# Novel Materials and Concepts for ABC in Moderate and High Seismic Zones

**M. Saiid Saiidi**

**http://wolfweb.unr.edu/homepage/saiidi/**

Professor, Department of Civil and Environmental Engineering

University of Nevada, Reno

Caltrans

NEVADA DOT

NSF

NEES

U.S. Department of Transportation
Research and Innovative Technology Administration

# Research Assistants

NCHRP

Mostafa Tazarv, PhD, Post-doc

Sebastian Varela, PhD

Fatemeh Kavianipour, PhD

Brian Nakashoji, MSCE

Washington State Department of Transportation

U.S. Department of Transportation
Federal Highway Administration

University of Nevada, Reno

# Question: Why novel materials?

- ABC already presents **challenges** even with conventional concrete and steel

- **Answer:**

**Challenges = Opportunities**

**…opportunities to raise the bar.**

**>>>Improve seismic performance**

## Novel Materials in Earthquake Design

- Performance **during** earthquake
- Serviceability **after** earthquake ← New

## Novel Concept in Earthquake Design

- Design for deconstruction (DfD)

## Target performance for standard bridges **during** earthquake: No Collapse

Not Good!

OK!

- Serviceability after earthquake:
  Minimize **permanent drift** and **damage**
- Performance-based design
- Isolated systems
- Advanced materials/details
  - Shape memory alloys
  - Ductile concrete/UHPC
  - Columns w/ built-in elastomeric pads
  - Fiber-reinforced polymers
  - Post-tensioning

## Concrete + Steel >> One Combination

**Advanced Materials/Details >> Over 40 Combinations**

**Only 8 have been proof tested (mostly for CIP construction)!**

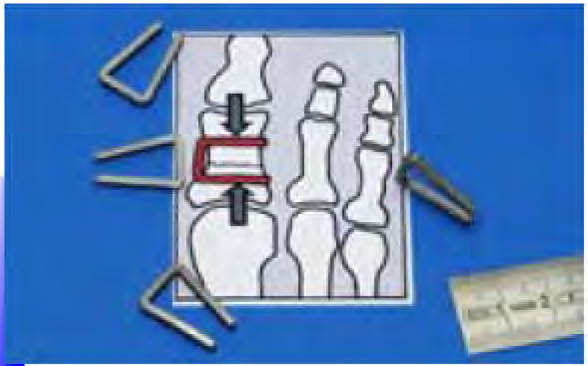
Washington State Department of Transportation
Bridge and Structures Office

Jed Bingle PE, SE
January 8, 2014

# Novel Materials (Research on ABC in high seismic zones)

- Shape memory alloys (SMA)- Nickel Titanium, Cu-based, etc.
- Engineering cementitious composites (ECC)
- Ultra-high performance concrete (UHPC)
- Rubber
- Fiber reinforced polymers (FRP)- glass, carbon, etc.; fabrics, hard shell, etc.

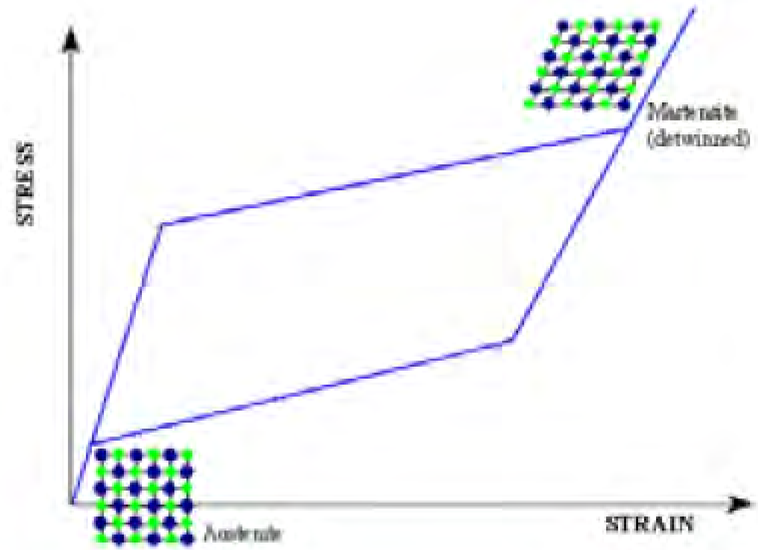
# SMA (Nickel Titanium)



**Also military applications**

# Shape Memory Alloy

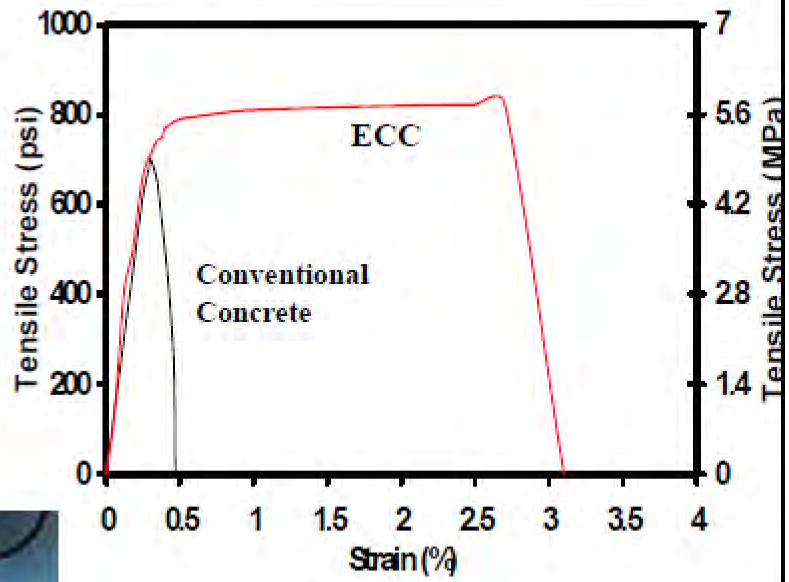
- Superelastic response
- Shape memory effects
- NiTi SMA developed in1962
- Cu-Al-Mn SMA being developed




**Superelastic SMA bars eliminate permanent drift**

# Engineered Cementitious Composites (ECC, "Ductile Concrete")

Polyvinyl Alcohol Fiber




# Ultra-High Performance Concrete (UHPC)

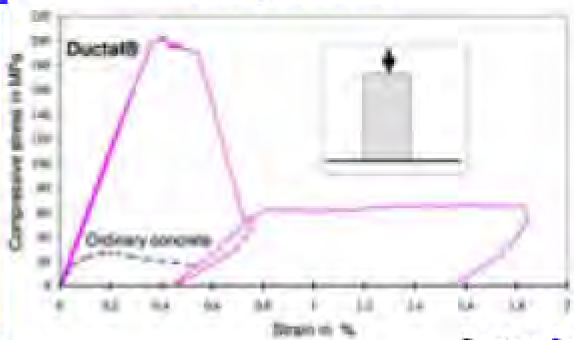
- Significantly higher compressive and tensile ductility
- Five times higher compressive and tensile strength

} Compared to Conventional Concrete

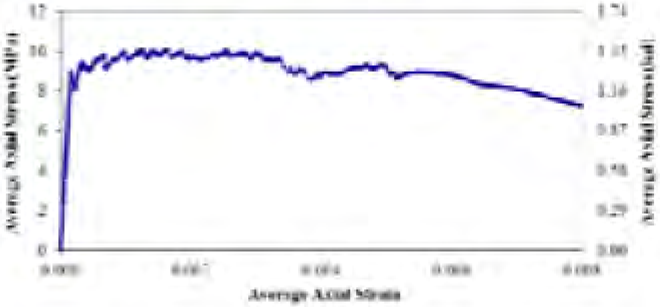
(a) Steel Fibers

(b) UHPC Sample Section Cut

Compression




Tension



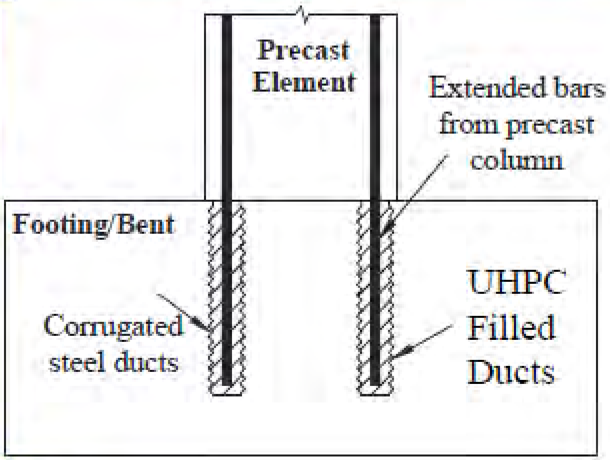


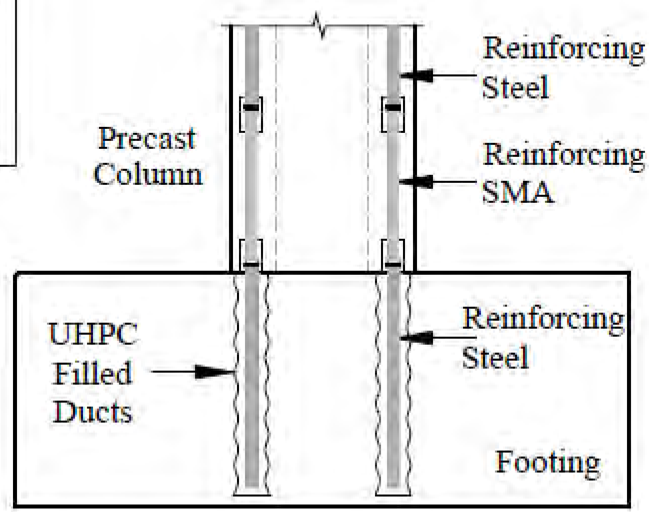

Courtesy: Lafarge.com

# UHPC-Filled Duct Column Connections

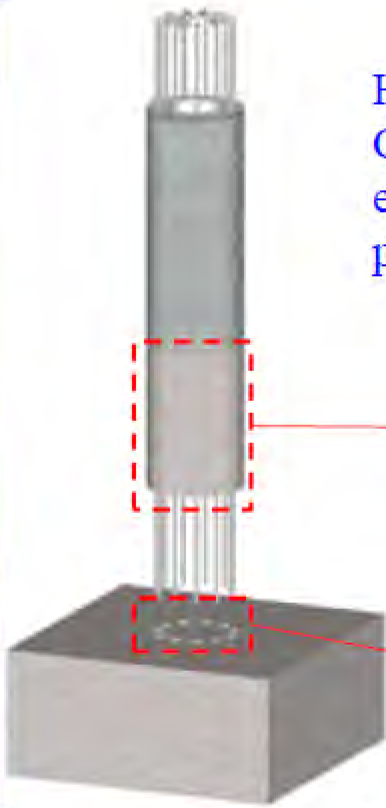
- **Two Prefabricated Column Models**
  - Conventional Materials in Plastic Hinge ("PNC")
  - SMA-ECC in Plastic Hinge ("HCS")
- **Connection to Footing**
  - UHPC-Filled Duct Connections
- **Column Geometry**
  - Half-Scale; Hollow; Filled w/ SCC after connecting
  - Height: 9 *ft* (2.74 *m*)
  - Diameter: 24 *in*. (610 *mm*)
  - 11-#8 (Ø25 *mm*) Longitudinal Bars ($\rho_l$=1.92%)
  - Spiral, $\rho_s$=1.03%
  - Axial Load Index: 10% (200-kip axial load on specimens)

# Column ABC Connections w/ UHPC Grouted Ducts



# Low-Damage Precast Column w/ UHPC Grouted Ducts



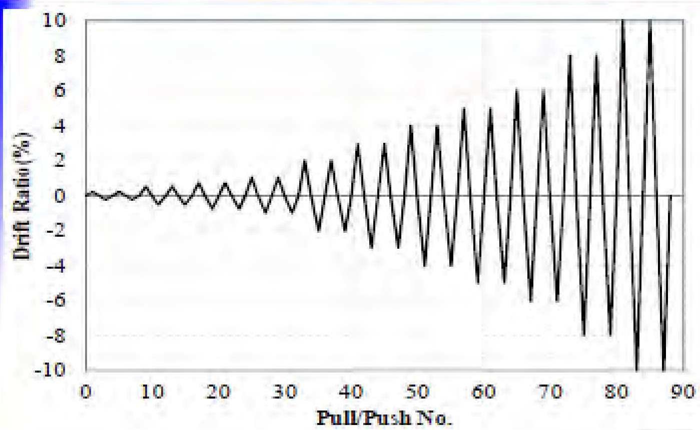
Headed Coupler Columns tested by Haber et al. (2014), emulative performance

SMA-Reinforced ECC section

UHPC-Filled Duct Connection

# UHPC-Filled Duct Columns Connections - Construction

# UHPC-Filled Duct Column Connection Tests

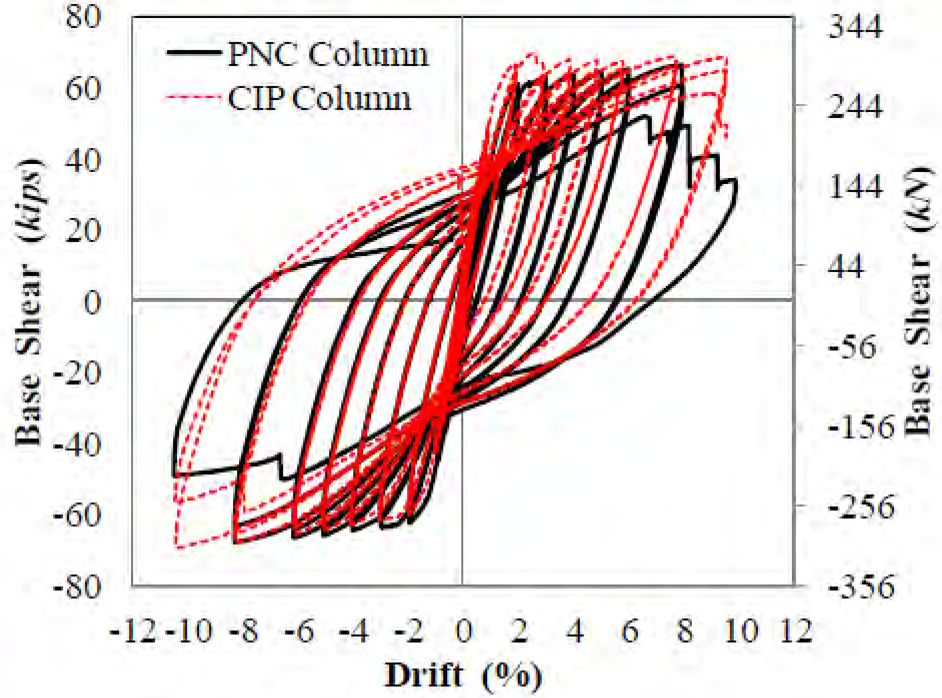



- Cantilever Configuration
- Displacement-Control Loads

Drift= Head Displacement/ Height

# UHPC-Filled Duct Column Connections - Performance

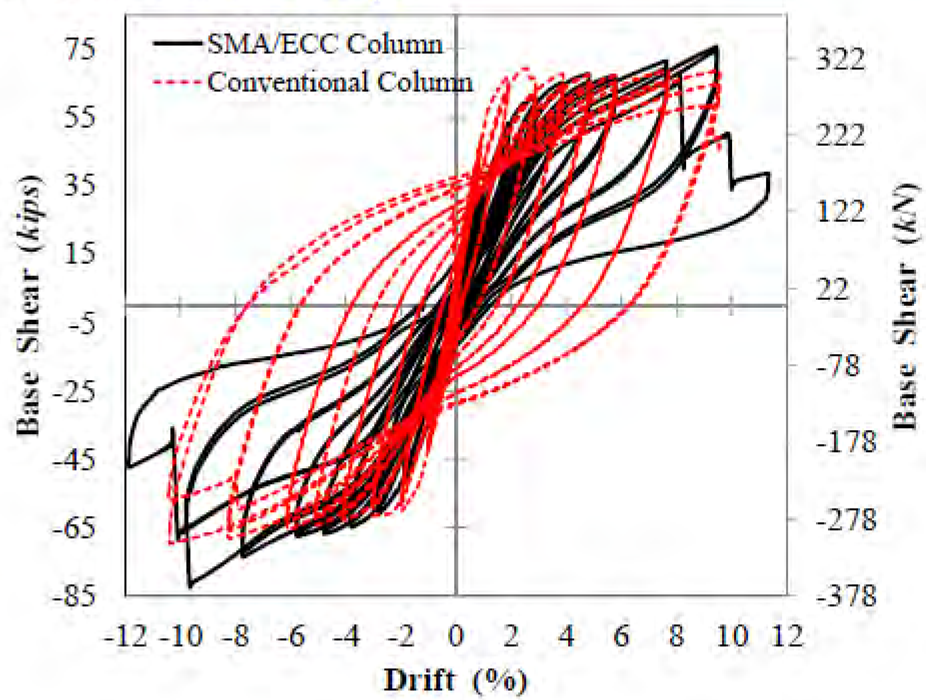
PNC vs. reference Cast-in-Place Model (CIP)



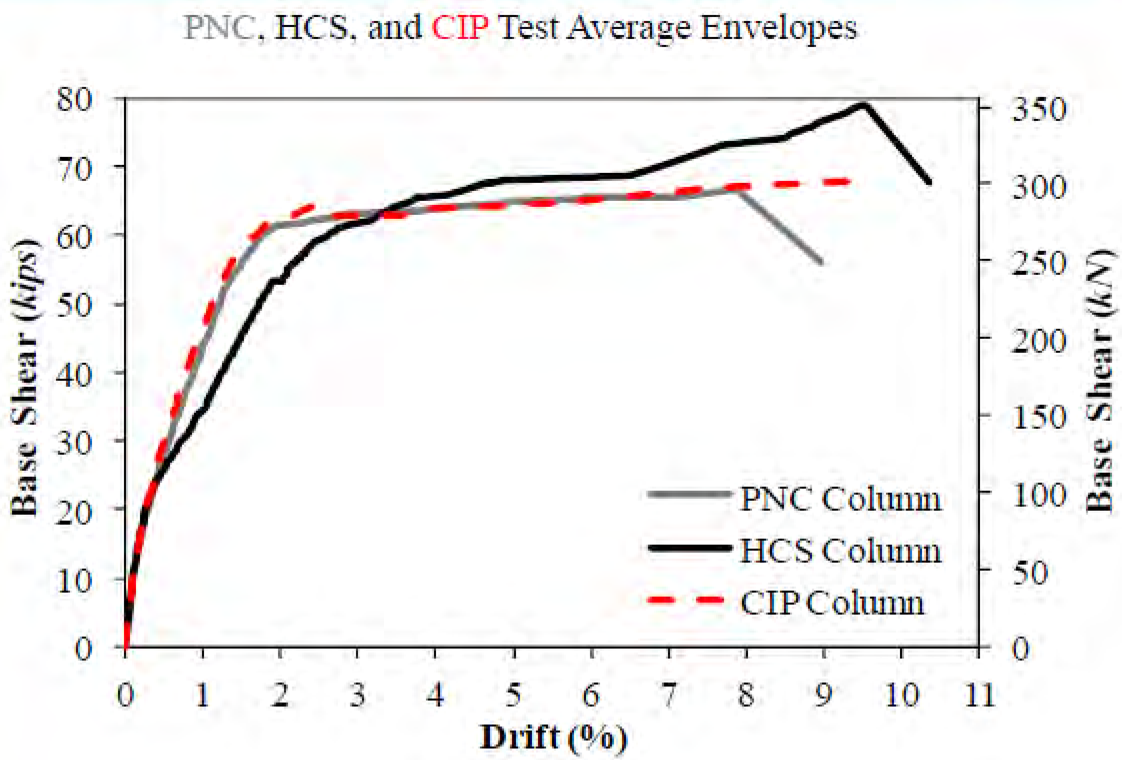

9% Drift Capacity

# Low-Damage Precast Column

Test Results: *Force-Drift*



# UHPC-Filled Duct Column Connections- Test Results



# UHPC-Filled Duct Connections

Columns w/ UHPC-Filled Duct Connections

PNC HCS CIP

@ 10% Drift Ratio

# UHPC-Filled Duct Connections

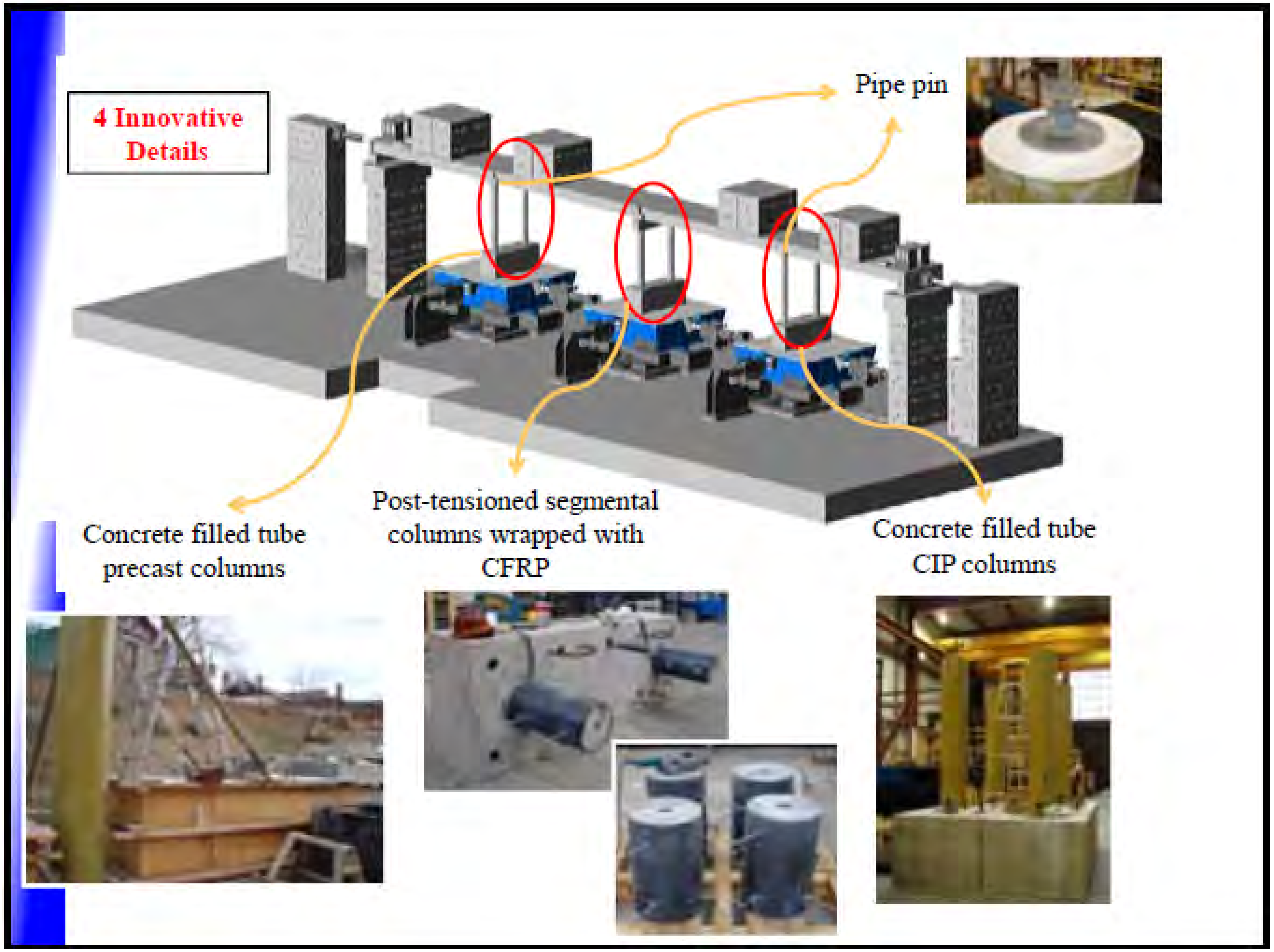
**After the test to 12% drift**

**Columns w/ UHPC-Filled Duct Connections**


**PNC**


**HCS**

**No damage of UHPC-filled duct connections even after 12% drift cycles**


4 Innovative Details
Pipe pin
Concrete filled tube precast columns
Post-tensioned segmental columns wrapped with CFRP
Concrete filled tube CIP columns

# Precast Pier

# Segmental Pier

# Design for Deconstruction (DfD)

**Objectives:**

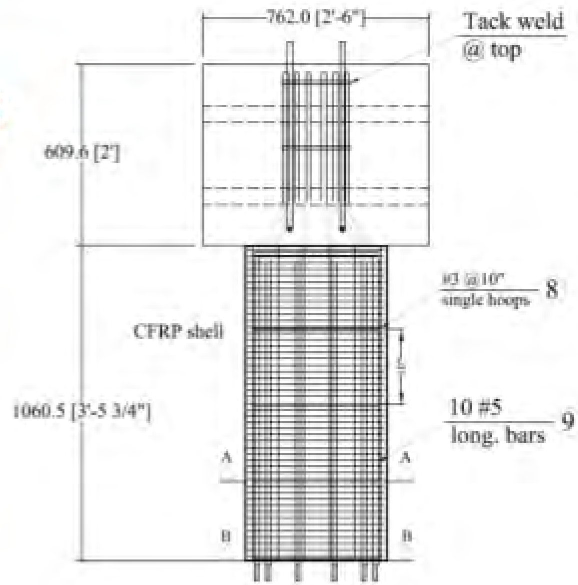
**Develop structural members that**
**1- Withstand strong earthquakes with no or minor damage so they are useable after earthquakes.**
**2- Can be disassembled and reused.**

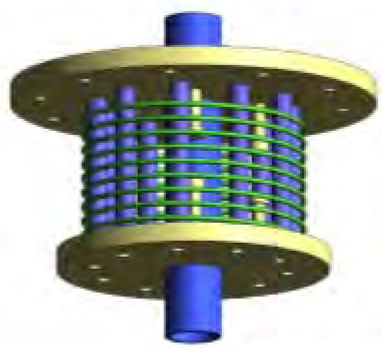
**Note: 5% of $CO_2$ emission in the world is from cement factories.**

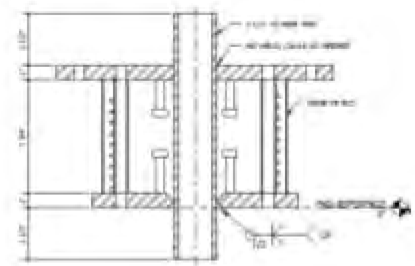
# ECC; NiTi; Copper Based SMA; Rubber; CFRP Shell
# (Patent Filed)



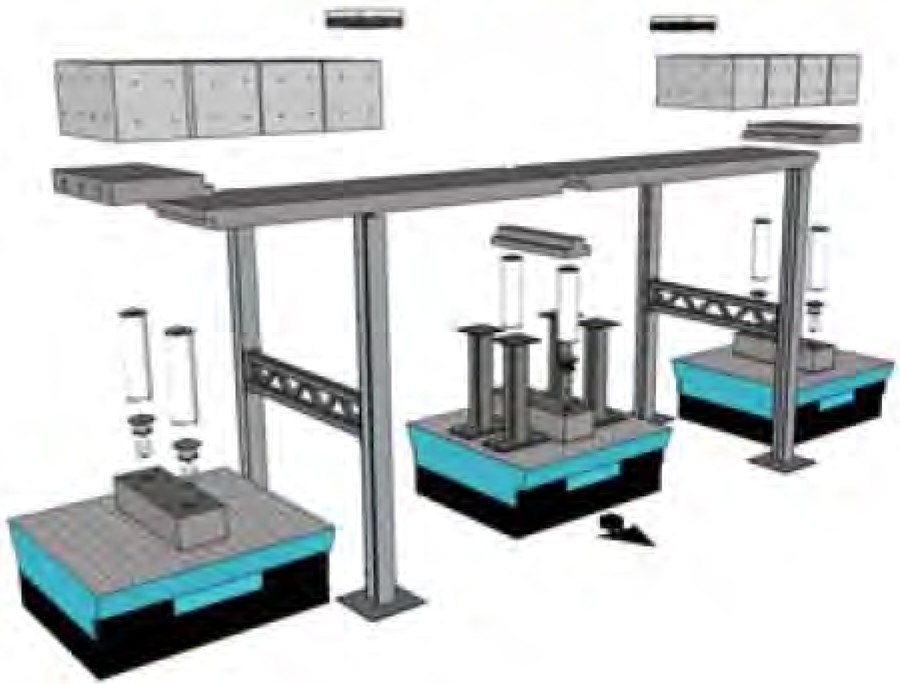
# Column Test Models





# Two-Span DFD Bridge




Bent 3

## Summary

- ABC provides opportunity to embrace innovation.
- With novel materials and details ABC can go beyond emulative seismic connections.
- Permanent drift and plastic hinge damage can be reduced substantially with innovative materials and details.
- The DfD bridge takes ABC yet another step further. With sufficient research and deployment we may recycle obsolete bridges in the future.