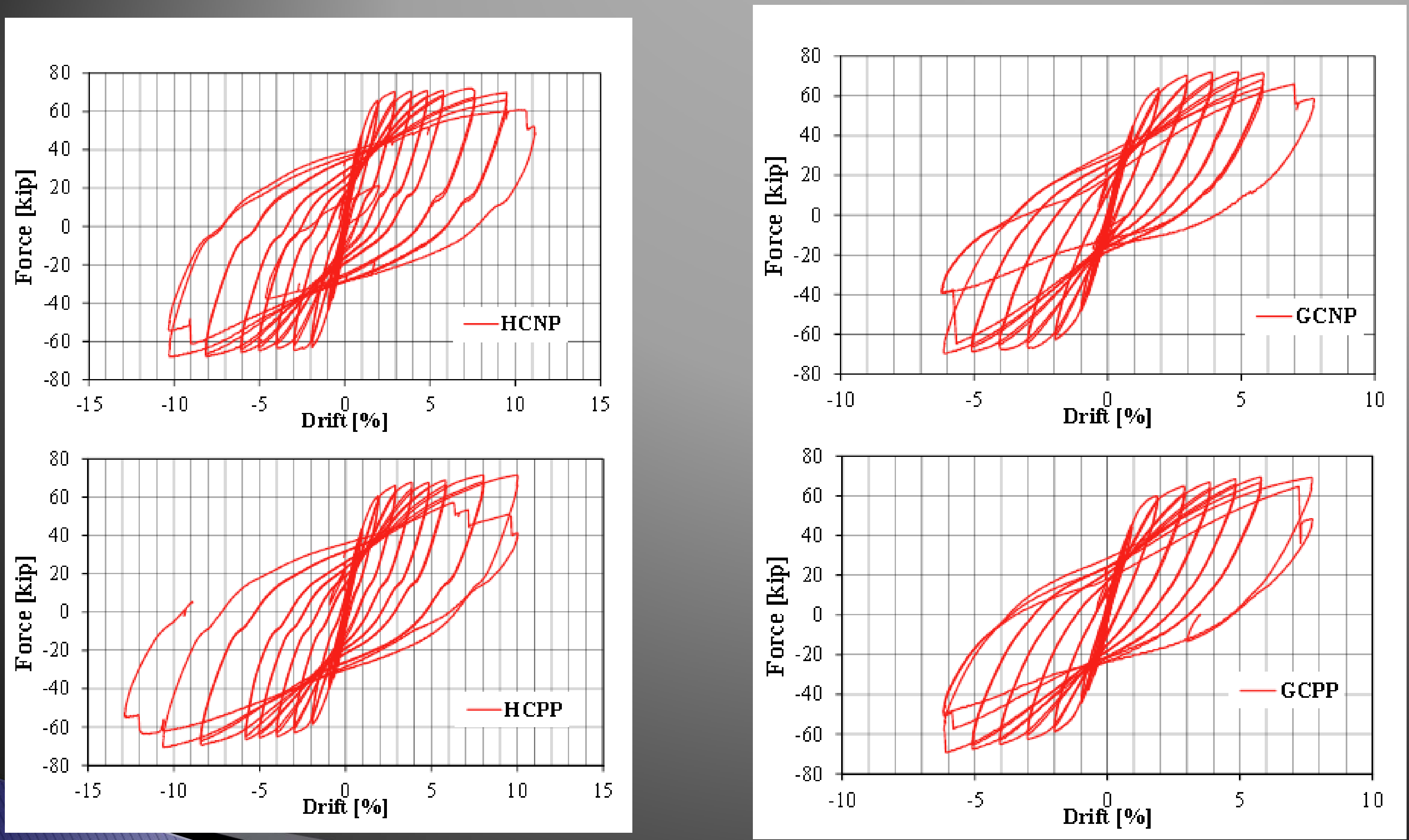
Force-Displacement Responses

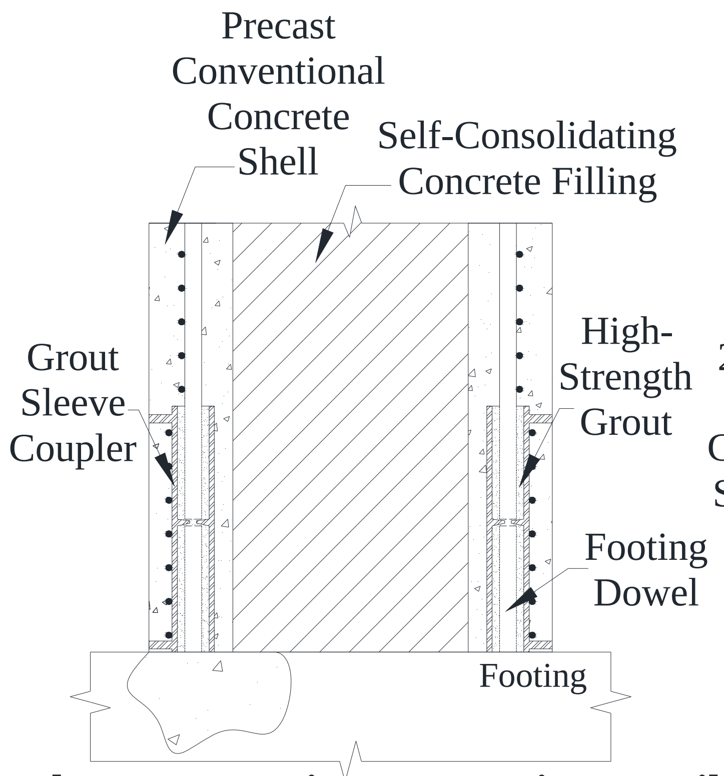




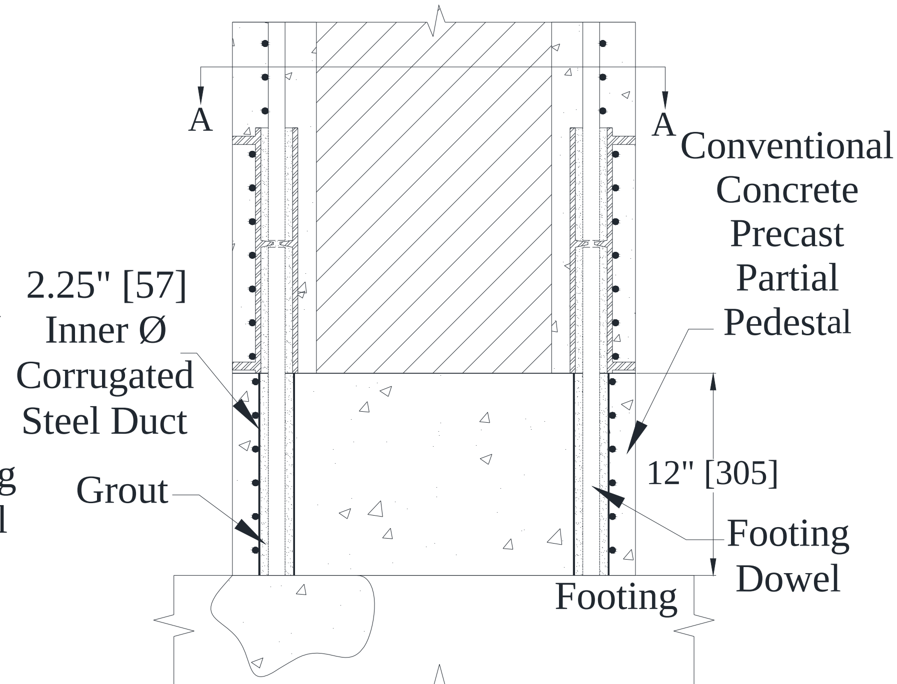


Effect of Pedestal in Grouted Ducts



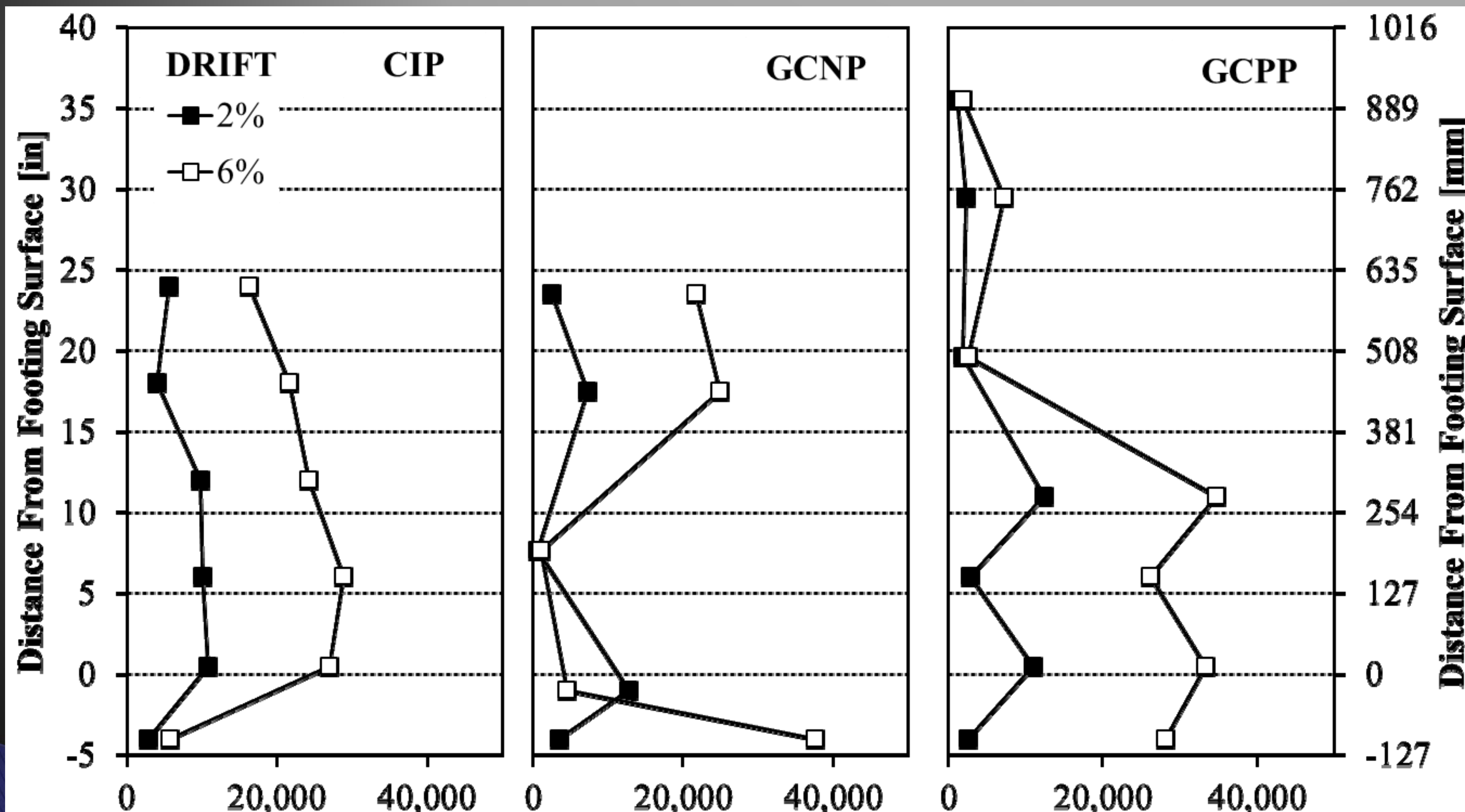


Column-to-Footing Connection Detail (GCNP)

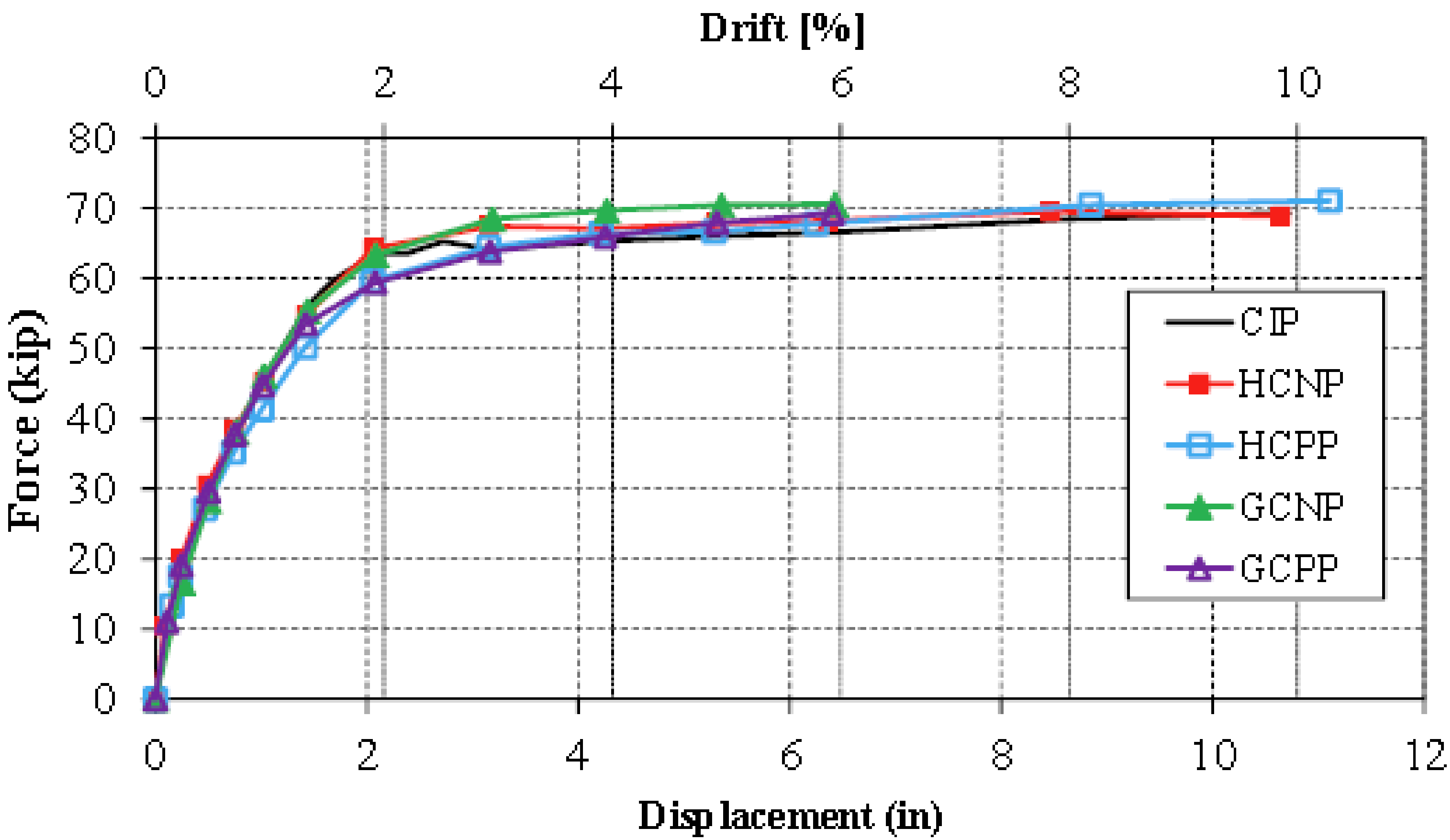


Connection Detail with Partial Pedestal (GCPP)

Longitudinal Bar Strains



Results – Pushover Curves



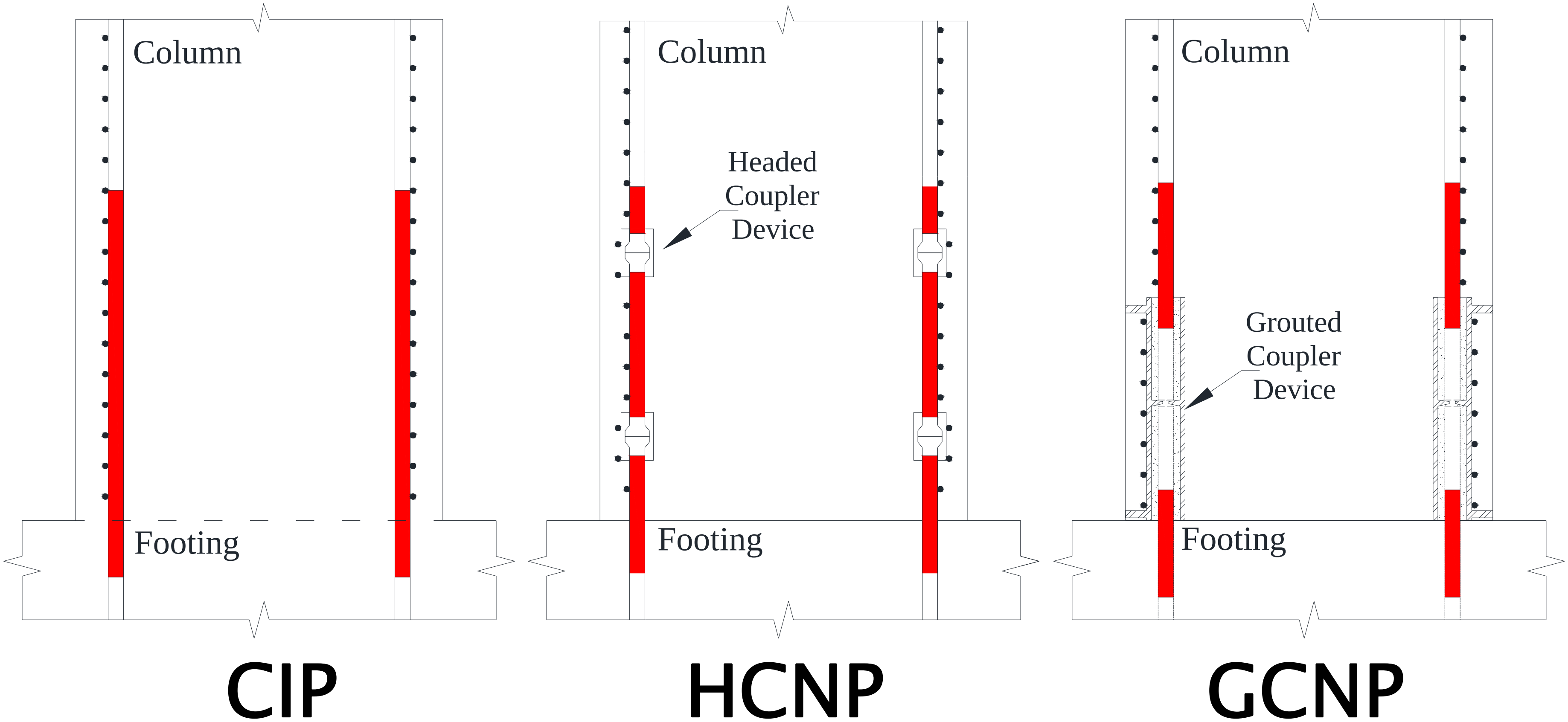
Observations:

- Headed couplers performed well and may be appropriate even under high seismic demand.

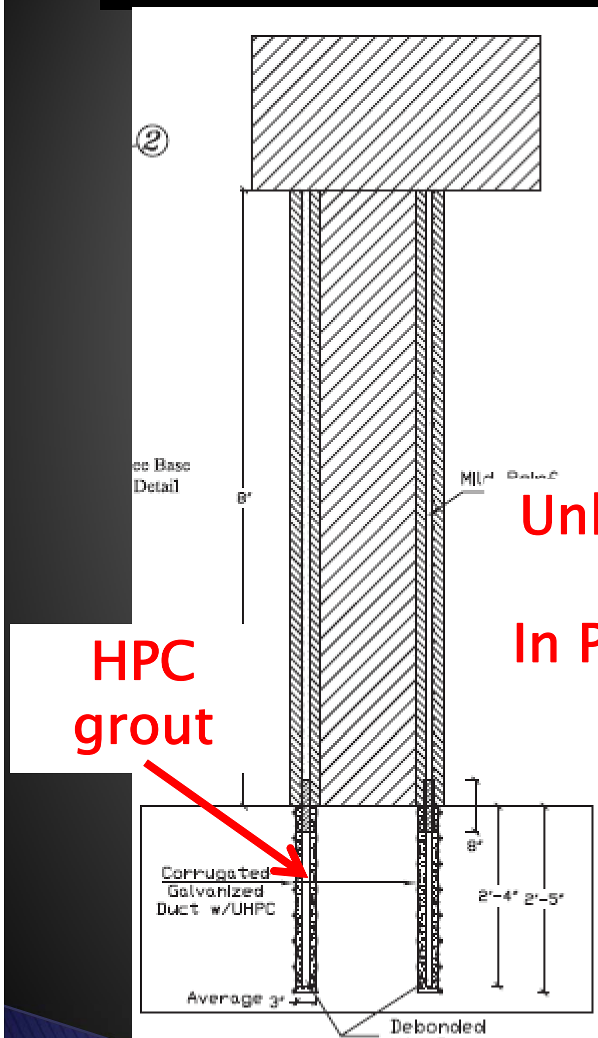
- Grouted couplers performed reasonably well. With a drift capacity of 6%, slight improvement might make them qualify as “ultimate couplers.”

- Grouted couplers are much easier to construct than HRC couplers.

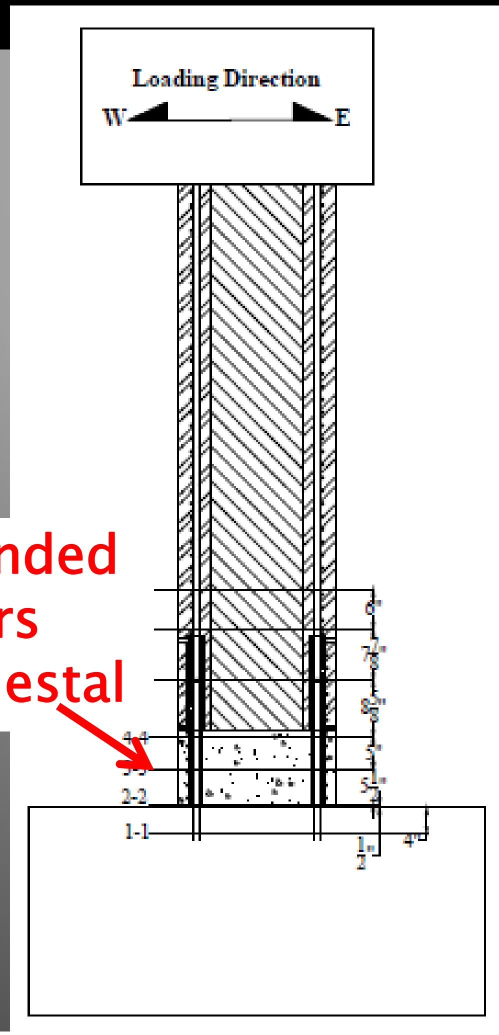
Plastic Hinge Behavior



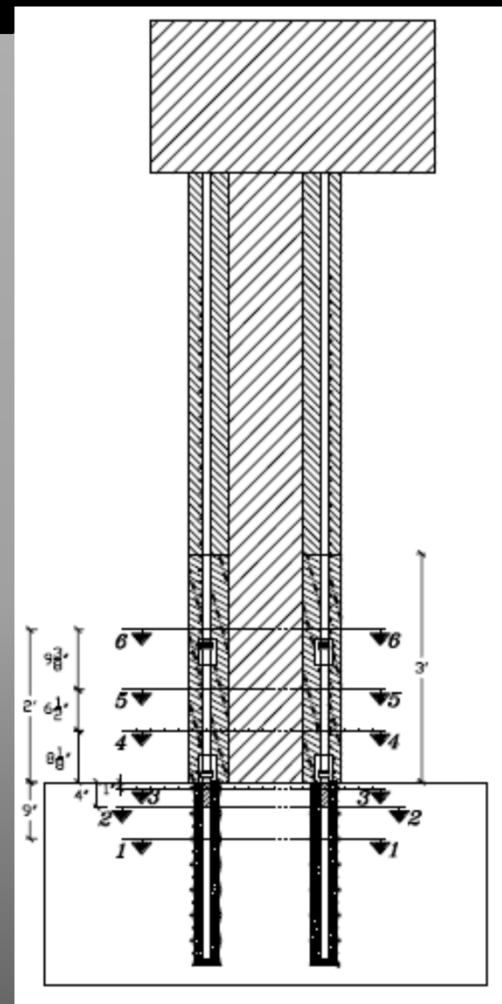
Phase II– 3 Half-Scale Column Models



ABC w/ No Couplers (PNC)



Grouted Couplers w/ Unbonded Pedestal (GCDP)



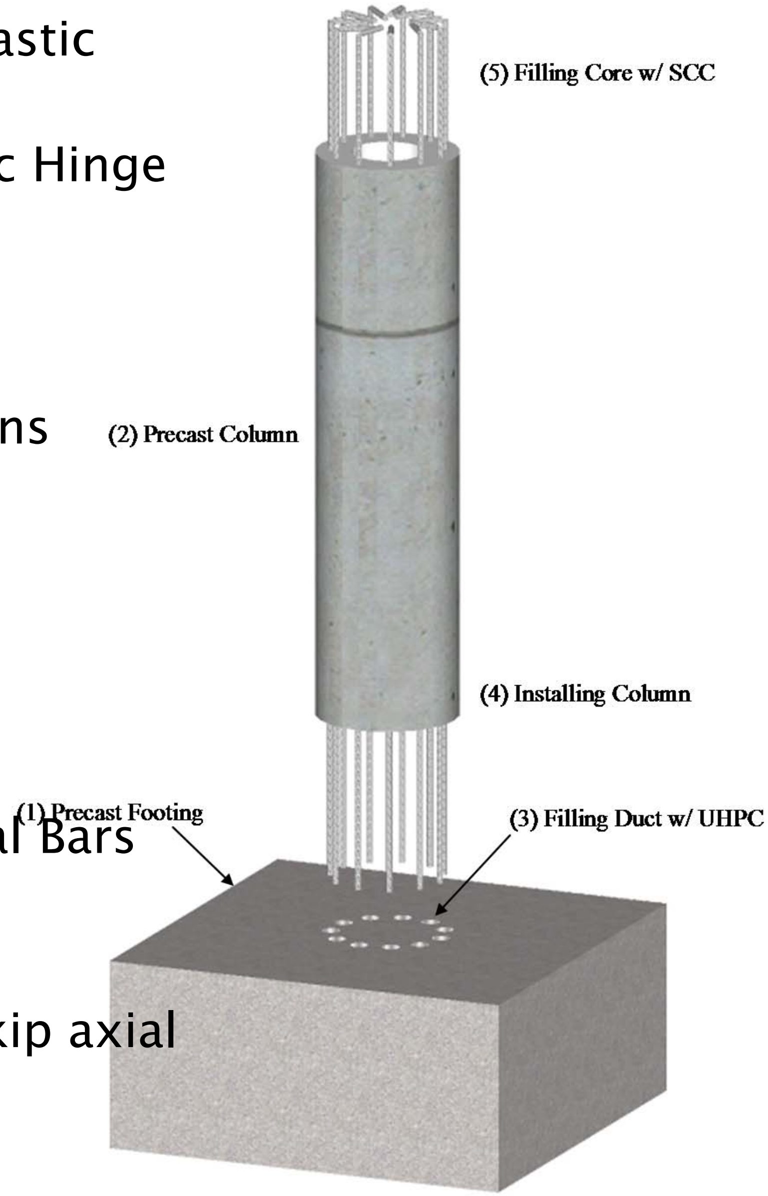
ABC w/ SMA/ECC

Precast Columns Incorporating UHPC-Filled Duct System:

- Two Column Models
  - Conventional Materials in Plastic Hinge (PNC)
  - Advanced Materials in Plastic Hinge (HCS)

- Connection
  - UHPC-Filled Duct Connections

- Column Geometry
  - Half-Scale
  - Height: 9 *ft* (2.74 *m*)
  - Diameter: 24 *in*. (610 *mm*)
  - 11-#8 (Ø25 *mm*) Longitudinal Bars (ρ_l=1.92%)
  - Spiral, ρ_s=1.03%
  - Axial Load Index: 10% (200-kip axial load on specimens)

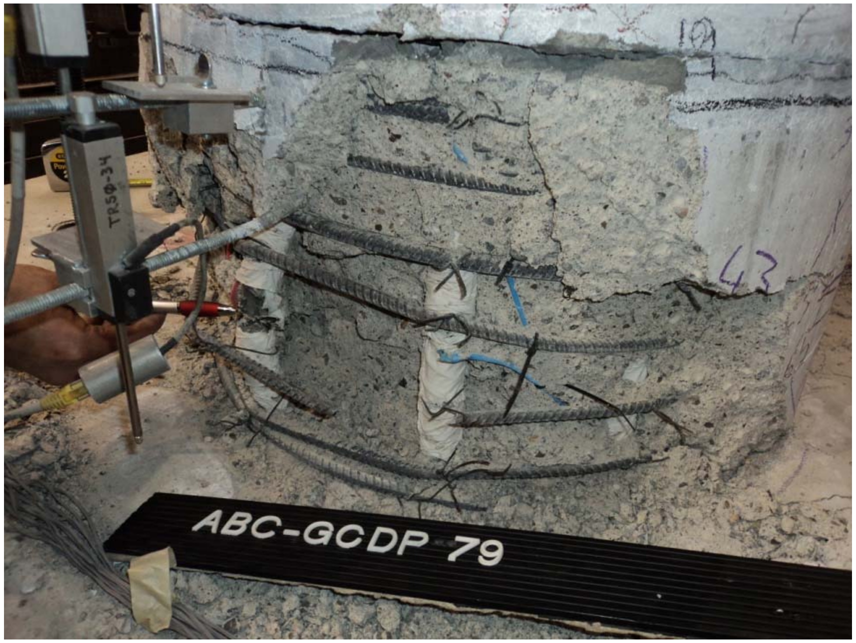



DEWALT

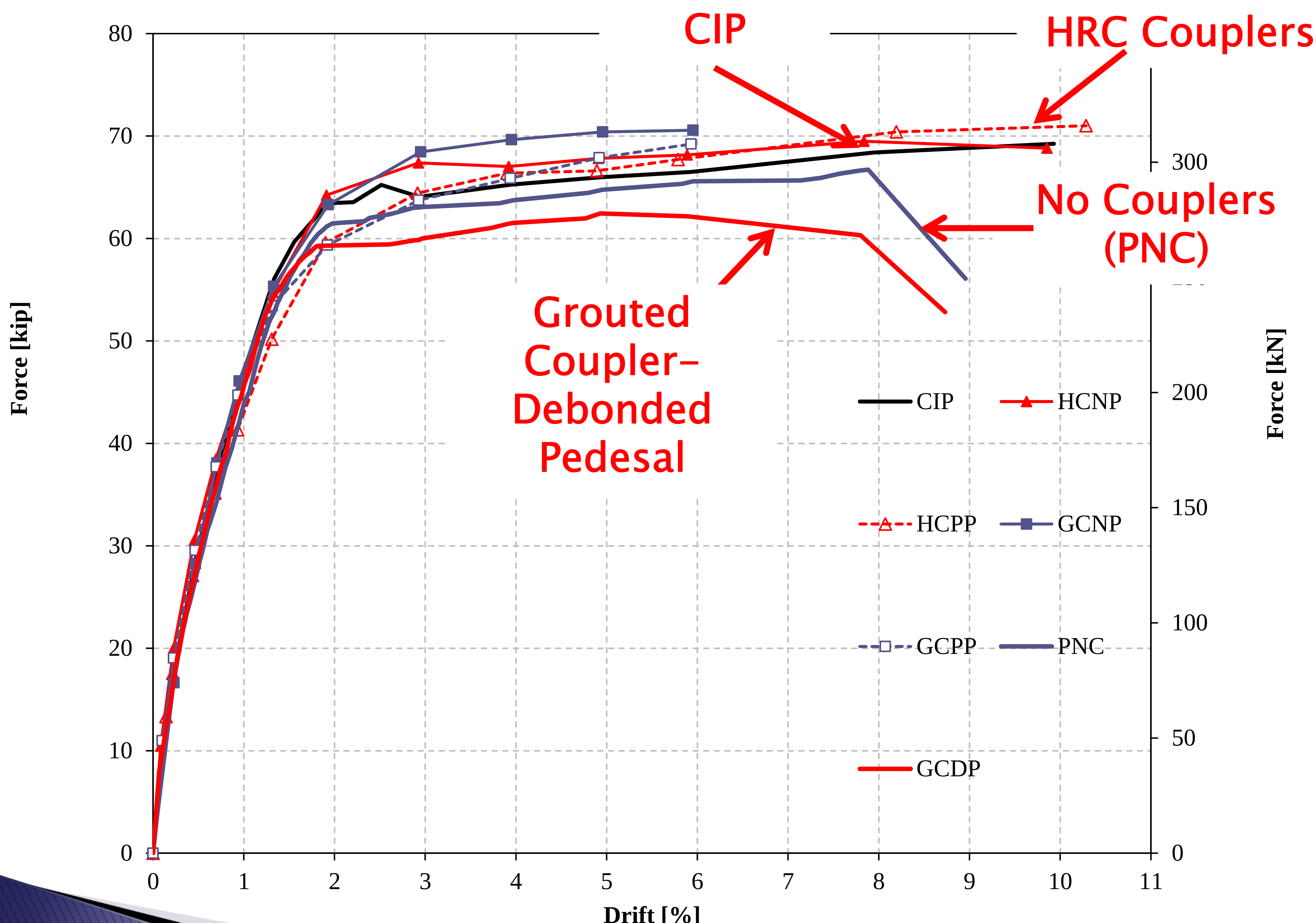

SONOTUBE
round
SW
24
12


SONOTUBE
round
SW
24
2
29

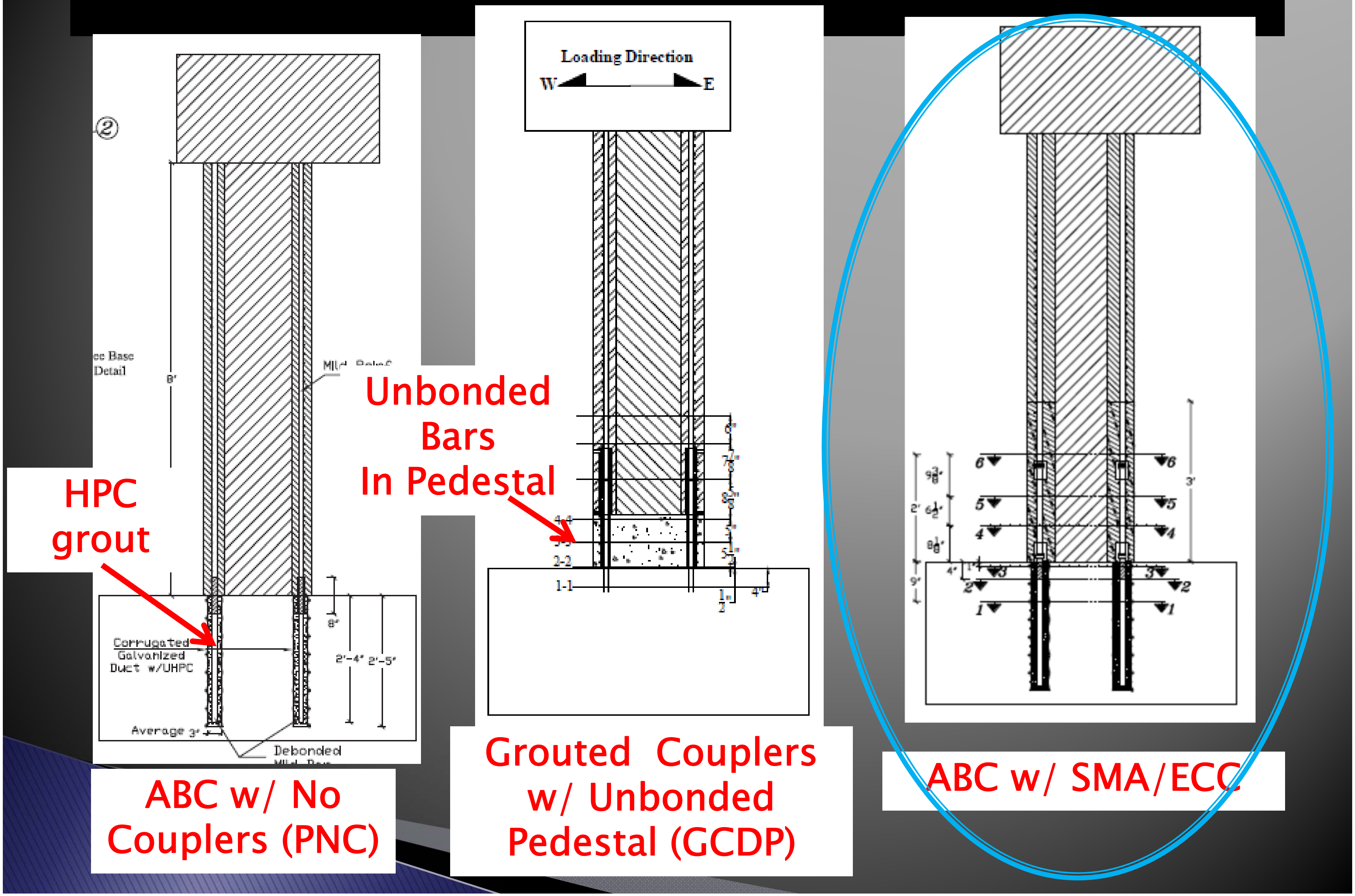
Column w/ no couplers
at 8% drift (failure)



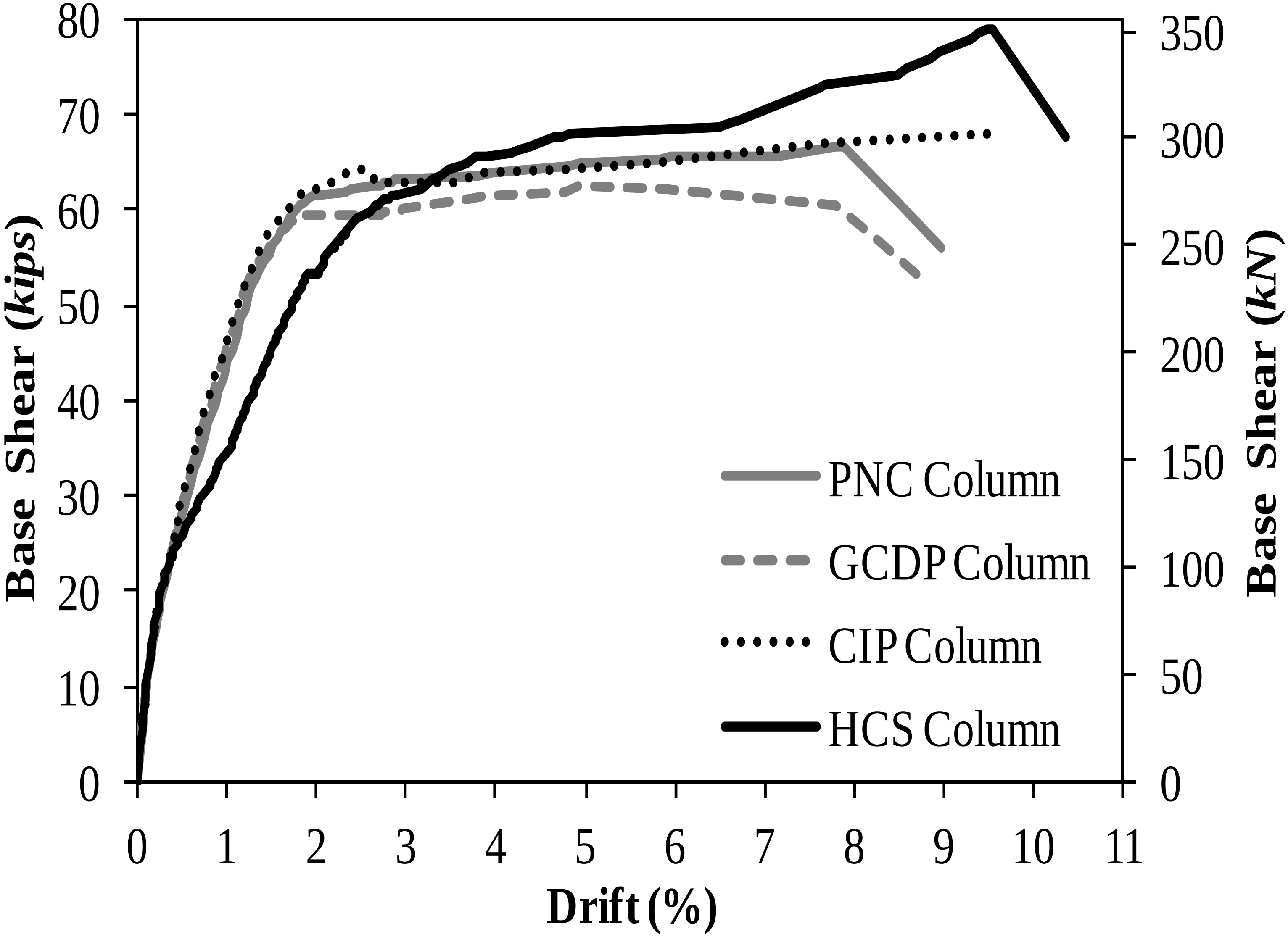
Column w/ offset grouted couplers
and unbonded pedestal bars
at 8% drift (failure)


CIP
HRC Couplers
No Couplers
(PNC)
Grouted
Coupler-
Debonded
Pedesal
Force [kip]
Force [kN]
Drift [%]
CIP
HCNP
HCPP
GCNP
GCPP
PNC
GCDP
80
70
60
50
40
30
20
10
0
0
1
2
3
4
5
6
7
8
9
10
11
300
200
150
100
50
0

Phase II- 3 Half-Scale Column Models



#10 SMA Bars w/ HRC Couplers



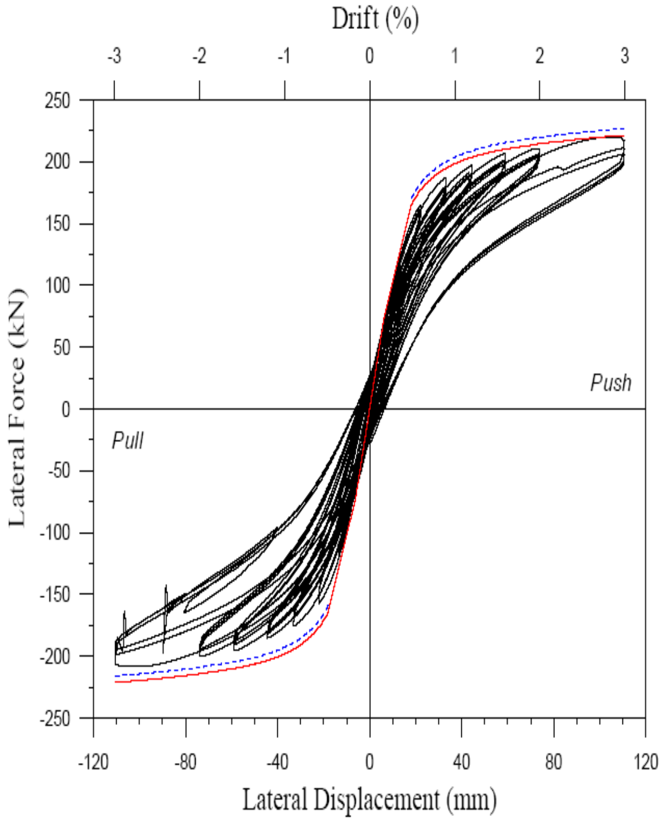
Base Shear (kips)
Base Shear (kN)
Drift (%)
PNC Column
GCDP Column
CIP Column
HCS Column
0
10
20
30
40
50
60
70
80
0
50
100
150
200
250
300
350
0
1
2
3
4
5
6
7
8
9
10
11

Innovation and ABC

- ABC--- Innovation in construction

- In addition, ABC provides opportunity for innovation in connection detailing and materials.

Segmental Precast Columns-- Post-tensioned



Advantage: Recentering by PT

Disadvantage: Low energy dissipation; Damage

Conventional RC vs Conventional Post-tensioned Columns

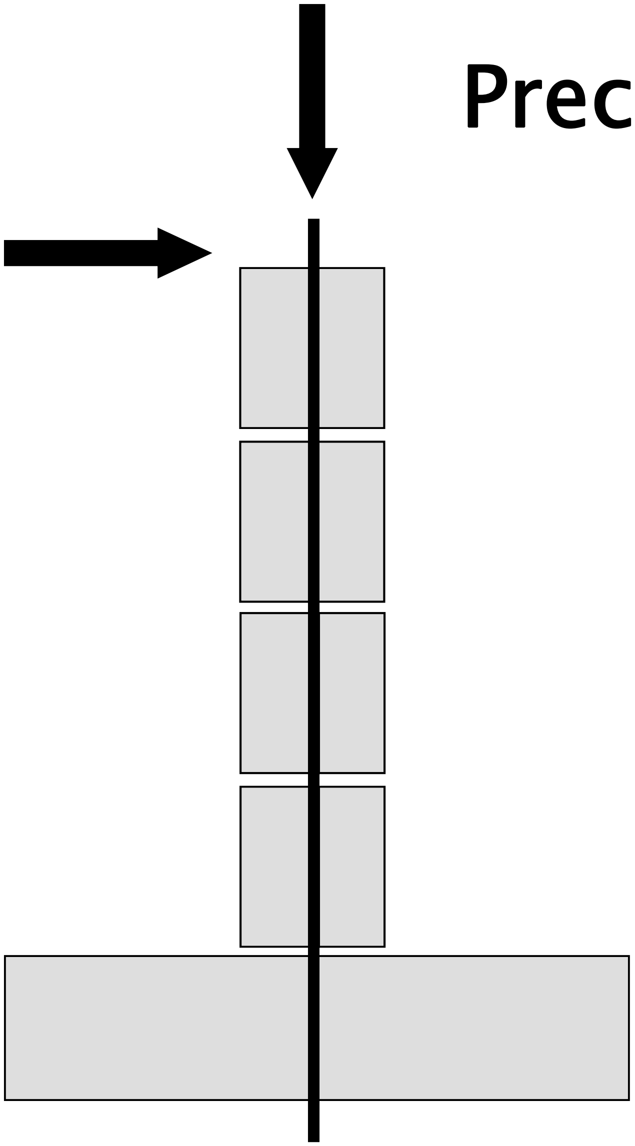
Conventional RC:

- High energy dissipation
- Permanent drift
- Damage

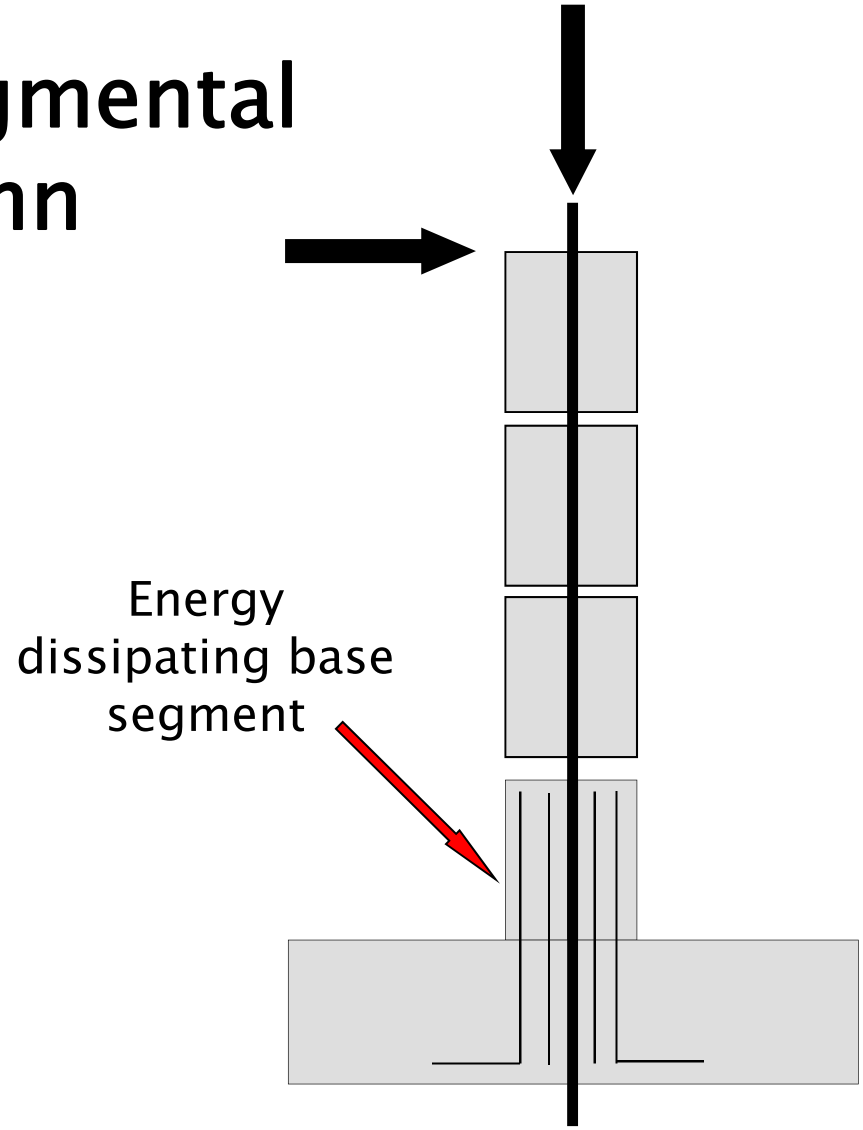
Conventional PT:

- Low energy dissipation
- No permanent drift
- Damage

Precast Segmental Column



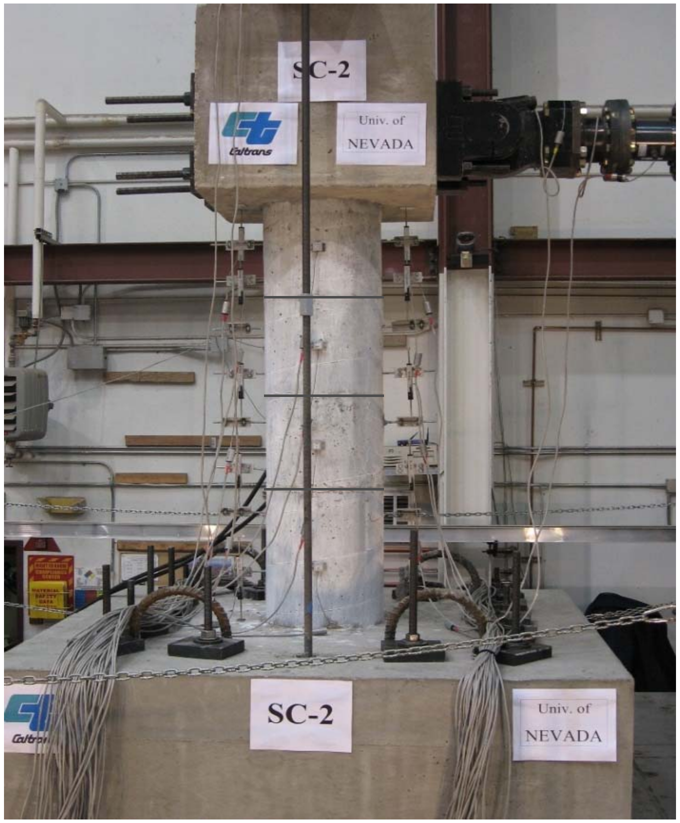
Standard PT Segmental Column



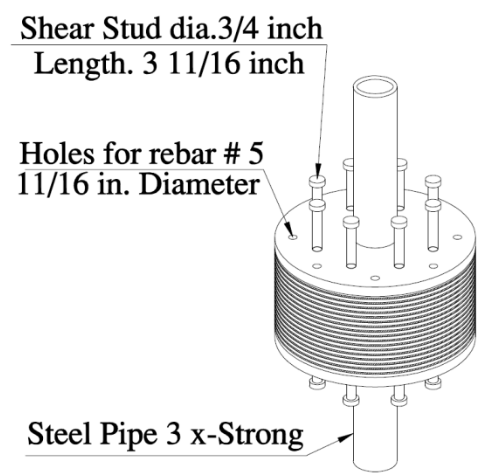
New Detail for PT Segmental Column

Columns	Name Description	Detail
SC-2	Segmental with Concrete	Conventional RC
SBR-1	Segmental with Built-in-Rubber Pad	Built-in Elastomeric Pad
SF-2	Segmental with FRP	CFRP Wrapped 2 Lower Segments
SE-2	Segmental with ECC	ECC in 2 Lower Segments
SC-2R	Segmental with Concrete-Repaired	Conventional RC- Repaired w/ FRP

SC-2
Reference Case-Conventional RC



SBR-1
Rubber Pad

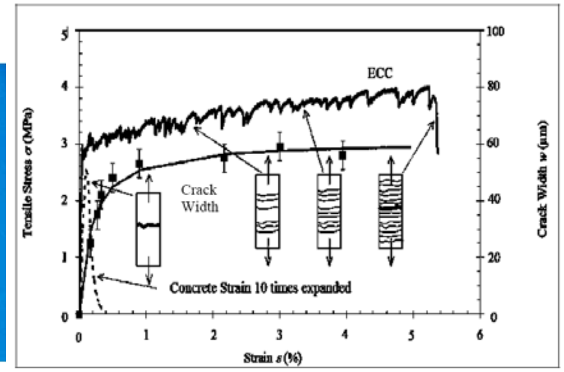


SF-2

CFRP Wrapped

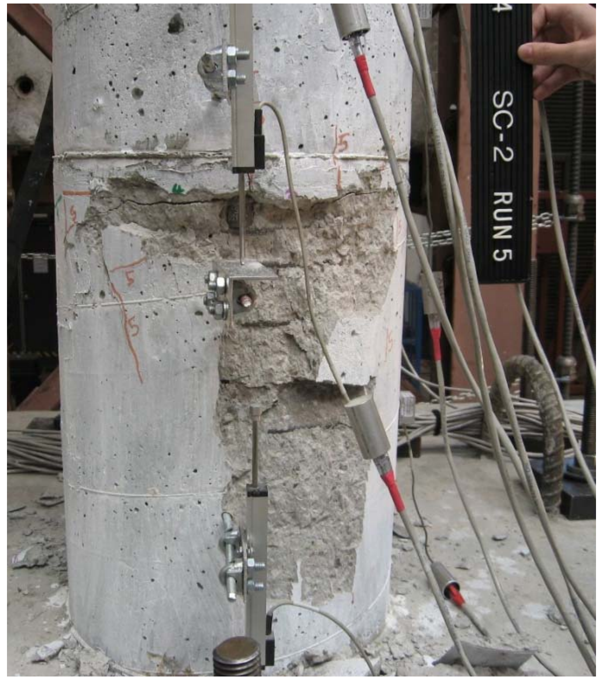
SE-2

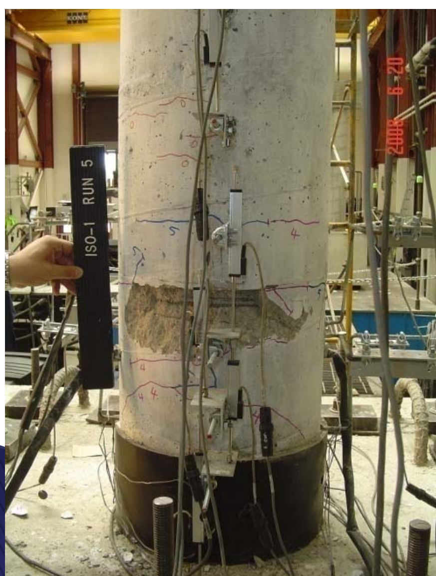
Engineered Cementitious Composite



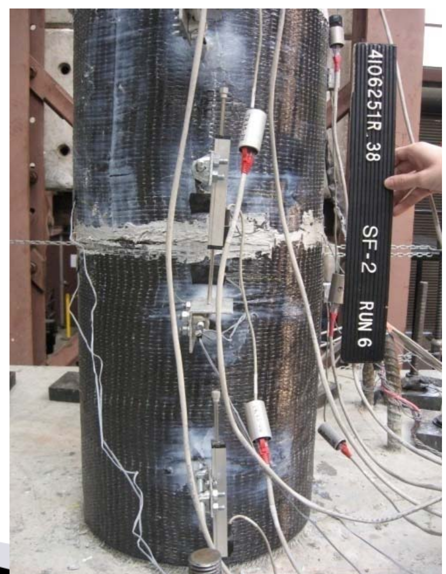
Typical ECC Tensile Stress Strain Curve

Damage after 5% Drift Ratio



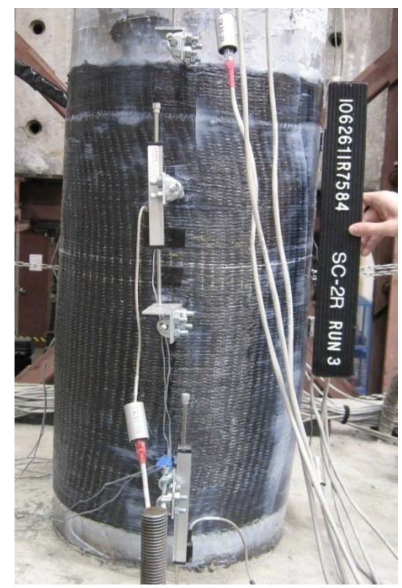


SBR-1



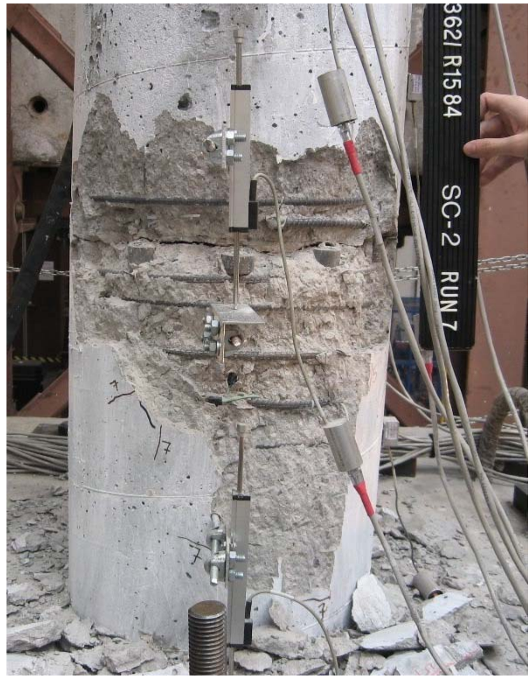
SF-2

SE-2



SC-2R

Damage after 10% Drift Ratio (Failure)

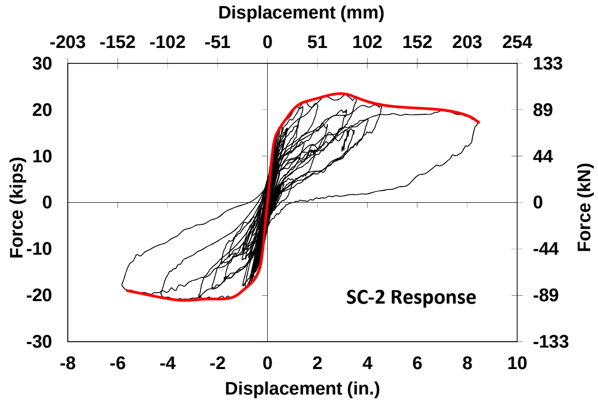


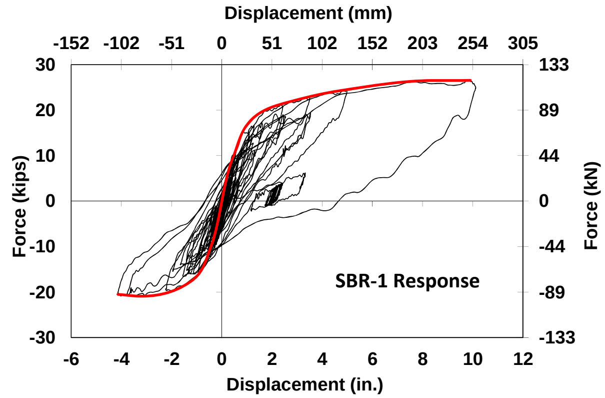
SBR-1

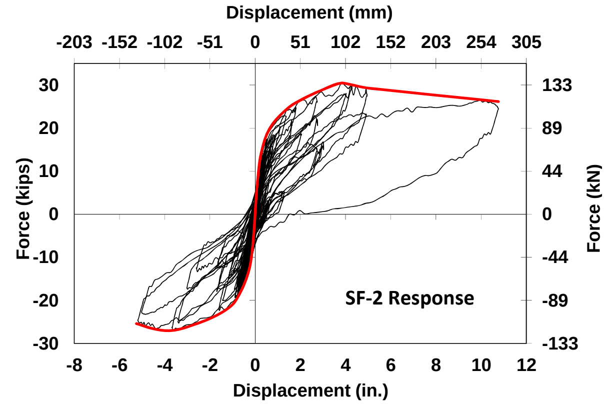
SF-2

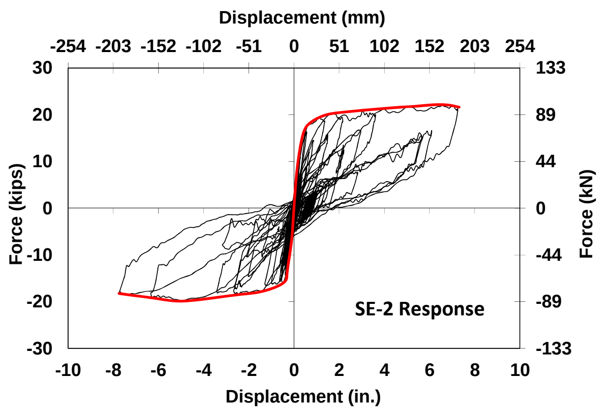
SE-2

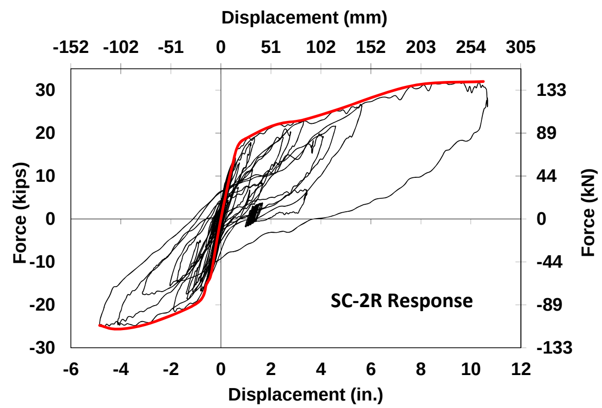
SC-2R


Displacement (mm)
Force (kips)
Force (kN)
SC-2 Response
Displacement (in.)


Displacement (mm)
Force (kips)
Force (kN)
SBR-1 Response
Displacement (in.)

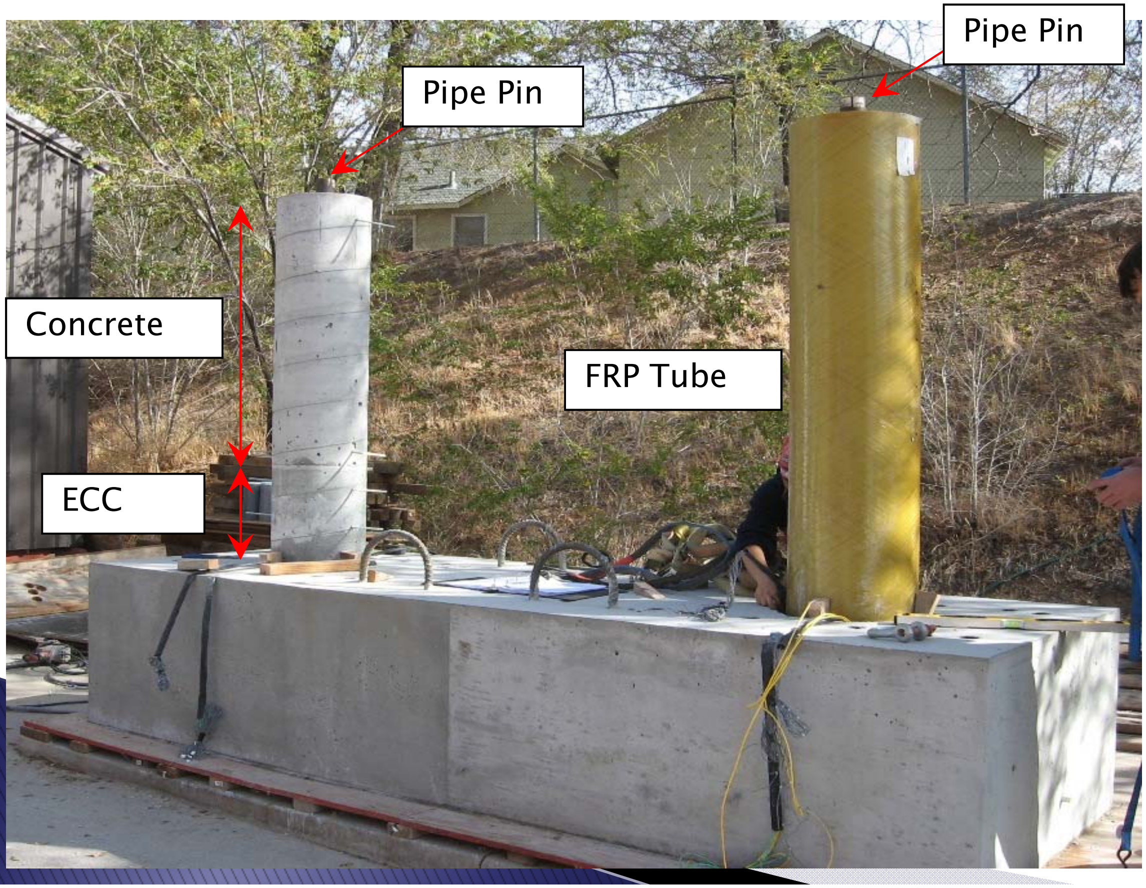

Displacement (mm)
Force (kips)
Force (kN)
SF-2 Response
Displacement (in.)

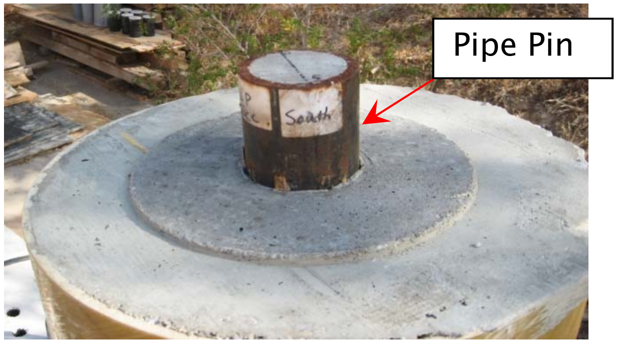

Displacement (mm)
Force (kips)
Force (kN)
SE-2 Response
Displacement (in.)

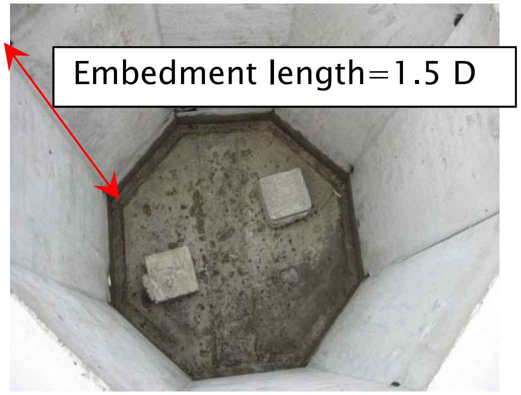

Displacement (mm)
Force (kips)
Force (kN)
SC-2R Response
Displacement (in.)

Precast Two-Column Bent

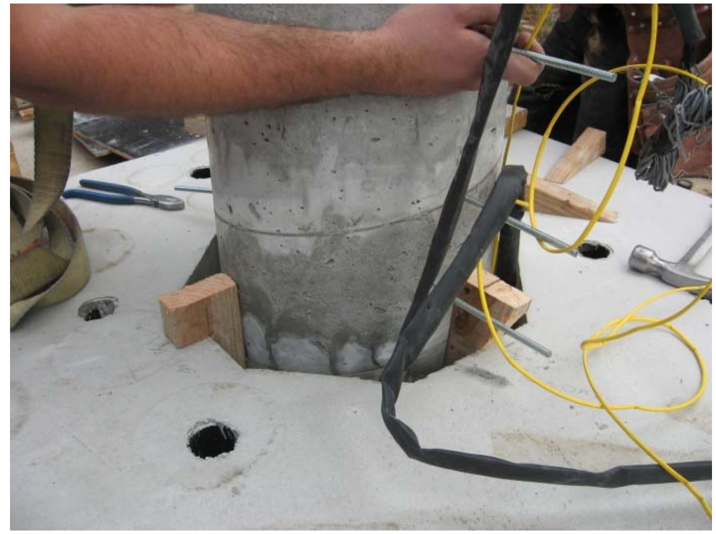
- Pipe pins used on top of columns
- One column was conventional RC with ECC in plastic hinge
- One column was FRP tube filled with concrete (FRP fibers were+/- 55 degree)



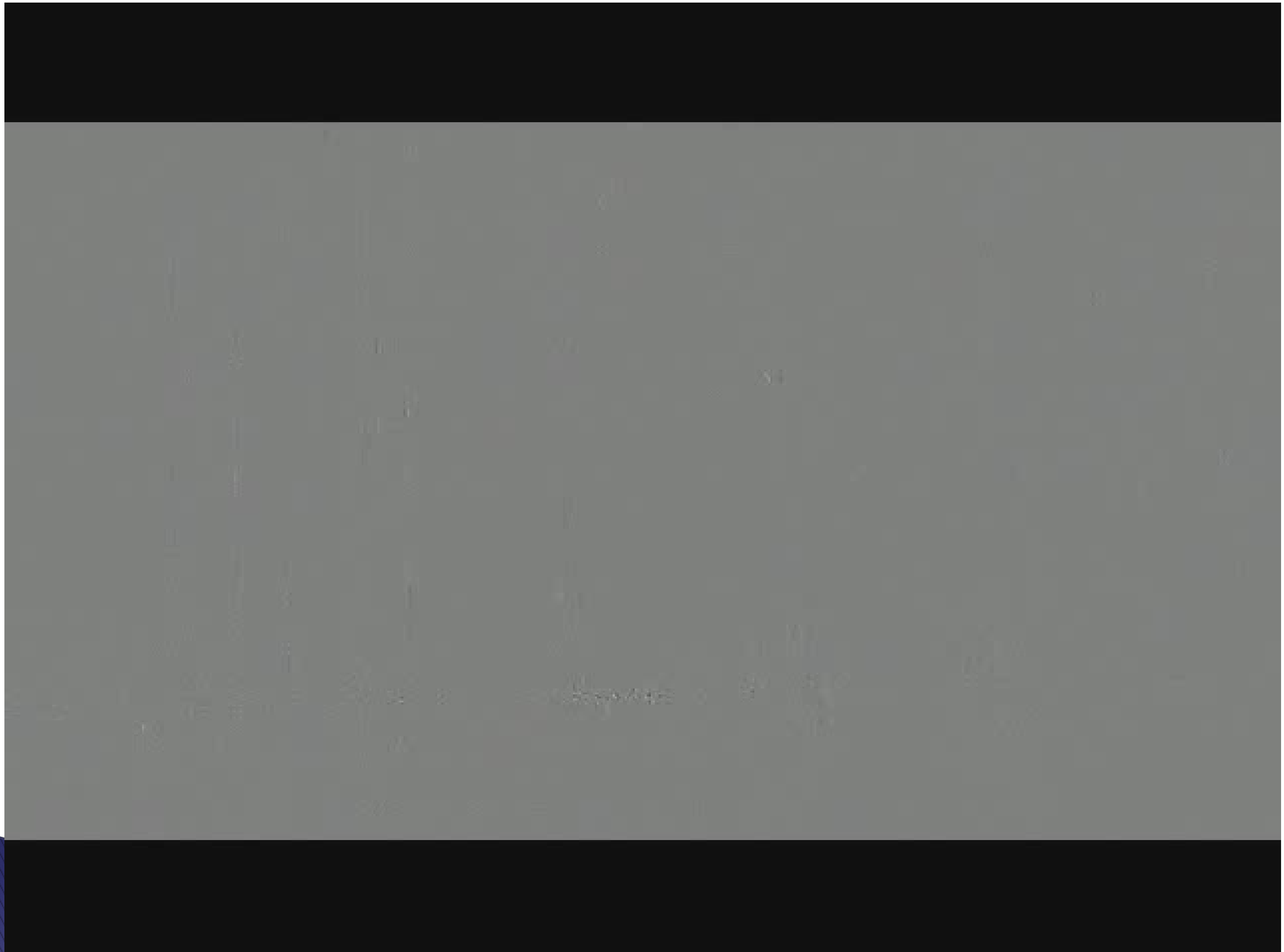




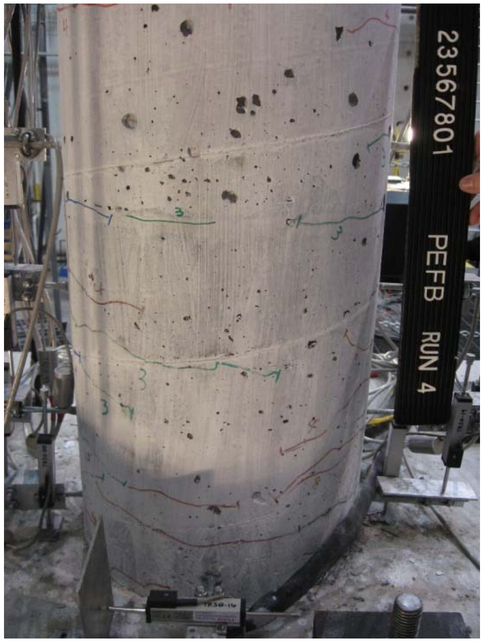
Bent Construction



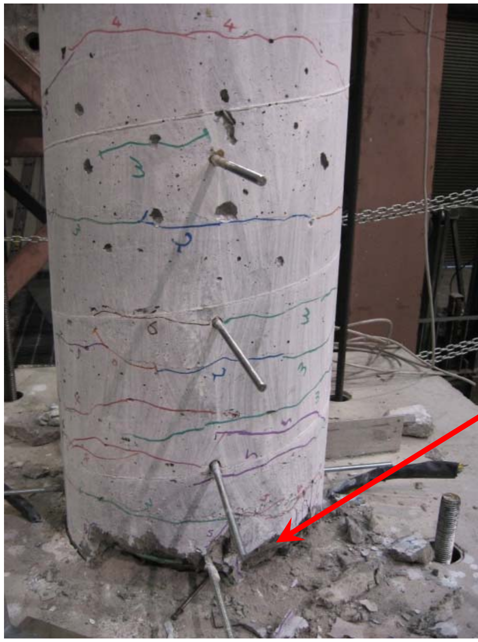
Shake table test at UNR



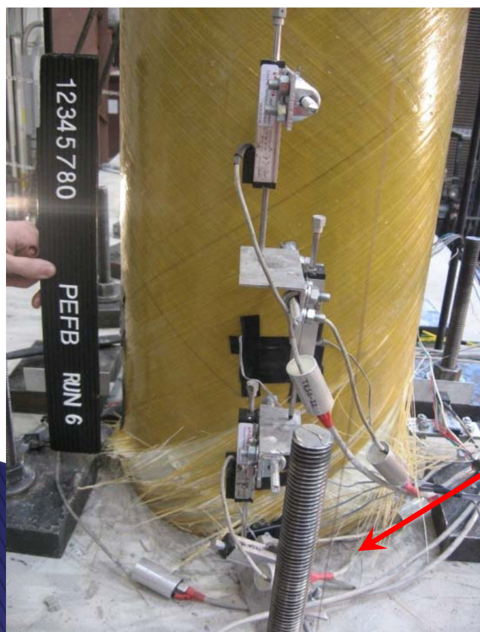
Columns condition at 5% Drift



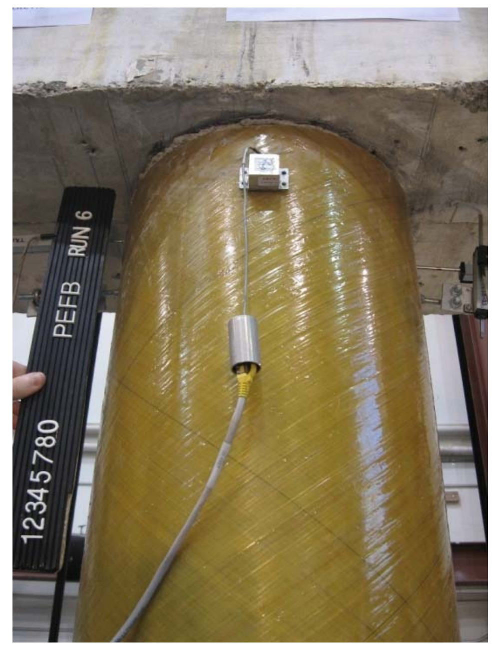
Columns condition at 11% Drift (Failure)



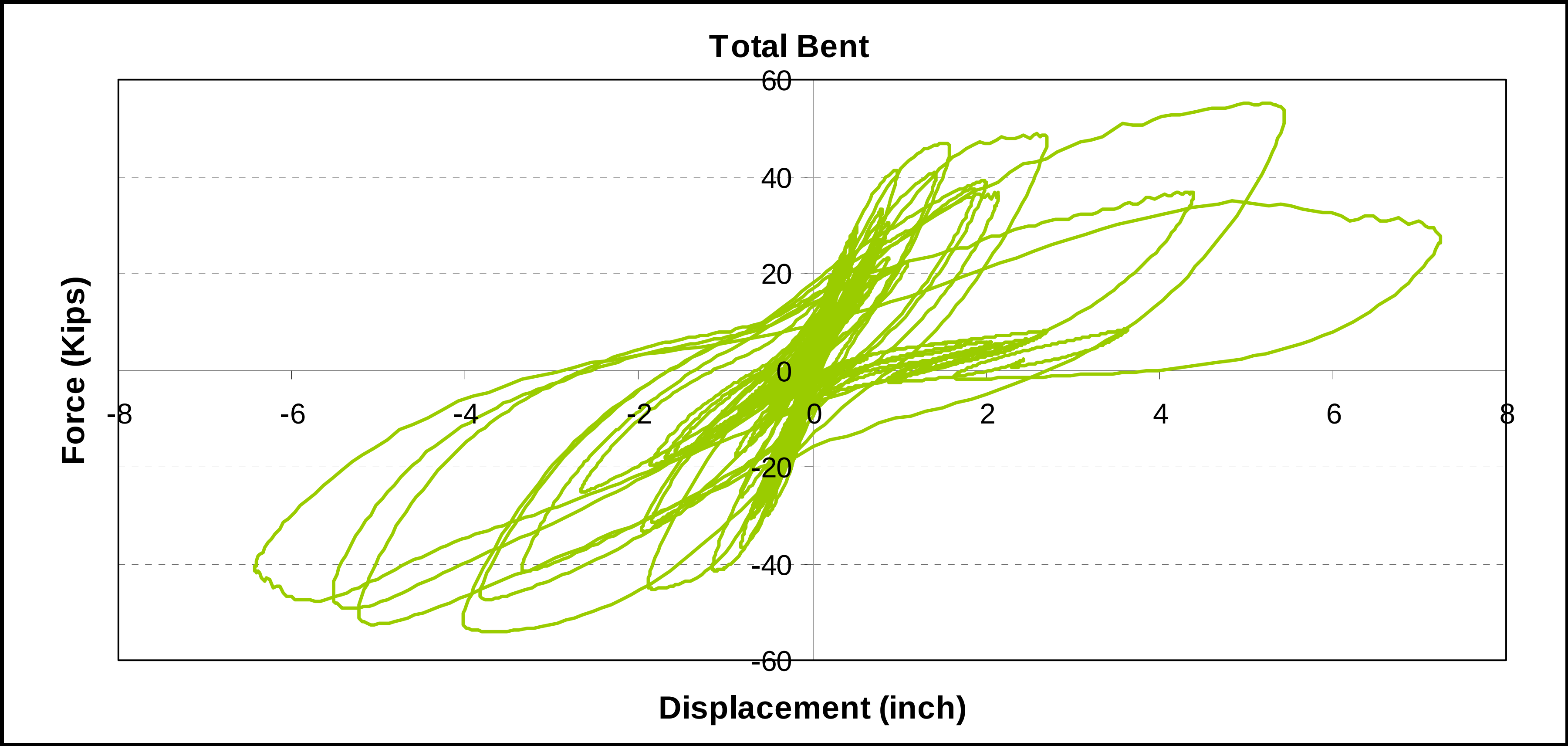
Ruptured bars



Ruptured FRP Fibers

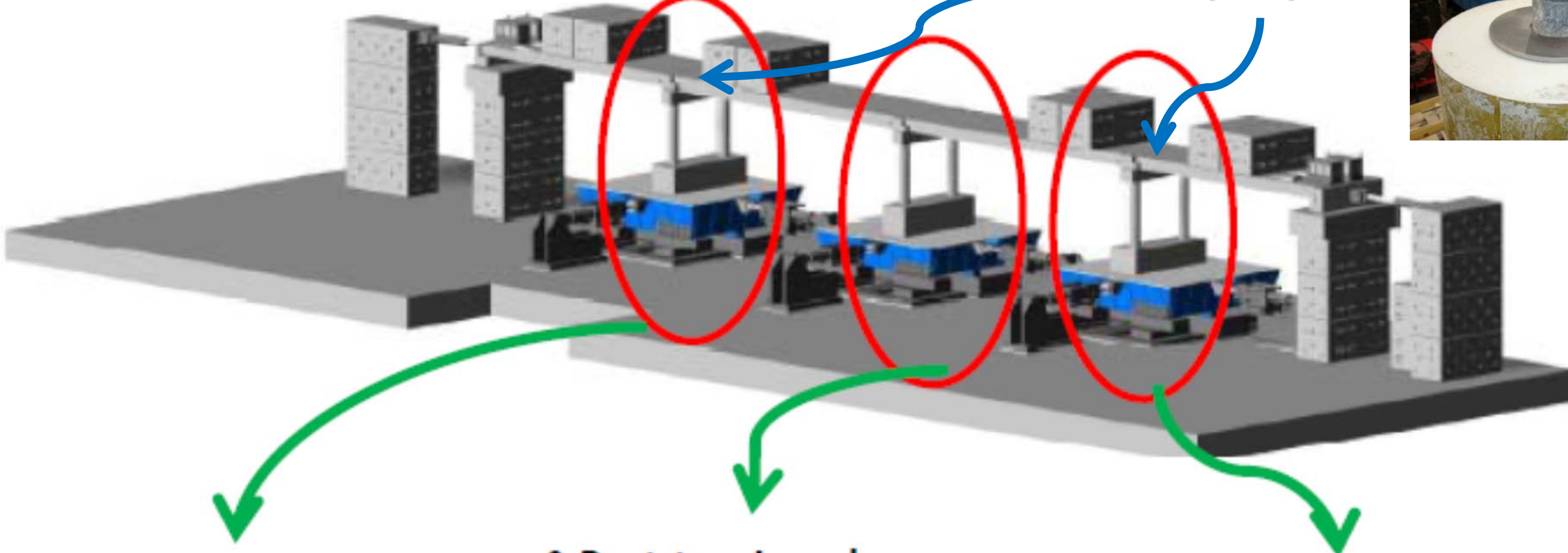


Force-Displacement Relationships



NSF-NEES 4-Span FRP Bridge

4 New Details



- Concrete filled tube precast columns

- Post-tensioned segmental columns

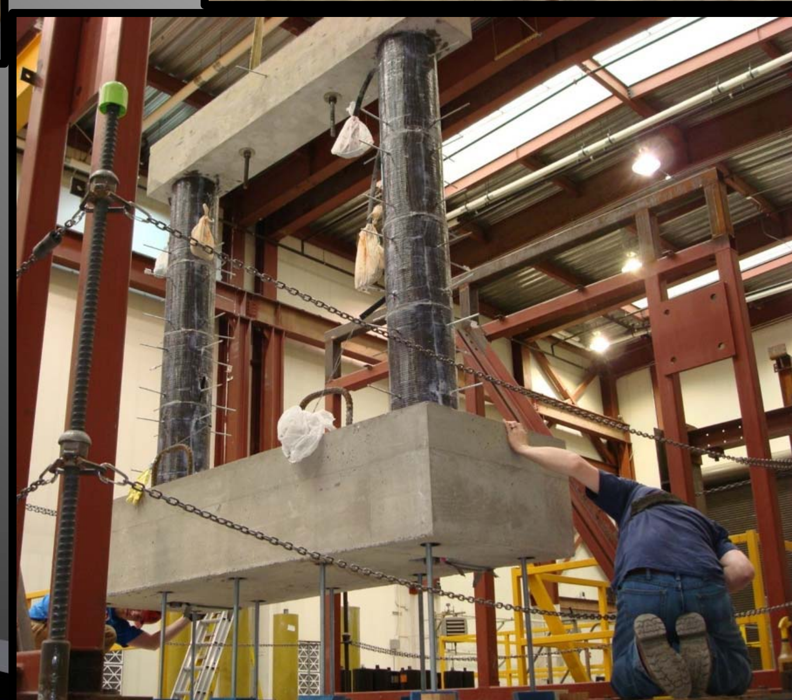
- Concrete filled tube cast-in-place columns

Concrete-filled FRP tubes piers

Precast

Cast-in-place

Segmental Pier Construction

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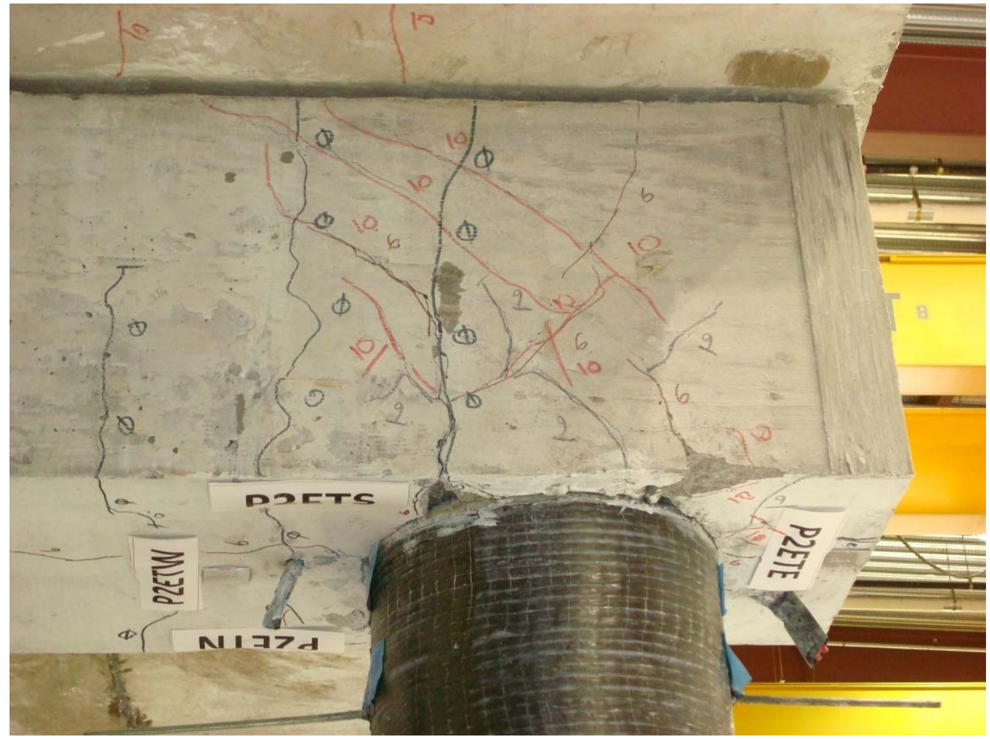
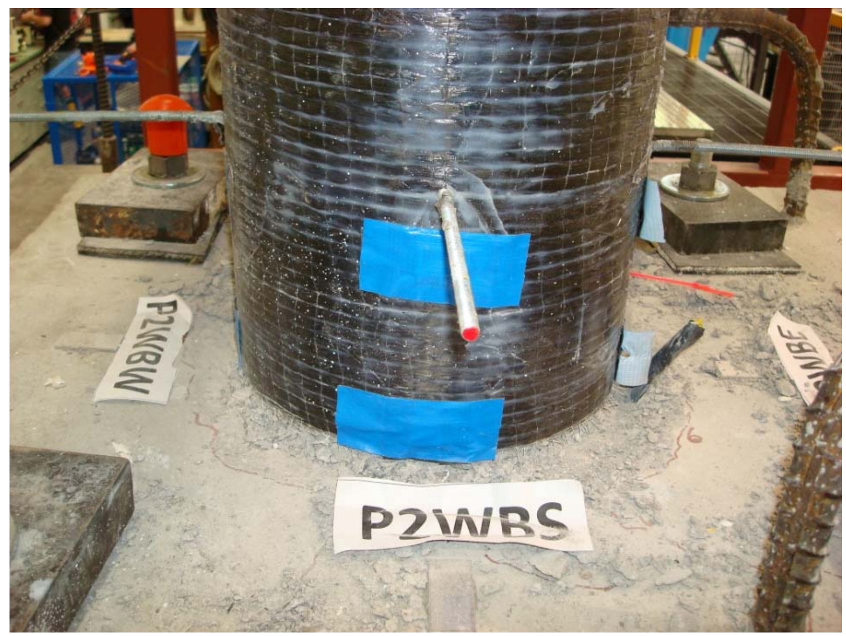
Precast vs. CIP Column Damage


P2ETS
P2ETW
P2ETE


Pier 2

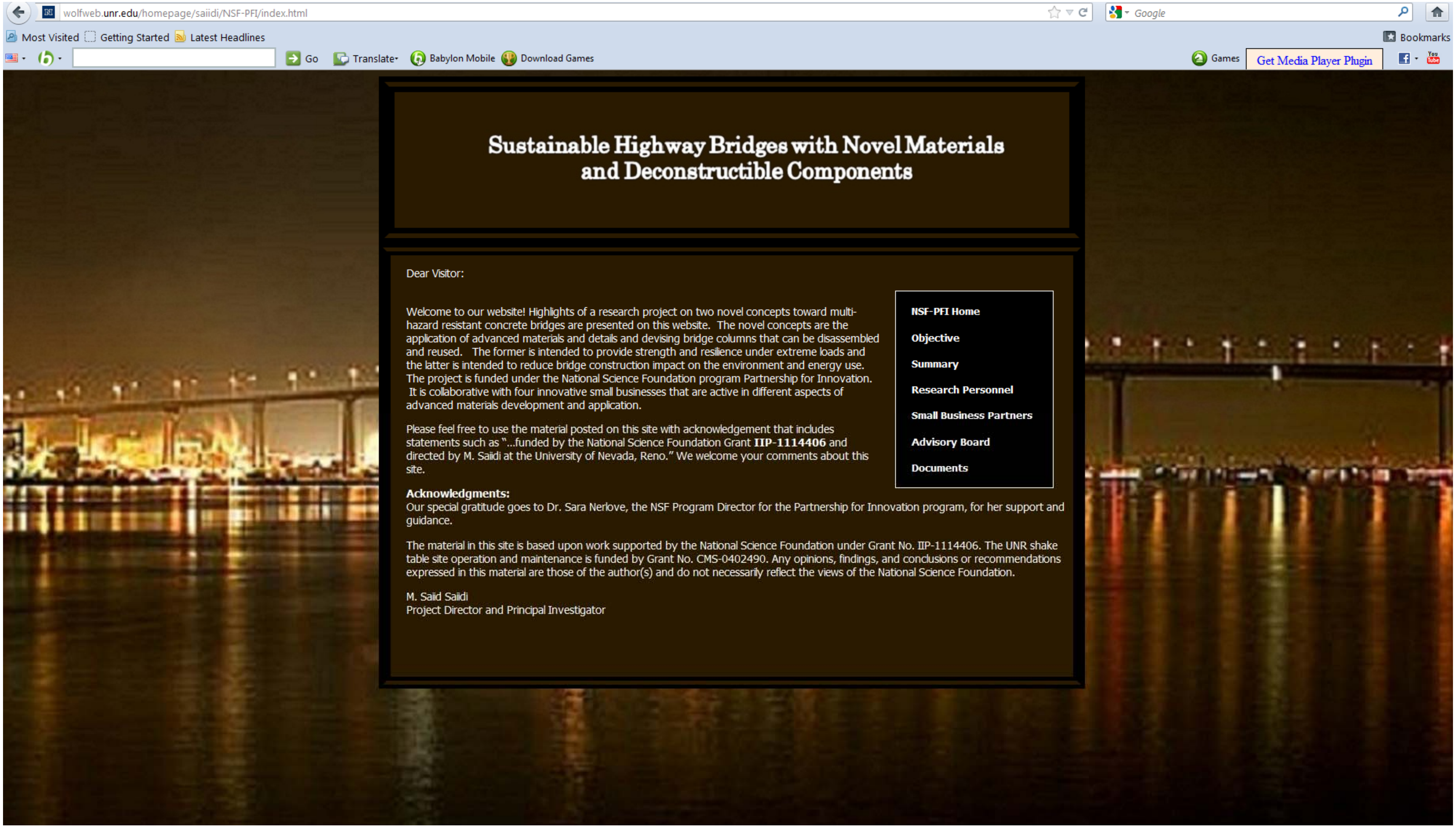

P2WBS

Conclusions on ABC w/ Innovative Materials/Connections

- ABC provides the opportunity to go beyond emulative design using advanced materials.
- The high initial cost of high-performance materials should be viewed in light of life cycle cost.
- Specifications and codes are needed to help promote ABC with advanced materials.

ABC Design for Disassembly (DFD)

Sustainable Highway Bridges with Novel Materials and Deconstructible Components



Sustainable Highway Bridges with Novel Materials and Deconstructible Components

Dear Visitor:

Welcome to our website! Highlights of a research project on two novel concepts toward multi-hazard resistant concrete bridges are presented on this website. The novel concepts are the application of advanced materials and details and devising bridge columns that can be disassembled and reused. The former is intended to provide strength and resilience under extreme loads and the latter is intended to reduce bridge construction impact on the environment and energy use. The project is funded under the National Science Foundation program Partnership for Innovation. It is collaborative with four innovative small businesses that are active in different aspects of advanced materials development and application.

Please feel free to use the material posted on this site with acknowledgement that includes statements such as "…funded by the National Science Foundation Grant **IIP-1114406** and directed by M. Saiidi at the University of Nevada, Reno." We welcome your comments about this site.

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Our special gratitude goes to Dr. Sara Nerlove, the NSF Program Director for the Partnership for Innovation program, for her support and guidance.

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M. Saiid Saiidi
Project Director and Principal Investigator

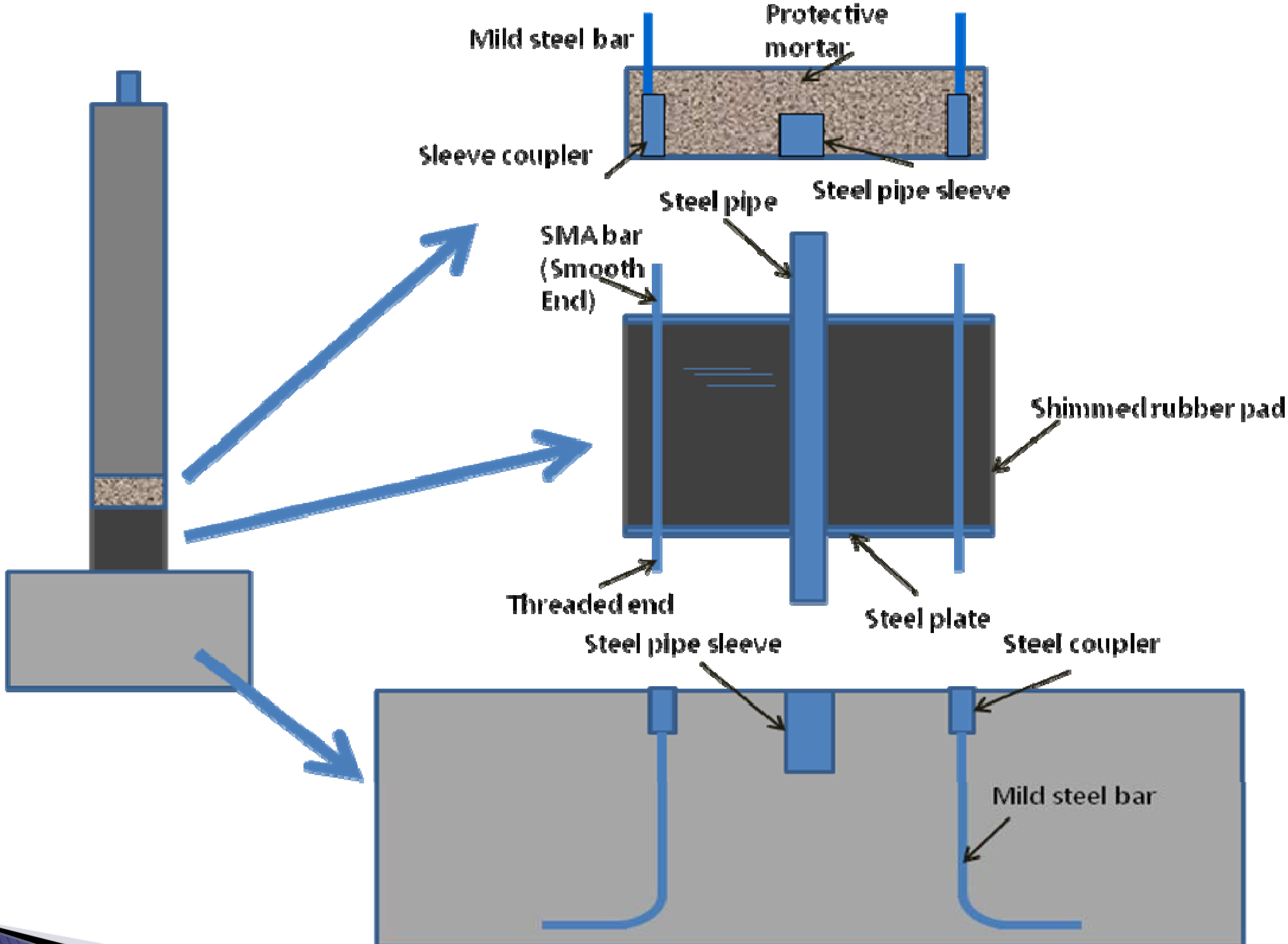
Small Business Partners

DYNAMIC ISOLATION SYSTEMS

Fiber Matrix, Inc.

FYFE Co. LLC
Tyfo® Fibrwrap® Systems

NiTINOL TECHNOLOGY INC.


Mild steel bar
Protective mortar
Sleeve coupler
Steel pipe sleeve
Steel pipe
SMA bar (Smooth End)
Shimmed rubber pad
Threaded end
Steel plate
Steel pipe sleeve
Steel coupler
Mild steel bar