FRP COMPOSITES FOR REHABILITATION OF HYDRAULIC STRUCTURES

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Navigating the New Millennium

INTRODUCTION

- Goal is to expand use of Fiber Reinforced Polymer (FRP) composites in Civil Works projects. Currently extensively used in Auto, Aviation, and Marine applications.
- Make use where there is a material property advantage.
- Approach is to crawl, walk, and run.

Known Composite Gates from Innovative WG

Golbey Gate Replacement - Composite Miter Gates , France

Lock Spieringsluis, Netherlands

BACKGROUND

- 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.

Preliminary uses of FRP

Composite Beams in lieu of Timber

Preliminary uses of FRP

Replacing wheels on floating mooring bits with polymer slides.

Replace Frozen Rollers on Lift Gates at Bankhead Lock & Dam, AL.

- The reaction rollers ceased up due to corrosion and drag when gate is raised or lowered. Design a repair using polymer composite glides with no moving parts.

Replace Frozen Rollers on Lift Gates

Rollers on lift gates no longer functioning due to corrosion that has caused the bearings to seize up.

New pads installed

No moving parts

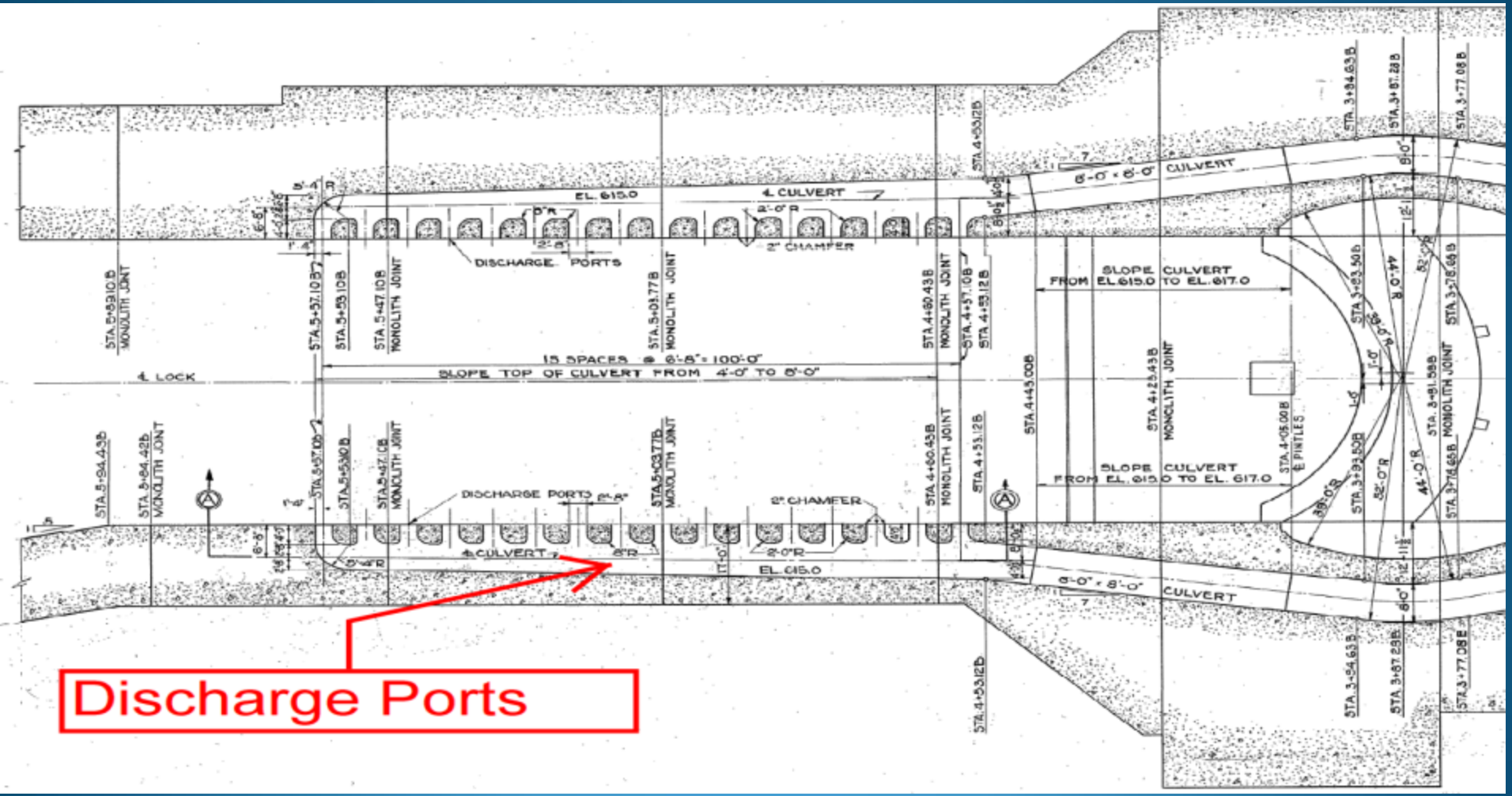
Current Research Projects

Designing and developing FRP composite wraps, shapes, and components to replace or rehabilitate:

1. Underwater curable FRP wrapping of submerged concrete discharge ports.
2. FRP blocks for miter gates.
3. FRP recess filler panels.
4. Abrasion resistant composite coatings.
5. Repair of corroded steel columns of a concrete bridge deck.

1- UNDERWATER WRAPPING

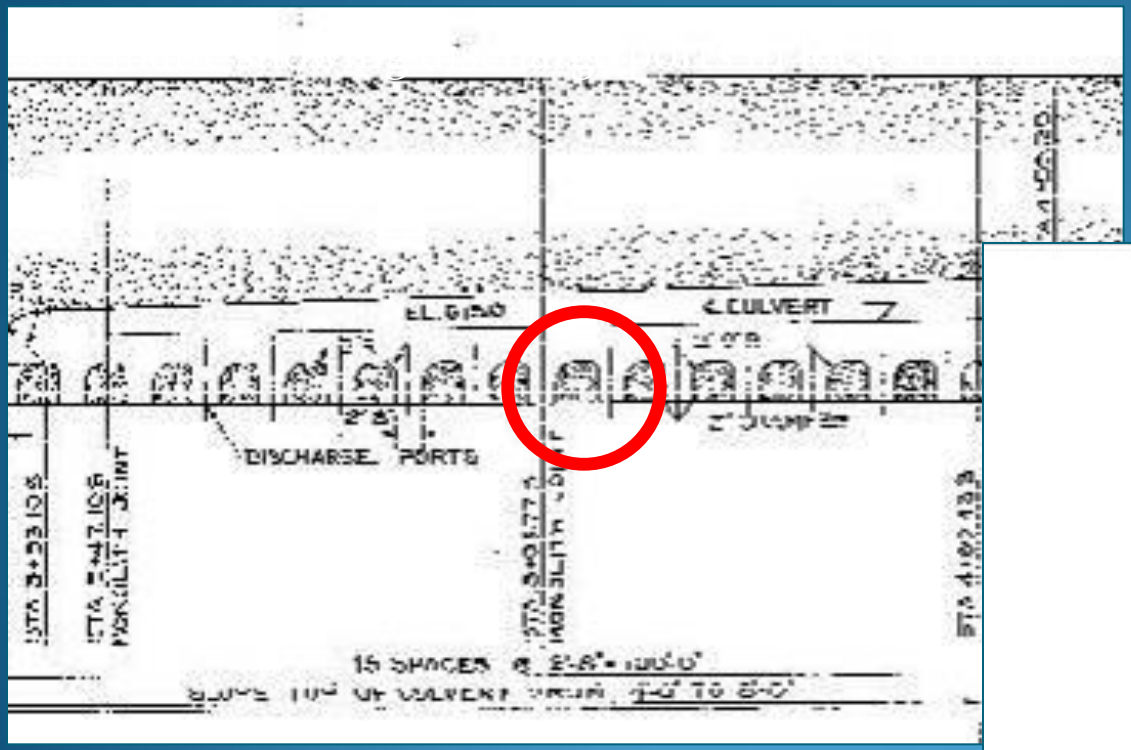
- Repair water submerged concrete discharge ports with FRP



View of discharge ports

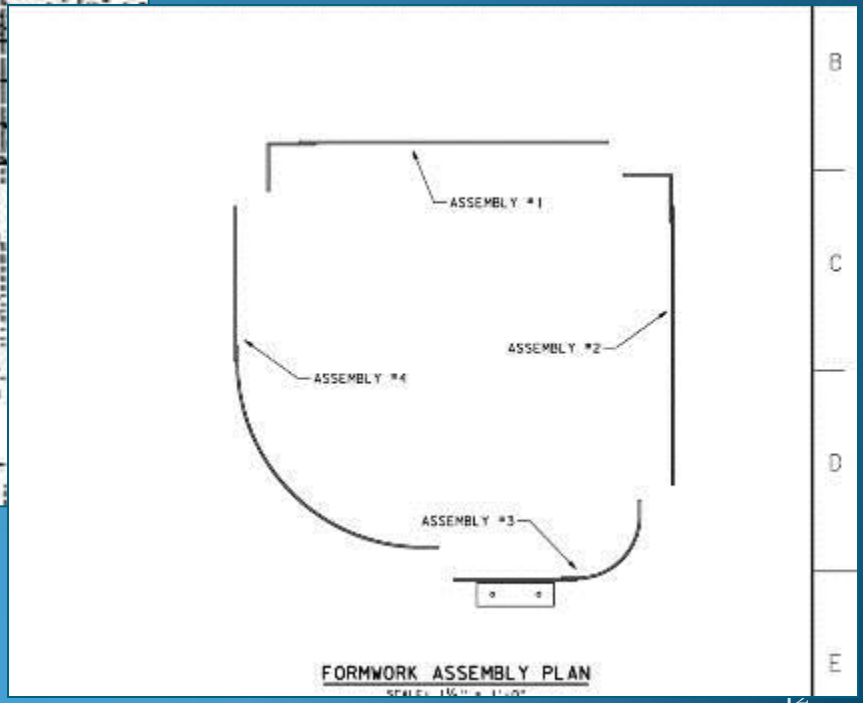
FRP Composites Demonstrations

Repair concrete discharge ports at Chickamauga Dam 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



Cracking concrete columns

Steel repair shell
358 lbs total weight !



1- LAB STUDY AND MATERIALS

Concrete cylinders (4”x8”)- 36 cylinders

Resin impregnated & heat resistant Aquawrap 142 ^{0}C (288 ^{0}F).

BP-4 primer

Stricture banding
(Compresses & consolidates Aquawrap)

Perforator tool
(Releases curing generated gas buildup)

1-SURFACE PREPARATION & PRIMER APPLICATION

- **Surface Preparation**
  - *Fill cavities with grout.*
  - *Abrade protrusions.*
- **Application of BP-4 Adhesive/Primer**
  - *Mix BP-4 part B and part A (1:2 by vol).*
  - *Apply ~40±5 mils on concrete surface.*
- **Aquawrap Wrapping**
  - *Open the pouch and wrap around the concrete by creating tension (hand-pulling) for desired number of layers.*
  - *Apply 2-4 layers of stricture banding over Aquawrap and perforate with perforator tool. Let it stay for 1-2 hours.*
  - *Remove stricture banding and apply final coat of BP-4 primer. Let it cure for 48 hours.*

1- CYLINDER TESTS

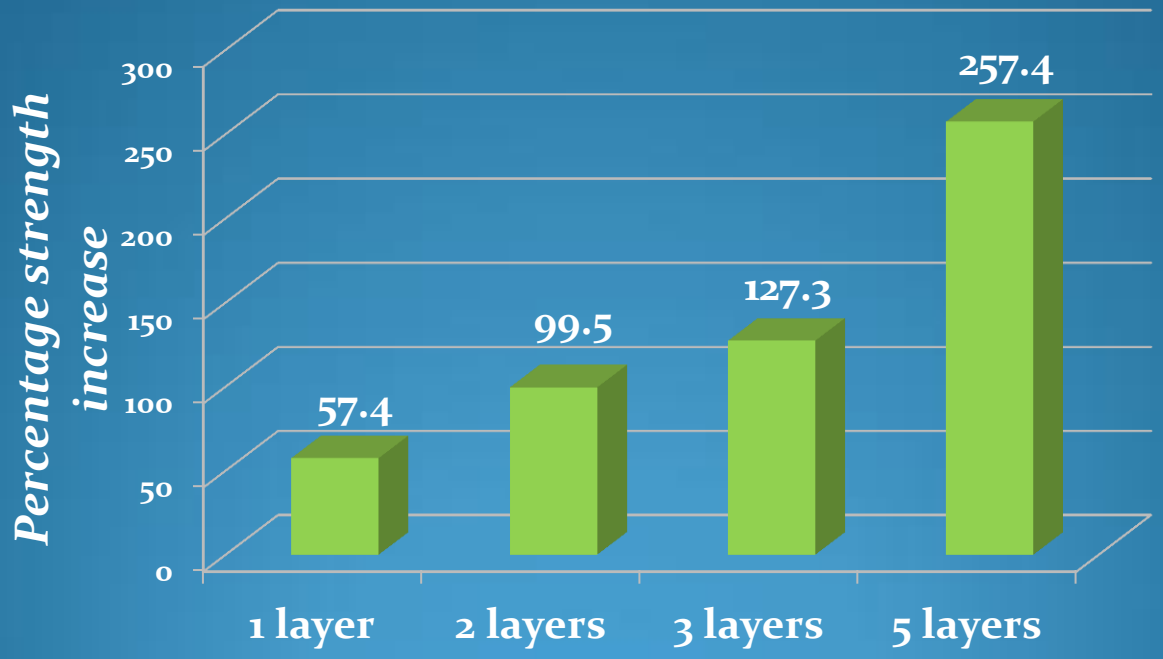
- Concrete cylinders with & without wrap (4”x8”) were tested under axial compression (ASTM C-39).
- Cylinders were capped on both ends with elastomeric pads to achieve concentric axial loading.

Number of wraps	Avg. Axial Strength KN (lbs)
0 (None)	107 (24139.5)
1	169 (37999.0)
2	214 (48152.7)
3	244 (54869.0)
5	384 (86268.3)

Compression tests on wrapped cylinder

1- TEST RESULTS AND ANALYSIS

- 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%.



1- TWO LAYERS OF WRAP FOR REPAIR

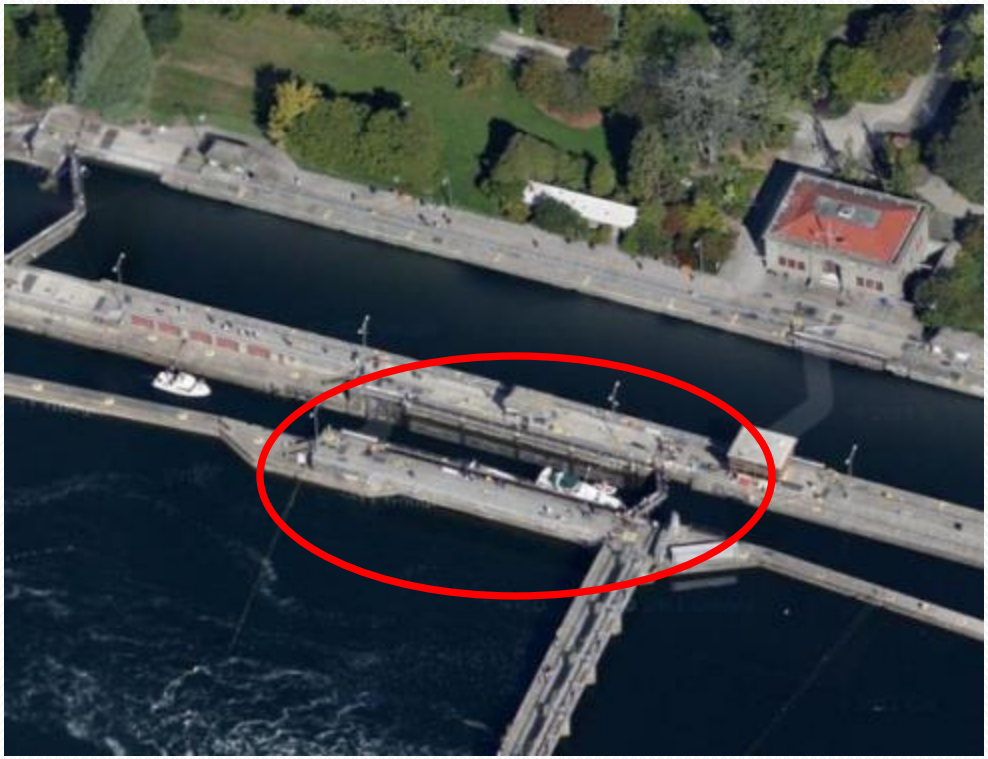
Repair concrete discharge ports at Chickamauga Lock in Tennessee.

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

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

2- MITER BLOCKS

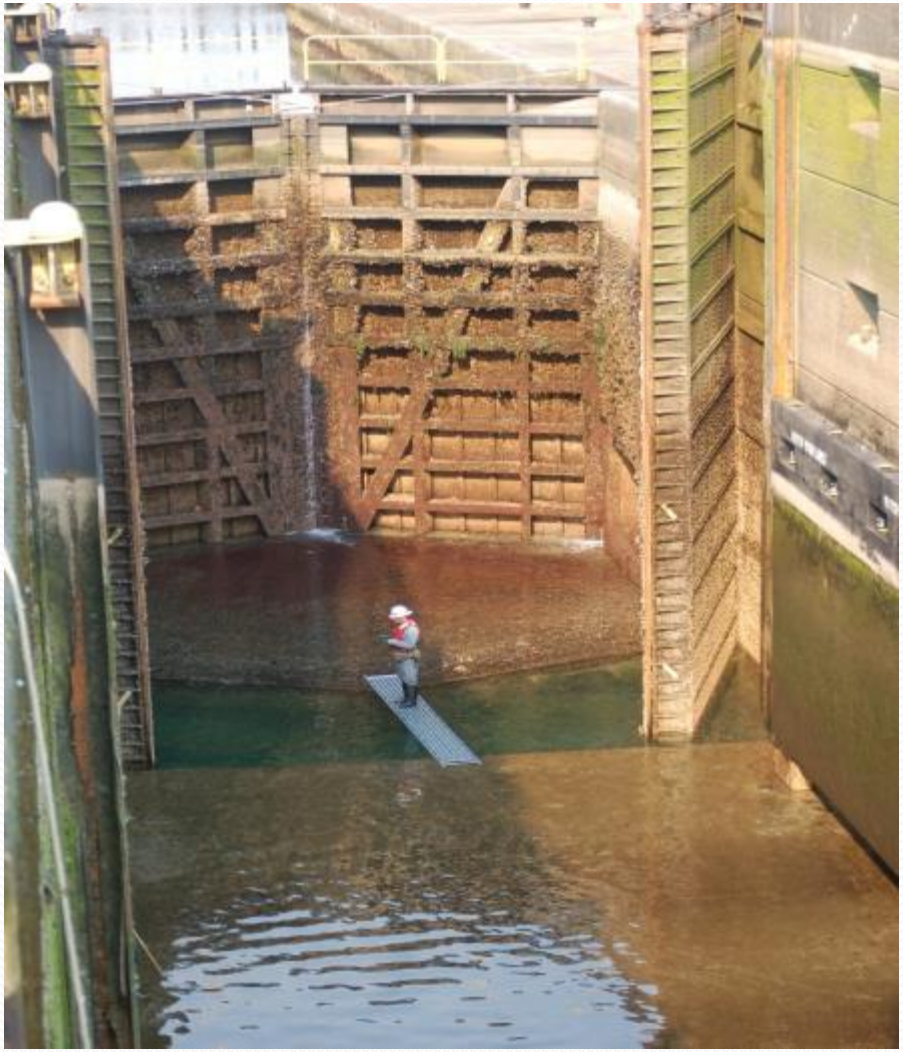
- **FRP Composite Miter Blocks for small lock on Washington Lake Canal, WA.** Corrosion of steel miter blocks can lead to leakage and gate misalignment.

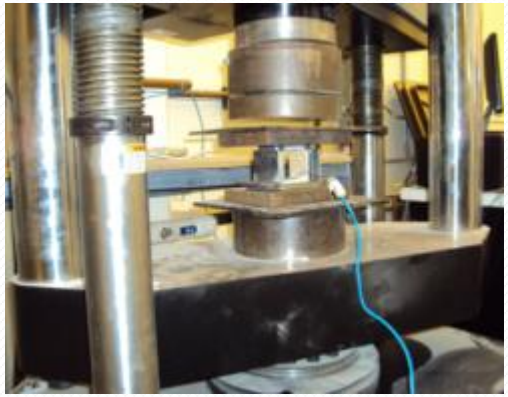


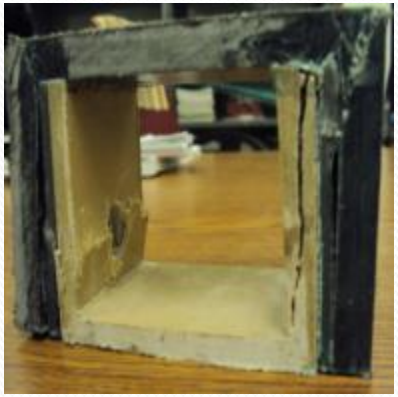
Small lock at Hiram Chittenden (Washington Lake Canal) Locks, Seattle, WA.

Corroded steel miter blocks.

2- CORROSION RESISTANT FRP FOR MITER GATE BLOCKS (Washington Canal)







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)

2- FRP COMPOSITE MITER BLOCKS FOR SMALL LOCK ON WASHINGTON LAKE CANAL, WA.

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

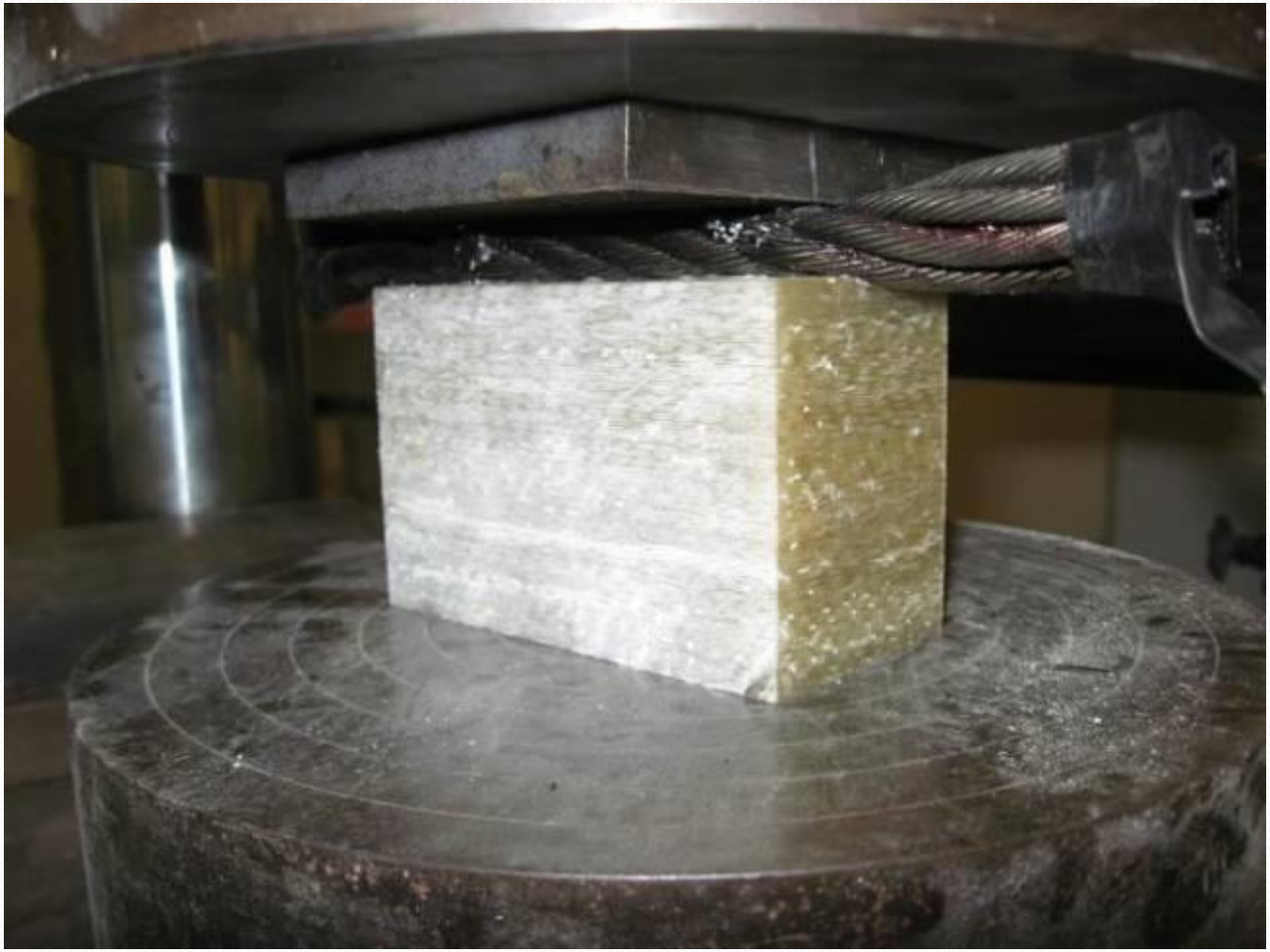
2- FRP MITER BLOCKS (4”X2.5”X2”)

Group	No. of Variations	Example	Load Range Kips	
I	5		Max. 84 kips (with core)	No-cracking & Group IV specimen is selected for field installation. Specimen provided ~ 51 ksi failure stress.
II	4		Max. 145 kips	
III	1		Max. 192 kips (at deflection limit of 0.23”)	
IV	1		> Max. is 224 kips (UTM limit)	

Note: Groups I & II consist of trimmed FRP tubes & plates with foam core or solid square tube cores. Groups III & IV consist of solid FRP sheets and block.

2- MITER BLOCK PINCH TESTS

Pinching Behavior with Foreign Object



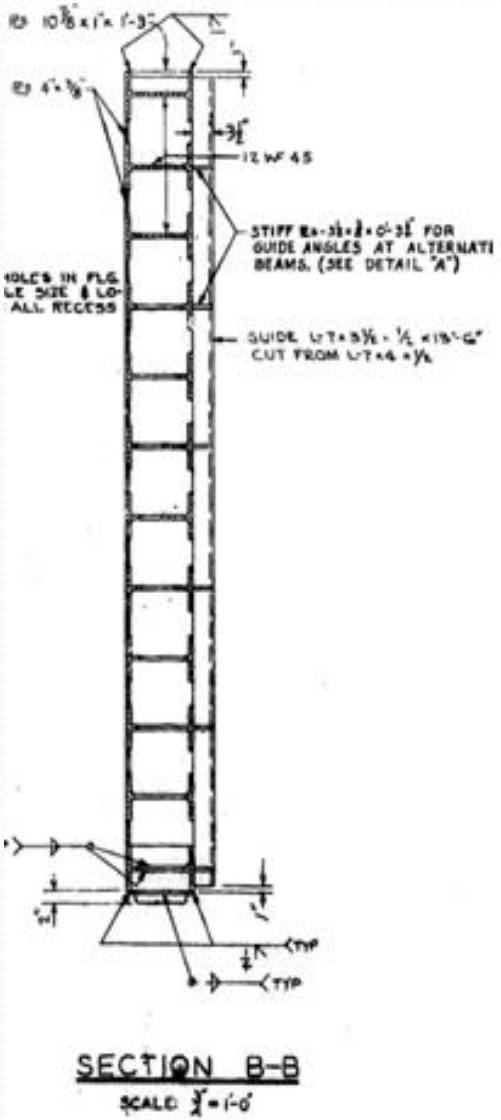
2- FRP COMPOSITE MITER BLOCKS FOR SMALL LOCK ON WASHINGTON LAKE CANAL, WA.

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. Scheduled for installation during dewatering in October 2014.

3- RECESS PROTECTION PANEL (LOCKS & DAMS)

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

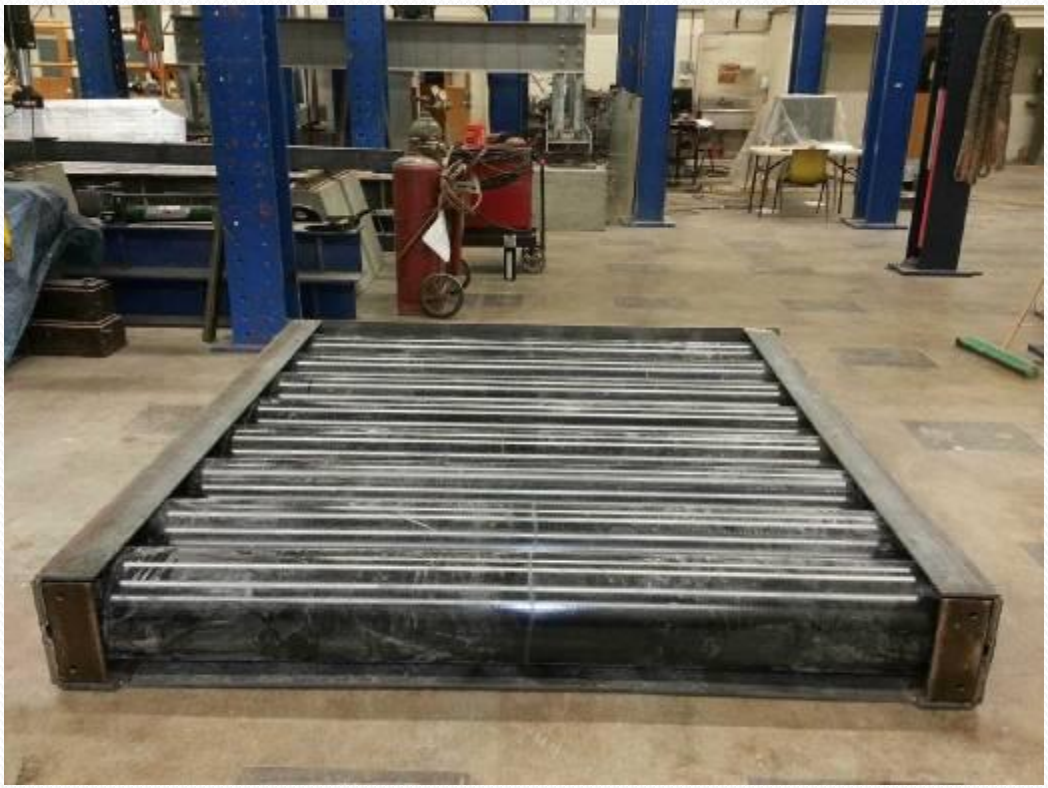
Existing panel is requires difficult and extensive welding to fabricate



3- FRP COMPOSITES DEMONSTRATIONS

- **Recess Filler Panels at Willow Island Locks and Dam, Ohio.** Steel panels costly, heavy, and they corrode.

Current steel panels

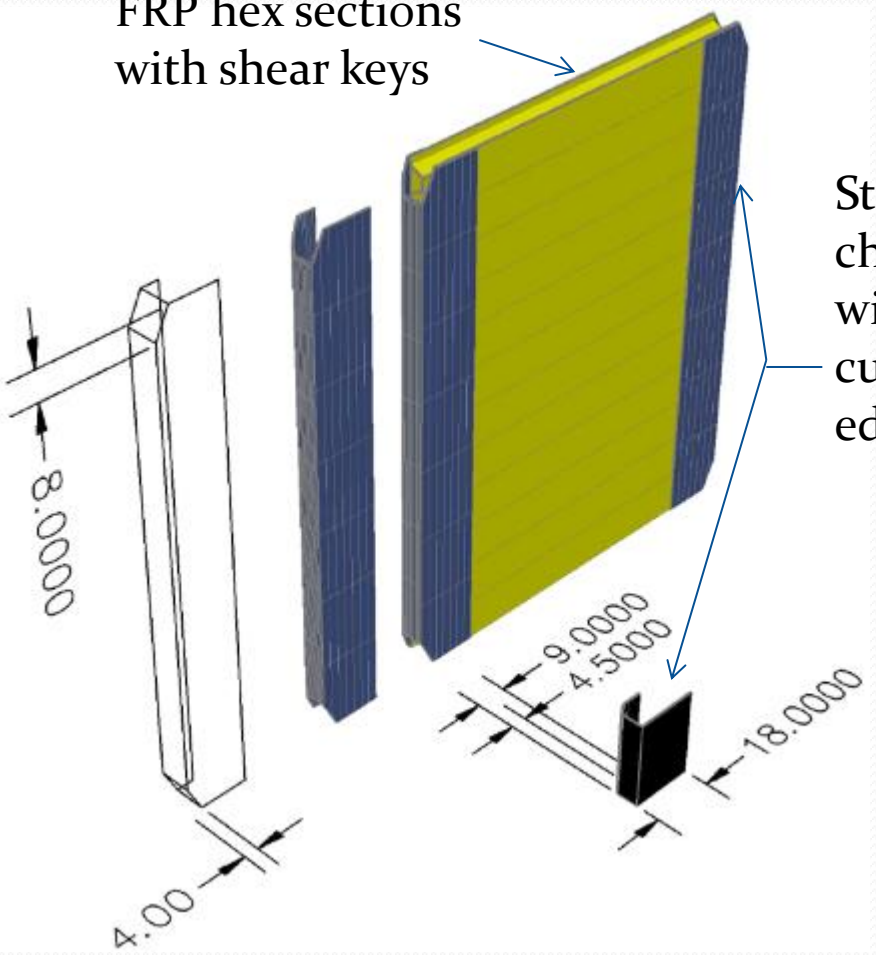


Initial tube and plate design

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

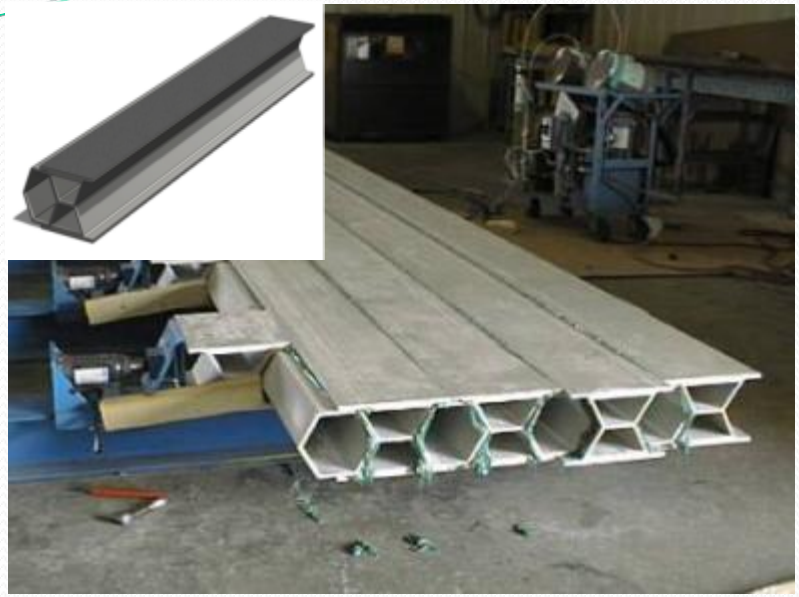
Finished DimensionS: 9’10.5”x11’10”

Laboratory testing



Final design

3- RECESS PANEL WITH FRP SUPERDECK



FRP superdeck required an edge steel frame housing.
Finished panels to be installed Spring of 2014.

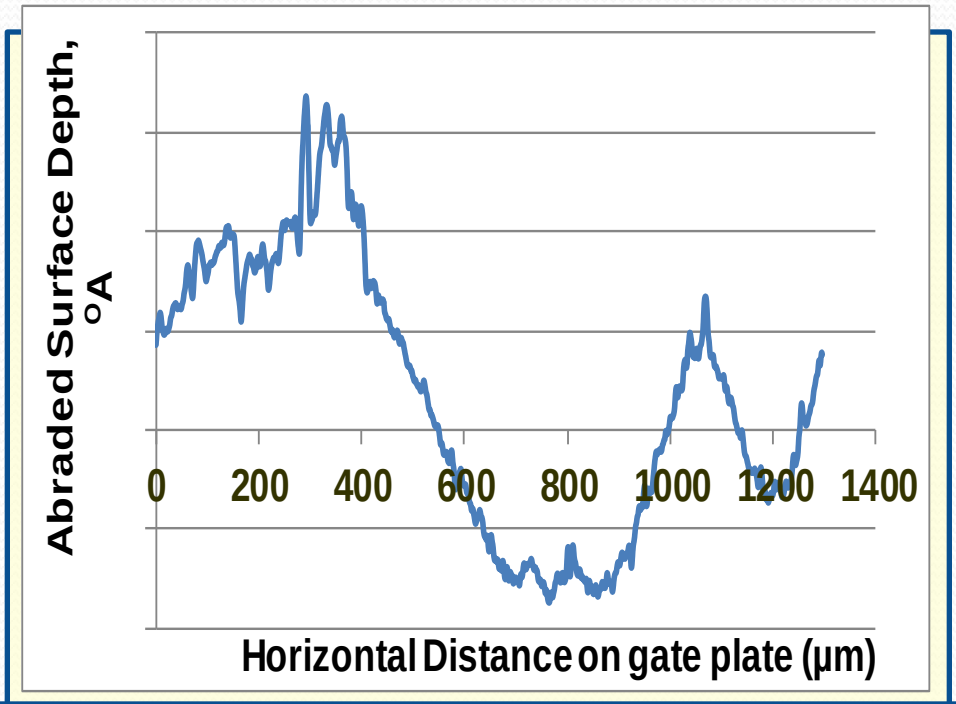
4- FRP COMPOSITES DEMONSTRATIONS

- **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

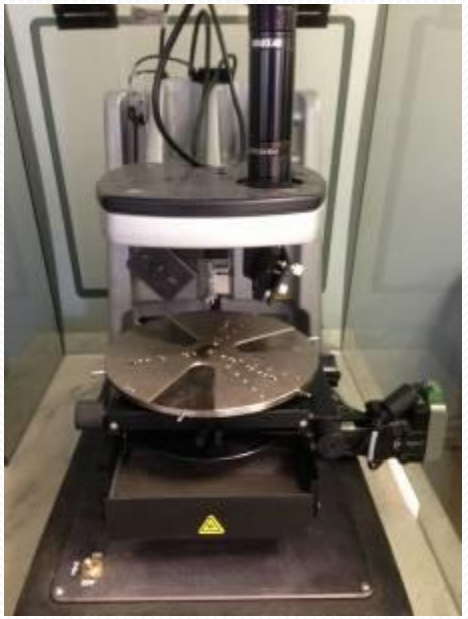
4- ABRASION-RESISTANT COATING SYSTEMS FOR TAINTER GATES

Profilometer
(1 ºA sensitivity)



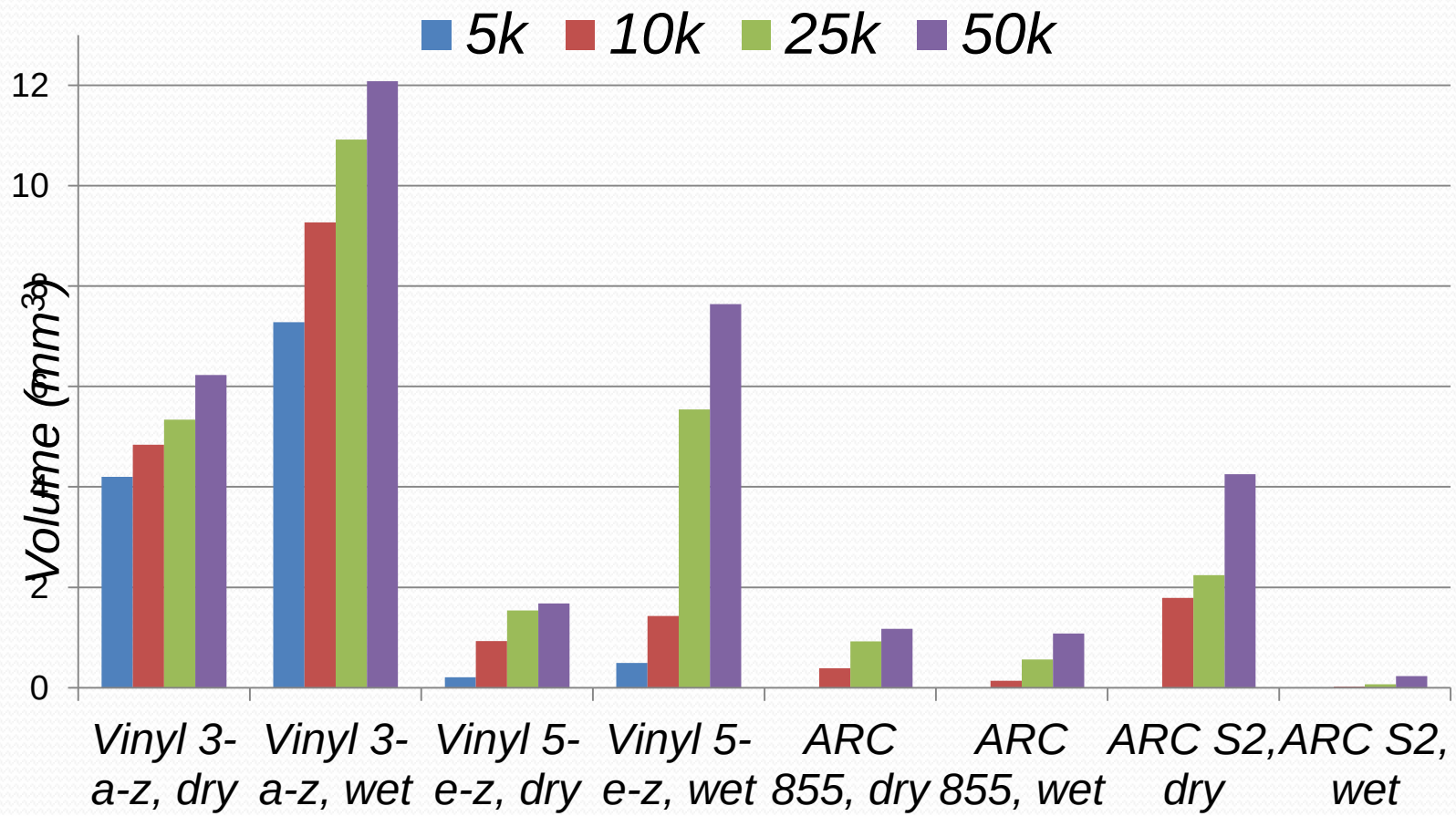
Samples	Coatings	Abrasion
	Vinyl 3-E-Z (Current)	~1 mil 500 cycles
	ARC 855 Ceramic Comp.	~0.14 mil 1500 cycles
	Vinyl 5-A-Z	~ 0.14 mil 2000 cycles
	Tar guard	Similar to 3-E-Z

4- ABRASION - RESISTANT OVERLAYS FOR TAINTER GATES AT HEFLIN DAM, AL.



Reciprocating Abrading Steel Ball System (L) with Computerized Control & Profilometer (R) (Note: the tank will accommodate both securing of specimen and conditioning with liquid)

4- ABRASION - RESISTANT OVERLAYS FOR TAINTER GATES

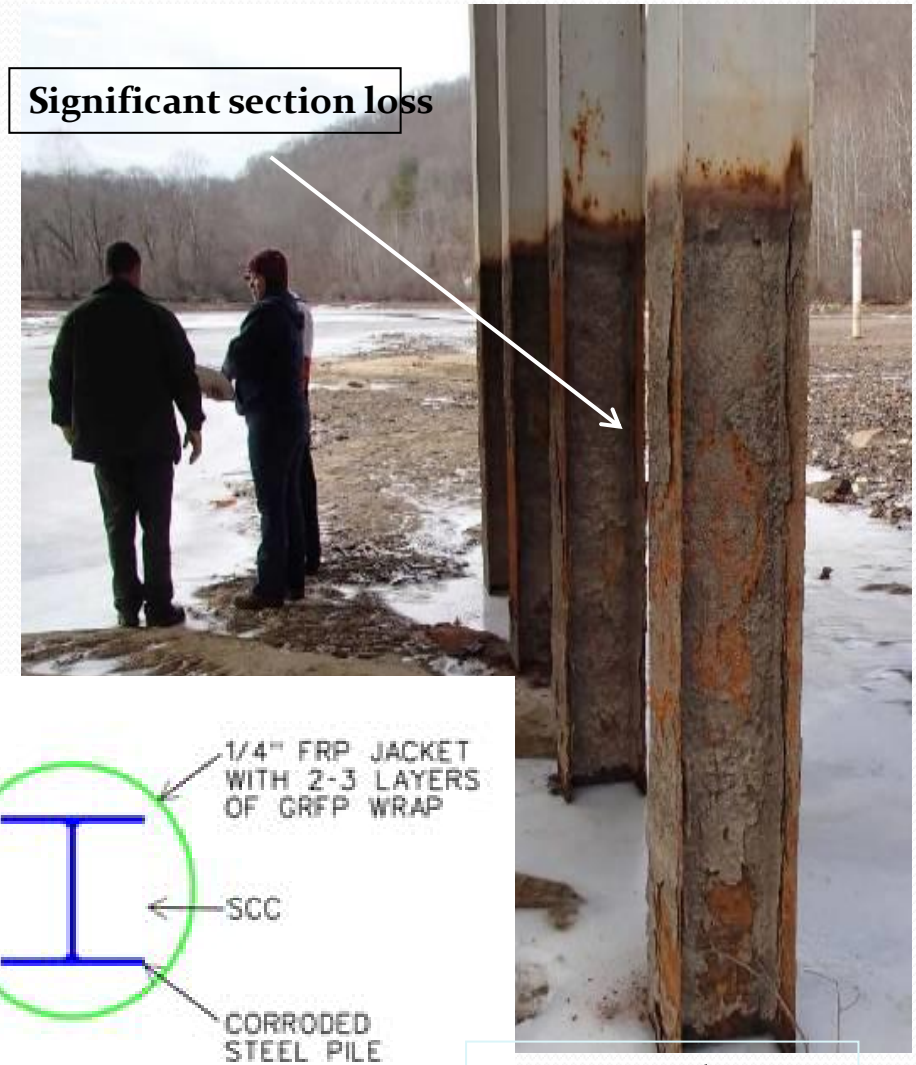


Due to scheduling problems, now planning to install these coatings/overlay on a gate along the Arkansas River, Little Rock District.

5- 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).

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



Repair design

Wrapping the piles with FRP

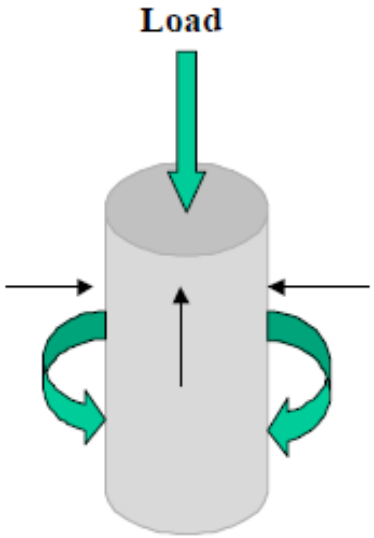
5- FRP SHELL AND WRAP WITH SCC FILLING

5- BRIDGE OPEN TO TRAFFIC AFTER REHABILITATION

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.



CONCLUSIONS

FRP miter block:

- Solid FRP miter block met strength requirements under both the static and fatigue loads, carrying an average failure stress of 51 ksi (vs. required 1.4 ksi). Additional warping studies are underway. Non-corrosive and better sealing.

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.

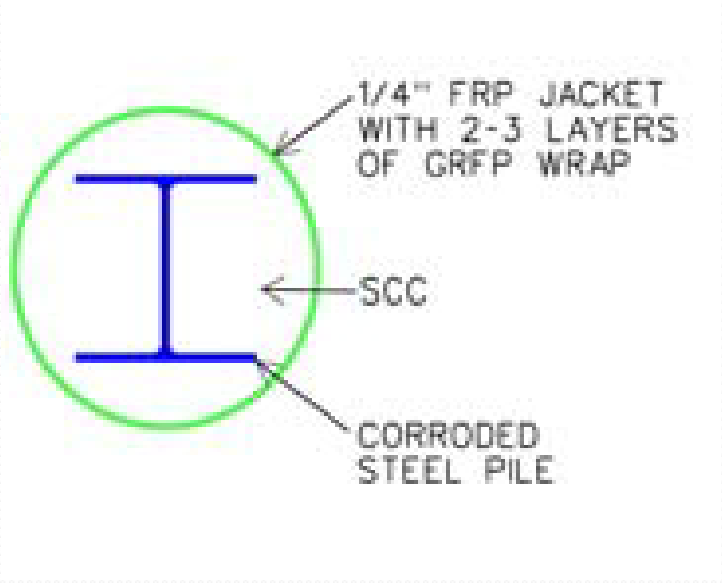
CONCLUSIONS

Abrasion resistant coating:

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

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.



6- FRP COMPOSITES R&D – NEXT STEP

- **FRP Composite Wicket Gates.** Timber wicket gates: rapid deterioration, costly to replace. infrastructure.

Rapid and severe deterioration in traditional wooden wickets. Replacement is costly.

Building on Success!

- Prototype wicket gates will be developed using both thermoset and thermoplastic composites to be installed along the Illinois River, Rock Island District.
- Stepping stone to future design and application of other larger FRP composite valves and gates.
- Extend the life of new and existing infrastructure.

Composites will increasingly be utilized in civil works projects.

If you have questions or know of other applications please contact:

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