UNIVERSITY of WASHINGTON

ACCELERATED BRIDGE CONSTRUCTION IN SEISMIC REGIONS: RESEARCH AT THE UW

John Stanton
Travis Thonstad

WSDOT ABC Workshop
1 April 2015

Acknowledgments

Funding:

NEES

PEER Center

FHWA Highways for Life

WSDOT

TransNow Center

PacTrans Center

Valle Foundation

UNIVERSITY of WASHINGTON

Accelerated Bridge Construction

Accelerated Bridge Construction

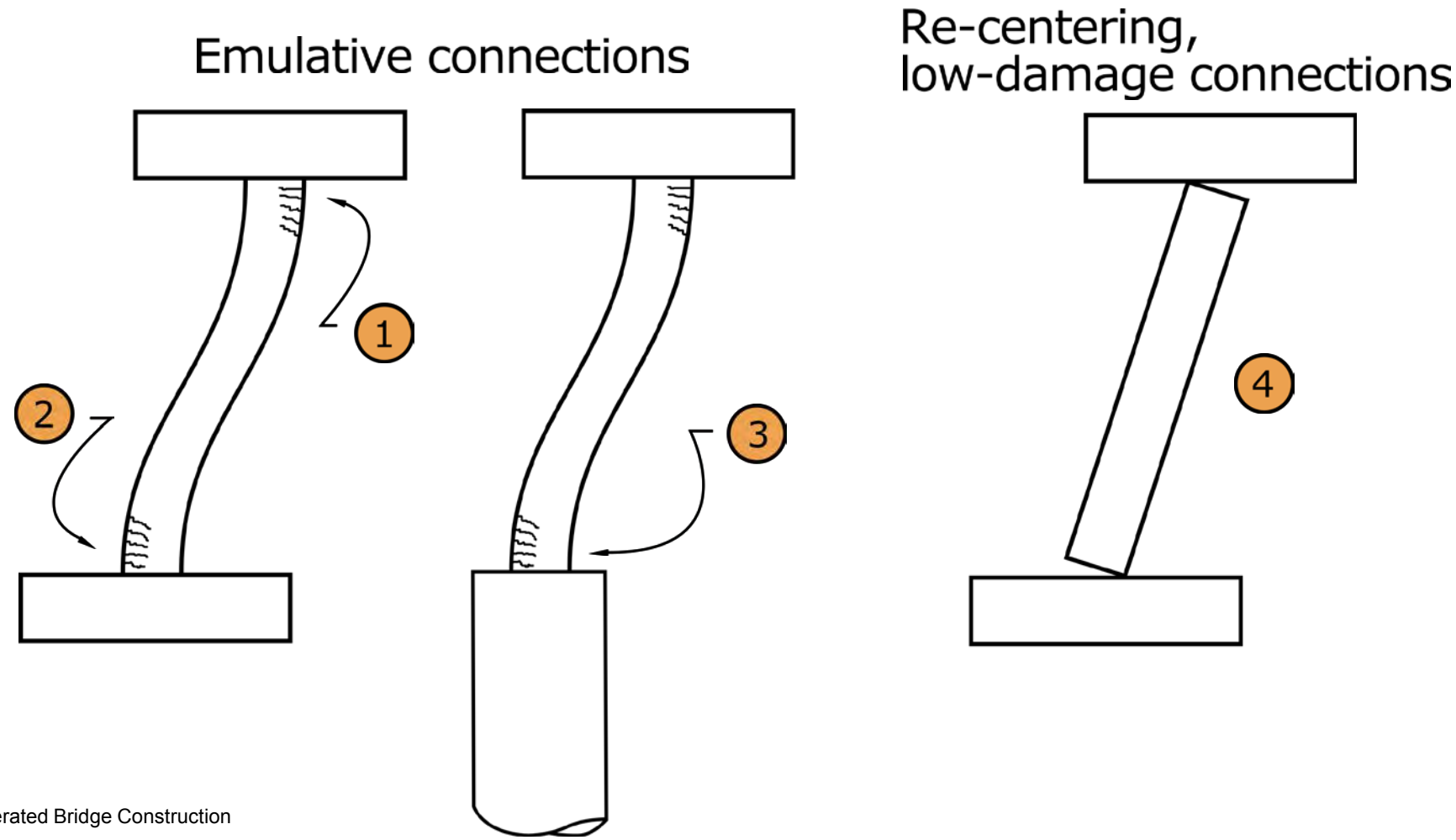
Use:

- Incentives in contracting
  - Place value on time.
- Big toys
  - Slide-in, SPMTs, etc.
- Precast Elements and systems
  - Prefabricate off-site, assemble on-site

Accelerated Bridge Construction

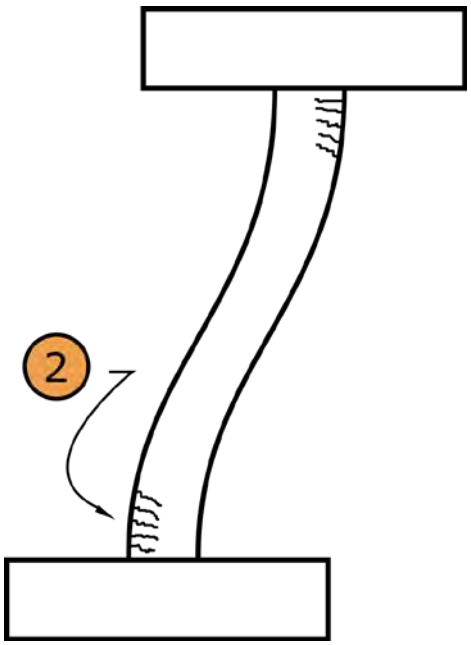
- *Prestressed girders are already pre-fabricated.*
- *Concentrate on substructure (bridge bents)*
- *Connections are the key*
  - *Ease of assembly (simplicity, speed, tolerances)*
  - *Seismic resistance*

Systems Developed



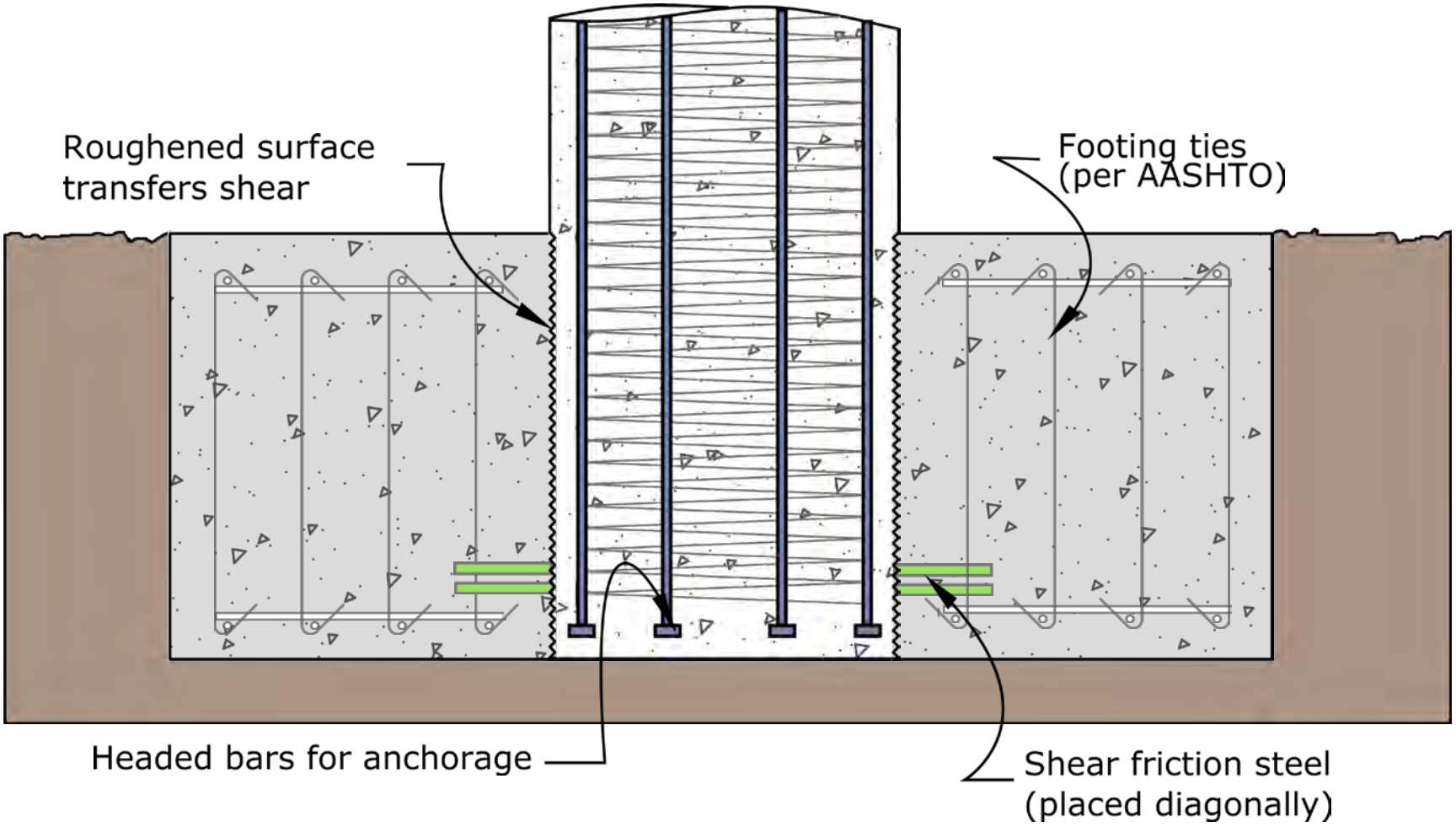
Spread Footing Connection

Spread Footing Connection

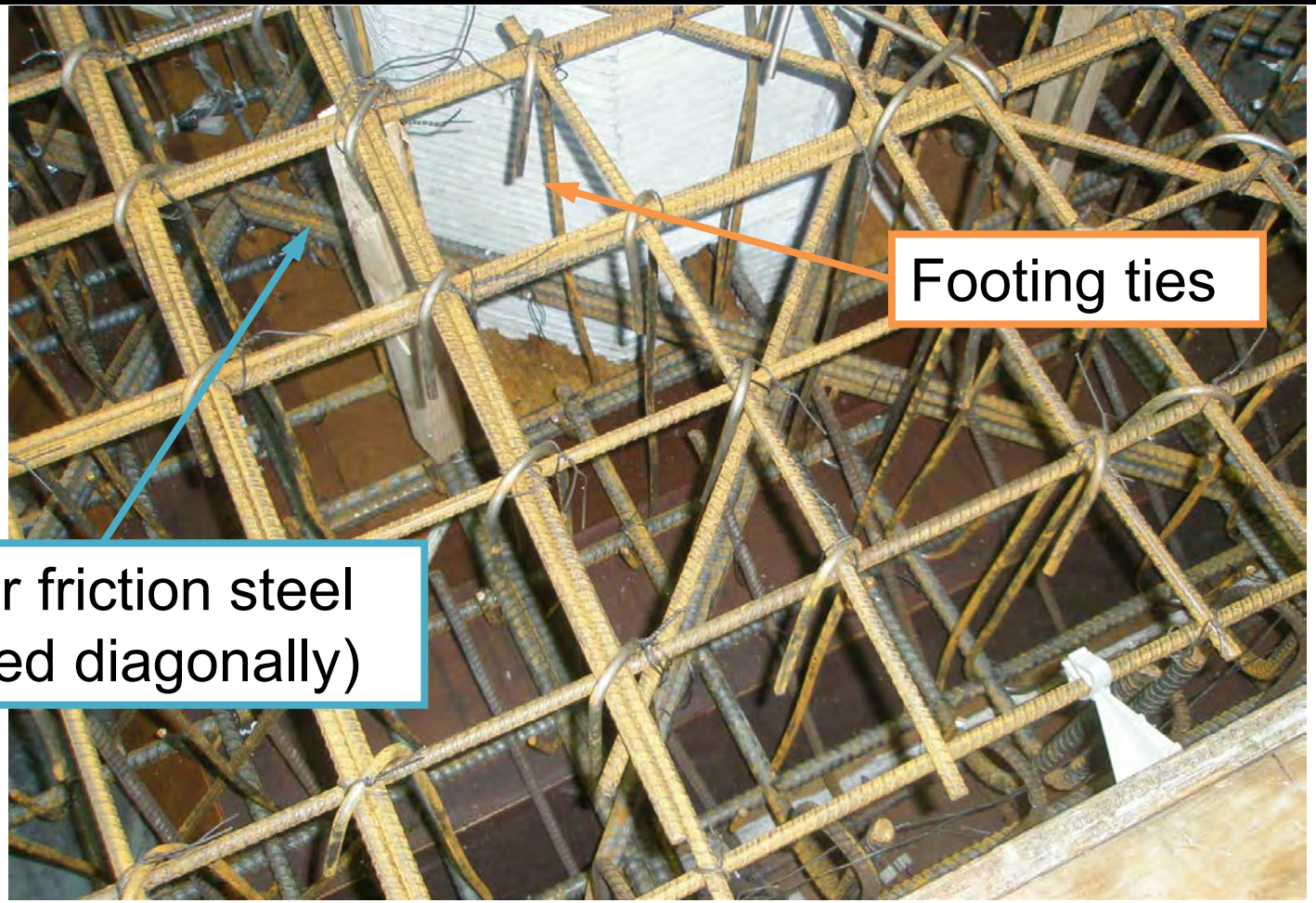


- *"Wet Socket" connection*
- *Precast column*
  - *Can be built in a plant.*
  - *No projecting bottom bars.*
  - *Easy transportation.*
- *Cast in place footing*

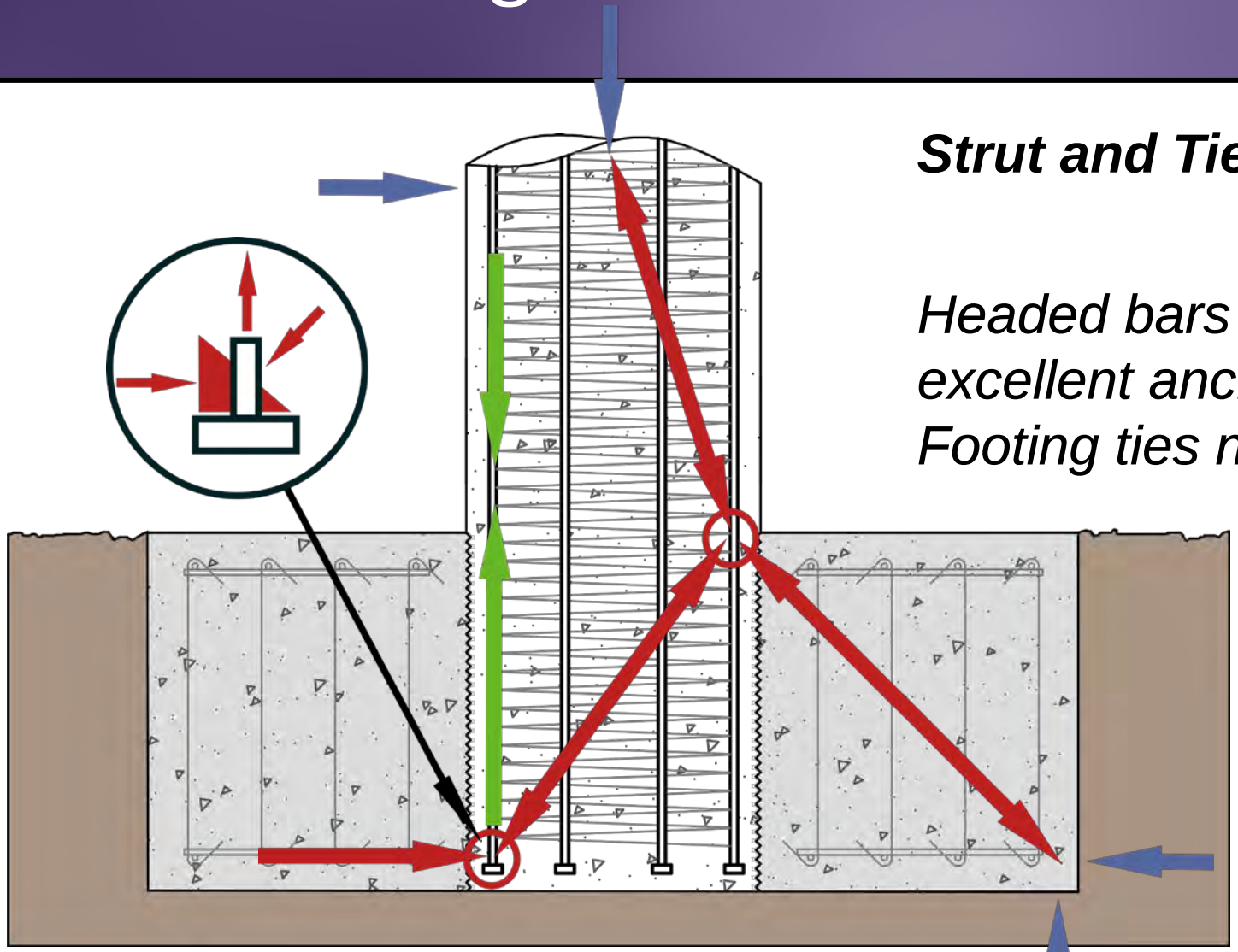
Spread Footing Connection



Wet Socket – Lab Specimen



Footing Connection - Forces



Strut and Tie Model.

Headed bars provide excellent anchorage. Footing ties not needed.

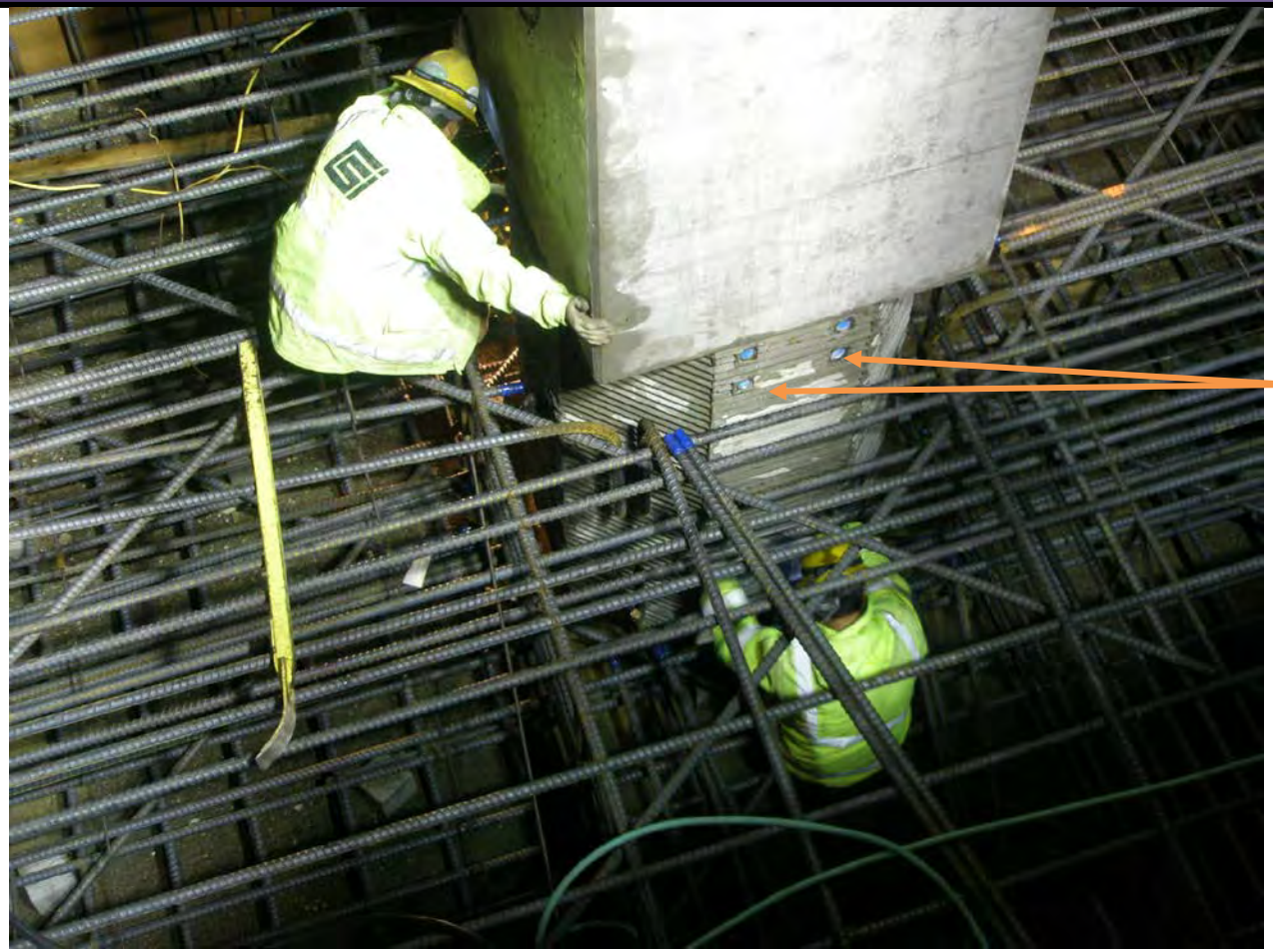
Test Results

- ***Lateral load:***
  - *Behaved exactly as conventional cast-in-place, but*
  - *footing ties experienced very low stress*
- ***Vertical load***
  - *Loaded to 3.5 times factored load: footing not even cracked*

Spread Footing Connection

After lateral load testing. Foundation undamaged.

Field Implementation



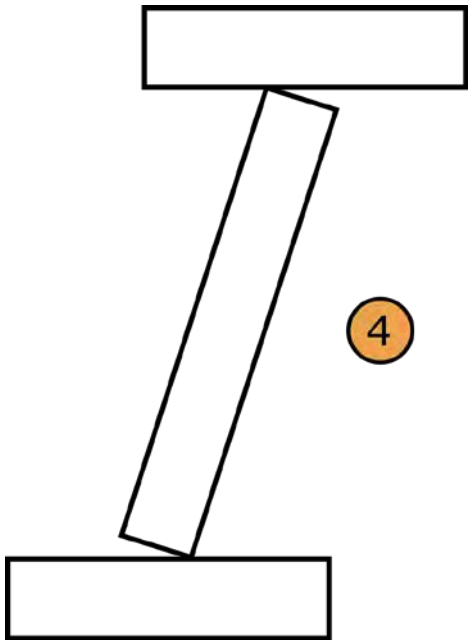
Tri-State Construction. SR520, Redmond

UNIVERSITY of WASHINGTON

Re-centering Low Damage System

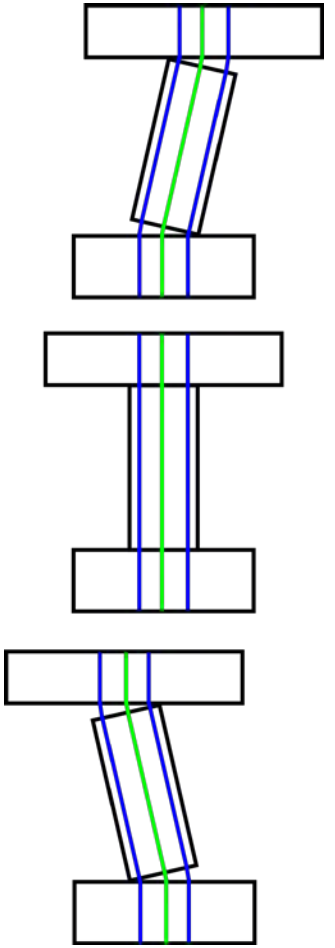
Re-Centering Low Damage System

- *Precast column for fast on-site construction.*
- *Use unbonded prestressing to re-center the column. Rocking minimizes column damage.*
- *Pre- (not post-) tension the column.*
- *Connections:*
  - *Bottom: Wet socket*
  - *Top: New ("Dry Socket")*



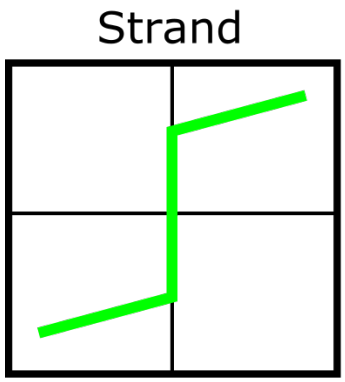
Re-Centering Low Damage System

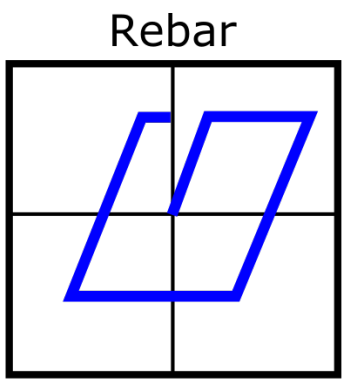
Partially Unbonded Pre-tensioning

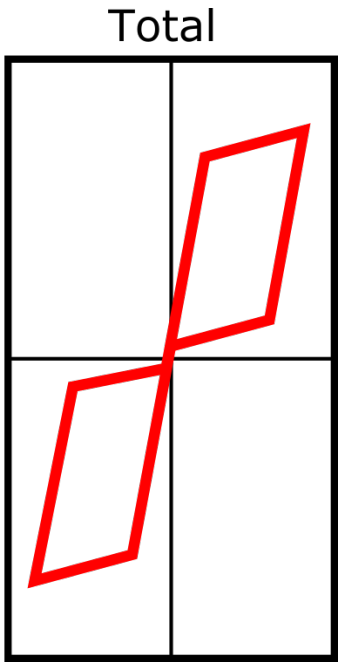


Strand: Stays elastic, provides re-centering force

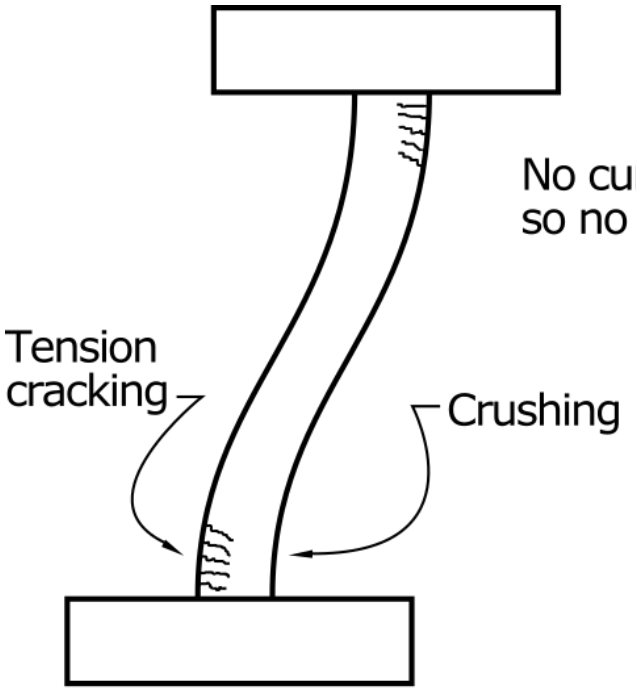
Rebar: Yields and dissipates energy



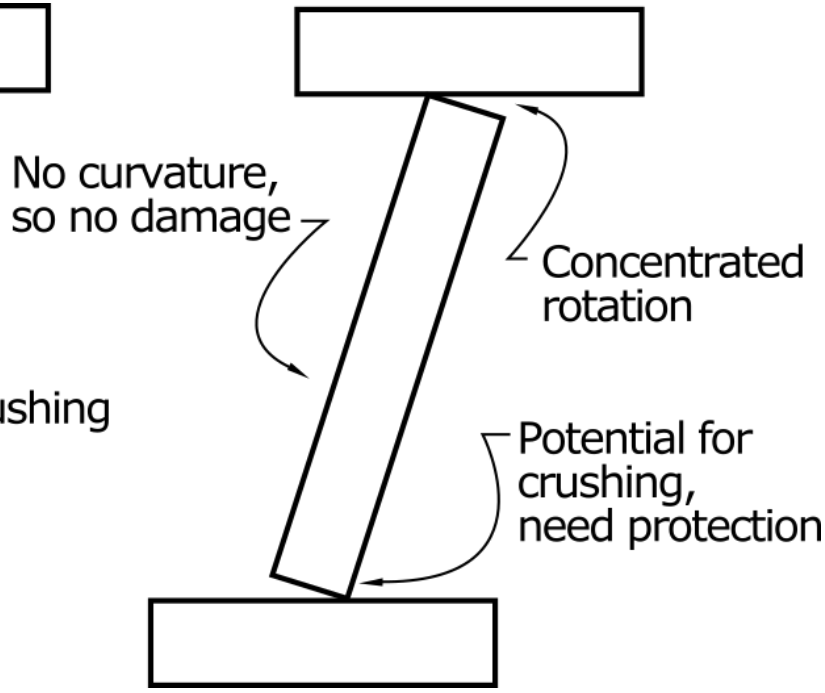




Low-Damage, Rocking Behavior

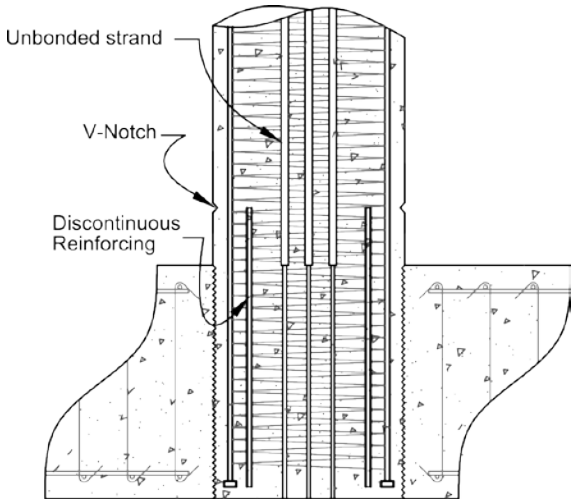


Bending: Tension cracks and compression crushing inevitable

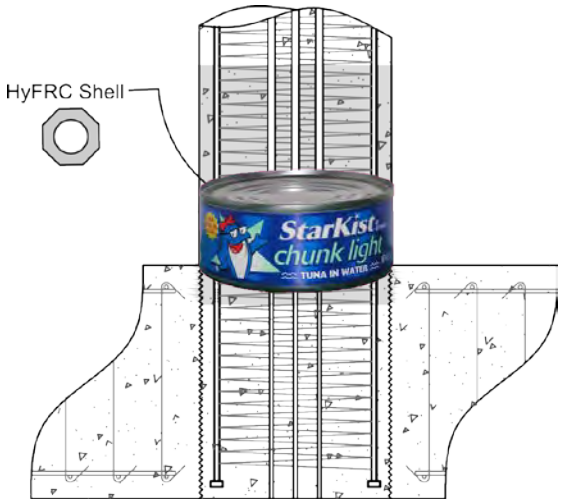


Rocking: High contact stresses

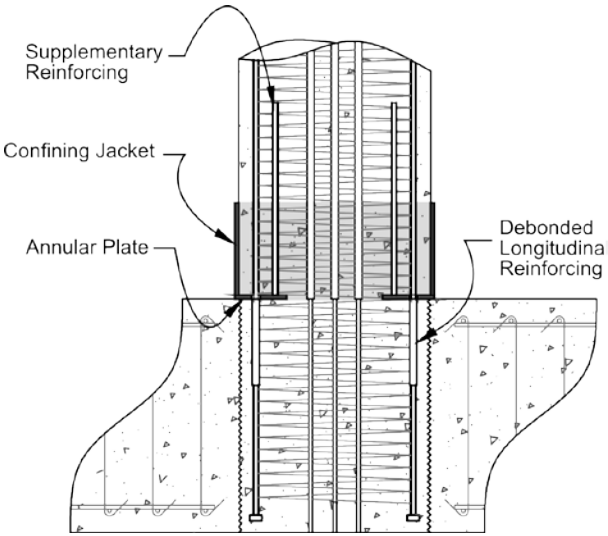
Detailing Strategies



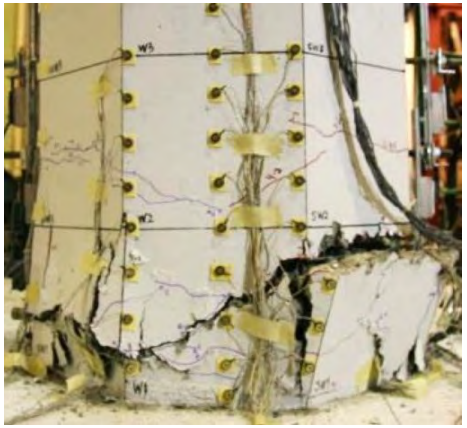
Conventional concrete only

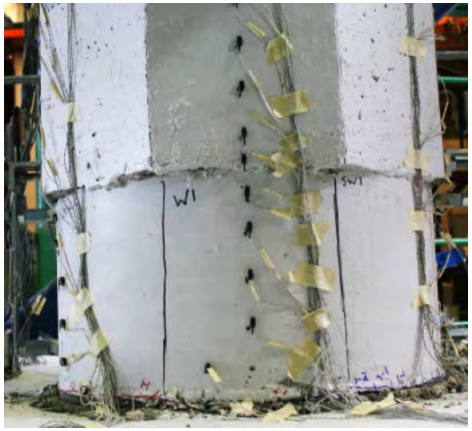


HyFRC in plastic hinge region



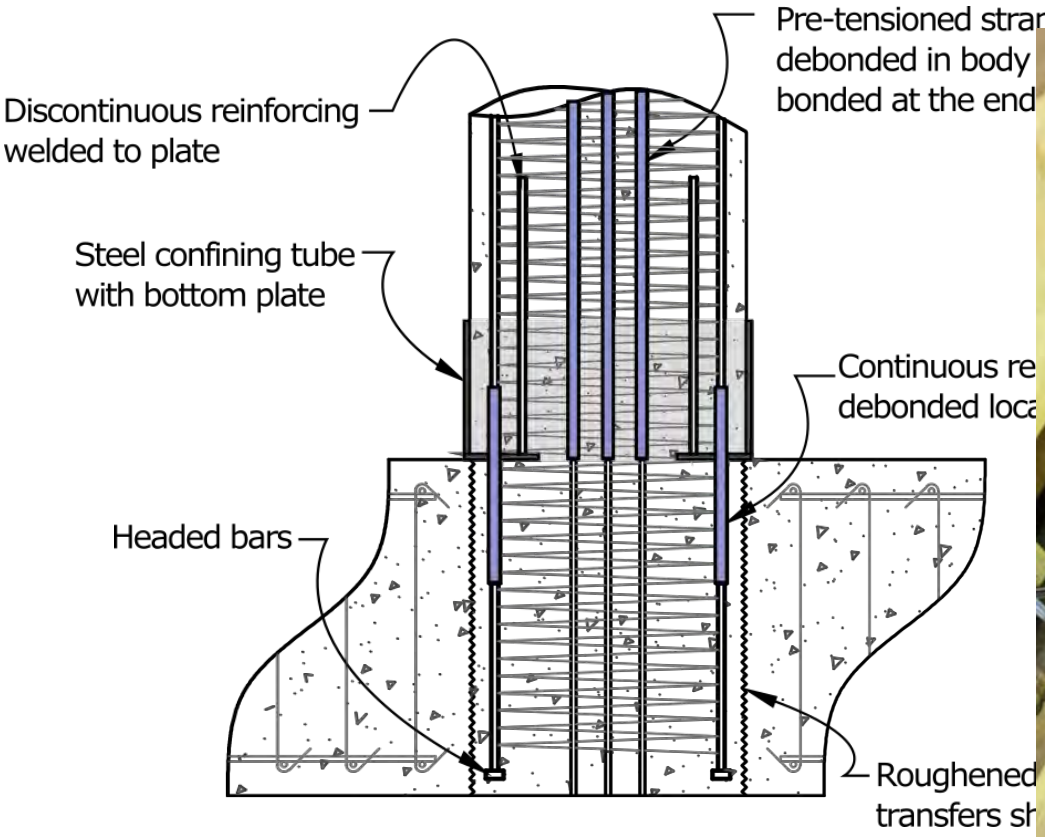
Steel tube confinement

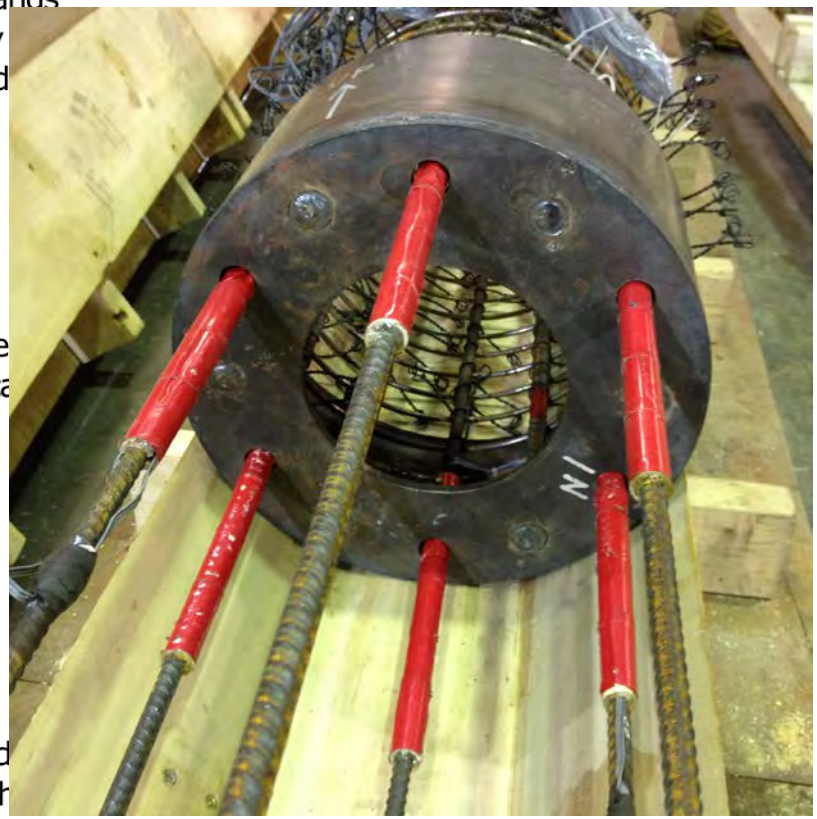




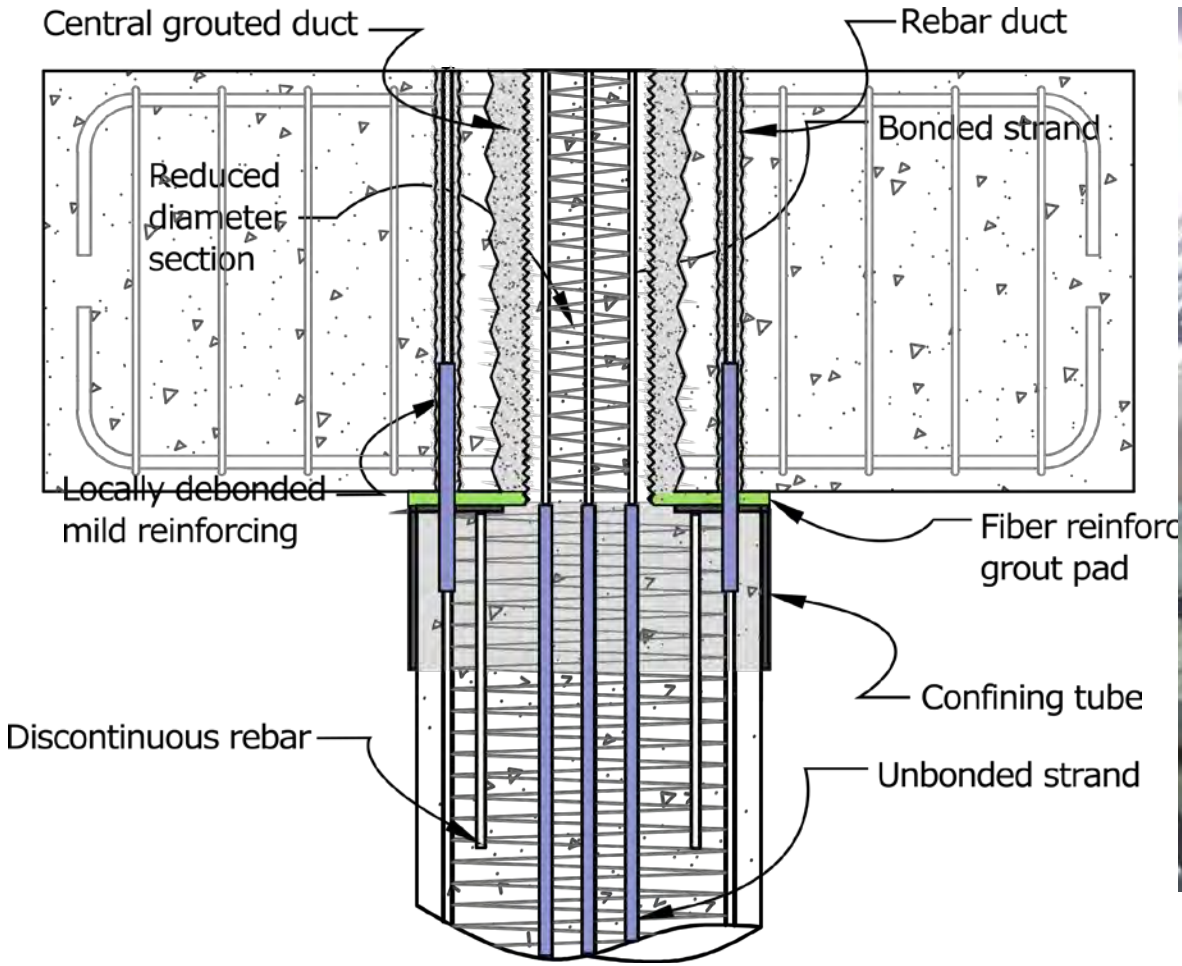
Re-centering Low Damage System→ **Low Damage Detailing**

"Wet Socket" Spread Footing Connection



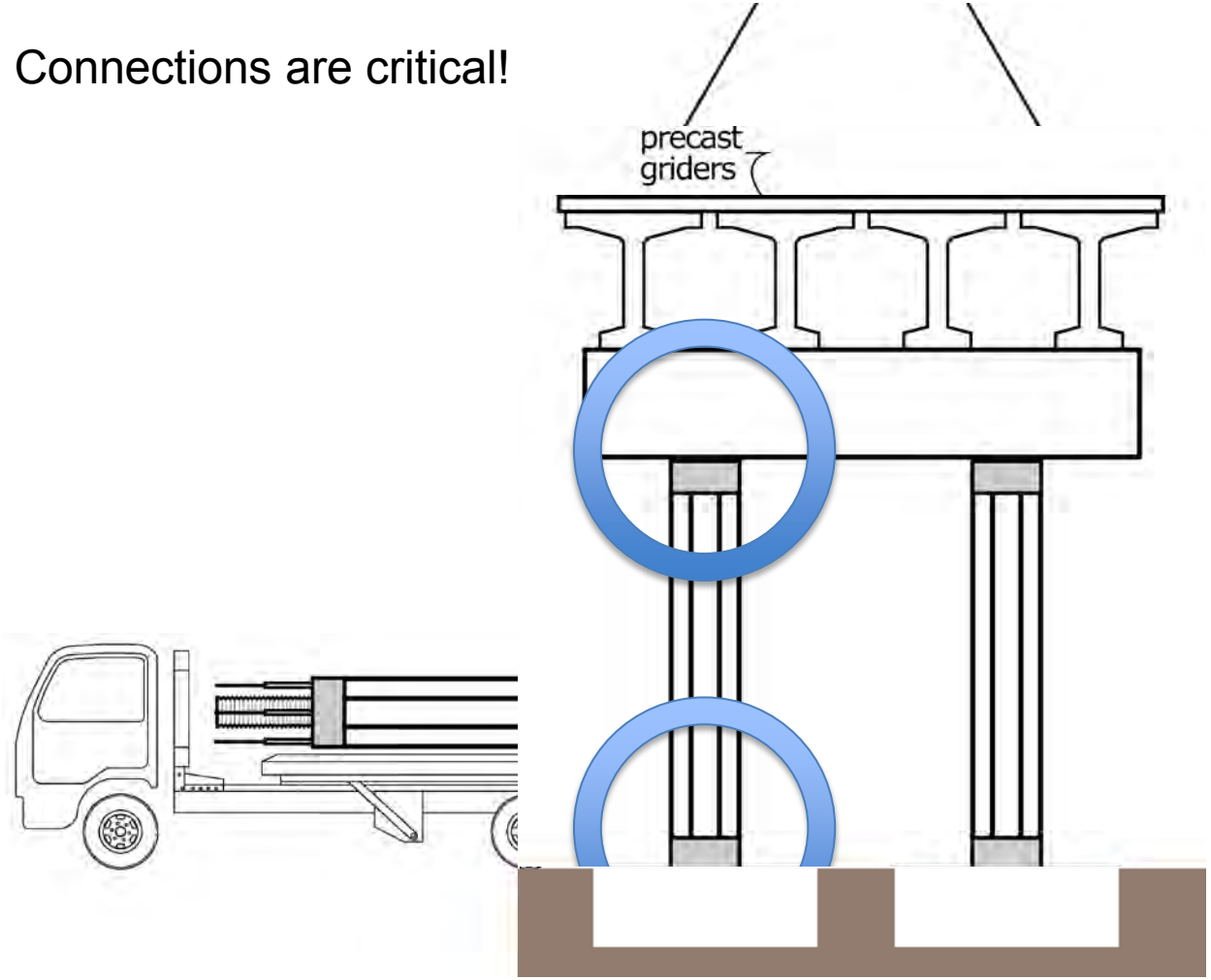


"Grouted-Bar-Socket" Cap Beam Connection



Construction Sequence

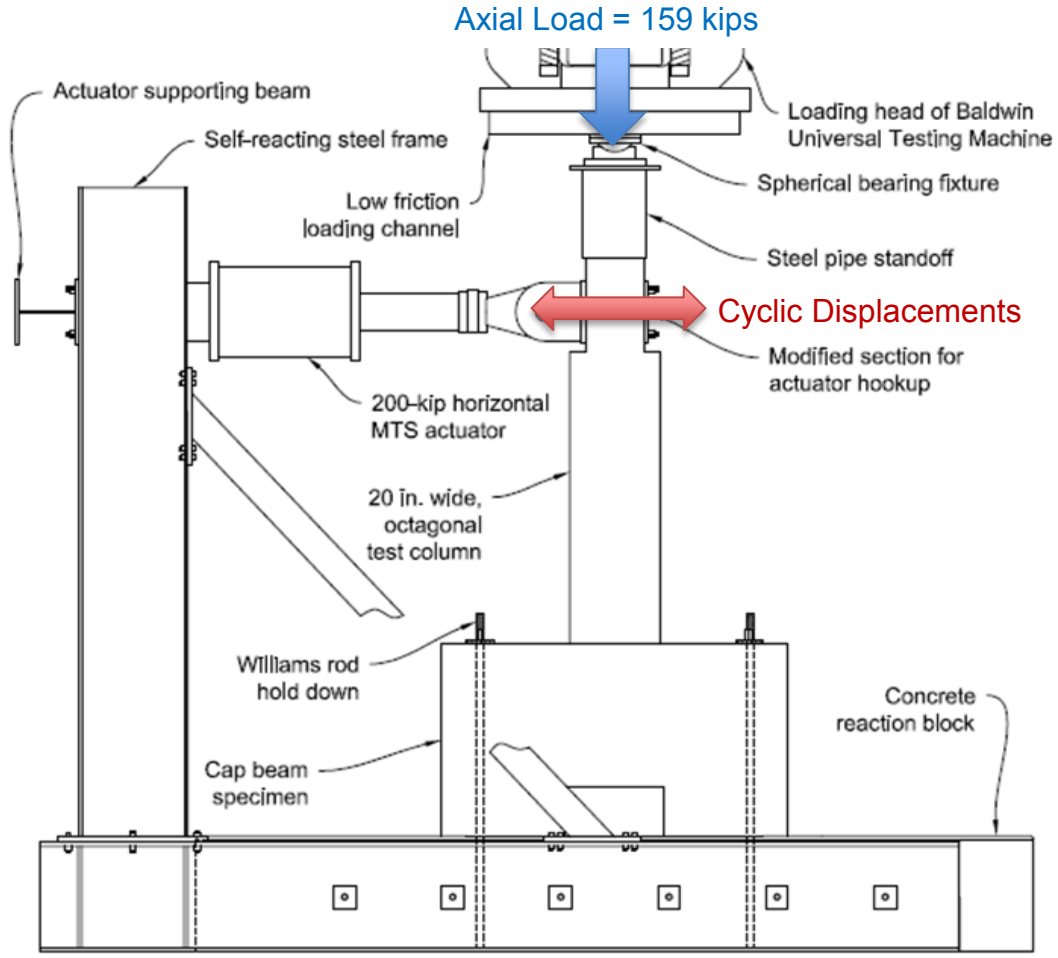
Connections are critical!



UNIVERSITY of WASHINGTON

Subassembly Tests

Test Configuration



Observations

After 10% drift:

- No concrete damage,
- No footing damage,
- No cap beam damage.

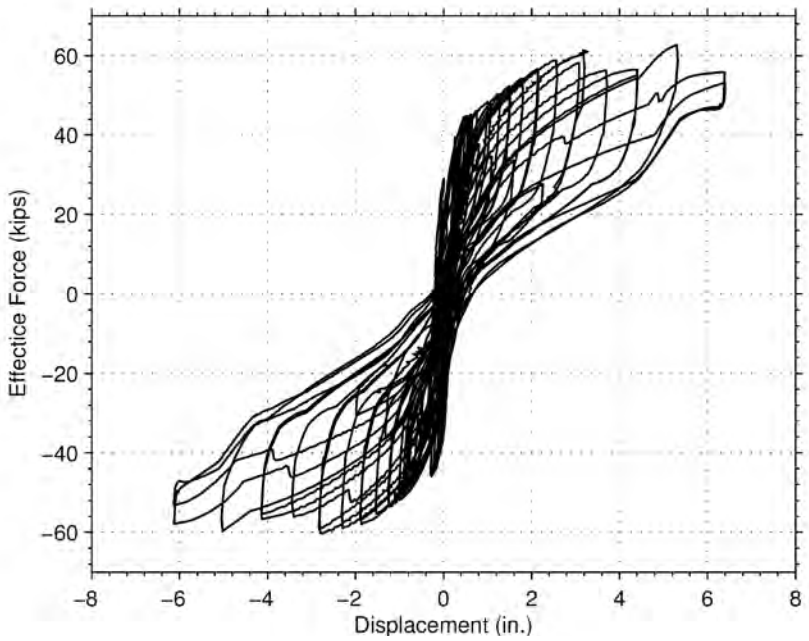
- Rebars broken (θ = 6%)
- Strand yielded (θ = 3%)

Column Performance

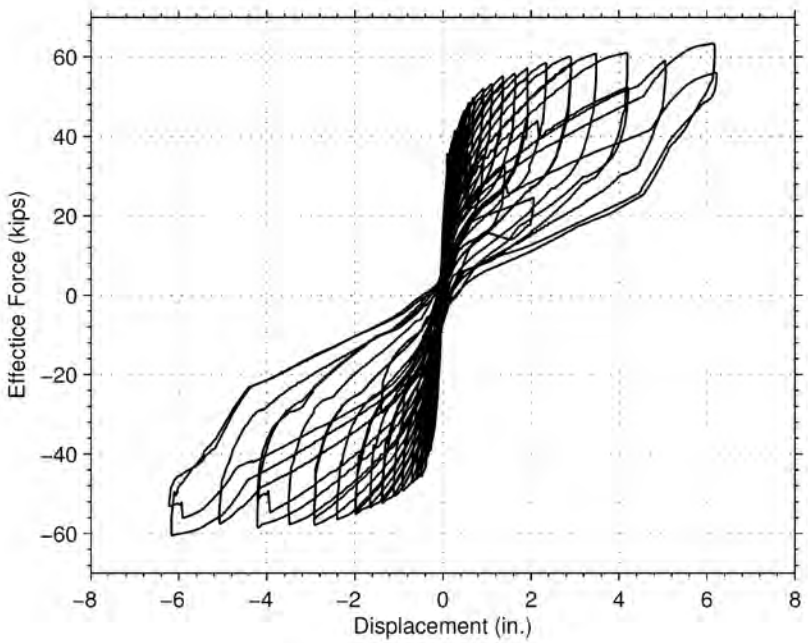
After 10% drift:

- Limited strength degradation (over 80% peak strength)
- Returns to within 0.1 d_{peak} residual displacement

Spread Footing Rocking Connection



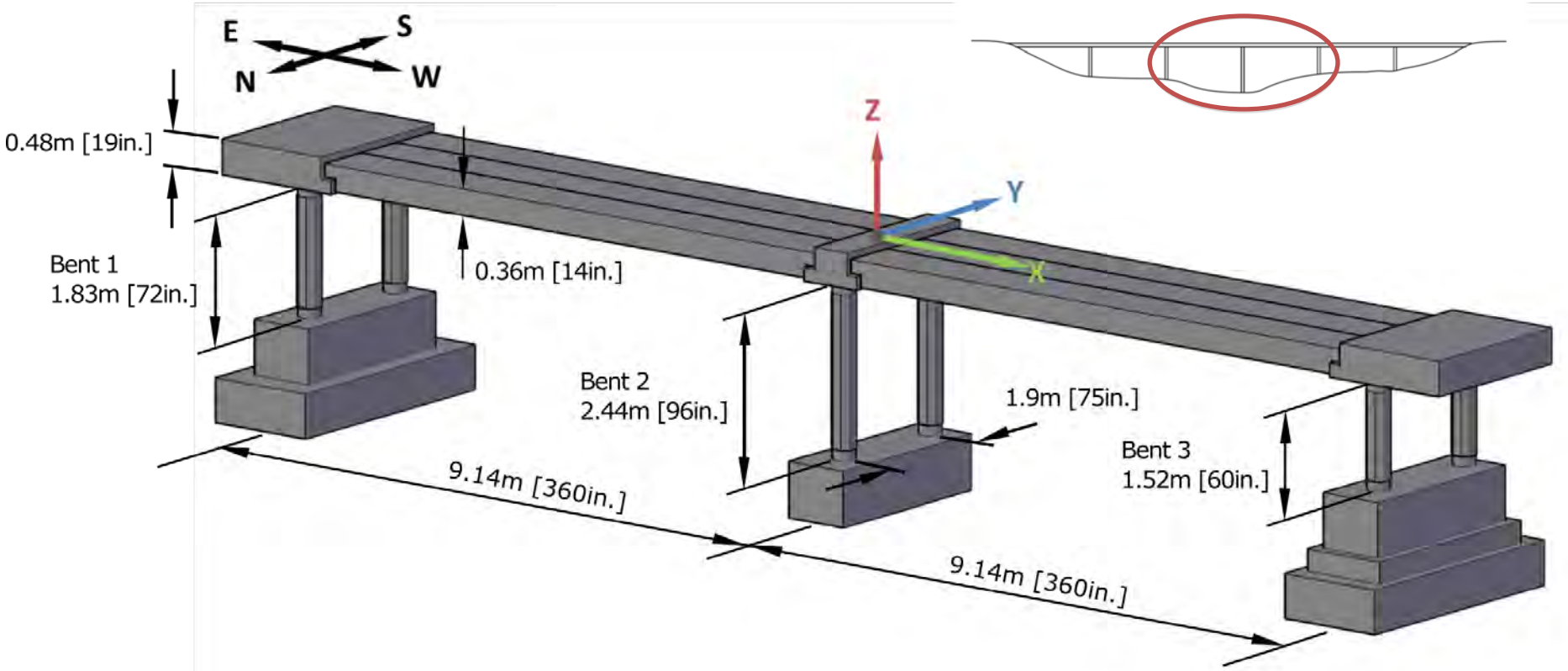
Cap Beam Rocking Connection



Shake Table Test

Specimen Dimensions

- Two-span portion of a typical bridge in the western united states supported by two column bents on drilled shafts.



2005 RC Bridge Motion 19 (220% Design Level)
1994 Northridge - Century City CC North (PGA=1.66g)

2005 RC Bridge Motion 19 (220% Design Level)
1994 Northridge - Century City CC North (PGA=1.66g)

- Bent 3 columns fully spalled, spiral fracture, bar buckling.
- Load over bent 3 was removed due to safety concerns.

2014 PreT Bridge Motion 19 (220% Design Level)
1994 Northridge - Century City CC North (PGA=1.66g)

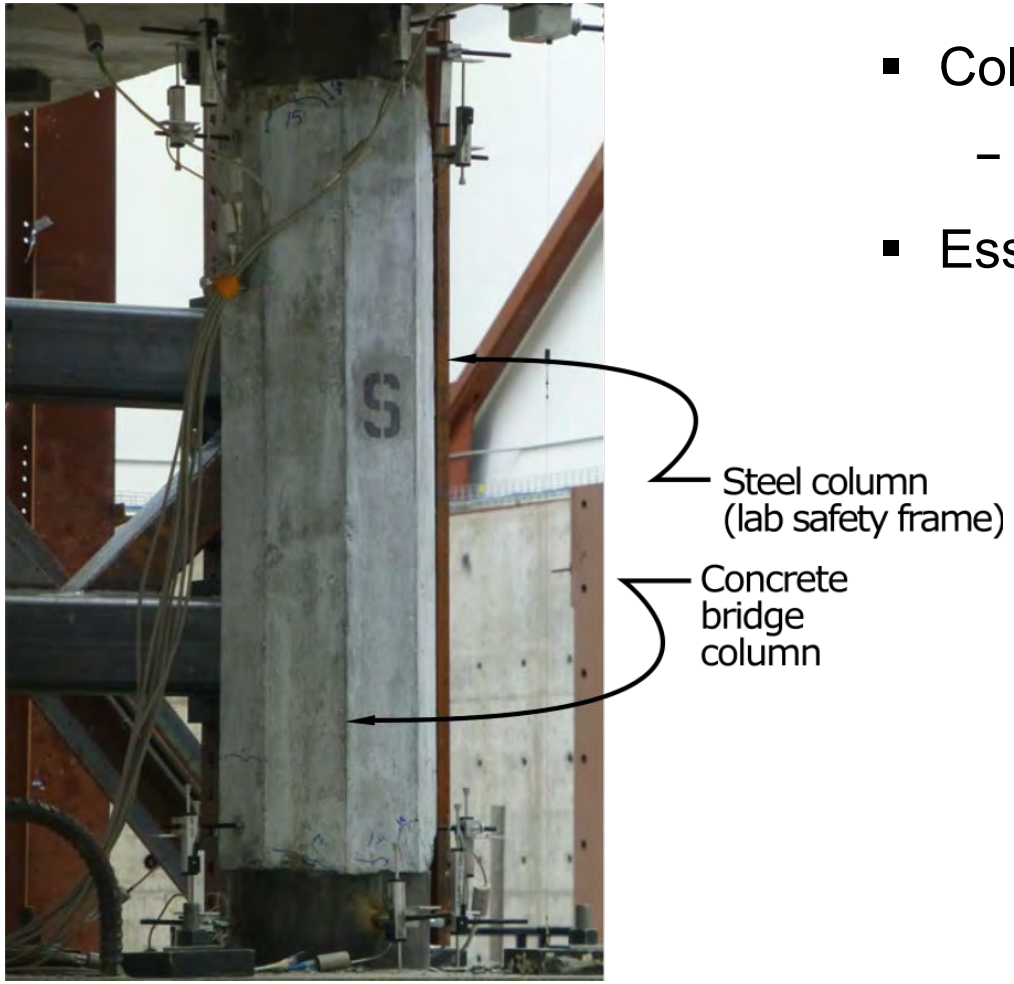
2005 RC Bridge Motion 19 (220% Design Level)
1994 Northridge - Century City CC North (PGA=1.66g)

- Hairline horizontal cracks (3 in total) minor flaking at steel tube,
- rebar fracture, bulging of steel confining jackets.

Shake Table Test → **2014 PreT Bridge Motion 21C**

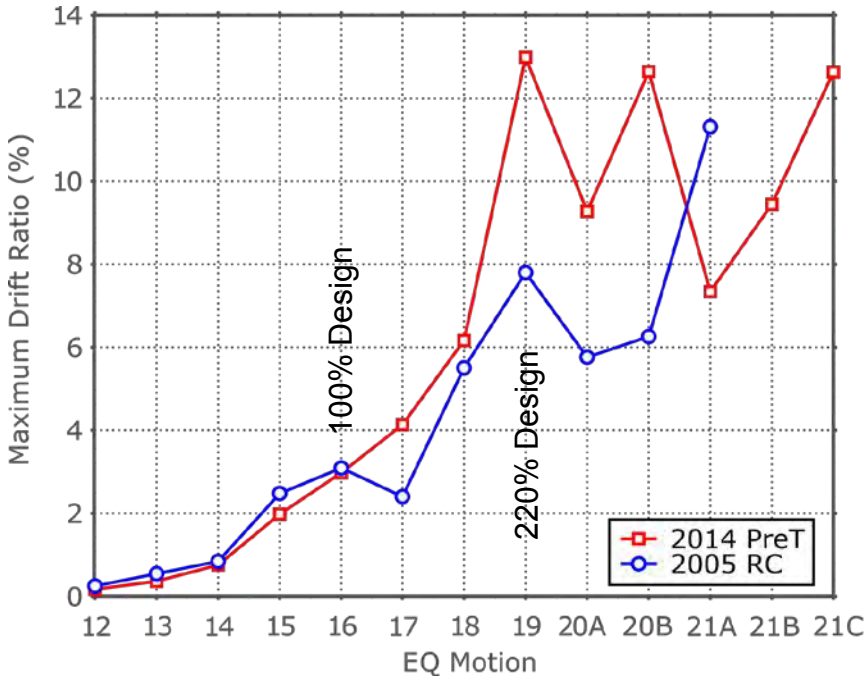
2014 PreT Bridge Motion 21C
1995 Kobe – Takatori Station (PGA=0.8g)

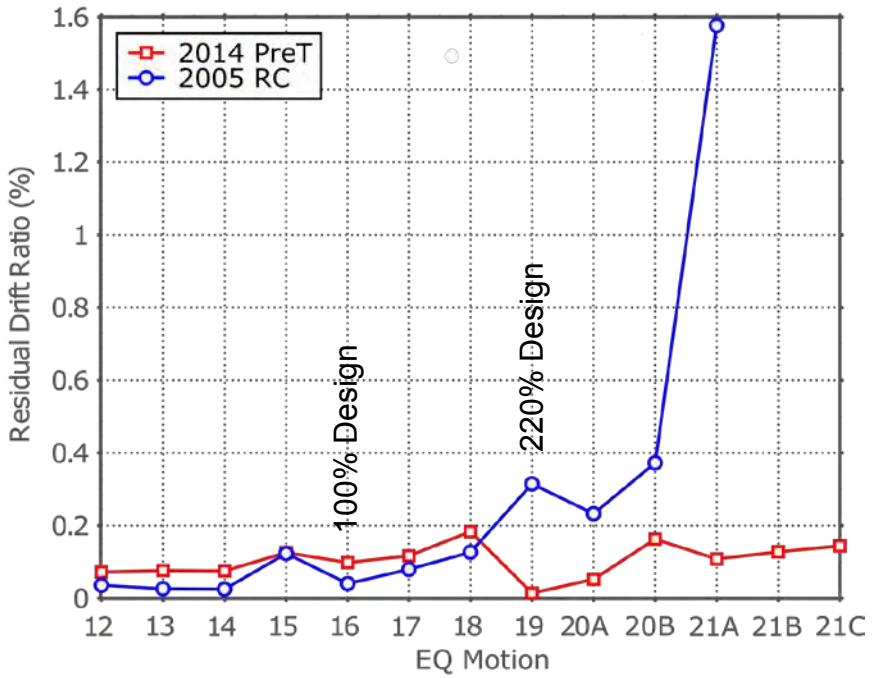
2014 PreT Bridge Motion 21C
1995 Kobe – Takatori Station (PGA=0.8g)



- Columns were vertical
  - Residual Drift < 0.2%
- Essentially no damage to concrete

Column Performance





Conclusions

Performance Goals: Accelerated Construction

- Easy, rapid assembly on site.
- Precast cap beam saves a lot of time.
- Critical components (e.g. prestressing) done in plant under good QC.
- No Post-Tensioning needed on site.
- No anchorages susceptible to corrosion.
- Uses only common construction materials.

Performance Goals: Improved Seismic Performance

- Zero residual drift even after 13% peak drift.
- Concrete damage only cosmetic even after 13% drift.
- Bridge safe for emergency vehicles after motion with pga = 1.66 g (Motion 19).
- Strand remained elastic to 3% drift, as designed. (Could go higher if desired.)
- First rebar fracture at 6 – 7% % drift, as designed. (Could go higher if desired.)

Thank You