



TRI - REGIONAL JETS 2025



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JETS 2025**

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FRPs Steal the Day in Civil Works Infrastructure



US Army Corps
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Haskoning
Enhancing Society Together

FRPs Steal the Day in Civil Works Infrastructure

Moderator:

- Gerald Morris, CDT, LEED AP BD&C, PMP, CCM, F.SAME, AVP National Market Lead – Civil Agencies, Michael Baker Intl

Presenters:

- Craig R. Morin, PE, National Practice Director Federal Civil Works, Jacobs
- Lee Canning, PhD, Senior Associate Director FRP Composites, Jacobs
- Liesbeth Tromp, FRP Specialist and Lead Engineer, Haskoning
- Eric O. Johnson, PE, SE, CCT-VIP, Technical Manager, INDC USACE

Agenda

- FRP Momentum in Civil Works
- FRP Technology
- FRP Case Studies in Civil Works
- Q&A / Discussion

FRP Momentum in Civil Works



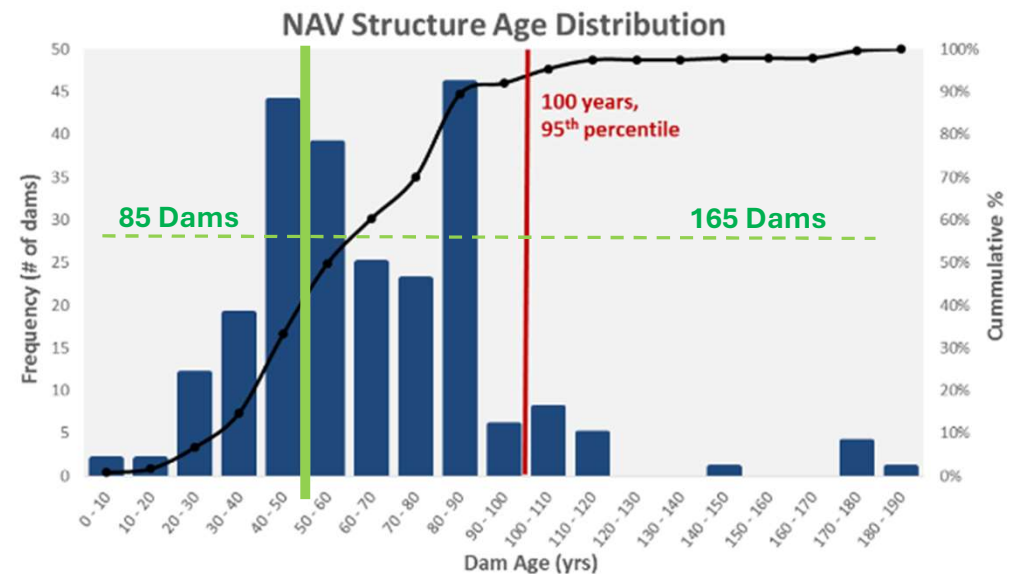
Why FRPs? / Why USACE?

Problem

- Steel structures require reoccurring & costly maintenance.
- Approximately 13,000 steel structures within Navigation and Flood Risk Management (FRM) portfolios.
 - **Approximately 70% exceed 50-year design life**
- Based on 50-year design life, USACE is on the cusp of replacing 260 hydraulic structures per year that were built 1920 – 1975.
 - **Annual cost for 260 structures would range from \$1B - \$2B**

Solution

- FRPs offer significantly low-maintenance solution for 100-year life
- Similar first cost as steel
- Faster design (more like design-build) & faster fabrication (more like precast concrete than detailed steel)
- **Significant Life Cycle Cost Savings - Ranges up to 10:1**



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Credit: Eric Johnson, P.E., S.E., CCT-VIP

USACE Composites History

- 1990's:** USACE ERDC, Universities, & American Composite Manufacturer's Association begin composite collaboration
(ETL 1110-2-548 "Composite Materials for Civil Engineering Structures" pub.1997)
- 2003:** SAJ Canaveral Lock FRP Chamber Wall w/FRP Piling & Fendering
- 2010's:** USACE Civil Works demonstration projects in collaboration (ERDC, INDC, Academia, and Districts)
- 2015:** Start of FRP knowledge exchange w/Rijkswaterstaat, Netherlands Ministry of Infrastructure.
- 2018:** UFGS Guide Spec for FRP Low-Head Water Control Structures



Canaveral Lock – Chamber Wall on Right, 2003



ERDC Thermoplastic Bridge (circa 2008)



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Credit: Eric Johnson, P.E., S.E., CCT-VIP

Types of USACE Applications

As the FRP industry has matured, so too have the applications.

No longer are FRPs only considered for secondary components in hydraulic infrastructure.

Now, we are incorporating FRPs into the primary structural elements of major facilities and their components.



Flap Gates



Dewatering Structures



Sector Gates



Navigation Locks and Dams



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Credit: Eric Johnson, P.E., S.E., CCT-VIP

Credit: Eric Johnson, P.E., S.E., CCT-VIP

USACE Civil Works Projects

6 Completed Projects

- 1) Canaveral Lock Guide Wall
- 2) Willow Island Lock Bulkhead Panel
- 3) Chickamauga Lock F/E Port Repair
- 4) Peoria Dam Wicket Gates
- 5) Chittenden Lock Miter Blocks
- 6) Loyall Flood Protection Flap Gate

8 Large Design Charrettes

5 Projects Currently Under Contract

15+ Projects Currently in Development

40+ Projects Future Projects Under Evaluation



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Credit: Eric Johnson, P.E., S.E., CCT-VIP

FRP Technology



Why FRP in Infrastructure?

- Low maintenance
- Sustainable and durable
- Strong
- Lightweight and prefabricated
- Cost effective



60m span Carbon fibre composite bridge (2003), Fredrikstad, Norway

FRP Construction Opportunities & Challenges

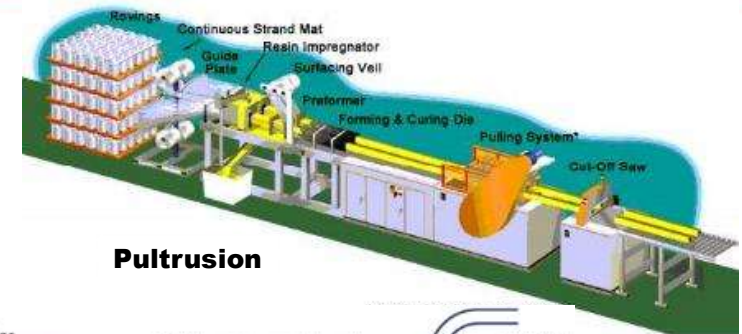
- High strength / stiffness
- Durability
 - Materials & coatings
- Sustained loading
 - Creep
 - Fatigue



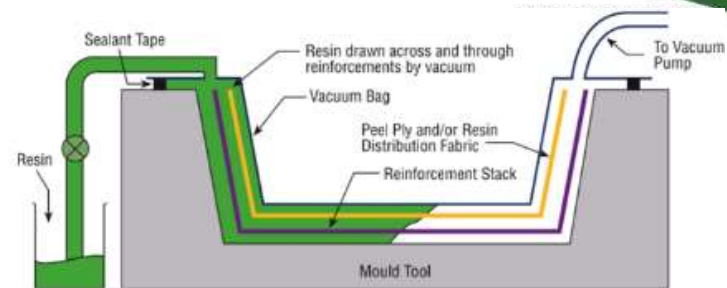
Spieringsluis, Werkendam, 2002 | Mitre gate

Manufacturing Techniques

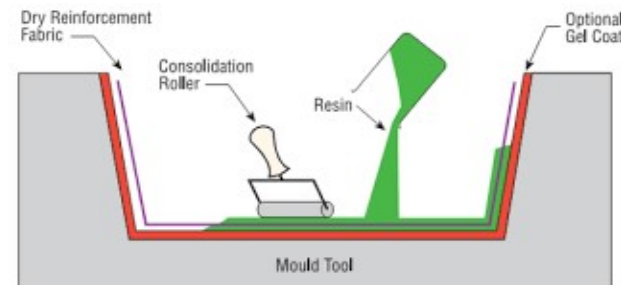
- Pultrusion
 - Automated fiber placement and infusion
 - High fiber volume percentage (50 - 60%)
- Resin infusion
 - Manual fiber placement
 - Infusion under vacuum, closed mould
 - High fiber volume percentage (40 – 60%)
- Hand lamination
 - Manual fiber placement
 - Manual resin application
 - Low fiber volume percentage (15 - 30%)
i.e. high resin content



Pultrusion



Resin Infusion



Hand Lamination



Production Technologies

- Vacuum Infused, Integrated Structures



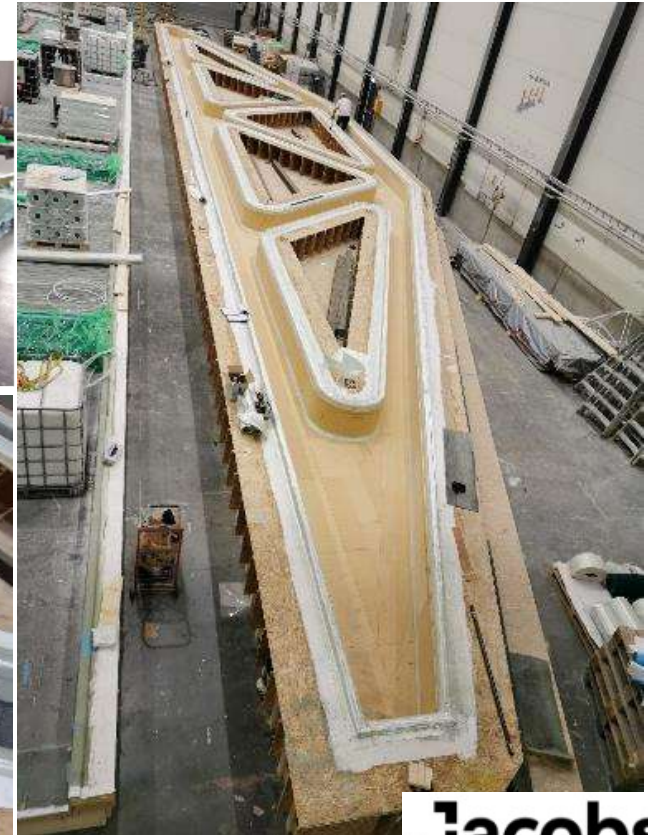
Production Technologies

- Pultrusion, Bonding/Bolting

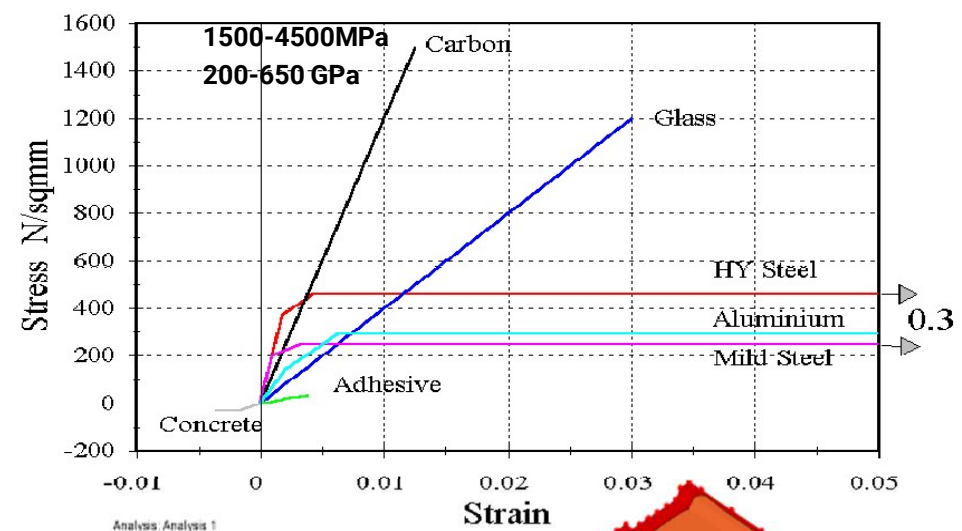


FRP Manufacturing Opportunities and Challenges

- Moulds
- Design guidance / Quality Control procedures
 - Link design => contract => manufacturing
 - QC composite
 - Production checks
 - Material tests
 - Acceptance checks
- Locks – similar technology to bridges



Materials & Design Approach



Full Structure



Qualification of Structural
Performance

Component



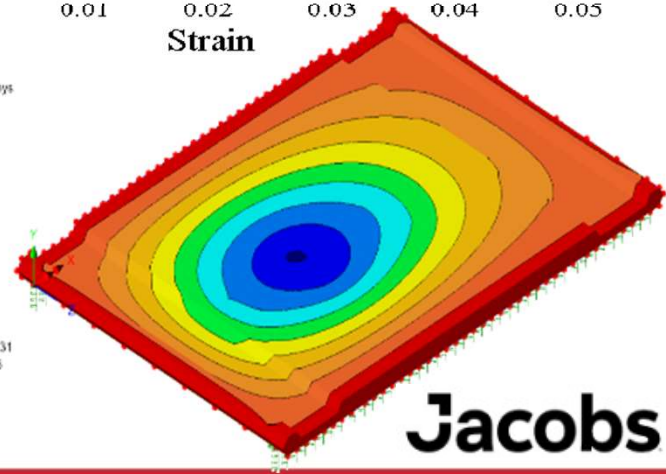
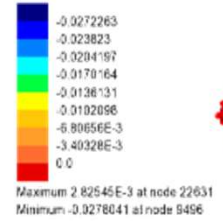
Critical Detail Verification

Coupon



Characteristic Properties
- Design
- Quality Control

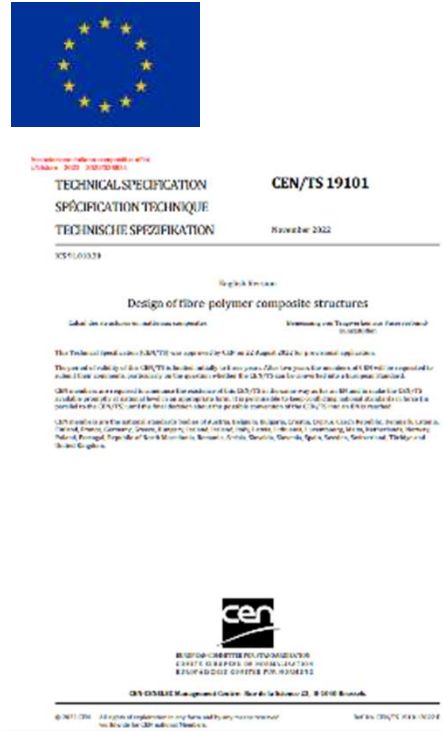
Analysis: Analysis 1
Loadcase: 1: Loadcase 1
Results file: Church Bridge final.mys
Entity: Displacement
Transformation: Global
Component: DY (Units: m)



FRP Design Guidance (...not exhaustive...)



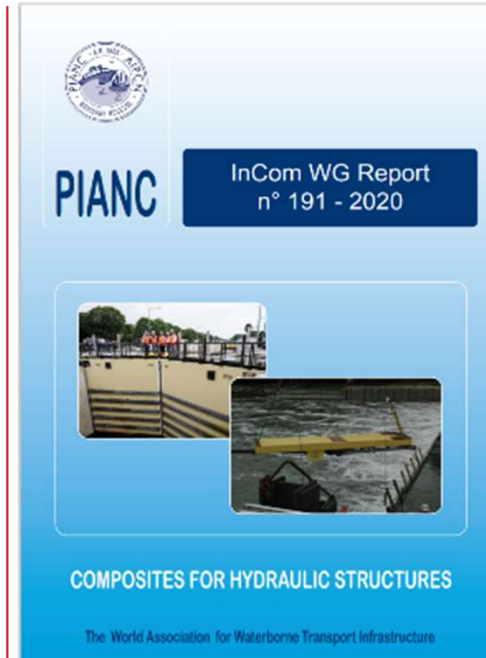
CUR96 FRP in Buildings and Civil Eng. Structures



TS 19101 Design of fibre-polymer composite structures



ASCE 74-23 LRFD Pultruded FRP Structures, USACE ECB Design of FRP Hydraulic Composite Structures



PIANC – Composites For Hydraulic Structures

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FRP Case Studies in Civil Works





First FRP Gates, Netherlands

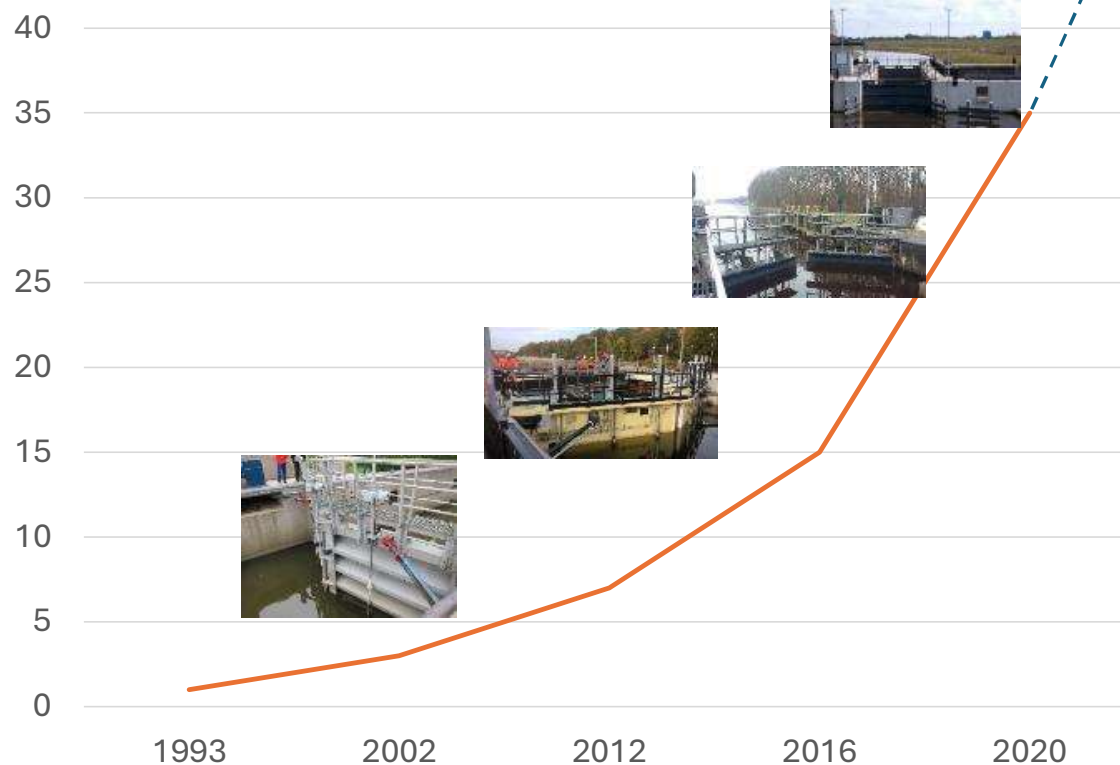


Kreekrakschuif
1993 | Vertical Gate



Spieringsluis, Werkendam,
2000 | Mitre Gate

Number of Gates, trend



**FRP vertical gate
in Afsluitdijk**



2022/23





FRP Lock Doors Wilhelmina Canal

- Largest in FRP mitre gates worldwide!
- 6,2 by 13 m
- Difference in water level of 8m
- Client: Rijkswaterstaat
Dutch Ministry of Infrastructure and the Environment
- Haskoning: FRP expertise;
a.o. technical specifications, design review and quality control
- Contractor: Heijmans/Boskalis
FRP supplier: Fibercore Europe





World's Largest FRP Miter Gates Wilhelmina Canal

- One piece polyester and glass fiber composite closed webcore sandwich structure of 6.3 x 12.3 x 0.51 meters
- Skin solid 30 mm thick. 5 mm solid webs spaced 102 mm
- Single leaf weight is 32 tonnes





FRP Specific Requirements Rijkswaterstaat – Wilhelmina Canal Lock III

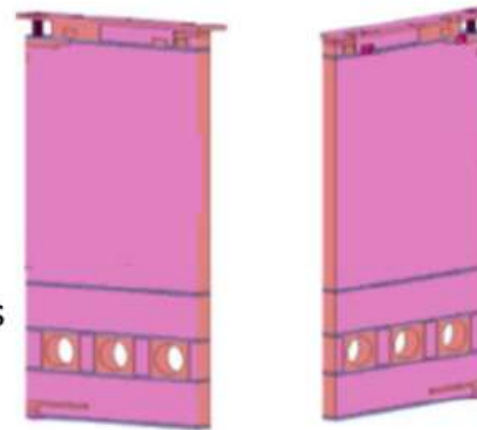
- Maximum deflection (out-of-plane due to hydraulic load: $L/350$)
- Maximum shortening – in plane due to hydraulic load: $L/2000$
- No hydraulic load transfer to the pintles
- Continuous fiber reinforcement and lay-up
- Damage tolerant structure
- Production in 1 piece (integrated structure)
- Design for 100 years including creep, humidity and fatigue.
- FAT - Deflection test on final products
- Monitoring deflection during operation (optic fibers)
- Repairability of local damage

General Construction

- Z-shaped fiber and PU foam build-up.
- Fibers connecting the skin and de webs are continuous



- E-Glass fibers / Polyester
- Flow holes 1000 mm in diameter
- Structural solid Polyester - Glass fiber beams on locations of high stresses and deflection



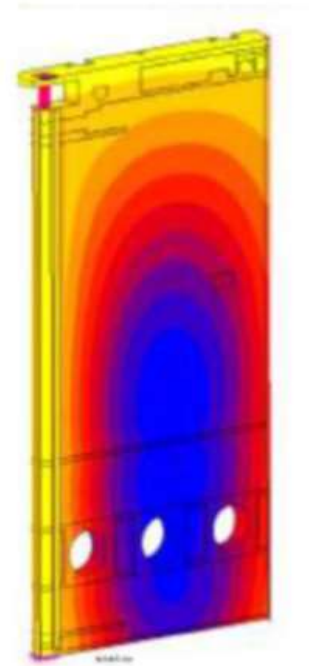


Calculations, FE model: deformations

- Maximum Calculated deflection SLS
18 mm at structural beams (100 years)
including creep, humidity and fatigue

Theoretical distortions:

- | | |
|-----------------------------|---------|
| • Hinges (bottom Pintle) | 4.0 mm |
| • Gate paddles (center one) | 1.4 mm |
| • Heel post (quoin blocks) | 1.3 DEG |
| • Sill (leaf center) | 14 mm |



Durability

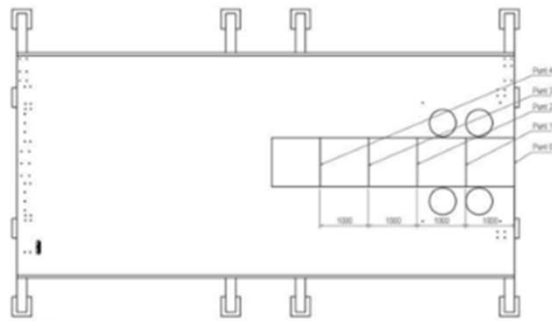
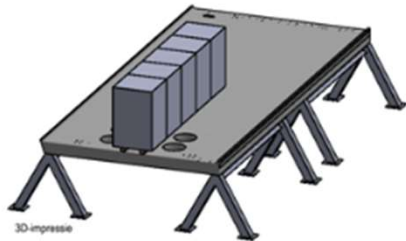
- Integral structure
- Chemical resistant resins
- Chemical resistant coating
- Durable details (connections)



UpperLock doors Tilburg (5 m x 6,2 m)

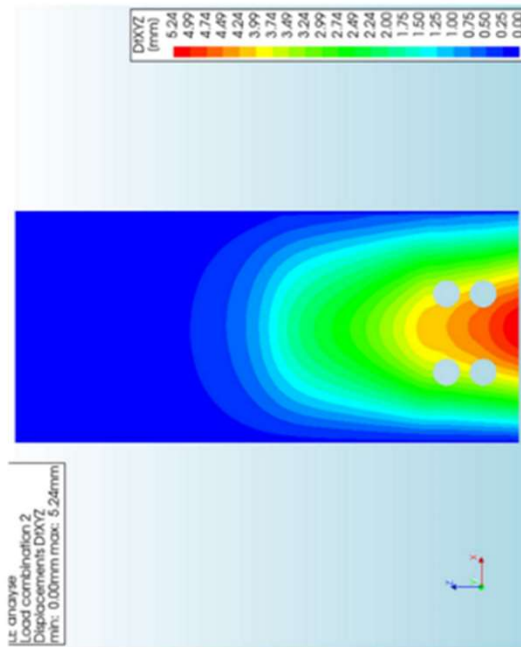
Acceptance test of lock doors

Test set up



Bovenkant met gewichten en de genoemde punten

FE-model of test: predicted value



Berekende doorbuiging t.g.v. alleen de proefbelasting

Execution of test



Installation



FRP Lock Doors – Wilhelmina Canal



Wilhelmina Canal; Lock III after installation; May 2016



Costs benefits FRP lock doors

- Slightly lower initial costs
- Significant reduction of maintenance costs

Why FRP? Life Cycle Cost Savings

Findings:

- GFRP is cheaper/same for first cost vs steel
- **HUGE Life Cycle Cost savings!**
- **\$72M LCC savings per Tainter gate!**

Costs from 2023 Felsenthal Tainter Gate Charrette:

Cost Comparison for 3 Gates	COA 1, 2, 3, 4, 5
Construction Cost (First Cost)	
Description	Total
COA 0 - Baseline Replace in Kind - All New Steel Gates	\$13,661,608
COA 5 - New Full FRP Gate Double Skinplate	\$12,413,508

Cost Comparison for 3 Gates	COA 0, 1, 2, 3, 4, 5
Life Cycle Cost	
Description	Total
COA 0 - Baseline Replace in Kind - All New Steel Gates	\$237,311,000 **
COA 5 - New Full FRP Gate Double Skinplate	\$21,454,000 **

US Army Corps of Engineers • Inland Navigation Design Center

Credit: Eric Johnson in USACE Presentation

https://acmanet.org/wp-content/uploads/2024/02/NAPC23_Johnson.pdf



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Q&A / Discussion

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