Update on UNR ABC Seismic Research–Couplers in Plastic Hinges

M. Saiid Saiidi
Professor, Civil and Environmental Engineering Department
Co–Director, USDOT University Transportation Center–ABC

NCHRP–IDEA
Caltrans
DEPARTMENT OF TRANSPORTATION
UNITED STATES OF AMERICA
NEES
University of Nevada, Reno
NSF
Topics

Ongoing research on seismic response of ABC elements, connections, and systems
  ◦ 4–span composite bridge
  ◦ Precast bents w/ pipe pin footing connections
  ◦ 2–span bridge w/ pretensioned columns
  ◦ Precast bents w/ pinned pile connections
  ◦ Replaceable precast plastic hinges
  ◦ Precast deck connections
  ◦ UTC–ABC seismic (covered in next presentation)

Couplers in plastic hinges
  ◦ CIP columns w/ couplers
  ◦ Precast columns w/ conventional or advanced materials

(project websites available–contact Saiidi@unr.edu)
NSF-NEES 4-Span FRP Bridge

4 New Details

Pipe pins

Pl: Saiidi
Co-Pl: Mirmiran

- Concrete filled tube precast columns
- Post-tensioned segmental columns
- Concrete filled tube cast-in-place columns
Precast Pier
Precast bents w/ pipe pin footing connections

Pl: Sadiid
Lateral Force–Displacement Response
2-span bridge w/ pretensioned columns UW and UNR
PI: Stanton Co–PI: Eberhardt, Sanders

Precast Columns, Cap Beams and Girders
Unbonded Pretensioned Columns
Confined Rocking Interface
“Socket” Footing Connection
Minimal damage at 6% drift.

Connection to Spread Footing

Sub-assembly tests at UW
2-Span bridge tests at UNR–July 2014

Connection to Cap Beam
Precast bents w/ pinned pile connections

Bent w/ Pipe-pin (BPSA)

Bent w/ Rebar-pin (BRSA)
Pipe-pin Modes of Failure

Concrete break out failure under shear force
Shake Table Test – Fall 2014
Objectives:

Develop bridge columns that
1– Withstand strong earthquakes with no or minor damage so they are useable after earthquakes.
2– Can be disassembled and reused.

Note: 5% of CO₂ emission in the world is from cement factories.
Column Test Model
Cu–Al–Mn Bars
Two-Span DfD Bridge Model

Bent arrangement A

To be tested in Fall 2014
Objectives:
- ABC: Designed to be constructed rapidly on-site
- Innovative anchor connections between the R/C deck and bridge longitudinal girders
- Full live load performance
- Resilience to in-plane seismic force transfer
- Ability of deck replacement during bridge life-span
Couplers in Column Plastic Hinges
# Current US Code Provisions on Couplers

<table>
<thead>
<tr>
<th>Code</th>
<th>Coupler Type</th>
<th>Plastic Hinge</th>
</tr>
</thead>
<tbody>
<tr>
<td>AASHTO</td>
<td>Full Mech. Connection</td>
<td>No</td>
</tr>
<tr>
<td>Caltrans</td>
<td>Service</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Ultimate</td>
<td>No</td>
</tr>
<tr>
<td>ACI</td>
<td>Type 1</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Type 2</td>
<td>Yes</td>
</tr>
<tr>
<td>Code</td>
<td>Splice Designation</td>
<td>Stress Criterion for Spliced Bar</td>
</tr>
<tr>
<td>----------</td>
<td>--------------------</td>
<td>----------------------------------</td>
</tr>
<tr>
<td>ACI</td>
<td>Type 1</td>
<td>$1.25f_y$</td>
</tr>
<tr>
<td></td>
<td>Type 2</td>
<td>$1.0f_a$</td>
</tr>
<tr>
<td>AASHTO</td>
<td>Full-mechanical connection (FMC)</td>
<td>$1.25f_y$</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caltrans</td>
<td>Service</td>
<td>none</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ultimate</td>
<td>6% for No. 11 and larger</td>
</tr>
<tr>
<td></td>
<td></td>
<td>9% for No. 10 and smaller</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

$1” = 25.4\text{mm}$

Existing criteria are not directly related to seismic performance.
Common Couplers

Long

- Shear-Screw (SS)
- Grouted Sleeve (GS)
- Swaged (SW)

Short

- Tapered Thread (TT)
- Upset Headed (UH)
- Straight Thread (ST)

- Hybrid Grouted Sleeve (HG)
- Mechanically Deformed Steel Sleeve
- Male Threaded Steel Collar
- Mild Steel Shim (if needed)
- Female Threaded Steel Collar
- Bar Stop
- Torque-Controlled Screws

- Grout Inlet
- Grout Outlet
- Ductile Cast Iron Sleeve
- Tapered Threads
- Tapered Sockets
- Threaded Section
- Position Lock Ring
- Threaded Coupler

- Discrete Force-Transfer - Mechanism
- Gradual
CIP columns w/ couplers:
Threaded couplers
steel/shape memory alloy (SMA)

Straight Thread (ST)
CIP columns w/ shear screw couplers steel and SMA
Column repair w/shear screw couplers
(UNR/MS&T/UH Saiidi/Sneed/Belarbi)
Column repair swaged couplers (UNR/MS&T/UH Saiidi/Sneed/Belarbi)
Couplers for ABC Columns

Upset Headed (UH) Ultimate coupler

Grouted Sleeve (GS)

Service Coupler
Connection Details – HC Model w/ Mild Steel
Connection Details – HC Model w/ SMA Bars and ECC

Footing
Connection Details – GC Models
5% Drift

CIP  HCNP  HCS  GCNP
Damage at Failure

| CIP 10% Drift | HCNP 10% Drift | HCS 10% Drift | GCNP 6% Drift |
Force–Displacement Responses

- CIP
- HCNP
- GCNP

Drift [%] vs. Force [kN] and Force [kip]

Base Shear (kips) vs. Drift (%)
Plastic Hinge Behavior

CIP

HCNP

GCNP

Footing

Column

Headed Coupler Device

Grouted Coupler Device
Observations on GCNP
- Drift capacity of 6% may be sufficient in many applications
  - But GCNP capacity = 6% < CIP capacity = 10%

Shift plastic hinge by 0.5D to improve drift capacity using pedestals (D = column diameter)
- Grouted ducts in precast pedestal
- Debonded bars in CIP pedestal
2 Column Models w/ GC and Pedestals

- Precast pedestal w/ grouted ducts (GCPP)
- CIP pedestal w/ debonded bars (GCDP)
GCPP
at 6% drift (failure)

GCDP
at 8% drift (failure)
Observations:

- Current AASHTO/Caltrans ban on couplers in plastic hinges in SDC C and D should be re-visited.

- Columns w/ headed couplers performed well.

- Columns w/ grouted couplers performed reasonably well with a drift capacity of 6%.

- Drift capacity of column w/ offset grouted couplers & unbonded pedestal bars was 8% and was satisfactory.

- Grouted couplers are more constructible than HRC couplers.

- Column plastic hinge behavior is affected by coupler type.

- New acceptance criteria for plastic hinge couplers might be needed.