ERDC
Engineer Research and Development Center

Polymers / Composites for the Rapid Repair and Maintenance of Navigation Structures

Technology Exchange Meeting
Vicksburg, MS

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US Army Corps of Engineers®

R&D Activities and Field Demonstrations

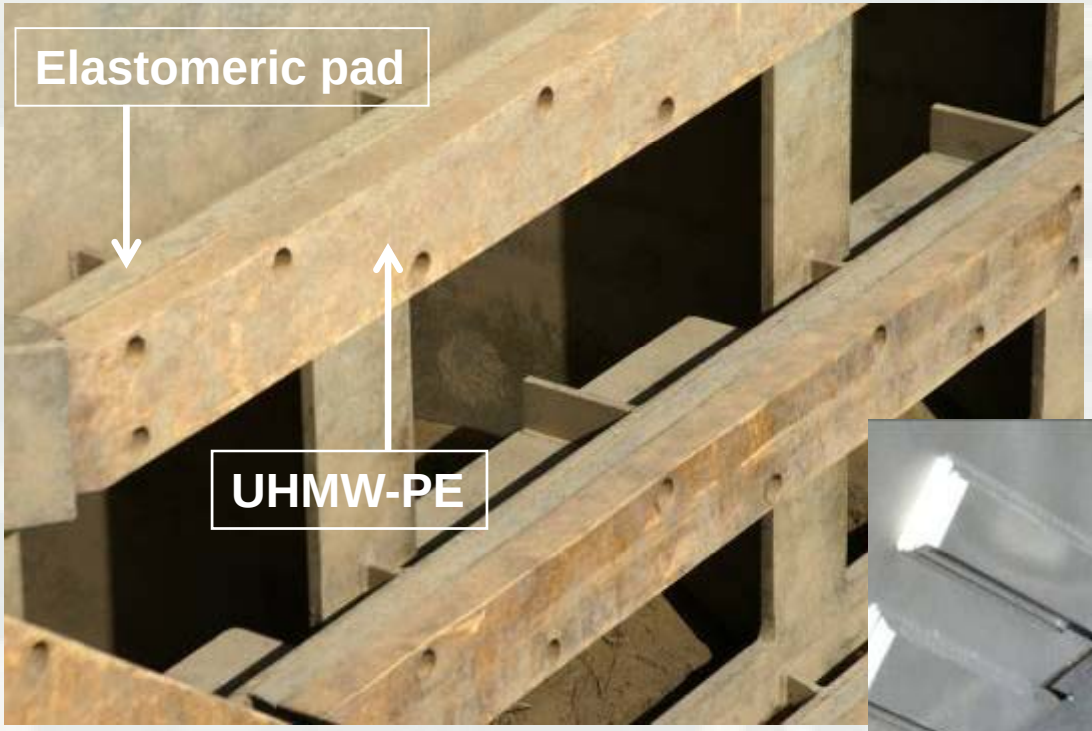
- **FRP Composite Timbers for Guide Walls and Gates.** Lack of guidance and mixed success with use in the field.
- **Replace Frozen Rollers on Lift Gates at Bankhead Lock & Dam, AL.** Replace rollers with polymer composite slides with no moving parts.
- **FRP Composite Miter Blocks at Washington Lake Canal, WA .** Non-corrosive and better sealing.
- **Repair Concrete Discharge Ports at Chickamauga Dam, TN.** Underwater curable composite wrap – easier and more durable than using steel jackets and grout.
- **Recess Filler Panels at Willow Island Locks and Dam, OH.** Steel panels costly, heavy, and they corrode – designed using off-the-shelf products.
- **Abrasion - Resistant Overlays for Tainter Gates at Heflin Dam, AL.** Swirling debris quickly damages traditionally used vinyl coatings.

R&D Activities and Field Demonstrations

- **Rehab of Corroded Steel H-Piles, East Fork Bridge, Huntington, WV.** Bring load capacity back to original at 35% of cost using traditional methods.
- **FRP Composite Wicket Gates.** Timber wicket gates: rapid deterioration, costly to replace. Stepping stone to future design and application of other larger FRP composite gates and valves.
- **Evaluation of Emerging Filler Materials for Miter and Quoin Blocks.** The Unified Facility Guide Specifications UFGS 35 20 16.33 "Miter Gates" is outdated and the epoxy filler specified in the guide specification is no longer available.

FRP Composite Timbers for Guide Walls and Gates

- **Lack of guidance and mixed success with use.**



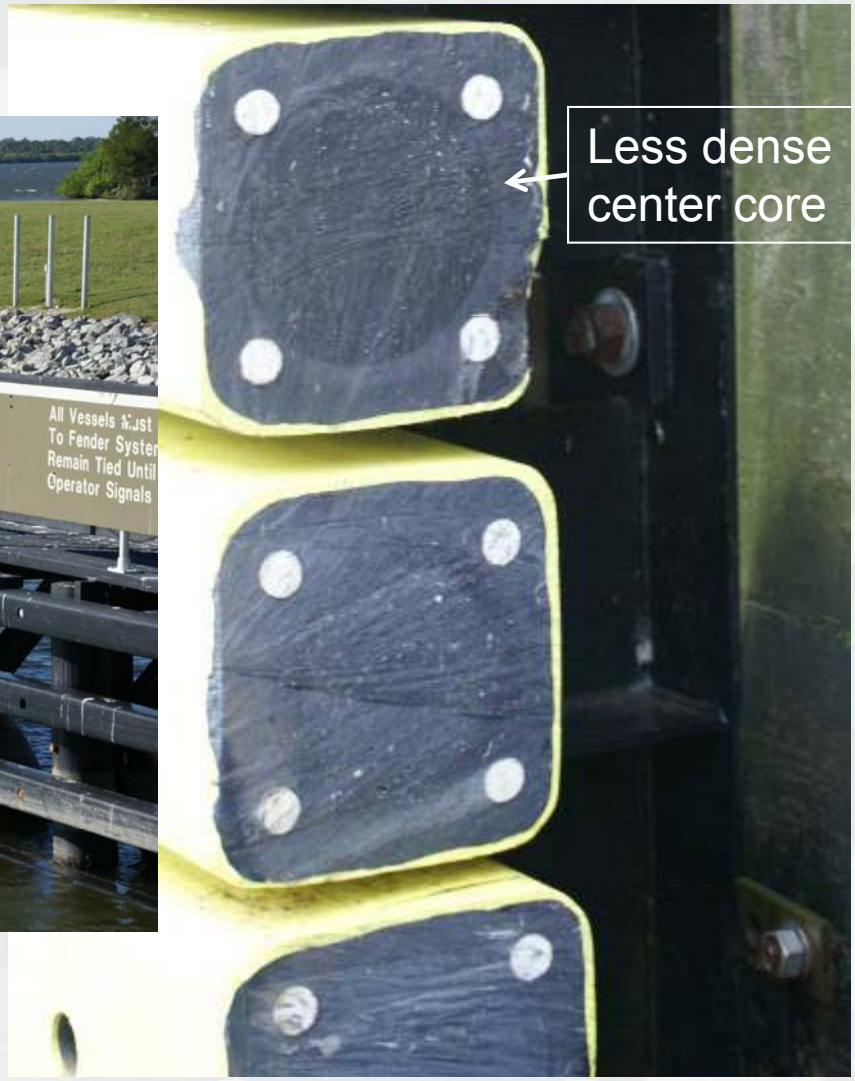
Plastic timbers can be "less" energy adsorptive than natural wood.

Per current designs, question the usefulness of the elastomeric pad behind the UHMWPE in an impact situation.

- **FRP Composite Timbers for Guide Walls and Gates.**

Hollow steel tubes will provide some energy adsorption on impact, but may only be functional in that regard for one impact. After that, they will need to be replaced.

- **FRP Composite Timbers for Guide Walls and Gates.**



FRP Composite Timbers for Guide Walls and Gates.

L&D #52 – Need a cost-effective, 10-15 year solution.

Using UHMWPE sheets bolted to approach/lock wall.

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UHMWPE rub rails on lock approach wall being knocked off.

Working with Bonneville Dam and Portland District for solution.

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

- **The reaction rollers cease 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 at Bankhead Lock & Dam in AL.

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

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

BUILDING STRONG®

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

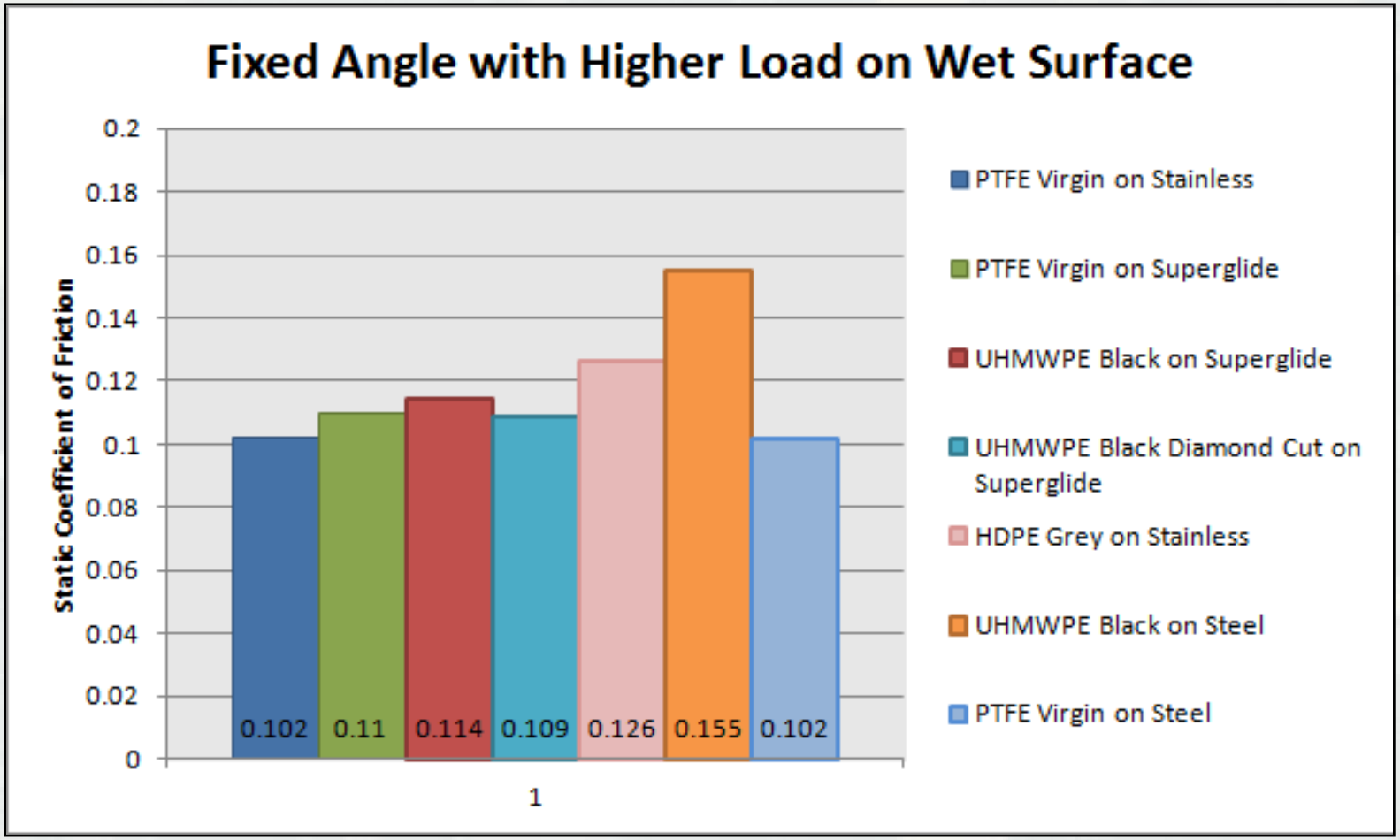
Adhesively applied UHMW-PE for Slides

(Instead of mechanical fastening)

1-inch thick piece of ultra-high molecular weight polyethylene (UHMW-PE).

Deep pitting and unevenness at bottom of the steel plate causing problems with slide action of the gate. Conducted study to assess coefficient of friction for various repair methods as well as for silicon and wax modified UHMWPE .

Friction Testing Results



Reimbursable – Replace Rollers on Lift Gates at Bonneville Dam

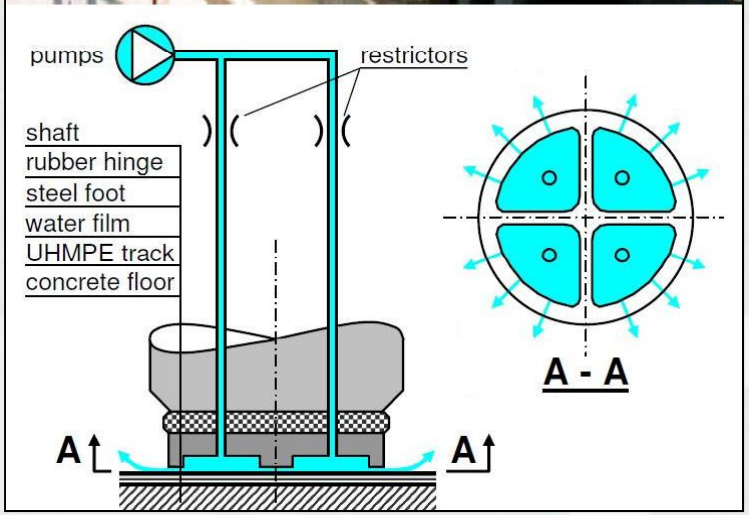
Taller gates, higher head than at Bankhead present additional challenges due to the higher forces. Solution requiring some material development as related to Nav Structures R&D efforts.

Hydraulic/Pneumatic Assist

- Europeans using hydraulic system on sliding gates
- Hydrofeet

Oranjesluis – Netherlands

Mersey Docks – Great Britain



FRP Composite Miter Blocks for small lock on Washington Lake Canal, WA.

- **Corrosion of steel miter blocks can lead to leakage and gate misalignment.**

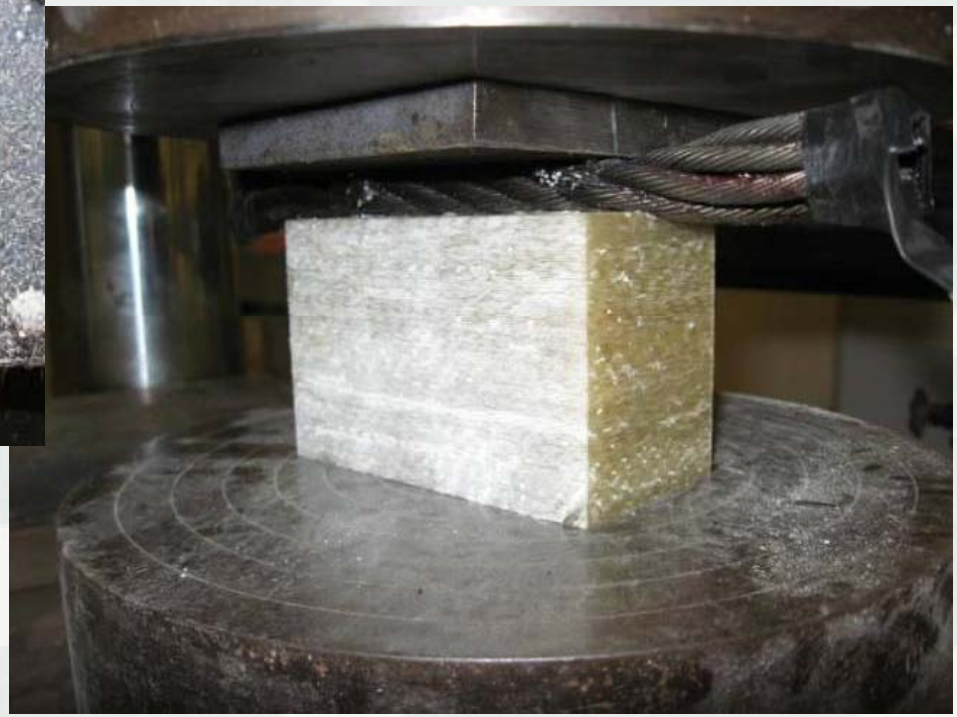
Corroded steel miter blocks.

FRP composite miter blocks were to be installed April 2014. However, a material / fabrication problem is delaying installation until the next scheduled dewatering in March 2015.

- **FRP Composite Miter Blocks for small lock on Washington Lake Canal, WA.**

Composite blocks need to be able to withstand having foreign body trapped between the blocks during closure.

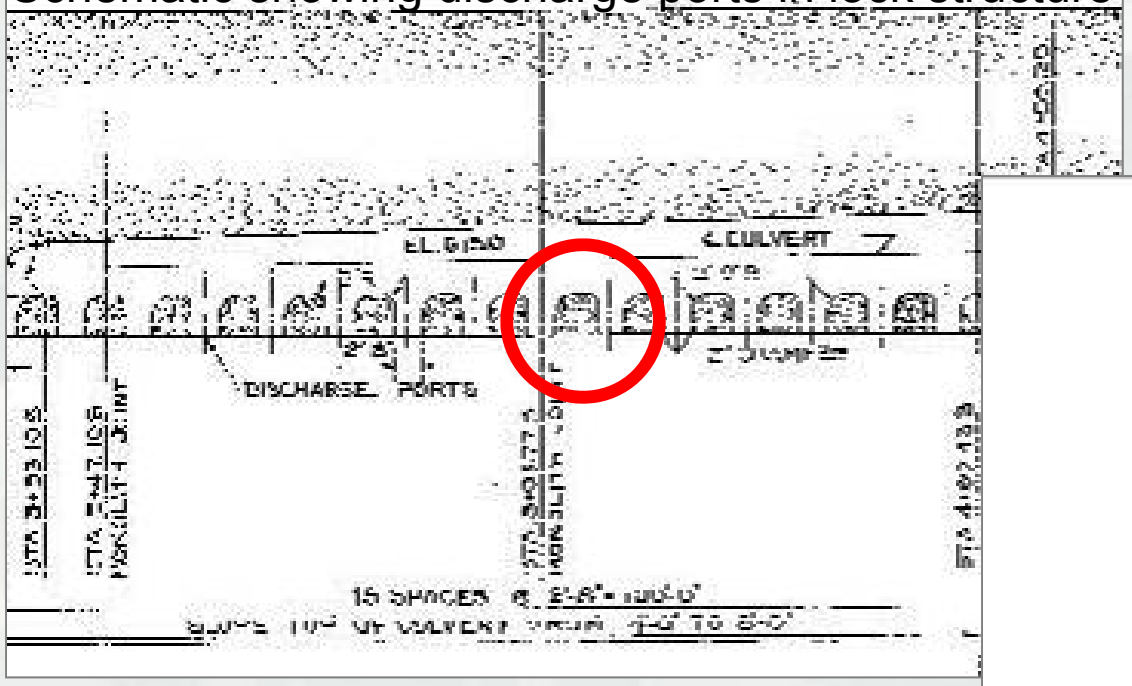
Testing Behavior When Pinching Foreign Object



Repair concrete discharge ports at Chickamauga Dam in Tennessee.

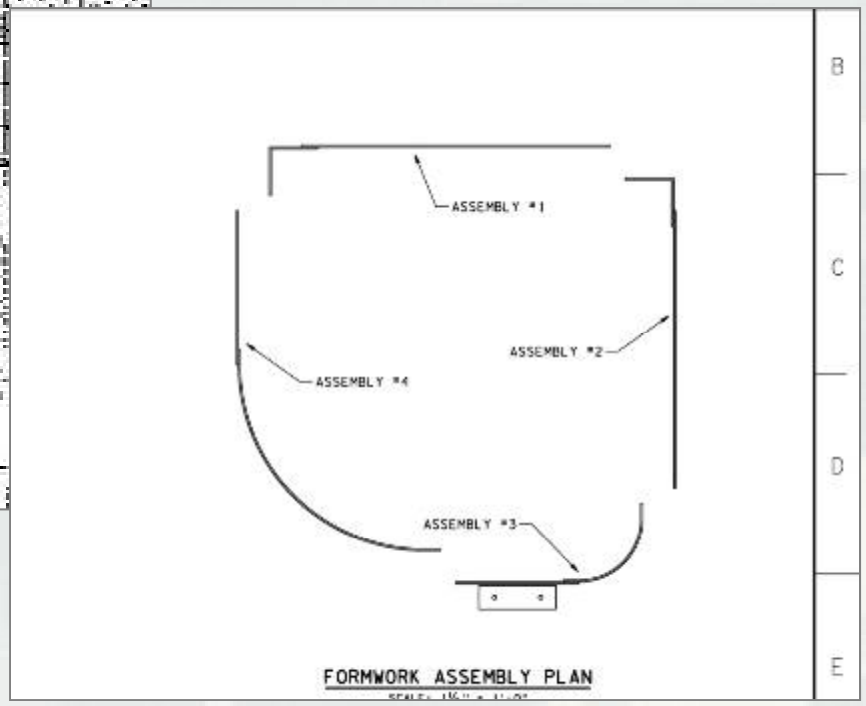
- Structural movement due to alkali aggregate reaction has caused cracks to develop on columns that define the discharge ports. Will repair using polymer mastic grout and composite wrap that cure underwater. Easier and more durable repair than using steel jackets and grout.

Schematic showing discharge ports in lock structure



Cracking concrete columns

Steel repair shell
358 lbs total weight !



Repair concrete discharge ports at Chickamauga Dam 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.

Nashville District paying to wrap four more columns.

Recess Filler Panels at Willow Island Locks and Dam, Ohio.

- Steel panels costly, heavy, and they corrode.

Current steel panels

Fabrication of composite structure.

- **Recess Filler Panels at Willow Island Locks and Dam, Ohio.**

Finished panels to be installed early FY15.

Abrasion - Resistant Overlays for Tainter Gates

- 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.

Preparing to vacuum bag the UHMWPE sheets.

Abrasion - Resistant Overlays for Tainter Gates

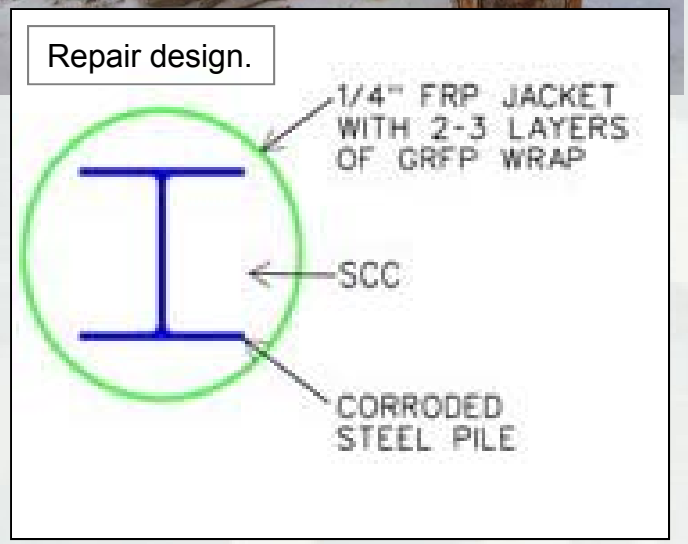
First coat of ceramic coatings applied by roller.

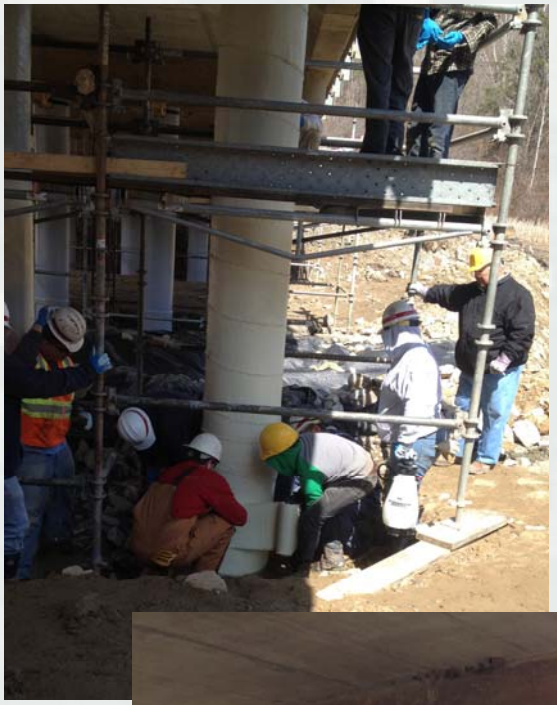
After topcoats applied. Gates expected to see abrasion and impact during upcoming high water season.

Rehab of Corroded Steel H-Piles, East Fork Bridge, Huntington, WV.

Bring load capacity back to original at 35% of cost if using traditional methods.
Use composite shell, wrapped, and then filled with grout.

Rehab of Corroded Steel H-Piles, East Fork Bridge, Huntington, WV.

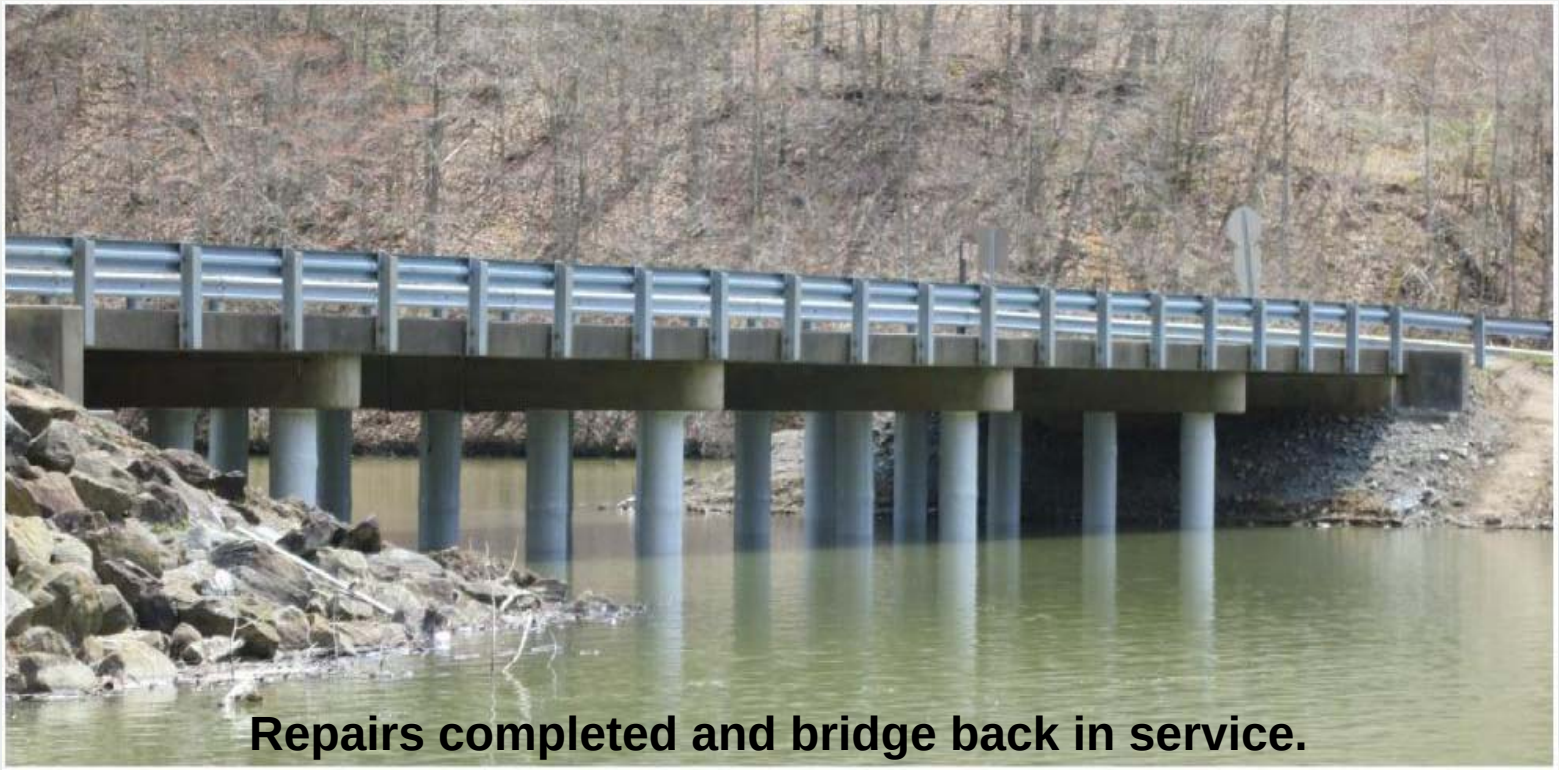




Wrapping the piles with FRP composite wrap system

Near completion of the repair

Rehab of Corroded Steel H-Piles, East Fork Bridge, Huntington, WV.



Repairs completed and bridge back in service.

- Repairs quicker and less expensive than traditional methods.
- Instrumented for strain and corrosion long-term monitoring.
- 2014 GL&ORD Engineering Award of Excellence.
- 2014 USACE Innovation of the Year Award.

FRP Composite Wicket Gates.

Timber wicket gates: rapid deterioration, costly to replace. Stepping stone to future design and application of other larger FRP composite gates and valves. Prototype gates will be developed using both thermoset and thermoplastic composites. To be installed along the Illinois River, Rock Island District.

Traditional wooden wickets showing severe deterioration

FRP Composite Wicket Gates.

- Wooden wickets fabricated by Rock Island District.
- Working with WVU and Rock Island District folks to develop design concepts for composite gates.
- Determined thermoplastic composites not feasible at this time.
- Fabrication and delivery to Illinois Waterway Project at Peoria, IL in April 2015.
- IWW to install during maintenance schedule, May-June 2015.

Future of Composite Gates

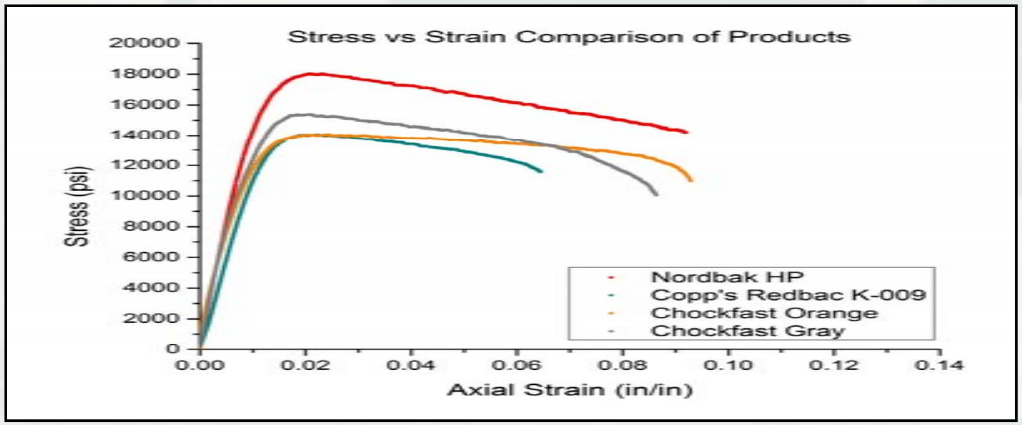
Composite miter gates in France

Evaluation of Emerging Filler Materials for Miter and Quoin Blocks

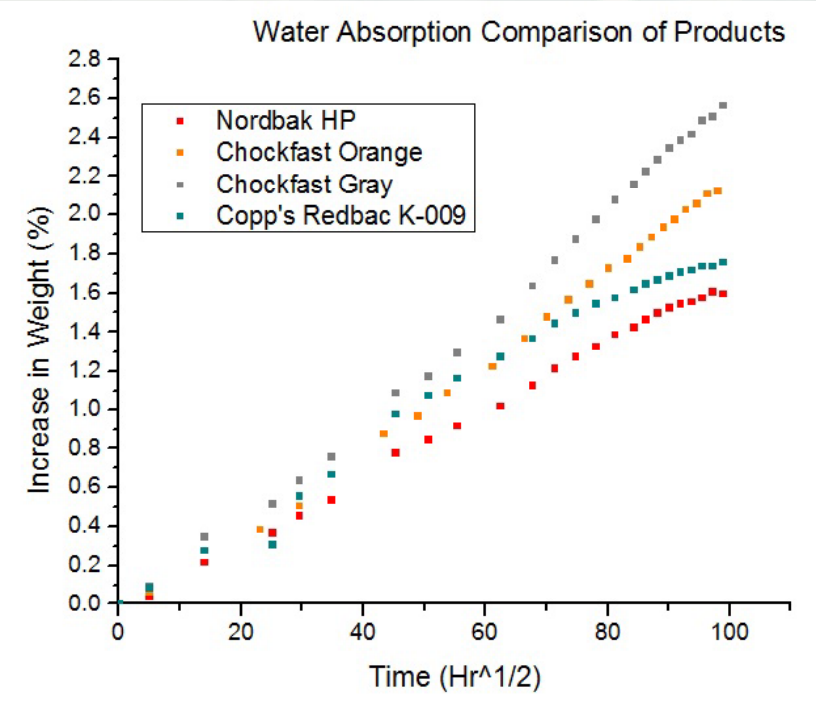
- **Mechanical Property Tests**:
  - Water Absorption
    - ASTM D 570 – Standard Test Method for Water Absorption of Plastics
    - Testing in progress, waiting for saturation
    - 8 month and 14 month immersion Compressive Specimens
  - Freeze Thaw
    - Developed protocol for freeze thaw testing.
    - Testing on 30 day and 60 day (60 and 120 cycle) samples.
  - Accelerated Aging
    - Arrhenius based degradation models.

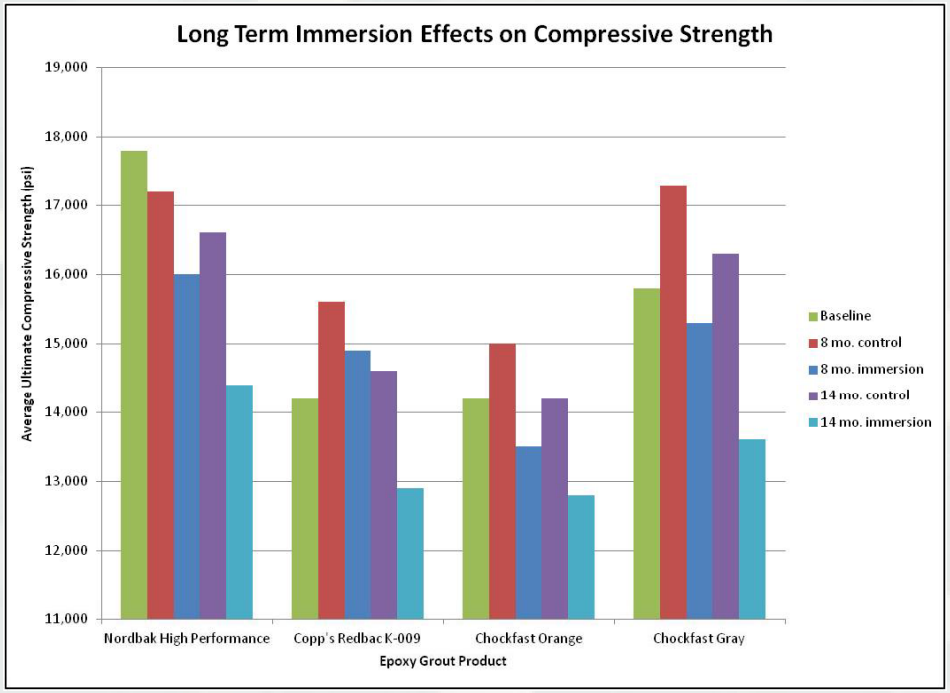
Compression Data

Sample	Average Compressive Strength (psi)	Literature Value Compressive Strength (psi)	Average Compressive Yield Strength (psi)	Average 0.2% Offset Yield Strength (psi)
Nordbak High Performance	17,800	18,000	15,400	15,400
Nordbak PC 9020	15,700	19,000	13,600	****
Copp's Redbac K-009	14,200	19,000	12,800	13,200
Copp's XP2000	15,900	18,000	14,400	****
Chockfast Orange	14,200	19,000	12,200	12,900
Chockfast Gray	15,800	16,000	13,500	14,000



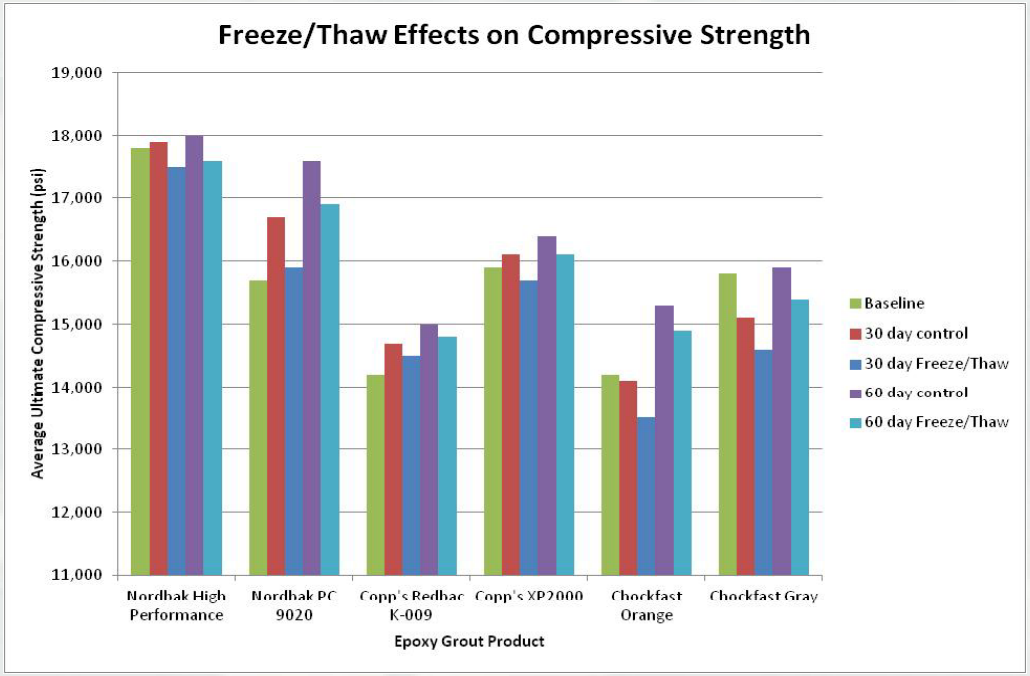
Water Absorption/Immersion





Sample	Average Compressive Strength after 8 mo. cure (psi)	Average Compressive Strength after 8 mo. Immersion (psi)	Difference @ 8 mo. from control (psi)	% Reduction @ 8 mo. from control	Difference @ 8 mo. from baseline(psi)	% Reduction @ 8 mo. from baseline	Average Compressive Strength after 14 mo. cure (psi)	Average Compressive Strength after 14 mo. Immersion (psi)	Difference @ 14 mo. from control (psi)	% Reduction @ 14 mo. from control	Difference @ 14 mo. from baseline	% Reduction @ 14 mo. from baseline
Nordbak High Performance	17,200	16,000	1,200	7%	1800	10%	16,600	14,400	2,200	13%	3,400	19%
Copp's Redbac K-009	15,600	14,900	700	4%	-700.00	-5%	14,600	12,900	1,700	12%	1,300	9%
Chockfast Orange	15,000	13,500	1,500	10%	700	5%	14,200	12,800	1,400	10%	1,400	10%
Chockfast Gray	17,300	15,300	2,000	12%	500	3%	16,300	13,600	2,700	17%	2,200	14%

Freeze Thaw / Accelerated Aging



The accelerated aging model uses Arrhenius based rate equations, considers three degradation mechanisms, "Post-Curing", Thermal Degradation, and Hygro-Thermal Degradation.

$$\frac{\partial a}{\partial t} = k_a (1-a)^{n_a} \exp\left(\frac{-E_a}{RT}\right)$$

Sample	Average Compressive Strength after 30 day cure (psi)	Average Compressive Strength after 30 day Freeze/Thaw (psi)	Difference @ 30 days from control(psi)	% Reduction @ 30 days from control	Difference @ 30 days from baseline(psi)	% Reduction @ 30 days from baseline	Average Compressive Strength after 60 day cure (psi)	Average Compressive Strength after 60 day Freeze/Thaw (psi)	Difference @ 60 days from control (psi)	% Reduction @ 60 days from control	Difference @ 60 days from baseline (psi)	% Reduction @ 60 days from baseline
Nordbak High Performance	17,900	17,500	400	2%	300	2%	18,000	17,600	400	2%	200	1%
Nordbak PC 9020	16,700	15,900	800	5%	-200	-1%	17,600	16,900	700	4%	-1,200	-8%
Copp's Redbac K-009	14,700	14,500	200	1%	-300	-2%	15,000	14,800	200	1%	-600	-4%
Copp's XP2000	16,100	15,700	400	2%	200	1%	16,400	16100	300	2%	-200	-1%
Chockfast Orange	14,100	13,500	600	4%	700	5%	15,300	14,900	400	3%	-700	-5%
Chockfast Gray	15,100	14,600	500	3%	1200	8%	15,900	15,400	500	3%	400	3%

Questions ???