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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



2014/02/18

2014/02/18

East Lynn Bridge, WV During Rehab



East Lynn Bridge, WV After Rehab



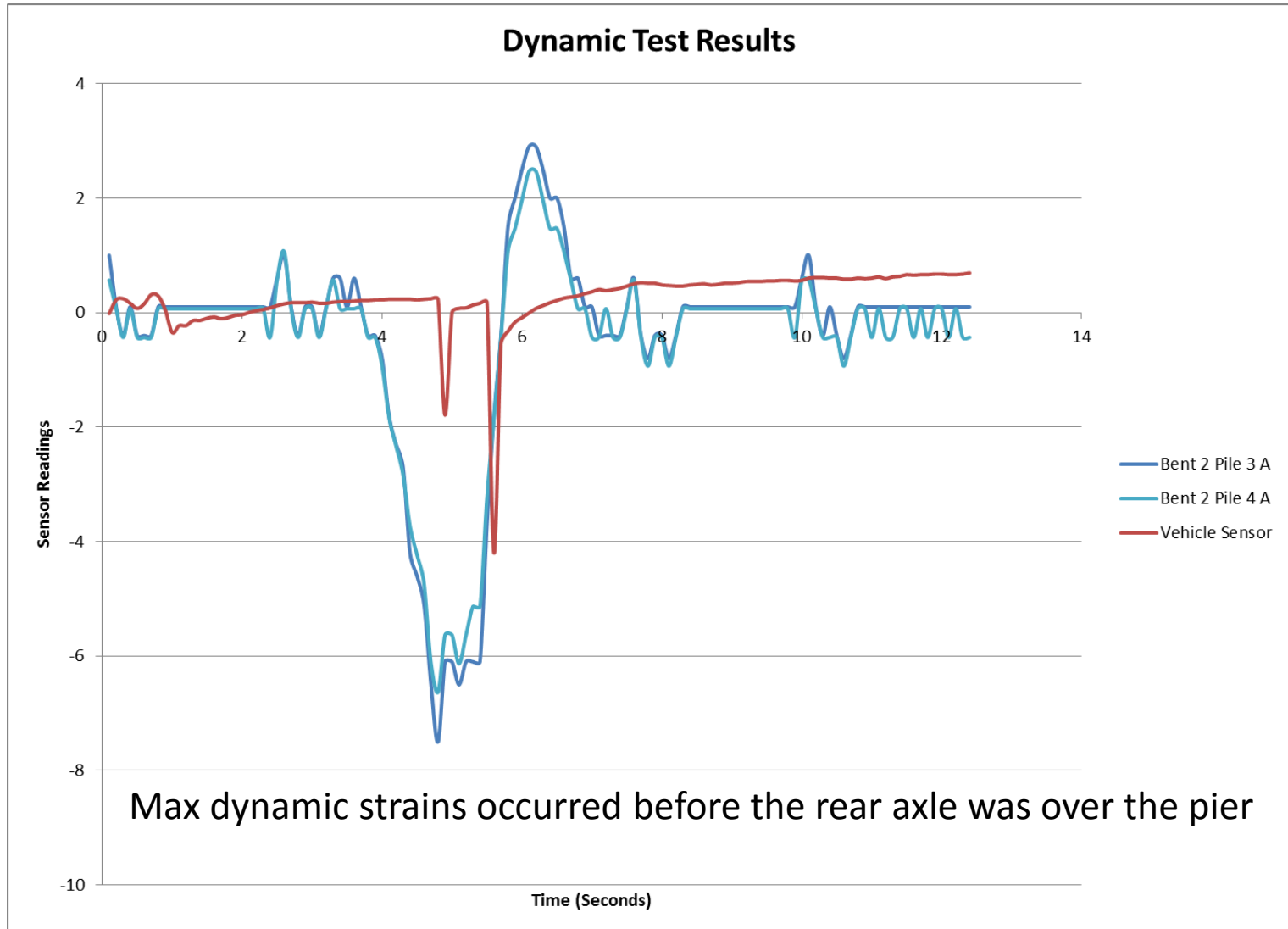
Material Properties Used in East Lynn Bridge Repair

- **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



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

Sensor	Location	Type	Normalized Stresses (psi/kip of truck load)				Reduction	
			Static Testing		Dynamic Testing		Static	Dynamic
			Pre-repair	Post-repair	Pre-repair	Post-repair		
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



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March 29, 2014

WVU students bridge infrastructure gap

Composites repair deteriorated Wayne County span; e nationally



Kenny Kemp

West Virginia University engineering students remove scaffolding f Lynn Lake after its piers were fixed with a WVU-designed repair p

Sunday, March 30, 2014

WVU design uses composites to fix W

by Rick Steelhammer, Staff writer



KENNY KEMP | SUNDAY GAZETTE-MAIL

Huntington District Corps of Engineers Col. Leon F. Parrott looks at a roll of composite wrap used on the bridge piers and being held by engineering grad student Luis Perra.

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April 1, 2014



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EAST LYNN, W. Va. -- When an inspection revealed corrosion-damaged piles weakened the utility of a 40-year-old bridge linking State Route 37 to a popular recreation site, authorities' first concerns were for public safety. Visitors who long-enjoyed camping, boating, fishing, hiking and picnicking at the recreation site were inconvenienced by the unsafe conditions. Solutions included reducing traffic on the bridge to one lane

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