FRP Composites for the Corps of Engineers

Dr. Vijay P.V., P.E., WVU

Dr. Hota VS GangaRao, P.E., WVU

John D. Clarkson, P.E., US Army Corps of Engineers*

Richard G. Lampo, US Army Corps of Engineers

* Presenter

Washington DC, 21 June 2016

Why Composites for USACE?

Hydraulic structures are exposed to demanding loads and severe corrosive conditions. Fiber Reinforced Polymer (FRP) composites may provide excellent choice of materials for use with their strength, corrosion, and wear resistance for these extreme environments.

INTRODUCTION

- Goal is to expand use of composites in Civil Works projects.
- Make use where there is a material advantage.
- Approach is to crawl, walk and run.
- If you know of other applications please send.

BACKGROUND

- GFRPs and CFRPs are being increasingly employed in civil engineering infrastructure.
- FRPs have high strength/weight ratio, ductility, and durability (act as protective members).
- FRPs are manufactured as bars, shapes, and wraps.
- FRPs are lightweight, easy to transport and implement.
- FRP wraps are resin saturated and applied on structures (wet-layup).
- FRP wraps act as protective membranes and inhibit the flow of moisture/air into concrete, and reduce steel rebar corrosion.

Some of the suppliers of composites are offering 25 and some 50 year warranties that demonstrate the longevity expected for FRP Composites.

Examples

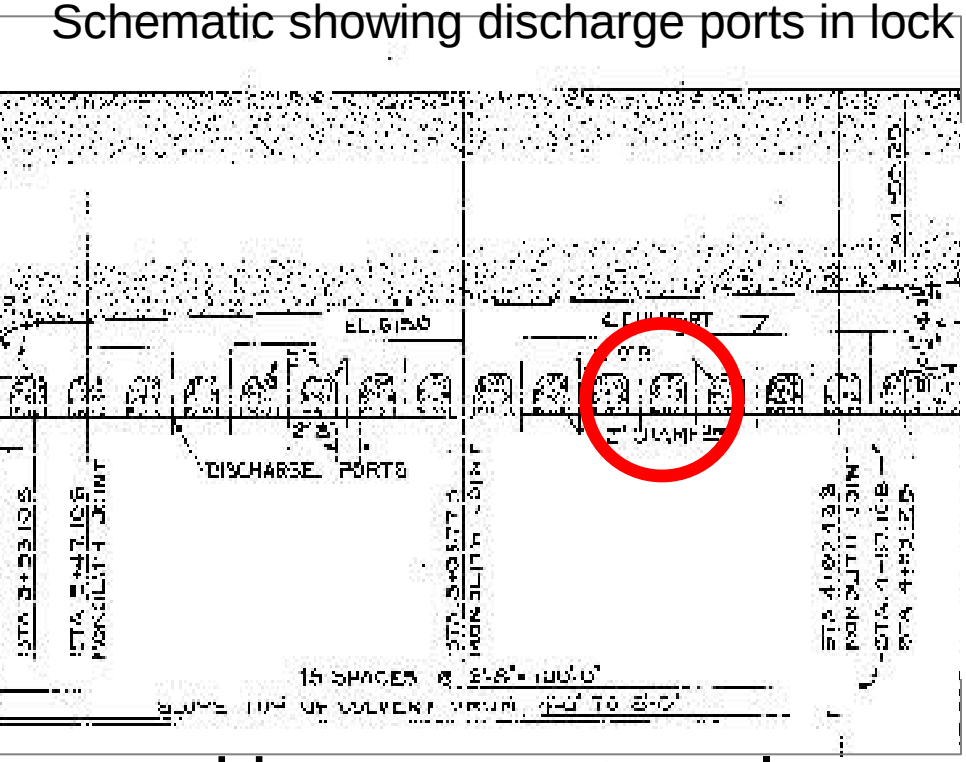
Other presentations in the conference will cover some of these examples in depth.

- Underwater curable FRP wrapping of submerged concrete discharge ports.
- FRP blocks for miter gates.
- FRP recess filler panels.
- Abrasion resistant composite coatings.
- Repair of corroded steel columns of a concrete bridge deck.
- FRP Wicket Gates

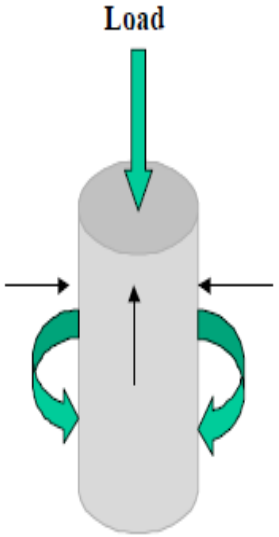
UNDERWATER FRP WRAPPING

- **Repair concrete discharge ports at Chickamauga Lock in Tennessee.** Structural movement due to alkali aggregate reaction has caused cracks to develop on columns that define the discharge ports. Will repair using polymer mastic grout and composite wrap that cure underwater. Easier and more durable repair than using steel jackets and grout.

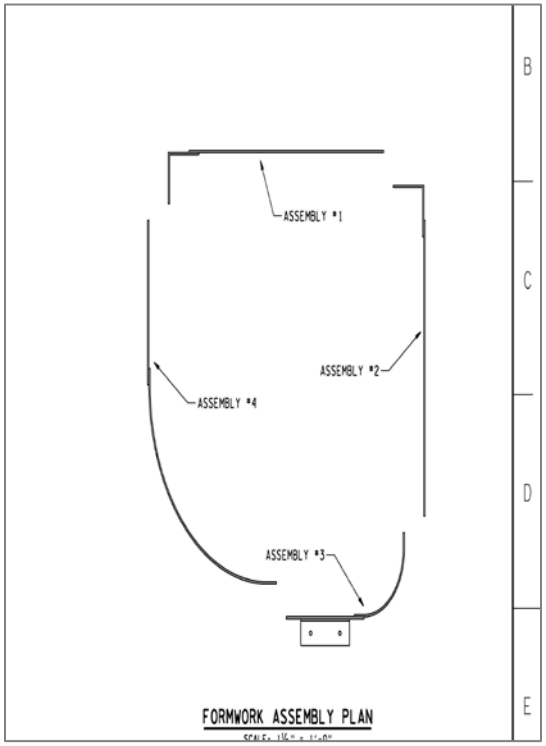
Schematic showing discharge ports in lock structure



cracking concrete columns

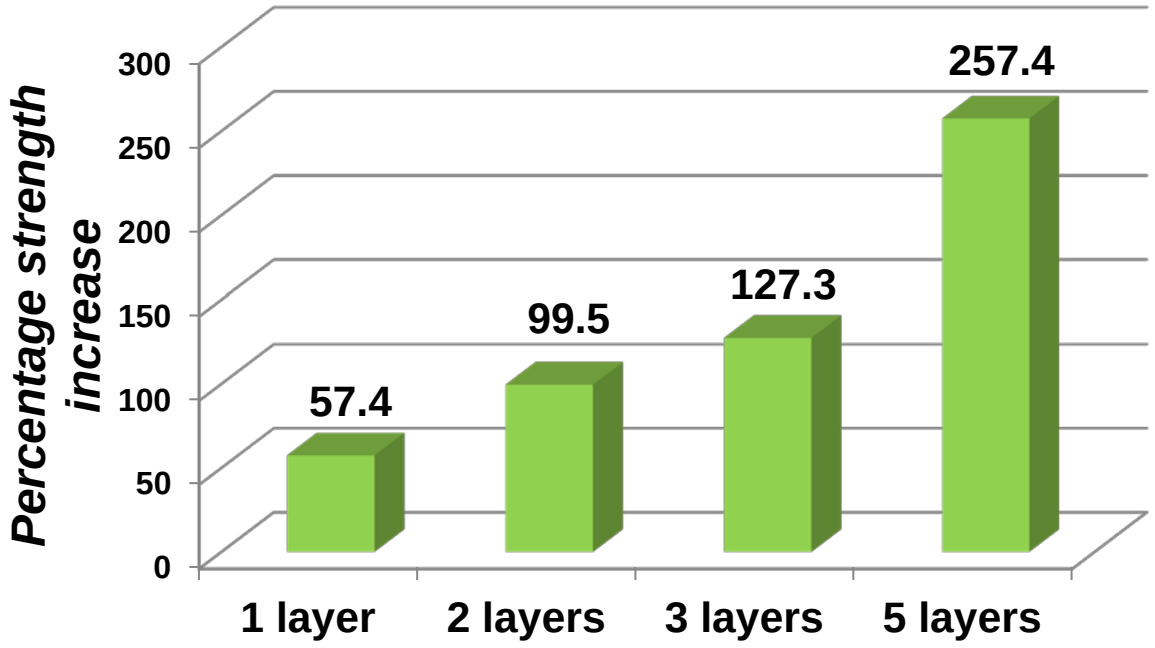


Steel repair shell

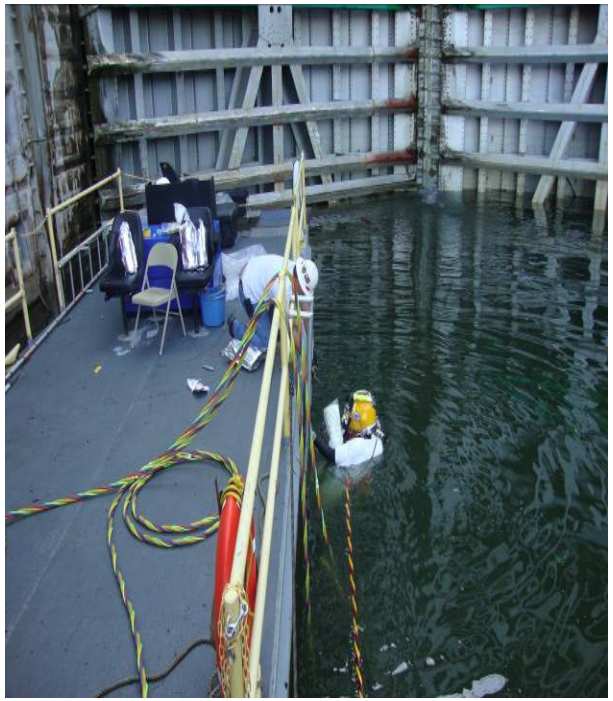



A. C. S.
APPLIED COMPOSITE SYSTEMS
BP-4 - Base Primer Part A
½ Gallon Kit
Light Grey
A. C. S.
BP-4 - Base Primer Part B

- Wrapped cylinders with 1, 2, 3 and 5 layers of Aquawrap showed an avg. strength increase of 57.4%, 49.8%, 42.4% and 51.5%, respectively.
- Average strength increase per layer was noted to be ~50%.

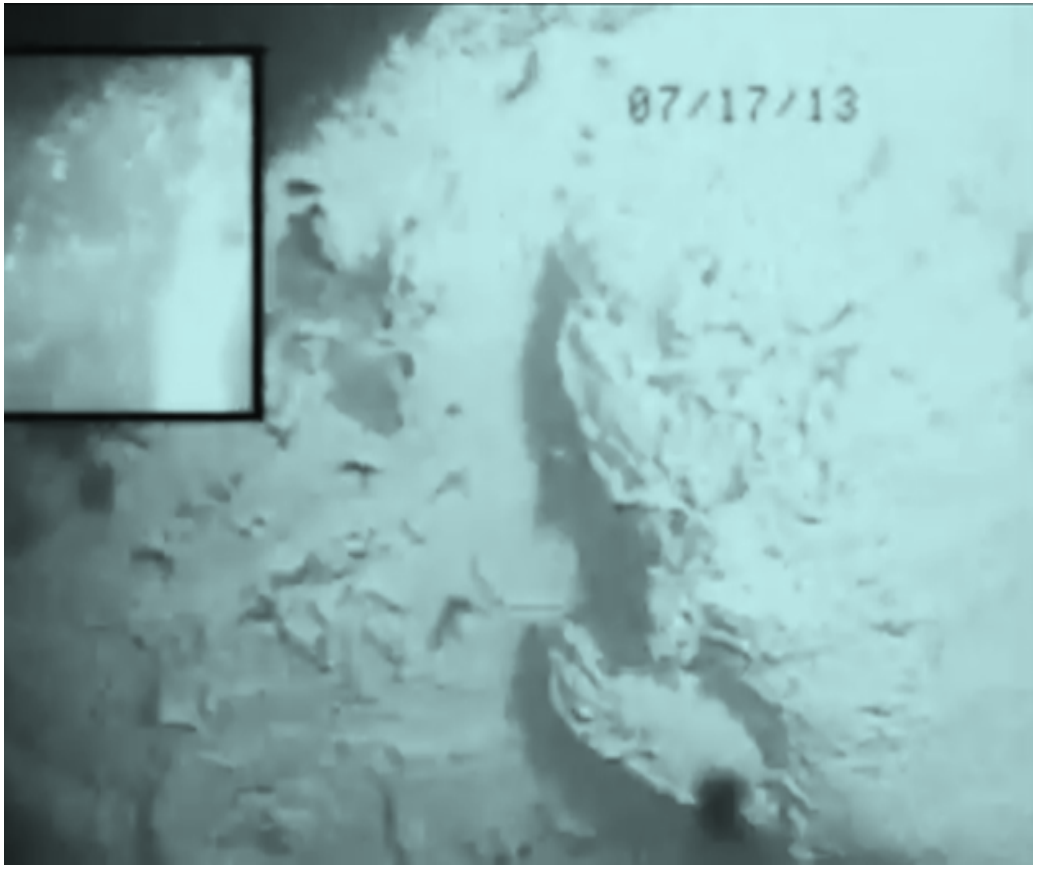


Repair concrete discharge ports at Chickamauga Dam in Tennessee.



Helper handing diver roll of composite wrapping – much easier than handling 100 lb-plus piece of steel.

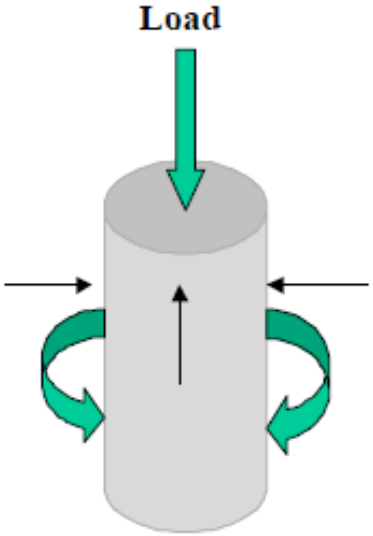
Video monitoring of installation – subsequent diving inspection has shown the composite wrap to look like the day it was installed.



CONCLUSIONS

Underwater wrapping:

- Strength increase of ~50% per wrap for concrete cylinders.
- The Aquawrap materials were found to be in original condition after three months of installation on discharge ports in Chickamauga L&D, TN.
- Underwater curable composite wrap – easier and more durable than using steel jackets and grout.



FRP Composites Demonstrations

- **FRP Composite Miter Blocks for small lock on Lake Washington Shipping Canal, WA.** Corrosion of steel miter blocks can lead to leakage and gate misalignment.

Small lock at Hiram Chittenden (Lake Washington Shipping Canal) Locks, Seattle, WA.

Corroded steel miter blocks.

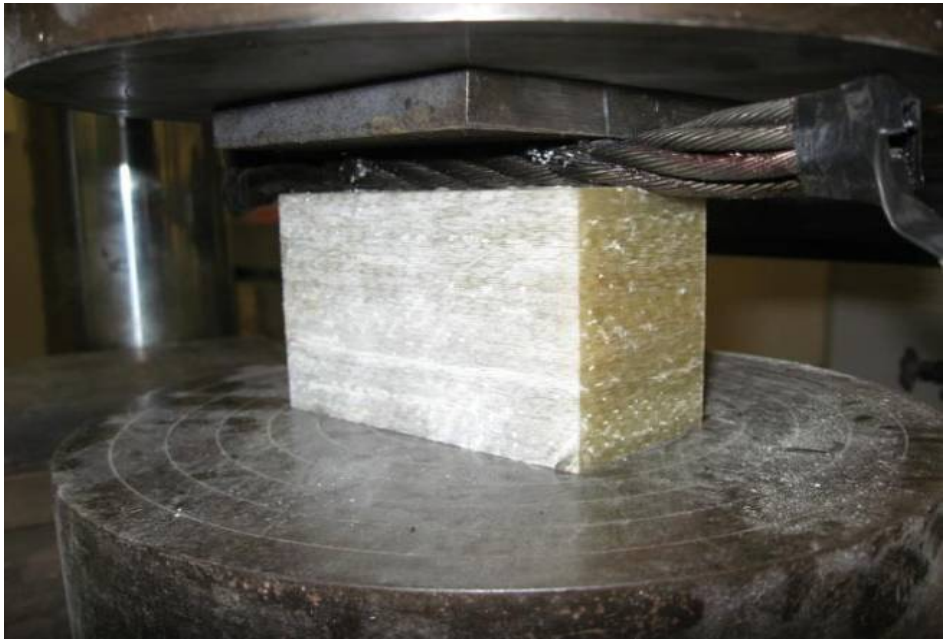
Condition of Steel Blocks

Very corroded existing steel blocks.

Previous attempts to repair with epoxy material not very successful – repair lasted but a few months.

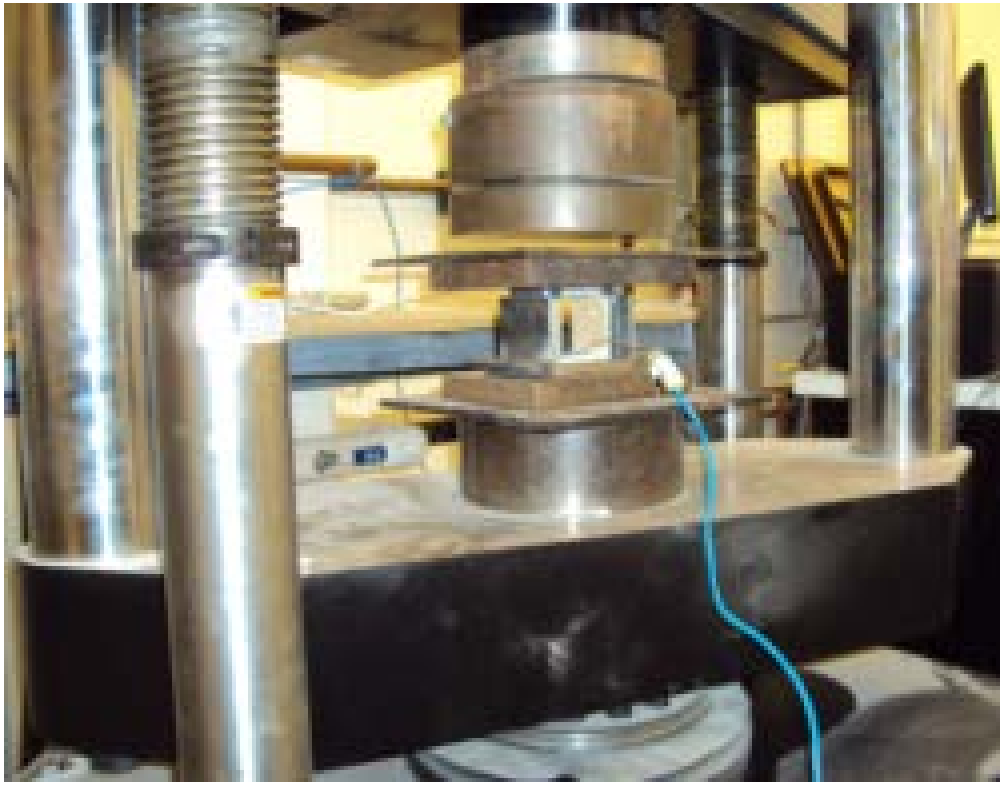
Composite blocks have to resist cyclic loadings and occasional foreign objects trapped between the blocks during gate closure.

Composite Test Pinching Behavior with Foreign Object



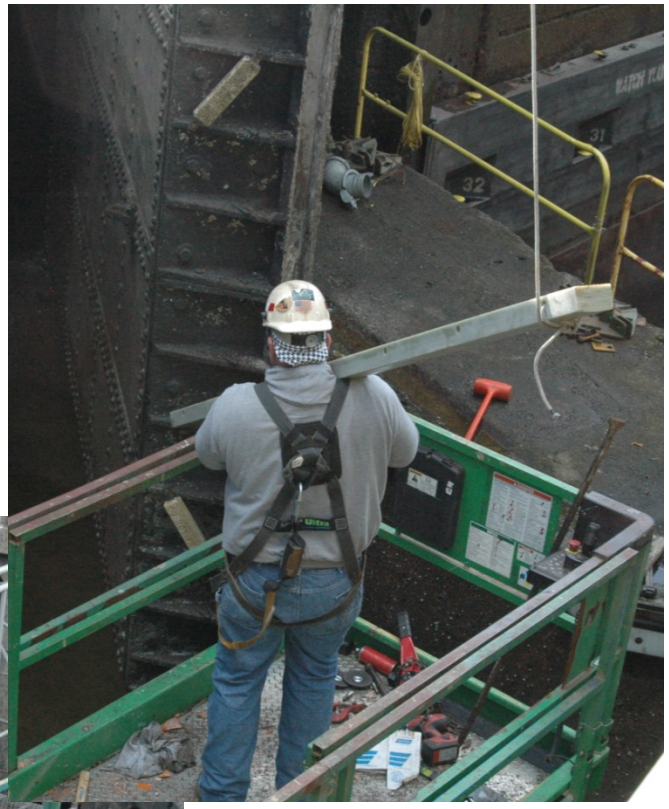
FRP BLOCKS FOR MITER GATES

Miter block required to withstand compressive pressure and 12,000 cycles of operation per year



Composites designed to resist hydro-static pressure, water-jet knife, and comp. pressure (70 kips/ft length)

Installing the FRP Blocks



Lightweight, easier and safer to handle than steel.

CONCLUSIONS

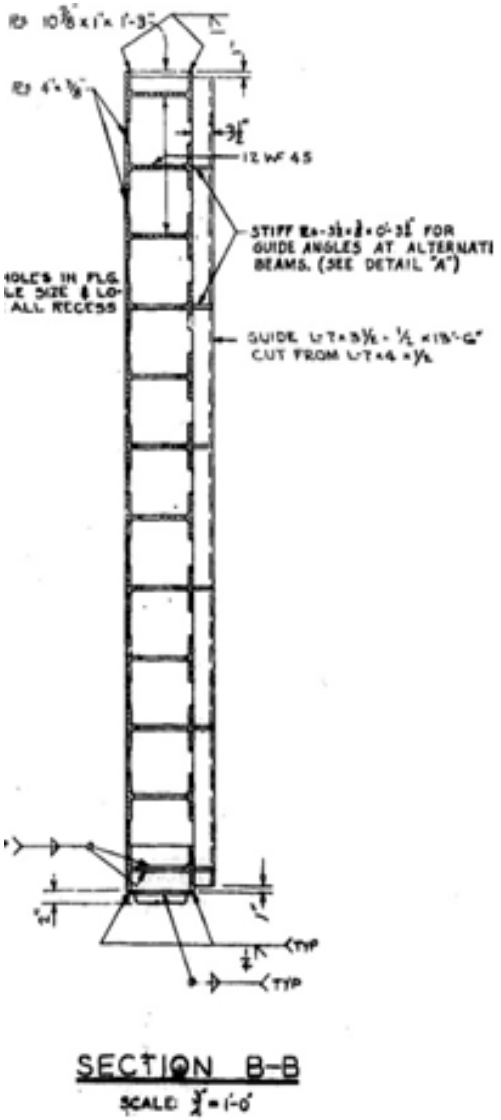
FRP miter block:

- FRP composite miter blocks selected survived 50 ksi that far exceeds the required 1.4 ksi with no cracking after fatigue load in excess of 500,000 cycles

RECESS PROTECTION PANEL (LOCKS & DAMS)

10’x12’ steel protection panel with heavy weight & corrosion

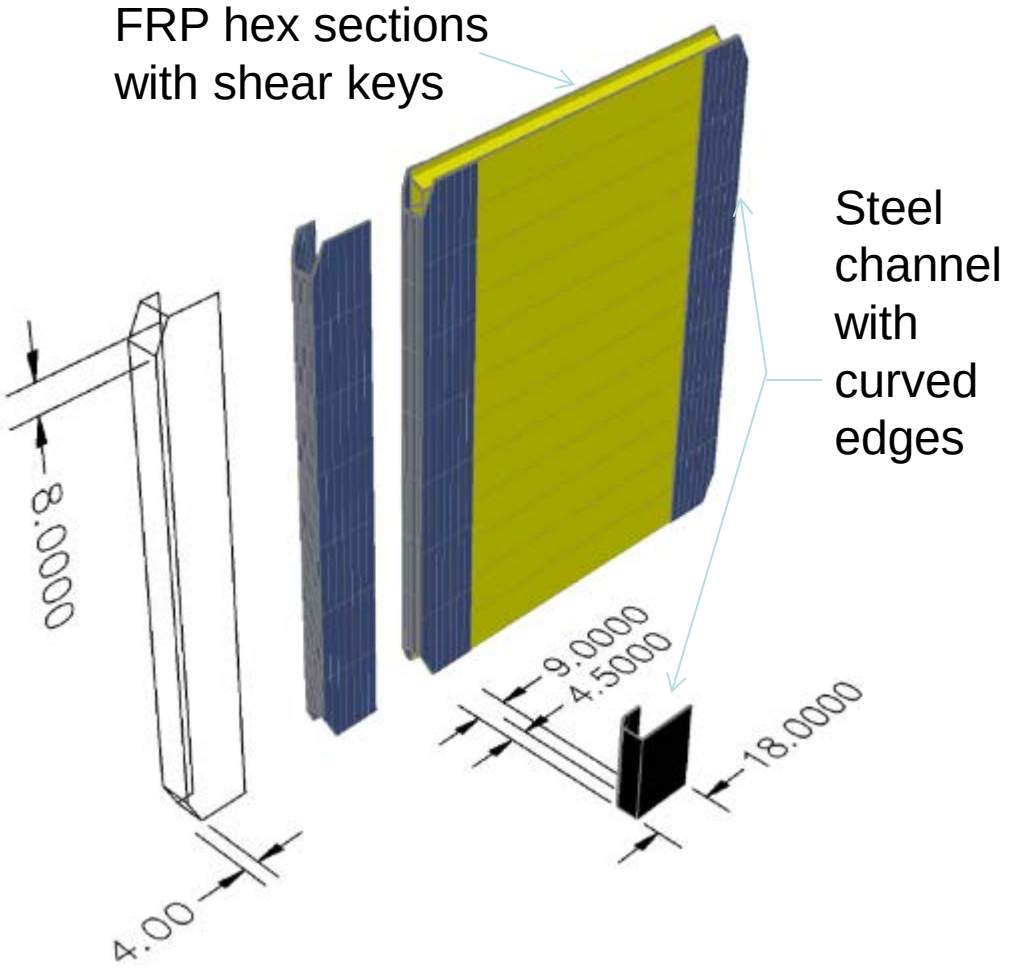
Existing panel requires difficult and extensive welding to fabricate



3- RECESS FILLER PANELS AT WILLOW ISLAND LOCKS AND DAM, OHIO.

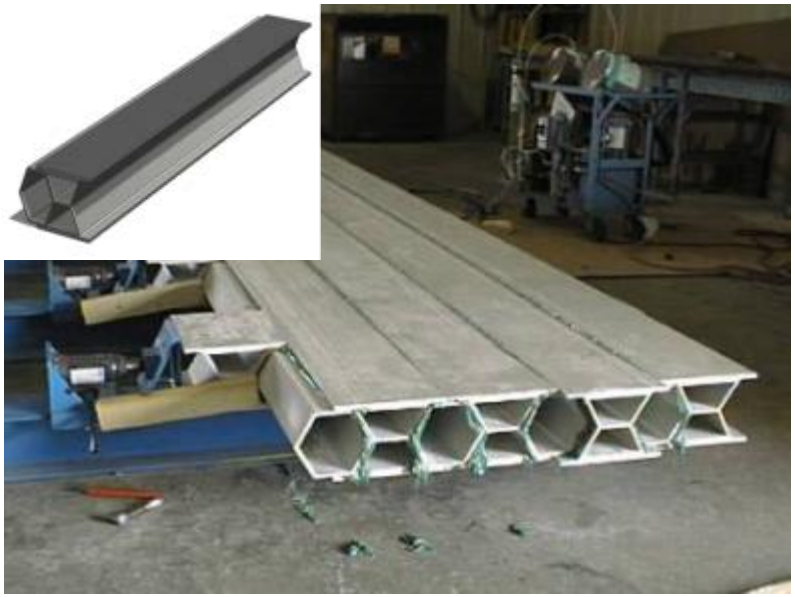
Finished Dimensions: 9’10.5”x11’10”

Laboratory testing



Final design

RECESS PANEL WITH FRP SUPERDECK



FRP superdeck required an edge steel frame housing.

Finished panels to be installed.

CONCLUSIONS

FRP recess panel:

Hexagonal FRP superdeck panel system showed excellent energy absorption characteristics. Steel panels costly, heavy, and they corrode – designed using off-the-shelf products.

FRP COMPOSITES DEMONSTRATIONS

- **Abrasion - Resistant Overlays for Tainter Gates at Heflin Dam, AL.** Swirling debris quickly damages traditionally used vinyl coatings.

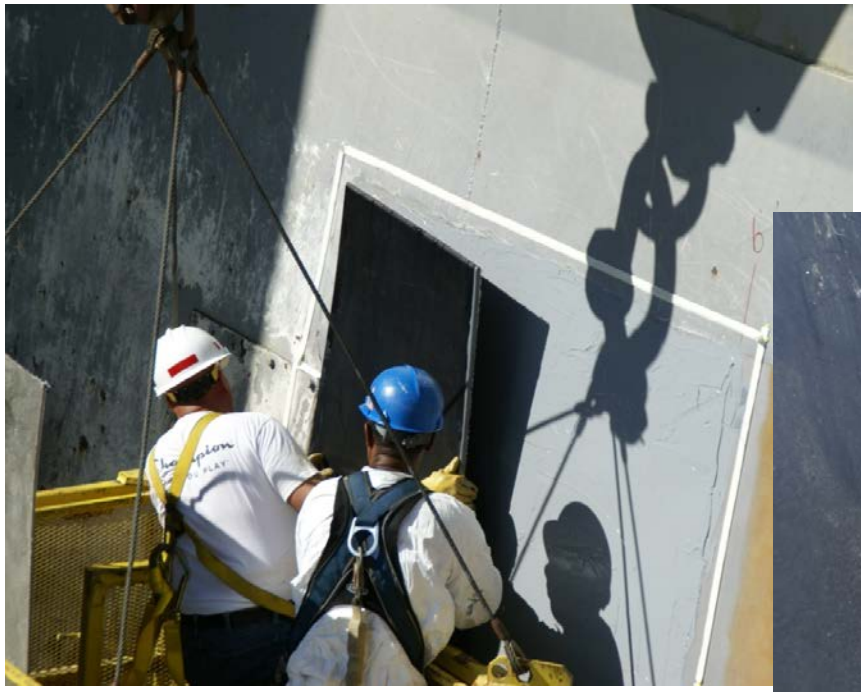
Use organic and ceramic composites for overlays

Abrasion - Resistant Overlays for Tainter Gates

Five systems to be applied: UHMWPE, two different ceramic composite coatings, same two coatings over vinyl 3-A-Z.

Adhesive being applied for bondable UHMWPE.

Abrasion - Resistant Overlays for Tainter Gates



3/8-inch thick UHMWPE sheets being set into adhesive.

Ceramic composite coatings applied by roller.

- **Will be inspecting condition this Fall after one year's exposure.**
- **UHMWPE panels to be applied to tainter gate at Meldahl L&D along with course ceramic-filled urethane modified epoxy mastic.**

CONCLUSIONS

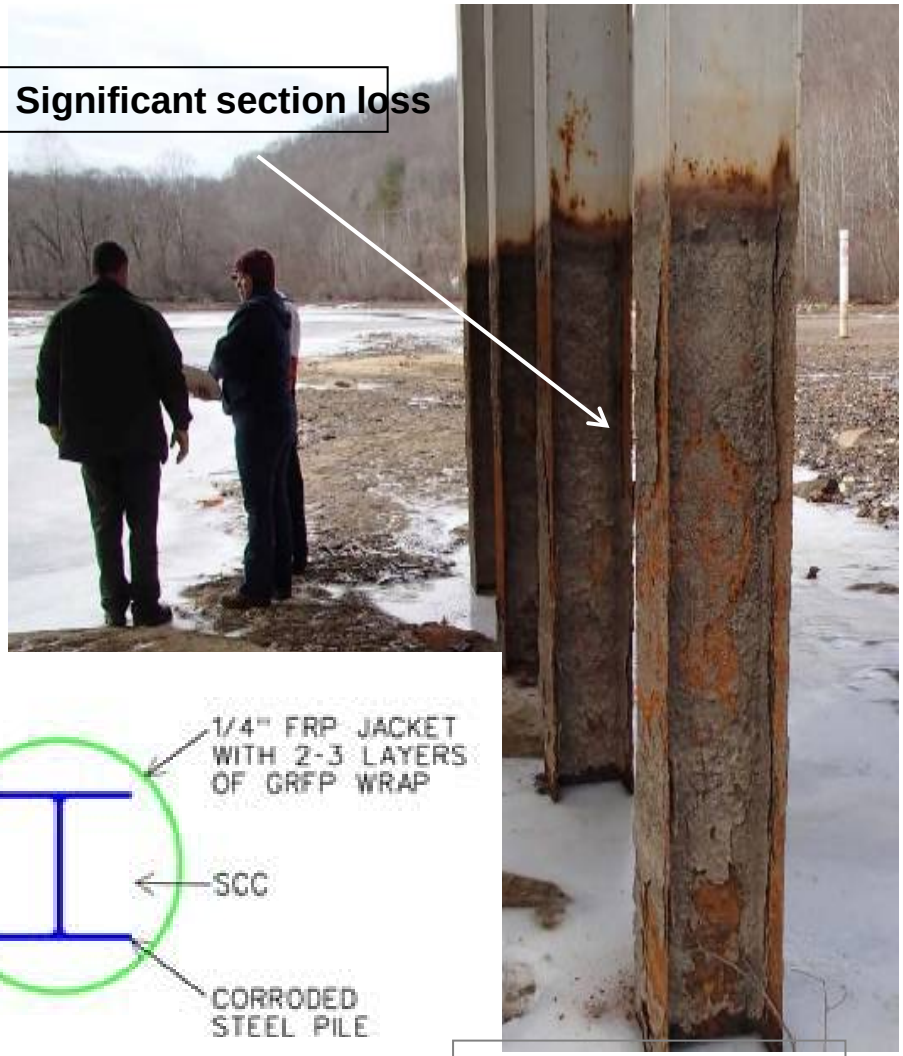
Abrasion resistant coating:

Traditional coatings fail. Lab results show the UHMW-PE plate and ceramic composite coatings performed the best under dry (none) and water immersion abrasion testing.

REHAB OF CORRODED STEEL H-PILES, EAST FORK BRIDGE (1969), HUNTINGTON, WV.

Bring load capacity back to original at 35% of cost using traditional methods. Use composite shell with wrap, and fill with self consolidating concrete (SCC).

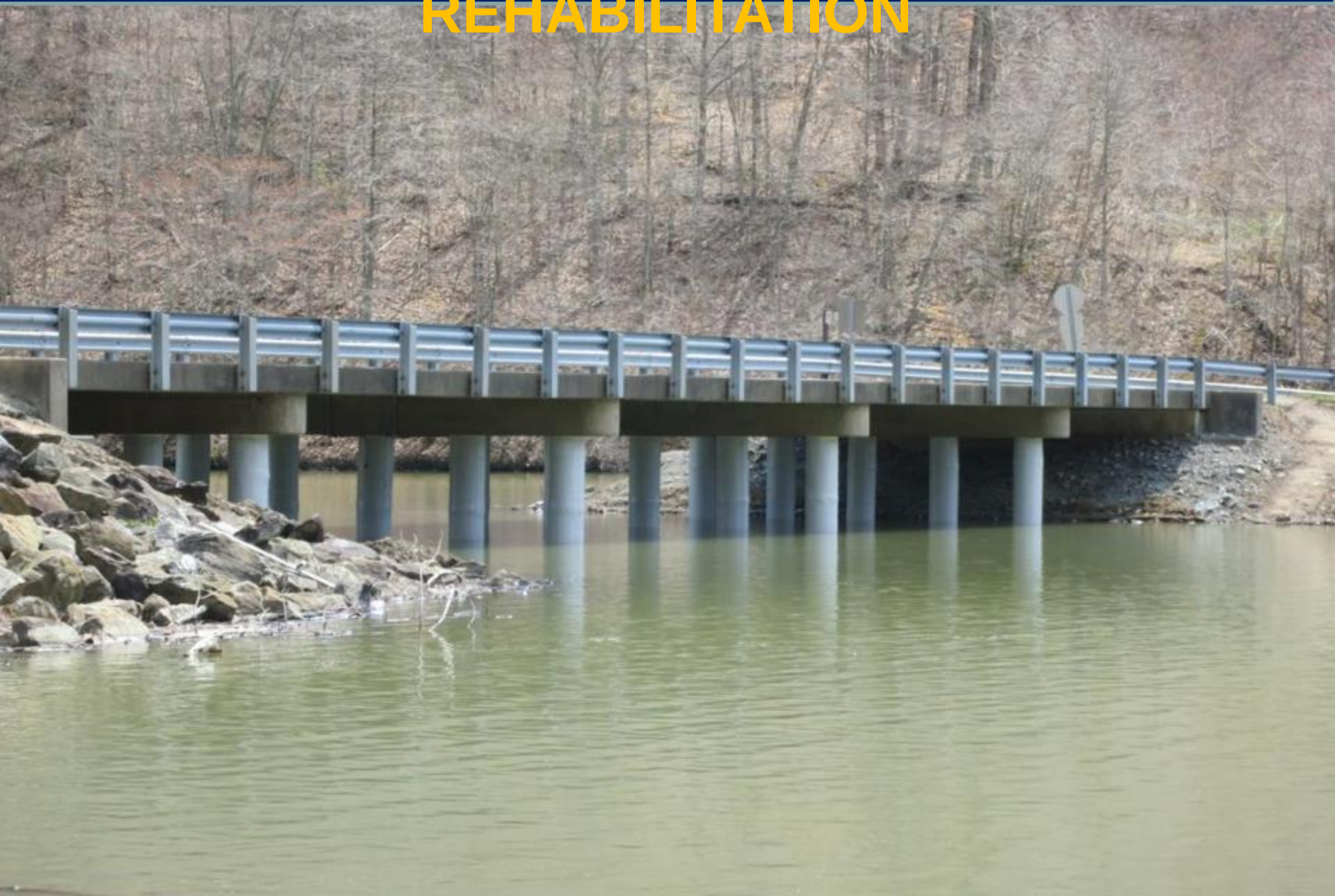
REHAB OF CORRODED STEEL H-PILES, EAST FORK BRIDGE, WV.



Repair design

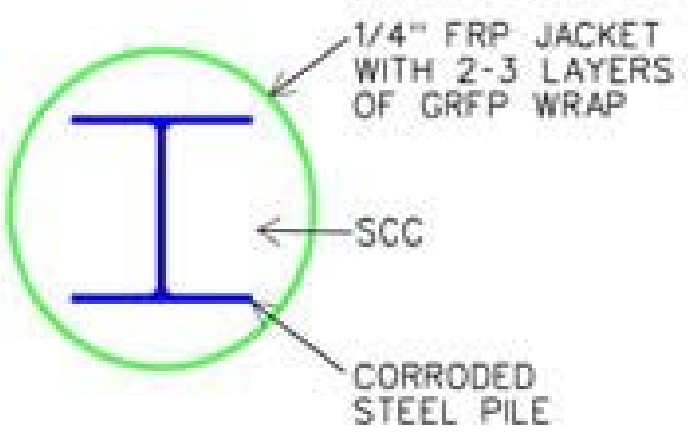
Wrapping the piles with FRP

5- BRIDGE OPEN TO TRAFFIC AFTER REHABILITATION



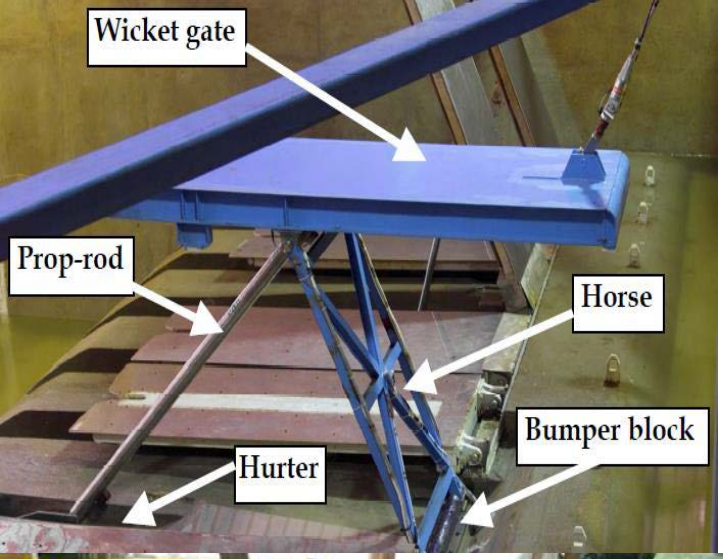
CONCLUSIONS

Rehab of Corroded Steel Piles:
Conventional fix of welding steel plates only good for 10-15 years. Corroded steel piles were rehabilitated to original load capacity with FRP jackets at 35% of cost using conventional methods.

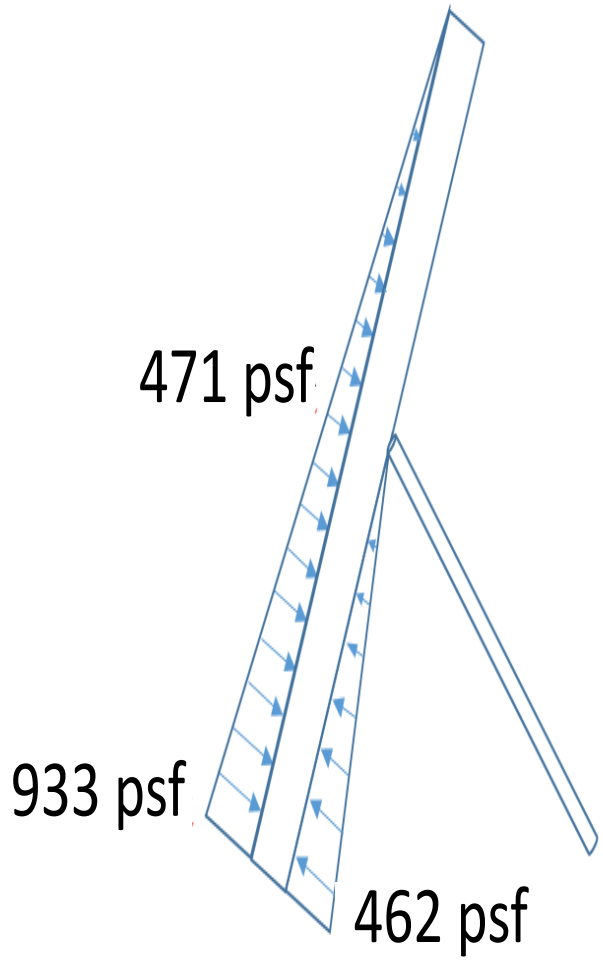


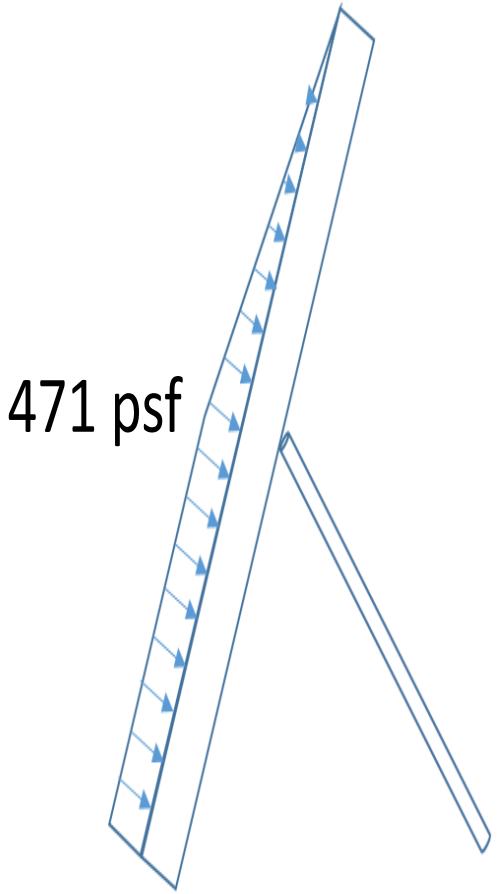
REPLACE TIMBER WICKET GATES

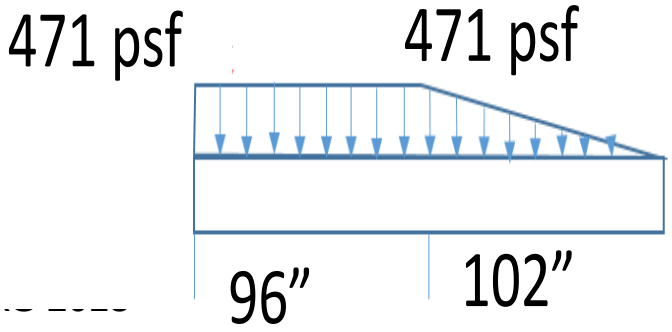
- The length and width of the gate is 16.5 ft. (5 m) and 46 inch (1.2 m).


Wicket gate
Prop-rod
Horse
Bumper block
Hurter


Gate-top
Prop Connection Zone
d/s side
Gate Bottom


471 psf
933 psf
462 psf


471 psf


471 psf
471 psf
96”
102”

“SMAR

- Three gates were fabricated with FRP using the old hardware.
- In August of 2015 all three gates were installed and appear to be functioning properly.
- Given the high safety factors obtained (4 for bending, 12 for shear) and demonstrated through physical testing and the corrosion resistance of the FRP, the 3 wicket gates should provide many years of satisfactory service.

New PIANC Working Group on Composites for Hydraulic Structures

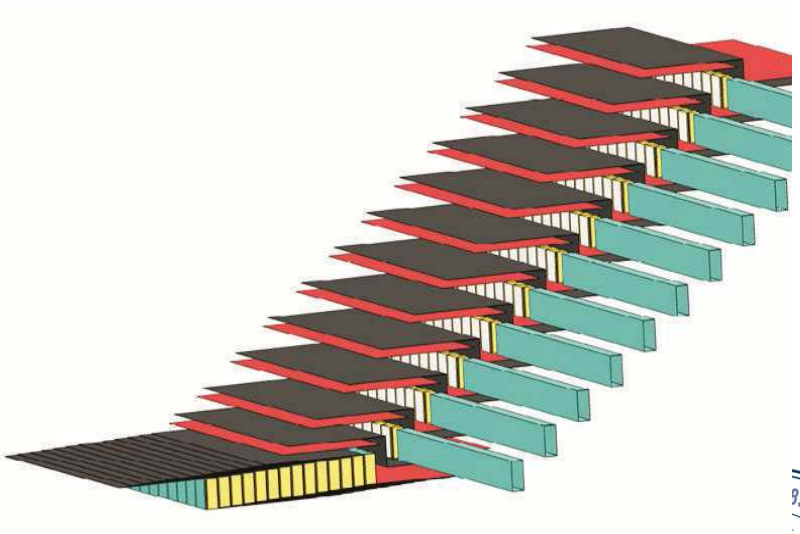
Will identify “Best Practices” where composites provide a benefit over conventional materials for hydraulic structures and to gather any applicable guidance documents. The design guidance will need to cover design parameters, fabrication, testing and inspection procedures to assure that a safe product is provided for field service.

We are also working with the Dutch Rijkswaterstaat to share Composite knowledge gained

Rijkswaterstaat
Ministry of Infrastructure and the Environment

WORLD'S LARGEST FRP COMPOSITE MITER GATE

- Upper gate single leaf - 6.3 x 4.8 m (20.7 x 15.7 ft)
- Lower gate single leaf - 6.3 x 12.3 m (20.7 x 40.4 ft)



Future Possible Additional Applications for Composites

- **Valves**
- **Quoin blocks**
- **Bulkheads / stop logs**
- **Repair cracked steel**
- **Rehab lock walls and approaches**
- **Miter/Tainter gates**
- **Suggestions?**

Aluminum vs. FRP

There is a future in Civil Works projects for composites that will improve reliability at a lower cost. We just need to make the right choices. We also need your help to make this a reality.

Questions

If you are interested in the new Composite WG contact:

john.d.clarkson@usace.army.mil