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Rehabilitation of East Lynn Lake Bridge Steel Pile Bents With Composites

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Introduction to Polymer Composites

- **Composite:**

  - A heterogeneous combination of two or more materials
  - ➢ reinforcing elements such as fibers, fillers
  - ➢ binders such as resins or polymers

  - These materials differ in form or composition on a macroscale

  - There exists interface between these materials - compatibility

- **Fiber:**
  - ➢ Load-bearing component
- **Resin:**
  - ➢ Dissipate loads to the fiber network
  - ➢ Maintain fiber orientation
  - ➢ Protect the fiber network from damaging environmental conditions such as humidity and high temperature
  - ➢ Dictates the process and processing conditions

Fiber Reinforced Polymer (FRP) Composite Advantages

- Superior corrosion resistance
- Excellent thermo-mechanical properties
- High strength-to-weight ratio
- Nonmagnetic
- Cost effectiveness
- Greener in terms of embodied energy
- Many others

Overview of East Lynn Lake Bridge, WV - Steel H-pile Rehab with Composites Project

West Virginia University Constructed Facilities Center

March 2014

BRIDGE DATA

Built in 1969, Length – 126’6”, 5 spans, 2 lanes, continuous reinforced concrete slab, H-15-44 loading.

PROBLEM

Corrosion of H-piles resulted in section loss up to **50%,** load rating of **6 tons**, speed reduction to 10 MPH, and one lane closure.

SOLUTION

Advanced FRP composite materials were used to bring the bridge back to original design capacity at **25%** of conventional construction cost in **3 weeks**.

PARTNERSHIP

WVU-CFC, USACE Huntington District and USACE ERDC, NSF, FHWA

Comprehensive Composite Approach

1) Polymer concrete as a foundation barrier where FRP shells and SCC concrete rest on;
2) Glass fiber reinforced polymer (GFRP) composite shells/jackets of 20” in diameter to enclose steel piles;
3) Self-consolidated concrete within the shell surrounding H-piles;
4) Glass FRP fabric wrap over FRP shell.

East Lynn Bridge, WV
Before Rehab

East Lynn Bridge, WV
During Rehab

East Lynn Bridge, WV
After Rehab

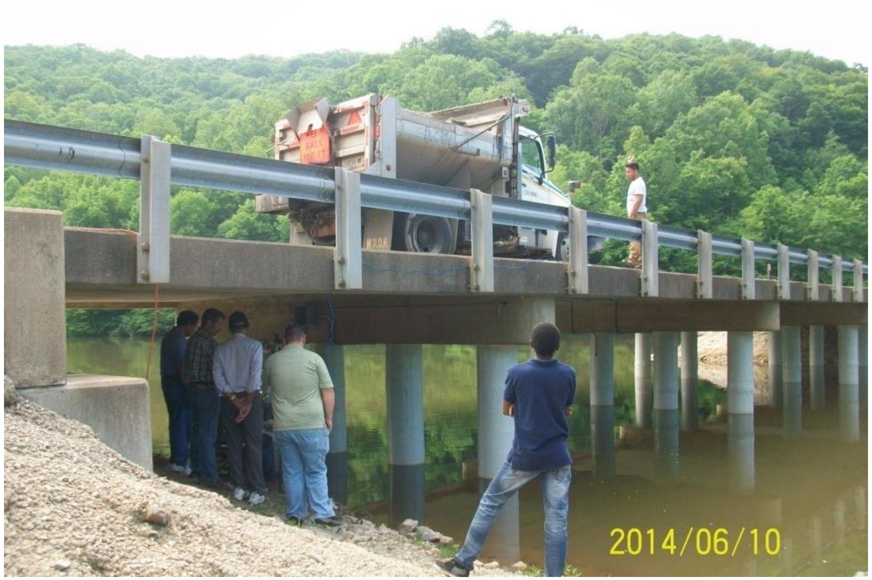
Material Properties Used in East Lynn Bridge Repair

- **SCC Concrete:**
  - ➢ Concrete Cylinders (14 days strength): 2760 psi, 2800 psi, 2844 psi (Avg. 2801 psi)
  - ➢ Concrete Cylinders (28 days strength): 3100 psi, 3103 psi, 2948 psi (Avg. 3050 psi)

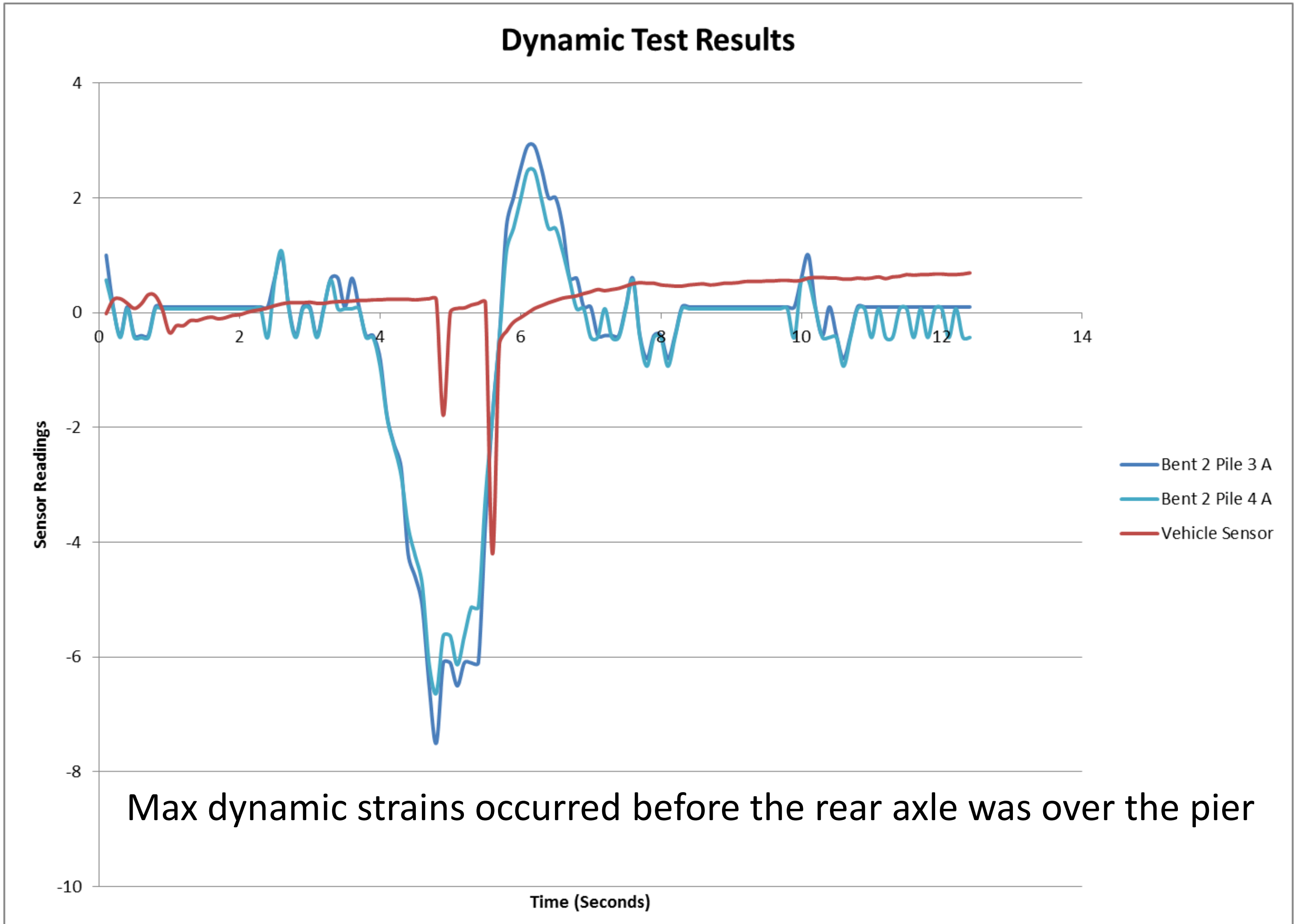
- **FRP Jacket/Shell with Glass Strand Mat (Surrounding/housing SCC Concrete):**
  - ➢ Tensile stress (hoop direction): 13.7 ksi
  - ➢ Tensile stress (longitudinal direction): 15.4 ksi

- **AQUAWRAP FRP Wrap with Bi-directional Glass Fabric (Outermost 2 layers):**
  - ➢ Tensile stress (hoop direction): 40.7 ksi

Pre- and Post- Repair Load Testing



Sensor Readings as a Function of Time during a Dynamic Load Test



Max dynamic strains occurred before the rear axle was over the pier

Pre- and Post- Wrap Load Testing of East Lynn Lake Bridge

			Normalized Stresses (psi/kip of truck load)				Reduction	
			Static Testing		Dynamic Testing			
Sensor	Location	Type	Pre-repair	Post-repair	Pre-repair	Post-repair	Static	Dynamic
Strain 1	Bent 2 Pile 3	Beam - Axial	-19.3	-1.9	-20.6	-5.7	10%	28%
Strain 2	Bent 2 Pile 3	Beam - Axial	-20.6	-2.0	-22.8	-6.2	10%	27%
Strain 3	Bent 2 Pile 4	Beam - Axial	-16.5	-1.2	-15.1	-5.1	7%	34%
Strain 4	Bent 2 Pile 4	Beam - Axial	-17.3	-1.7	-15.8	-5.3	10%	33%
Strain 5	Bent 1 Pile 3	Beam - Axial	-11.0	-2.0	-13.1	-4.3	18%	33%
Strain 6	Bent 1 Pile 3	Beam - Axial	-11.0	-1.9	-13.1	-4.2	17%	32%
Strain 7	Bent 2 Pile 3	Wrap - Axial	N/A	-0.1	N/A	0.7	N/A	N/A
Strain 8	Bent 2 Pile 3	Wrap - Hoop	N/A	0.3	N/A	-2.7	N/A	N/A
Strain 9	Bent 2 Upstream	Concrete Cap	ND	0.4	ND	0.4	N/A	N/A
Strain 10	Bent 2 Downstream	Concrete Cap	ND	0.6	ND	0.7	N/A	N/A

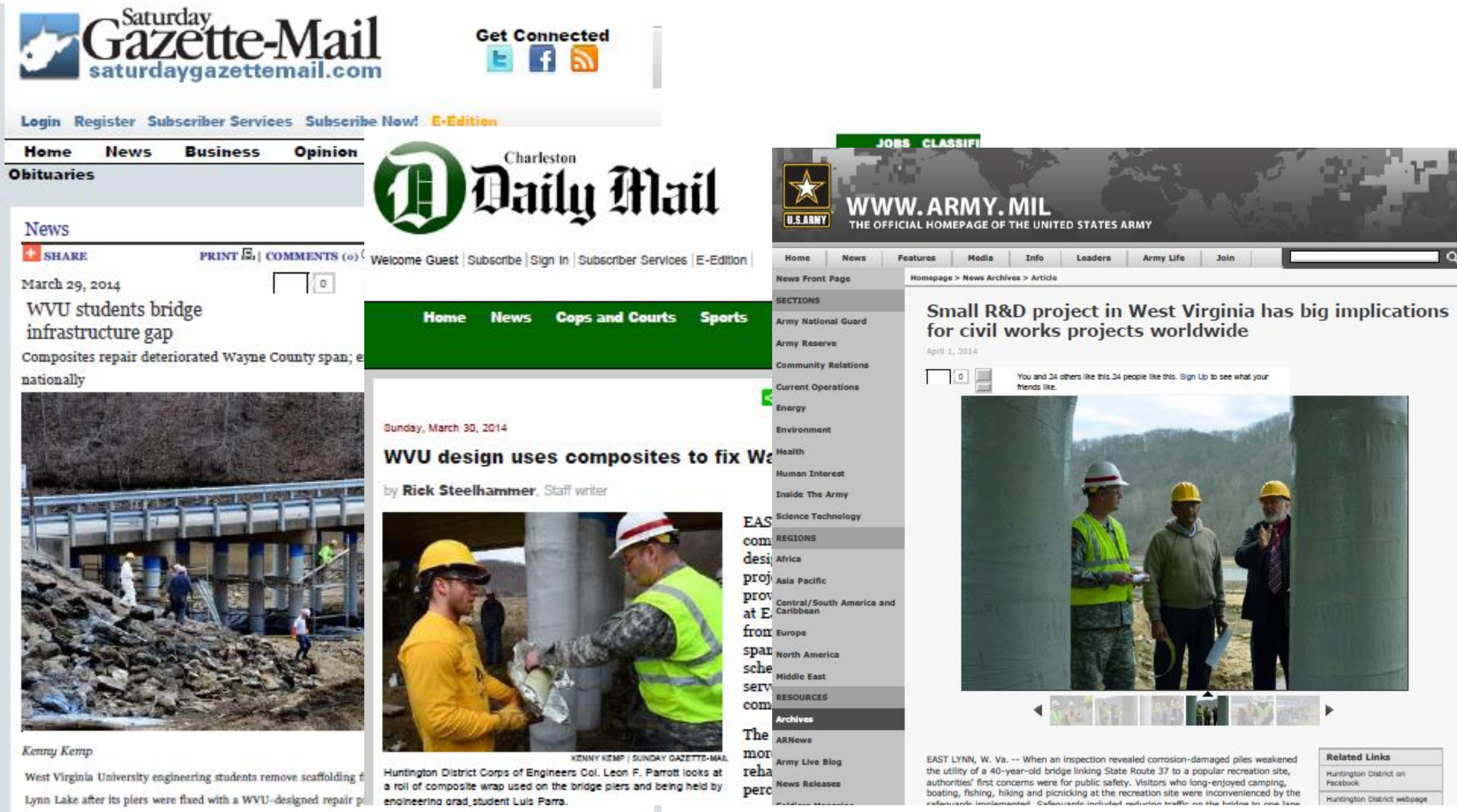
- ND: Concrete cap sensors were not operational during pre-wrap test.
- Stresses computed by multiplying the averaged strains with modulus for each material.
- Normalized stresses are defined as the stresses per kip of truck load.

Before and After Repair

Conclusions

- Advanced composites were successfully used to retrofit heavily corroded steel piles and have transformed a deteriorated bridge into a new structure.
- The load tests revealed that the load carrying capacity was enhanced 10 times higher under static loads and 3 times higher under dynamic loads.
- This work demonstrated several composite advantages: 1) design flexibility, 2) innovative, 3) rapid deployment, 4) cost-effective, 5) outstanding performance.
- Composite rehab approach offers great potential for strengthening a wide range of timber, steel, concrete structures and will play an important role in sustaining existing constructed facilities.

Questions and Discussions



East Lynn Lake Bridge won the ENGINEERING EXCELLENCE AWARD for Year 2014 CELRD of US Army Corps of Engineers (June 17, 2014)