Glass Fiber–Reinforced Polymer (GFRP) Composite Wicket Gates for Chanoine Type Wicket Dams

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Jonathan Trovillion

Engineer Research and Development Center –
Construction Engineering Research Laboratory

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Collaborators

- Research Team
  - ERDC-CERL: Richard Lampo, Jonathan Trovillion, Jeffery Ryan
  - West Virginia University: Hota GangaRao, P.V. Vijay, Piyush Soti, Ray Liang
- Partners
  - Rock Island District, Illinois Waterway: Michael Zerbonia, Bill Cross, Doug Morgan
  - Inland Navigation Design Center: Fred Joers, Andy Harkness
  - USACE HQ: Tom Hood
  - Huntington District: John Clarkson
  - Composite Advantage: Scott Reeve, Andy Loff

Background: Composite Materials

- **DEFINITION:** A combination of two or more materials (reinforcing elements, fillers, and matrix binder), differing in form or composition on a macroscale.

- **OPPORTUNITY:** Fiber reinforced polymer (FRP) composites offer the potential for repair of critical components of navigation systems at a reduced cost and greater durability than traditionally used materials.

Advantages

- Light Weight / High Strength
- Corrosion Resistant
- Rot and Insect Resistant
- Durable
- Very-low Maintenance
- Environmentally Friendly
- Offer Modular / Rapid Construction or Repair
- Avoid Lengthy / Costly Shutdowns
- An “Engineered” Product

IMTS Challenge and Opportunity

U.S. Inland Marine Transporta
- ~ 12,000 navigable miles
- > 200 lock chambers
- ~ 565 million tons of cargo r
- ~ 265 billion ton-miles of co

Vehicle	Capacity	Truck Equivalency
Barge	1500 Tons 52,500 Bushels 453,600 Gallons	57.7 (865.4 for 15 barges in tow)
Hopper car	100 Tons 3,500 Bushels 30,240 Gallons	3.8
100 car train unit	10,000 Tons 350,000 Bushels 3,024,000 Gallons	384.6
Semi-trailer truck	26 Tons; 910 Bushels 7,865 Gallons 9,000 for a tanker truck	1
Panamax containership	5,000 TEU	2,116
VLCC	300,000 tons 2 million barrels of oil	9,330
747-400F	124 tons	5

Chanoine Wicket Dams

- Moveable wicket dams were invented by Jacques Chanoine of the French Corps of Engineers, in 1852. His design was modified by the U.S. Army Corps of Engineers to serve the needs of Ohio and other river navigation.
- A movable dam that can be raised in times of low water to create a pool and lowered when the flow is adequate for navigation.

FRP Composite Wicket Gates

Problem: Timber wicket gates: rapid deterioration, costly to replace. Stepping stone to future design and application of other larger FRP composite gates and valves. Prototype designs are being developed using thermoset composites. Installed in Peoria Lock and Dam in Aug 2015.

Traditional wooden wickets showing deterioration

Peoria Lock and Dam

- The Peoria Lock and Dam on the Illinois River, located near Creve Coeur.
- The lock 600 ft. long by 110 ft. wide with a maximum lift of 11 ft. and an average lift of 6 ft.
- The dam is comprised of a Chanoine wicket dam, the navigable pass type, with an overall length of 570 ft.
- The wicket dam is 432 ft. long containing 108 wicket gates.

Composite Wicket Gates
Design Considerations

Worked with WVU and Rock Island District folks to develop design concepts for composite gates.

- **Same dimensions as timber gates**
- **Same weight and balance**
- **Use existing steel hardware: Prop rod, horse, bail etc.**
- **Infuse as single monolithic unit**

Currently used timber wickets.

Composite Wicket Gates
Fabrication and Lab Testing of Initial Prototype

Layup in the mold.

After resin infusion but before clean-up.

Tested to twice the working load of a timber wicket.

Design Calculations/Experimental

Load Cases

- Rest Position
- Operating Position
- Lifting Position

Testing Methods

- Tensile coupons
- 4 point bending of FRP gate
- 4 Point bending of timber gate
- Shear/pull test on wicket bails

The safety factors obtained were 4 for bending and 12 for shear.

Based on the experimental results, the FRP composite wicket gates should provide many years of satisfactory service.

Composite Wicket Gates

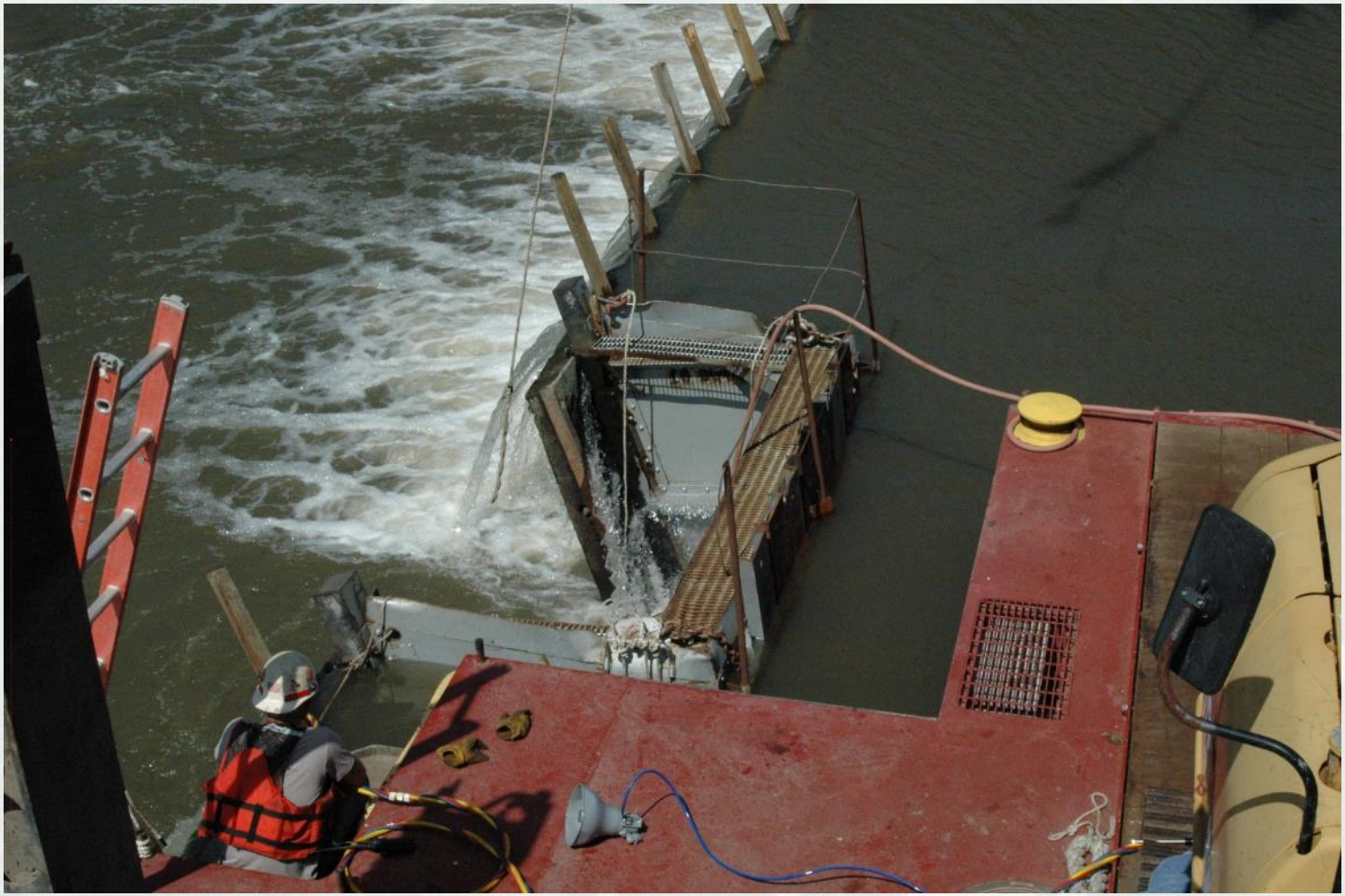
- **Fabrication of two additional prototype gates using agreed upon design changes, including UHMWPE on sides and face.**
- **Three gates were installed, one with steel angles on the edges as used in the lab testing and two with UHMWPE on upstream face and sides for abrasion-protection.**

Gate #2 after demolding but before trimming and attaching steel hardware; yellow UHMWPE for better visibility.

IWW Installed 3 composite wickets during Aug15 maintenance activities.

Composite Wicket Gate Installation

Composite Wicket Gate Installation



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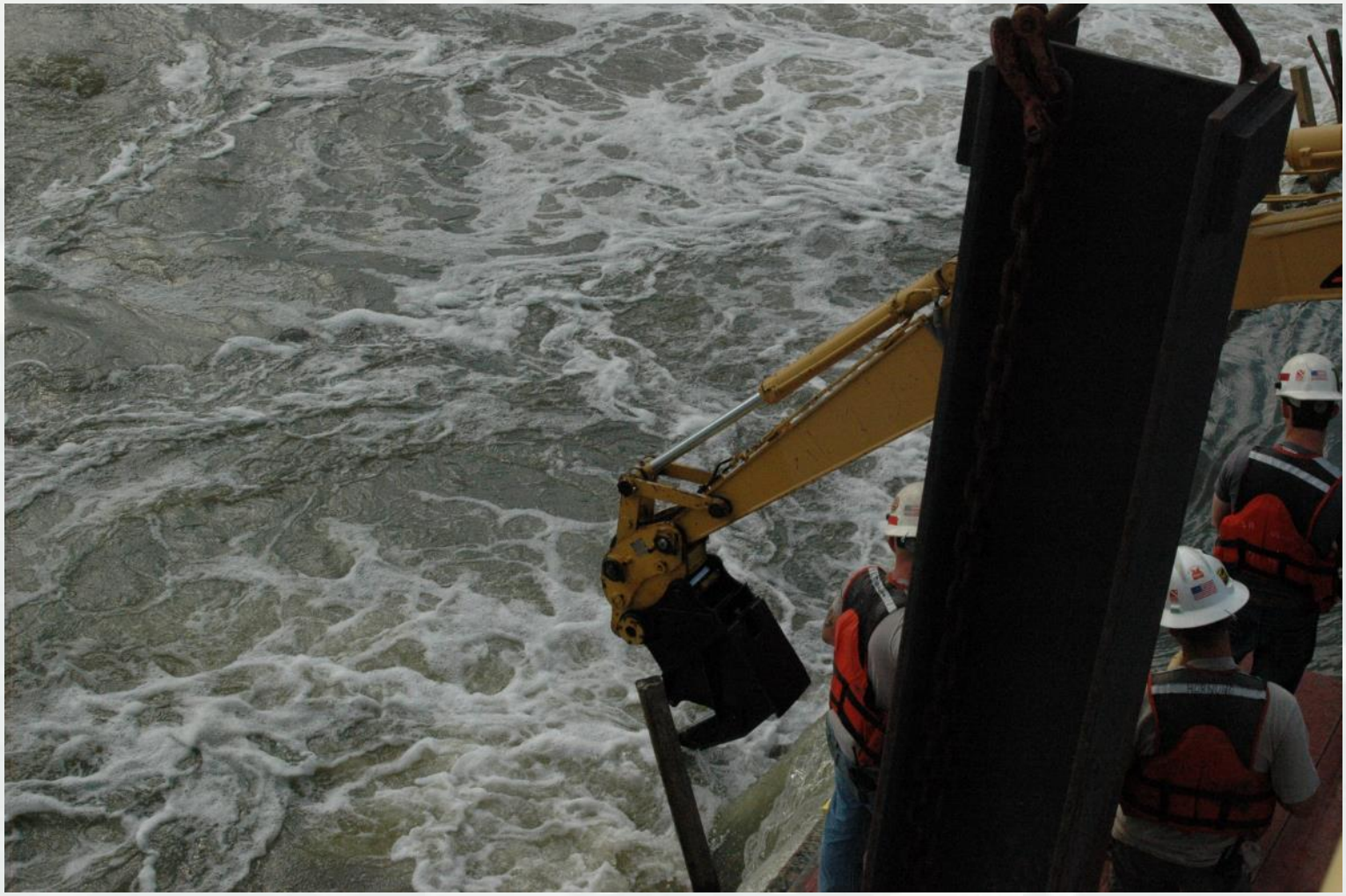

Composite Wicket Gate Installation

- Performing very well after 10 months of service.
- Will be dewatered and inspected in August 2016.

Summary and Conclusions

- Timber wicket gates provide an opportunity for the use of FRP composites.
- About 2/3 the cost of timber gates on a first cost basis.
- Expected life > 50 years (timber gate is ~15 years).
- Future Opportunities -- Even with limited wicket gates in use by the Corps, the economics for using FRP composites is still significant. It is expected that this success will lead to the use of FRP composites for even larger gates with even greater demands in performance
- Potential Cost Savings

Location: Peoria Lock and Dam			
Wicket Type	**# Wickets, First Cost**	**Total Repl. Cost**	**50-Year Cost**
Timber	108 @ $18,000	$1.944 million	$6.48 million
Composite	108 @ $11,000	$1.188 million	$1.188 million
Total savings for location: $5.292 million (materials only)			
Location: LaGrange Lock and Dam			
Timber	109 @ $18,000	$1.962 million	6.54 million
Composite	109 @ $11,000	$1.199 million	1.199 million
Total savings for location: $5.341 million (materials only)			
Total savings for two locations: $10.6 million			

Questions ???

Jonathan Trovillion
Jonathan.c.trovillion@usace.army.mil
217-373-4551

Richard Lampo
Richard.g.lampo@usace.army.mil
217-373-6765

Jeffrey Ryan
Jeffrey.p.ryan@usace.army.mil
217-373-3479