SHAPE MEMORY ALLOY AND HIGH-PERFORMANCE GROUT IN EARTHQUAKE-RESISTANT BRIDGES- FROM RESEARCH TO IMPLEMENTATION

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Seismic performance objective for standard bridges: No Collapse

“Failure”

“Success”
Damaged bridges have to be closed

- Ambulances and fire trucks
- Other emergency response vehicles
- Public transportation
- Major economic impact (local, maybe global)
Serviceability after earthquake:
   Minimize permanent drift and damage
Performance-based design
Advanced materials/details
   Shape memory alloys/ductile concrete
   Columns w/ built-in elastomeric pads
   Fiber-reinforced polymers
Evolution in SMA (Nickel Titanium) Use/Research

Also military applications
Superelastic Shape Memory Alloy

- Superelastic response
- Shape memory effects
- First developed in 1932
- NiTi SMA developed in 1962
Beam Tests at UNR

SMA bars
Load vs Deflection

SMA Reinf. Beam

Steel Reinf. Beam
Cyclic Load Tests of Columns

Objectives:
- (1) Determine residual displacement recovery of SMA reinforced columns under load reversals.
- (2) Study effect of using ductile concrete on damage.

>> 3 columns:
  Conventional RC,
  SMA/regular concrete,
  SMA/ECC (Engineered cementitious composite)
ECC

Polyvinyl Alcohol Fiber

![Image of ECC fibers]

![Graph comparing ECC and conventional concrete]

**ECC**

**Concrete**
Conventional

SMA/ECC

10% Drift
Shake Table Tests of Columns

Conventional

SMA/ECC Repair
4-Span Bridge Model w/ Advanced Details

Total model length = 35 m
Top Plastic Hinges: Conventional RC
Damage: Final Motion

TOP → RC

BOT. → SMA/ECC
Accelerated bridge construction
Precast Columns

8% Drift

To be replaced w/ SMA/ECC
30-mm SMA Bars
SMA/ECC Implementation: SR-99 Bridge in Seattle, Washington

- 3-Span Bridge 33m; 54m; 33m
- Single column piers with SMA/ECC
- ABC
- Square columns 1.5 x 1.5m
SMA Connections
Column Deformations

Longitudinal: Single Curvature

Transverse: Double Curvature

Pin
Damage: “Rare” Earthquake

SMA Bent

PT Bent

Elasto Bent

TOP

BOT.

SMA/ECC
Analytical Studies: Near-Fault EQ - Rinaldi (Northridge, 1994)

Residual drift Ratio = 3%
Observations

- All three details effective in minimizing residual displacements
- Only minor damage in SMA/ECC plastic hinges
- Only minor damage in elastomeric plastic hinges
- Analytical studies revealed major reduction in residual drift of the bridge when SMA/ECC or pot-tensioned elastomeric pads were used.
2 - ABC Connection Details (Cont’d)

- Substructure connection examples (Cont’d):
  III. Precast columns with extended bars inserted in grouted metal sleeves or couplers
Successful emulative ABC connections
- Precast columns embedded in footings/cap beams
- Large diameter bars embedded in corrugated ducts
- Various standard couplers
- Various methods to convert multi-girder pier cap connections to integral pier caps

Research continues