Incorporating Innovative Materials into a Seattle, WA Bridge to Improve Seismic Resilience

Shape Memory Alloy and Engineered Cementitious Composite

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Portland, Oregon
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Presentation Outline

- Shape Memory Alloy (SMA) and Engineered Cementitious Composite (ECC)
  - Current Seismic Bridge Design Philosophy
  - Improving Seismic Bridge Design with Innovative Materials
  - Examples of Research Results
  - Implementation SMA and ECC into a WSDOT Bridge

Current Seismic Design Philosophy

Primary Seismic Performance Objective:

Collapse Prevention

“Failure”

Current Seismic Design Philosophy

Primary Seismic Performance Objective:

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Photo: H.G. Wilshire, U.S.G.S.

Current Seismic Design Philosophy

Primary Seismic Performance Objective:

Collapse Prevention

“Failure”

Photo: Caltrans

Current Seismic Design Philosophy

- May result in bridge closures
  - Excessive column damage
  - Excessive lateral deflection
  - Limited access; may or may not allow emergency response vehicles

- Extensive Repairs
  - Patching of spalled concrete
  - Shoring of spans
  - Replacement

- Economic Impacts
  - Disrupts public transportation
  - Major economic impact

Current Seismic Design Philosophy

Primary Seismic Performance Objective:

Collapse Prevention

“Success”

Photo: PEQIT

Current Seismic Design Philosophy

Primary Seismic Performance Objective:

Collapse Prevention

“Success”

Current Seismic Design Philosophy

Primary Seismic Performance Objective:

Collapse Prevention

Photo: MCEER

“Success”

Photo: WSDOT

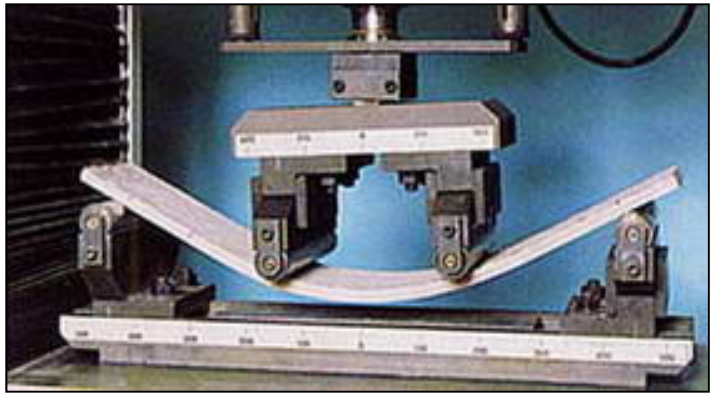
Improve Seismic Design

- Define Performance Based Design
  - Keep bridges operational
  - Minimize repair needs
    - Minimize residual drift
    - Reduce damage to the plastic hinges
    - Maintain an energy dissipation system

Innovative Materials

- Shape Memory Alloy Bars (SMA)

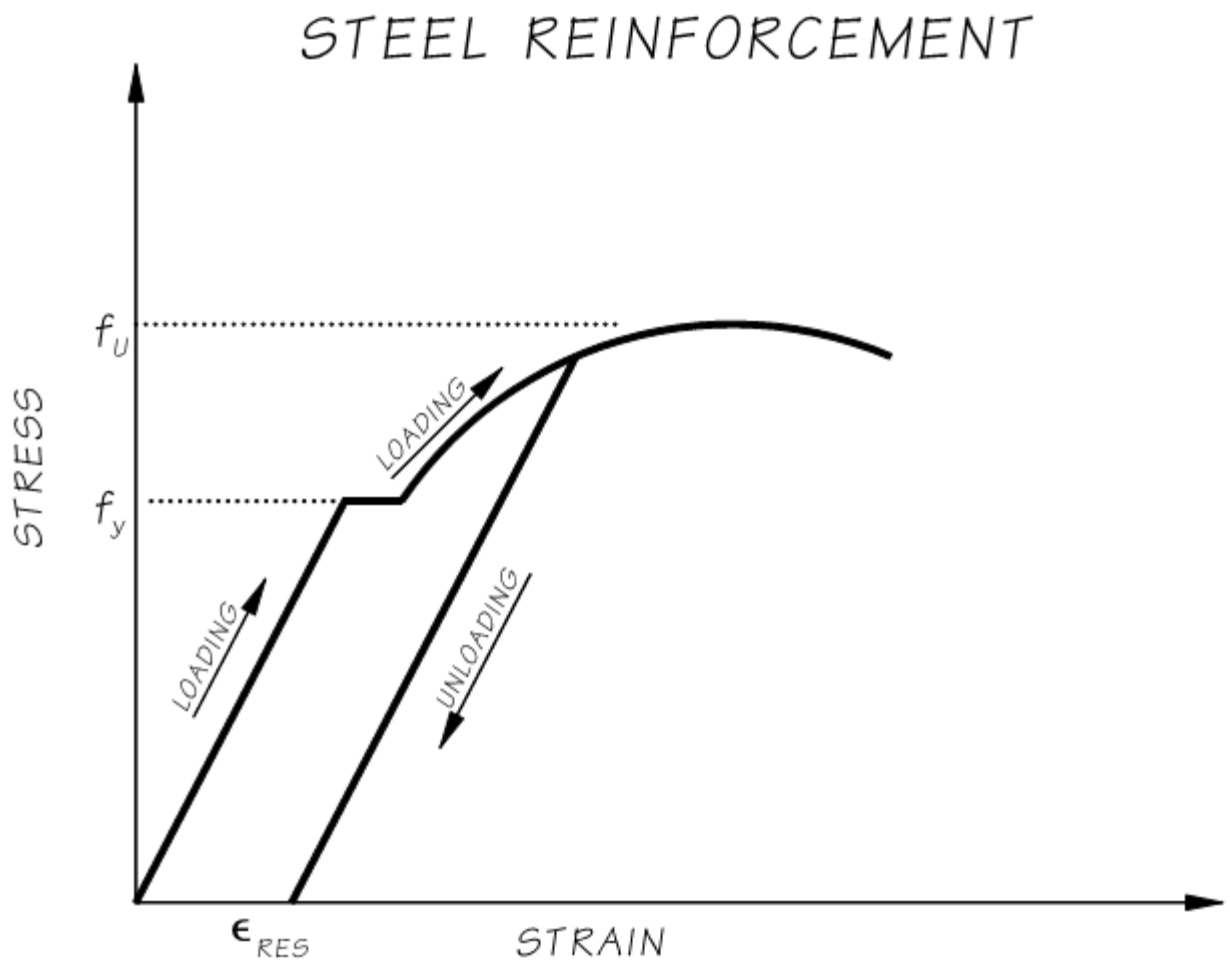
- Engineered Cementitious Composite (ECC)



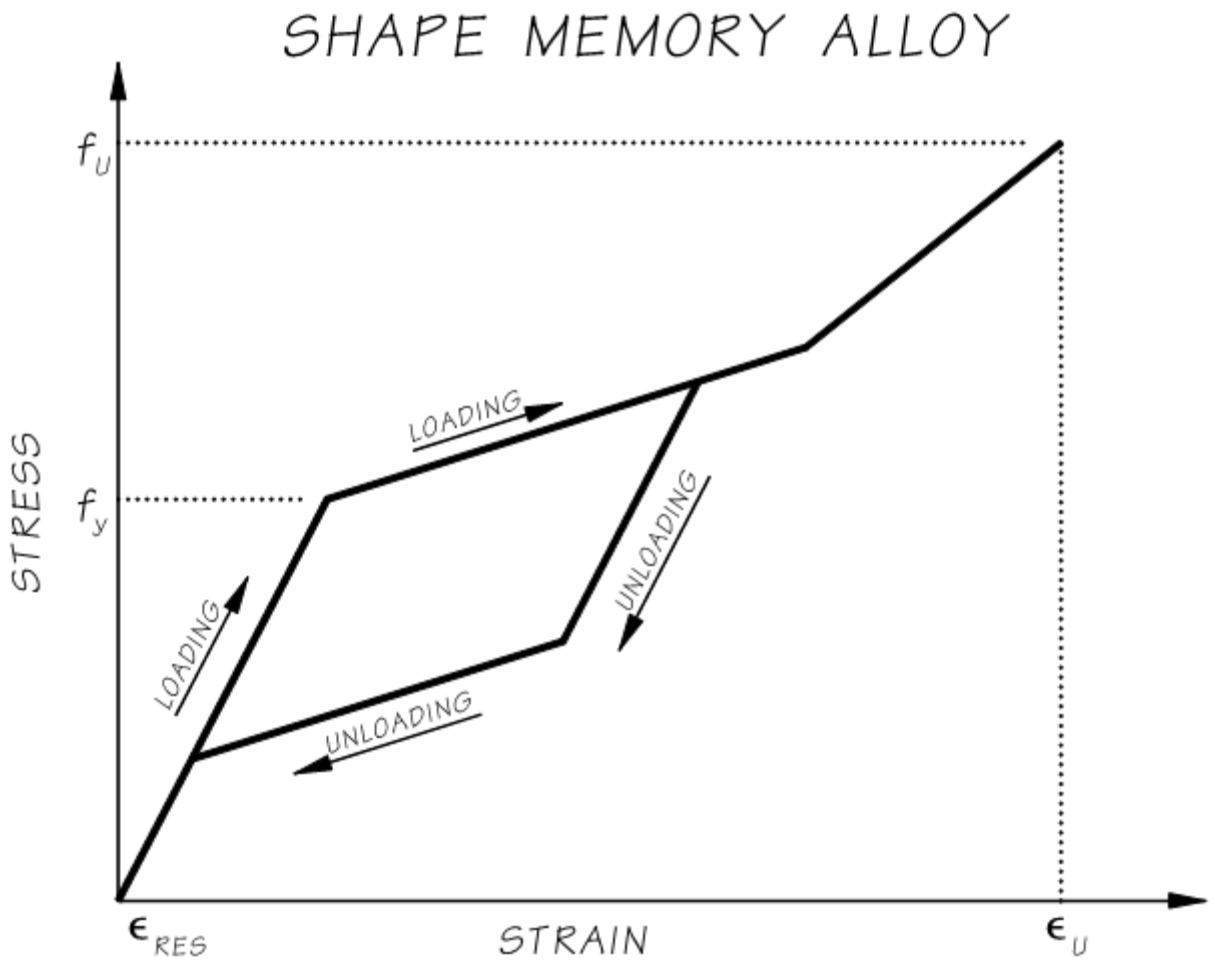
Innovative Materials SMA

- Shape Memory Alloy Bars (SMA)
  - Nickel-Titanium or Copper-Aluminum-Manganese
  - Superelastic

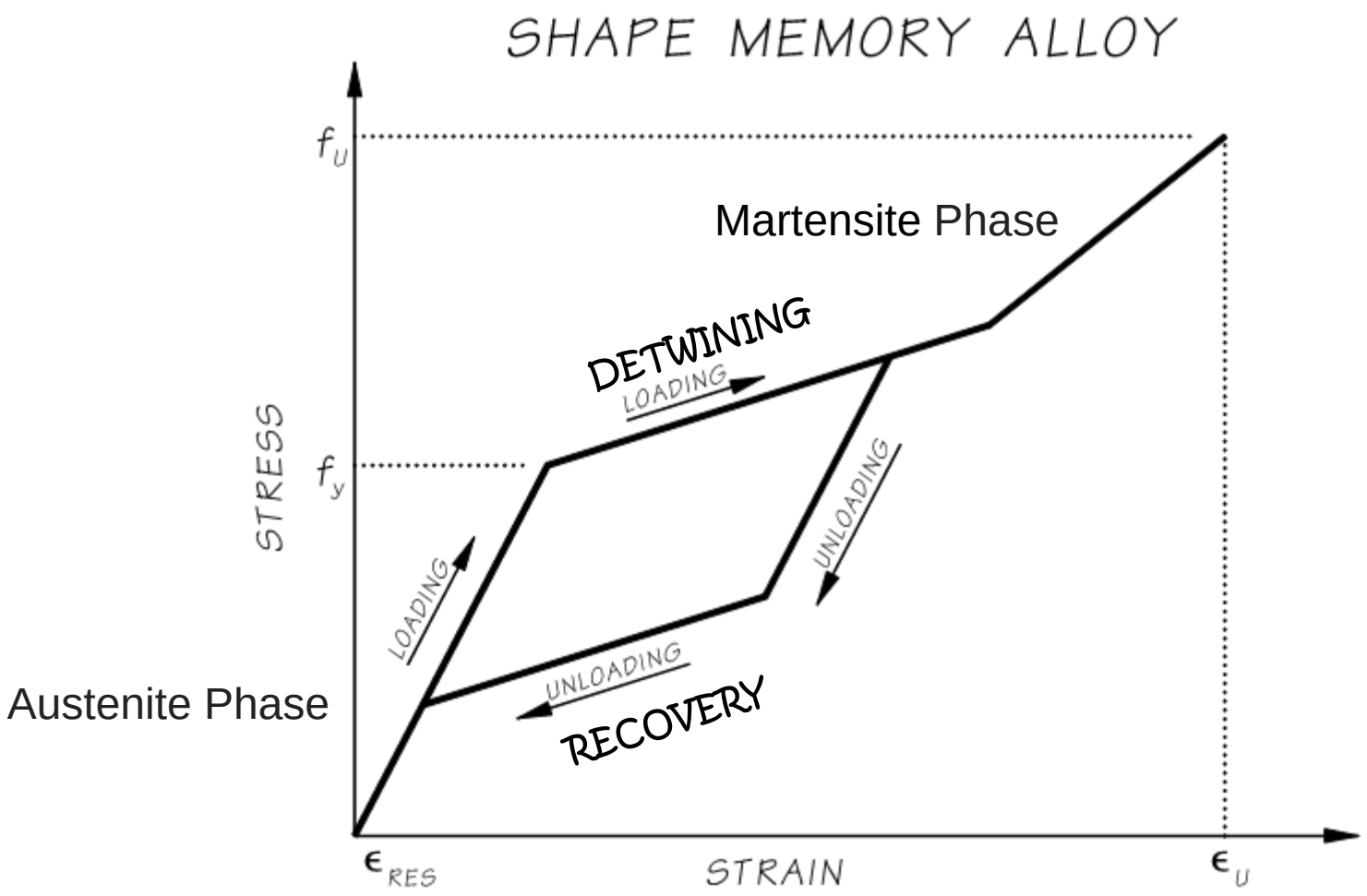
Conventional Material Steel



Innovative Materials SMA



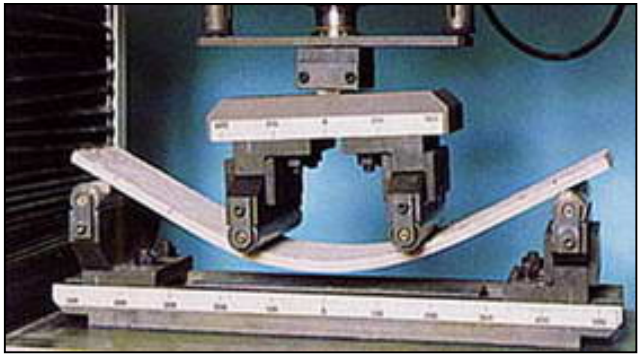
Innovative Materials SMA

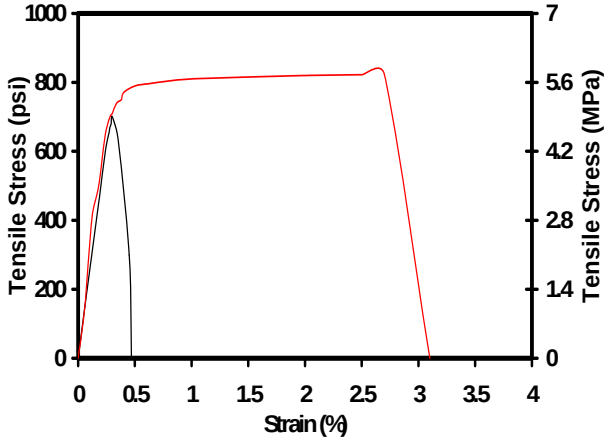


Spliced SMA into Column Cage

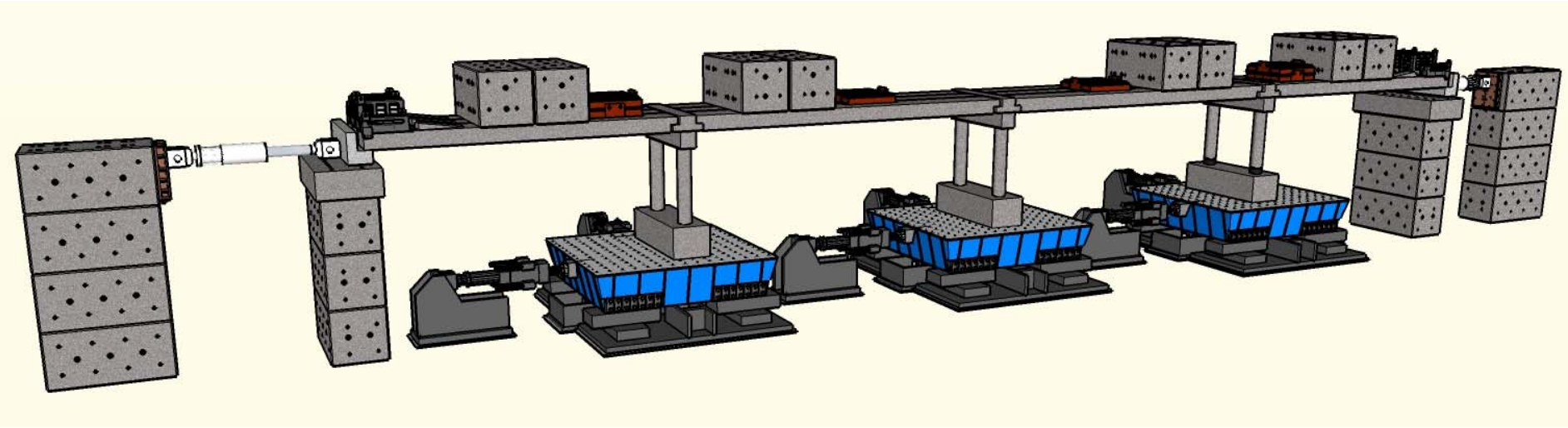
Innovative Materials ECC

- Engineered Cementitious Composite (ECC)
  - Cement, Sand, Fly Ash and Polyvinyl Alcohol Fibers
  - Reduce damage to hinge





Innovative Materials Bridge Research



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

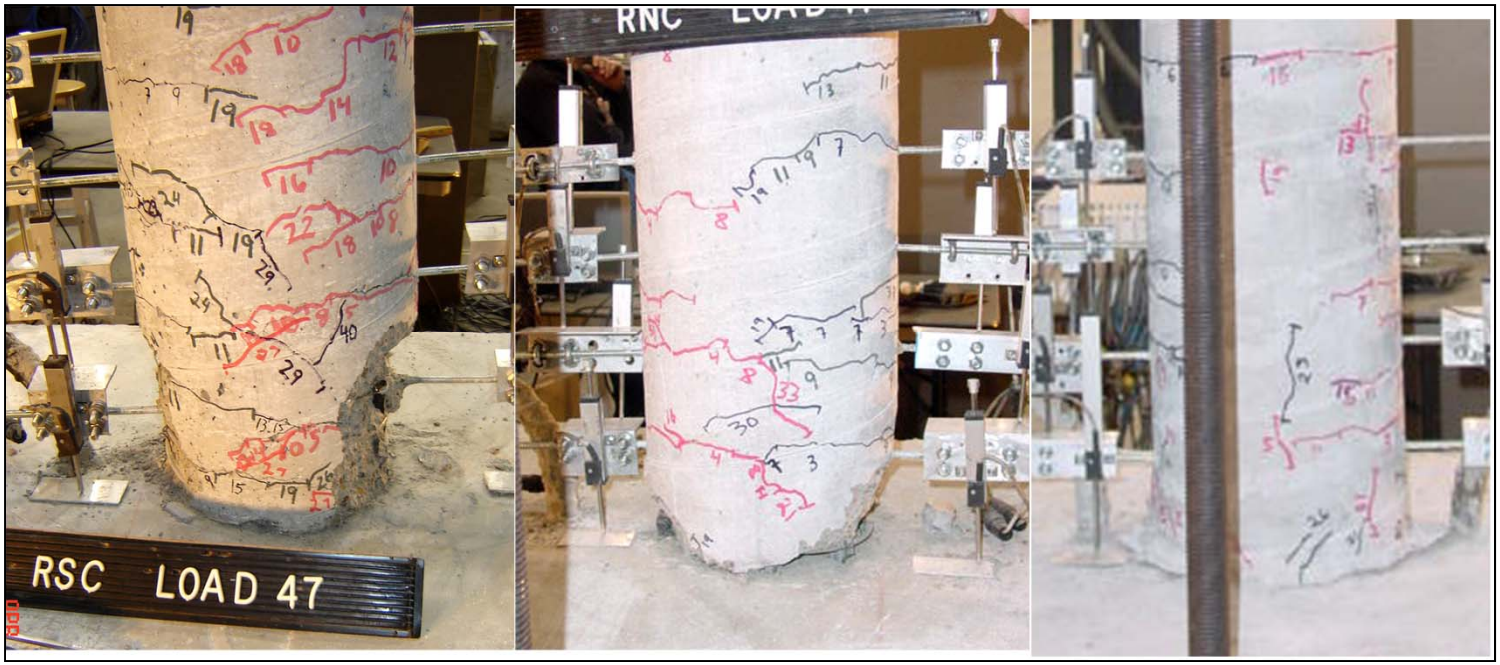
University of Nevada, Reno

NSF

NEES

Innovative Materials Bridge Research

Residual Damage After 10% Drift



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

Innovative Materials Bridge Research

- SR99-RC: Conventional RC Reference Model
- SR99-LSE: Long SMA with ECC Column
- SR99-SSE: Short SMA with ECC Column

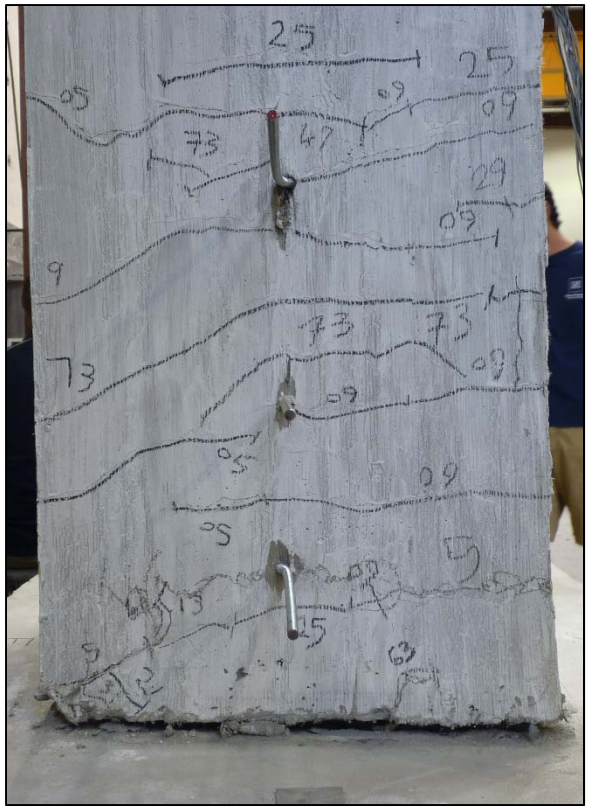
Innovative Materials Bridge Research

- 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

Innovative Materials Bridge Research

Damage at End of Testing

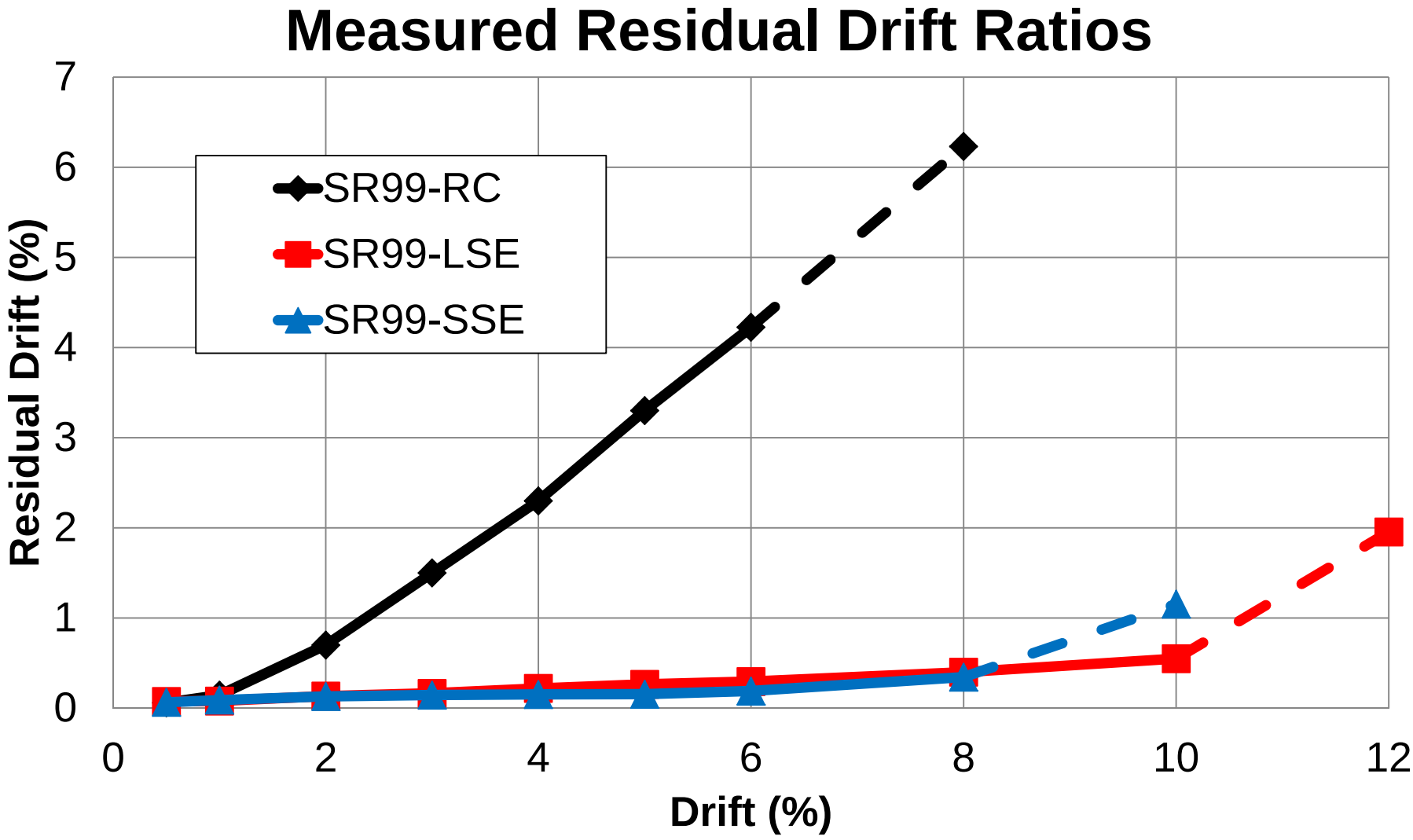
SR99-RC (8% Drift)



SR99-LSE (12% Drift)

SR99-SSE (10% Drift)

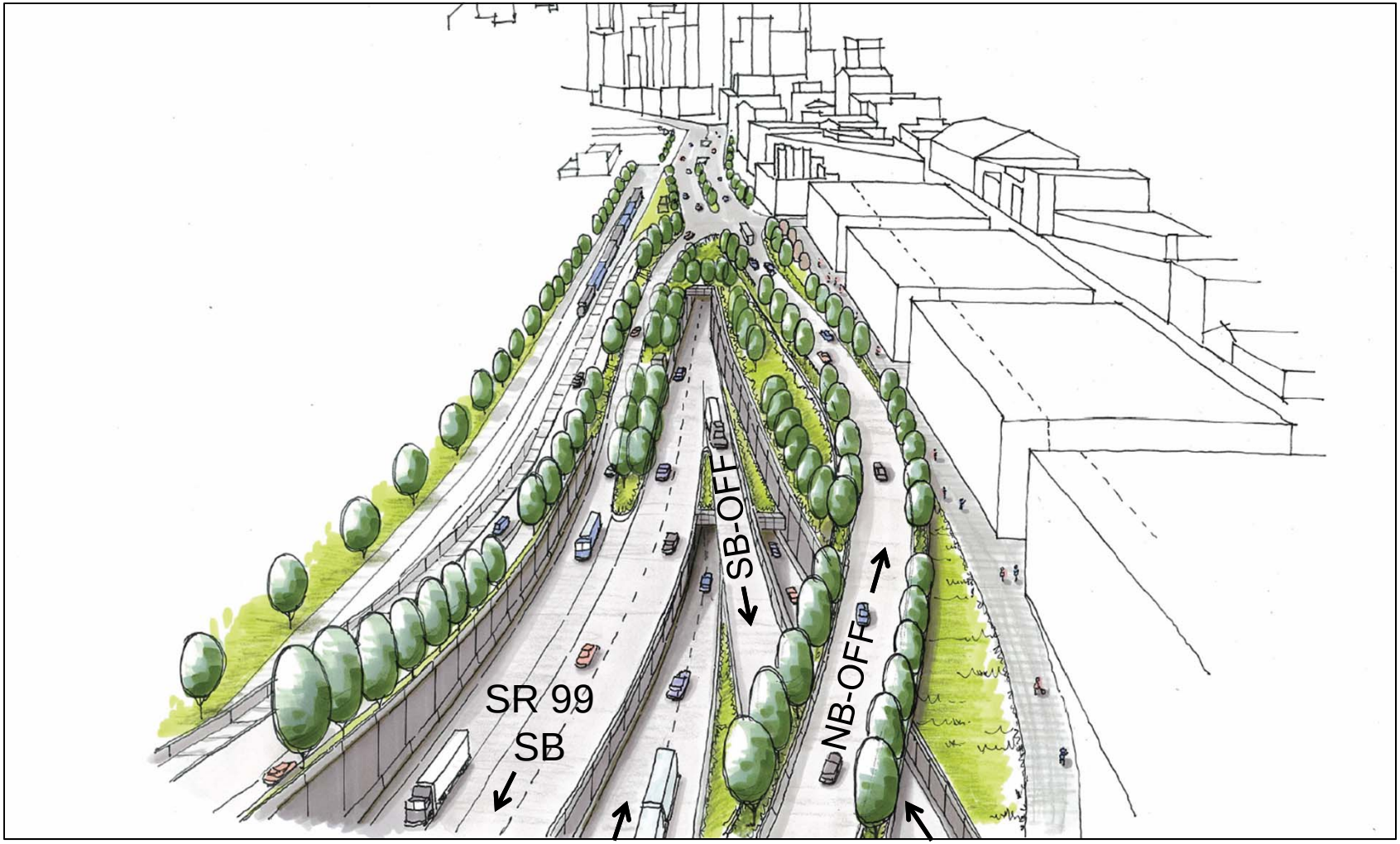
Innovative Materials Bridge Research



SR 99 South Access – NB Off Ramp

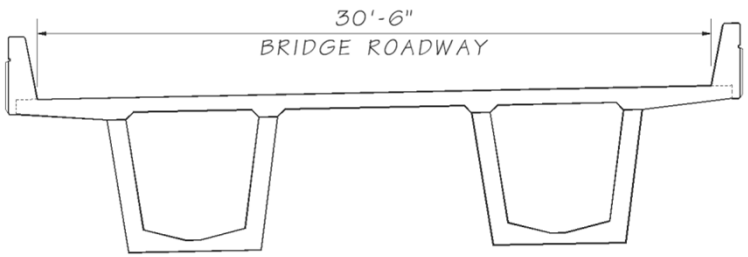
- Owner: Washington State Department of Transportation
- Engineer: Washington State Department of Transportation
- Contractor: Interwest Construction Inc.

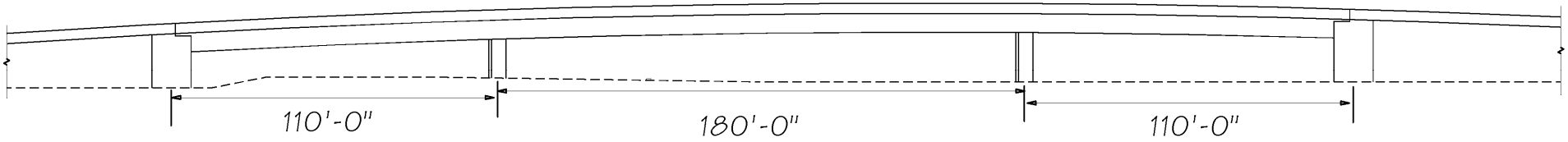
SR 99 South Access – NB Off Ramp



SR 99 South Access – NB Off Ramp

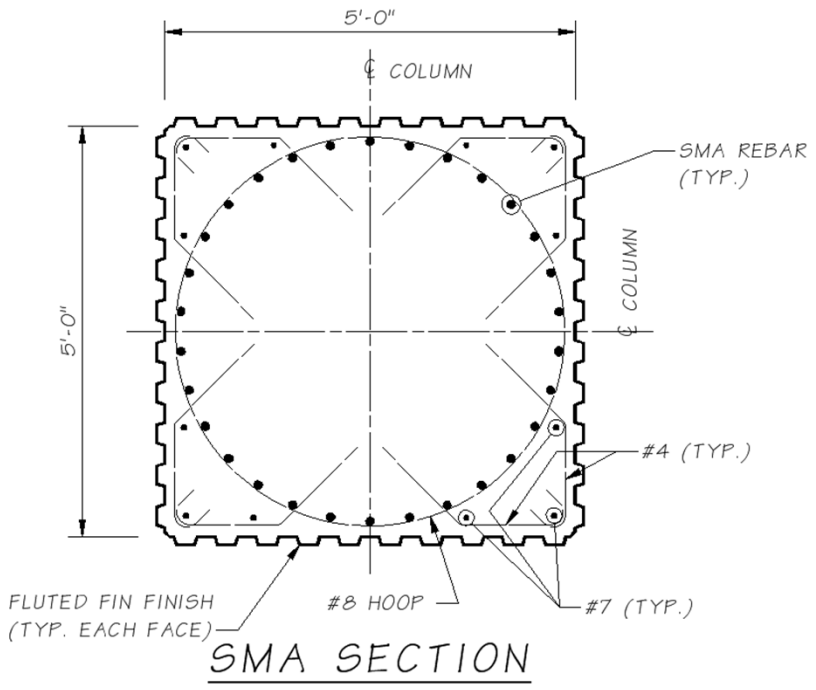
- Three Spans (110ft; 180ft, 110ft)
- Precast Post-Tensioned Splice Tub Girder
- Single Column Piers
- Square Columns (5ft x 5ft) w/ Circular Core
- ECC Top 5ft of Column



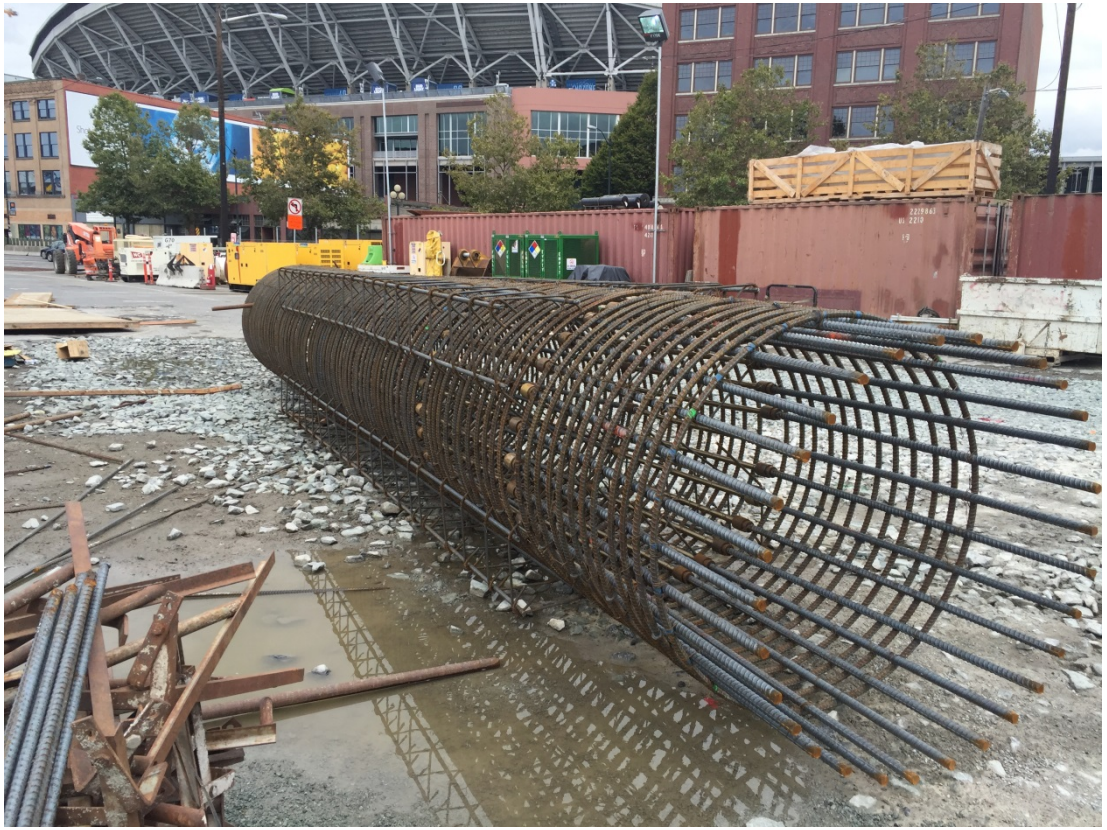


SR 99 South Access – NB Off Ramp

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



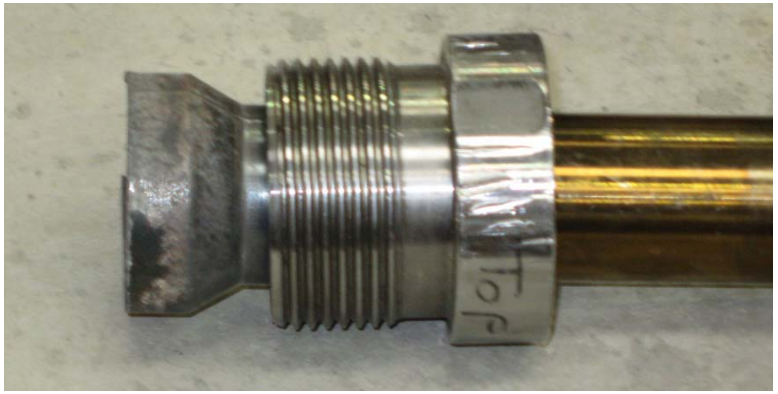
SR 99 South Access – NB Off Ramp Construction Photos



SR 99 South Access – NB Off Ramp Construction Photos

SR 99 South Access – NB Off Ramp

- Challenges with including SMA
  - Cost
    - ASTM A706 = $1 / lb. (installed)
    - SMA = $92 / lb. (delivered)
  - Schedule – 6 month delivery, not including process to head bar for mechanical splice
  - Mechanical splice required in hinge region

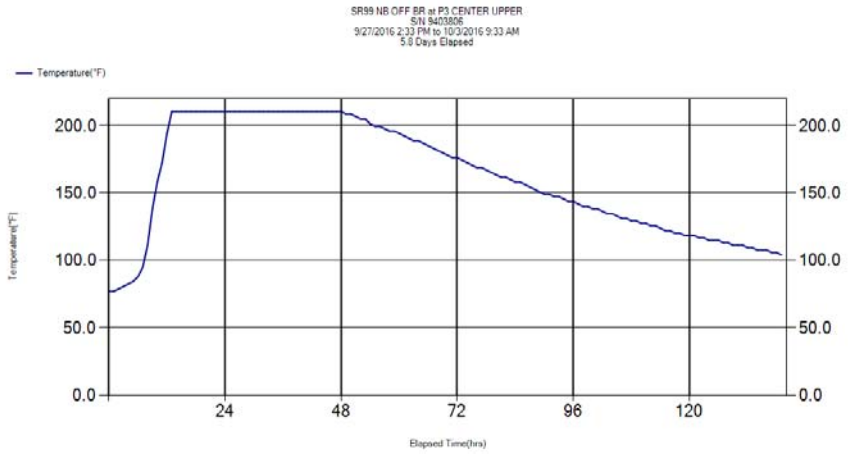


SR 99 South Access – NB Off Ramp

- Challenges with including ECC
  - Production rate
    - 10 to 12 ft^3 / batch
    - Total 125 ft^3 each column
    - One shift per column

SR 99 South Access – NB Off Ramp

- Challenges with including ECC
  - Curing temperature
    - Maximum temperature per Spec. 165 °F
    - w/ Cooling System



Questions?

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