FRP Composite Demonstrations in Civil Works Applications: Design Considerations and Lessons Learned

ERDC
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2015 Locks Maintenance Workshop

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US Army Corps of Engineers®

Outline

- Background
- Bankhead Lock and Dam: Polymer Gate Slides
- MVR IWW: Composite Wicket Gates
- Other Composite Material Demonstrations

Background

- **Problem/Objectives**: 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. New Work Unit initiated in FY12 under Nav Structures focused on the used of FRP composites for rapid repair of navigation structures. Additional funding opportunities became available under Nav Systems to demonstrate and showcase the use of FRP composite materials in low risk but useful applications.
- **Collaborators**:
  - Districts: Huntington, Louisville, Mobile, Nashville, Seattle, Rock Island and Portland
  - NSF Center for the Integration of Composites into Infrastructure
    - West Virginia University and Rutgers University
  - Inland Navigation Design Center

John Hollis Bankhead Lock & Dam

- On Black Warrior River, Tuscaloosa County, AL
- 22 Lift Gates

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

- **Problem**: The reaction rollers seize up due to corrosion and drag when gate is raised or lowered.

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

- Solution: Design a repair using polymer composite glides w/o moving parts.

Corroded, poorly functioning rollers

Mechanically fastened UHMWPE slides.

Polymer Slide Development Phase I

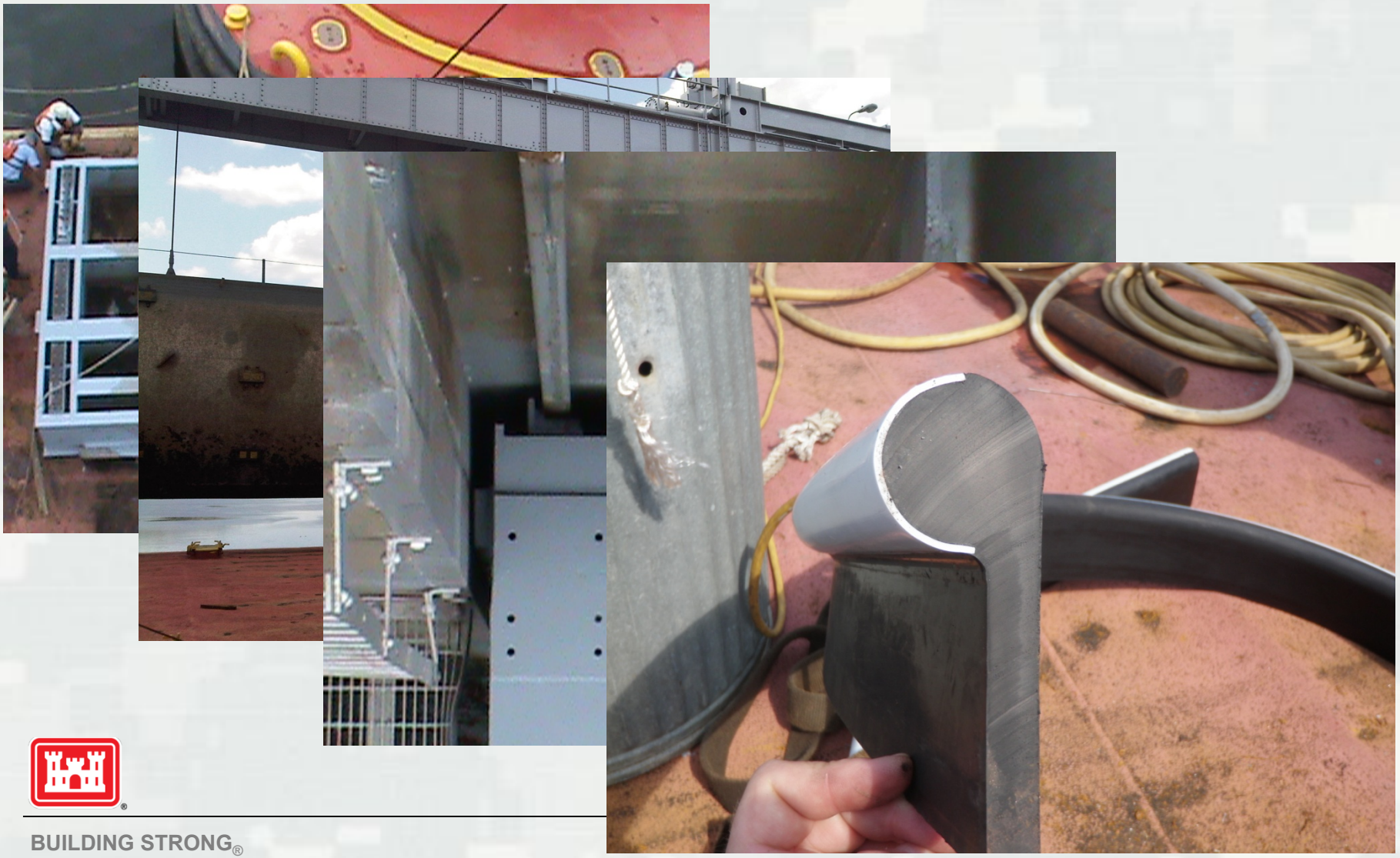
Mechanically Fastened Polymer Slides

Polymer Slide Development Phase I

Mechanically Fastened Polymer Slides

Polymer Slide Development Phase I

Mechanically Fastened Polymer Slides



Polymer Slide Development Phase II

Adhesively applied UHMW-PE for Slides

(Instead of mechanical fastening)

Polymer Slide Development Phase II

Adhesively applied UHMW-PE for Slides

Problems Develop: Site Visit

Gate 7 would not close properly.

Gate 9 would not move up or down.

Problems Develop: Site Visit
Gouged & Scraped UHMWPE

Problems Develop: Site Visit
You want me to do what??

Problems Develop: Site Visit

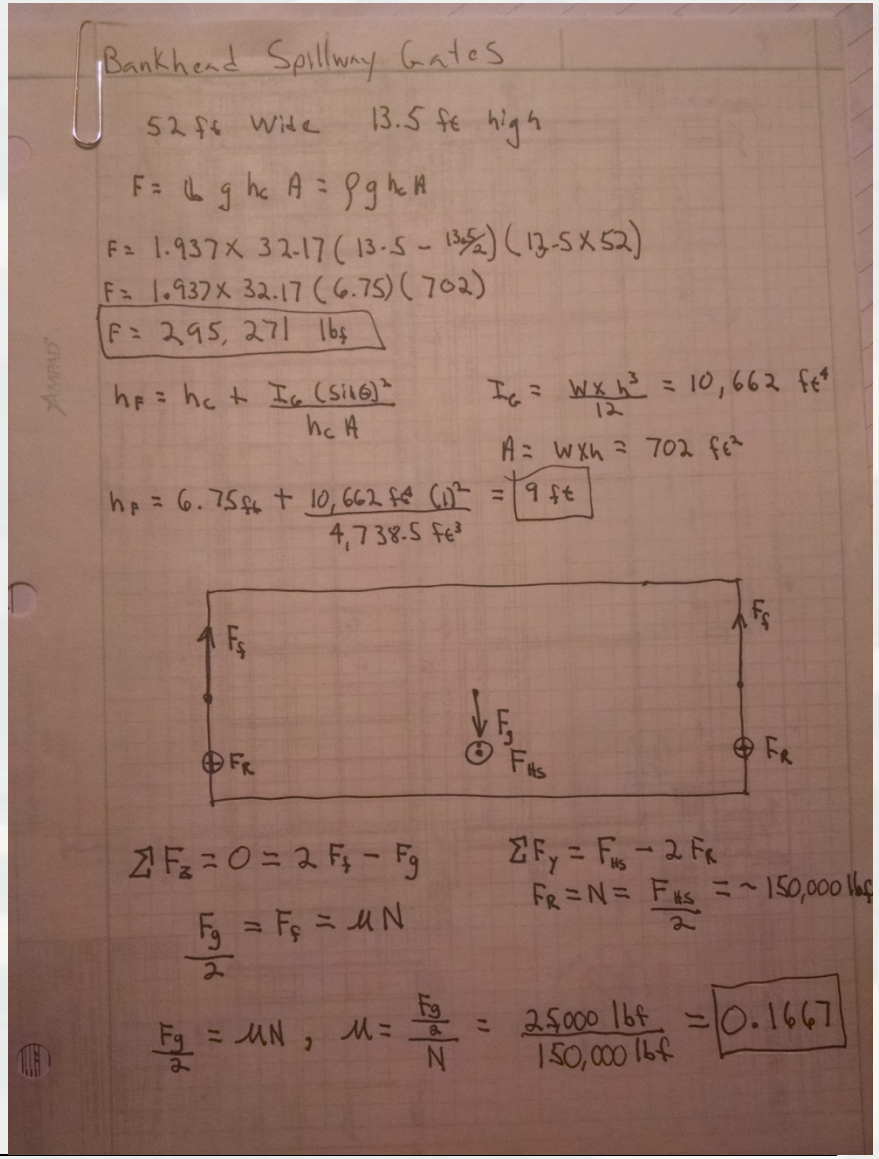
Hanging by a Thread!

Problems Develop: Site Visit

Deteriorated Steel.

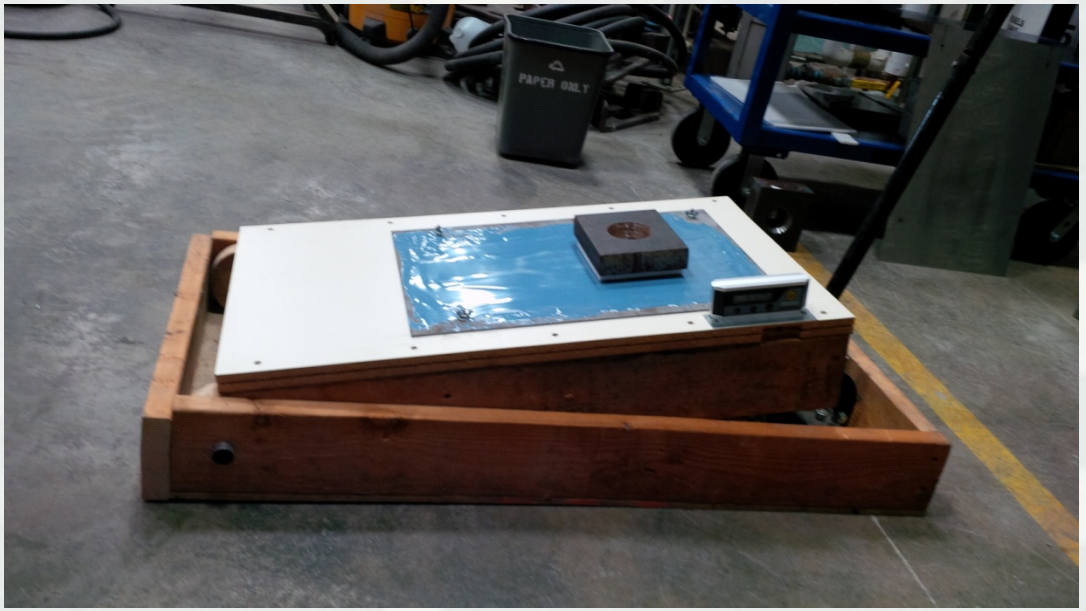
Hydrostatic Analysis

- ~ 300 kips Hydrostatic Force
- Critical Coefficient of Friction 0.167

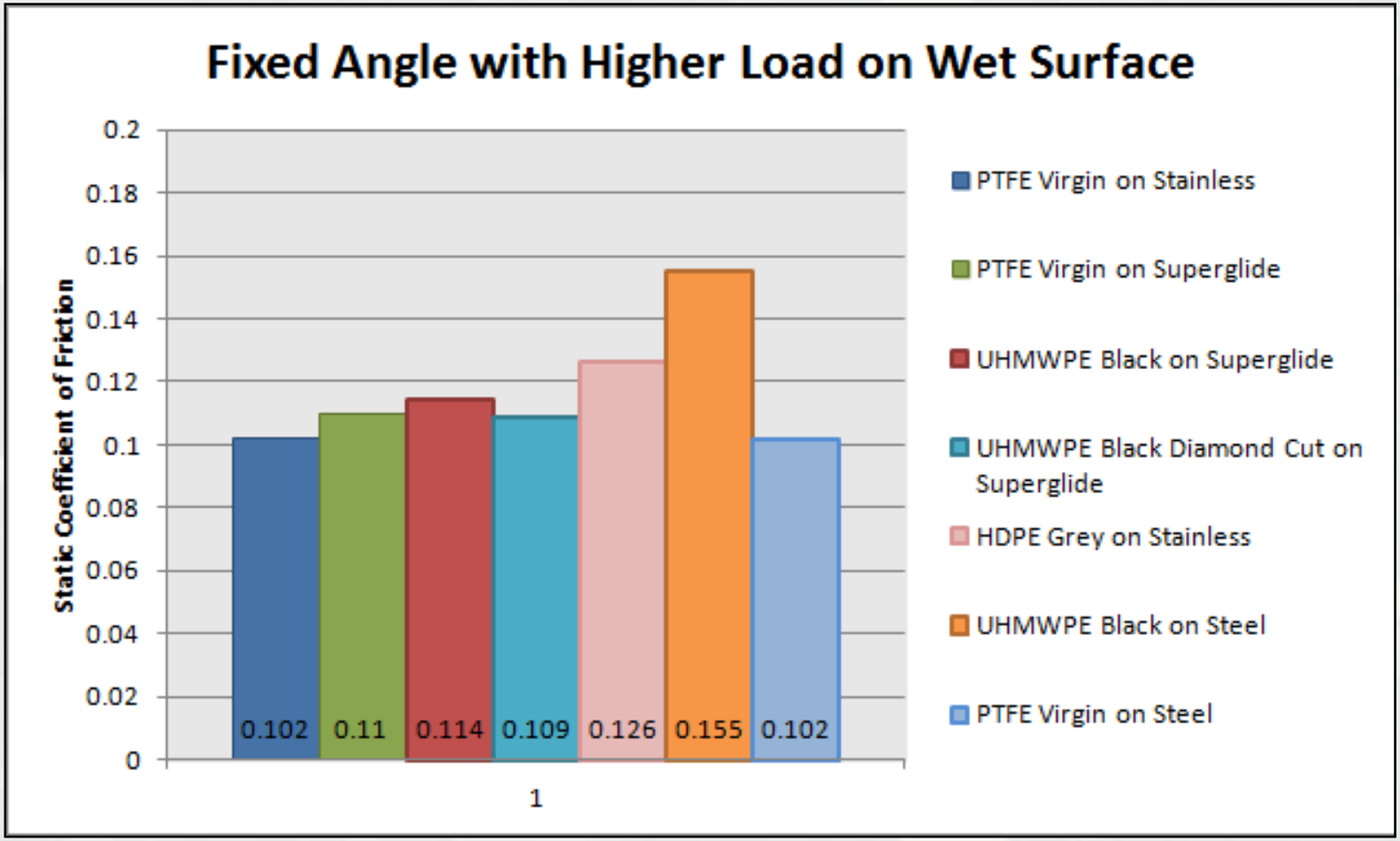


Friction Study Tests

- Conditions
  - Surfaces
    - Dry
    - Wet
  - Load
    - Light
    - Heavy
  - Ramp Rate
    - Slow
    - Fixed



Friction Testing Results



Remediation
Steel Repair

Remediation
Superglide Application

Replace Rollers on Lift Gates at Bonneville Dam

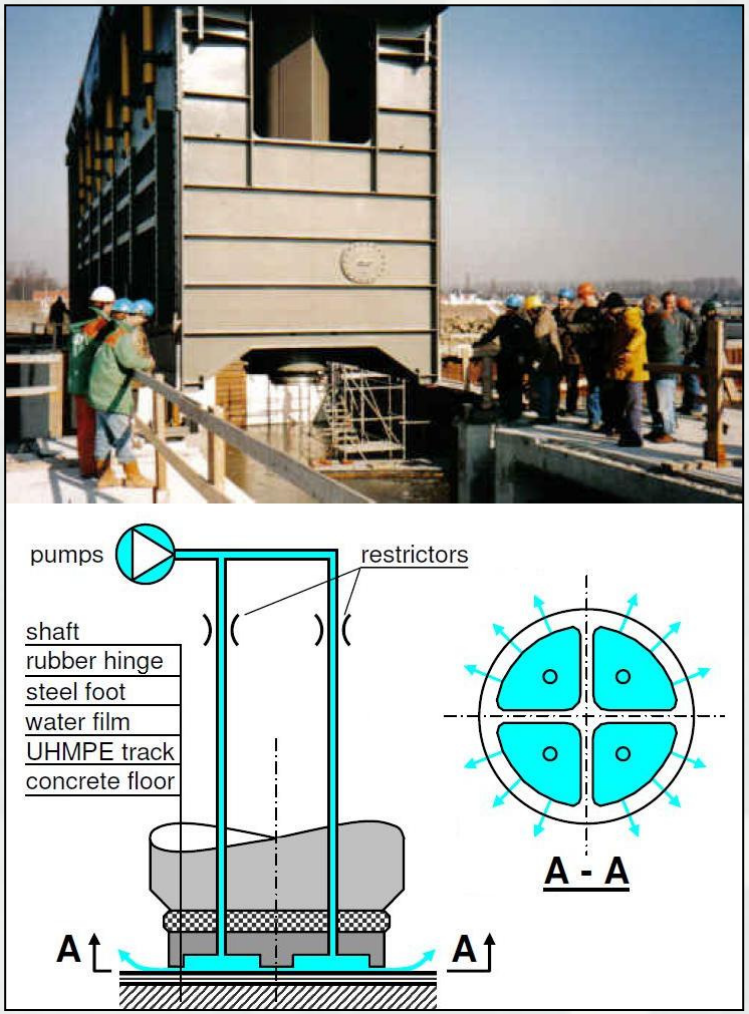
Taller gates, higher head than at Bankhead present additional challenges due to the higher forces. Requires mechanical as well as material solution

Hydraulic/Pneumatic Assist

- Europeans using hydraulic system on sliding gates
- Hydrofeet

Oranjesluis – Netherlands

Mersey Docks – Great Britain



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. To be installed along the Illinois River, Rock Island District.

Traditional wooden wickets showing 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 May 2015.
- IWW to install during maintenance schedule, Summer 2015.

Composite Wicket Gates
Design Considerations

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

Composite Wicket Gates
Status

•Introductory meeting at IWW. Sample wicket gate sent to WVU in JUN14.

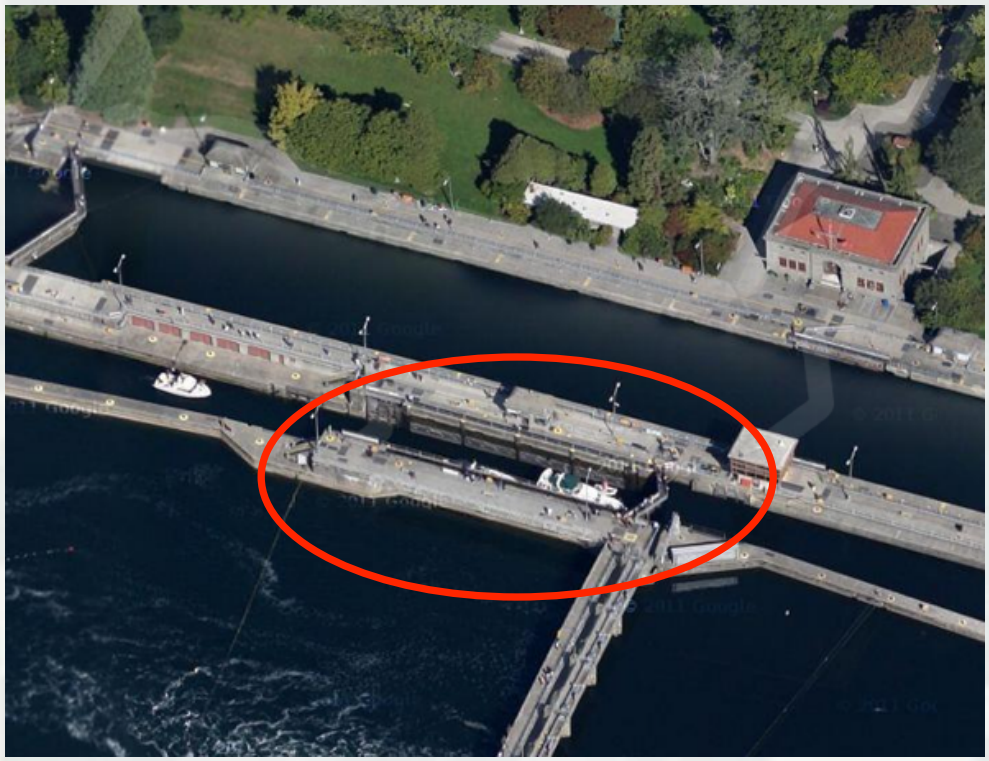
•WVU developed load cases to determine design allowables and ask team about specific design requirements. OCT14

•WVU presented preliminary design including manufacturing and fastening details. DEC14

•Second preliminary design prior to prototype fabrication. Conference call scheduled for week of 16FEB15.

FRP Composites Demonstrations

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



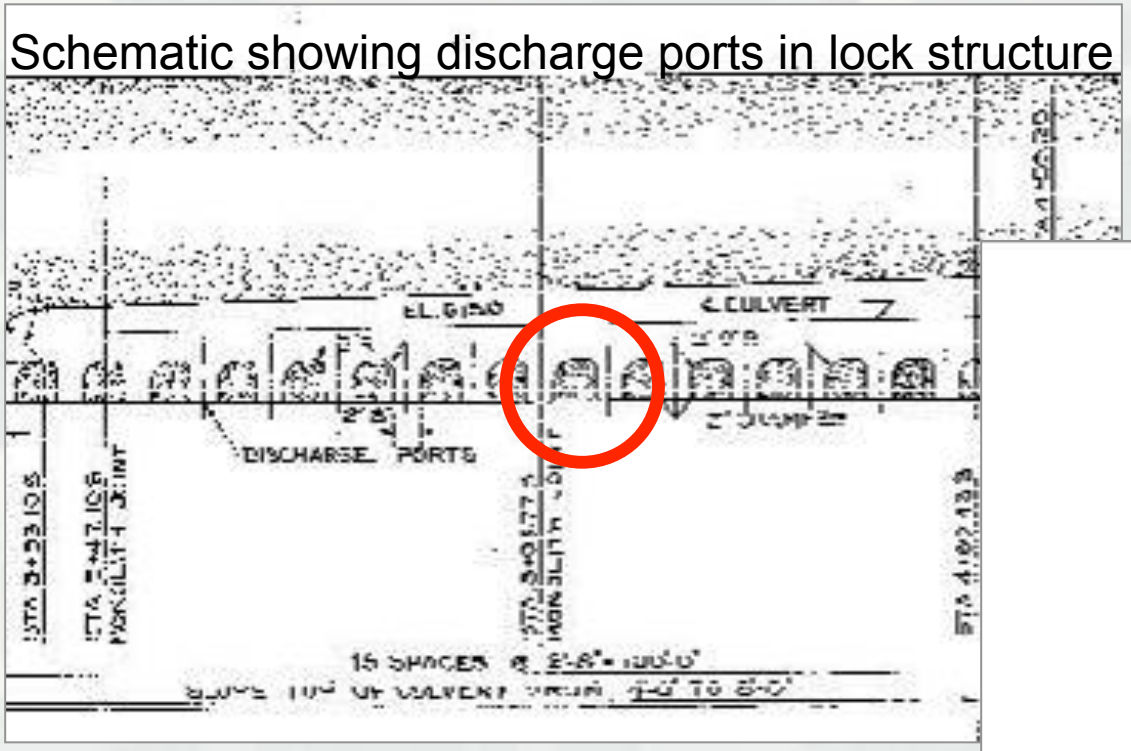
Small lock at Hiram Chittenden (Washington Lake Canal) Locks, Seattle, WA.

Corroded steel miter blocks.

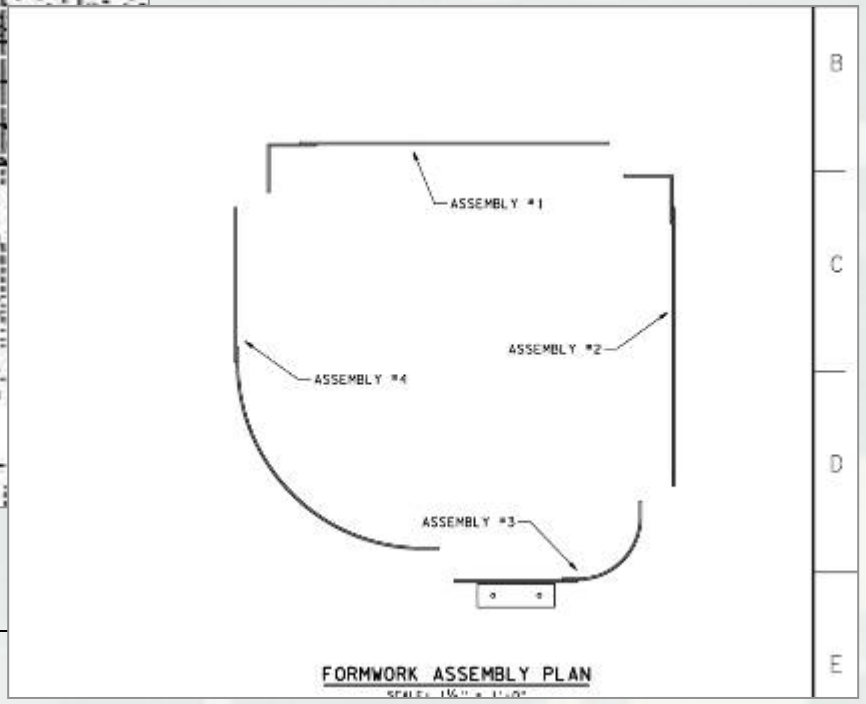
FRP Composites Demonstrations

- **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 grout.

Schematic showing discharge ports in lock structure



Steel repair shell
358 lbs total weight !



Cracking concrete columns

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.

Nashville District paying to wrap four more columns.

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

Finished panels to be installed early FY15.

FRP Composites Demonstrations

- **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 were applied: UHMWPE, two different ceramic composite coatings, same two coatings over vinyl 3-A-Z.

Adhesive being applied for bondable UHMWPE.

Questions ???

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