Designing for Bridge Seismic Resiliency with Novel Materials

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Standard Bridge Seismic Performance Objective:

No collapse under strong earthquakes
Failure and Success
Earthquake Damage in New Bridges—Damage and Permanent Drift

Plastic Hinge Damage
Residual Displacement

Residual Drift after the 1995 Kobe Earthquake
Cause of Plastic Hinge Damage

- Low ductility of concrete

Graph showing the relationship between strain and stress, with a peak indicating the onset of plastic hinge damage.
Cause of Permanent Drift

- Residual steel strain after yielding
Superelastic Shape Memory Alloy vs. Steel

**Steel**

**SE-SMA**

![Stress vs. Strain Diagram](image)

Permanent Strain
ECC- Engineered Cementitious Composite

Polyvinyl Alcohol Fiber

![Image of Polyvinyl Alcohol Fiber]

![Image of tensile stress-strain curve for ECC and conventional concrete]

- Tensile Stress (psi) vs. Strain (%)
- Tensile Stress (MPa) vs. Strain (%)

- ECC
- Conventional Concrete
10% Drift

Conventional  SMA/Conc.  SMA/ECC
Maximum Drift Reached (%)

Residual Drift (%)

- RSC
- RNC
- RNE Through -12% Drift
- Linear (RSC)
- Linear (RNC)
- Linear (RNE Through -12% Drift)

Conventional
82%

SMA/Conc.
27%

SMA/ECC
14%
Bridge 2: 4-Span Bridge Model w/ Advanced Details

Total model length = 110’
Top Plastic Hinges: Conventional RC
Plastic Hinge Elements for Deconstructible Bridges
Overview - Shake table test of a reassembled precast modular 2-span bridge model with innovative materials (Bridge #2)

2/6/2015
Run 7 - 1.225 x Rinaldi (PGA=1.2 g)

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Evaluation and Design Guidelines
Implementation of SMA/ECC in Showcase Bridge (SR-99 Off Ramp)

- Alaska Way Viaduct Replacement, Seattle, WA
- Three Spans (33 m; 54 m, 33 m)
- Single, Square Columns (1.5 m x 1.5m) w/ Circular Core
Damage at End of Testing

SR99-RC (8% Drift)  SR99-LSE (12% Drift)  SR99-SSE (10% Drift)
HRC Couplers in Seattle Alaska
Way Viaduct- CIP
AWARDS

- Outstanding Civil Engineering Achievement Award, ASCE, Seattle Section, 2018
- Lyman Award by the Precast Prestressed Concrete Institute for journal paper:
- SR-99 Bridge: Top 5 Outstanding Civil Engineering Achievement (OCEA) in the United States, ASCE (March 2019)
Superelastic SMAs are being considered as an alternative to improve seismic performance of structures.

For successful commercialization of novel materials in bridge engineering,
- Prices need to be reduced
- More test data are needed
- Connection technology needs to improve

Deconstructible, resilient bridges are feasible.