Seismic Performance of Bridge Systems with Innovative Design- Deployment of Research

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Importance of Innovative Materials

- **Primary Seismic Performance Objective:**

Collapse Prevention

"Failure"

"Success"

Collapse prevention– Necessary; not Sufficient

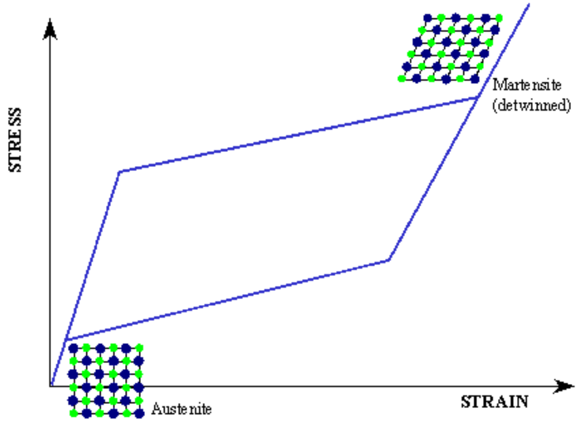
- **Bridge closures**
  - **Limited access; may or may not allow even emergency response vehicles**
- **Extensive Repairs**
  - **Disrupts public transportation**
  - **Major economic impact**

Improving Seismic Design

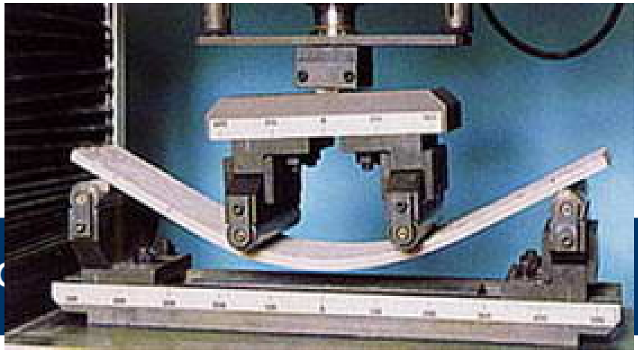
- **Performance Based Design**
  - **Keep bridges operational**
  - **Minimize repair need**
    - **Minimize residual drift**
    - **Reduce damage to plastic hinges**
  - **May use a number of different approaches**
    - **Base isolation**
    - **Advanced materials (not familiar to civil engineering structures)**

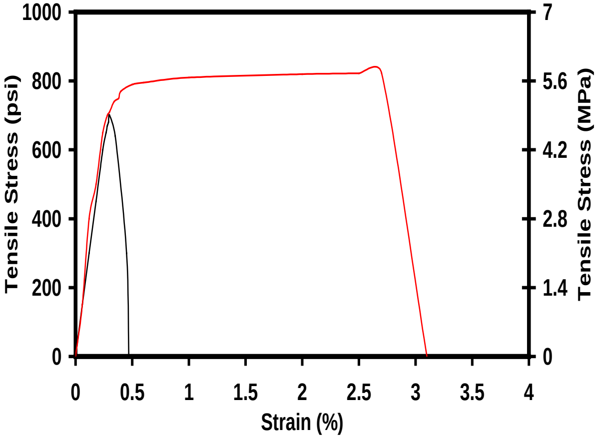
Use of Innovative Materials

- **Superelastic Nickel-Titanium Shape Memory Alloy (SMA) Bars**
  - **Reduce residual displacements**



- **Engineered Cementitious Composites (ECC)**
  - **Reduce damage to hinge**

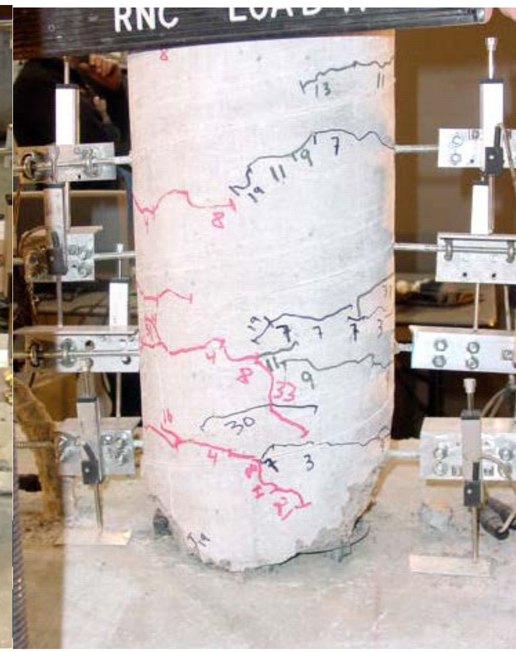


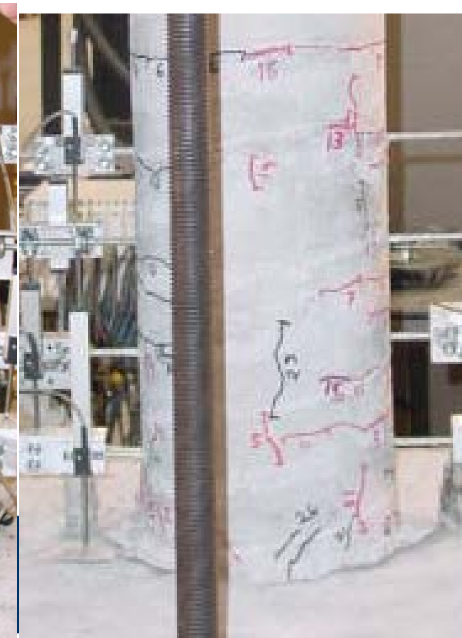


10% Drift

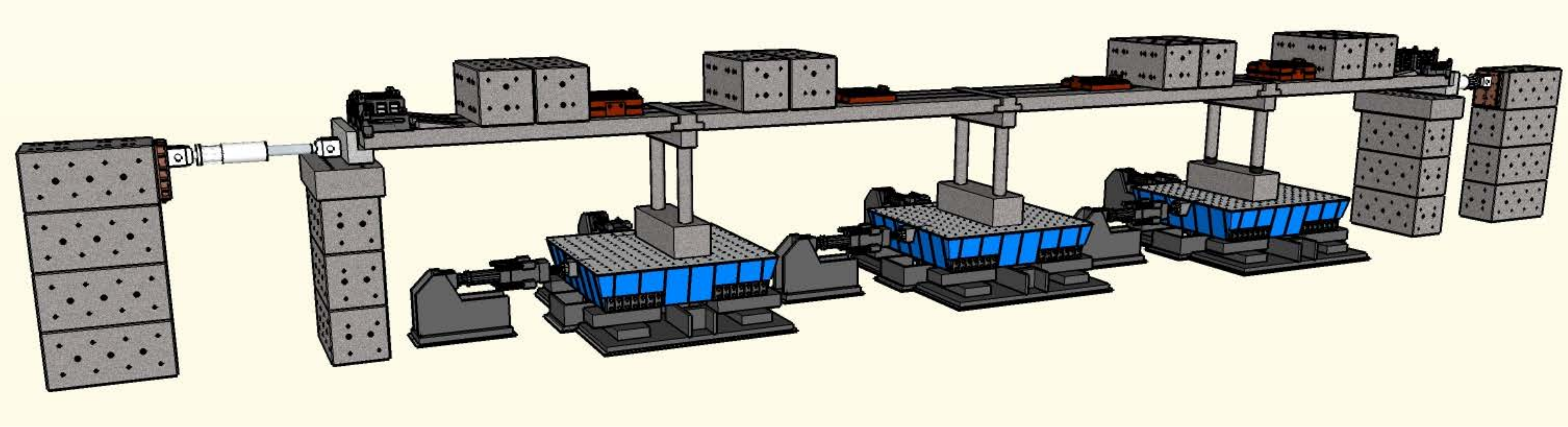
Conventional **SMA/Conc.** **SMA/ECC**

Residual After 10% Drift





4-Span Bridge with Innovative Materials



- ¼ Scale, 4 Span Bridge, Total Length=110ft
- Innovative Materials in Bottom Plastic Hinges
- Conventional RC in Top Plastic Hinges

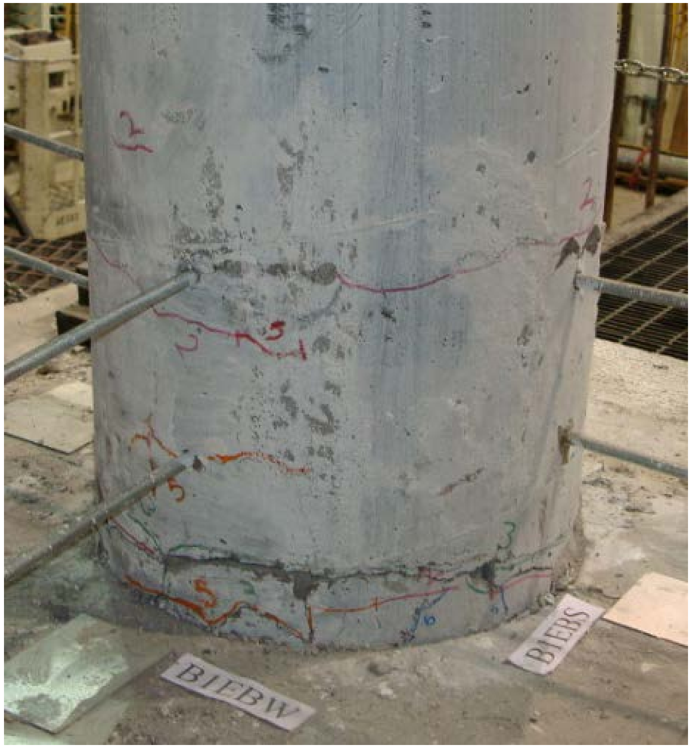
NSF

NEES

Results after Final Motion

Top Conventional RC Hinge

Bottom SMA/ECC Hinge



Experimental Studies for Seattle SR-99 Piers

- **Three - 0.3 Scale Columns**
  - **2 Incorporating SMA and ECC**
  - **1 Conventional RC**
- **62 in clear height**
- **18 in x 18 in cross section**
- **Reversed cyclic loading**

Objectives: Determine

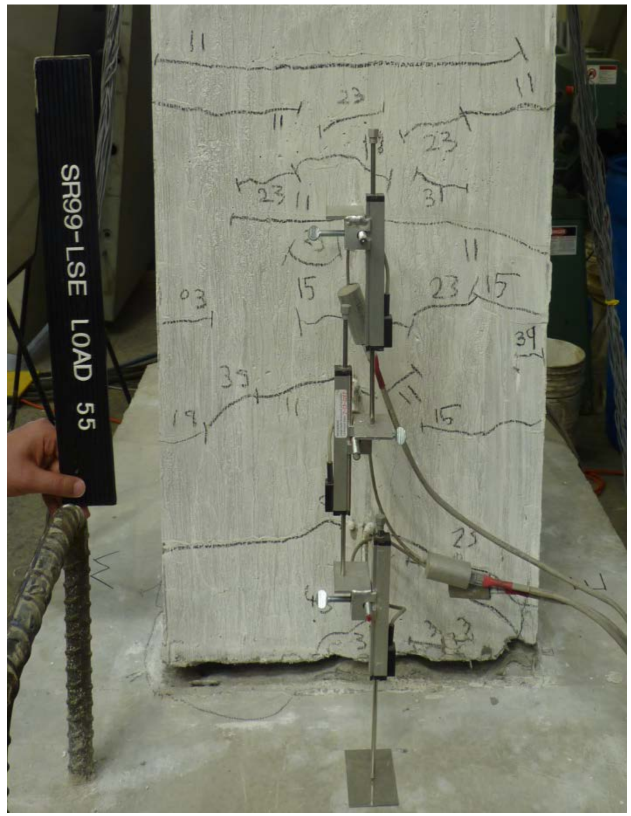
- Effectiveness of HRC couplers for SMA bars
- Self-centering characteristics of column models
- Damage to the plastic hinge area
- Effects of shortening SMA bar length
- Adequacy and refinement of analytical models

Test Models

- **SR99-RC: Conventional RC Reference Model**
- **SR99-LSE: Long SMA with ECC Column**
  - **18 in (one x col. side dim.) SMA in plastic hinge**
- **SR99-SSE: Short SMA with ECC Column**
  - **13.5 in (0.75 x col. side dim.) SMA in plastic hinge**

Damage Comparison

Damage at 6% Drift

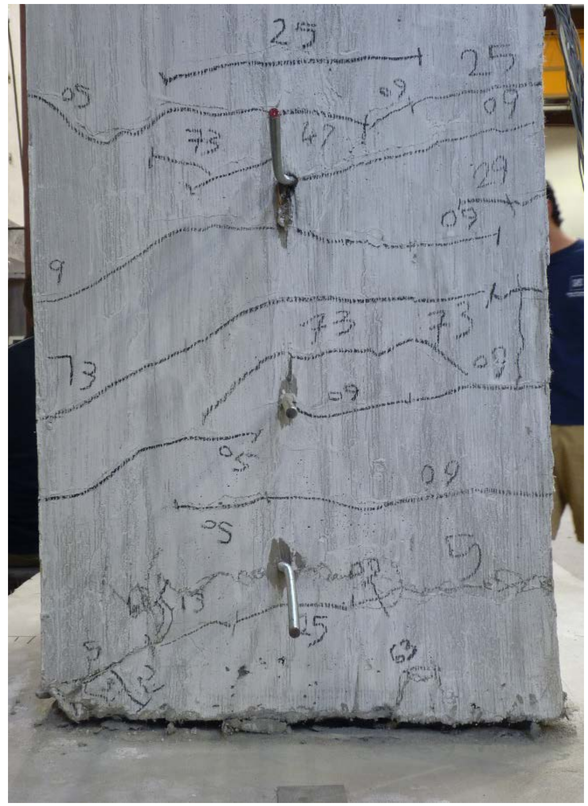
SR99-RC	SR99-LSE	SR99-SSE
 	 	

Damage Comparison

Damage at End of Testing

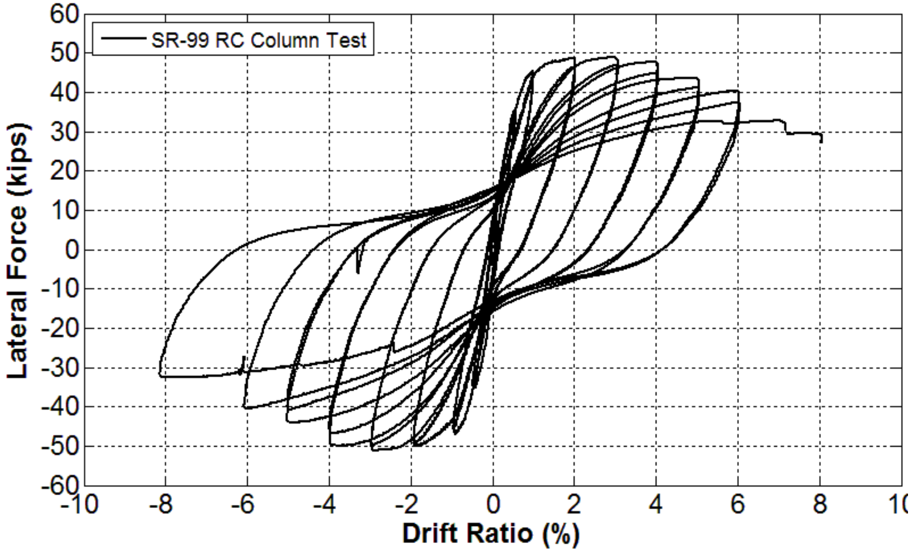
SR99-RC (8% Drift)

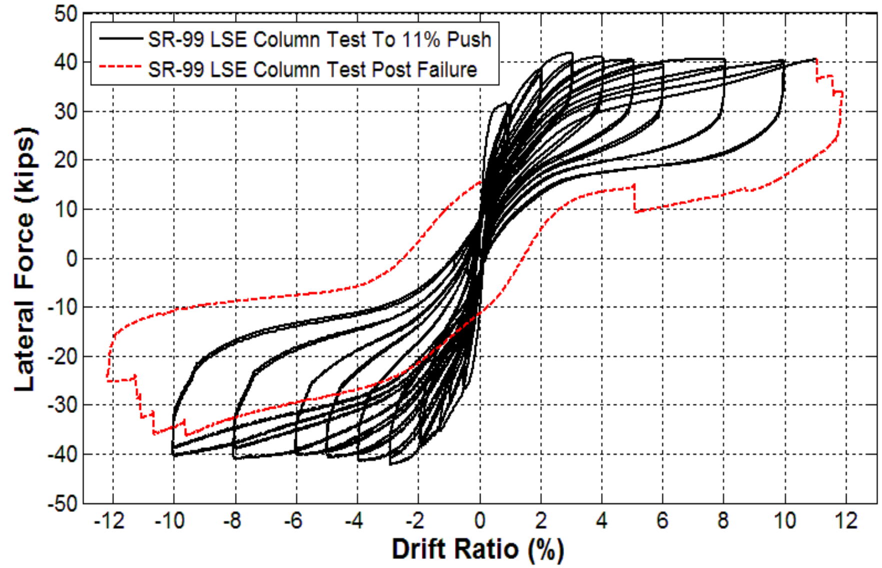
SR99-LSE (12% Drift)

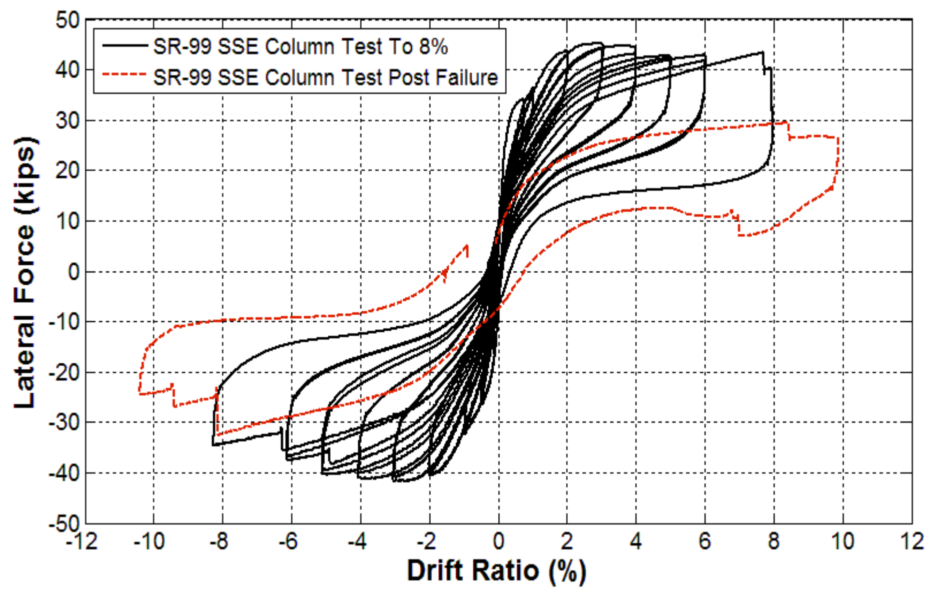


SR99-SSE (10% Drift)

SR99-RC Force-Displacement Hysteresis







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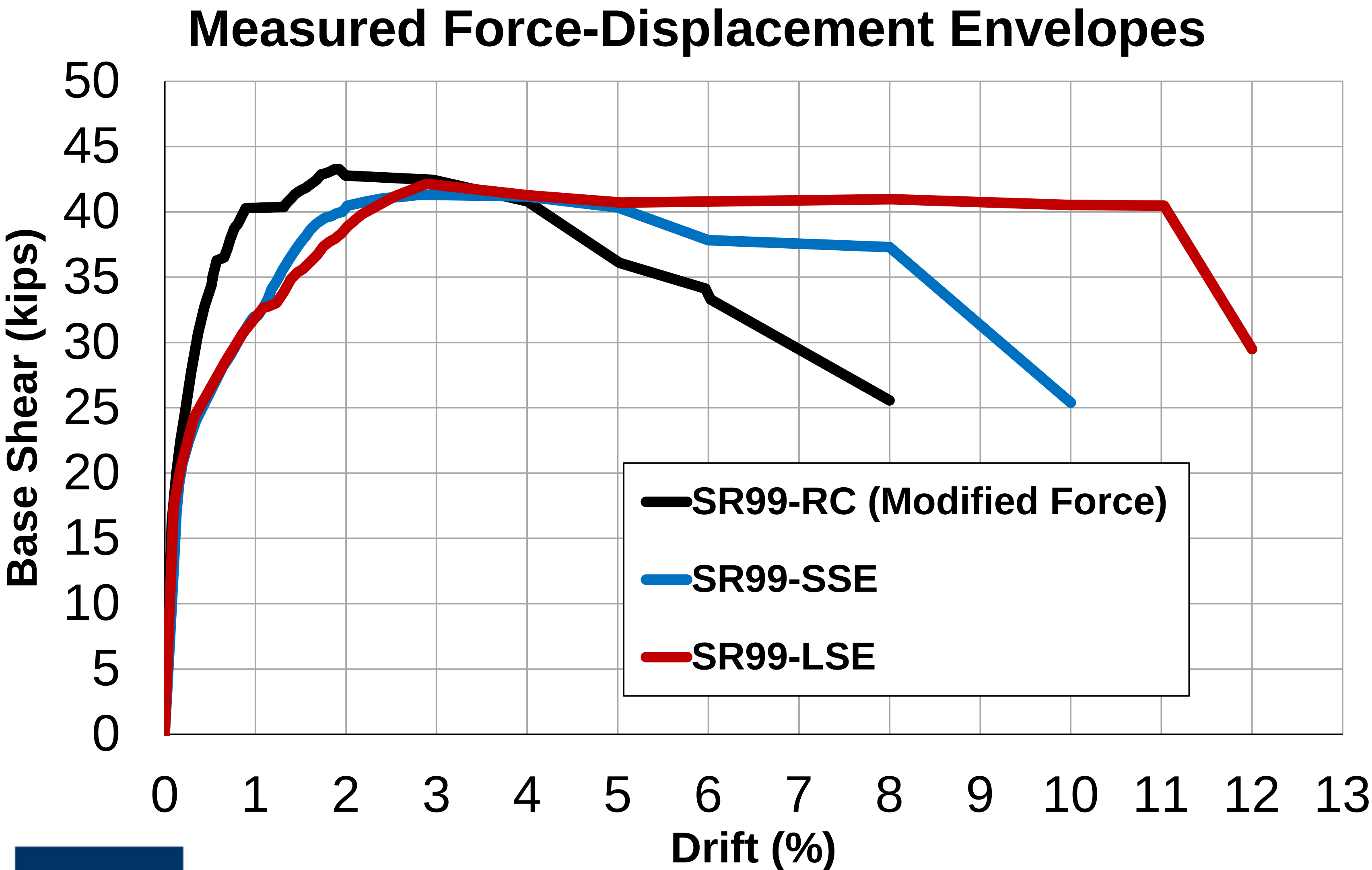
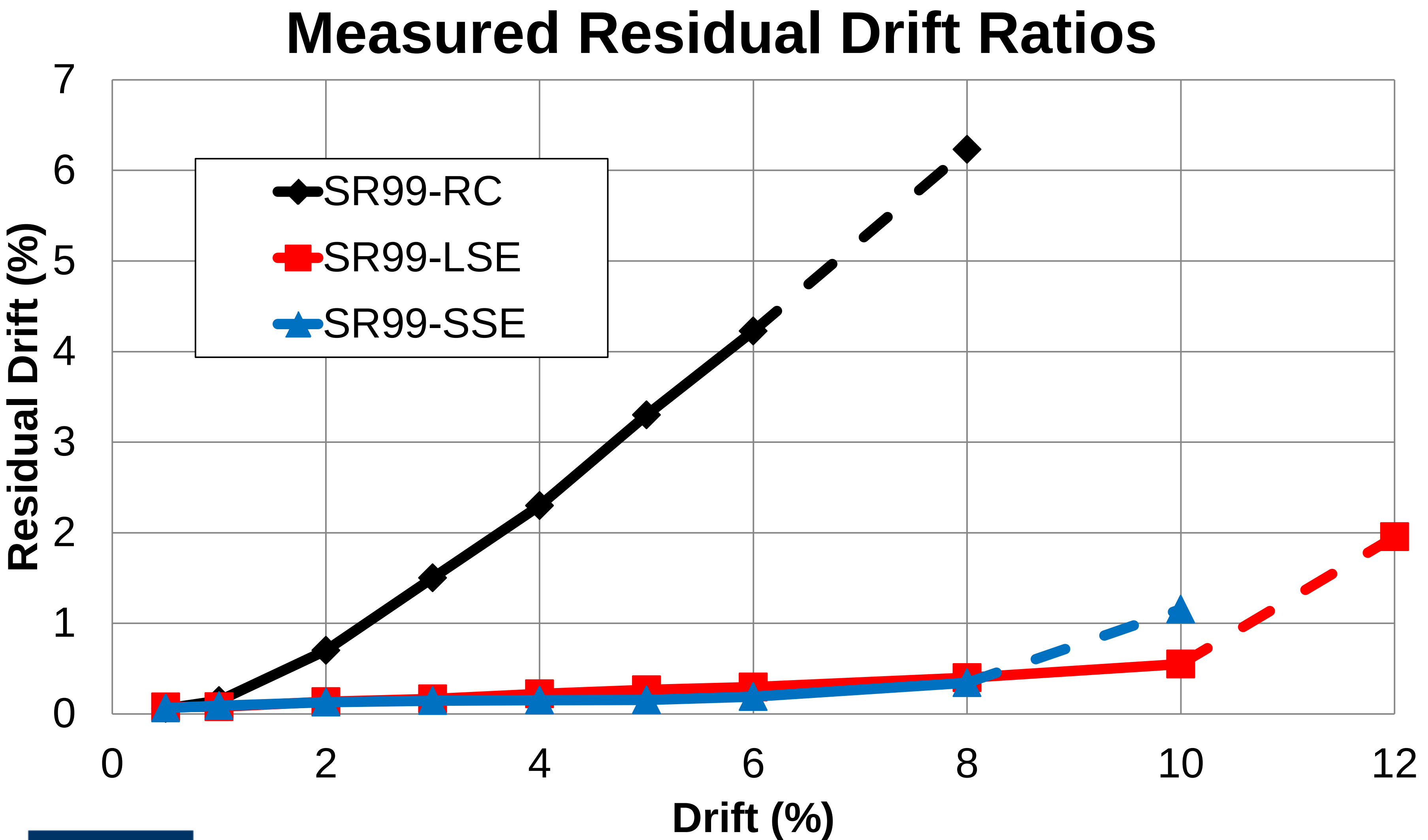
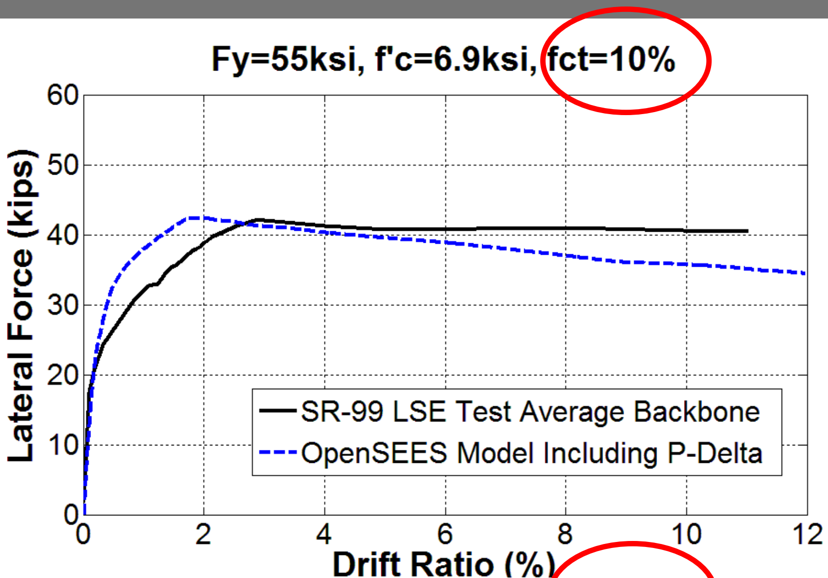
Average Force-Displacement Envelopes

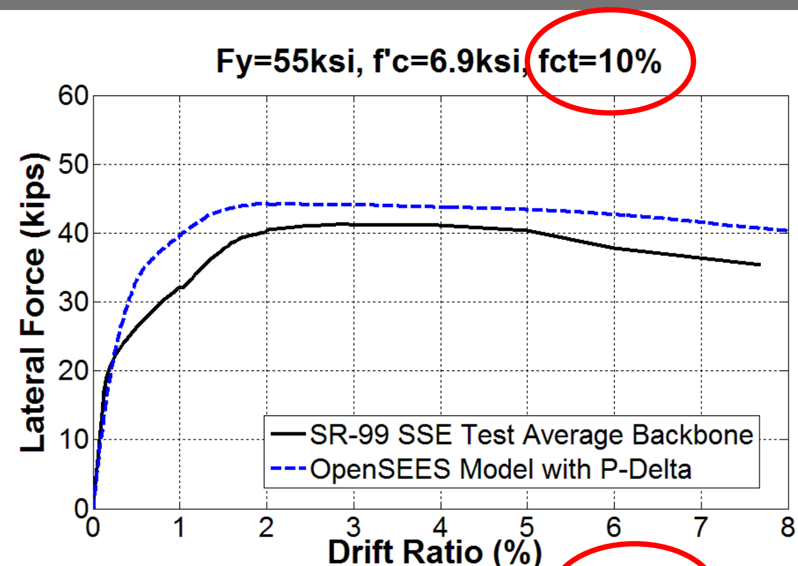


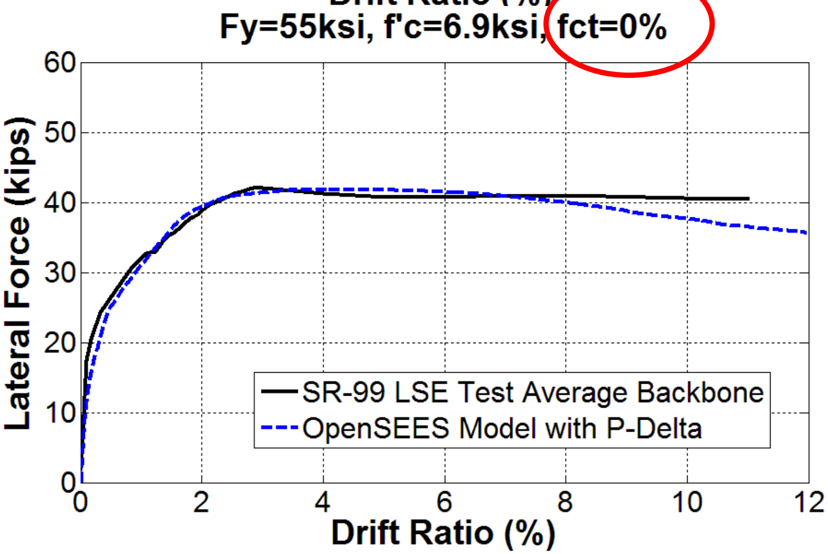
Residual Drifts

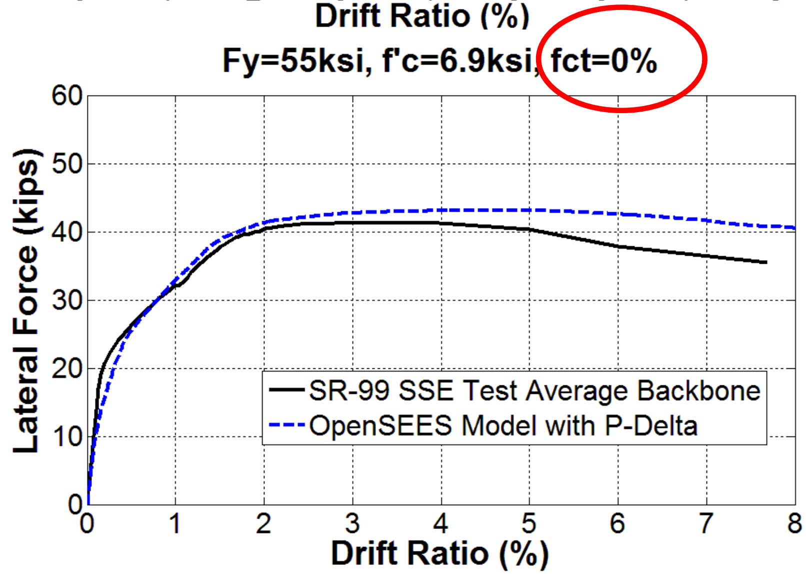


Comparison of Analytical and Experimental Results







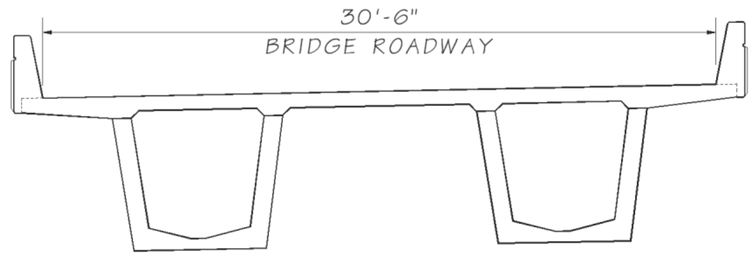


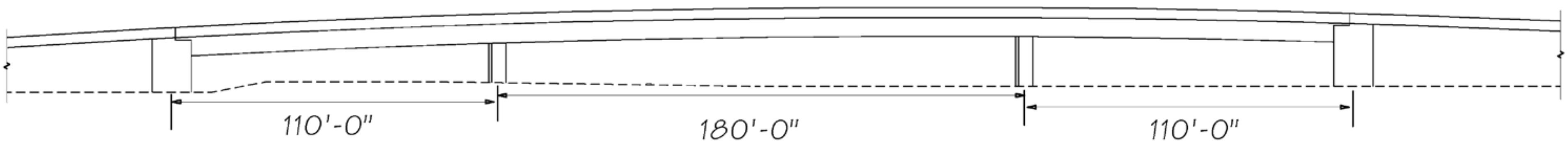
Conclusions from Research

- HRC couplers were effective
- Drift capacity of SMA/ECC columns was at least 33% higher than conventional RC column
- Average residual drift ratio of SMA/ECC columns was 80% less than RC column
- Plastic hinge damage was minimal in the SMA/ECC columns. Damage limited to a single repairable crack at the base
- Short SMA bars are recommended for use in the SR-99 Bridge
- Analytical modeling closely matched the test results when tensile strength of ECC was ignored .

Design Implementation of SMA/ECC

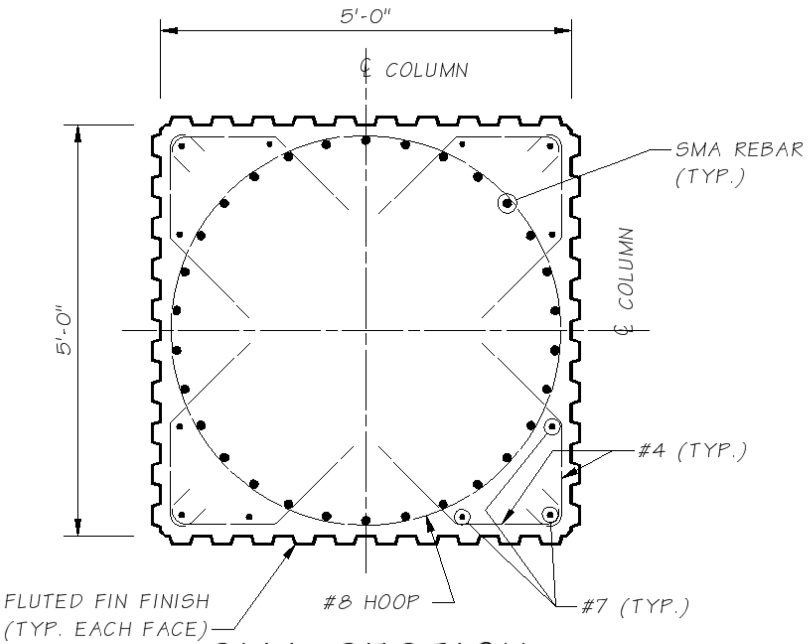
- Alaska Way Viaduct Replacement, Seattle, WA
- Three Spans (110ft; 180ft, 110ft)
- Precast Post-Tensioned Splice Tub Girder
- Single Column Piers
- Square Columns (5ft x 5ft) w/ Circular Core
- ECC Full Length of Column





Design Implementation of SMA/ECC

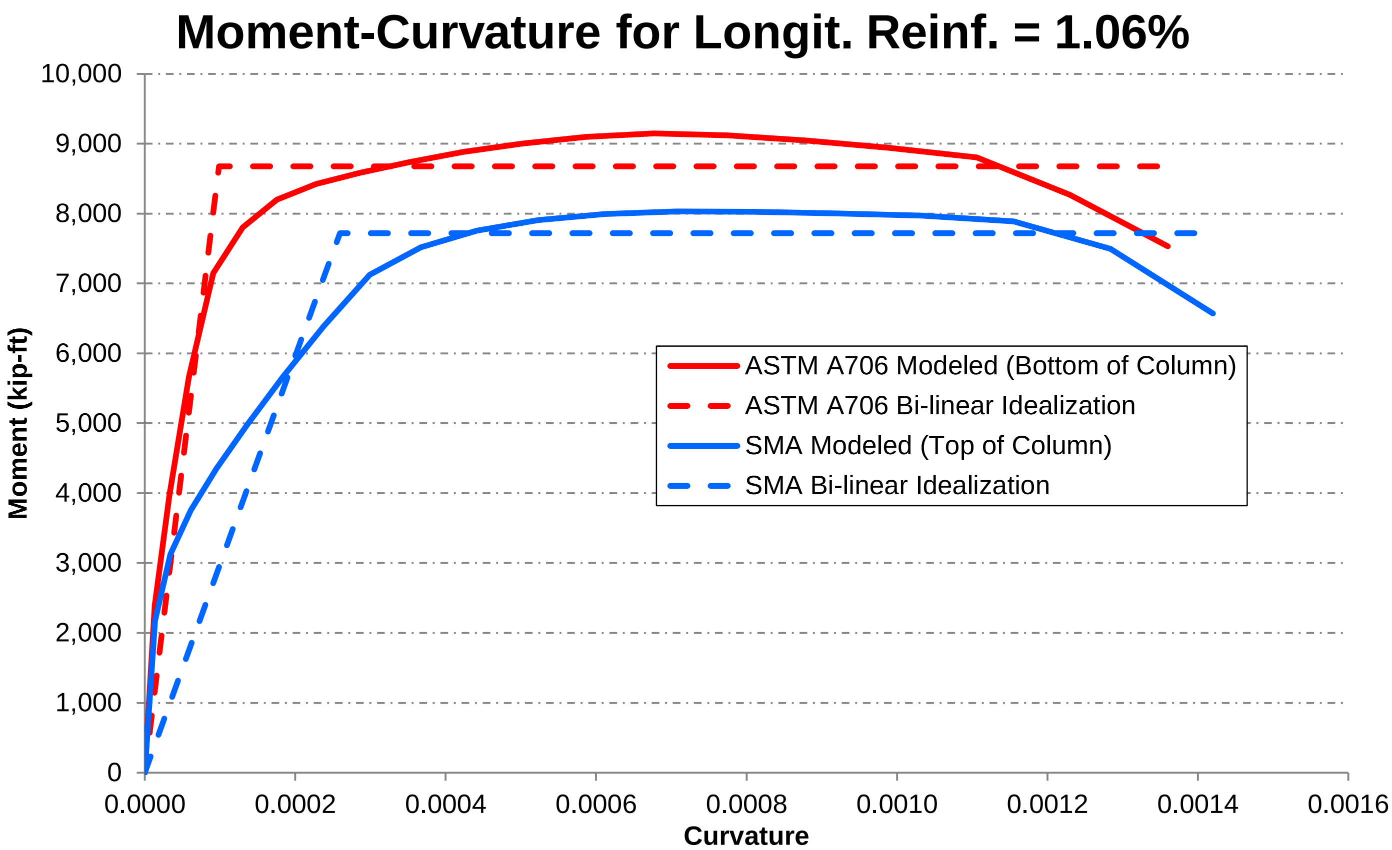
- **Limitation of research funding**
- **Shape Memory Alloy used in hinges at top of column**
- **Approximately 50 ft. liquefiable soil below existing ground line**
- **Ductility demand is greatest at the top of the column**



SMA SECTION

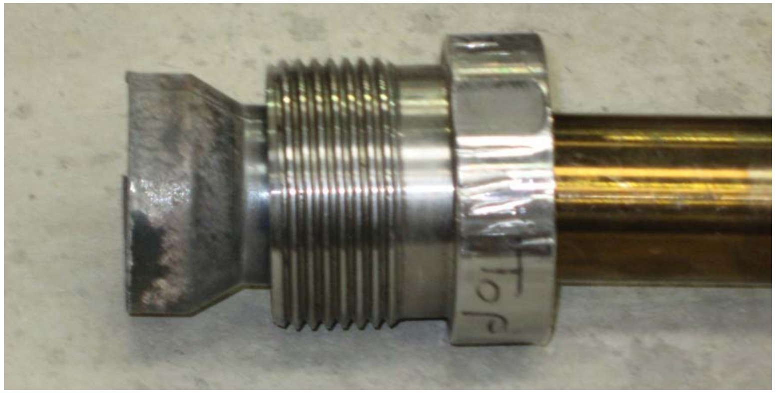
Design Implementation of SMA/ECC

- **Strength Limit state dictates design of column**
  - **Modulus of Elasticity, E_{SMA} = 5,000 ksi**

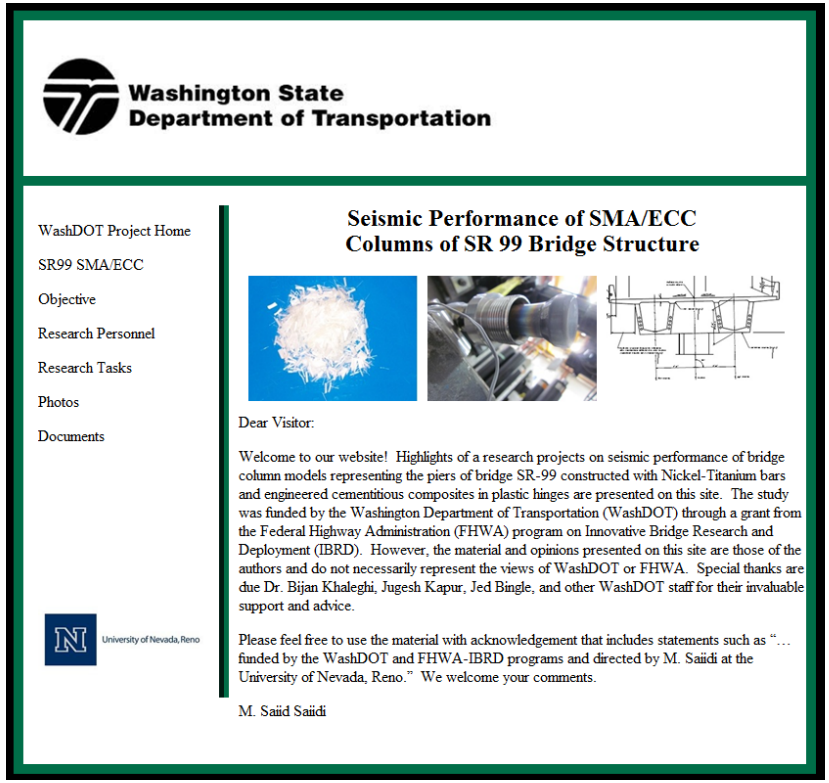


Design Implementation of SMA/ECC

- **Challenges with including SMA in a contract**
  - **Cost**
    - **ASTM A706 = $1 / lb.**
    - **SMA = $87 / lb.**
  - **Schedule – 6 month delivery, not including process to head bar for mechanical splice**
  - **Mechanical splice required in hinge region**



Project Website


Washington State
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WashDOT Project Home
SR99 SMA/ECC
Objective
Research Personnel
Research Tasks
Photos
Documents

University of Nevada, Reno

Seismic Performance of SMA/ECC Columns of SR 99 Bridge Structure

Dear Visitor:

Welcome to our website! Highlights of a research projects on seismic performance of bridge column models representing the piers of bridge SR-99 constructed with Nickel-Titanium bars and engineered cementitious composites in plastic hinges are presented on this site. The study was funded by the Washington Department of Transportation (WashDOT) through a grant from the Federal Highway Administration (FHWA) program on Innovative Bridge Research and Deployment (IBRD). However, the material and opinions presented on this site are those of the authors and do not necessarily represent the views of WashDOT or FHWA. Special thanks are due Dr. Bijan Khaleghi, Jugesh Kapur, Jed Bingle, and other WashDOT staff for their invaluable support and advice.

Please feel free to use the material with acknowledgement that includes statements such as "… funded by the WashDOT and FHWA-IBRD programs and directed by M. Saiidi at the University of Nevada, Reno." We welcome your comments.

M. Saiid Saiidi

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