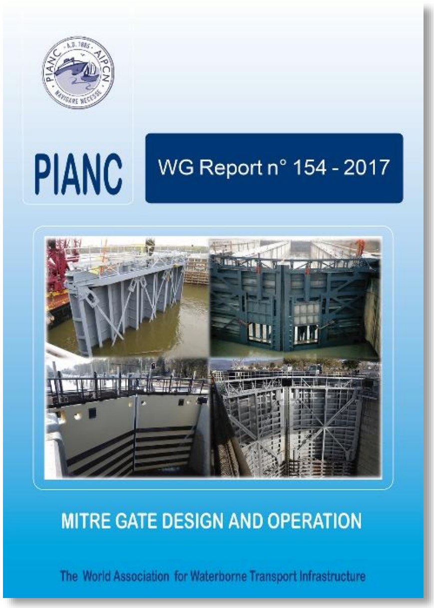
PIANC WORKSHOP

‘MITRE GATE DESIGN and OPERATION’



6 November 2017

Brussels – BELGIUM
PIANC Headquarters:
Ferraris Building,
Boulevard Albert II, 20 – 1000 Brussels

In the framework of
the PIANC InCom Report n°154

A similar conference (in French) will be organised in Paris on 7 November 2017, with most of the same speakers.
For more info contact: Mr Fabrice DALY - fabrice.daly@vnf.fr

!!! Maximum 80 participants including a maximum of 20 YP’s/students!!!

The workshop on 6th Nov. is a one day event to launch and promote the new PIANC Report n°154 on **Mitre Gate Design and Operation** (published by PIANC in August 2017).

We will start by a presentation of the new PIANC Report by the members of the WG (focusing on the new innovative concepts – with an updated state of art), followed by an open forum with worldwide experts discussing about the lessons learnt from mitre gate failures that happened recently in several navigation locks.

REGISTRATION

http://www.workshopregistration.pianc.org/workshopmitregate.htm

AGENDA

8:00 Arrival - PIANC Headquarter Brussels

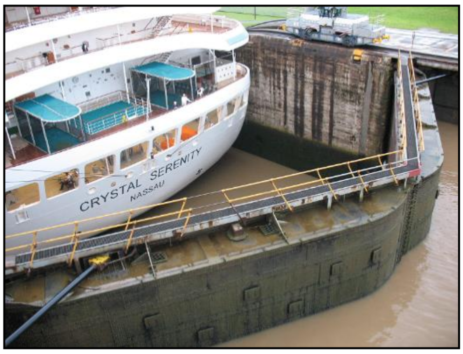
8:20 **Welcome** by Philippe Rigo, PIANC InCom Chair

8:30 - 10:15 **MITRE GATES DESIGN AND OPERATION – Part 1**

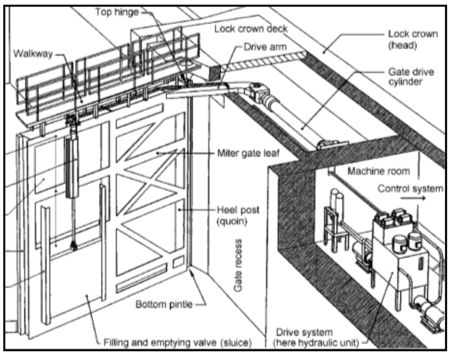
Presentation of the PIANC Report n°154 on Mitre Gates (*)
Chair: Fred Joers, Moderator: Philippe Rigo

Focus on the new innovative concepts & updated state of art by

- Fred Joers (USACE, USA): Introduction
- Ryszard Daniël, PhD. Eng. (RADAR Structural, NL): Load transfer, Hinge, Pivot, …
- Joshua Repp (Bergmann Assoc., USA) – Mitre Gate Design



Mitre Gates of the 1st & 2nd Set of Miraflores Locks, Panama



10:15 - 10:45 Break

10:45 - 12:30 **MITRE GATES DESIGN AND OPERATION – part 2**

Presentation of the PIANC Report n°154 on Mitre Gates (*)
Chair: F Joers, Moderator: Ph Rigo

- Jos Vorstenbosch (RWS, NL) – Materials & Use of FRP in MitreGates
- Eric Johnson (USACE, USA) – Mitre Gate Seals
- Yvan Cordier (VNF, FR) – Operations and Maintenance and Ancillary Components

12:30 - 14:00 Lunch

14:00 - 17:30: **Expert Panel**

Exchanges of experience & lessons learnt from the failures happened recently at few mitre gates,

Introduction by Fred Joers, WG154 Chair

14:00 - 15:30 **PRESENTATIONS OF THE STUDY CASES (lessons learnt)**
Moderator Ph Rigo

The following speakers will present the
- Lanaye Mitre Gates (BE), by David MONFORT, Bureau Greisch (BEG)
- Ivoz-Ramet Mitre Gates (BE), by Stéphane BARLET, SPW
- Evergem Mitre Gates (BE), by Jeroen VERBELEN, W&Z
- Cracking of USA Mitre Gates, by Eric JOHNSON, USACE, USA
- Cracking of Embedded Anchorage, by Fred JOERS, USACE, USA
- Maasbracht Lock Gates, by Jos VORSTENBOSCH, Rijkswaterstaat, NL

15:30 - 16:00 Break

16:00 - 17:15 **OPEN DISCUSSIONS**
Moderator Ph Rigo, InCom Chair, Prof. ULg

Expert Panel composed of:
- Rigoberto H. Delgado V., Panama Canal Authority
- James Costello, TetraTech, USA
- David Monfort, Bureau Greisch (BEG), Belgium
- Stéphane Barlet, SPW, Belgium
- Jeroen Verbelen, W&Z, Belgium
- Uwe Enders, BAW, Germany

and the PIANC WG 154 Members (*)

17:15 - 17:30 **CONCLUSION**:

Ph. RIGO, INCOM Chairman, and
Fred JOERS, WG154 Chairman on Mitre Gates (2017)

17:30- 18:00 Drink

(*) With the support of the WG 154 members:

- Frederick Joers, Eric Johnson, John D. Clarkson and Thomas Hood, USACE, USA
- Andrew Bator, St Lawrence Seaway, Canada
- Yvan Cordier, VNF, France
- Richard Daniel, RADAR Structural, NL
- Jos Vorstenbosch, RWS, NL
- Michael Hough, TetraTech (USA)
- Joshua M. Repp, Bergmann Associates, USA
- Juan Ollero, INROS LACKNER, Germany,
- Joris Meersschaert and Dieter Gevaert, SBE, Belgium

EXPERT PANEL (from 2 pm to 5:30pm)

Exchanges of experience & lessons learnt from the failures happened recently at few mitre gates

PRESENTATIONS OF THE STUDY CASES (lessons learnt)

1) Lanaye Mitre Gates (BE),

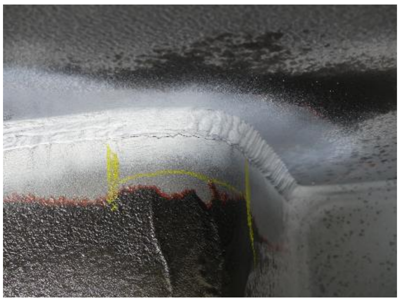
Speaker:

Name: David MONFORT
Position: Head of Department of infrastructures
Company: Study Office Greisch, (BEG)

Title: Crack Initiation on stiffeners & repair method, Downstream mitre gate - 4th lock of Lanaye (BE)

The new class VIb lock of Lanaye (225mx25m) is equipped with a downstream mitre gate. The lock water head is 14 m. The lock was inaugurated in July 2015.

One year later, a series of cracks were detected along the vertical stiffeners of both leaves of the miter gates.



A close collaboration started straight away between all the involved services (Public Administration, Contractors, Study Office, Supervising Office and Insurance). A series of investigations and additional calculations were performed (residual stresses due to welding method, combination of bending and shearing effects in the stiffeners, fatigue induced cracking,...).

The technical explanation was found out a few weeks later: the filling and emptying cycles of the lock generate a repeated local distortion of the horizontal box girders, whose webs are directly connected to the vertical stiffeners (U-rib). Local bending stresses appear and lead to fatigue cracking (oligo-cyclic phenomenon).

2) Ivoz-Ramet Mitre Gates (BE)

Speaker:

Name: Stéphane BARLET
Position: Civil servant - Project Engineer
Administration: SPW – Waterways of Liège, Belgium

Title: Ivoz Ramet (BE) - Two locks equipped with mitre gates - Two modes of transmission of the forces

The Ivoz-Ramet lock site has two locks equipped with mitre gates. The problems met in these 2 locks relate both to the transmission of the forces coming from the mitre gates to the sidewalls. Indeed, the transmission mode of the forces to the sidewalls depends of the orientation of the contact surfaces of the support blocks. When closed (under differential water level), the gates of the 1st lock transmit a part of the water pressure to the support blocks and the other part to the hollow quoin and the bottom sill ("mixed solution").

The gates of the 2nd lock transmit all forces to the support blocks only ("pure solution"). This means that the support blocks are oriented to take all the forces. Each concept has advantages and disadvantages, which may induce troubles.

Indeed, the mixed solution (1st lock) allows a better sealing but the large number of degrees of freedom reduces the control of the behaviour. At this 1st lock, an upper tie rod breaks (Figure 1) and the seal (glue) using to fix the neoprene on its supports does not resist, allowing the neoprene moving (Figure 2), inducing navigation interruption. Corrosion of the spring washer, small ship impacts and manufacturing defects (neoprene sealing) are at the origin of successive failures (problems).

On the other hand the pure solution (2nd lock) requires more precise adjustment and is very sensitive.

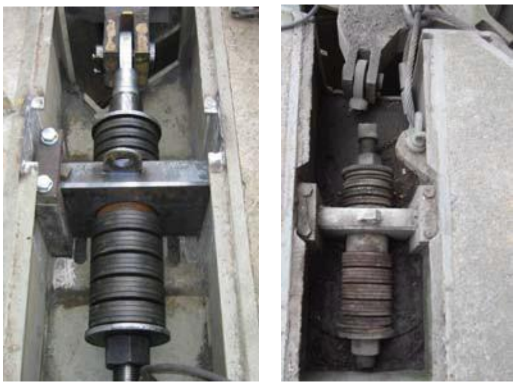


Figure 1: The "Belleville springs" elastic connexion (of the upper tie rod with the gate), which failed (cracks occurred in the springs).

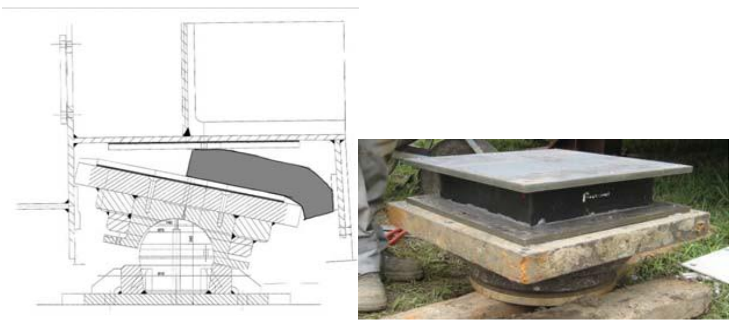


Figure 1: The lower support with the pintle (rotation around vertical axis) and a neoprene support (as in bridge) to allow heeling and a small horizontal displacement

3) Evergem Mitre Gates (BE)

Speaker:

Name: Jeroen VERBELEN
Position: Project Engineer
Administration: Waterwegen & Zeekanaal NV (W&Z)
Dpt. BovenSchelde, Flanders/Belgium

Short presentation of the technical problem(s) which occurred, the possible reasons (causes) and how the problem(s) where solved:

(5-15 lines: Start by giving the lock name (close City, Country), lock dimension and water head and explain the problem that occurred – please use pictures and drawing)

Title: Failure and adjustment of the gate alignment, Upstream and downstream mitre gates; 2nd lock of Evergem (BE)

The new class VIb lock of Evergem, near Ghent, was inaugurated in 2009. The lock has identical pairs of steel miter gates with a single leaf dimension of 14m x 8m and weight of 90 tons. The design lock water head is 3m.

In 2014 significant problems occurred when the gates reached the closed position only under a higher force (jacks). As part of a first repair was performed in March 2014. It concerned the upper connection between the gate and the pivot, which was strengthened on all gates, after a diving inspection had pointed out that almost all bolts of the upper connection were cut off. Several theoretical calculations and field investigations were made.

In August 2014 similar problems occurred during the closing of the gates. In addition a cracked pivot and some support blocks that was torn off the wall where observed. On all gates the support blocks at the back post showed severe wear. The repair strategy was threefold. First a detailed 3D alignment survey was carried out. Subsequently a virtual geometric simulation indicated that an unhindered gate motion was not possible. Finally the alignment of the rotation axis and all support blocks and seals were adjusted on all gates.

At present the lock is in full operation. The necessity of final adjustments is under investigation. Meanwhile a lawsuit against the contractor is ongoing.

4) McAlpine and Lower Granite Mitre Gates (USA),

Speaker:

Name: Eric Johnson
Position: Structural Engineer
Administration: US Army Corps of Engineers

Title: Cracking of USA Mitre Gates near the Pintle (Bottom Pivot)

In the USA, there has been widespread problems with miter gates cracking near the pintle (bottom pivot) of the gate. The main cause is lack of bearing contact of the gate-to-wall contact blocks. When contact is lost, the large hydrostatic forces acting on the gate are transferred horizontally along the gate through the main framing beams into the pintle (pivot) instead of into the wall bearing area. This causes large localized stresses in the pintle region which when coupled with poor material fracture toughness and poor geometrical detailing leads to cracks.

In 1998, cracks were discovered in the skin plates and bottom girders of both gate leaves at the Lower Granite Lock on the Snake River in the state of Washington (See figs on the right). A variety of repair techniques were used to get the gate back into operation.

In 2004, in the McAlpine Lock on the Ohio River cracks were found, which lead to emergency repairs and temporary lock closure. The lock gates were repaired using large patch plates (See Fig bottom left.

5) Poe Lock at Soo Locks Complex (USA)

Speaker:

Name: Frederick Joers
Position: Director, Inland Navigation Design Center
Administration: US Army Corps of Engineers

US Army Corps of Engineers®

Title: Cracking of Mitre Gate Embedded Anchorage (Top Hinge)

The Soo Locks are located on the St. Marys River at Sault St. Marie, Michigan, on the international border with Canada. There are two operating locks at the Soo, the MacArthur Lock, (1943) and the Poe Lock (1968). They are critical locks since half of all steel produced in the U.S. is manufactured with domestically mined ore and over 92 % of the iron ore mined in the U.S. traverses through the Soo Locks.

The miter gate embedded anchorages were being studied as part of a Rehabilitation Report. An analysis revealed a potential near-term risk of failure in the upper region of the embedded anchorage. The study concluded that Embedded Anchorages exceeded their life expectance and would likely perform until they experience a "SUNNY DAY" brittle failure with little to no outward signs of distress or warning – resulting in mitre gate collapse.

Based on the study findings, concrete was removed to uncover and inspect the anchorages. Inspection found cracks where the analysis predicted. All the embedded anchorages at the lock were rehabilitated to keep lock in good operation condition.

6) Maasbracht Lock Complex (The Netherlands)

Rijkswaterstaat

<u>Speaker</u>:

Name: Jos Vorstenbosch
Position: Senior Consultant
Administration: Rijkswaterstaat

Title: Maasbracht Lock Gates

The Maasbracht Locks (Sluizencomplex Maasbracht) located on the Juliana Canal in the Netherlands. A variety of interesting issues will be discussed including hinge design using FRP, anchorage failure, fatigue design of welded connections, and contact blocks using FRP.

PIANC INLAND NAVIGATION COMMISSION (INCOM)

WG154 – MITER GATES

WORSHOP 6TH AND 7TH NOV 2017

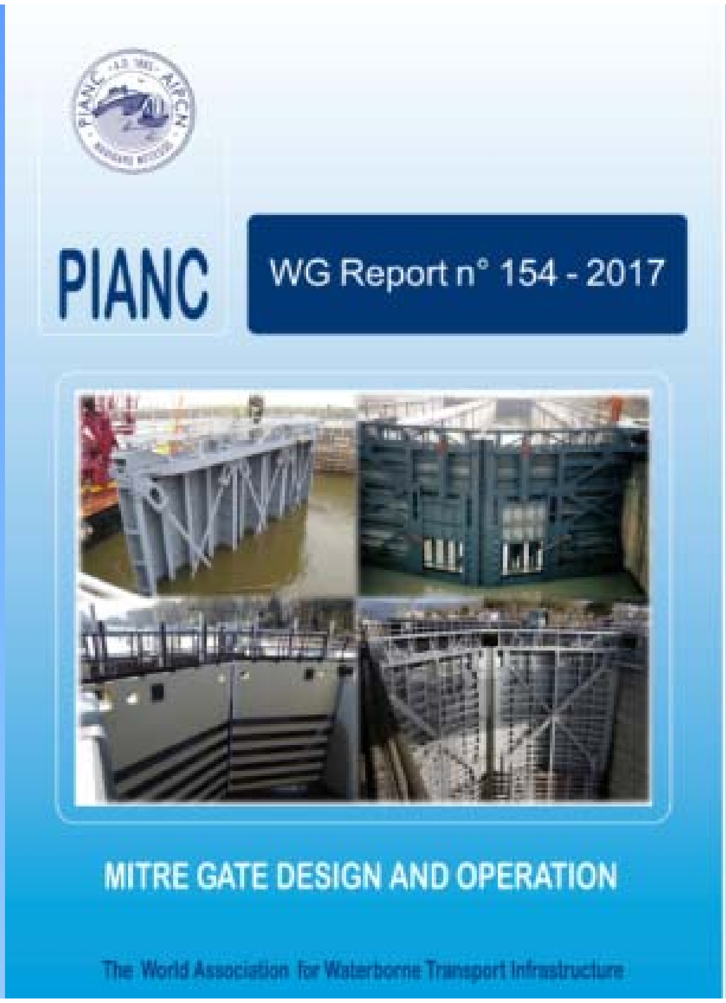
PHILIPPE RIGO
(Prof Ulg, BE)
INCOM CHAIRMAN

WG 154

Mitre Gate Design and Operation

(2017)

Chair F JOERS, USACE, USA



InCom WGs on Navigation Locks

State of Arts in Navigation Locks

PIANC proposes a series of integrated reports

- **PIANC Report on Locks – 1986 (state of art)**
- **WG 106 - Innovations in Navigation Lock Design (2009)**
- **WG 151 - Impacts of seismic loads and ship impact on lock gates**
- **WG 154 - Miter Gate Design and Operation**
- **WG 155 - Ship behavior in locks and lock approaches**
- **WG 173 - Movable Bridges and Rolling Gates**
- **WG 189 - Fatigue of Hydraulic Steel Structures**
- **WG 190 - Corrosion Protection of Lock Equipment**
- **WG 191 - Composites for Hydraulic Structures**
- **WG 192 - Automation and remote operation of locks and bridges**
- **WG 198 - Saltwater Intrusion Mitigations and Technologies for Inland Waterways**
- **WG 199 - Health Monitoring for Port and Waterway Structures**

PIANC Congress Panama , May 2018

34th PIANC WORLD CONGRESS
PANAMA 2018 May 7 to 12
Connecting Maritime Hubs Globally

- ❑ **Sustainable Inland Waterways (Values of IW)**
- ❑ **Innovations in Lock and Gate Design**
- ❑ **Rolling Gates and Operational Machinery Process Design**
- ❑ **Salt Water Intrusion Mitigation Techniques**
- ❑ **Inflatable Structures in Hydraulic Engineering**

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InCom (Inland Navigation Commission) is one of the 4 international technical commissions of PIANC.

(**PIANC**) Permanent International Association of Navigation Congresses

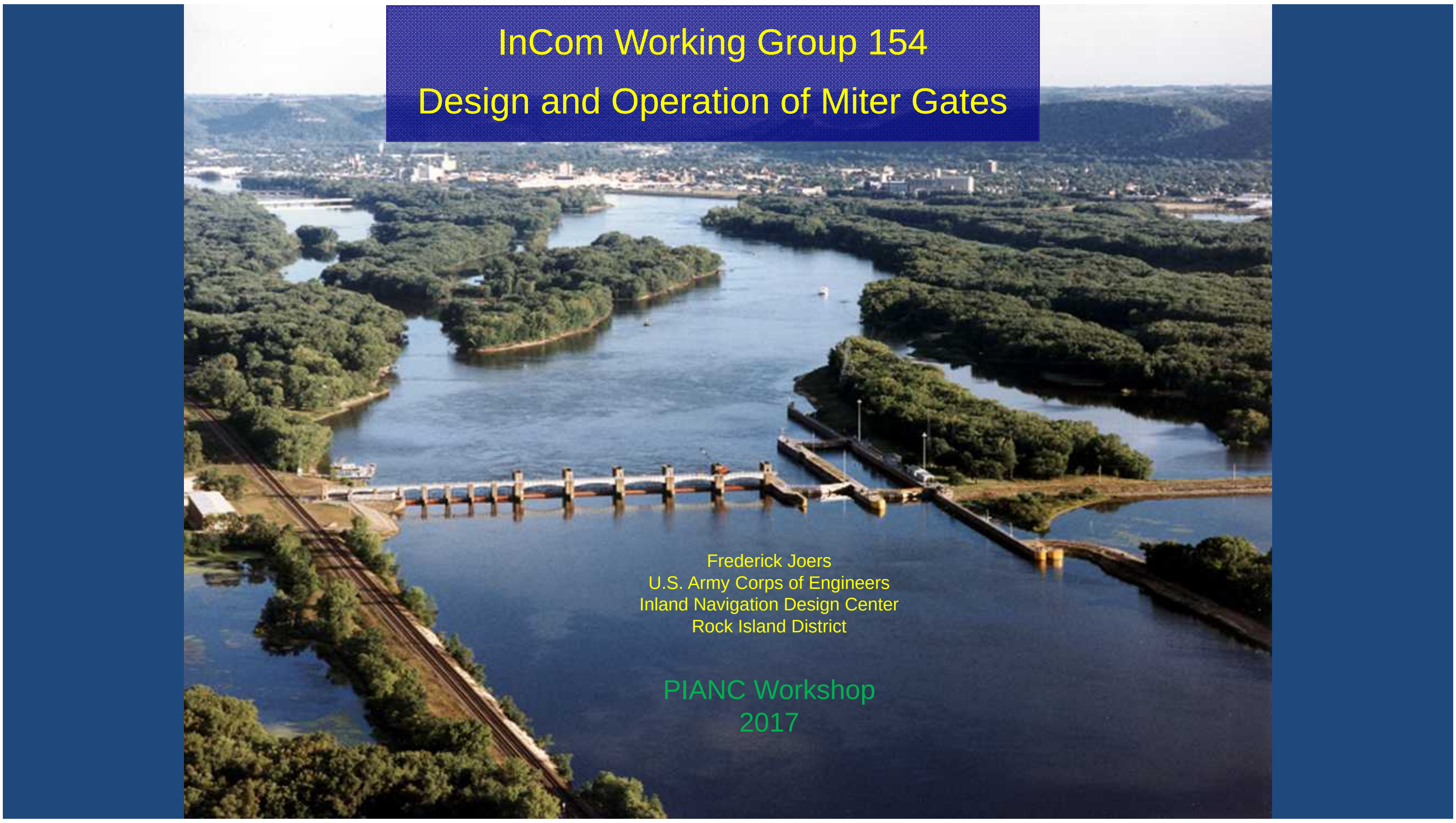
The InCom Commission focusses on Inland Navigation, Inland Waterways, River and Port Infrastructures, Inland Waterway transport and Logistics, ..

Contact : **Prof Ph RIGO.** , Univ of Liege, InCom Chairman; Tel: +32 4 366 93 66 (office), or use the CONTACT FORM in the Menu **Resources**

Latest Events

Presentations - Workshop INCOM ECLAC ANTAQ
24 October 2016 EVENTS

PIANC -ECLAC-ANTAQ WORKSHOP - COPEDEC 2016
24 October 2016 EVENTS



Working Group 154 Terms of Reference

- The objective for the working group was to identifying "Best Practices" for the design, fabrication, and operation of lock mitre gates
- The goal for this working group was to create a compilation of mitre gate designs that discusses the benefits and disadvantages and makes recommendations for typical sized low, medium and high head mitre gates.
- This group will build upon the information provided by *WG 29 Innovative Lock Design, WG 129 Asset Management, WG151 Impacts of Seismic Loads and Ship Impact on Lock Gates and WG 138 M&E Lessons Learnt*.

Members Working Group 154

Mr. Andrew Bator	Member	Canadian St. Lawrence Seaway Management Corp.
Mr. John Clarkson	Member & InCom Rep.	U.S. Army Corps of Engineers
Mr. Yvan Cordier	Member	Voies Navigables de France
Dr. Richard Daniel	Member	RADAR Structural, The Netherlands
Mr. Thomas Hood	Member	U.S. Army Corps of Engineers
Mr. Michael Hough	Member & YP	Tetra Tech (USA)
Mr. Frederick Joers	Chairman	U.S. Army Corps of Engineers
Mr. Eric Johnson	Member & YP	U.S. Army Corps of Engineers
Mr. Jos Vorstenbosch	Member	Rijkswaterstaat, The Netherlands
Mr. Joshua Repp	corresponding member, major contributor	Bergman Associates (USA)
Mr. Juan Ollero	corresponding member	INROS LACKNER AG (Germany)
Mr Joris Meersschaert	Part time member	SBE (Belgium)

Working Group 154

Meetings:

September 2013 Maastricht, Netherlands
February 2014 Brussels, Belgium
September 2014 St. Catharines, Canada
April 2015 Bremen, Germany
November 2015 Paris, France
November 2016 Seattle, USA
+ conference calls/ E-mail / SharePoint website/small group meetings

Working Group 154
Design and Operation of Miter Gates

This report gives an introduction, history, and terminology distinct to mitre gates. General design aspects, advantages, disadvantages of mitre gates and other types of lock gates are discussed to aid in selection of type of lock gate used. Mitre gate design guidance from around the world is listed for comparison and aid to designers. This report provides guidance and outlines potential issues that may be encountered during the design phase of a new mitre gate. In addition to outlining general guidance, an awareness is raised of both normal and unexpected design conditions that can alter design approach, methodology, and detailing of gate features.

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Working Group 154
Design and Operation of Miter Gates

Mitre gates have a long history of use with little modification to their historic geometric shape and have been adapted for many uses in navigation. There are a wide variety of conditions that mitre gates are used in with a wide variation of heights and widths. These site-specific conditions pose different advantages and disadvantages which are discussed in more detail in the report chapters. More general conclusions and recommendations are discussed at the end of the report.

Design and Operation of Miter Gates Report

1 MITRE GATE SYSTEMS
Gate Selection Process / Short History / Geometry of Gates and Recesses / Free, floating and fixed hinged systems / Horizontally and vertically framed systems / Drive Systems and connections

2 MITRE GATE COMPONENTS
Framing / Buoyancy Chambers / Top Hinge / Anchorages / Pintles / Heel (Quoin) and Mitre Blocks / Lock Filling and Emptying Valves / Diagonals / Struts / Drive Systems / Operating System Connections / Gate Controls

3 MITRE GATE DESIGN ISSUES AND GUIDANCE
Design Guides /General Load Conditions / Design and Analysis Methods / Fatigue / Connections / Bolted Mitre Gates
/ Flexibility/Stiffness of the Leafs and Structure / Gate Recess Design / High Lift Lock Mitre Gates

Design and Operation of Miter Gates Report

4 GATE and COMPONENT MATERIALS

- Materials for Structural Framing / Corrosion protection / Contact Materials / Seal Materials / Hinge Materials / Self-lubricating Fiber reinforced polymers / Sliding Materials / Bolts, nuts, and rivets / Anchorages in concrete / Ship arrestors

5 MITRE GATE SEALS

- Seal type/ bottom seals/ side seals/ contact surface

6 ANCILLARY COMPONENTS

- Walkways and Access / Lubrication / Mitre Guide and Alignment Features / Impact Protection Systems

Design and Operation of Miter Gates Report

7 OPERATIONS AND MAINTENANCE

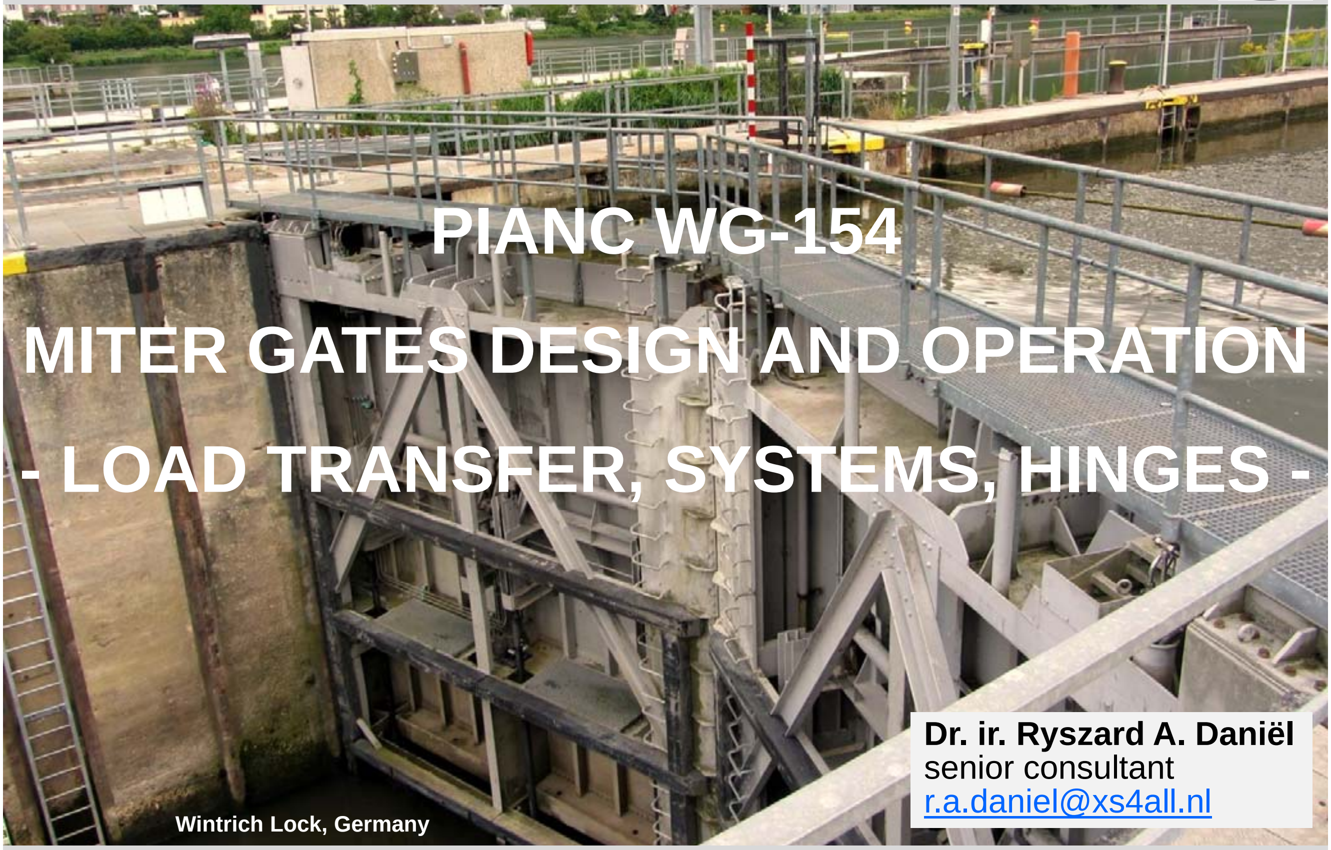
- Spare Parts / Emergency Parts / Spare Gates / Standardization of Replacement Parts / Methods of Repair / Ice and Debris Management / Inspections / Structural Heath Monitoring/Cranes

8 CONCLUSIONS

- Recommendations Related to Design, Geometry and Framing/Recommendations related to analysis/Recommendations Related to Materials and Maintenance

9 REFERENCES

APPENDIX A: Mitre Gate Operation Speed
APPENDIX B: Measure Leakage Rates
APPENDIX C: Cranes for Installation
APPENDIX D: Design Loads Guidance



PIANC WG-154

MITER GATES DESIGN AND OPERATION

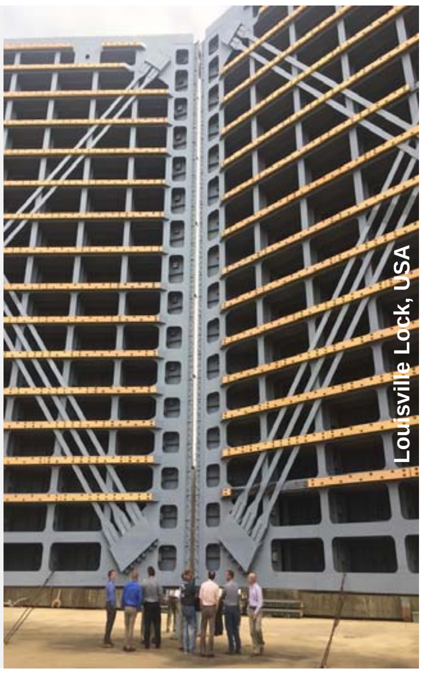
- LOAD TRANSFER, SYSTEMS, HINGES -

Wintrich Lock, Germany

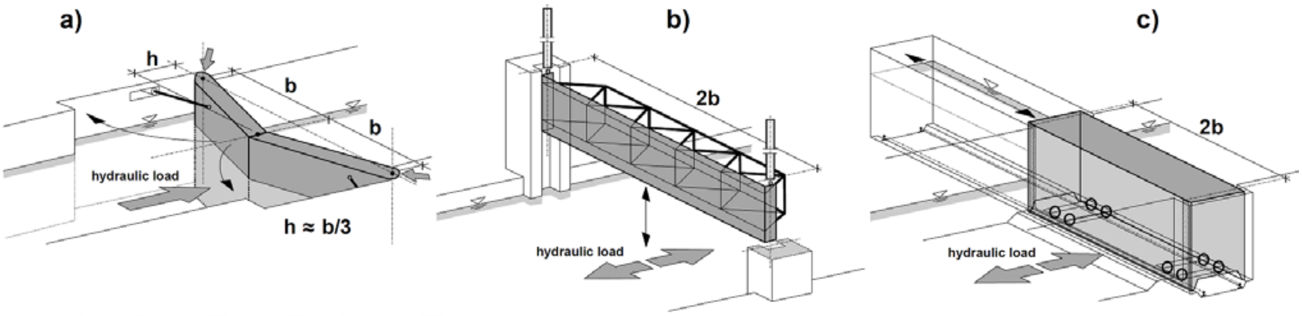
Dr. ir. Ryszard A. Daniël
senior consultant
r.a.daniel@xs4all.nl

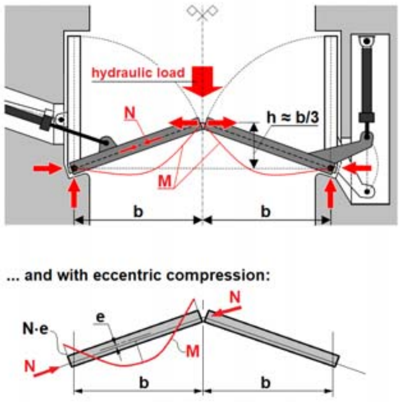
Personal note …

CONTENTS:



WHAT MAKES MITER GATES SPECIAL?



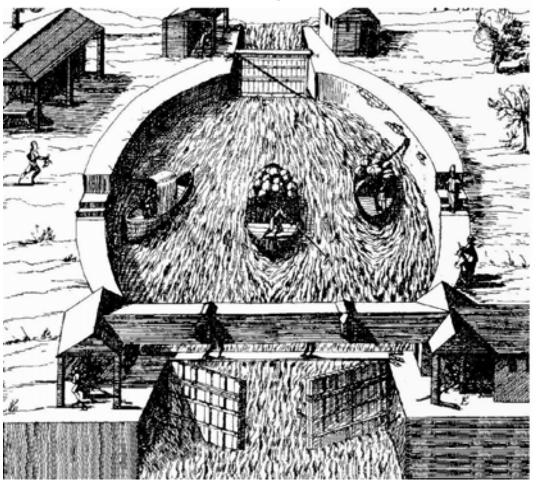


- Compact spatial layout
- Shorter leaf bending span, economical
- Symmetrical, navigation friendly closing
- Can carry high differential water heads
- “Water itself seals the gate”
- Various drive arrangements possible
- Relatively low drive forces required

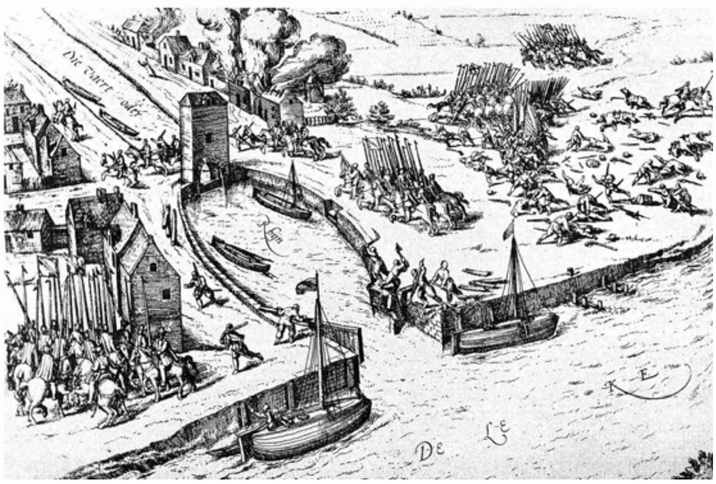
HOW IT ALL BEGAN … (1)

Bertola da Novate or Leonardo da Vinci ?

a)



b)

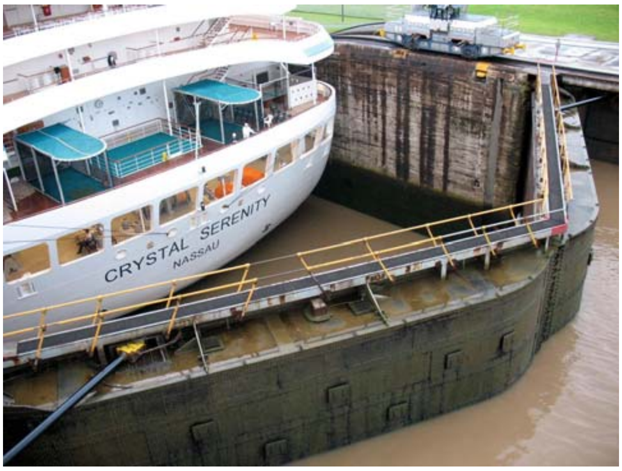


Early Italian lock with a miter gate
(after R. Pohl, Dresden University of Technology)

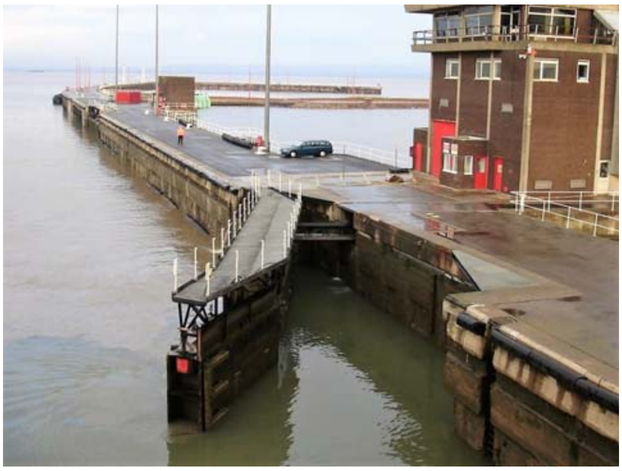
Netherlands’ Vreeswijk Lock in XVI century
(after G.J. Arends, Delft University of Technology)

HOW IT ALL BEGAN … (2)

Development in XIX and XX century



Old Panama Canal lock gates
(here Crystal Serenity in Miraflores Locks)



Bristol Portbury Lock gate (42.7 m)
(photo F. de Crescenzo)

ADVANTAGES AND DISADVANTAGES

Advantages	Disadvantages
• The most frequently used type of gate – well-proven technology	• Single-sided operation, although low reverse loads can be carried under some provisions
• Sustainable principle of operation: "water head itself fixes and seals the gate"	• Double gates required when high water heads can occur from both sides
• Many different structural systems possible – nearly all in proven technology	• Not economical for very wide navigation locks (e.g. sea harbors), wider than about 40.0 m
• Construction and maintenance costs low or moderate in a wide range of dimensions	• Closing under flow very difficult
• Gate recesses along the lock chamber → small space consumption	• Number of system components relatively high due to two sets of gate leaves and drives → increased risk of failure
• No limit to overhead space for navigation → fit for locking ships of any height	• Necessity to synchronize the motion of leaves
• Opening and closing times low or moderate	• High motion resistance in wide locks → high drive energies and powerful drives required
• Can be constructed with entirely free lock deck – valued for special transports, mooring of large ships, emergencies, etc.	• As above, with as a result slower gate opening and closing
• Symmetric flow patterns during opening and closing – favored by navigation	• High loads on gate hinges during motion → wear problems by intensive operation
• Filling and emptying devices easy to fit to gate and accessible for small maintenance	• Gate locking necessary if water head can appear on both sides – difficult and not leak-free
• Less vulnerable to sediment and sunk obstacles than rolling gates (but care required)	• Hydraulic load transfer not entirely in plane of chamber walls → massive crowns required
• In double-sided service, lock crowns can be shorter than for double sets of miter gates	• Very sensitive components (bottom pintles) practically inaccessible for maintenance
• Relatively easy in transport and installation due to compact dimensions of components	• Gate maintenance in site possible only after (partial) dewatering of lock chamber
• Architectural advantage of free horizon	• Operation in winter (ice floes) and in situations with floating debris can present a problem

GATE SYSTEMS - CLASSIFICATION

"EUROPEAN" VIEW:

- **Character of hydraulic load transfer:**
  - a) free hinged (load transfer through heel posts)
  - b) floating pintle (load transfer through heel posts)
  - c) fixed hinged (load transfer through hinges)
- **Direction of main girders:**
  - d) horizontally framed
  - e) vertically framed
- **Arrangements for skin plate location:**
  - f) plate girders with skin upstream
  - g) skin plate double-sided
  - h) plate girders with skin downstream
  - i) fold plate and other systems
- **Arrangements for vertical load transfer:**
  - j) bottom pintle – top hinge
  - k) bottom hinge – top pintle
  - l) support or suspension outside hinges
  - m) buoyancy tanks
- **Drive connection:**
  - n) direct to (top) girder
  - o) indirect through drive arm

The focus in all the structural systems (a) through (o) is put on the properties of the gate structure and not of its drive mechanism. When drive mechanisms are concerned, the following systems be identified:

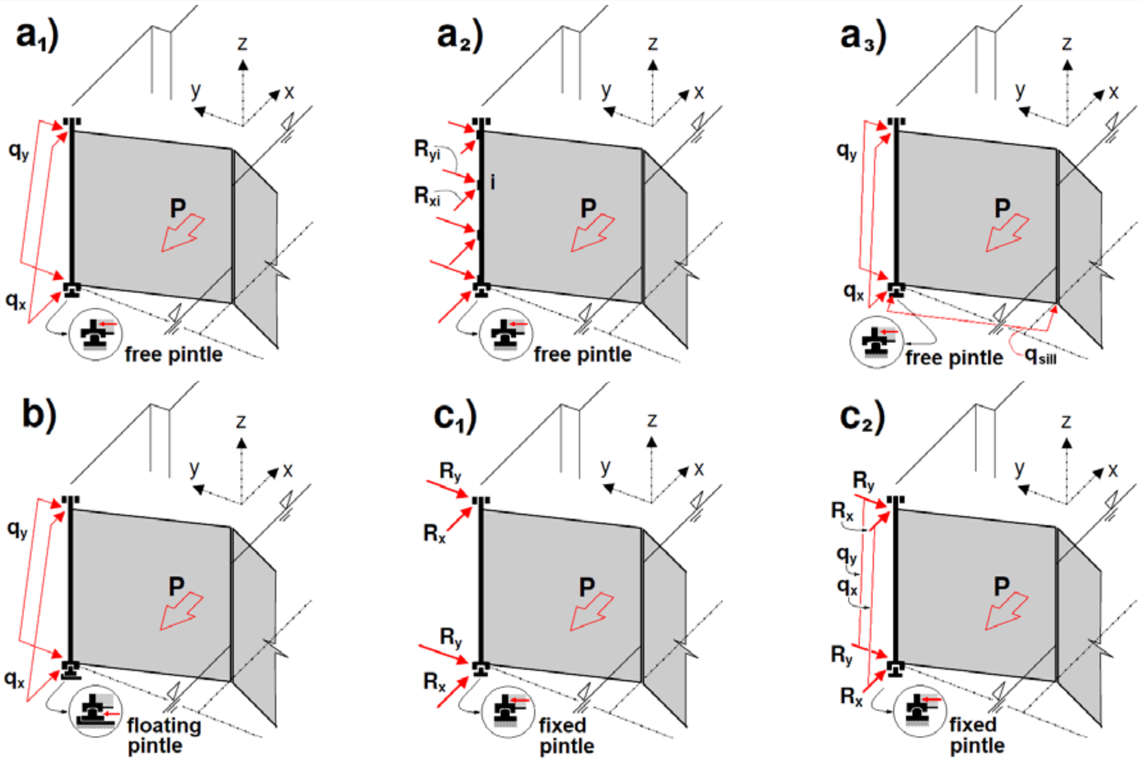
- **Drive mechanism:**
  - p) manually driven (directly or geared)
  - q) electro-mechanically driven
  - r) electro-hydraulically driven
  - s) hydrostatically or otherwise driven

"AMERICAN" VIEW:


Ohio River Lock 2


Ohio River Lock 52

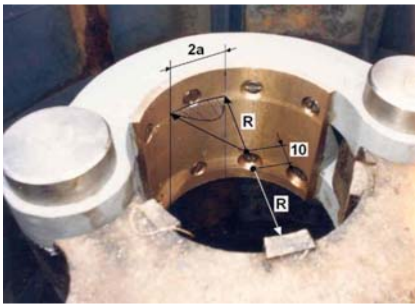
HYDRAULIC LOAD TRANSFER (1)



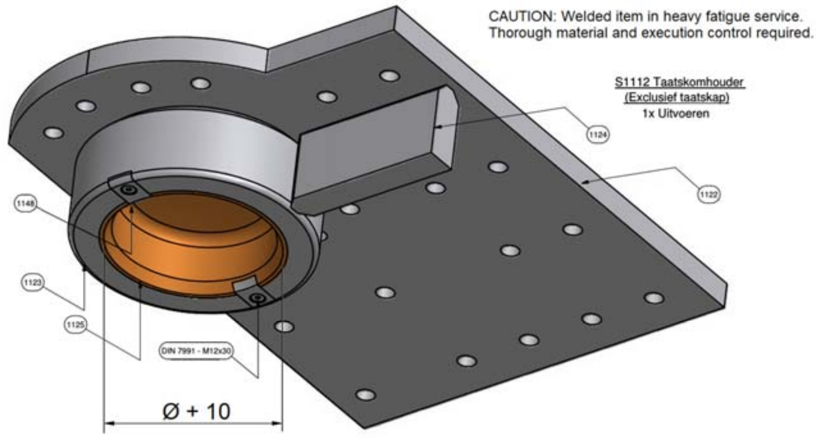
HYDRAULIC LOAD TRANSFER (2)

European free hinged gates, typical hinge assemblies:

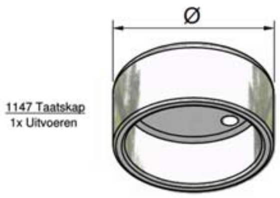
TOP HINGE BRACKET



Bushing: Aluminum bronze
Pin (in gate): Steel 34CrMo4



BOTTOM PINTLE ASSEMBLY



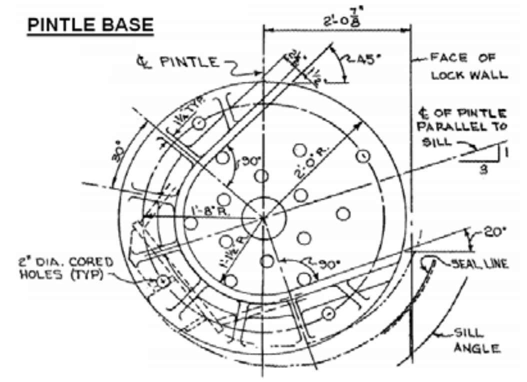
Pos	Aantal	Benaming	Materiaal	Lengte	Breedte	Hoogte	Gewicht
M12x 30	2	Hexagon socket countersunk head cap screws	Steel, Mild DIN 7991	30			0,1 kg
1148	2	Borgplaat 15mm	S355J2+N	74	50	15	0,7 kg
1147	1	Taatskap rond 280	Mangaanstaal	280		140	29,0 kg
1125	1	Taatskom rond 330	34CrNiMo6	330		155	43,4 kg
1124	1	Plaat 60 mm	S355J2+N	320	155	60	21,9 kg
1123	1	Rond 440	S355J2+N	440	440	155	76,3 kg
1122	1	Plaat 50 mm	S355J2+N	1122	810	50	315,9 kg

Hillebrand Konstruktiebedrijf B.V. Kleverkerkseweg 83 4338 PM Middelburg Tel: 0118-612348

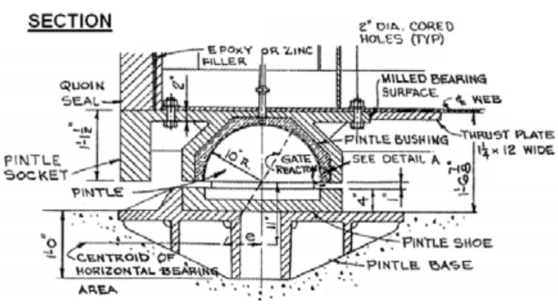
HYDRAULIC LOAD TRANSFER (3)

American floating pintle gates, typical hinge assemblies:

PINTLE BASE



SECTION



TOP HINGE **THREE-PIN ANCHORAGE**

FIVE-PIN ANCHORAGE

HYDRAULIC LOAD TRANSFER (4)

2nd Lock Evergem, Belgium:

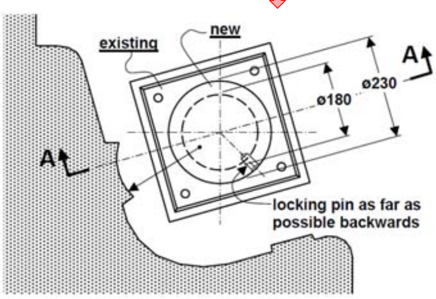
Heel post (quoin) compression:

photos Dept. MOW

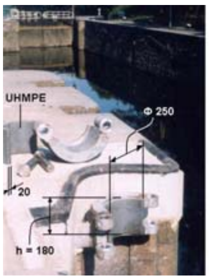
HYDRAULIC LOAD TRANSFER (5)

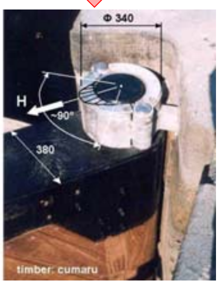
Free hinged gates, new contact materials:

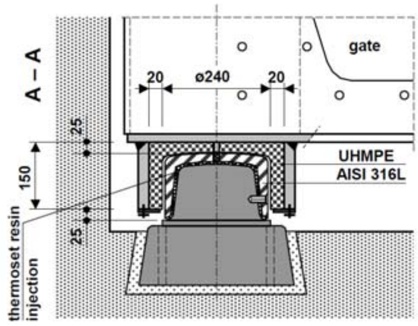
UHMPE in pintles



UHMPE in top hinges





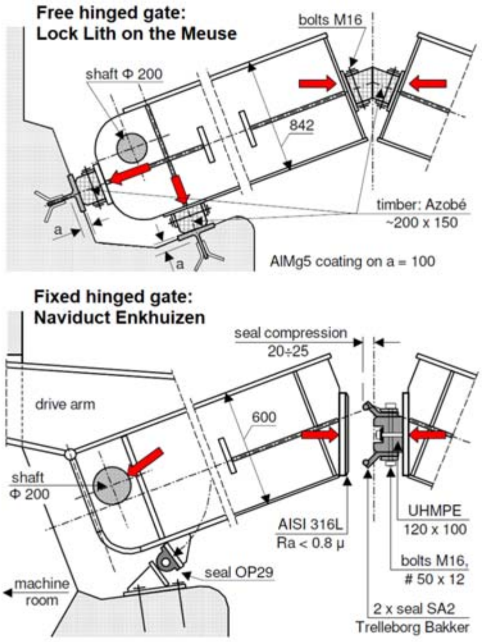


Detailing questioned

FEROFOFM T814 in hinges and pintles

HYDRAULIC LOAD TRANSFER (6)

European fixed hinged gates:



source: Daniel R.A.: Contact behavior of lock gates and other hydraulic closures, Lambert Academic Publishers, Saarbrücken, 2011

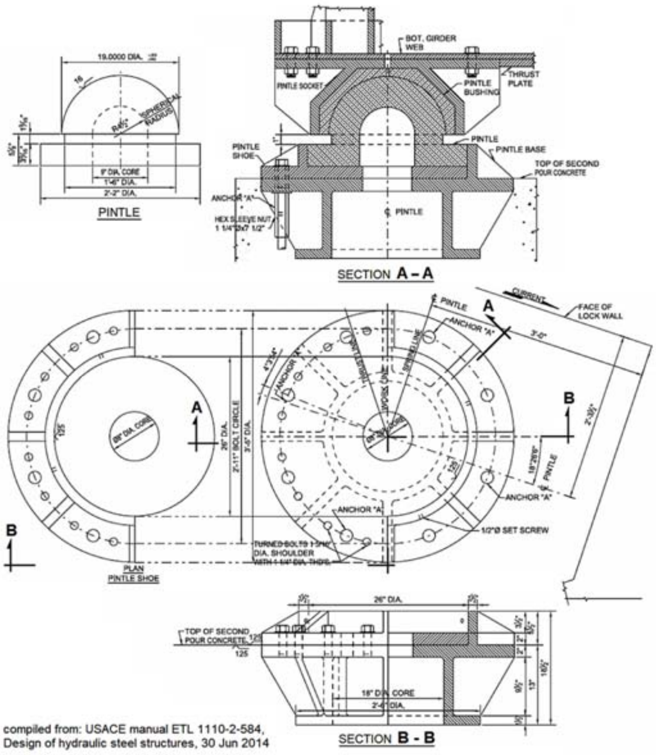
Naviduct pintle cap

Naviduct pintle

HYDRAULIC LOAD TRANSFER (7)

American fixed hinged gates:

Louisville Lock miter gate

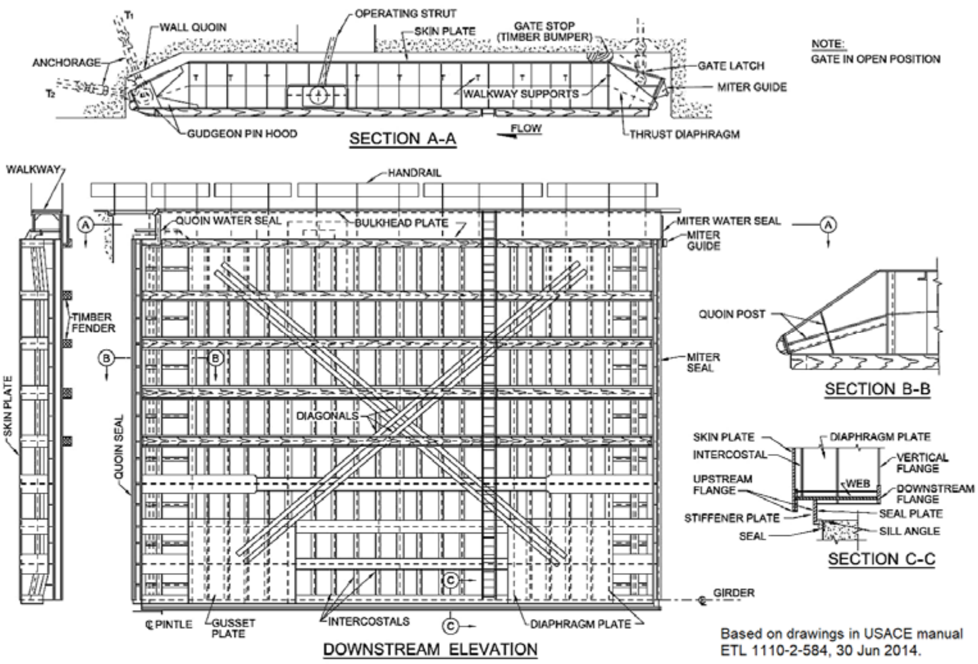


compiled from: USACE manual ETL 1110-2-584, Design of hydraulic steel structures, 30 Jun 2014

Louisville Lock pintle assembly

MAIN GIRDER DIRECTION (1)

Horizontally framed gates:



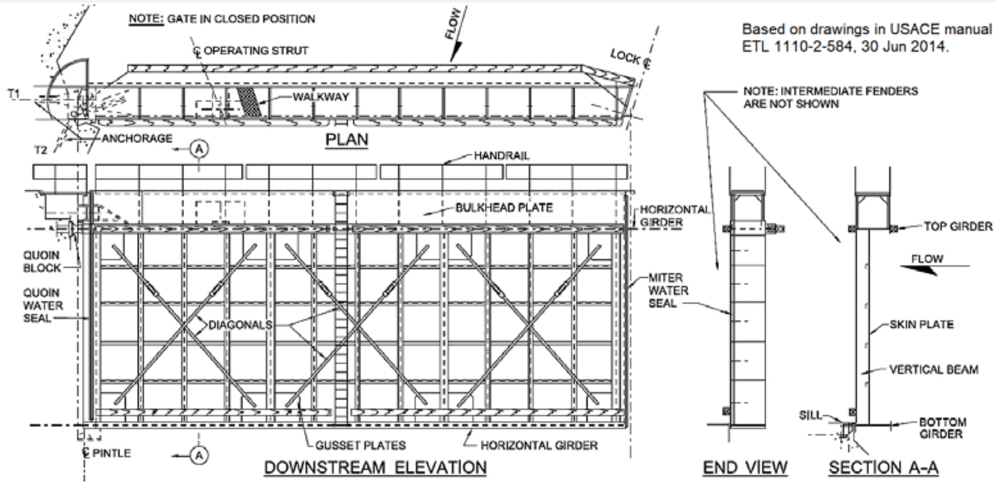
Based on drawings in USACE manual ETL 1110-2-584, 30 Jun 2014.

Three Gorges Lock, Yangtze, China

Écluse de Châteauneuf du Rhône, France

MAIN GIRDER DIRECTION (2)

Vertically framed gates:



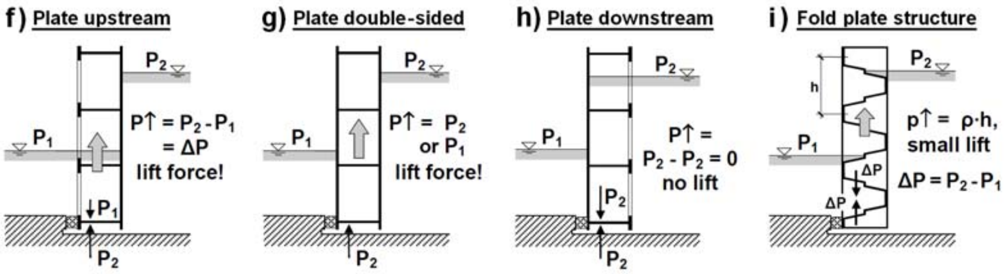
Based on drawings in USACE manual ETL 1110-2-584, 30 Jun 2014.

Mississippi, Lock & Dam 21, USA

Mississippi, Lock & Dam 52, USA

SKIN PLATE LOCATION (1)

Possibilities, general:



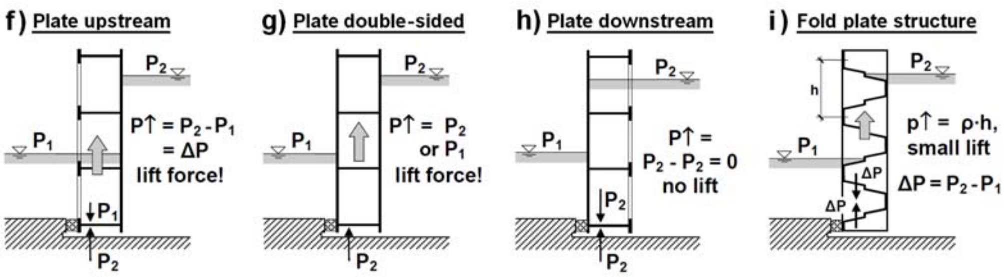
European problem, because:

Kiel-Holtenau Lock, Germany (1895)

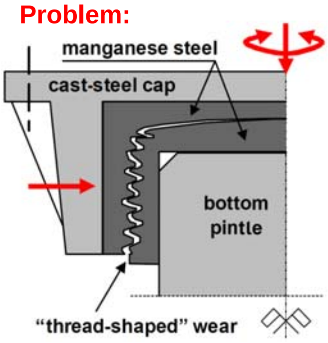
Mississippi Lock 19, Keokuk, Iowa

SKIN PLATE LOCATION (2)

Possibilities, general:



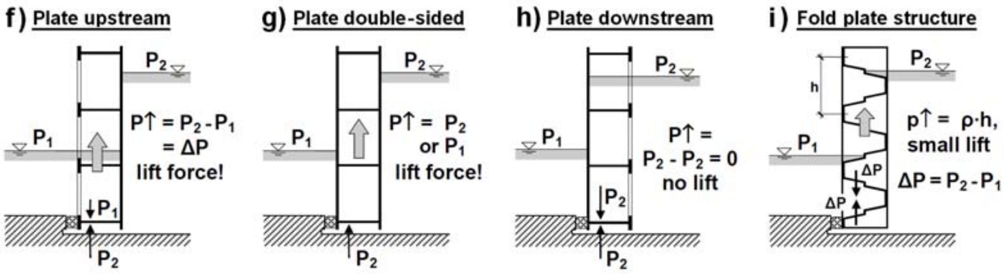
Detail of conventional bottom pintle
Problem:



Solution: plate downstream
Miter gates of the 2nd Lith Lock on the Meuse

SKIN PLATE LOCATION (3)

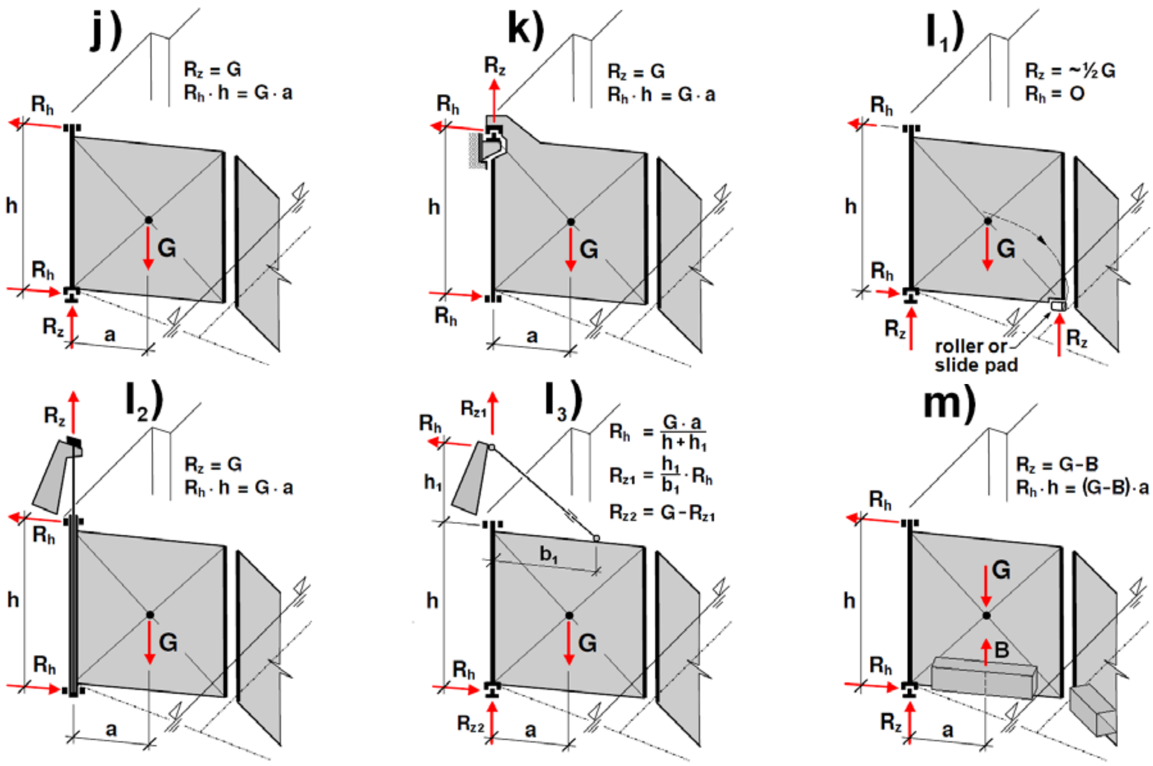
Possibilities, general:



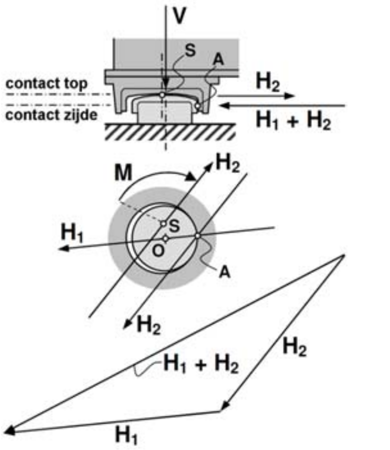
Kattendijksluis Antwerp, Belgium

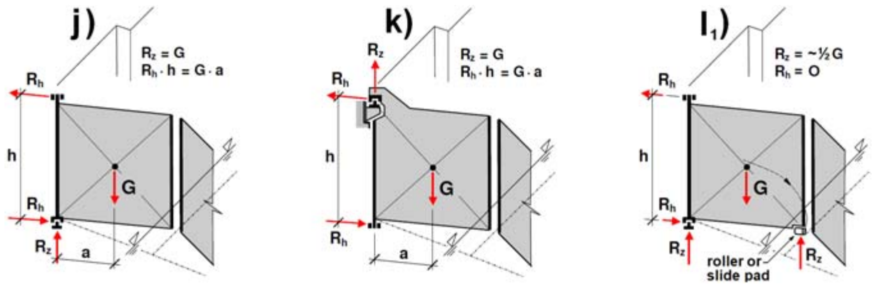
Uelzen Lock II, Germany

VERTICAL LOAD TRANSFER (1)



VERTICAL LOAD TRANSFER (2)



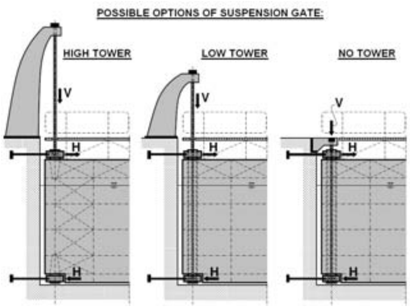


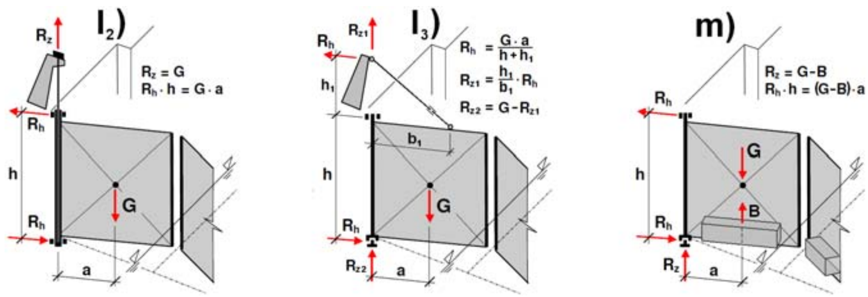
Amsterdam, NL

Bristol, UK

Groningen, NL

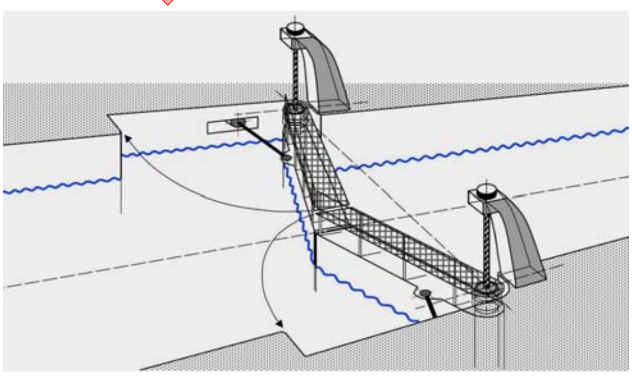
VERTICAL LOAD TRANSFER (3)



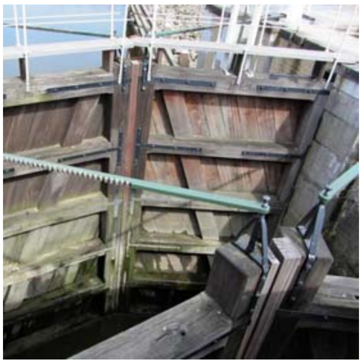


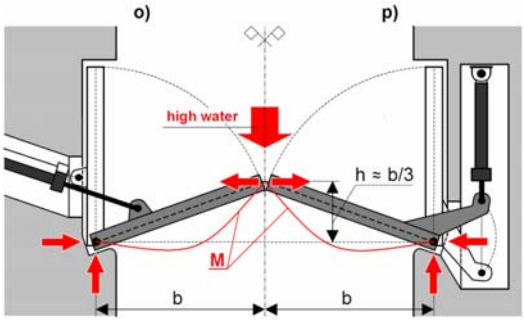
Concept, not realized yet

New Orleans, USA



DRIVE CONNECTION (1)

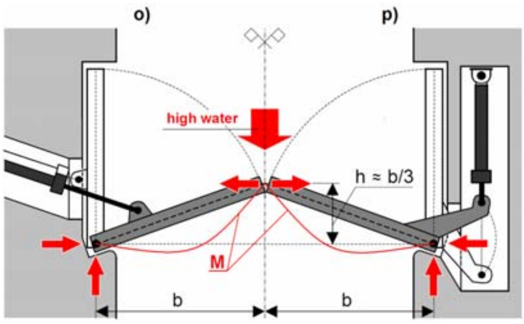




Old Born Lock on the Meuse

Orange Locks, Amsterdam

DRIVE CONNECTION (2)



BUT DRIVES ARE ANOTHER STORY

Afsluitdijk Lock, Kornwerderzand

Orange Locks, Amsterdam

CONCLUDING REMARKS:

- Miter gates are an ingenious concept of hydraulic closures; and have a long and stunning history. They are particularly favored in inland navigation locks.
- The advantages of miter gates resulted in a lagre number of their systems. These systems can be distinguished with respect to various aspects, like:
  - **hydraulic load transfer** – **vertical load transfer**
  - **direction of main girders** – **gate drive connection**
  - **position of skin plate** – **type of drive mechanism**.
- Most essential is the division in view of hydraulic load transfer. The systems are: free hinged gates, fixed hinged gates, floating pintle gates, gates without and with load transfer to sill.
- Miter gate systems require specific designs of **bottom pintles, top hinges**, **quoins** and seals. Both conventional and innovative arrangements are practiced.
- The most common in America is the division in view of main girder direction. It distinguishes **horizontally framed** gates and **vertically framed** gates. The latter perform particularly well in wide but relatively shallow locks.
- The **position of skin plate** affects the gate operation in many ways, including vertical load variation. This and the **vertical load transfer** lead to yet other systems. Generally:
  - Downstream skin plate location reduces uplift in European gates.
  - Vertical load transfer through top hinge becomes increasingly common.
- Gate drives are usually coupled either **directly or through lever arms** to the top girders. The latter is more complex but it offers advantages in terms reliability and maintenance.

Naviduct Enkhuizen, Netherlands

RADAR Structural, Gouda, Netherlands
http://radaniel7.wix.com/radar-structural
International Navigation Association PIANC
Inland Navigation Commission (InCom)

Thank you for your attention

Dr. ir. Ryszard A. Daniël
senior consultant
r.a.daniel@xs4all.nl

Naviduct Enkhuizen, Netherlands

PIANC Workshop
Mitre Gate Design and Operation
PIANC Report No. 154 Overview

Mitre Gate Design

Prepared by:

Josh Repp, P.E. BERGMANN ASSOCIATES

Report Overview

Part 1 (morning):

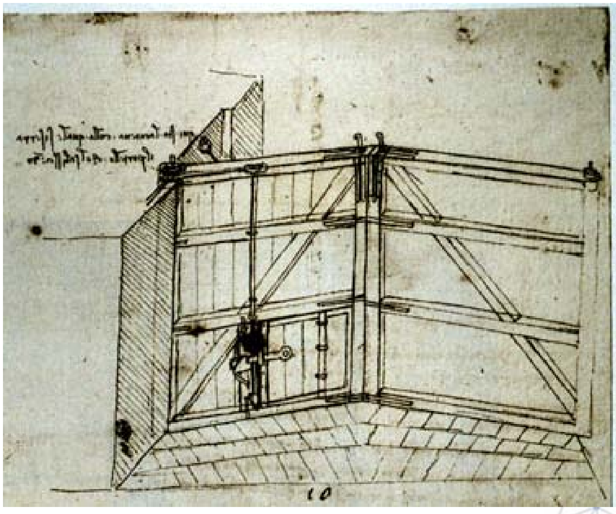
1. Mitre Gate Systems
2. Mitre Gate Components
3. Mitre Gate Design Issues and Guidance

Part 2 (afternoon):

4. Gate and Component Materials
5. Mitre Gate Seals
6. Ancillary Components
7. Operations and Maintenance
8. Conclusions
9. References

Chapter 1: Systems

- **Goals:**
  - Identify History
  - Terminology
  - Selection Process
  - Geometry
  - Structural System



Chapter 1: Gate Selection Process

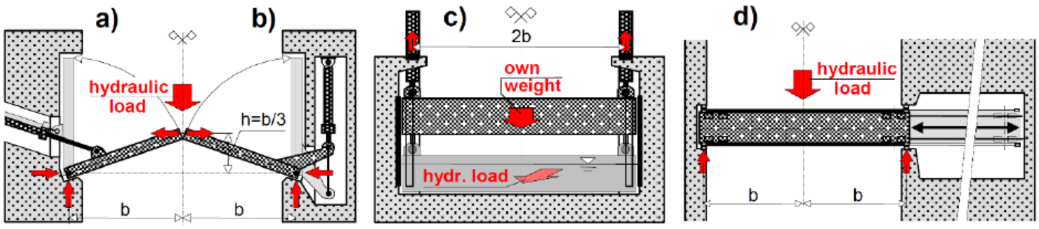


Figure 1-5: Four gate types for the Princess Moaxima Lock in Lith

Criterion	Gate Type			
	Mitre Gate (a)	Mitre Gate (b)	Vertical Gate (c)	Rolling Gate (d)
1. Total costs	+	+/-	+	- -
2. Reliability	+	+	++	+
3. Navigation	+	++	-	+/-
4. Maintenance	+/-	+	+	-
5. Environment	+	+	+	-
6. Aesthetics	++	+	- -	+/-
Total score	+	+	+/-	-

Key:

++	very good
+	good
+/-	fair
-	poor
- -	bad

Chapter 1: Gate Selection Process (example)

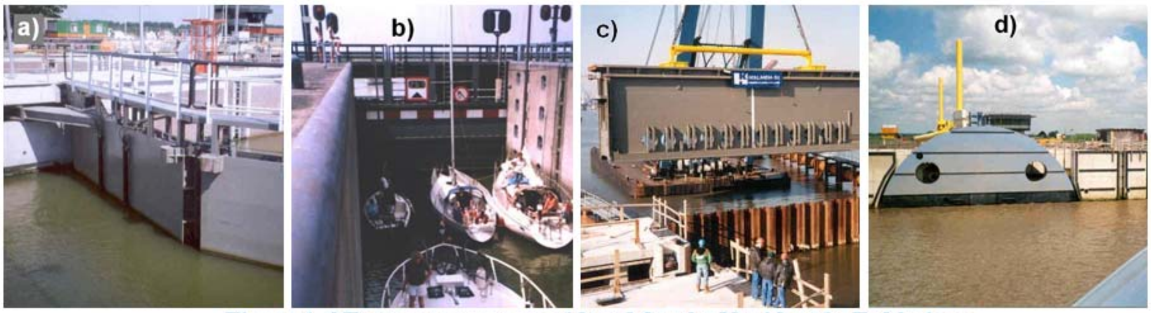
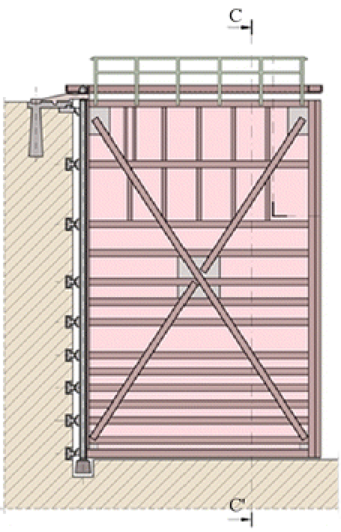


Figure 1-6 Four gate types considered for the Naviduct in Enkhuizen

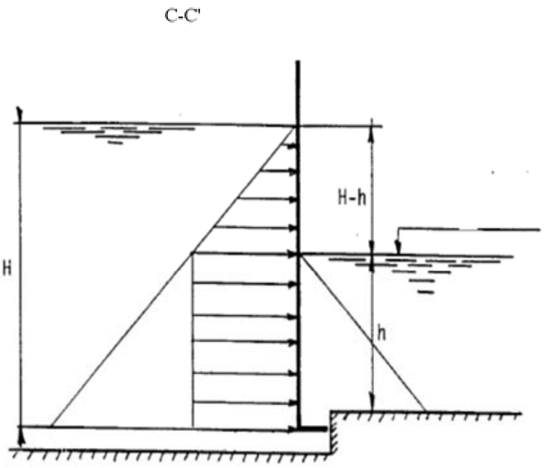
Table 1-2 Gate assessment in weighted criteria for the Naviduct in Enkhuizen

Criterion	Weight Factor	Gate Type			
		Mitre Gate (a)	Mitre Gate (b)	Vertical Gate (c)	Rolling Gate (d)
1. Total costs	.40	8	9	6	6
2. Operation	.35	9	8	8	7
3. Navigation	.10	8	7	8	7
4. Maintenance	.10	8	7	8	6
5. Environment	.05	7	7	6	7
Total score	**1.00**	**8.30**	**8.15**	**7.10**	**6.50**

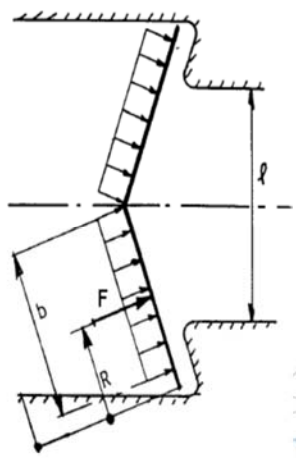
Chapter 1: Gate Geometrics/Loading



Gate Elevation

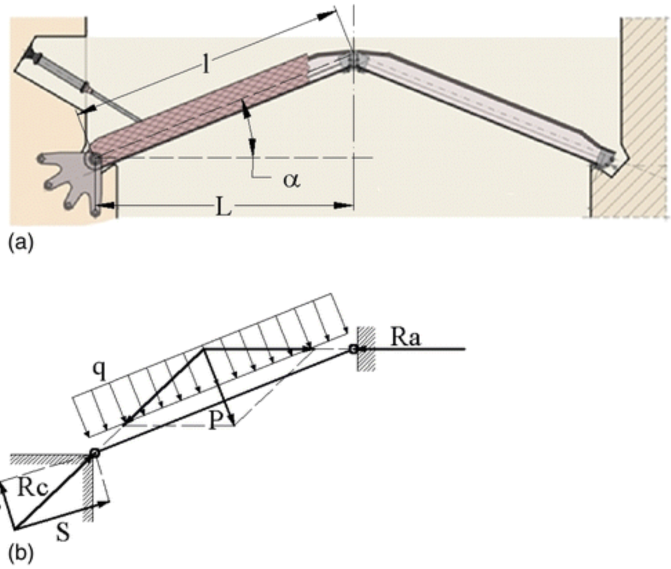


Gate Section

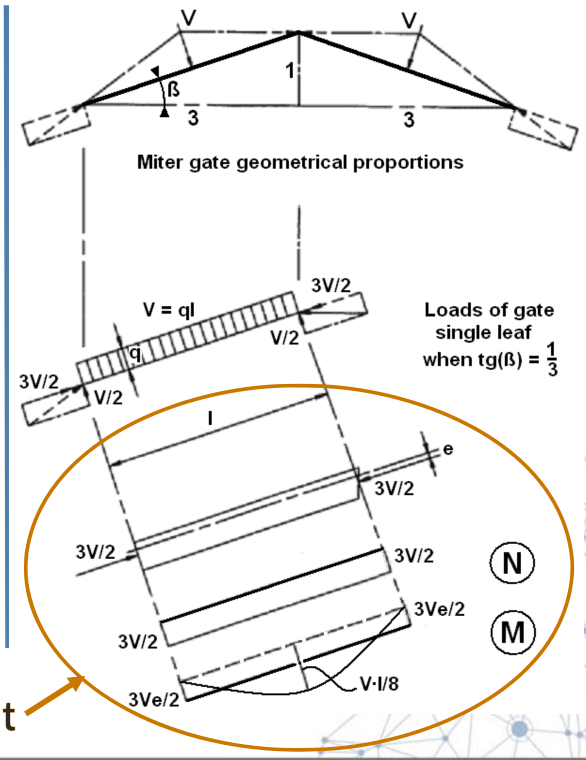


Gate Plan

Chapter 1: Gate Geometrics/Loading



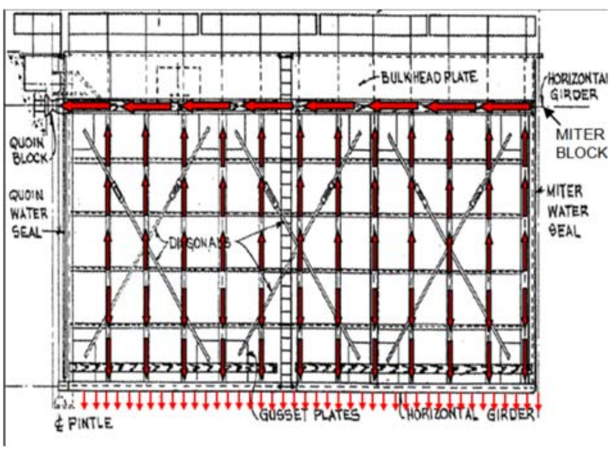
Gate Plan – End Reactions



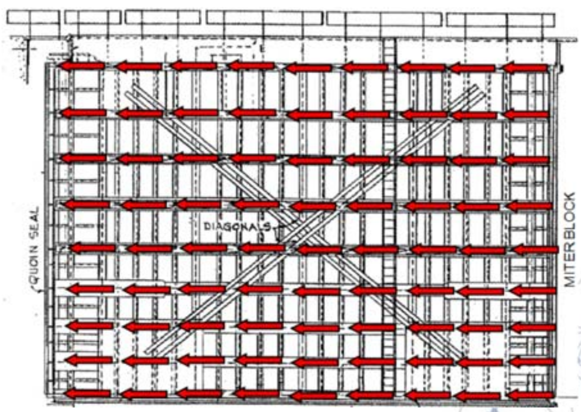
Eccentricity lessens positive moment

Chapter 1: Gate Framing Types

Vertically Framed Gate

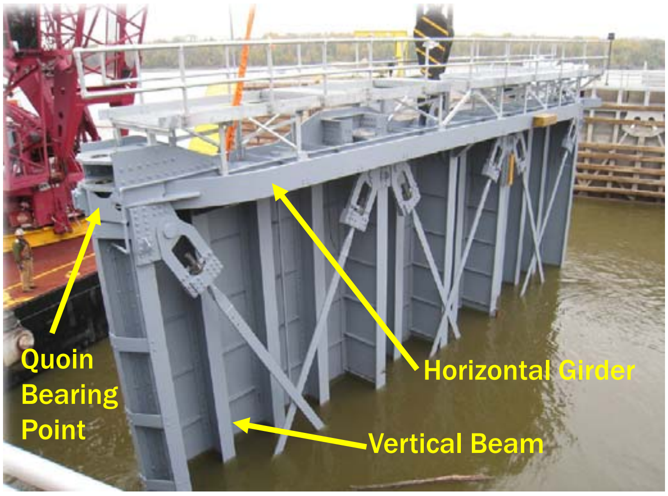


Horizontally Framed Gate



Chapter 1: Gate Framing Types

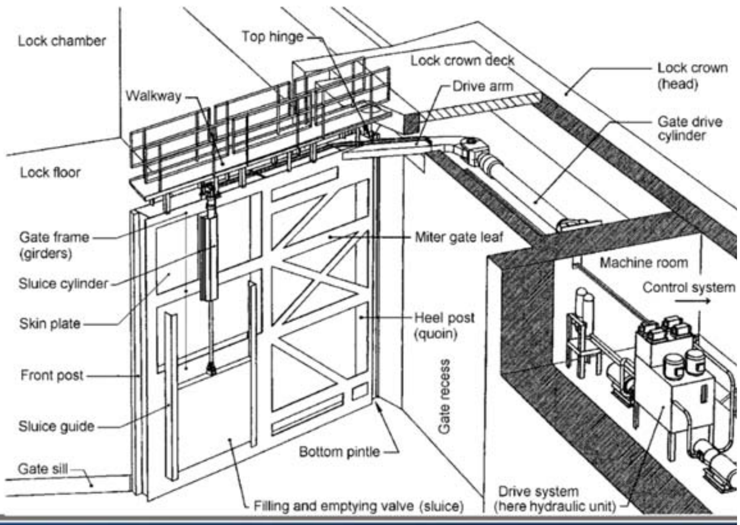
Vertically Framed Gate



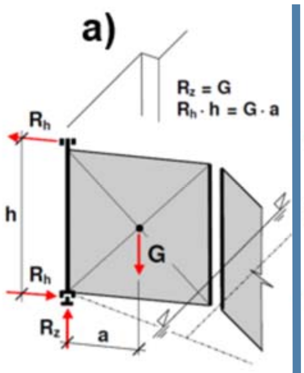
Horizontally Framed Gate

Chapter 2: Components

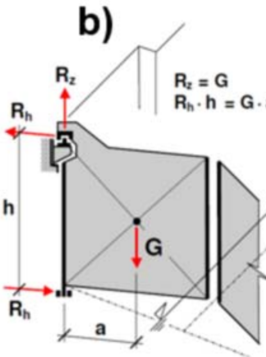
- **Goals:**
  - Structural Arrangements
  - Hinges / Gudgeon / Pintles (Pivots)
  - Anchorage
  - Heel (Quoin) / Mitre Blocks
  - Diagonals
  - Operating Machinery
  - Control System



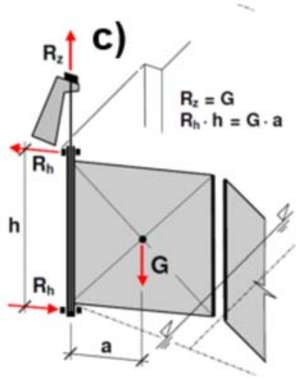
Chapter 2: Components (Structural Arrangements)



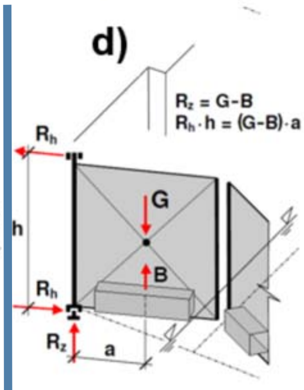
a)
Bottom pintle, top hinge arrangement



b)
Bottom hinge, top pintle arrangement



c)
Gate suspension outside hinges



d)
Application of buoyancy tanks

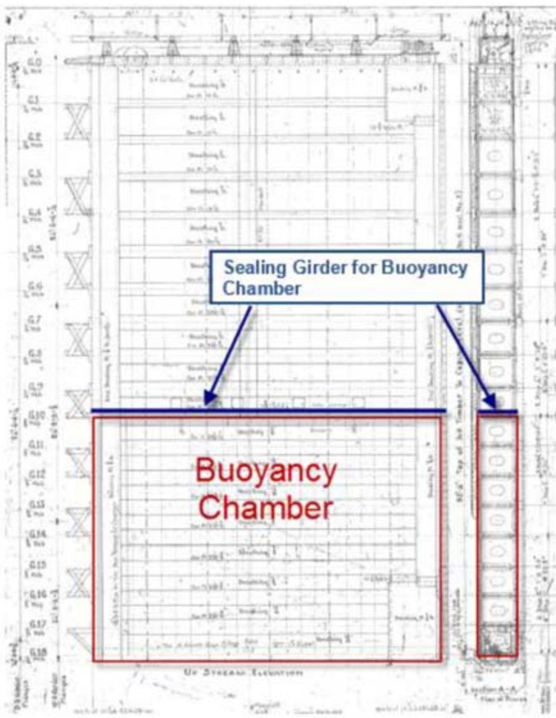
Chapter 2: Components (Buoyancy Chamber)

Advantages:

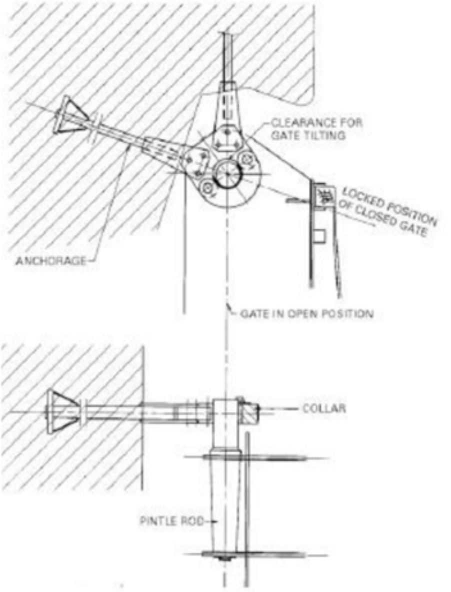
- Effectively lessens gate weight during operation.
- Less wear on support components.

Disadvantages:

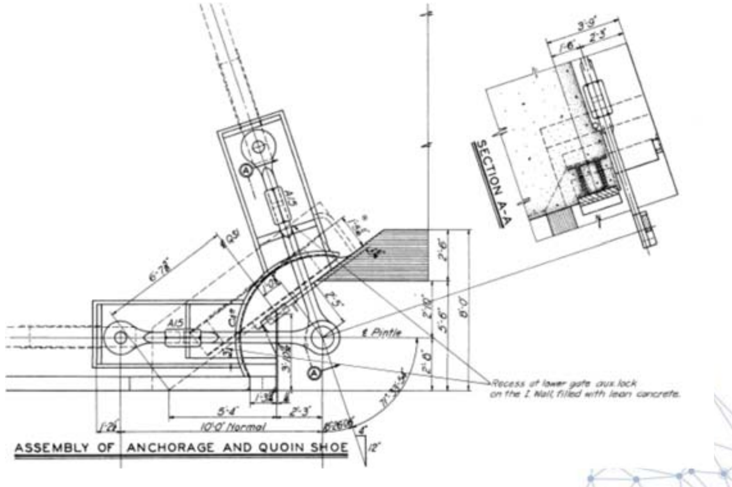
- Difficult to inspect inside surfaces.
- Need to maintain sealed condition (can't leak).



Chapter 2: Components (Anchorages)

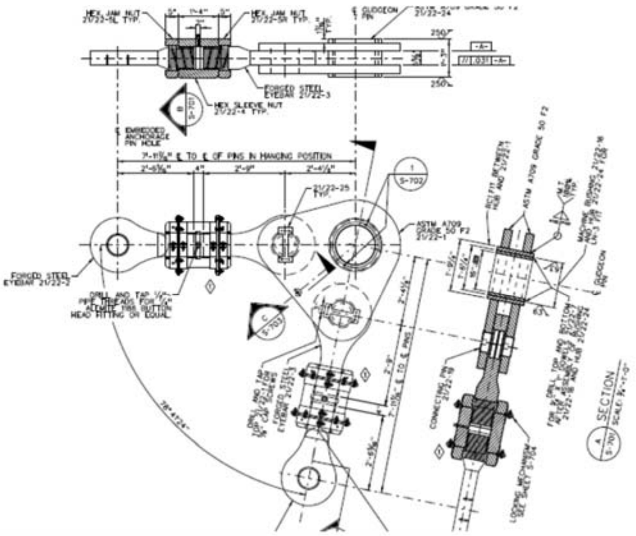


Top hinge design typical in Europe (ROK Design of Locks – Part 1)
Figure 2-

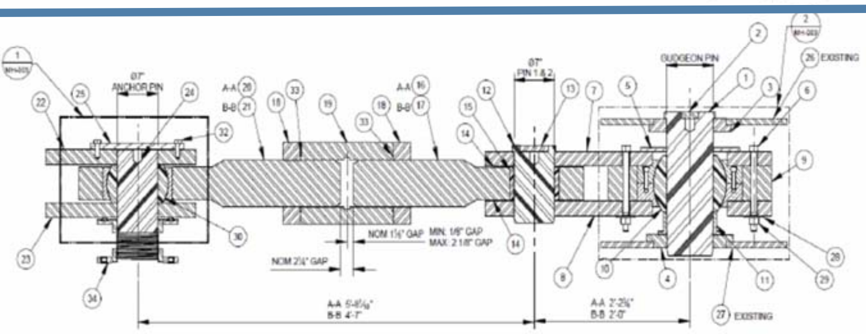


Typical Upper Mississippi (3-pin) lapped

Chapter 2: Components (Anchorages)



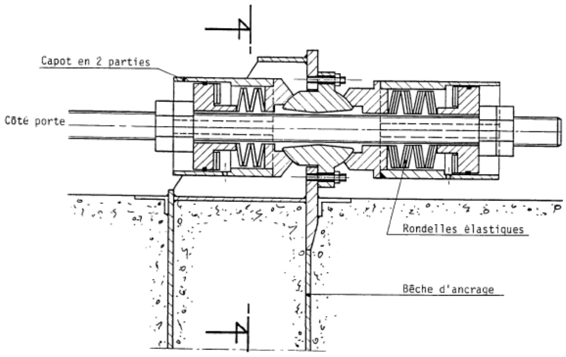
Five-pin anchorage (USACE, Greenup Lock).



Five-pin anchorage cross-section with spherical bushings (USACE, The Dalles Lock)

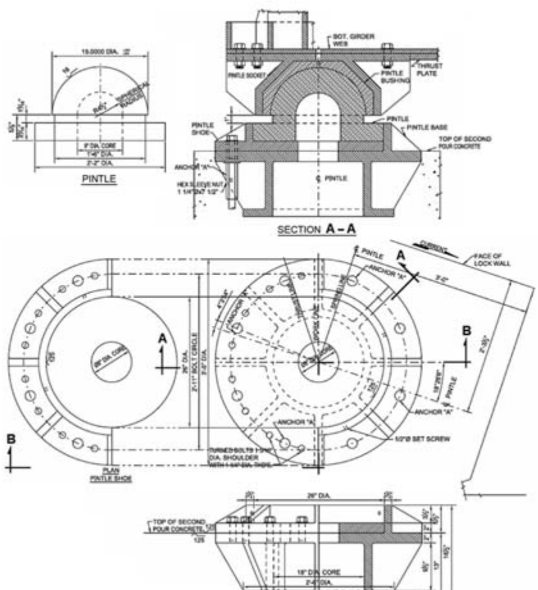
Chapter 2: Components (Anchorages)

Belleville Springs: Spring-loaded anchorage linkage

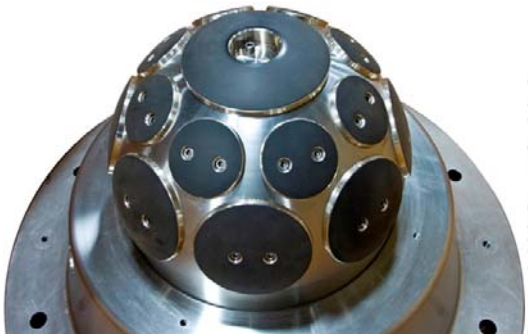


- Preferred in France.
- Allow the gates to hang and swing with a clearance in the heels (quoins) and then when a head builds up on the gates, the springs compress in the linkages allowing the heel (quoin) to make contact.

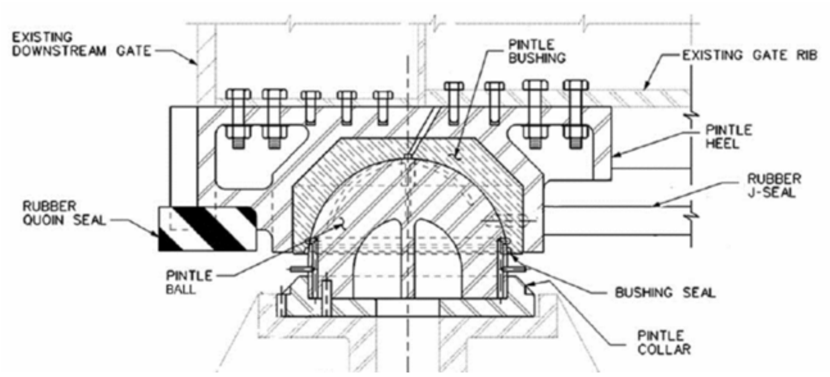
Chapter 2: Components (Pintles)



compiled from: USACE manual ETL 1110-2-584, Design of hydraulic steel structures, 30 Jun 2014



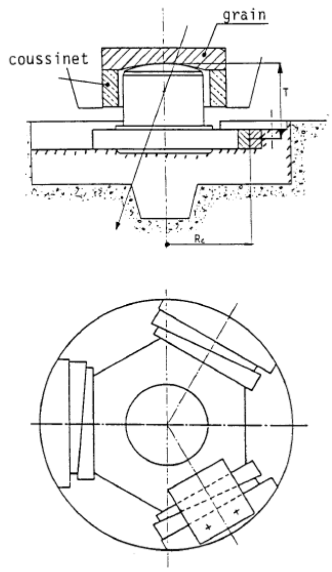
Chapter 2: Components (Pintles)



Chapter 2: Components (Pintles)

PIVOT A EMBASE INTEGREE MAINTENUE PAR DES COINS
SUR UNE PIECE SCELLEE

VI. 2. Figure 4



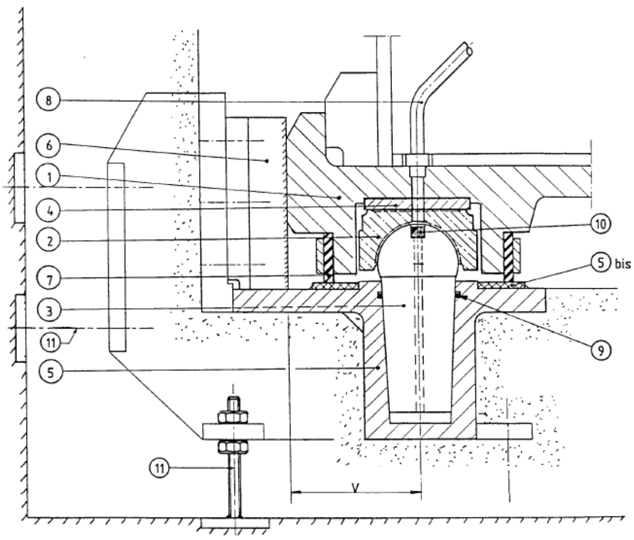
Inconvénients

- Nombreuses interfaces
- Précontrainte par coins insuffisante
- Problèmes d'instabilité fréquents Lorsque la direction de F_R s'incline : efforts de manoeuvre élevés, frottement important sur le grain lors du buscage. La résultante sort du noyau central de l'appui, entraînant des efforts de soulèvement des coins.
- Les efforts alternés finissent également par desserrer les coins
- Maintenance très difficile, resserrage sous l'eau impossible

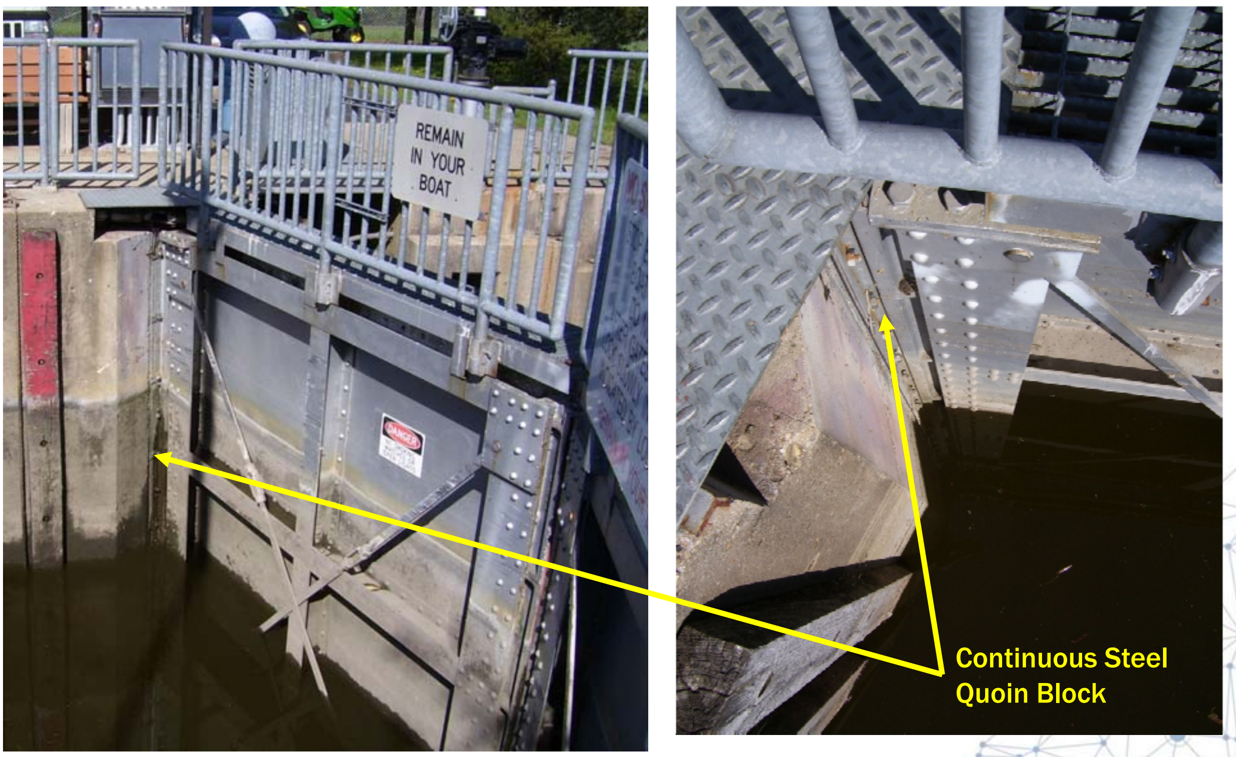
Avantage unique

- Permet de régler la position du pivot au montage

Chapter 2: Components (Pintles)



Chapter 2: Components (Blocks)



Chapter 2: Components (Blocks)

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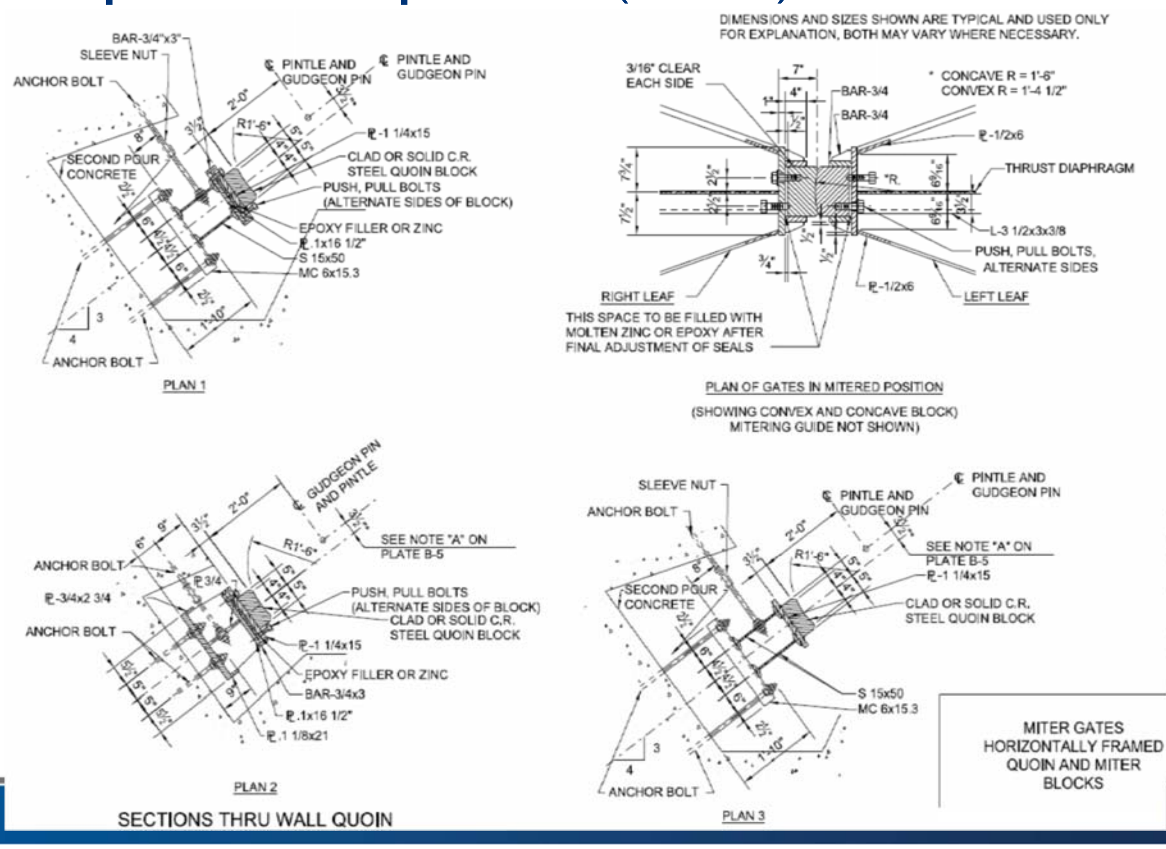


Chapter 2: Components (Quoin Blocks)

Contact blocks need good alignment and adjustability

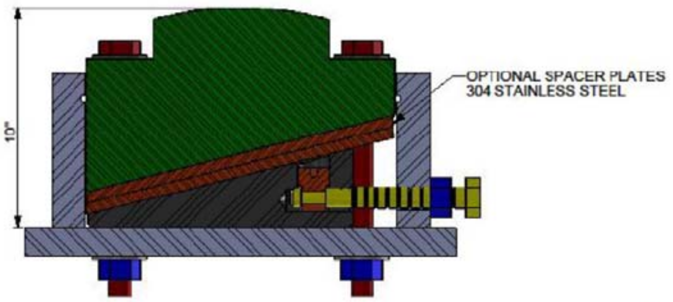
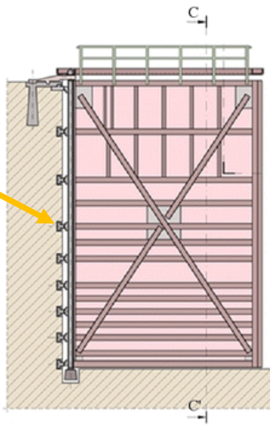


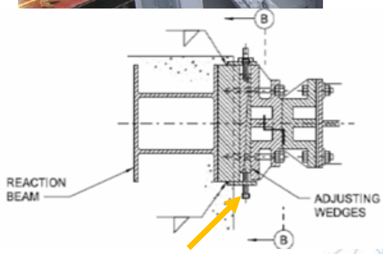
Figure 2-16: Mechanically adjustable quoin blocks of The Dalles mitre gate, USA

Chapter 2: Quoin Blocks

Intermediate Blocks



Vertically Framed Gate Block (Adjustable)



Chapter 2: Quoin Blocks

Timber Quoin (Flight of Five – Erie Canal)

Chapter 2: Quoin Blocks

Timber Quoin (Flight of Five – Erie Canal)

Chapter 2: Quoin Blocks

Timber Quoin (Flight of Five – Erie Canal)

- **Challenge**
  - New Gate Fabrication
  - Surface of quoin is not uniform
- **Solution**
  - Core quoin

Chapter 2: Quoin Blocks

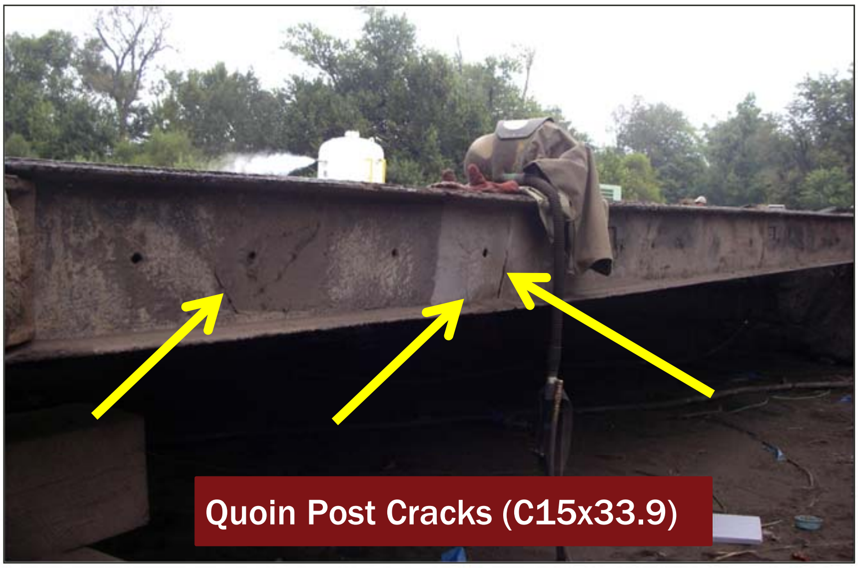
Timber Quoin (Kentucky River Locks, USA)

Pre-Renovation

Post-Renovation

Chapter 2: Quoin Blocks

Timber Quoin (Kentucky River Locks, USA)



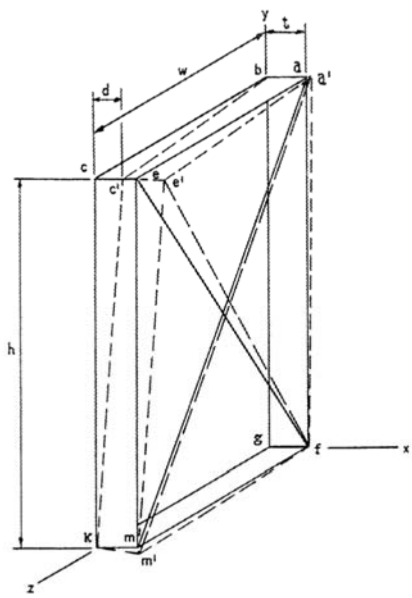
Chapter 2: Components (Diagonals)

Advantages:

- Keep Gate Plumb.
- Better Alignment at Contact Surfaces.
- Improved Stiffness During Operation.

Disadvantages:

- Difficult to Adjust.
- Impact Protection is Needed.
- Can be a Source of Cracking.



Chapter 2: Components (Diagonals)

Chapter 2: Components (Diagonals)

Chapter 2: Components (Diagonals)

Figure 2-17: Diagonal with threaded ends and large nut (115-mm diameter) and with hydraulic tensioner attached (right)

Chapter 2: Components (Diagonals)

Figure 2-18: Multiple nut tensioning mechanism using multiple stud tensioners

Chapter 2: Components (Diagonals)

Chapter 3: Design Issues and Guidance

- **Goals:**
  - Global Design Guidance
  - Design Load Conditions
  - Fatigue
  - Connections
  - Flexibility / Stiffness
  - Gate Recess Design
  - High Lift Lock Gates

Chapter 3: Design Issues and Guidance

Guideline, Reference, or Report.	Area of Orgin	Title	General Design	Locks General	Gate Type	Gate Loads	Fatigue	Primary Members	Materials Steel	Materials Concrete	Materials Timber	Materials Composites	Diagonals	Seals	Skin Plate	Pintle	Anchorages	Mechanical / Electrical	Quoin / Mitre Blocks
			Gate Feature / Design Component																
PIANC	International	Final Report of the International Commission for the Study of Locks (1986 Lock Report)		♦															
PIANC InCom WG 106	International	Innovations in Navigation Lock Design		♦															
PIANC InCom WG 151	International	Design of Lock Gates for Ship Collision				♦													
Eurocodes (0) to (8)	Europe	Various codes related to Structural Design, Loads, and Various Materials	♦					♦	♦	♦	♦								
University of Liege	Belgium	Navigation Locks - Ecluses de Navigation by Nicolas M. Dehousse (1985)		♦															
FRT 101	France	Parts of Rollers																♦	
FRT 102	France	Joints, Bearings, and Trunions																♦	
FRT 103	France	Critical Mechanical Components of Miter Gates																♦	
FRT 104	France	Sealing System Works												♦					
FRT 105	France	Fixed/Embedded Pieces (Anchorages)															♦		
FRT 106	France	Elastomeric Bearings																♦	
FRT 107	France	Actuators																♦	
DIN 19704-1	Germany	Hydraulic steel structures - Part 1: Criteria for design and calculation				♦													
DIN 19704-2	Germany	Hydraulic steel structures - Part 2: Design and Manufacturing				♦													
DIN 19704-3	Germany	Hydraulic steel structures - Part 3: Electrical Equipment																♦	
RWS	Netherlands	Design of Locks (ROK Ontwerp Van Schutsluizen) - Part 1 (English Translation)			♦														
RWS	Netherlands	Design of Locks (ROK Ontwerp Van Schutsluizen) - Parts 1 & 2 (Dutch)			♦														
ROK 1.2 (1)	Netherlands	Richtlijnen Ontwerpen Kunstwerken (Miter Gate Guideline)			♦	♦	♦												
SB260	Belgium	Hydaulic Structures							♦										
SB270	Belgium	Mechanical and Electrical Devices																♦	
USACE TR-02-7	US	Advanced Materials Selection Guide for Lock, Dam, and Hydro Elec Plant Components							♦										
USACE ETL 1110-2-584	US	Design of Hydraulic Steel Strucutres	♦		♦	♦	♦	♦	♦				♦	♦	♦	♦	♦	♦	♦
USACE ETL 1110-2-566	US	Advanced Reliability Analysis of Fatigue Cracking in Horizontally Framed Miter Gates					♦												
USACE EM 1110-2-1612	US	Ice Engineering				♦													
USACE EM 1110-2-2602	US	Planning and Design of Navigation Locks			♦	♦													
USACE EM 1110-2-2610	US	Mechanical and Electrical Design for Lock and Dam Operating Equipment																♦	
USACE EM 1110-2-2703 (2)	US	Lock Gates and Operating Equipment					♦		♦				♦	♦	♦	♦	♦	♦	♦
USACE EM 1110-2-6054	US	Inspection, Evaluation and Repair of Hydraulic Steel Structures					♦												
ASCE Journal	US	Optimal Design of Horizontally Framed Miter Gates						♦											
AWS (Various)	US	Welding Guidelines							♦										
AISC	US	American Institute of Steel Construction - Steel Construction Manual							♦										
AASHTO	US	Bridge Design Specifications					♦		♦										
CAN/CSA - S6	Canada	CAN/CSA - S6 Canadian Highway Bridge Design Code					♦		♦										
CSA S16	Canada	Design of Steel Structures							♦										

Notes:
(1) This document is unoffical and is under development.
(2) EM 1110-2-2703 has been superseded by ETL 1110-2-584. However, the EM still contains valuable information on miter gate design that may not be found within the ETL.

Figure 3-2: Global design references table

Chapter 3: Design Issues and Guidance

- **Load Considerations (Usual and Unusual Conditions)**
  - Impact Loads (PIANC WG 151)
  - Environmental Load (Waves, Ice, Silt, Obstructions)
  - Construction
  - Load Redistributions with Worn / Misaligned Gates
- **Analysis Considerations**
  - 2D vs. 3D Modeling
  - Fatigue
  - Connections
  - High Lift Locks

Chapter 3: Design Issues and Guidance

Load Cases			Loads/Load Factors							
			D	G	H_s	H_d	Q	EV	IM	EQ
Limit State	Description	Case	γ_D	γ_G	γ_{Hs}	γ_{Hd}	γ_Q	γ_{EV}	γ_{IM}	γ_{EQ}
Strength I	Gate Closed	1a	0	0	1.4	0	0	0	0	0
Strength I	Gate Closed	1b	0	0	1.4	1.0	0	0	0	0
Strength II	Gate Open	2	1.2	1.6	0	1.0(1)	1.2(1)	0	0	0
Extreme I	Gate Closed	3	0	0	1.4	0	0	0	1.0(1)	1.0(1)
Fatigue I	Finite Life	4a	0	0	1.0	1.0	0	0	0	0
Fatigue II	Infinite Life	4b	0	0	1.0	1.0	0	0	0	0
Notes: (1) Select one at a time										

D = Dead Load (self-weight);
G = Gravity Load (mud or ice);
H_s = Hydrostatic Force;
H_d = Hydrodynamic;
Q = Operating Machinery (max load);
EV = Wind (not applicable in table);
IM = Barge Impact (or vessel impact);
EQ = Earthquake.

Chapter 3: Design Issues and Guidance

Analysis Type	Advantage	Disadvantage
2-D Modeling	• Accomplished in less time given its simplicity. Is easier to check and verify accuracy of results. • Generally accurate for determining stresses in primary members.	• Poor in identifying stresses at connection areas (girder to quoin, pintle forces on gate, load from diagonals). • Lacks ability to evaluate misalignments or other anomalies that could result in redistribution of stresses. May also lack ability to evaluate stresses from unusual loading, since stresses are not easily redistributed between members (e.g. impact or gate obstruction cases)
3-D Modeling	• Provides ability to size various members in one analysis (girder, skin plate, and quoin/mitre blocks). • Better ability to predict stresses for unique or unusual loading. • Provides more accuracy of stresses in connection areas, particularly for fatigue resistance design. • Checks for fabrication fit-up and interference	• Can require a lot of effort depending on the detail of the model and loading. • Verifying results (checking) can be more difficult and timely. Comparing results with a simplified 2-D model or other hand calculations must be performed to confirm accuracy of modelling.

Table 3-1: Analysis methods

Chapter 3: Design Issues and Guidance

G = Gravity Load (mud or ice);

Chapter 3: Design Issues and Guidance

G = Gravity Load (mud or ice);

Chapter 3: Construction and Maintenance Loads

Gate Removal and Installation:

- *Consider Lifting Points*
- *Consider Gate Stresses During Lifting*

Chapter 3: Construction and Maintenance Loads

Chapter 3: Construction and Maintenance Loads

Chapter 3: Construction and Maintenance Loads

Chapter 3: Construction and Maintenance Loads

Chapter 3: Construction and Maintenance Loads

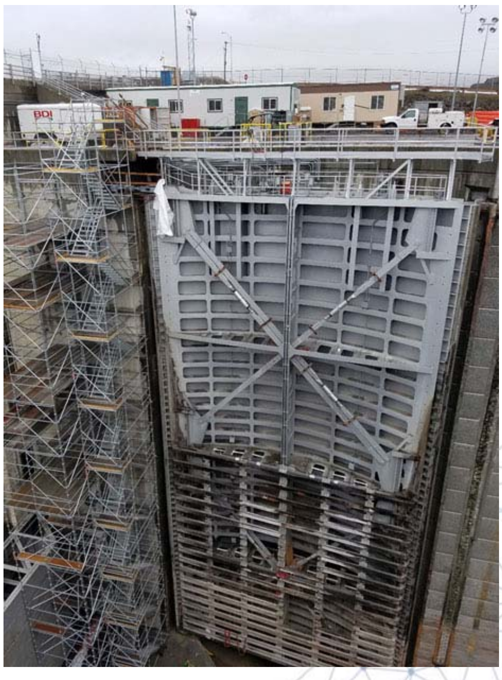
Chapter 3: Construction and Maintenance Loads

Chapter 3: Bolting vs. Welding (Repair)

Chapter 3: Repair Access

Chapter 3: High Lift Gates

- **Considerations**
  - Increased sensitively to gate tolerances and alignment
  - Temperature (solar loading)
  - Constructability
    - Crane access
    - Lifting points
  - 3D modeling



Questions? Feedback?

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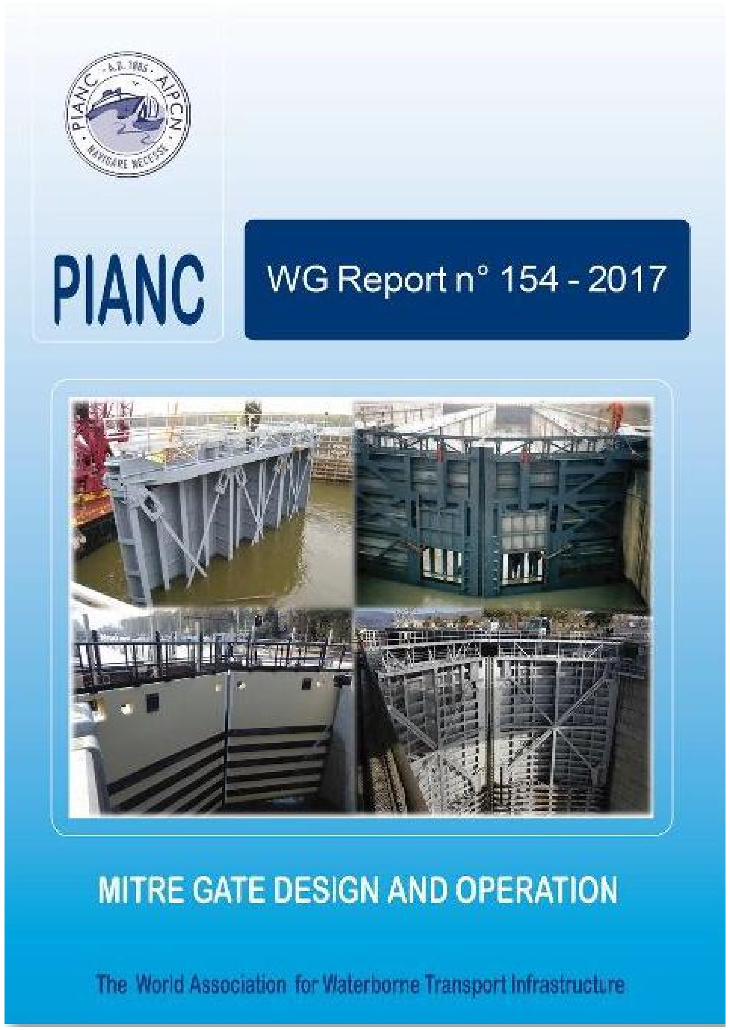


Rijkswaterstaat
Ministerie van Verkeer en Waterstaat

INCOM PIANC Working Group 154

MATERIALS AND FRP COMPOSITES in Mitre Gates

Jos Vorstenbosch, Brussels, November 6 th 2017

Working Group 154 Materials and Composites

Steel:

Structural framing and Machinery Protection

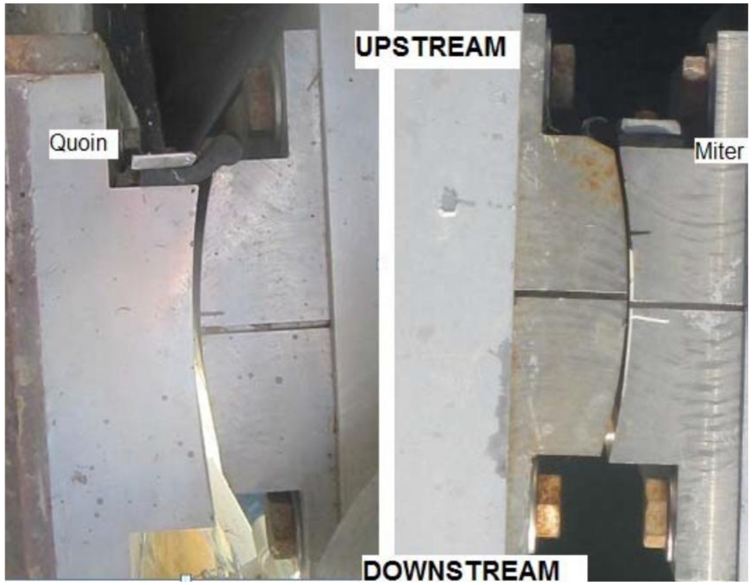
Corrosion fatigue on 12% Mn steel Pivot

High Strength Steel (YS > 360 MPa) only for Mooring and Impact protection

Working Group 154 Materials and Composites

Steel:

Anchorage failure due to low ductility of Steel (YS < 1000 MPa is recommended)

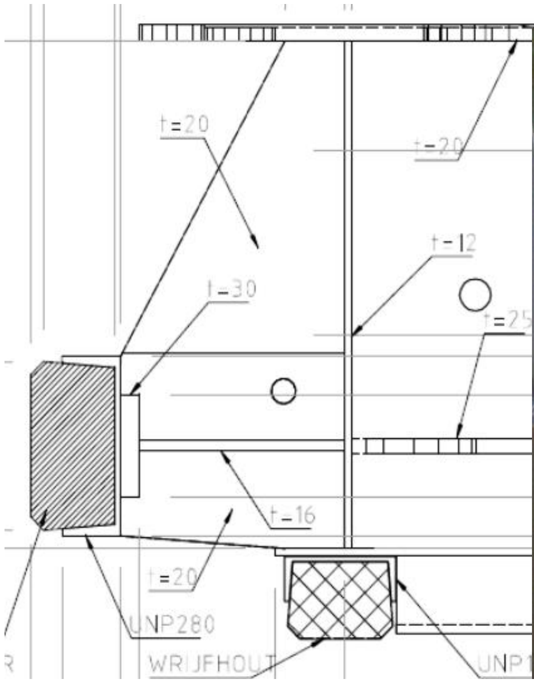


Contact blocks with Rubber Seals

Working Group 154 Materials and Composites

<u>Timber:</u>

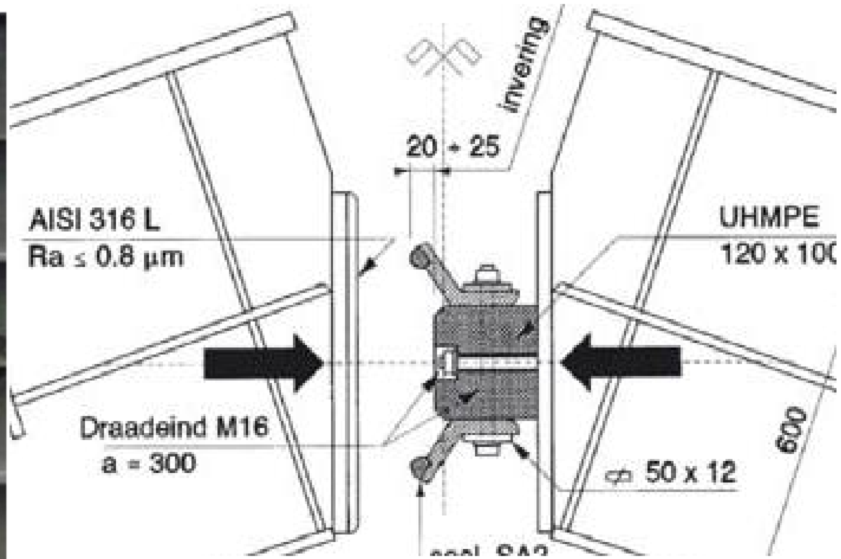
Structural framing



Sealing and Contact blocks (rubber insert)

Working Group 154 Materials and Composites

Polymers:



UHMWPE Sliding blocks on Stainless steel

UHMWPE Contact blocks on Stainless steel

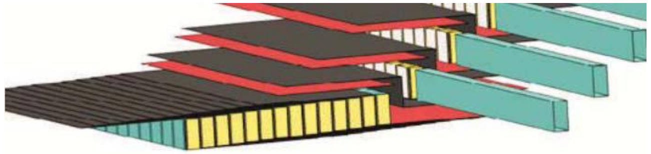
Working Group 154 Materials and Composites

Fiber Reinforced Polymer Composites:

Structural framing and Walkways

Working Group 154 Materials and Composites

World's largest Fiber Reinforced Polymer composite Mitre Gates

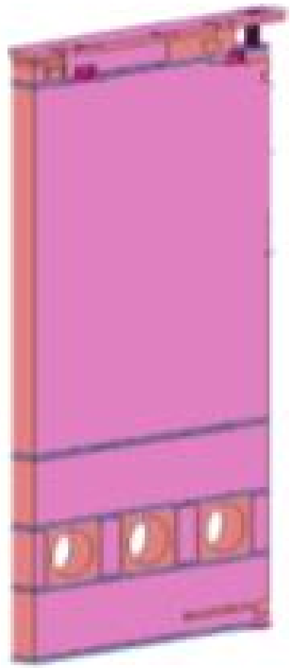


Monolitic sandwich with PU foam, Glass fibers and Poly ester resin.

Leaf dimension 12 m x 9 m x 0,5 m

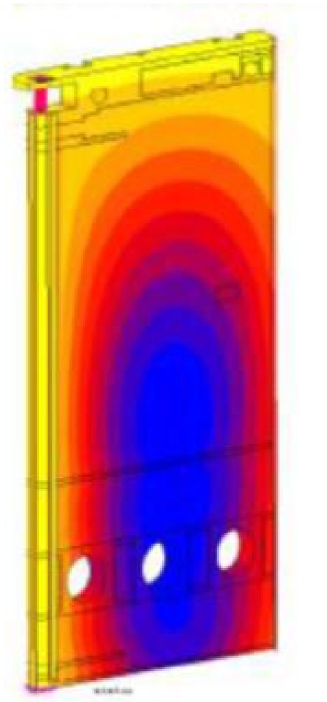
Working Group 154 Materials and Composites

World's largest Fiber Reinforced Polymer composite Mitre Gates



Maximum calculated deflection SLS including creep, humidity and fatigue after 100 years:

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



Working Group 154 Materials and Composites

Fiber Reinforced Polymer Composites:

Grease less bearings

Full scale testing

De-lamination hazard

Working Group 154 Materials and Composites

<u>Fiber Reinforced Polymer Composites:</u>

Fiber Reinforced Polymer contact blocks

Fatigue and pinching test

Working Group 154 Materials and Composites

Conclusions:

Polymers and Fiber Reinforced Polymer Composites in Mitre Gates have been be used for:

- Structural framing
- Hinges
- Contact blocks
- Sliding blocks

Full scale testing on strength, wear, aging and fatigue is recommended to prove structural integrity and reliability.

As long time experience is not available, extra material safety factors are recommended.

PIANC Workshop
Mitre Gate Design and Operation
PIANC Report No. 154 Overview

Mitre Gate Seals

Prepared by:

Eric Johnson, P.E., S.E.

Overview

- **Miter Gate Seals**
  - Seals serve an important purpose in sealing the perimeter of the gate to the lock walls and sills
  - Bottom Seal
    - The bottom seal of the gate against the lock sill is important since the high water pressures can cause excessive leakage and damaging vibrations to the gate.
  - Side Seal
    - The side seals of the gate against the lock walls are primarily for water retention.

Chapter 5: Mitre Gate Seals

- **Three primary sealing configurations:**
  - Elastic polymers (rubber) bearing on metal or concrete contact
  - Metal bearing on metal contact
  - Wood bearing on metal contact or concrete lock wall

Chapter 5: Mitre Gate Seals

- **There are several factors to consider in choosing a seal:**
  - Durability
  - Maintenance
  - Leakage Limits
  - Load Transfer Ability (Stiffness)
  - Environmental Conditions (Temperature, UV)

Seal Locations

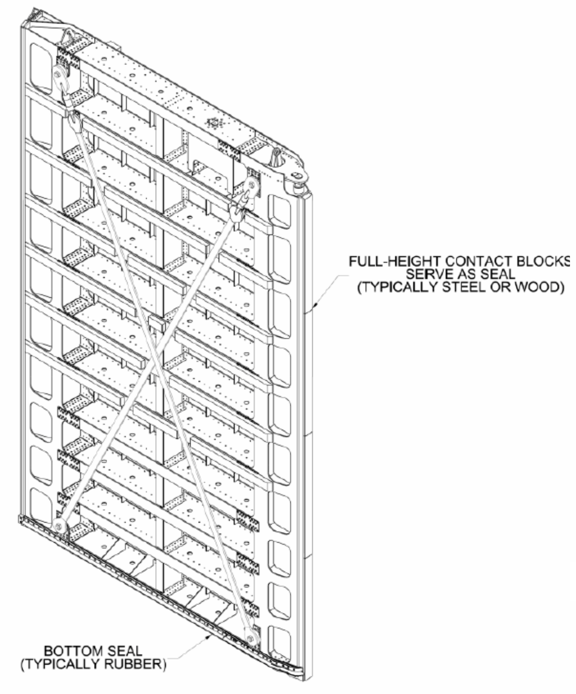


Figure 5-1: Seals on horizontally framed mitre gates

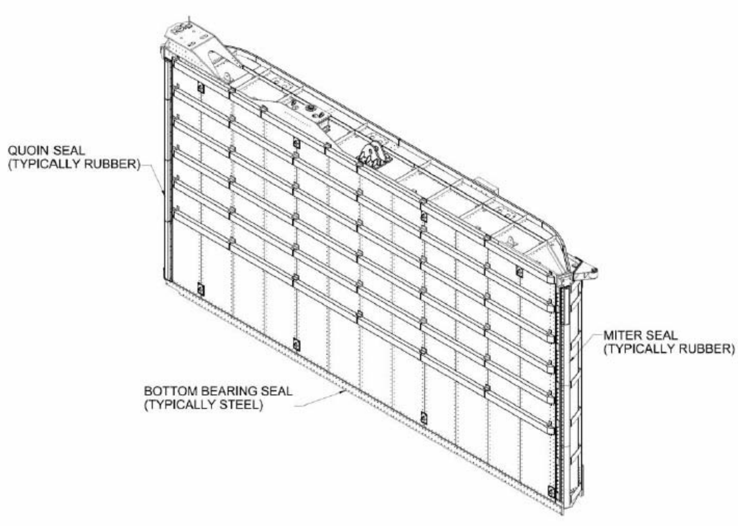


Figure 5-2: Seals on vertically framed mitre gates

Bottom Sill Seals

- **Types**
  - Bottom Round Rubber Seal
  - Bottom J-Bulb (Music Note) Seal
  - Bottom Pork Chop Seal
  - Inclined J-Bulb Seal
  - Bottom Wood Sill Seal
  - Bottom Block Seal in the Pintle (Pivot) Region

Bottom Sill Seals - Bottom Round Rubber Seal

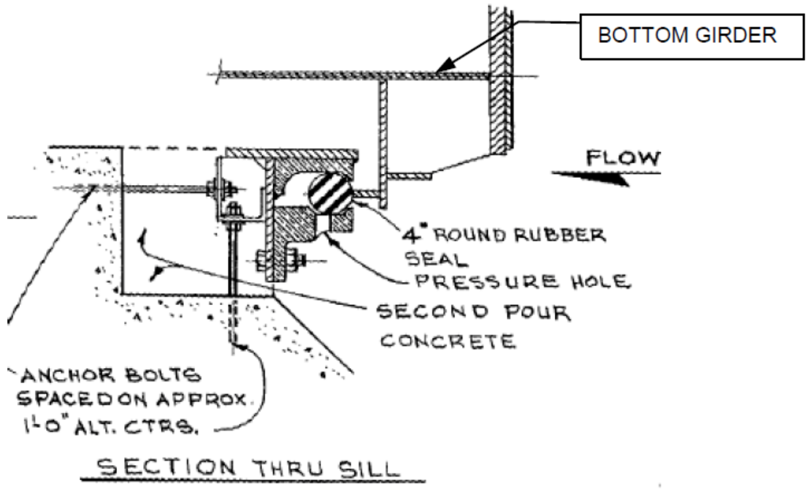
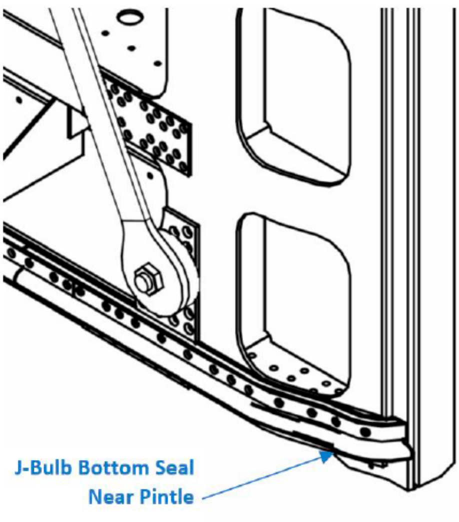
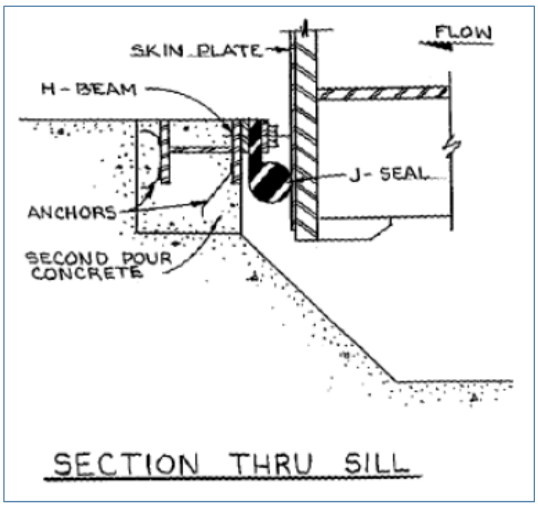


Figure 5-3: Round rubber seal
(USACE EM 1110-2-2703 Plate B-21)

- **Typically 100-mm (4-in) in diameter**
- **Can accommodate gate's thermal expansions**
  - 25 mm (1 in) of horizontal misalignment
  - 10 mm (3/8 in) +/- of vertical misalignment

Bottom Sill Seals - Bottom J-Bulb (Music Note)





- **Perform well around sharp bends (pivot area)**
- **Problematic along bottom sill**
  - Prone to vibration
  - Debris can get stuck behind seal and affect performance

Bottom Sill Seals - Bottom “Pork Chop” Seal

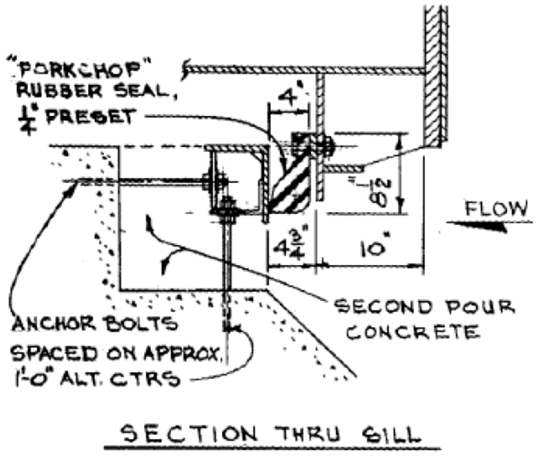
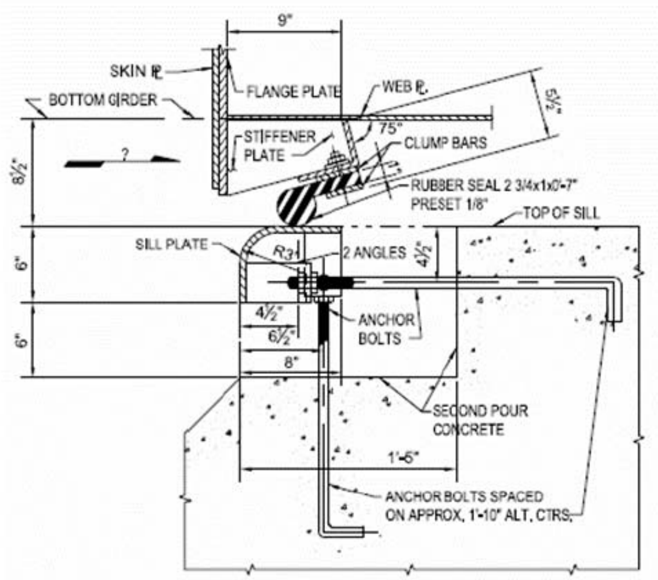


Figure 5-10: Pork chop seal

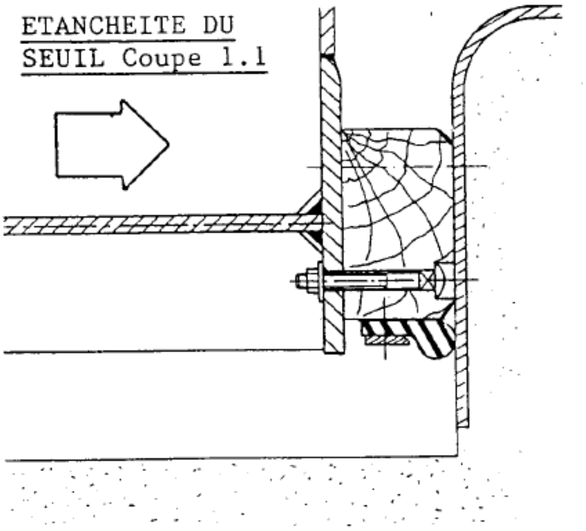
- **Less vibration problems**
- **Cannot accommodate large gate thermal expansions**
  - 16 mm (5/8 in) of horizontal misalignment
  - Over 25 mm (1 in) of vertical misalignment

Bottom Sill Seals - Inclined J-Bulb Seal



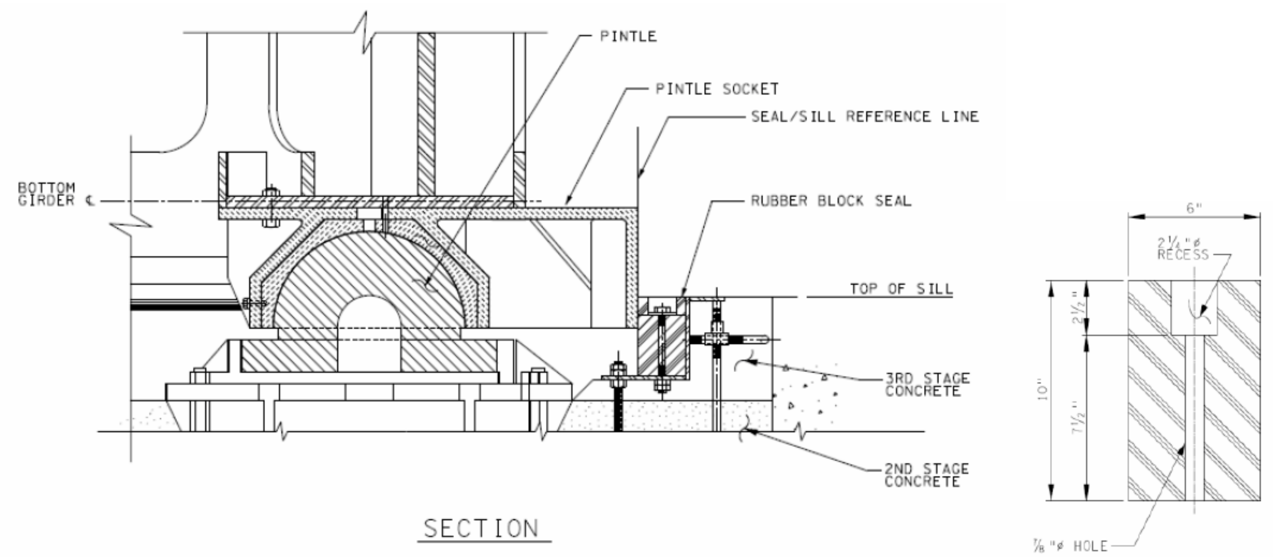
- **Recommended**
- **Best for withstanding damage from sill debris**

Bottom Sill Seals - Bottom Wood Sill Seal



- Extensive use, good if always submerged
- Preferred sill seal in Netherlands

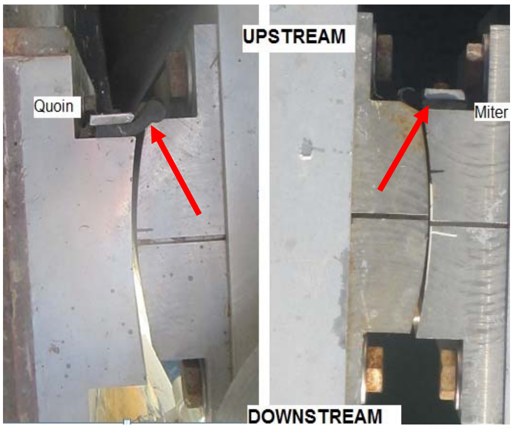
Bottom Block Seal in the Pintle (Pivot) Region



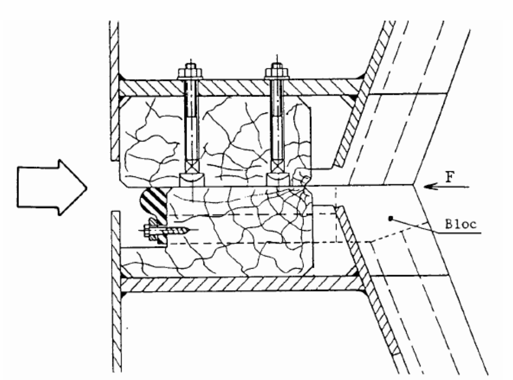
- Robust – long service life
- Disadvantage – attached to concrete, hard to service

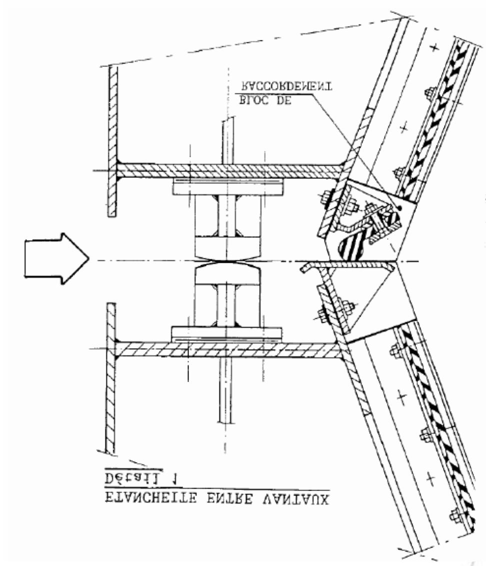
Side Seals

- Side seals run full-height of the quoin blocks
- Used to improve gate leak asthetic performance
- Be careful – Side seals can mask quoin block alignment issues

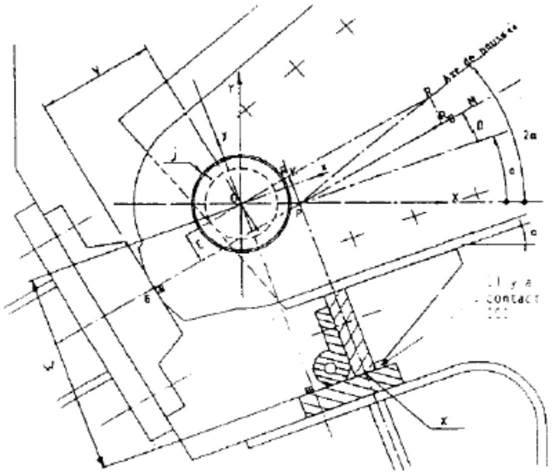


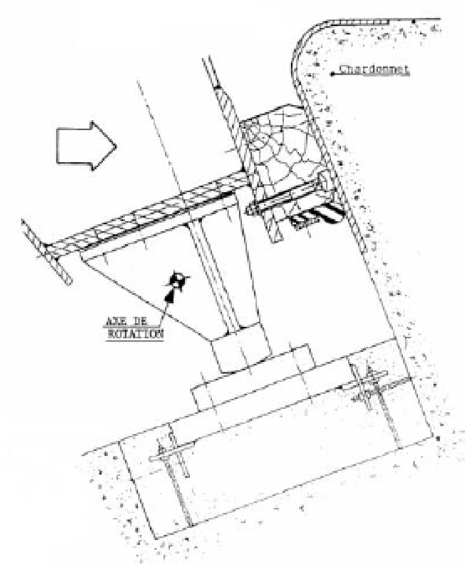
Side Seals at Mitre End



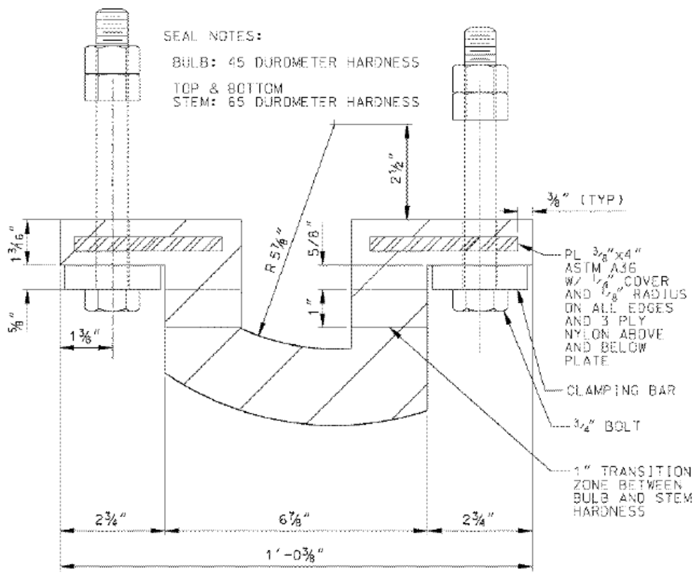


Side Seals at Quoin (Hinge) End





Side Seals – Omega Seal



- More durable and abrasion resistant than J-bulb (Music Note)
- 10-mm thick plate has been embedded in the stem to prevent seal from tearing from gate

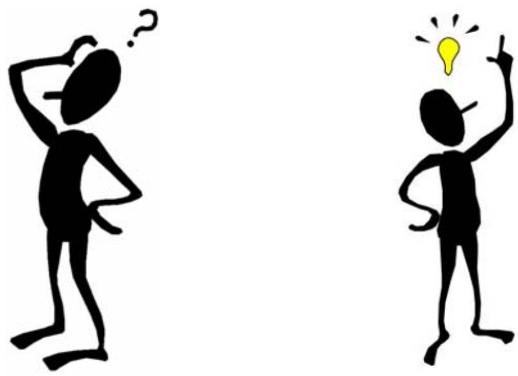
Seals – Best Practices

- **Consider factors in choosing a seal:**
  - Durability
  - Maintenance
  - Leakage Limits
  - Load Transfer Ability (Stiffness)
  - Environmental Conditions (Temperature, UV)

- **Where possible, make seal in one piece – minimize splices**

- **Attach to gate for ease of maintenance**

Questions? Feedback?



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Mitre Gate : Design and Operation
Chap 6 & 7: Components, O&M
PIANC Report No. 154 Overview

Prepared by:

Yvan Cordier, Op. Manager, VNF

Report Overview

1. Mitre Gate Systems
2. Mitre Gate Components
3. Mitre Gate Design Issues and Guidance
4. Gate and Component Materials
5. Mitre Gate Seals
6. Ancillary Components
7. Operations and Maintenance
8. Conclusions
9. References

Chapter 6

Ancillary Components

Chapter 6: Ancillary Components

Ancillary but essential components of a mitre gate are:

- Walkways and access
- Lubrication
- Mitre guide and alignment features
- Impact protection systems

Chapter 6: Ancillary Components

6.1 Walkways

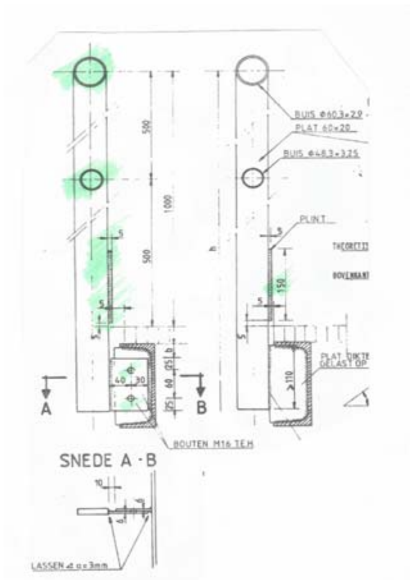
The section 6.1 presents a complete summary of all design suggestions for walkways built on leaf gates and the associated protective railings.

The essential safety points for protective railings lie:

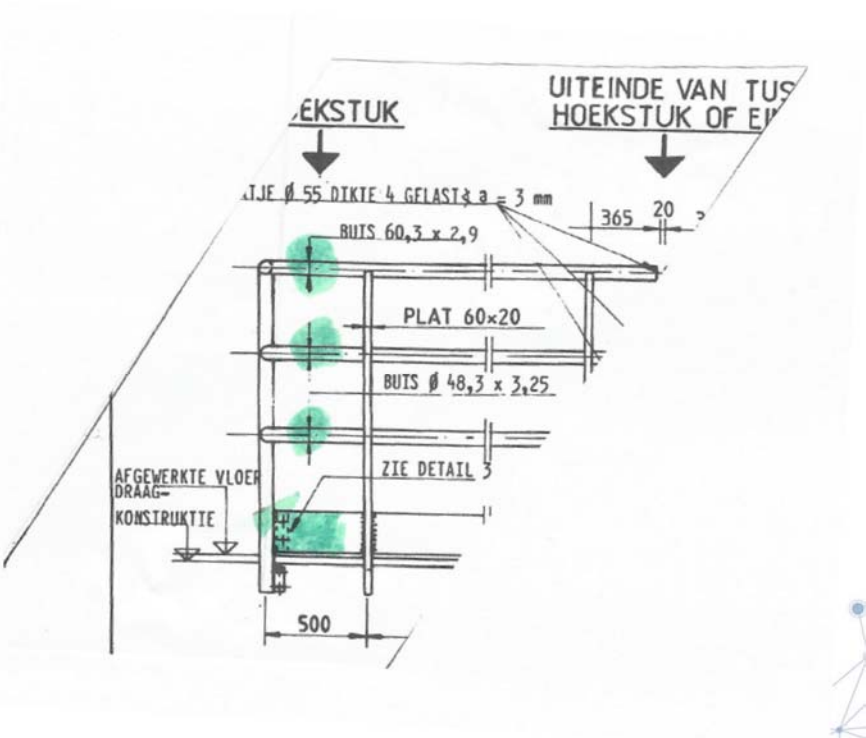
- **in their horizontal stiffness,**
- **in the use of longitudinal side baseboards: they not only prevent objects from falling off the walkway but moreover, these boards guide and recentre the steps bringing and confirming their true safety function for the user.**

Chapter 6: Ancillary Components

6.1 Walkways and railings



Chapter 6: Ancillary Components



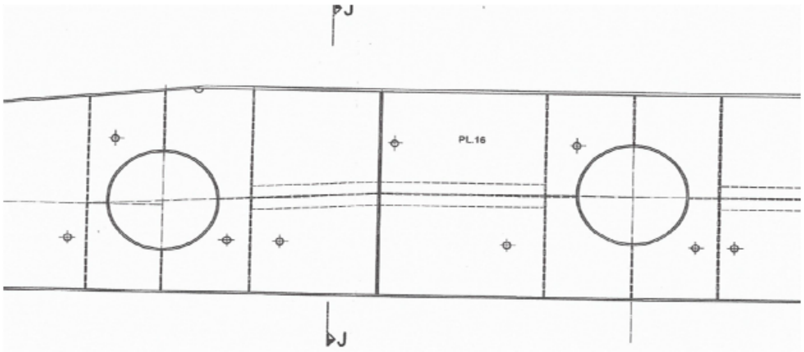
Chapter 6: Ancillary Components

6.2 Access in the gate

- Inside access holes in the horizontal beams – as the overall leaf thickness often allows - are in fact true manholes with or without covers. These access holes serve to inspect the leaf’s structural components.
- Exterior access holes make it possible to check the cleanliness of the gate pivot area and its possible sanding-up or silting. They are equipped with cover plates.

Chapter 6: Ancillary Components

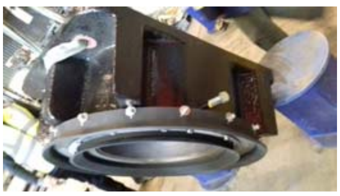
Inside access
Internal Manholes Phi 700 in horizontal girders (two upper girders)



6.3 Lubrication - General

- **Self-lubricating materials offer potential for improved performance.**
  - **Corrosion resistant**
  - **<u>Examples</u>: Kamatics KAron V, Deva, Bronze Pan, Tenmat Ferroform/Ferroglide**

As an additional measure related to lubrication and as far as the pintle is concerned, practical sense indicates that a supplemental forced lubrication FOR THE PINTLE should generally be scheduled for all the aforementioned reasons.



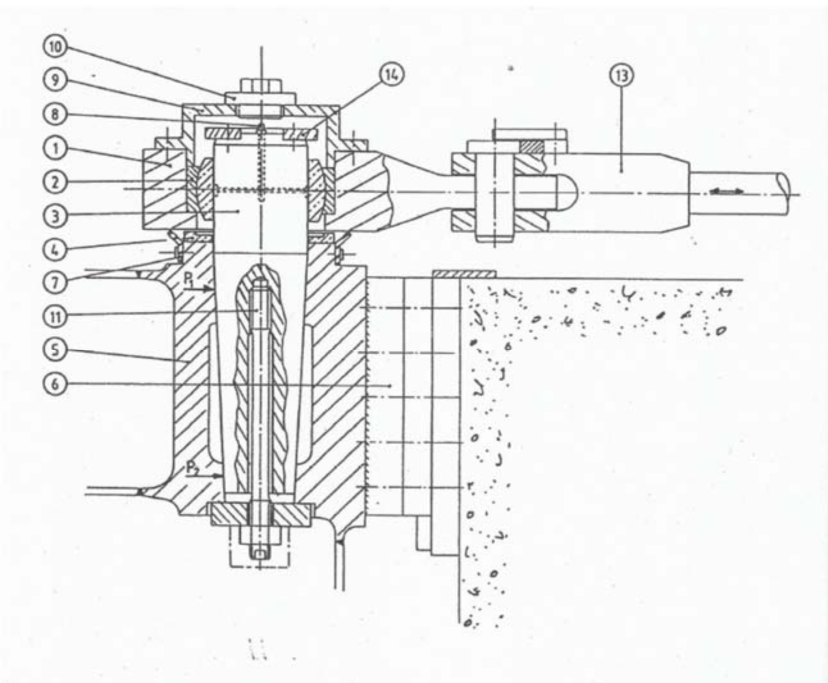
6.3 Lubrication - General

Chapter 6: Ancillary Components

- **Top Hinge**

  Design example

  Gate linking with the upper gudgeon by spherical joint.



Top Hinge

- **The convex spherical central part slides into the pintle: this part is usually manufactured in self-lubricating bronze with inserts for solid lubricants.**
- **This assembly makes perfect self-alignment possible between the upper gudgeon and the lower pintle.**
- **Dedicated grease ports (10 and 8) ensure the possible lubrication of the bushings.**

Chapter 6: Ancillary Components

- **Pintle Ball Lubrication Grease Lines**
  - Grease feed pipe lines must be robust, protected, accessible for inspection, able to be dismantled and easily replaced.
  - Pintle lines are used to evenly distribute grease across the pintle ball circumference
  - The lubrication Improves performance and corrosion resistance

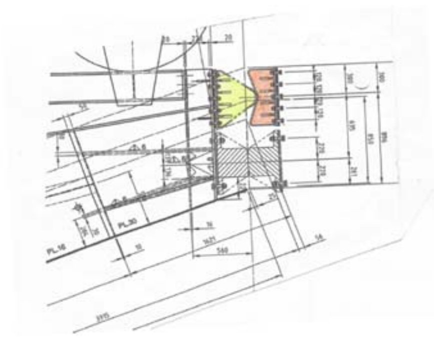
Chapter 6: Ancillary Components

- **Self Lubricating Pintle**
  - Improved service performance
  - Corrosion resistant
  - In my personal view, does not eliminate the need for grease systems
  - Higher initial cost

Chapter 6: Ancillary Components

Mitre Guide and Alignment Features

- Position and or distance sensors are usually installed on each leaf to detect whether a gate is in a good open condition or in a good closed condition.
- The use of gate latches can be justified during exceptional operating conditions of long durations because of the required protection towards wave shocks (recessed position).



Chapter 6: Ancillary Components

Impact Protection Systems

- VID (Very Important Document): PIANC WG 151, Design of Lock Gates for Ship Collision
- Mitre gates are very susceptible to impact damage by vessels entering and leaving a chamber.
- Protection Feature Types
  - Gate fenders, gate bumpers, guard gates , and ship arrestors

Chapter 6: Ancillary Components

Fenders on downstream side

Figure 6-16: Typical fendering (Lock 19, Mississippi River)

Fender recommended materials: timber, metal, polyethylene

6 5 1 Fenders on downstream side

Reminder

As far as the design of fenders and gates is concerned every design for impact load should be based on two different assumptions of friction:

- **Absence of sliding friction between ship hull and gate: f = tg φ = 0**
- **Maximum friction: f = fmax**

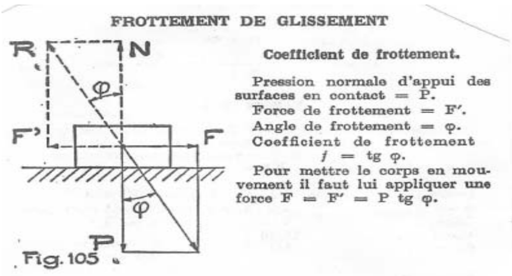


Fig. 105

Chapter 6: Ancillary Components

Timber Gate Fenders

- Economical
- Good energy absorption
- Potentially shorter service life than UHMW – rotting; friction properties becoming spoilt with aging

UHMW-PE Glass Reinforced Gate Fenders

- Low coefficient of sliding friction
- Reduces “Stick-Slip” behavior on contact
- Long service life

Chapter 6: Ancillary Components

Bumpers

In case of an accidental sliding impact, bumpers are used to minimize:

- the overall loading of the recessed gate,
- the simultaneous machinery loading.

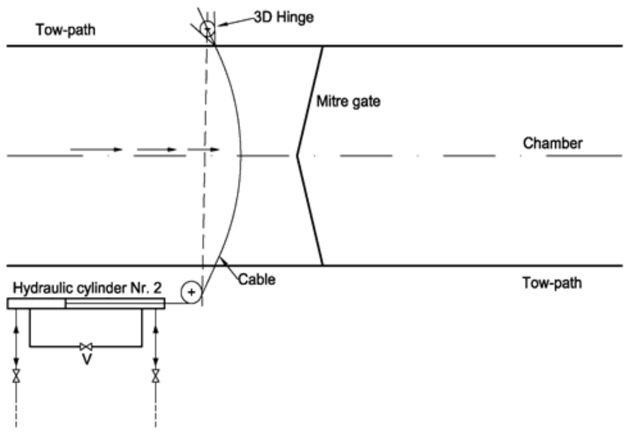
Chapter 6: Ancillary Components

Ship Arrestor System (not attached to gates)

- Design reduces the risk for mitre gate damage due to vessel impact
- The necessary elongation for proper cable function and energy absorption (order of magnitude: 4 to 5 metres) requires a corresponding lengthening of the lock chamber.
- This can be expensive construction for which investment has to be weighed against the risk of failure of the water retaining structure and navigation interruptions
- Mechanical system in itself: cost-effective and easy to maintain

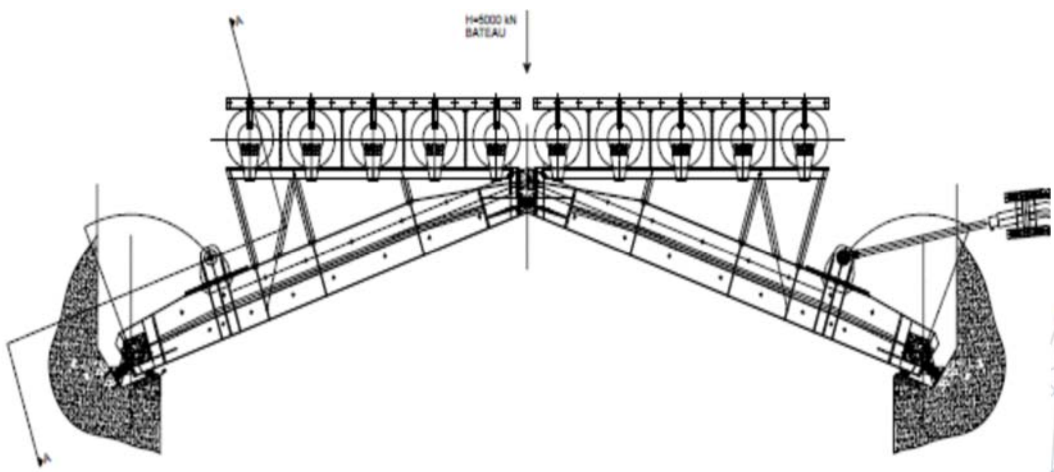
Chapter 6: Ancillary Components

Ship Arrestor System (not attached to gates)



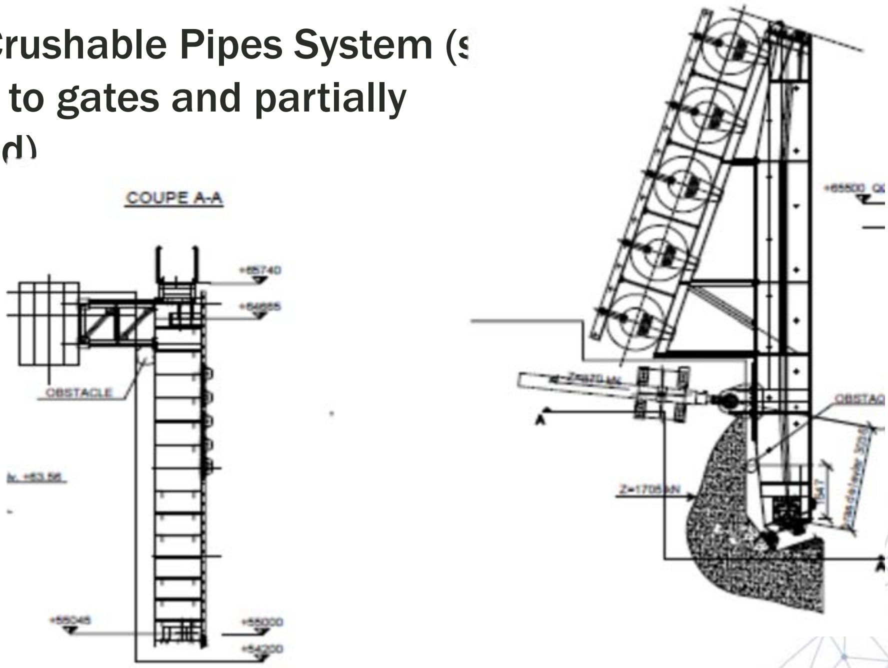
Chapter 6: Ancillary Components

Rubber Crushable Pipes System (system attached to gates)



Chapter 6: Ancillary Components

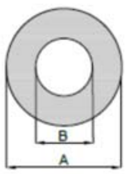
- Rubber Crushable Pipes System (s attached to gates and partially immerged)



Chapter 6: Ancillary Components

Crushable Pipes System (system attached to gates)

- When compared to the prior system, the crushing necessary for a pipe's proper function is less than the cable elongation; the resulting dynamic amplification is thus greater than that of the cable system.



Standard dimensions

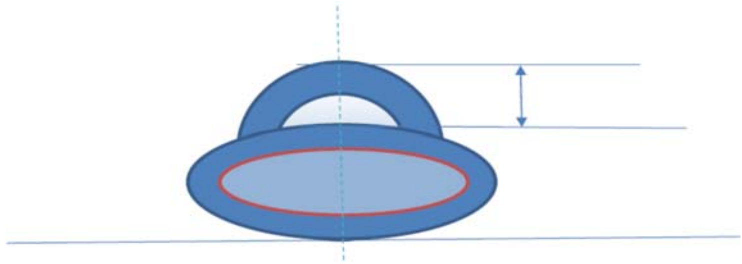
A (mm)	B (mm)	Weight (kg/m)
100	50	7.2
150	75	16.3
200	100	29.0
250	125	45.3
300	150	65.2
380	190	105
400	200	116
450	225	147
500	250	181
600	300	255
800	400	453
1000	500	707
1200	600	1018
1400	700	1386
1400	800	1240
1500	750	1591
1600	800	1810
1800	900	2273
2000	1200	2414

Other non-standard dimensions available on request.

Chapter 6: Ancillary Components

Crushable Pipes System (system attached to gates)

- Advantage: the space required along the length of the chamber is relatively small and the overall investment cost is reduced.
- Mechanical system: cost-effective and easy to maintain



Chapter 7: Operations and Maintenance

- Spare Parts
- Spare Gates
- Gate Repair
- Ice and Debris Management
- Inspections

Chapter 7: Operations and Maintenance

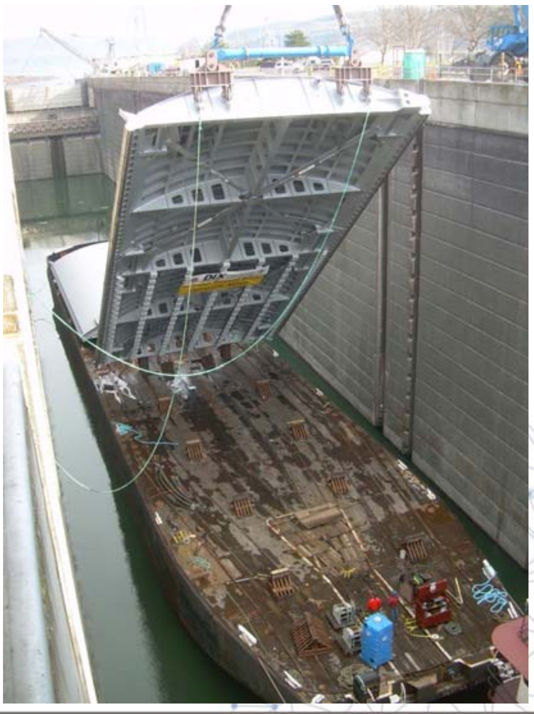
Spare Parts

- The operation of mitre gates requires stocking spare parts for the most fragile parts on a permanent basis.
- Split into two categories:
  - Emergency Parts
    - Replacement cannot be foreseen and therefore cannot be scheduled
    - Anchorage bars and linkages, pintles, gudgeon pins, diagonal bars, and operating strut arms
  - Scheduled Replacement Parts
    - Those parts which will need to be replaced due to normal wear and tear
    - Pintle bushings, gudgeon pin bushings, anchorage bushings, gate actuator parts and sensors, fenders, seals, and sensors

Chapter 7: Operations and Maintenance

Spare Gates

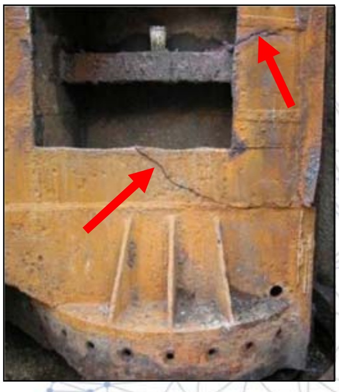
- Typically, the acceptable time period for navigation interruption is much shorter than the time required for major repairs or replacement.
- This is why there is a need for spare mitre gates that can be placed into operation in a relatively short amount of time.
- Depending on gate size and crane capacities, gates are stored at locks, on barges or in special buildings to preserve their condition.
- An analysis needs to be performed to determine the duration and costs of navigation interruption compared to the delay and costs of having spare gates.



Chapter 7: Operations and Maintenance

Gate Repair

- Gate weight, site accessibility and navigation interruption time will drive the need for repairing the gate in-place or removal of the gate.
- The mitre gate may contain lifting lugs that were used during construction
  - Facilitates handling during shop fabrication, erection, and initial placement of the gate
  - Facilitates maintenance operations
- Larger gates should be designed with jacking points
  - Allows the gate to be moved vertically using hydraulic jacks for initial placement, removal or maintenance of the pintle or seals



Chapter 7: Operations and Maintenance

Ice and Debris Management

- Ice prevention and ice breaking measures require flexibility. Why?
  - Disparity of the inland waterways
  - Geographical location within the country
  - Type of inland waterway traffic
- High volume air bubbler systems
  - Move ice and debris from the gate recess area such that the gate may fully recess
  - Low volume air systems or propeller systems can be attached to the gates to prevent the build-up of ice on the gates
- Electric thermal strip systems

Chapter 7: Operations and Maintenance

Inspections

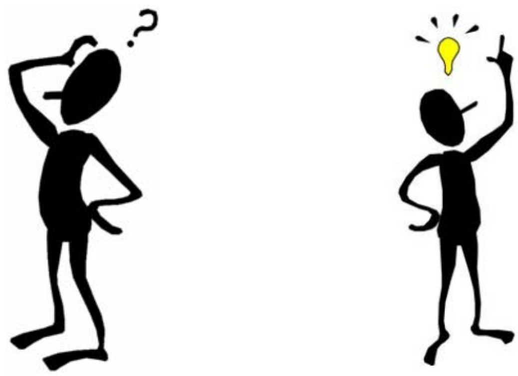
- Underwater divers
  - Historical method
- An alternative technique
  - Refers to a process which replaces and prevents diving (human immersion)
  - Remote camera inspection
- A complementary technique
  - Submerged or non-submerged assistance operations provided during an underwater diving operation
  - The main objective of complementary techniques to diving is to improve the safety of the underwater operations and reduce the risks faced by divers

Remote automatic dredging

Conclusions

- Design to accommodate safety of navigation, structural robustness, ease of future maintenance
- Consideration of new materials, weighing advantages and limits
- Standardization can be very useful

Questions? Feedback?



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Mitre Gate Design and Operation
PIANC Report No. 154 Overview

Operations
Appendix A – Charts to Assess Mitre Gate Opening/Closure Time

Prepared by:

Yvan Cordier, Op. Manager

Appendix A Overview

1. Mitre gate Operating Speed
2. Results of the WG 154 Survey and Proposal of Design Charts
3. Comparison with a US Design Specification EM 1110-2-2703
4. Conclusion

1. Mitre gate Operating Speed

The rotational speed value chosen for the miter gates is very important for…

- the total time taken for the closing and opening operations;
- working out the maximum operating forces;
- selecting the hydraulic equipment (pumps, pressure and pump flow rates for the actuators).

2. Results of the WG 154 Survey and Proposal of Design Charts

Group 154 conducted a survey to help the designers choosing relevant values of the opening and closing times.

These values can be used as reference points for classifying a movement as a slow, normal or fast movement.

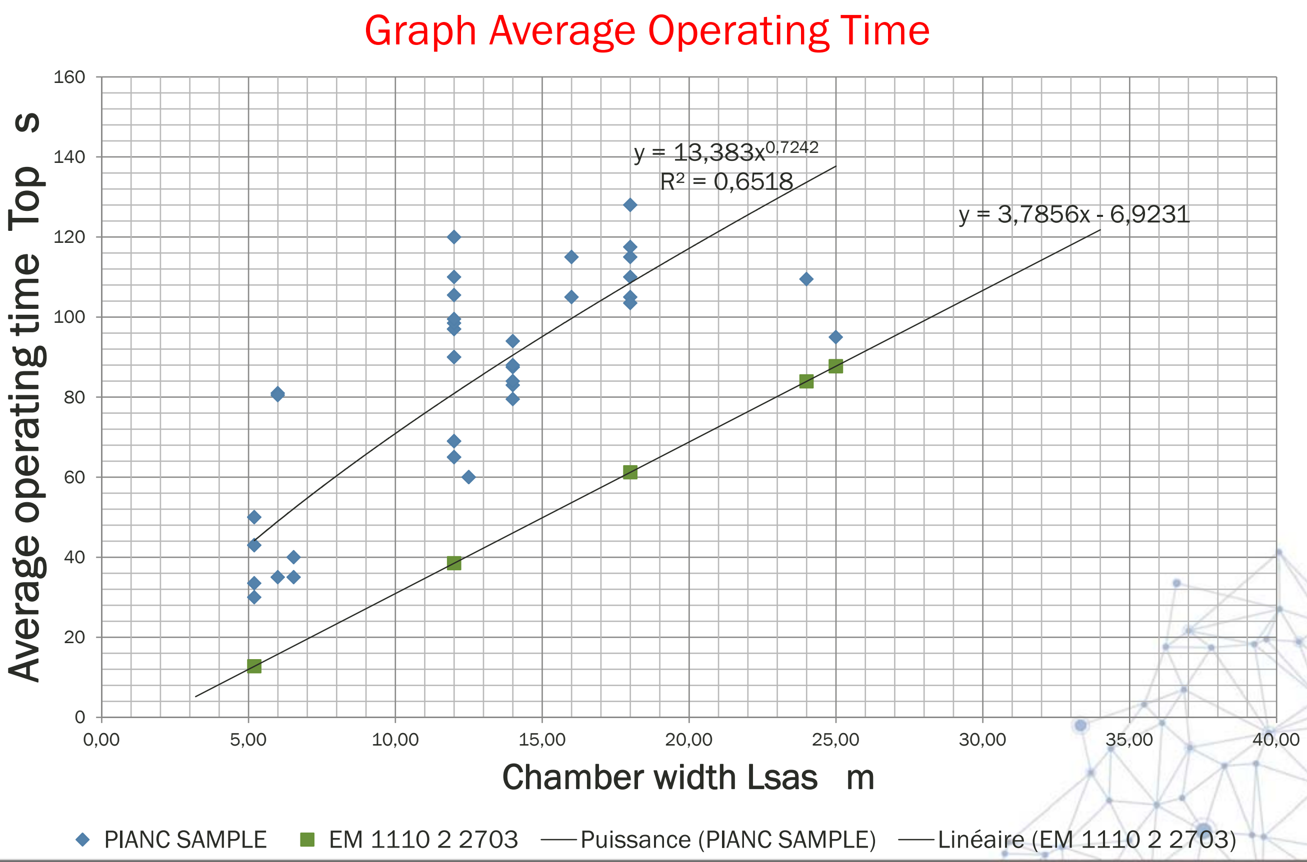
2. Results of the WG 154 Survey and Proposal of Design Charts

- Recap of the survey's assumptions
- The inventory does not take any lubrication type, or system of upper & lower hinges into account, and no water temperature effect. It only applies to steel gates.
- Gates are always supposed to operate during normal operating conditions without taking into account any particular design specification or code, wave, wind loading or other loading.

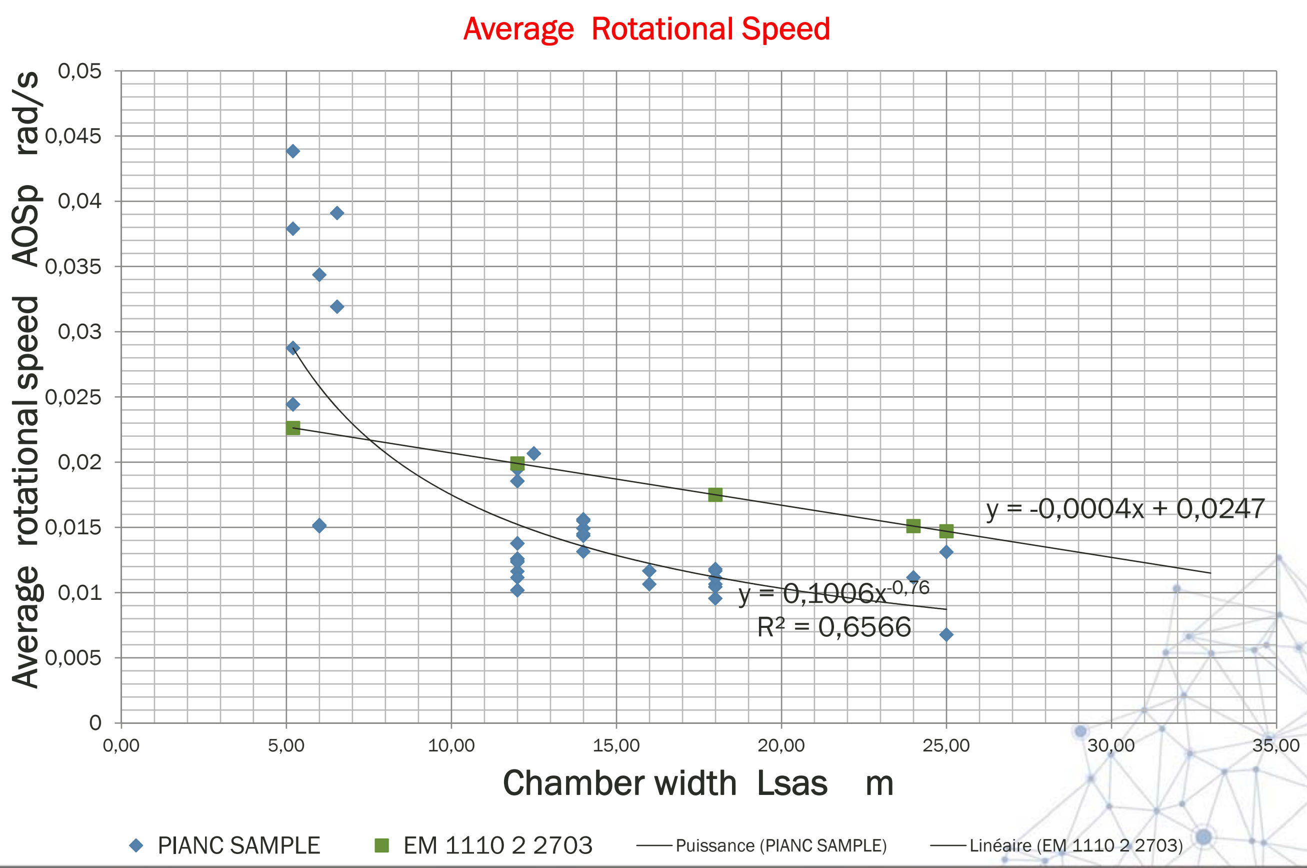
2. Results of the WG 154 Survey and Proposal of Design Charts

The operating time of a gate is between 50 s and 120 s.
See following graph :

- Average operating time
- Average rotational speed



Graph Average Operating Time
Average operating time Top s
160
140
120
100
80
60
40
20
0
y = 13,383x^0,7242
R² = 0,6518
y = 3,7856x - 6,9231
0,00
5,00
10,00
15,00
20,00
25,00
30,00
35,00
40,00
Chamber width Lsas m
PIANC SAMPLE
EM 1110 2 2703
Puissance (PIANC SAMPLE)
Linéaire (EM 1110 2 2703)



Average Rotational Speed
Average rotational speed AOSp rad/s
0,05
0,045
0,04
0,035
0,03
0,025
0,02
0,015
0,01
0,005
0
y = -0,0004x + 0,0247
y = 0,1006x^-0,76
R² = 0,6566
0,00
5,00
10,00
15,00
20,00
25,00
30,00
35,00
Chamber width Lsas m
PIANC SAMPLE
EM 1110 2 2703
Puissance (PIANC SAMPLE)
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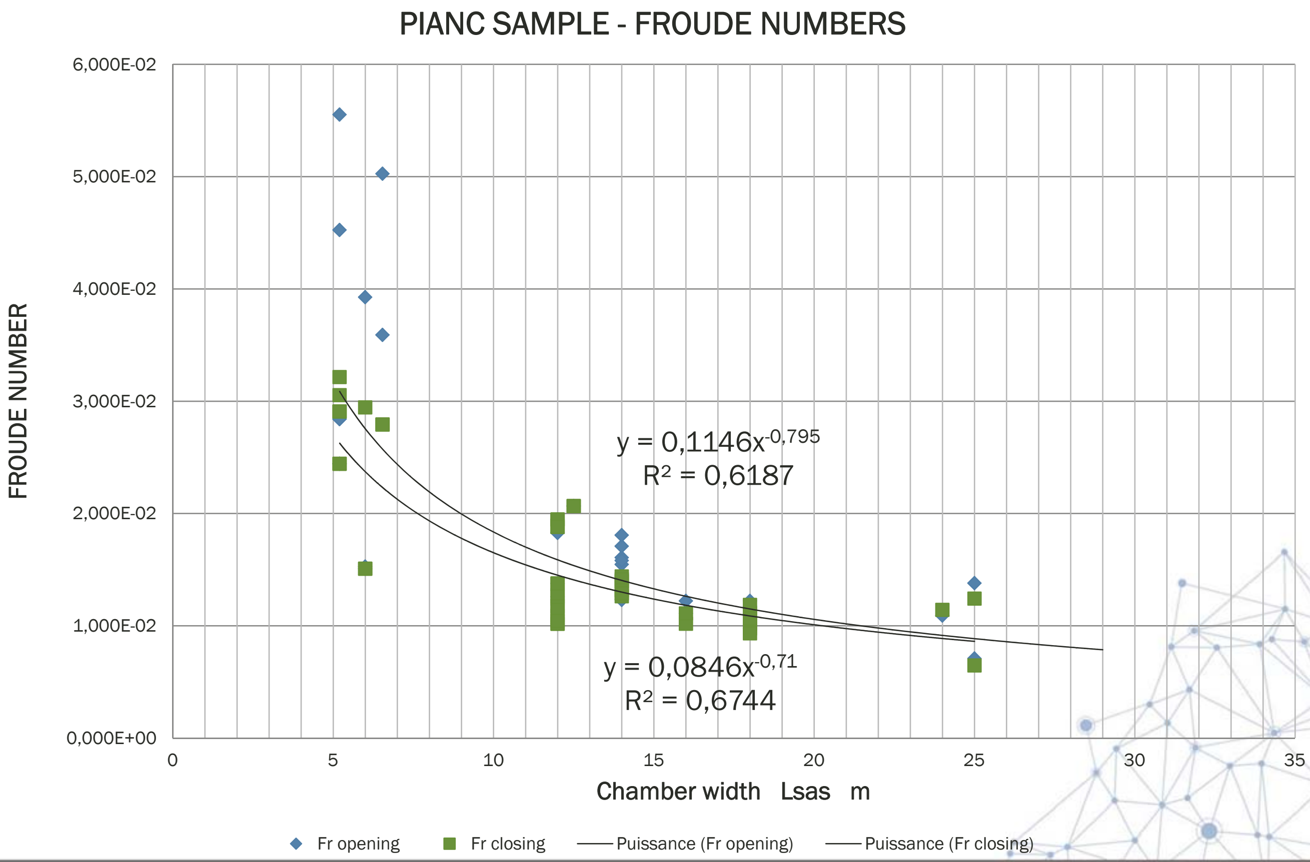


2. Results of WG 154 Survey and Proposal of Design Charts

How to hose a relevant closing (opening) time value and average rotational speed ?

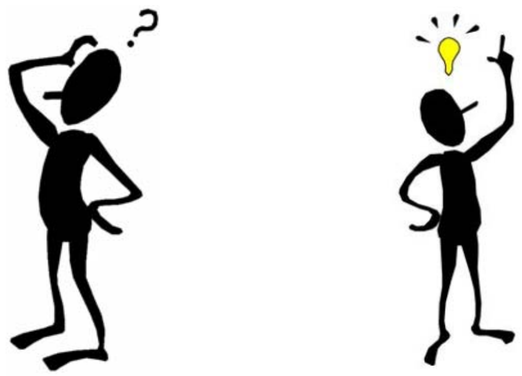
We interpret the standard deviation S intuitively, i.e. we state that:

- **Approximately 68% of the observations are within <u>one standard deviation</u> S of the mean M, i.e. within the interval M + - (1*S);**
- **Approximately 95% of the observations are within <u>two standard deviations</u> of the mean M, i.e. within the interval M + - (2*S).**

3. Comparison with US Design Specification EM 1110-2-2703 and conclusion

- Specification for chamber widths between 25 m (smaller gates) and 34 m (larger gates).
- The time proposed by the EM 1110 design specification is <u>shorter</u> and should be considered as belonging to ~~ 95% of the target group described in the PIANC sample; EM 1110 values are small and within two standard deviations S of the mean M, i.e. within the interval M - (2*S).

Questions? Feedback?



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PIANC Workshop
Mitre Gate Design and Operation
PIANC Report No. 154 Overview

Conclusions

Prepared by:

Eric Johnson, P.E., S.E.

Report Overview

1. Mitre Gate Systems
2. Mitre Gate Components
3. Mitre Gate Design Issues and Guidance
4. Gate and Component Materials
5. Mitre Gate Seals
6. Ancillary Components
7. Operations and Maintenance
8. Conclusions
9. References

Conclusions

- Mitre gates have a long history and have been used in a wide variety of conditions, heights, and widths
- This variety of conditions pose difference advantages and disadvantages

Recommendations for Design, Geometry, and Framing

- Vertically framed more economical and easier to maintain for height-to-width ratios of less than about 0.7
- Top and Bottom Hinges that accommodate tolerances for fabrication, wear, and construction improves load transfer and longevity
- Gate operating mechanism: Ohio River (direct connected mechanism)
- Design to accommodate ease of future maintenance
- Diagonals method of tensioning located near the top of the gate, preferably above the water line, for accessibility and corrosion prevention.

Recommendations for Computational Analysis

- Ship impact can be more easily considered at early design stage without having to use nonlinear finite elements
- Feedback from instrumentation and structural health monitoring is providing better understanding of gate behavior that can be modeled and improve design

Recommendations for Materials, Seals, and Maintenance

- For materials used, consider structural demands and match them with materials that have best properties to meet performance and longevity
- Consider new materials - applicability depends on the material properties, performance history, limitations and specific conditions.
- Attaching seals to the gate rather than to the concrete wall or sill results in easier maintenance
- Standardization: reduces part inventory, improves consistency in repair & replacement methods, and reduces overall maintenance costs

Questions? Comments?

Thank You for Your Kind Attention

PIANC – November the 6th 2017
Mitre gate design and operation
4th Lock of Lanaye
Study Office Greisch - David Monfort

Greisch Multidisciplinary team of engineers and architects
Bridges, hydraulic works, buildings, steel structures

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Fourth lock of Lanaye

TEN-T Network
Project nr 18: Rhine/Meuse – Main – Danube

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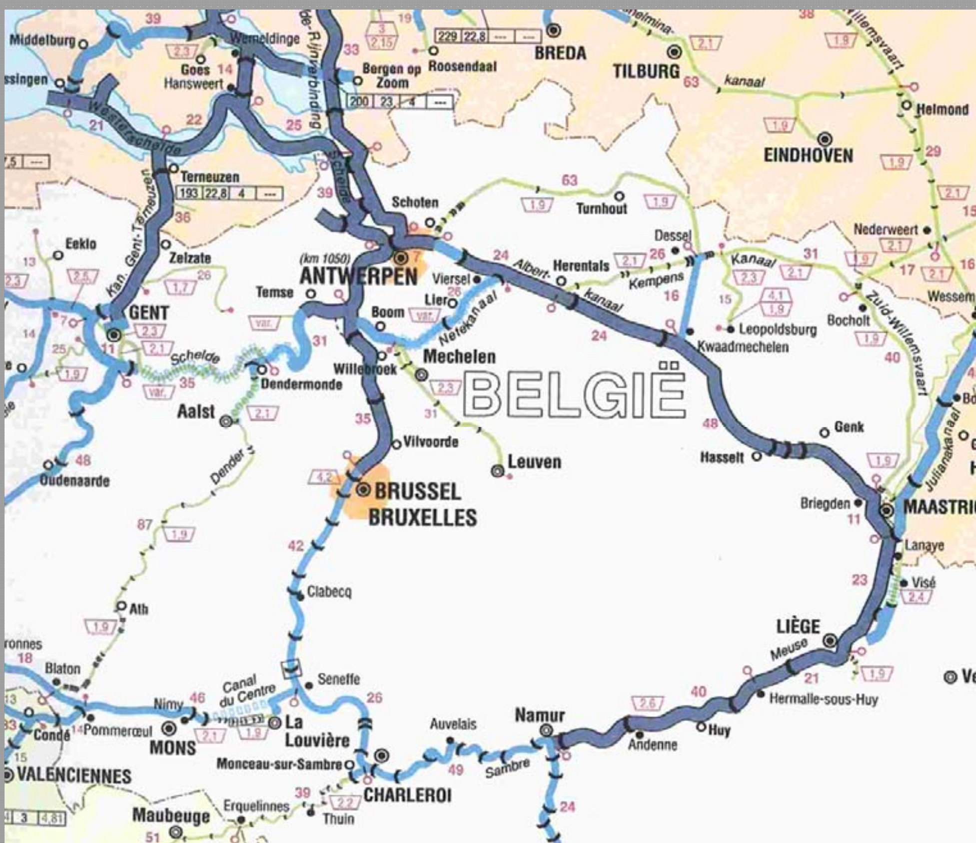

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main dimensions

class VIb lock

225 x 25 m

14m head

butterfly valves

2 longitudinal culverts

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Owner: SOFICO
Public Administration of Wallonia (SPW) – Liege Waterways

Main contractor (Infrastructure and gates) : BESIX
Main contractor (electromechanics) : SPIE-FABRICOM-SANOTEC-BALTEAU

Design: Study Office Greisch – SNC Lavalin + Tractebel Engineering

Works : June 2011 – March 2016

Co-financé par l'Union européenne
Réseau transeuropéen de transport (TEN-T)

Investment: Infrastructures : 110 M € excl. VAT
Electromechanics : 30 M € excl VAT

Funding: Walloon Region
Loan EIB (via Sofico)
European support (TEN-T)
The Netherlands

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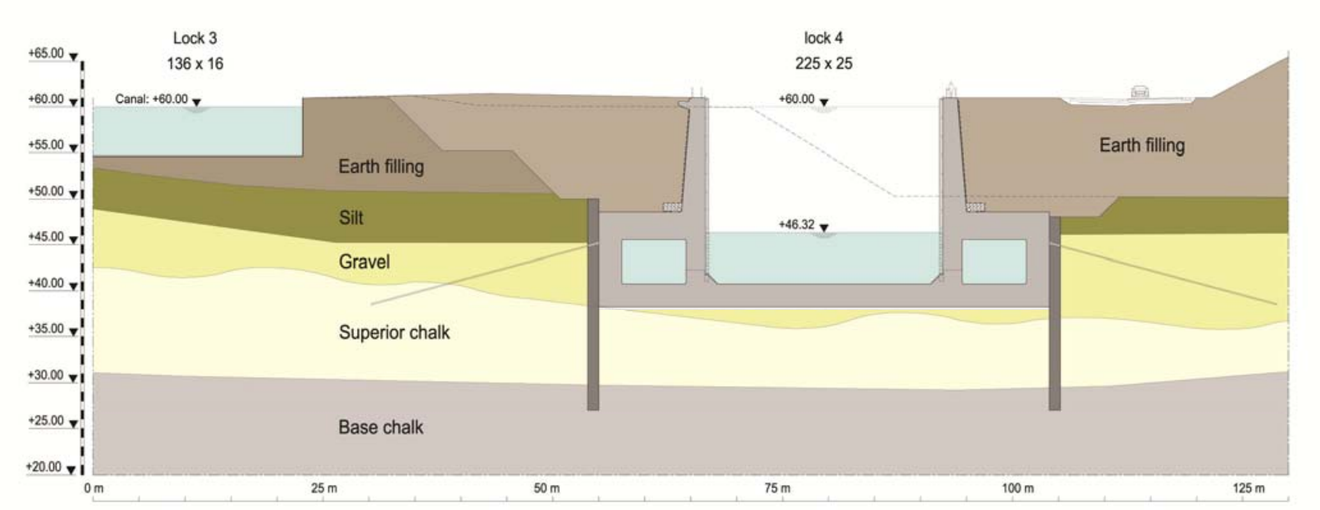
typical cross section



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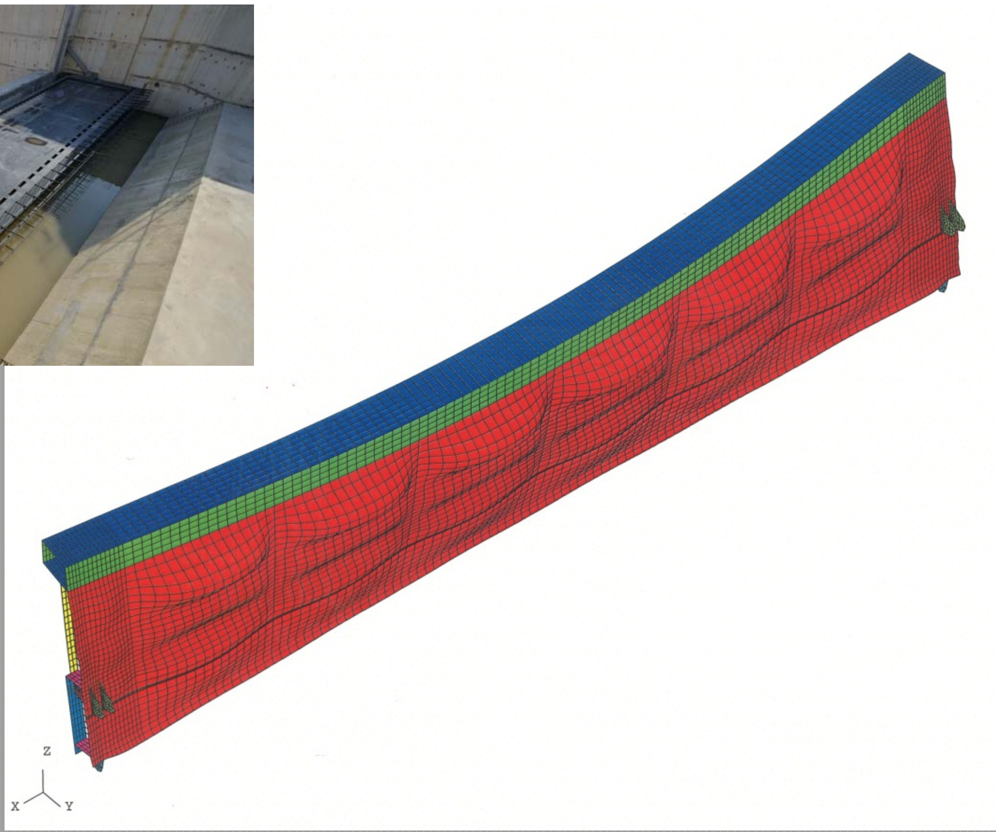

Flap gate upstream

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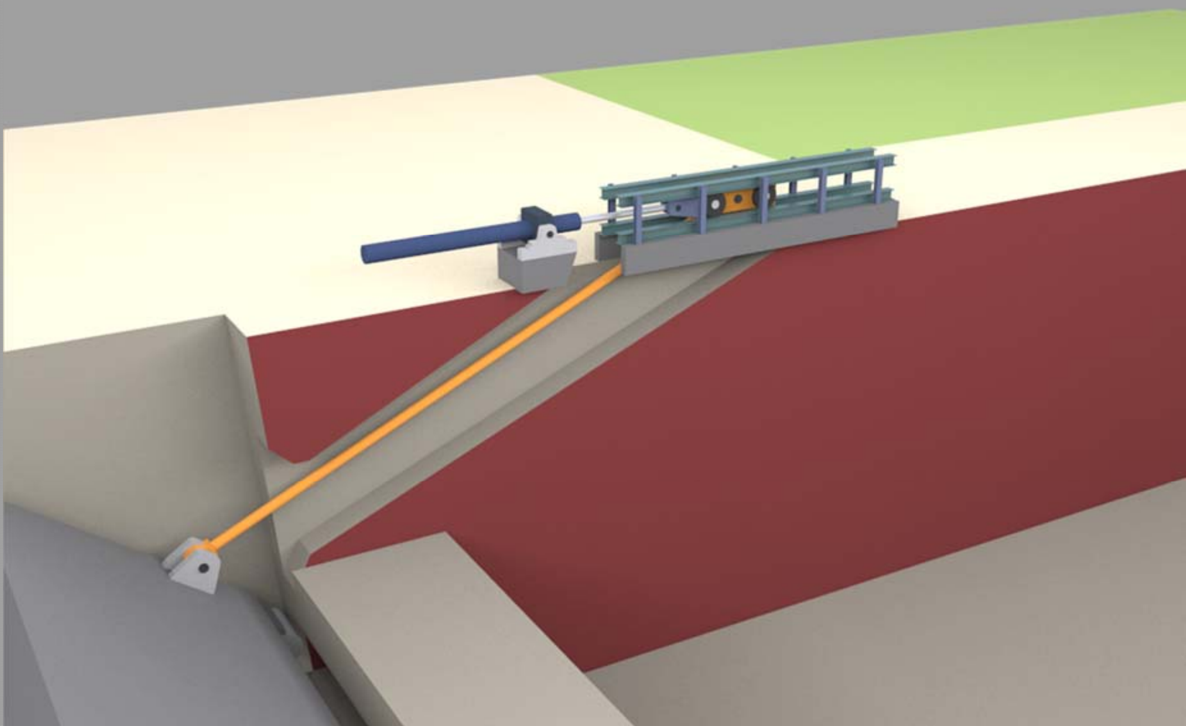

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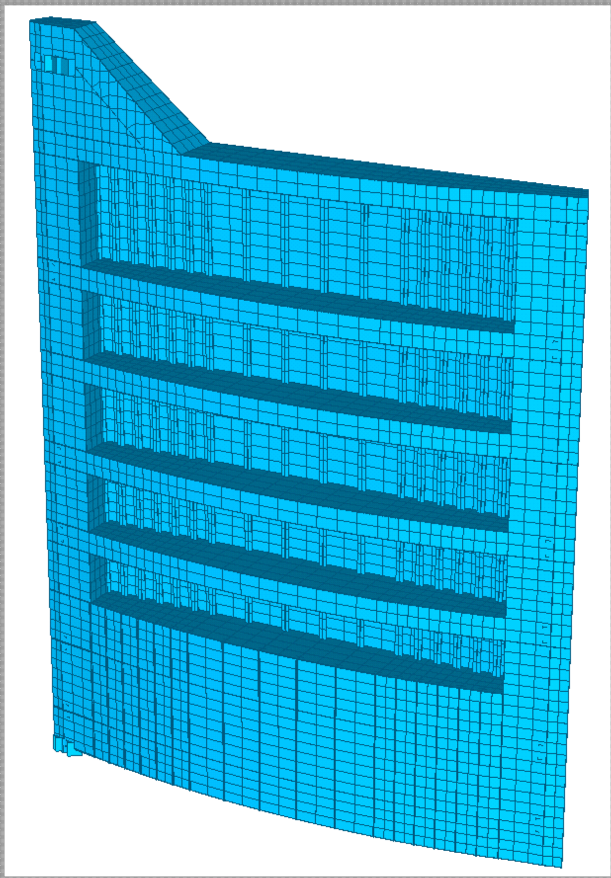

Mitre gate

DOWNSTREAM

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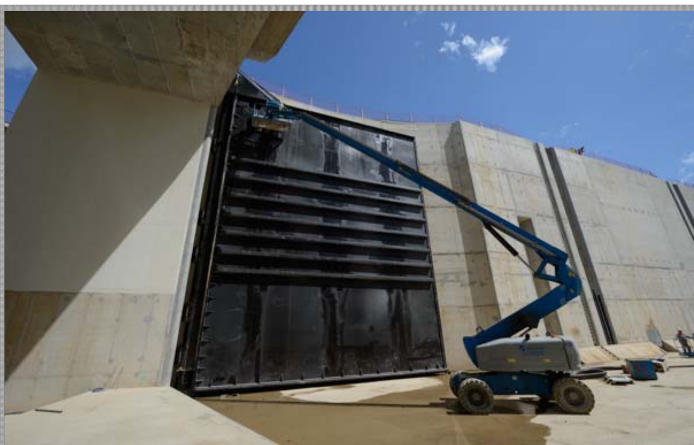

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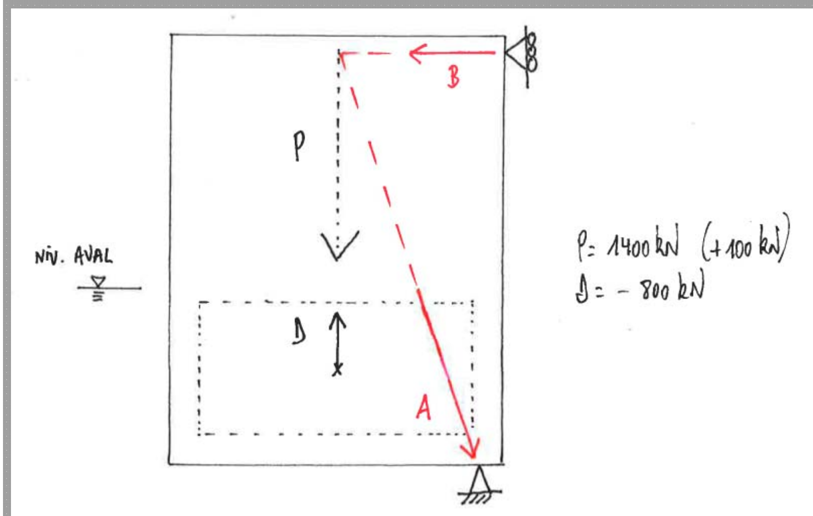
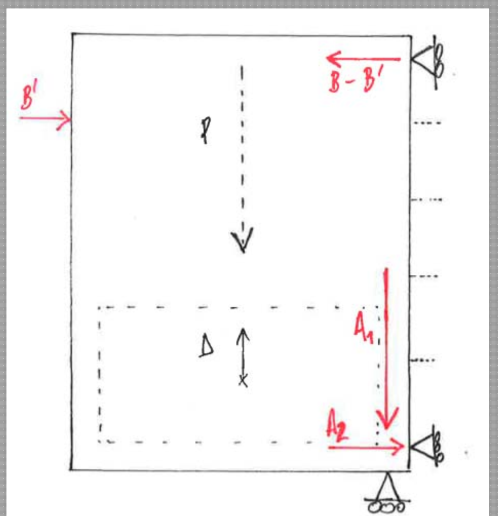
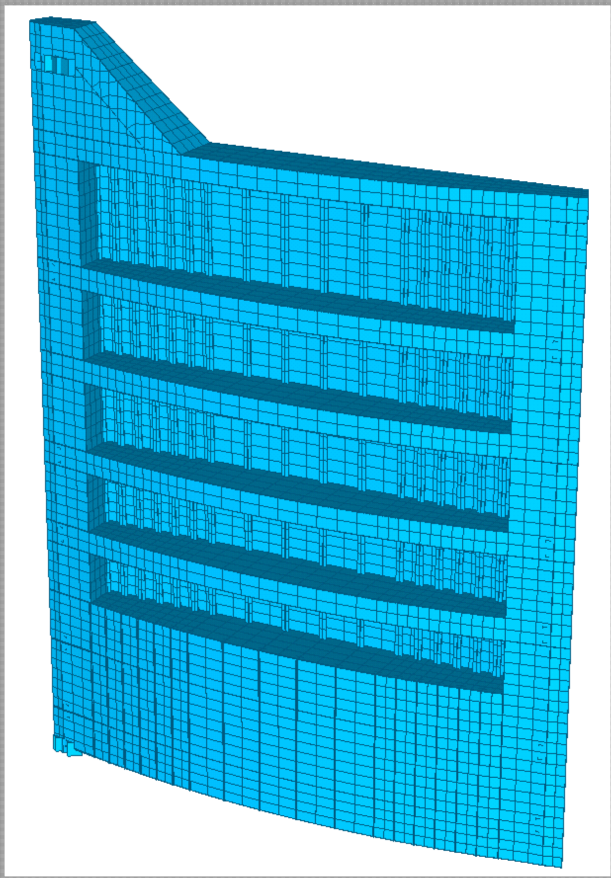
Supporting points of the gate during rotation



Supporting points of the closed gate





Mitre gate

DOWNSTREAM

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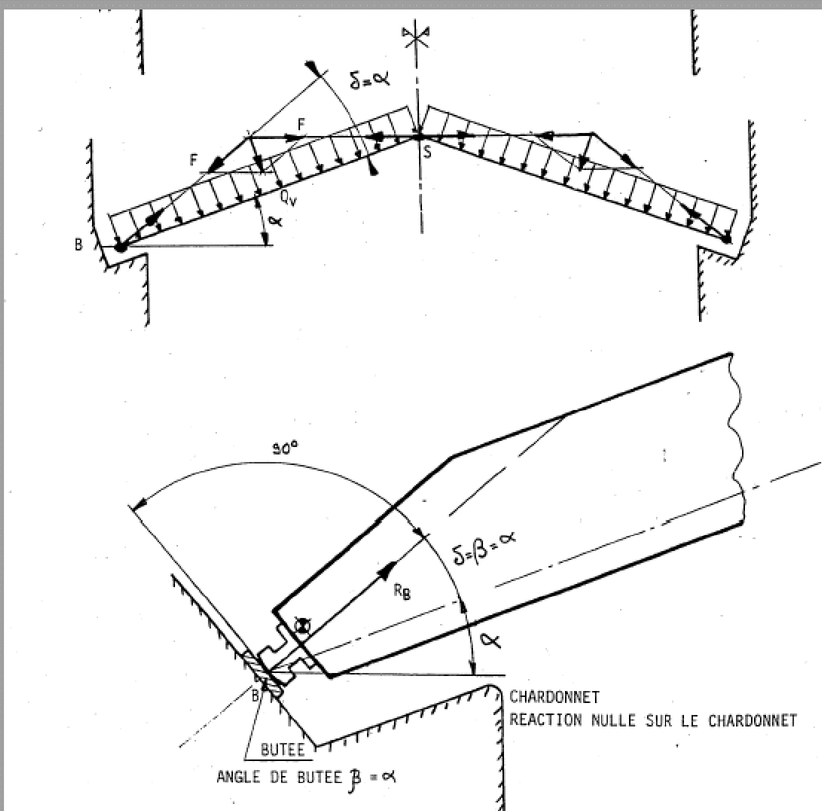

Box girder nr4

(depth. 13m)

- ***p = 127 kN/m²***
- ***$P_{\perp}$ = 3750 kN***
- ***F = 5000 kN***

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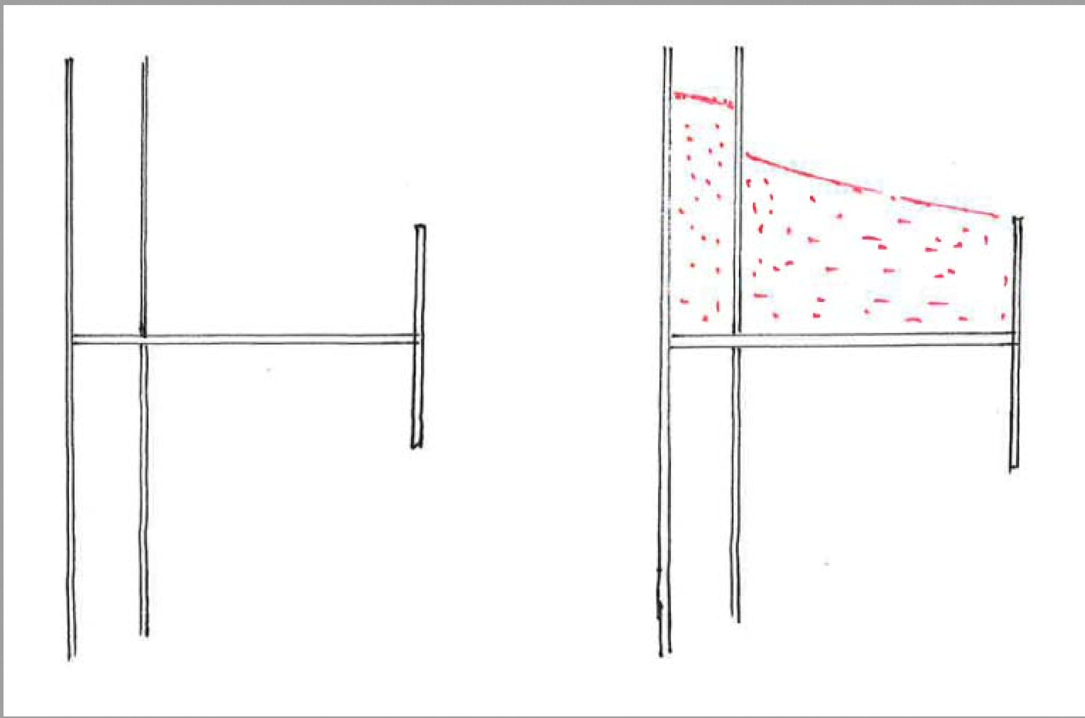

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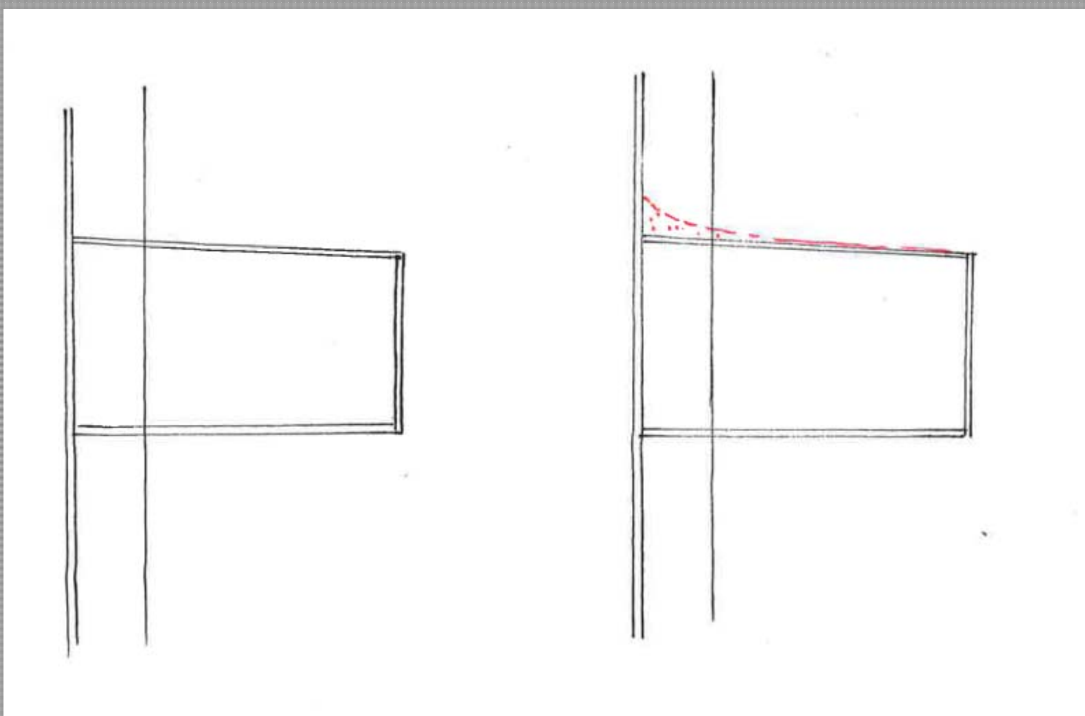

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greisch

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- Operations made under the authority of the Public Administration of Wallonia
- Close collaboration between all the involved services (Public Administration, Contractors and sub-contractors, Study Office, Supervising Office)
- Common goals : security of the people and the structure, identification of the cause(s), repair strategy, durability and impact minimization (navigation was interrupted during 2 months)

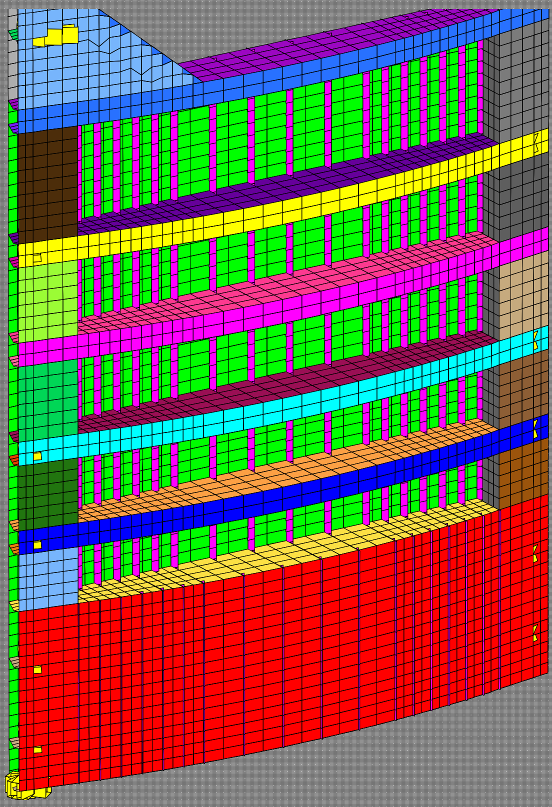
Investigation of causes

greisch

- Combination of bending and shearing effects in the stiffeners (acting as vertical continuous beams):
  → very low stresses
- Lack of ductility in the folded metal : 7mm fillet welds upon 7mm metal sheet
  → Internal bending radius of the sheet 35 mm : ratio ok
- Welding methods (Residual stresses) :
  → all procedures are correct and in accordance with the Execution class of the steel structure

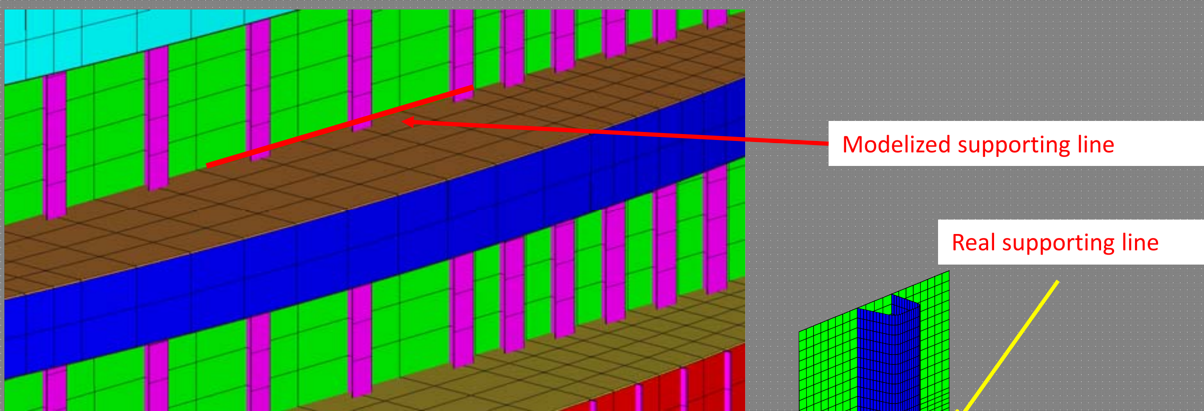
greisch

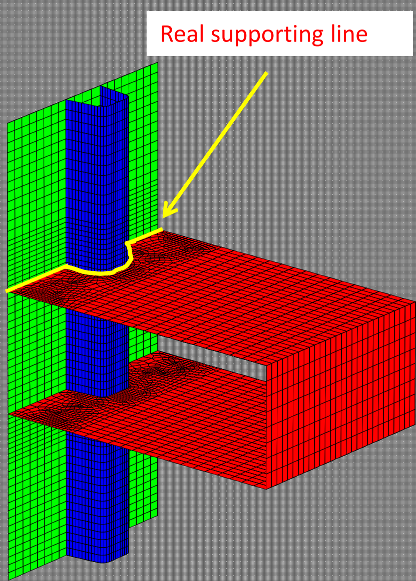
3D Calculation model of a single leaf



- Global behaviour of the structure
- Reactions
- Design of all constitutive sheets (thickness, steel grade)
- Design of beams and stiffeners, ...
- Instability verifications
- ...

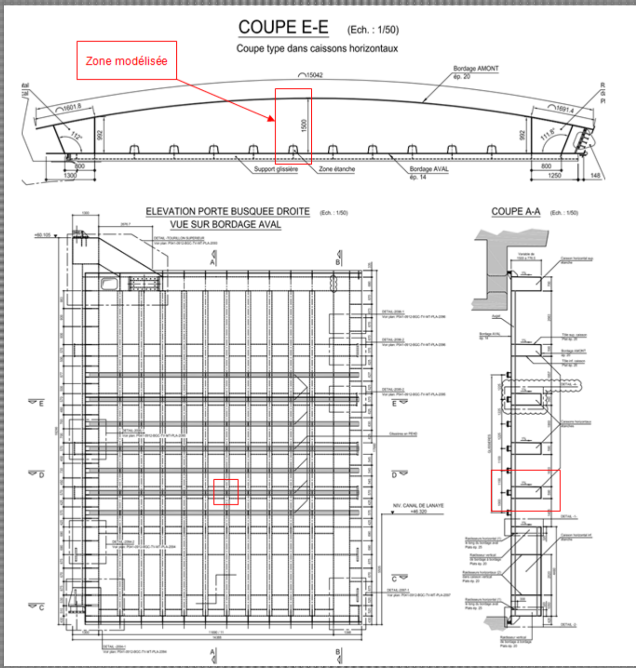
3D Model : focus on the cracked zone

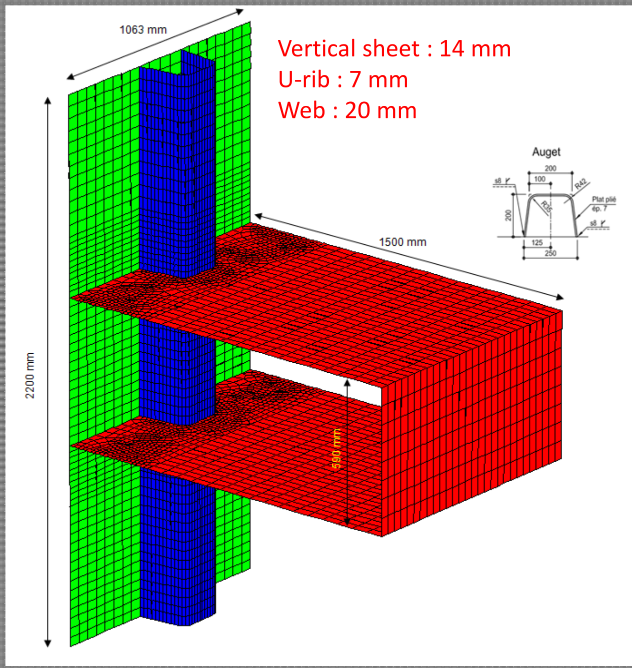




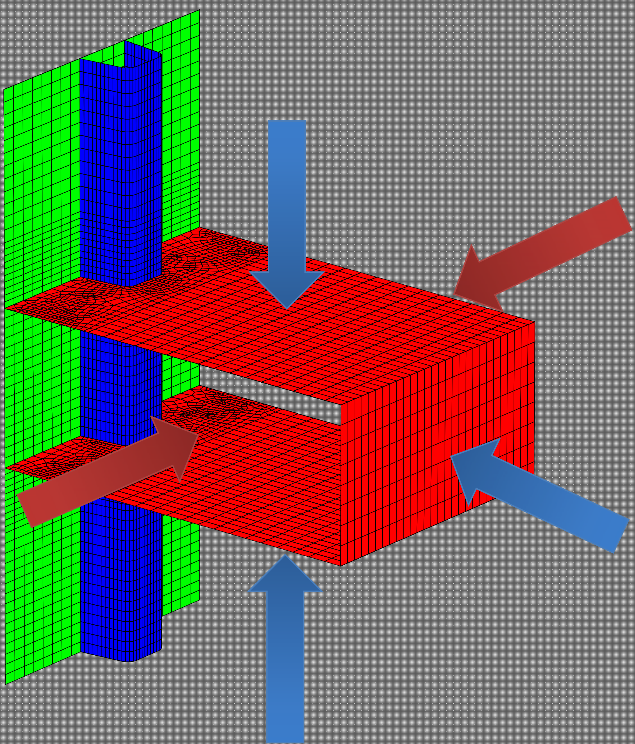
Stiffeners are simulated by equivalent beams, with the appropriate excentricity but the deformation of the webs of the main beams (brown sheet) is not exactly the same.

3D local model : represents one slice of the beam, of the U-ribs and of the main steel sheet





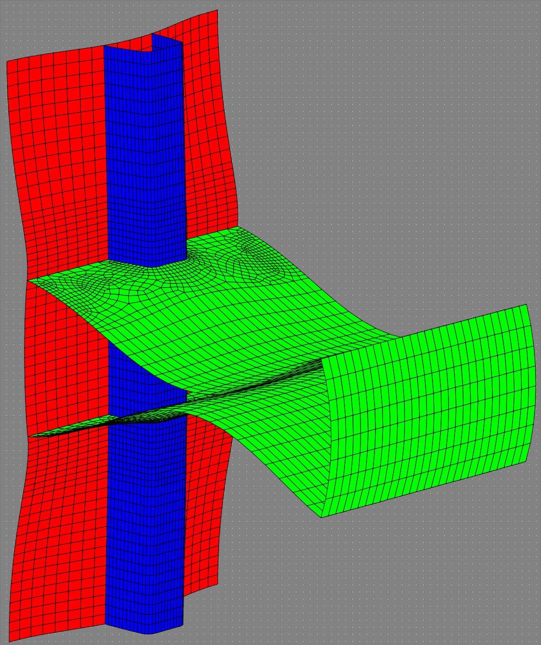
3D local model : defining the actions



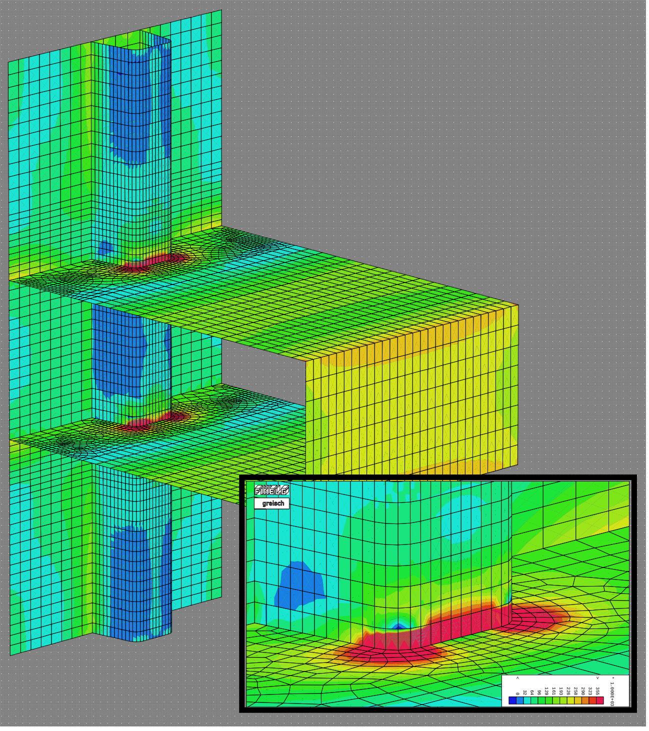
- BLUE : Water pressure upon each side of the box (up to 130 kN/m² for the lowest beam)
- RED : mitre effect (horizontal compression in the beams)

3D local model : results

Deformed shape



Local Von Mises stresses > 355 N/mm² in red

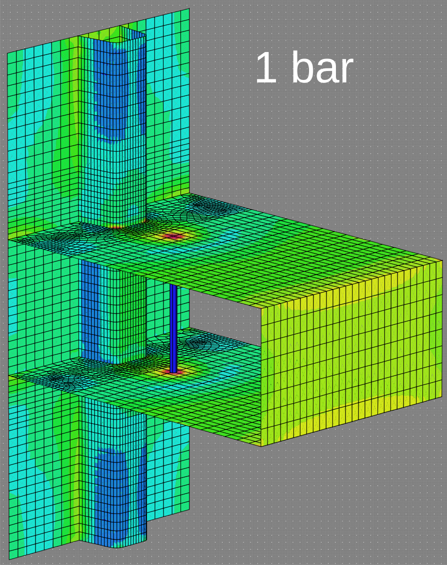


How to fix this?

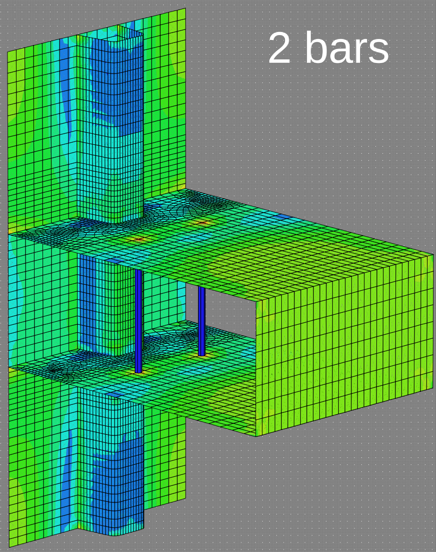
- From the outside? Addition of stiffeners or tie-rods between the box girders : welding , protection, painting + losing the initial simplicity of shapes
- Opening the boxes to balance the water pressure? The boxes are waterproof and not protected – no contact with external air nor water is allowed
- From the inside ? Vertical bars to balance the external pressure

3D local model : reinforcing with bars

Main goal: to minimize the bending stresses at the connexion between the webs and the U-ribs



1 bar

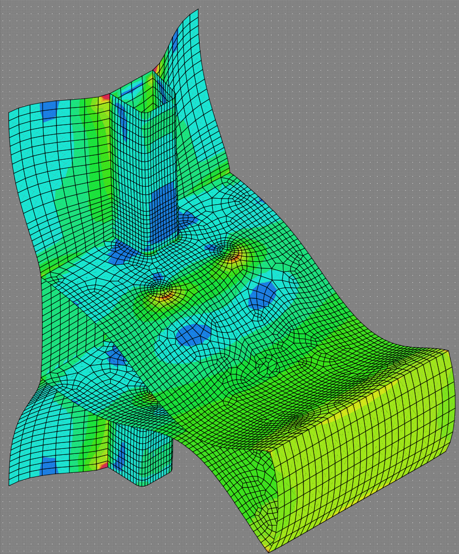


2 bars

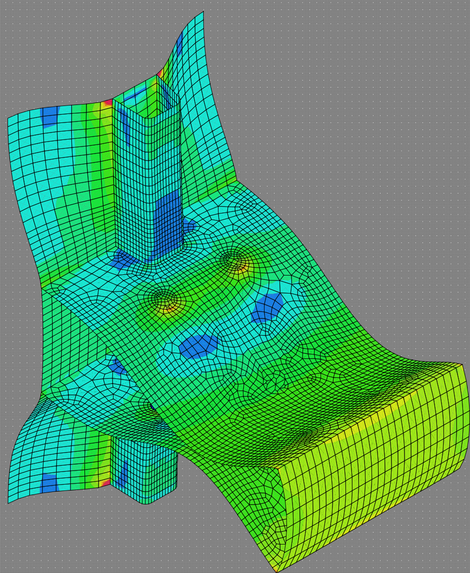
Local stress concentrations

3D local model : reinforcing with steel tubes

2 round welded tubes

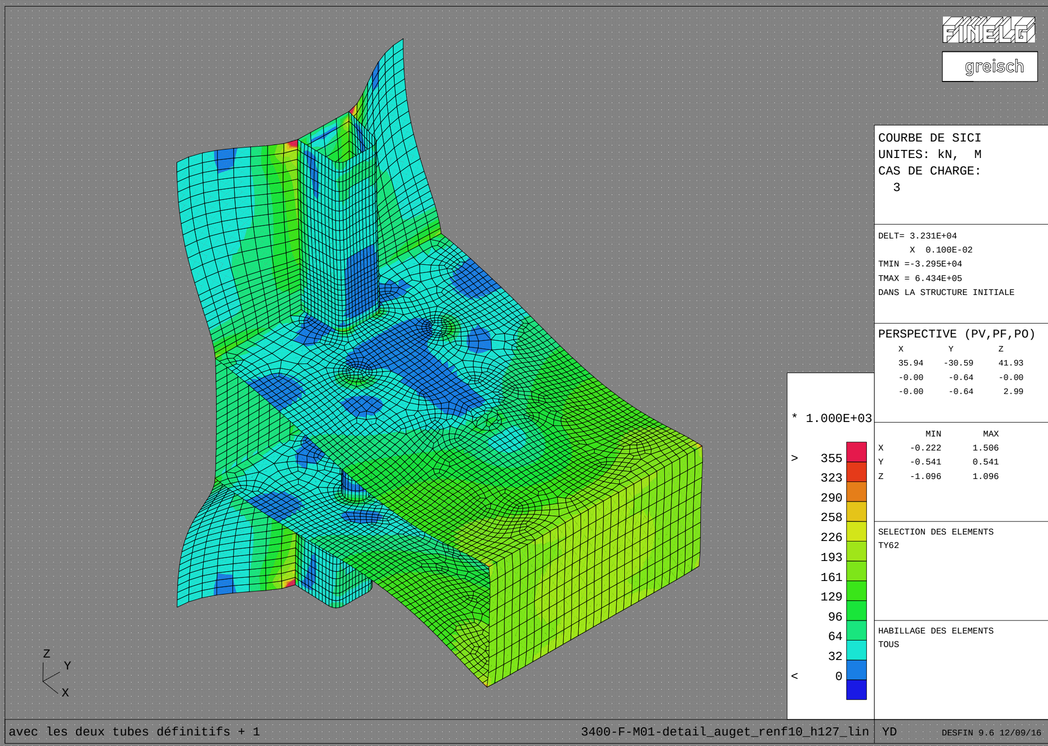


2 locally welded tubes



Easier to introduce, local welding for positioning, simple compression, limitation of bending stresses inside the tubes

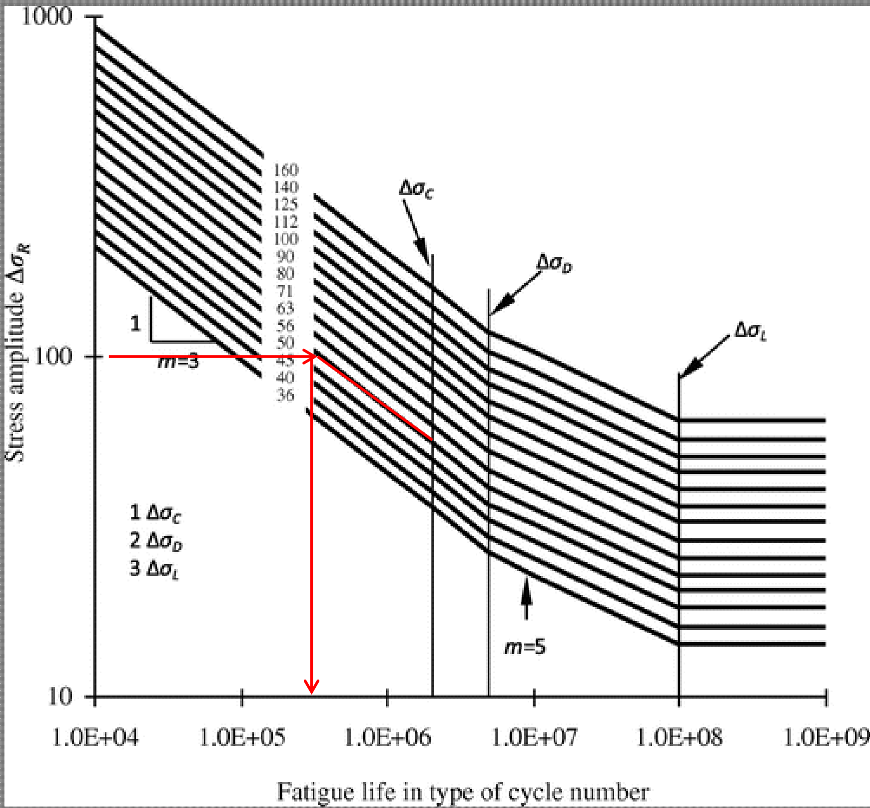
3D local model : reinforcing with steel tubes

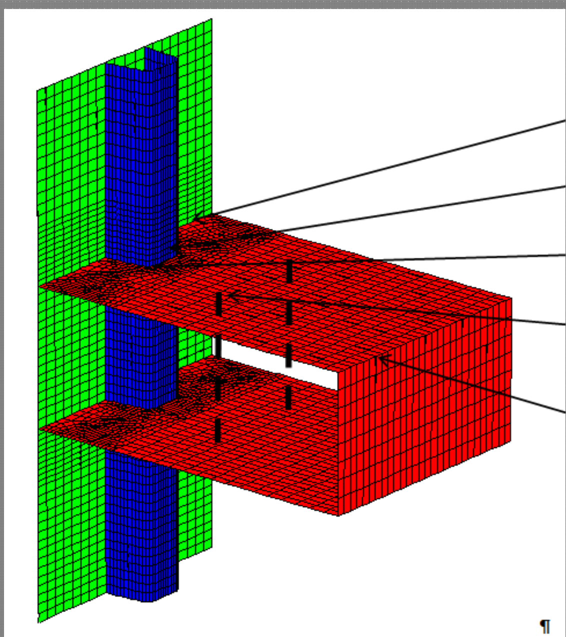


This operation cancels the oligo-cyclic fatigue phenomenon. No more damage is generated

The reinforced structure needs to be verified according to classical fatigue norms:
20 cycles/d * 300d/year * 50 years = 300 000 cycles

$$\Delta\sigma_{300\,000} \approx 2 * \Delta\sigma_{2\,000\,000}$$





connexion	detail
Beam web / vertical plate	36*
U-rib reconstitution	36* or 71
U-rib/beam web	36* or 71
Plain web facing the tube	160
Web / flange	100
+ Manholes closure	71

Some pictures…

greisch

greisch

PIANC - BRUSSELS
2017.11.06

greisch

PIANC - BRUSSELS
2017.11.06

greisch

PIANC - BRUSSELS
2017.11.06

Follow up

- Regular diving inspections (ultrasonic measures to check that the U-ribs keep dry)
- Periodical emptying of the lock for full welding inspection

greisch
PIANC - BRUSSELS
2017.11.06

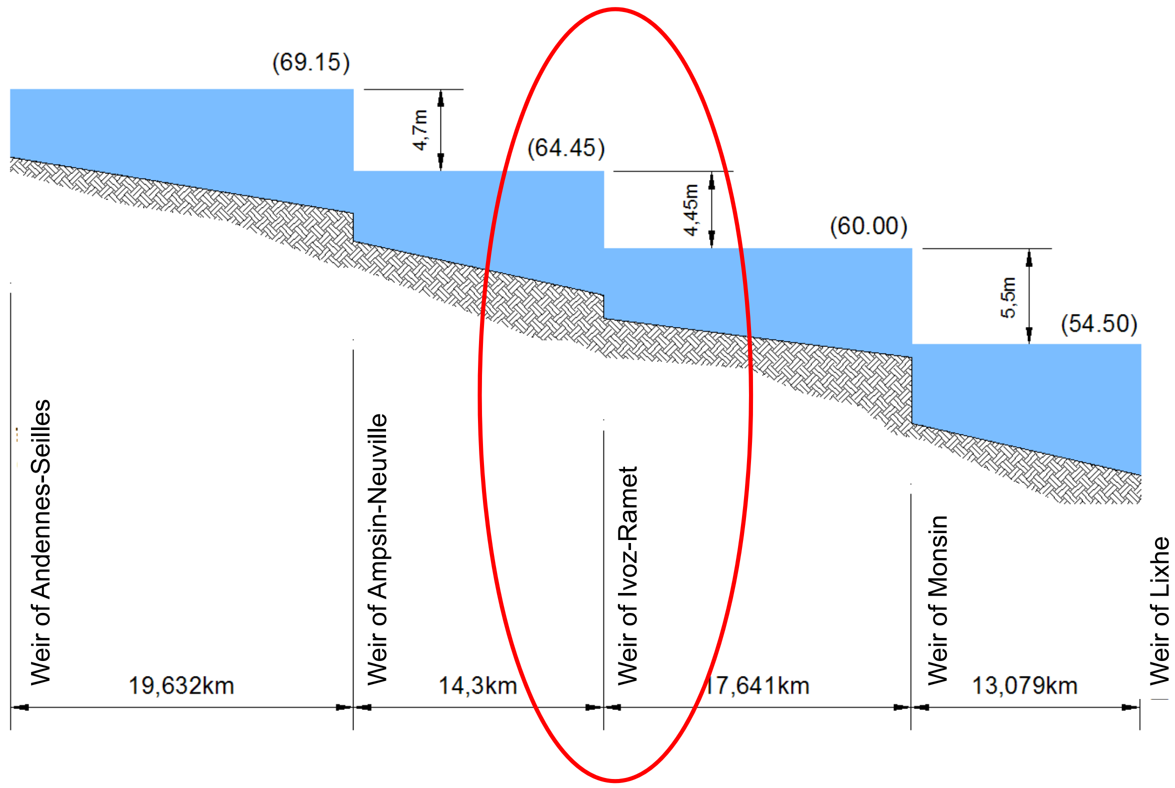
greisch

PIANC - BRUSSELS
2017.11.06

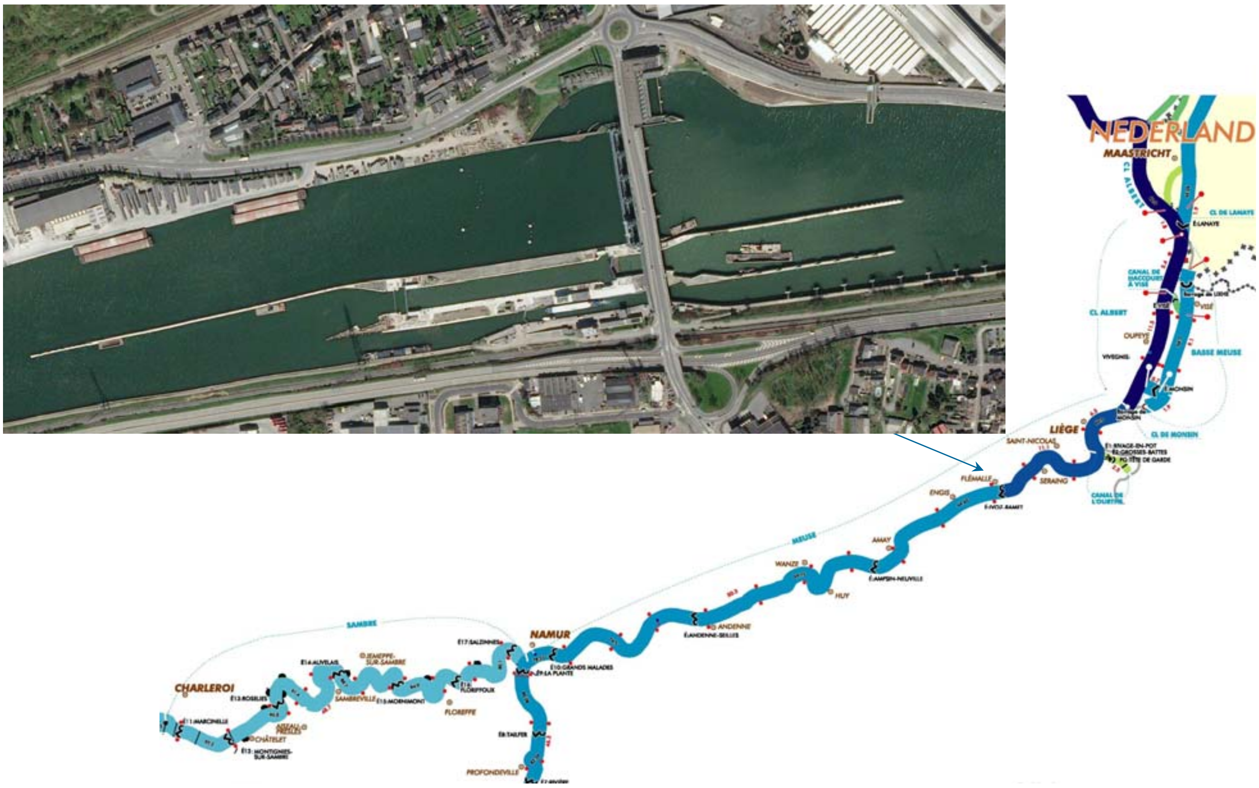
Ivoz Ramet (BE)
Two locks equipped with mitre gates
Two modes of transmission of the forces

6th November 2017 - Brussels

Meuse river



Situation

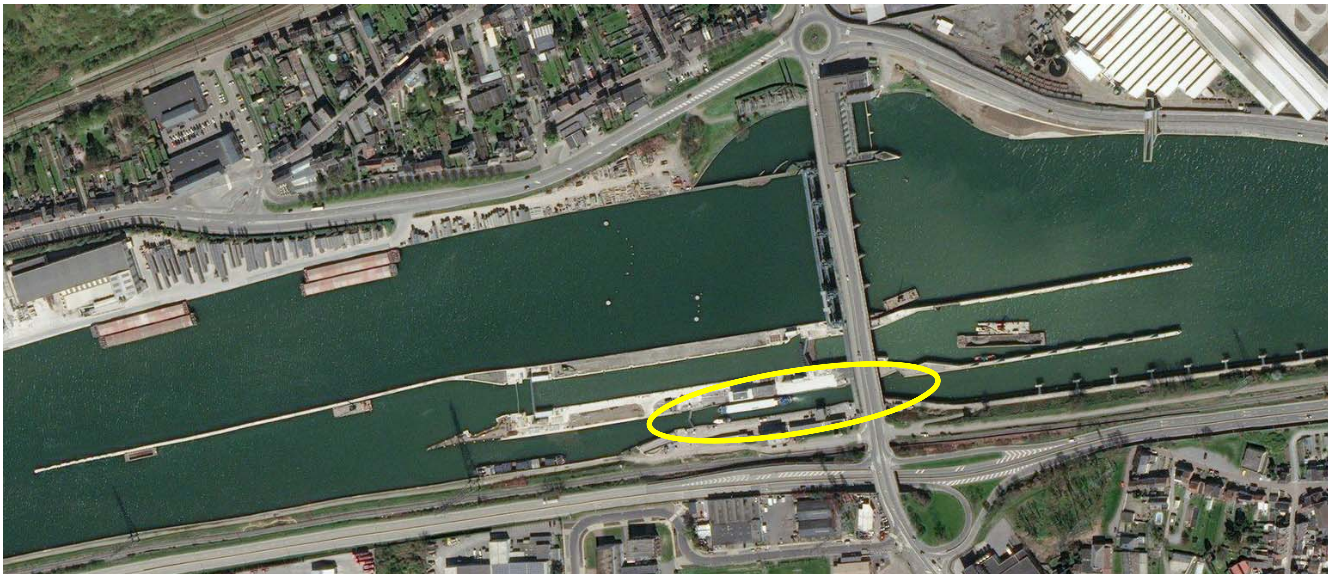


Ivoz-Ramet

- Two cases
- Hinges and thrust blocks

Medium lock 136 x 16 m

Free hinge - mixed solution



Lock 136x16m - Description

Filling and emptying system : 2 longitudinal culverts – 4 butterfly valves

Culvert - Valve

Side port

Ivoz-Ramet

Lock 136x16m - Restoration 1999 to 2001

Substitution

- Hollow quoins and sills
- Mitre gates (with buoyancy tanks)
- Valves

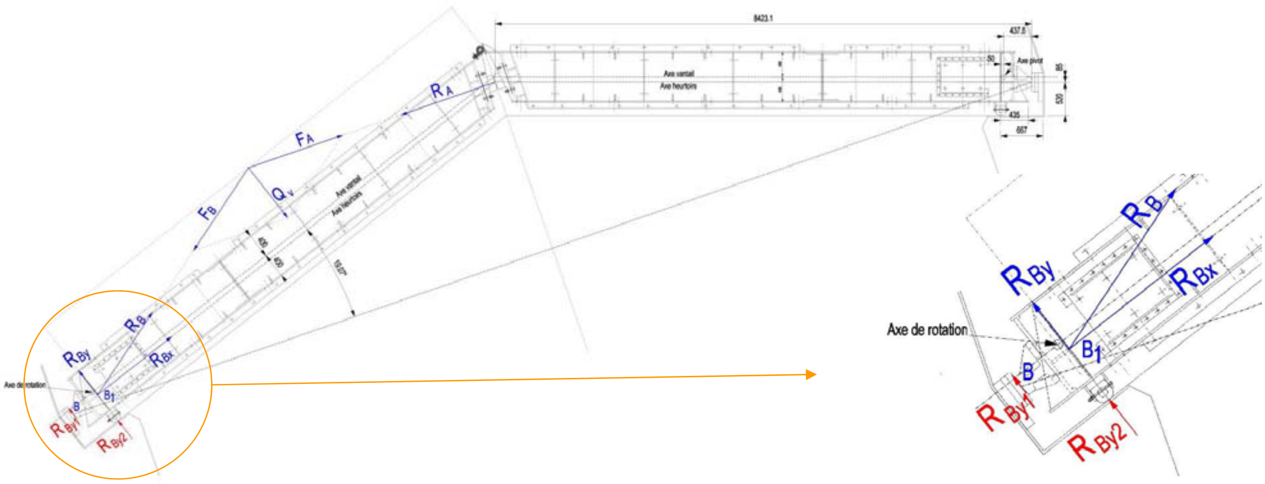
} in 3 weeks during july 1999

Ivoz-Ramet

Lock 136x16m

Mitre gate – Geometry – High: downstream 9.5 m - upstream 6.65 m – Width: 8.42 m

1. α = 19.07° and β = 0 ≡ **Mixed solution**
2. Hydrostatic force Q_v = 2340 kN/leaf
3. Reaction on thrust blocks R_{Bx} = 3400 kN
4. Reaction perpendicular to leaf axis: R_{By} = 1170 kN = friction. block R_{By1} + hollow quoin R_{By2}



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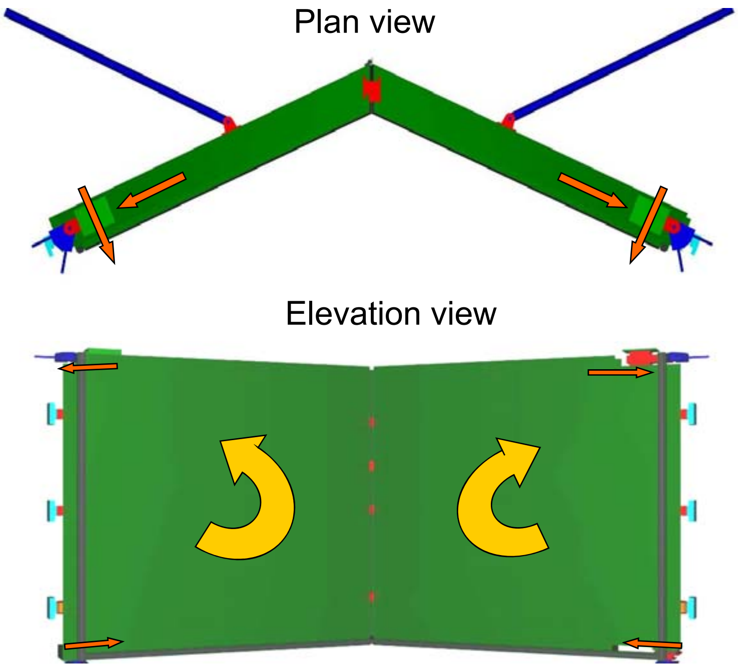
Lock 136x16m

Gate closing



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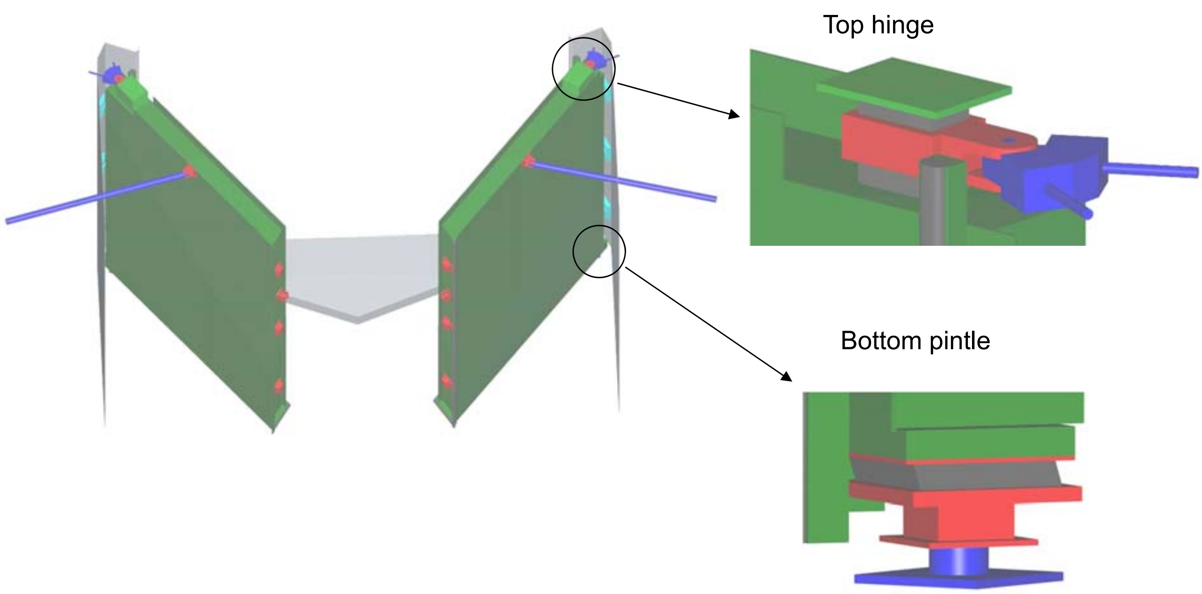
Lock 136x16m

Free hinge
Possible movement of the leaf during closing carried out by the neoprene



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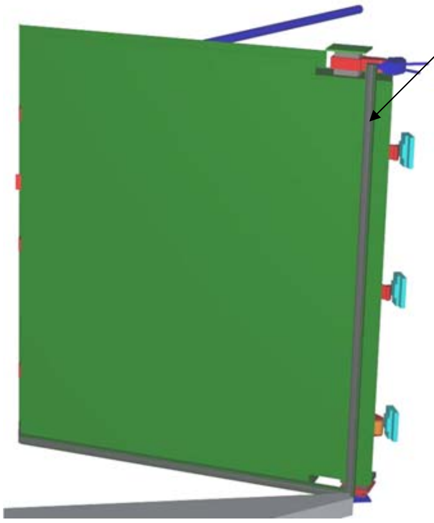
Lock 136x16m

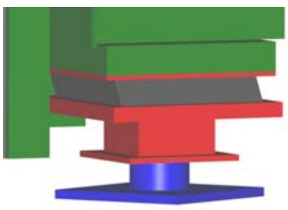
1. The seal of the gate is applied perfectly on the wall → very good sealing
2. Crushing of the seal – Buckling a part of stresses

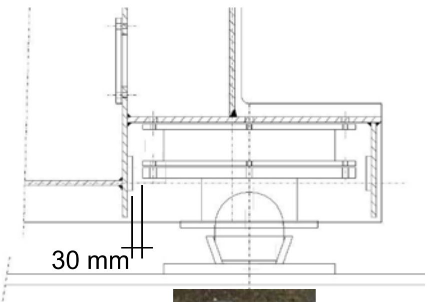


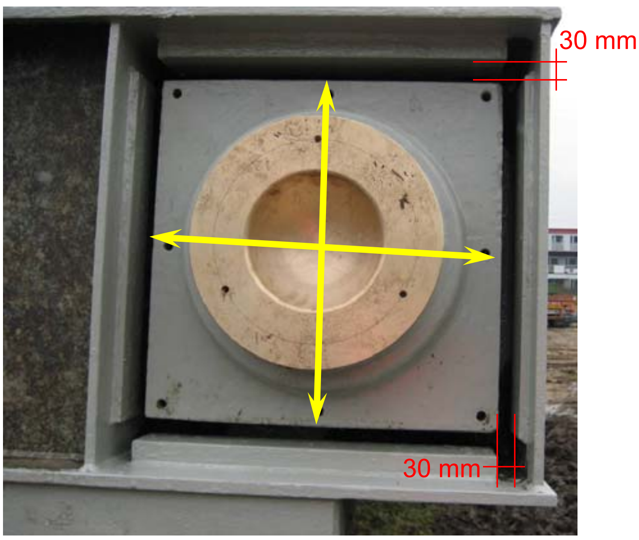
Ivoz-Ramet

Lock 136x16m

4. Elastomeric bridge bearing must be prestressed > 2N/mm² to avoid path → Ballast for the bottom part and bolts at the top hinge part
5. Limited clearance : 2 x 30 mm **in both directions** ≡ Free pintle system

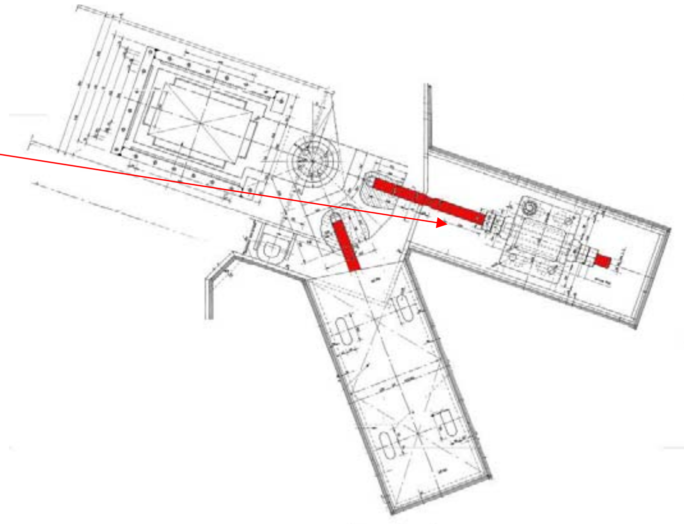






Ivoz-Ramet

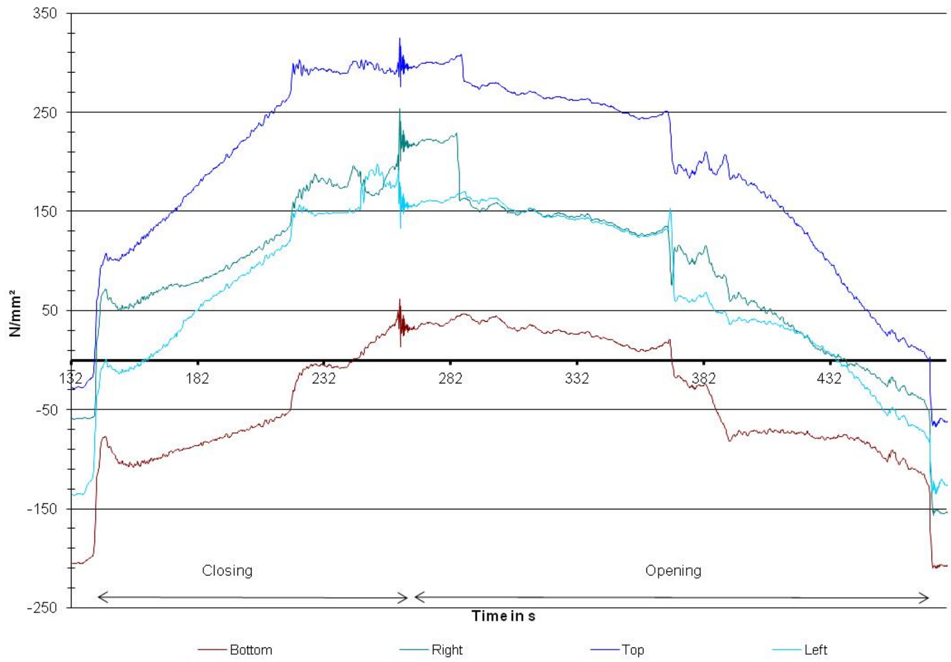
Breaking tie rods – Top hinge

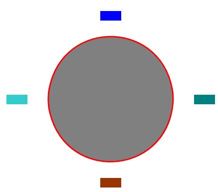


Ivoz-Ramet

Breaking anchor rod – Top hinge

Stress analysis using strain gauges
Upstream anchor rod

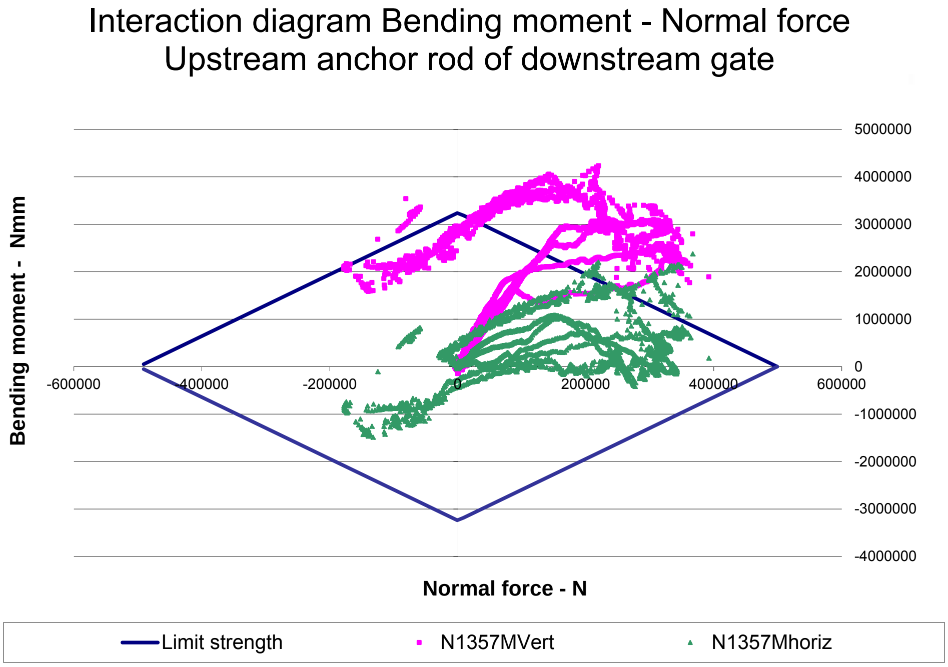




Ivoz-Ramet

Breaking anchor rod – Top hinge

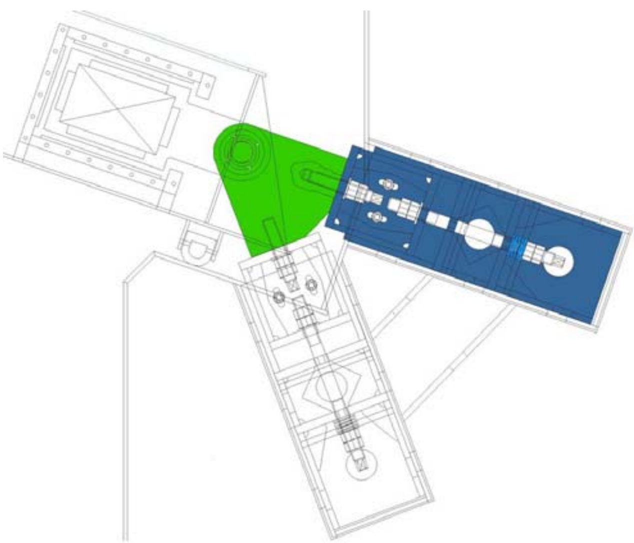
Stress analysis



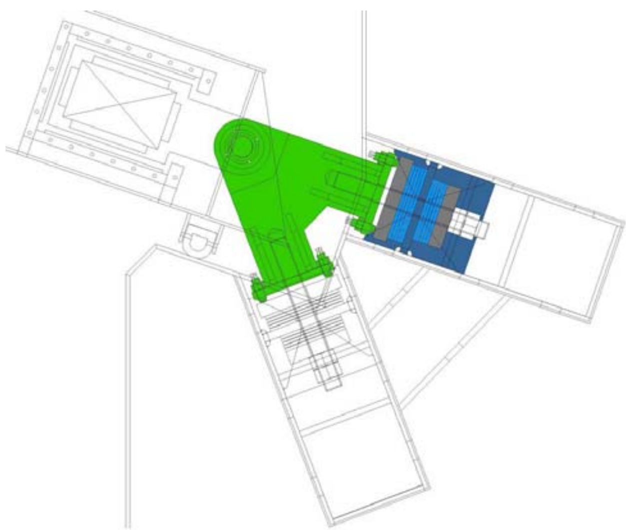
Ivoz-Ramet

Breaking anchor rod – Top hinge

Two designs projects



Stiffen

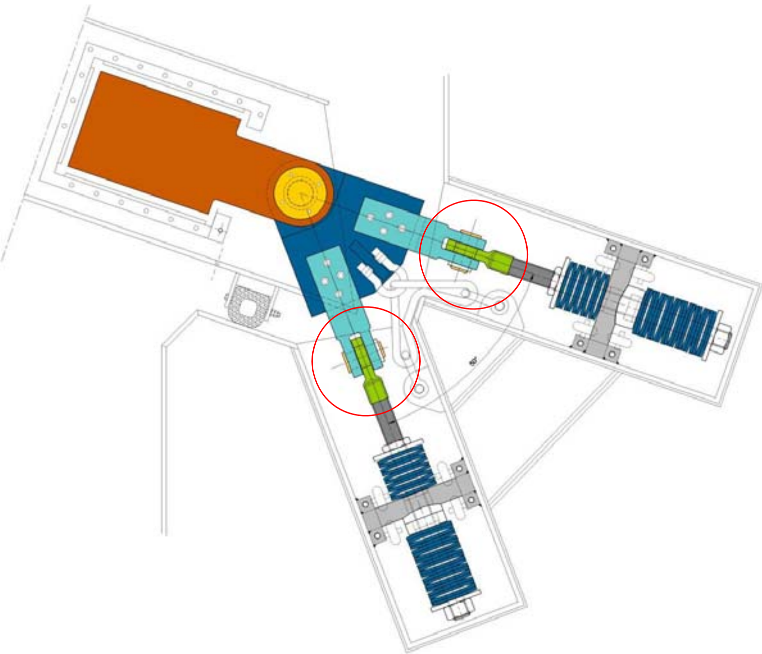


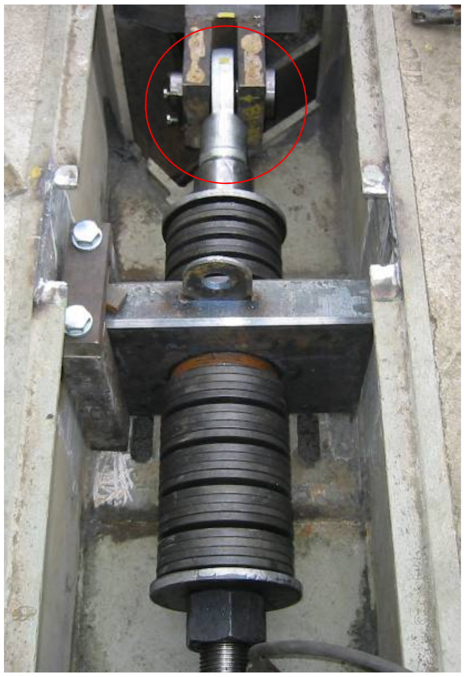
Releasing – Adding a bearing

Ivoz-Ramet

Breaking anchor rod – Top hinge

Executed : Bearing with spring washer (Belleville) adding spherical bearing





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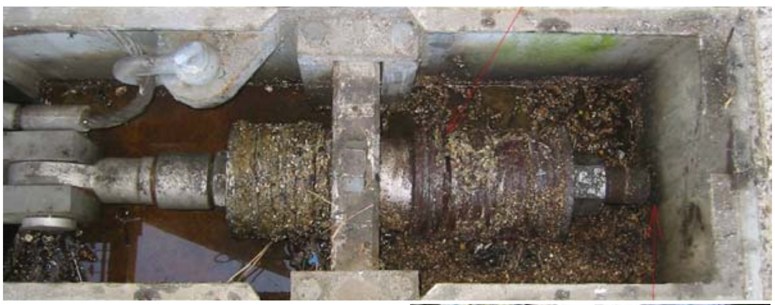
Anchor rod – Top hinge – Spring washer

Spring washer failure after 3 years ½

Diameter 200/102 mm



crack

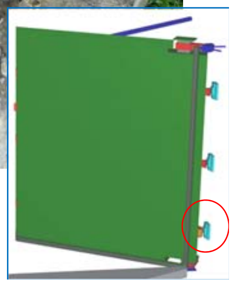
Corrosion increases the friction between washers and so the stiffness and therefore the forces

Ivoz-Ramet

Loch 136x16m

Lower fixed thrust block

Rolling thrust block



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Lock 136x16m

Seal on the hollow quoin

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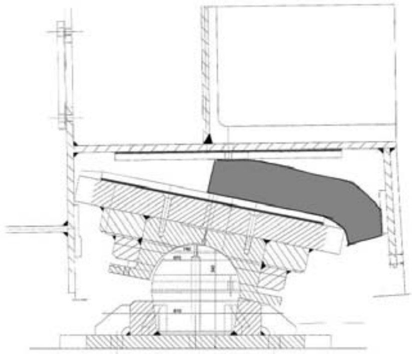
Lock 136x16m

Peeling off bottom hinge after 3 months due to a bad new gluing

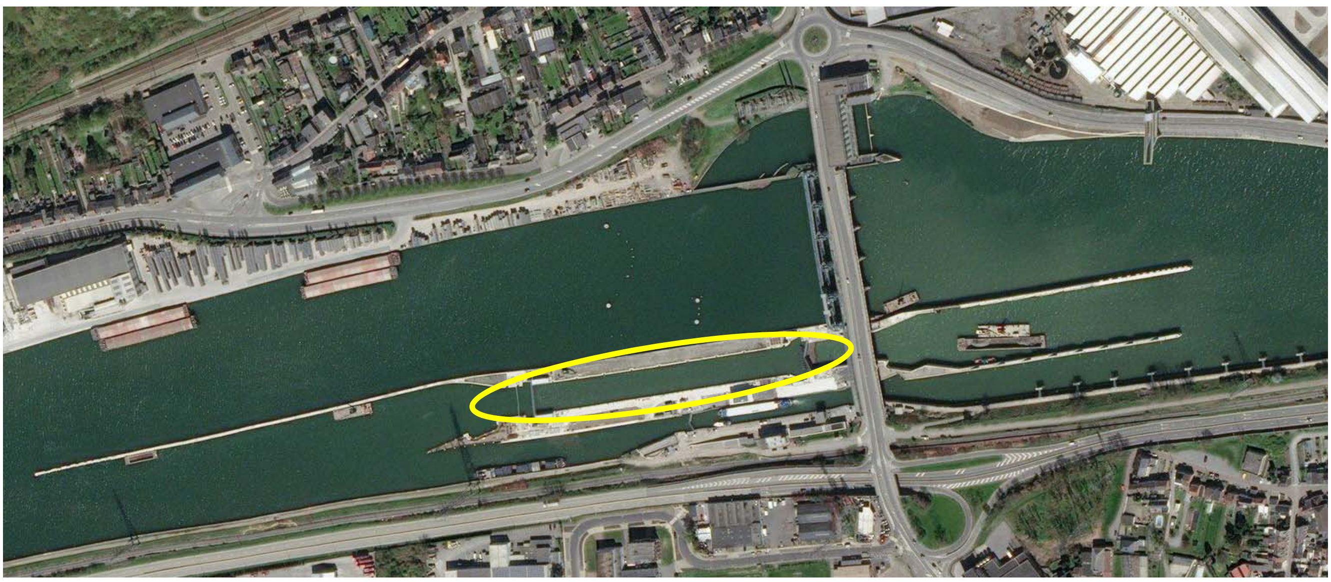
gluing



Ivoz-Ramet

Large lock 225 x 25 m

Free hinge - pure solution



Lock 225x25m

Downstream gate

Ivoz-Ramet

Lock 225x25m

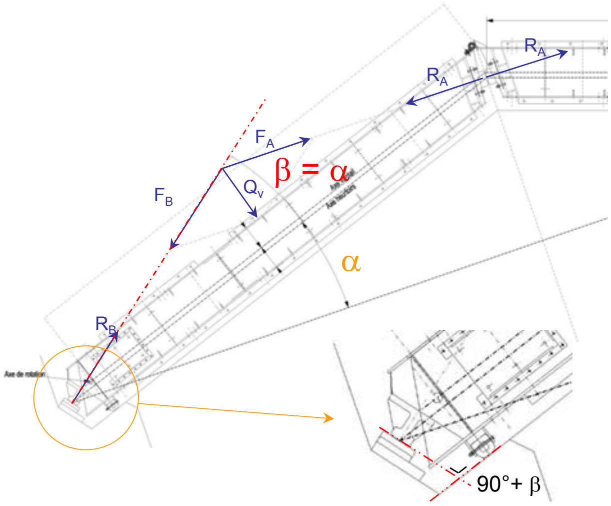
Plate girders with skin downstream - 14.07 x 10.91

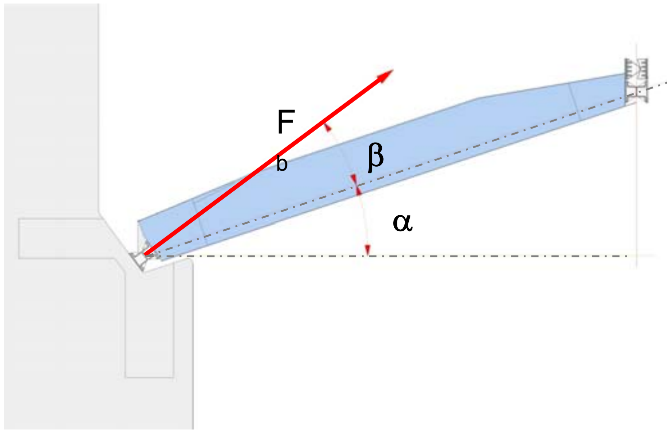
Ivoz-Ramet

Lock 225x25m

Mitre gate – Mode of transmission of forces

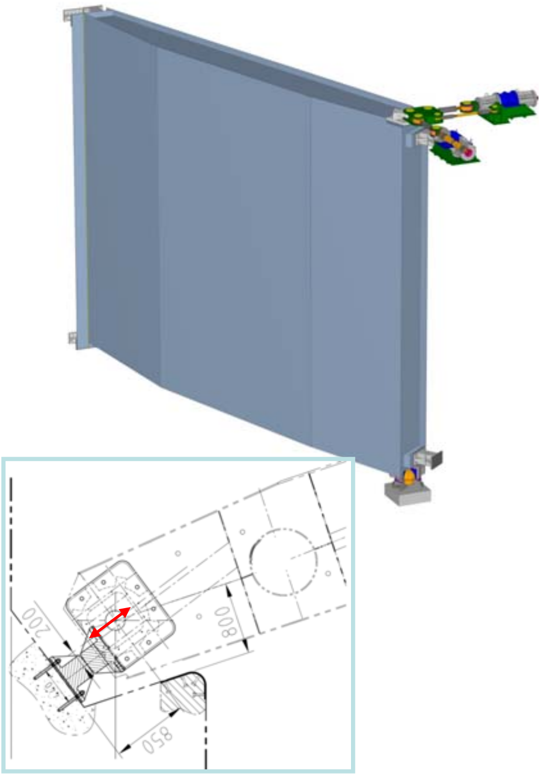
$\beta = \alpha = 18°.43 \rightarrow$ No force on the hollow quoin ≡ Pure solution

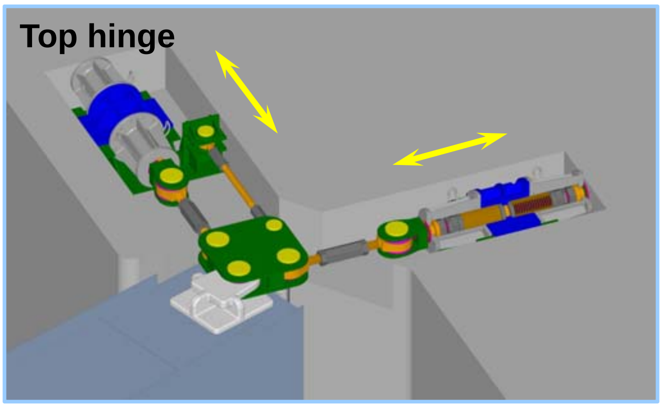


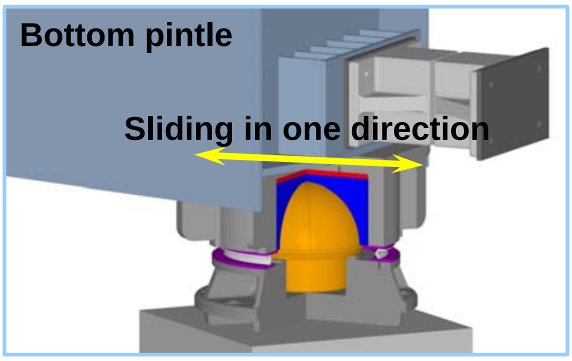


Ivoz-Ramet

Lock 225x25m

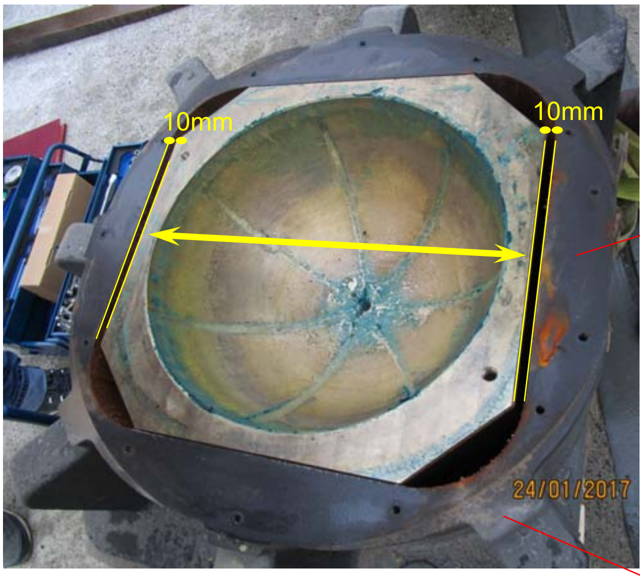






Ivoz-Ramet

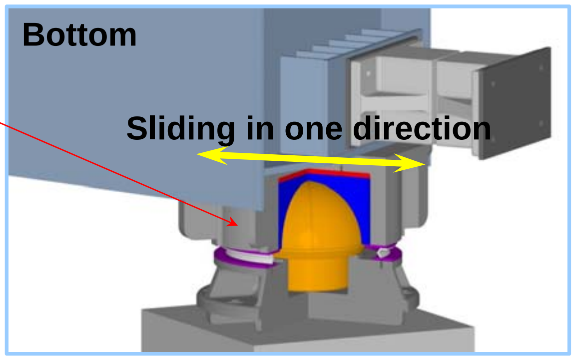
Lock 225x25m



Bushing in bushing socket

Limited clearance 2 x10mm

≡ Free pintle system **in one direction**



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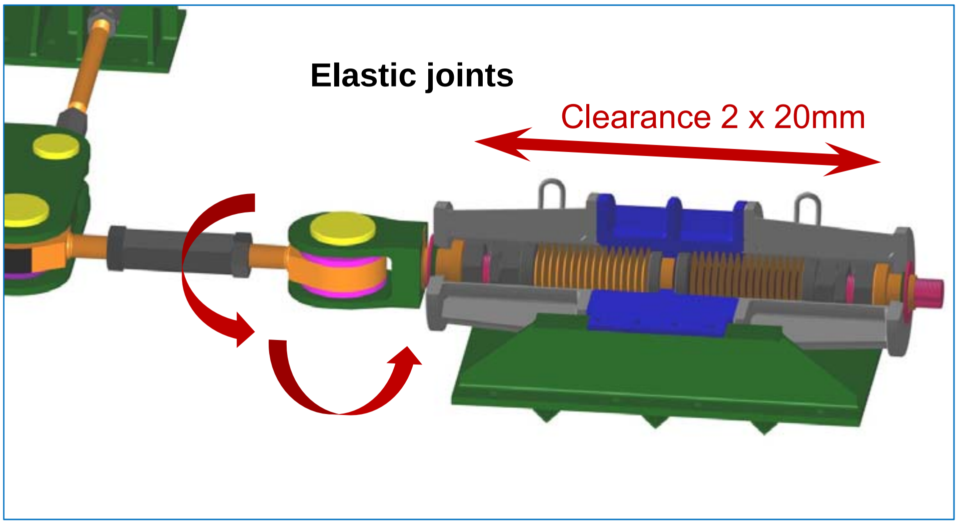
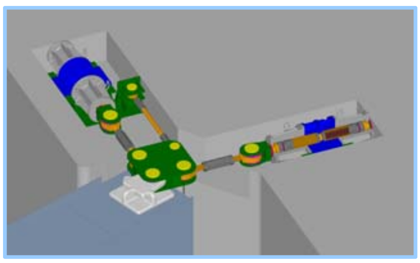
Lock 225x25m

Top





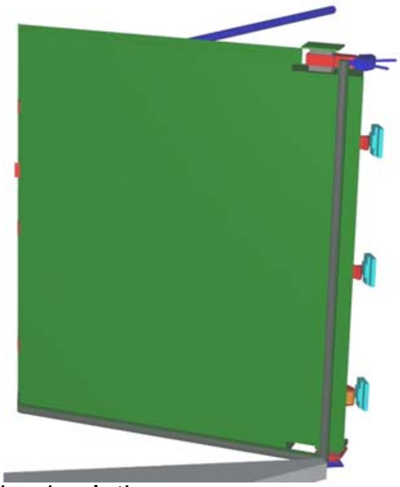
Spring washer protection by grease and box

Ivoz-Ramet

Lock 225x25m

Ivoz-Ramet

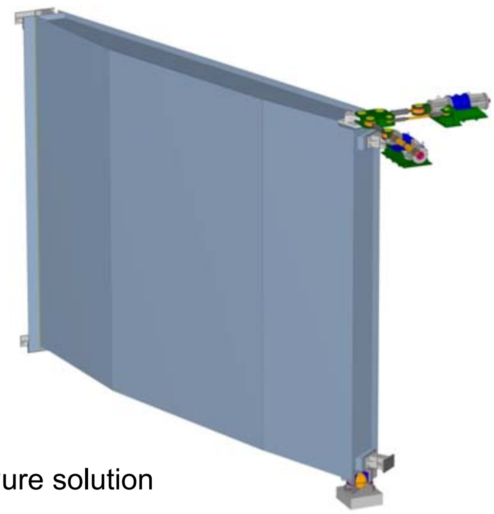
Comparison



Mixed solution

Advantages

- No hydraulic load on gate hinges
- Very good sealing
- Easy and fast gate installation



Pure solution

Advantages

- No hydraulic load on gate hinges
- Load transfer only over thrust block
- Well-controlled behavior

Ivoz-Ramet

Lock 225x25m

Ivoz-Ramet

Waterwegen en Zeekanaal NV
weg van water

De Vlaamse Waterweg nv

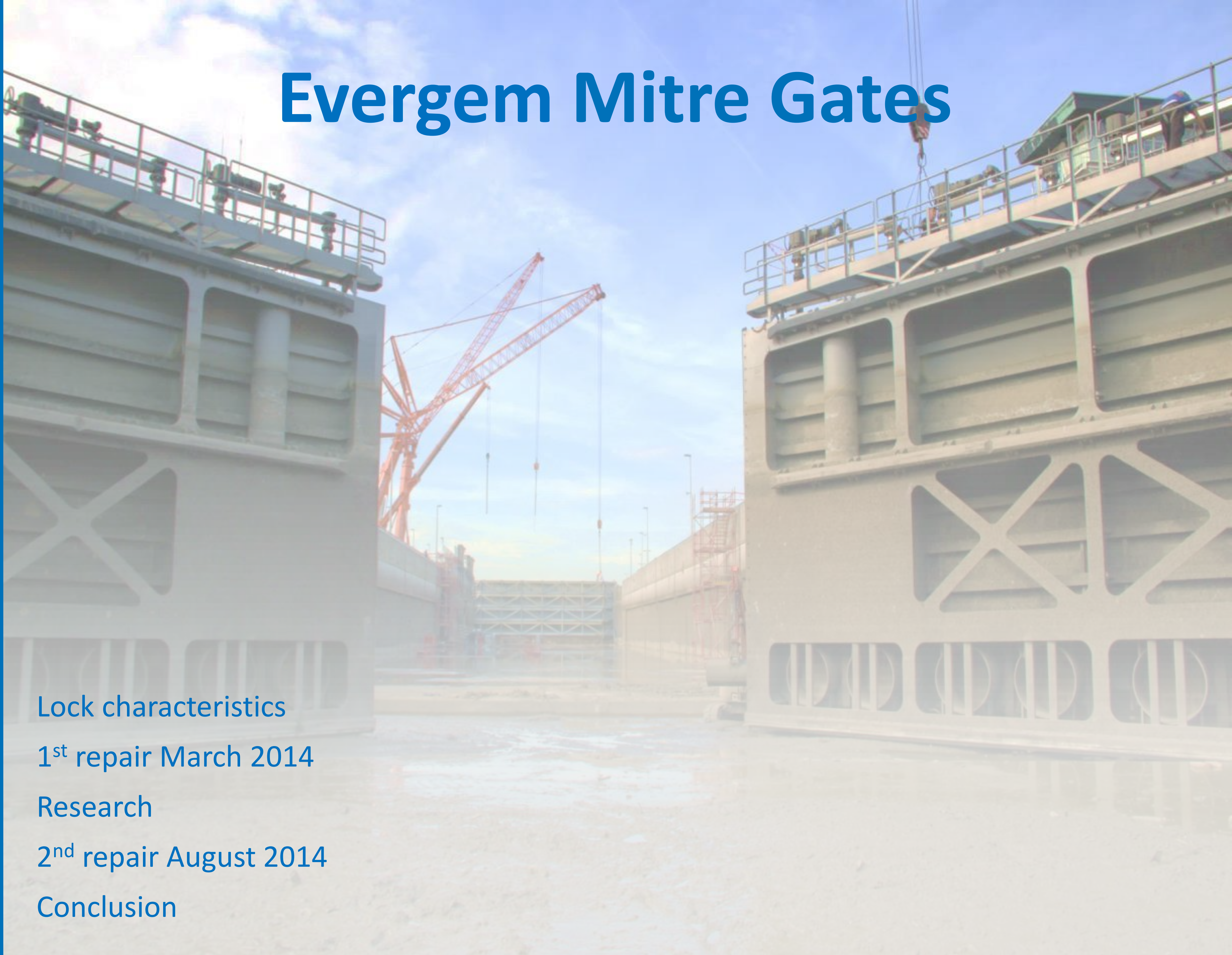
Waterwegen en Zeekanaal NV
wordt op 1/1/2018
De Vlaamse Waterweg nv

ir. Jeroen Verbelen
project engineer

Evergem Lock
Mitre Gates

Experience &
lessons learnt
from failures

Workshop Mitre Gate Design and Operation, PIANC WG154
Brussels, 6-Nov-2017



Evergem Mitre Gates

Lock characteristics

1st repair March 2014

Research

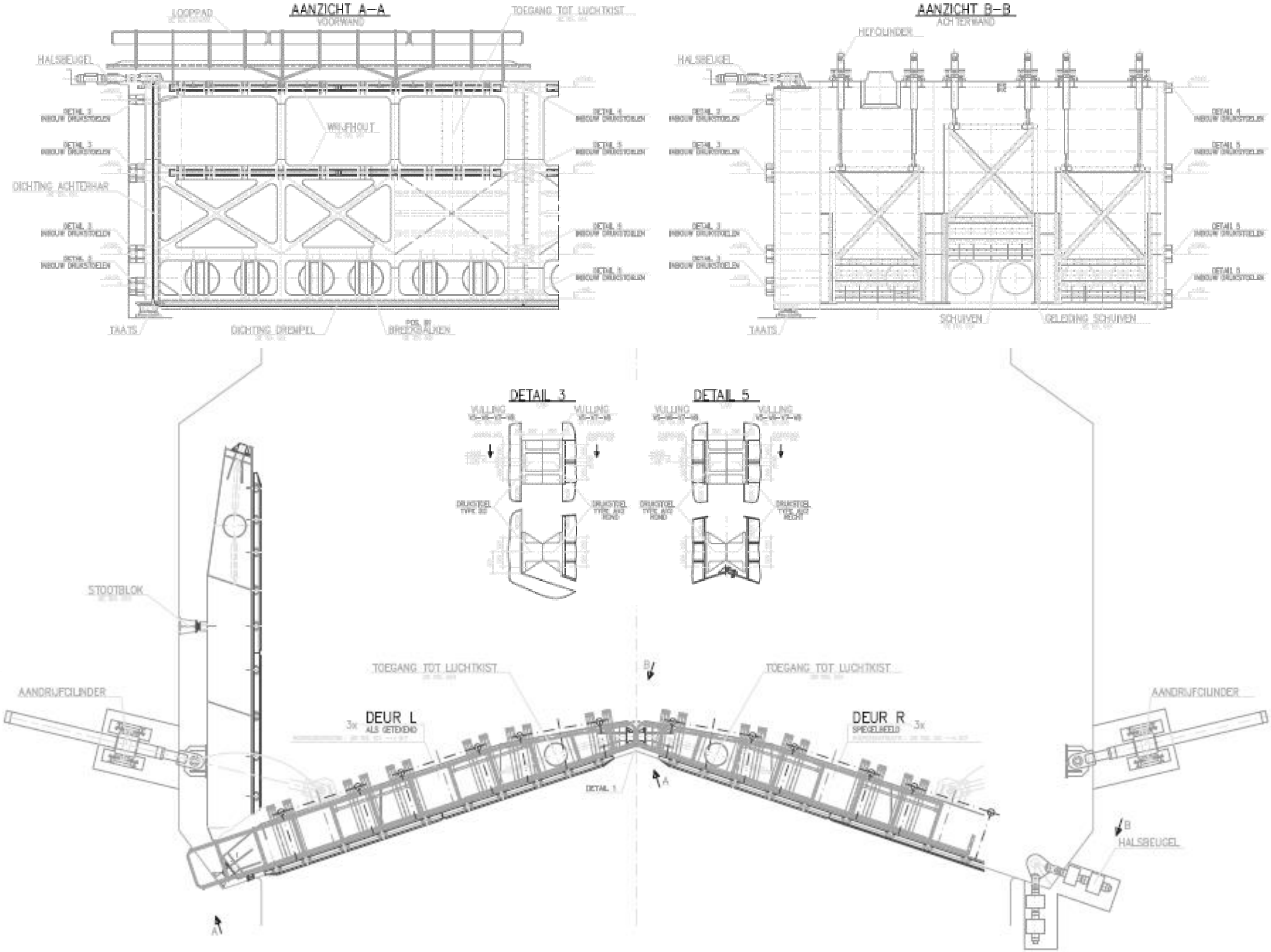
2nd repair August 2014

Conclusion

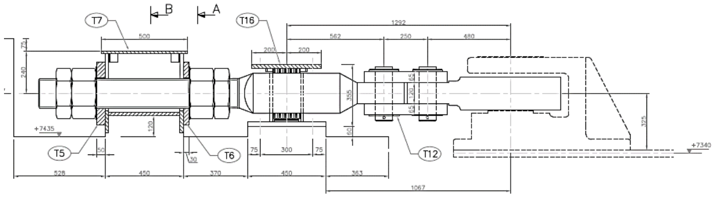
Lock characteristics

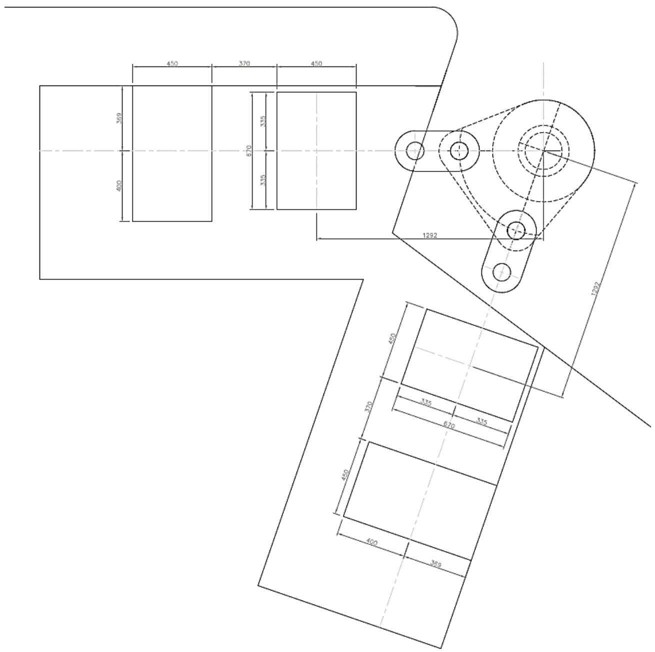
2nd lock of Evergem
CEMT VIb
In service since 2009
17 mio tonnes / a
80,000 TEU / a

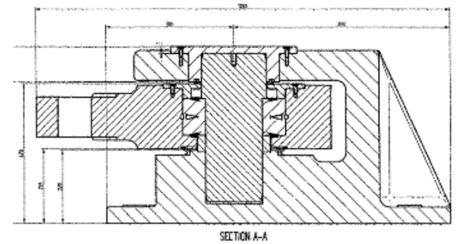
Waterwegen en Zeekanaal NV
weg van water

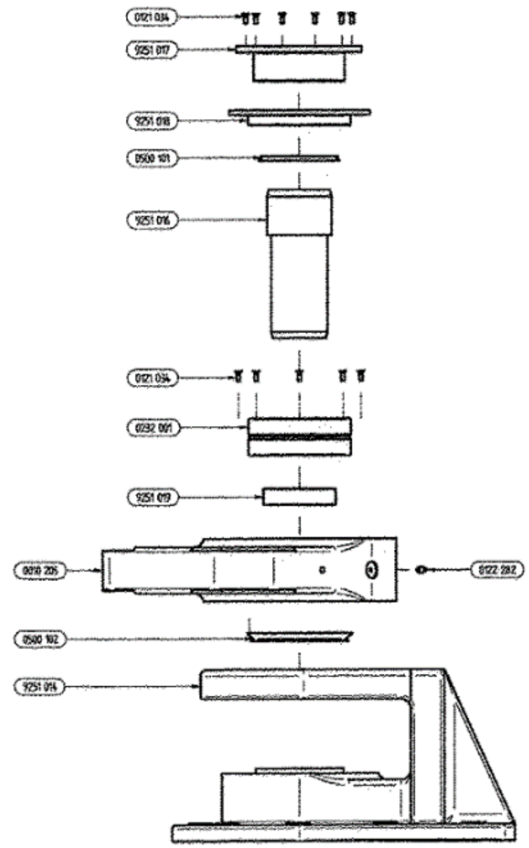


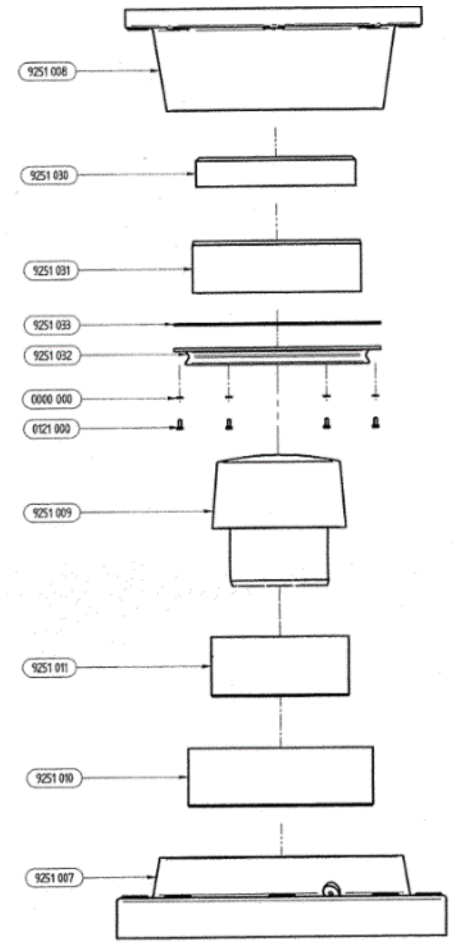
AANZICHT A–A
VOORWAND
LOOPPAD
TOEGANG TOT LUCHTKIST
HALSBEUGEL
WRIJFHOUT
DICHTING ACHTERHAR
TAATS
DICHTING DREMPEL
BREEKBALKEN
AANZICHT B–B
ACHTERWAND
HEFCILINDER
HALSBEUGEL
TAATS
SCHUIVEN
GELEIDING SCHUIVEN
DETAIL 3
DETAIL 5
VULLING
STOOTBLOK
TOEGANG TOT LUCHTKIST
TOEGANG TOT LUCHTKIST
AANDRIJFCILINDER
AANDRIJFCILINDER
3x
DEUR L
ALS GETEKEND
DEUR R
SPIEGELBEELD
3x
DETAIL 1
HALSBEUGEL

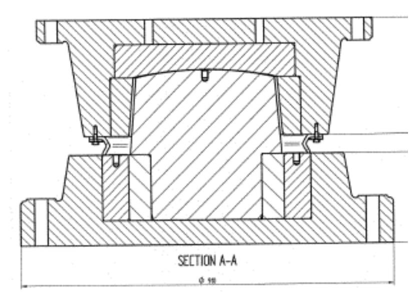












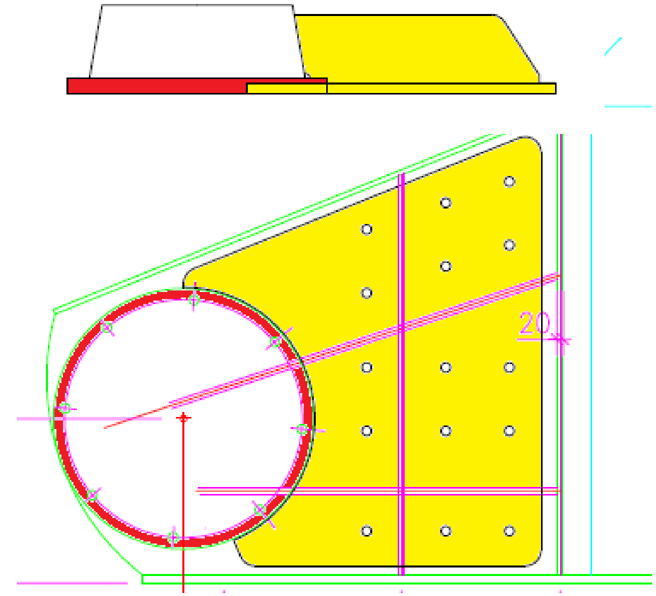
Waterwegen en Zeekanaal NV

weg van water

1st repair March 2014

closing problems on 4 gates
connection pintle socket - gate
>50% bolts failed
emergency repair

Waterwegen en Zeekanaal NV
weg van water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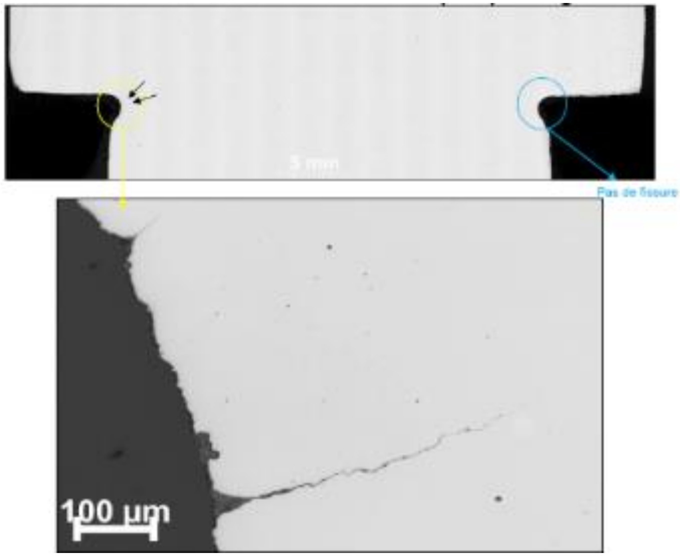
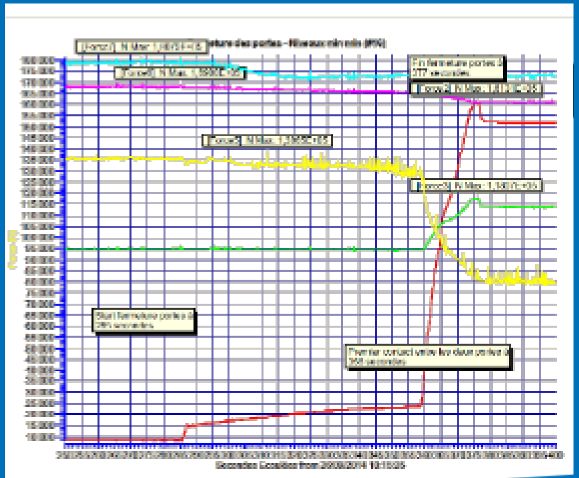
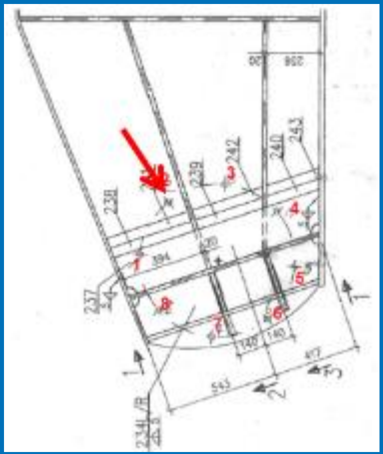


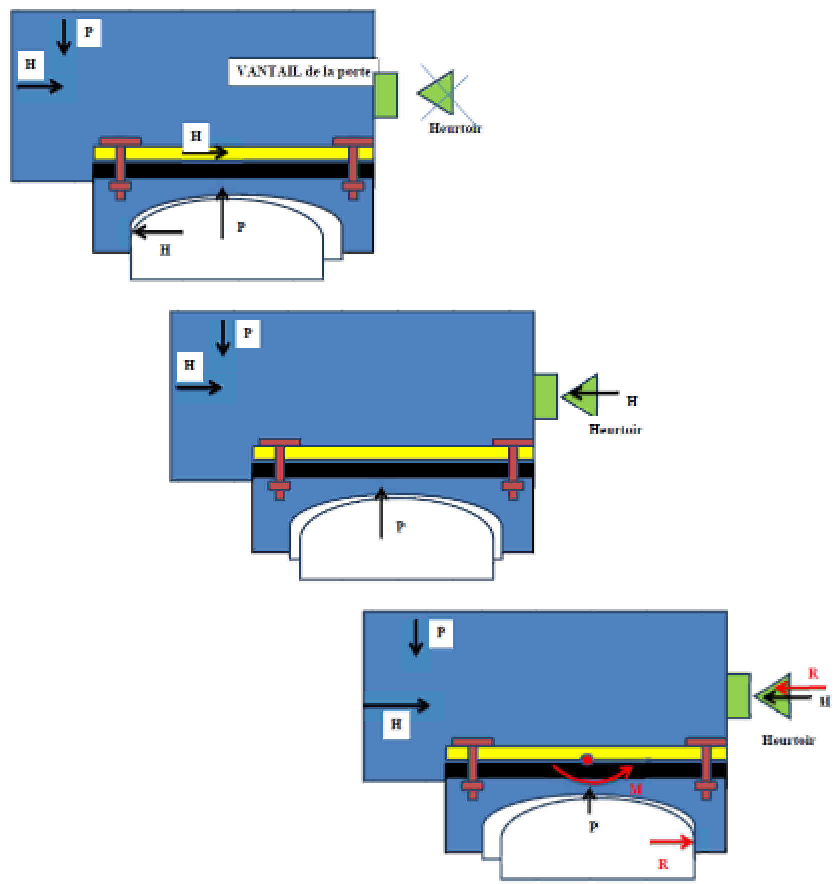


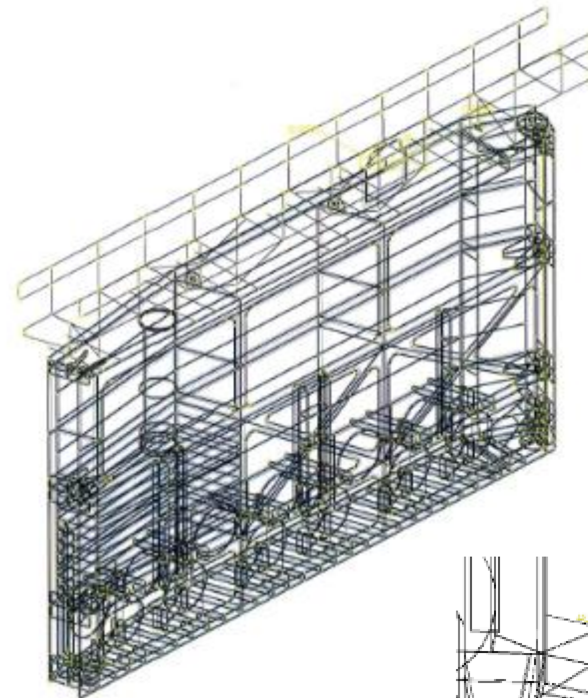


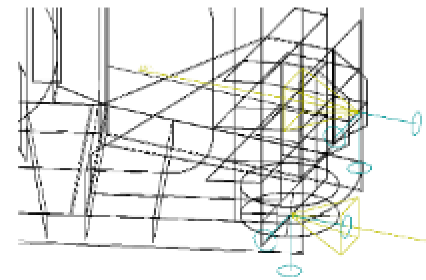
Research

type of bolts
metallographic composition
hardness
fatigue
stress in bolt measured

Waterwegen en Zeekanaal NV
weg van water

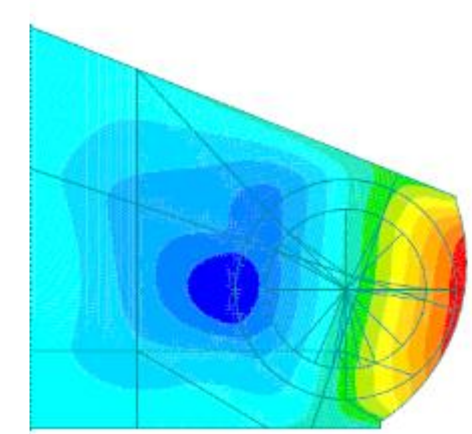






Research

turning movement
correct retaining position
misaligned position
FEM model
misalignment leads to failure

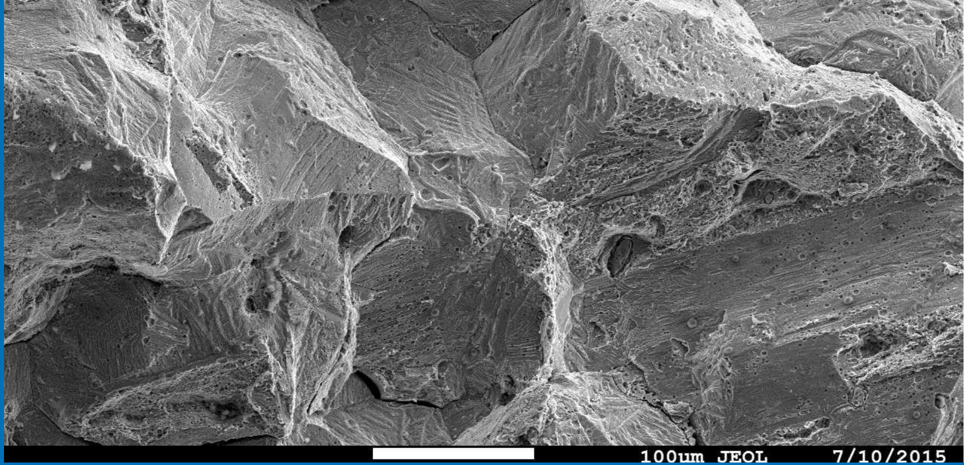


Waterwegen en Zeekanaal NV
weg van water

2nd repair August 2014

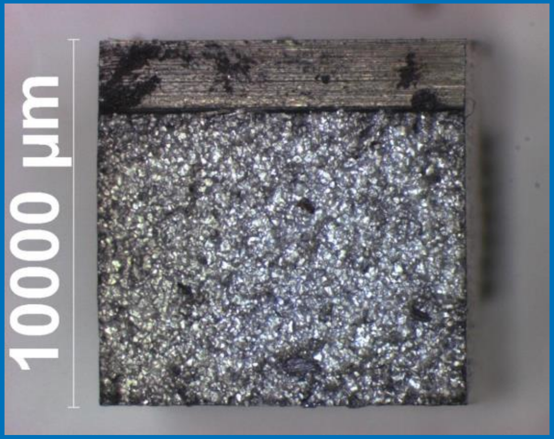
closing problems on 4 gates
diving inspection
one gate leaf immobilised
metal fragments found
inspection in-the-dry

Waterwegen en Zeekanaal NV
weg van water



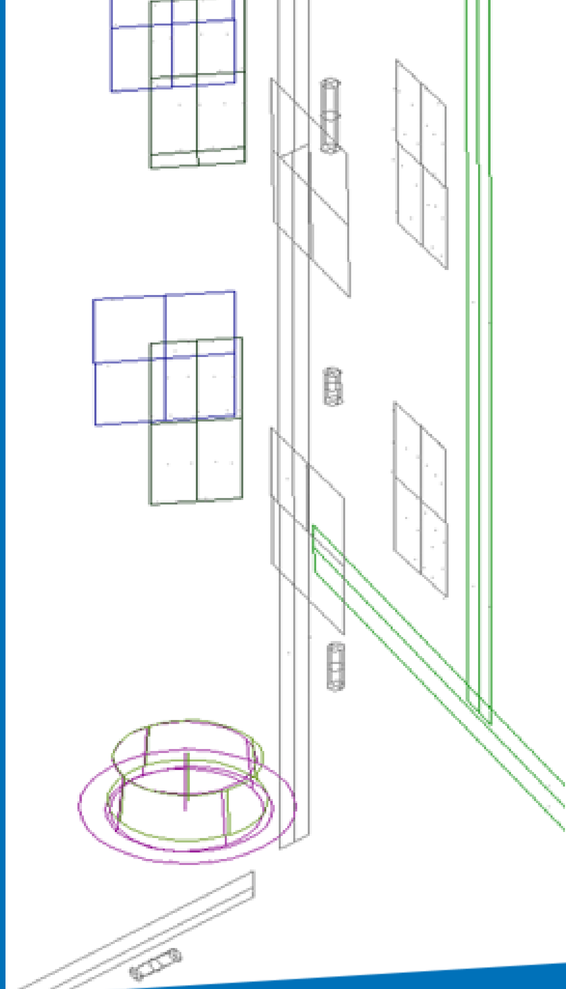
Research

tensile strength
hardness
notch toughness
metallography
brittle fracture
intra granular fracture



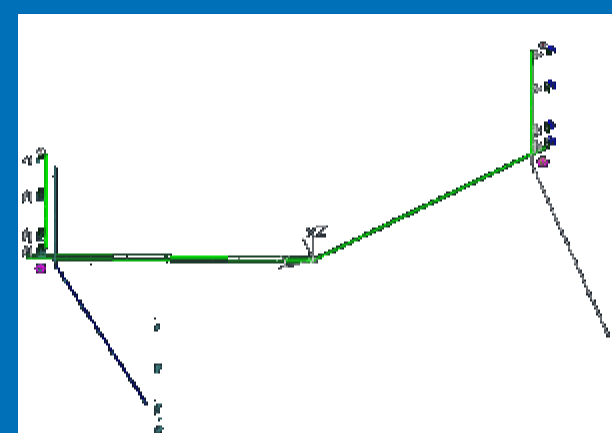
Waterwegen en Zeekanaal NV
weg van water



Research

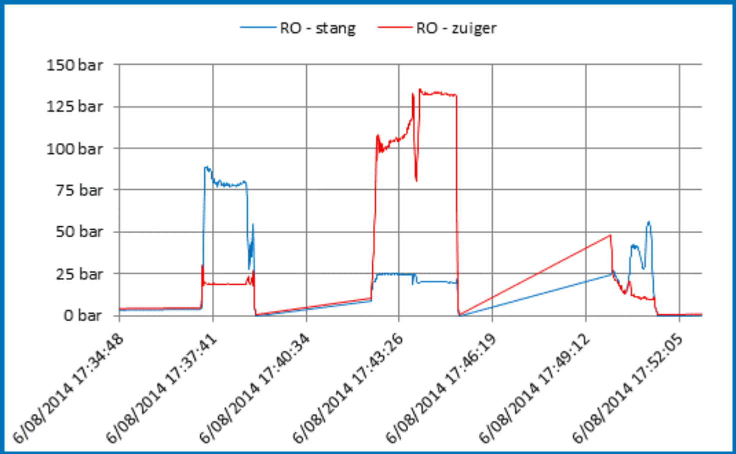
detailed 3D survey
virtually simulated alignment
hindered movement
contact surface re-milled
spacer / filling plates



Waterwegen en Zeekanaal NV
weg van water

Research

pressure registration
head side
rod side
safety valve



Waterwegen en Zeekanaal NV
weg van water

Conclusion

Alignment gate leafs
Material properties
Operating mechanism

Waterwegen en Zeekanaal NV
weg van water

contacts

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Van Immerseelstraat 66
B-2018 Antwerpen

www.imdc.be

Waterwegen en Zeekanaal NV
weg van water

IMDC

PIANC Workshop
Mitre Gate Design and Operation

Cracking of USA Mitre Gates

Prepared by:

Eric Johnson, P.E., S.E.

US Army Corps of Engineers ®
Louisville District

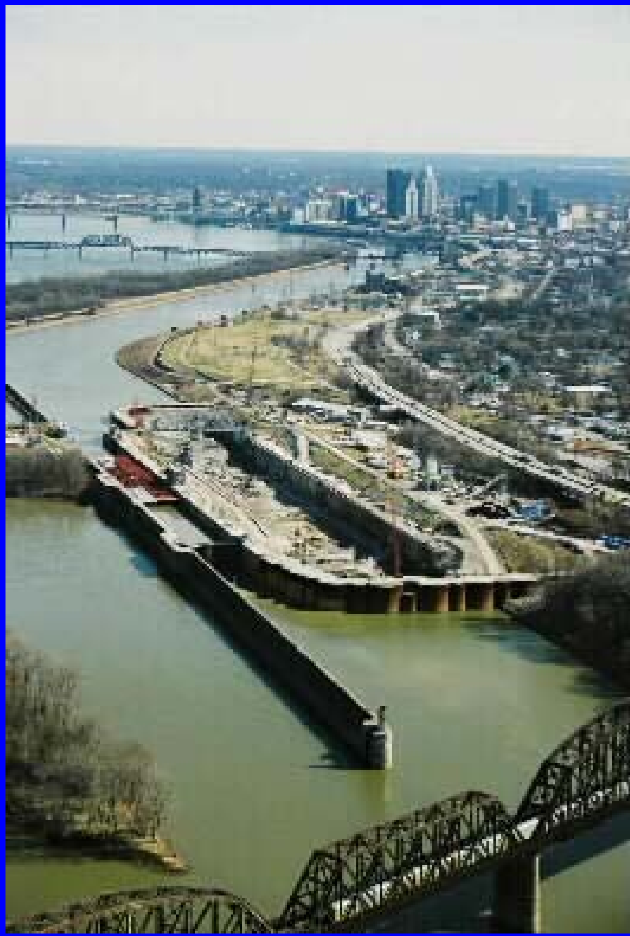
McAlpine Lock Closure and Emergency Repairs 9-19 August 2004

Peter W. Frick, PE

Lock & Dam Emergency Repairs Workshop
Vicksburg, MS
19 April 2006

US Army Corps of Engineers ®
Louisville District

Project Overview



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Historical Background

- McAlpine lock chamber construction required demolition of the antiquated auxiliary chamber.
- This leaves it as only Ohio River lock project with no auxiliary chamber.
- McAlpine main chamber closure = Ohio River closure at Louisville.

The Problems

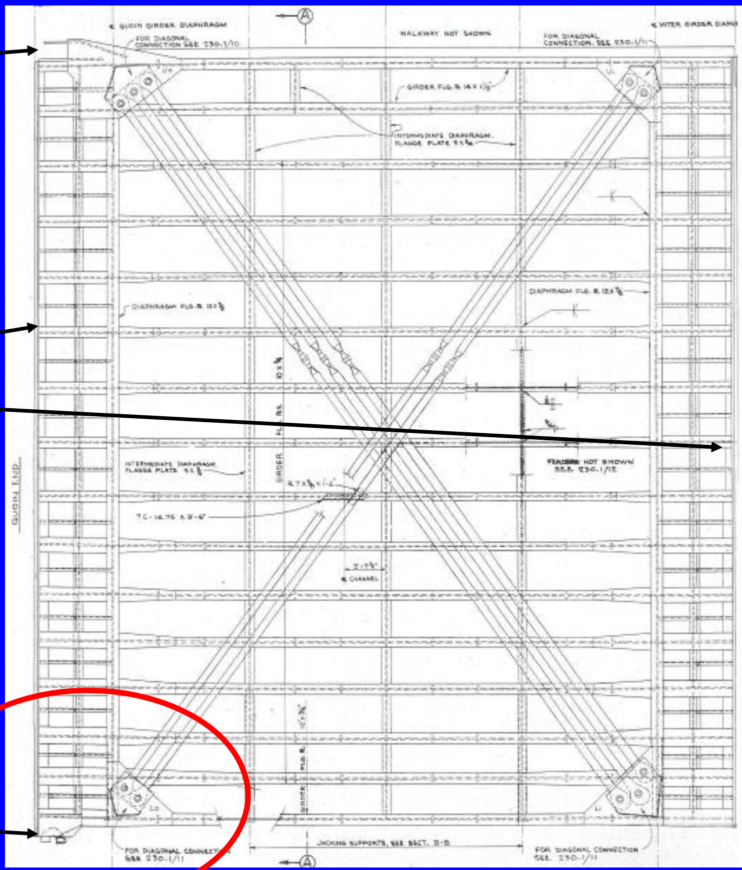
Gudgeon Pin & Anchorage

Quion Blocks

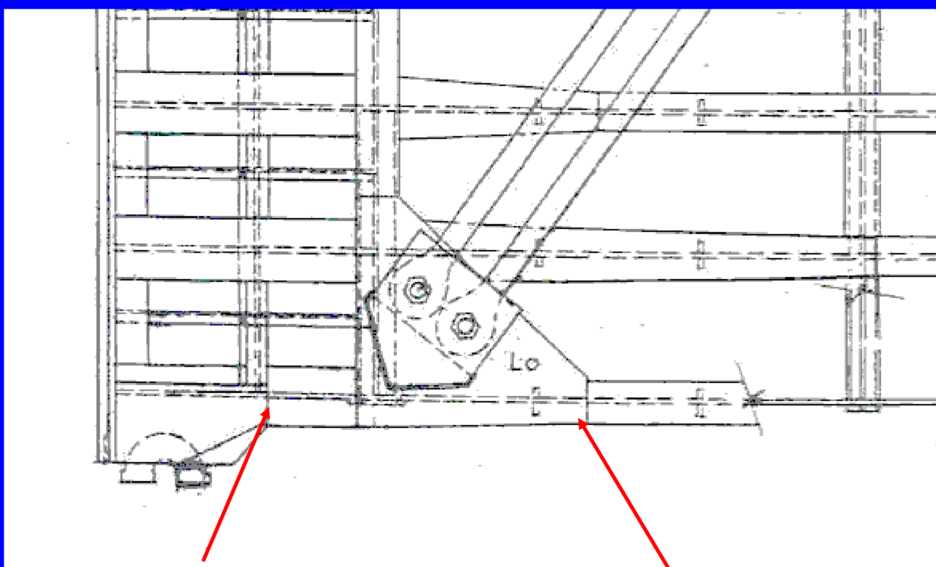
Miter Blocks

Problem Area

Pintle



The Problems



Cracked welds at pintle socket connection to gate.

Cracked welds across girder flange and web.

Cracks

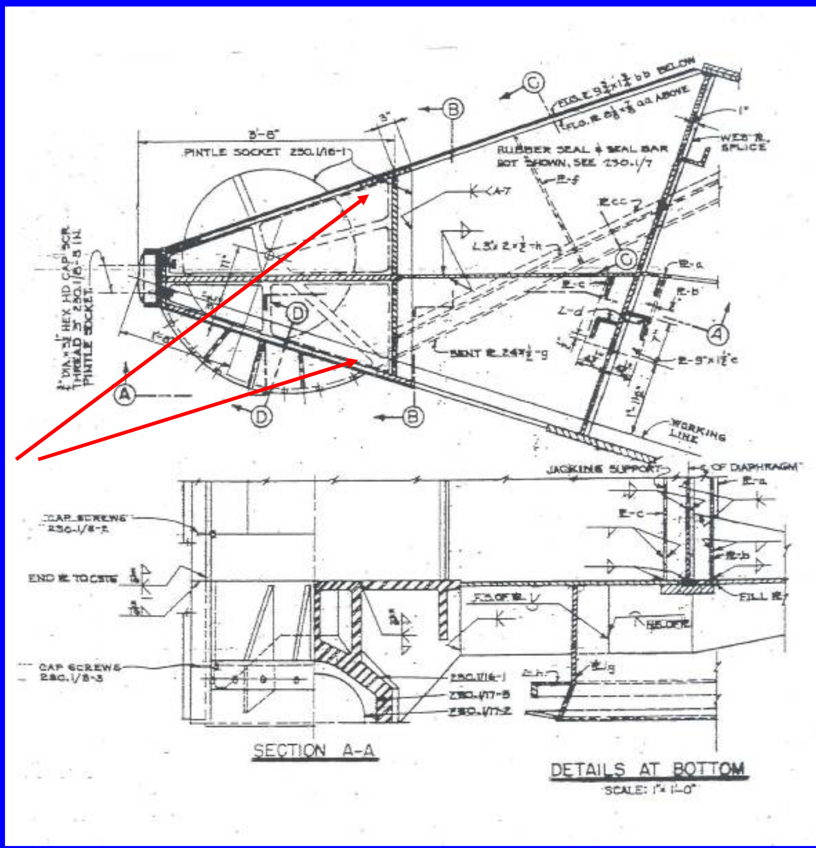


Plate Reinforcing Repair Overview

- Reinforce U.S & D.S Lower Quoin/Pintle Area and D.S. Lower Miter End with 19 mm (¾”) Pre-Fab Plate
- Design plates to be installed easily in the field
- Cracks under plate will not be repaired unless deemed necessary by the Engineer.
- Irregular surfaces under plate areas to be ground smooth for plate to fit flush
- Clean and Blast areas of gate where plates will be welded

Plate Reinforcing Repair Overview (Cont.)

- Tack Weld plates to gate after positioning
- Following Weld Sequence shown on the plate drawings
- Check gap between Plate and Gate. Increase weld size if gap is > 1.6 mm (1/16")
- Inspect Welds MT, VT
- Paint w/ Epoxy Primer
- Silicone Caulk around inside perimeter of joining surfaces

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Work in Progress

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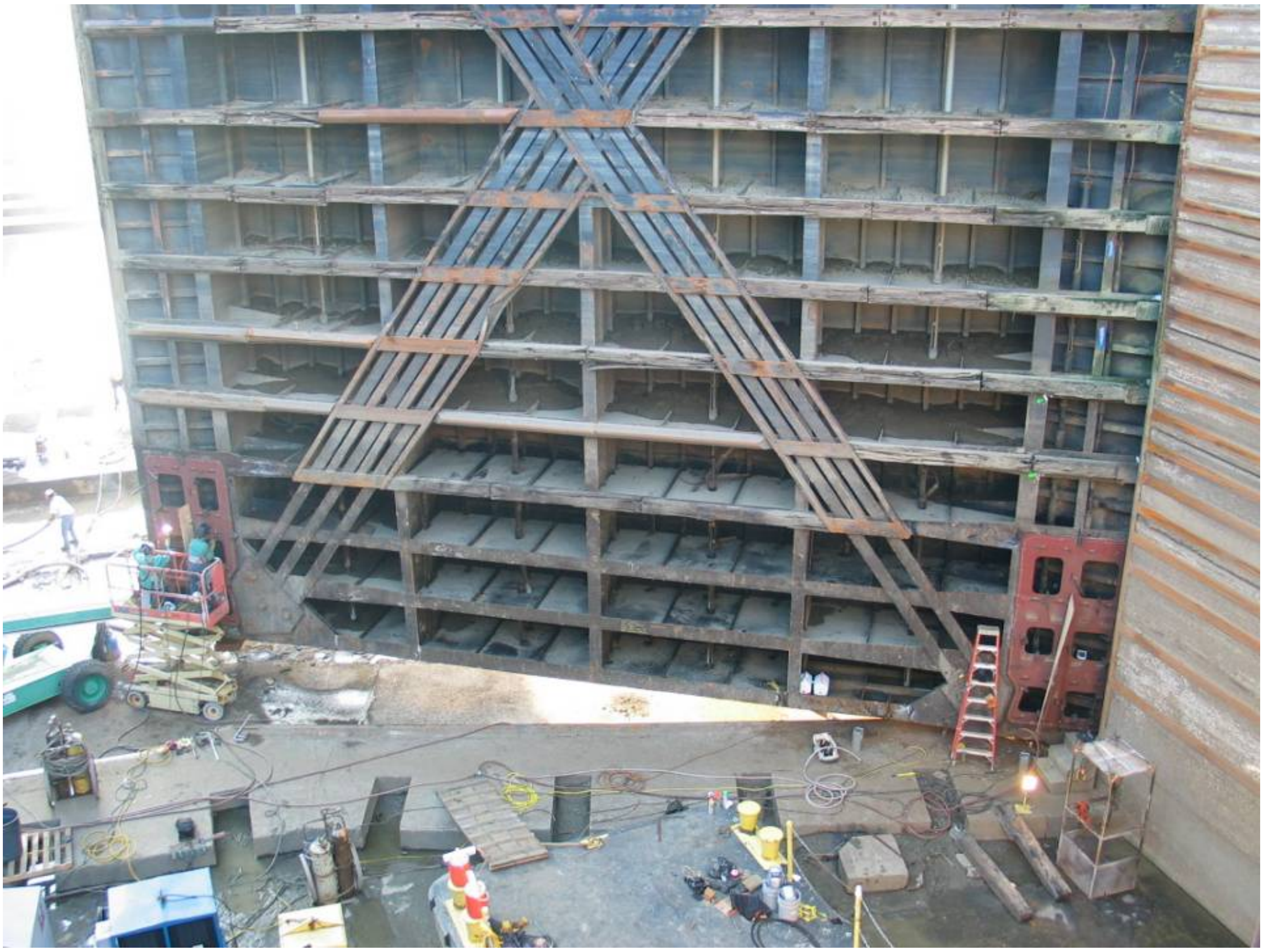
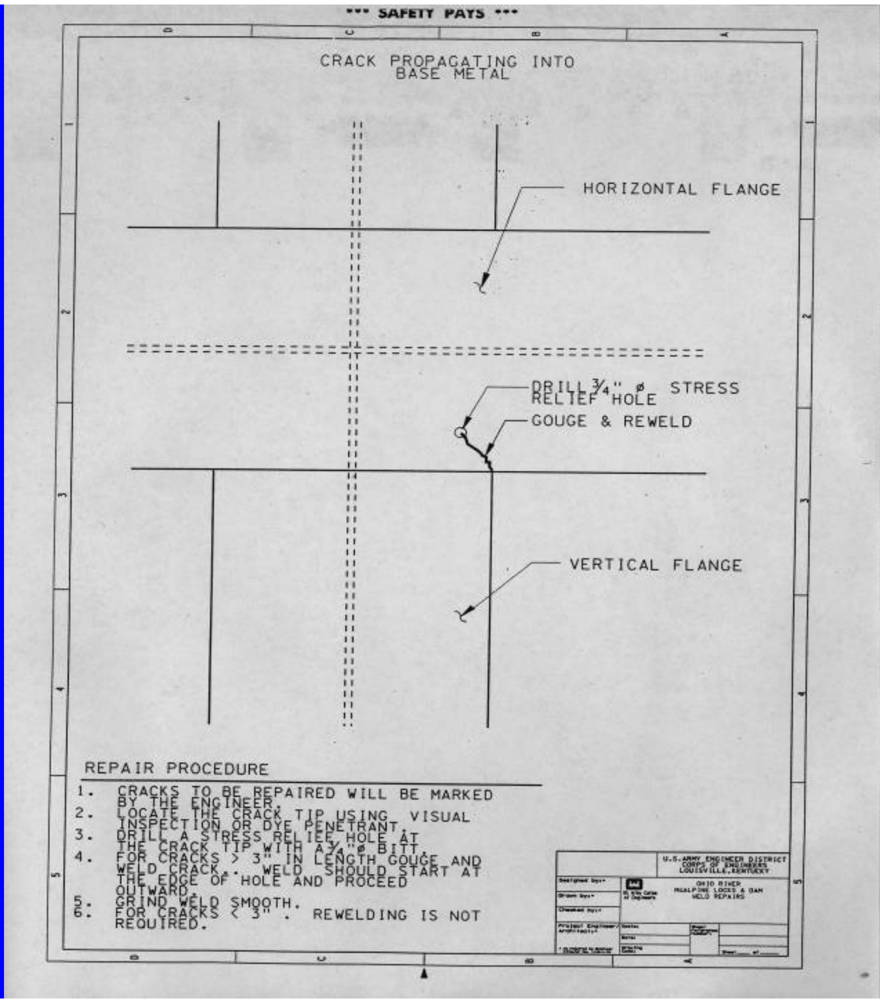
Work in Progress



Crack Repair Overview

- Cracks will either be drilled at the tip or gouged and rewelded
- Inspectors will identify cracks and the repair procedure to be used
  - Drill Only
  - Gouge and Reweld
  - Gouge, Reweld and Grind Smooth
- In general, cracks > 75 mm (3”) will be gouged & rewelded. Cracks < 75 mm (3”) will be drilled only.
- Visually Inspect welds. Some repairs may be UT’d.




C.W

Web Straightening and Repair

- Web buckling in critical areas need to be repaired
- Will probably require heat straightening or in a severe cases, plate replacement.
- Provide angle stiffeners to strengthen buckling capacity of the web

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Reopening

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Closing Observations

- Successful accomplishment attributed to intensive planning and advance preparation.
- Intense cooperation between LRL Engineering, Operations and Contracting provided the materials, equipment and expertise when needed.
- Availability of engineers on site 24 hours per day assured no delays or re-work when questions arose.

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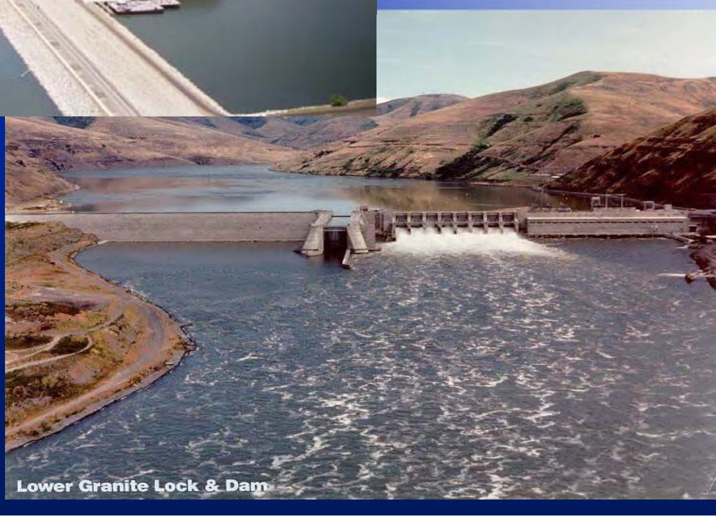
Closing Observations

- The Esprit de Corps during this job was incredible. Everyone realized the importance of the work and made their best efforts.

Lower Granite Lock Downstream Mitre Gate Repair

by Mr. Robert Hollenbeck
Walla Walla District, USACE

Lower Granite Dam Navigation Lock
On Lower Snake River (tributary of Columbia River)



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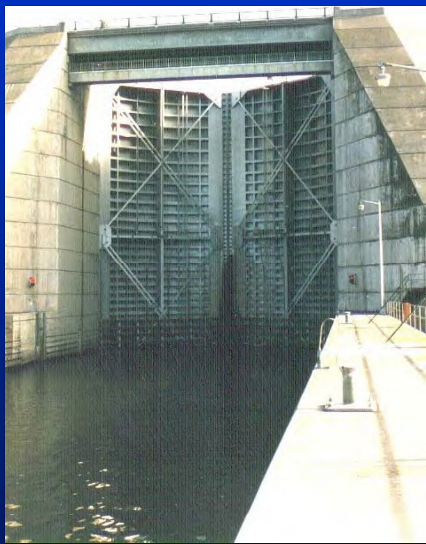
Walla Walla District

Lower Granite Dam Navigation Lock,
Downstream miter gate



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Walla Walla District

Lower Granite Dam Navigation Lock, Downstream miter gate

- Arch miter gate r = 16.6 m (54’-6”) to face of skin plate
- Lock width = 26 m (86 feet)
- Lock length = 206m (675 feet)
- **Gate height = 37.5m (123 feet)**
- **Weight = 337 tonne (372 tons/leaf)**
- Total hydrostatic head = 37 m (121 ft)
- Operates with hydraulic cylinders

Lower Granite Dam Navigation Lock,
Downstream miter gate

Lower Granite Dam Navigation Lock
Downstream miter gate

In March 1998 cracks were discovered in the skin plates of both gate leafs during a periodic dam safety inspection of the navigation lock

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Walla Walla District

Lower Granite Dam Navigation Lock
Downstream miter gate

The crack also propagated from reentrant corner across the bottom horizontal girder

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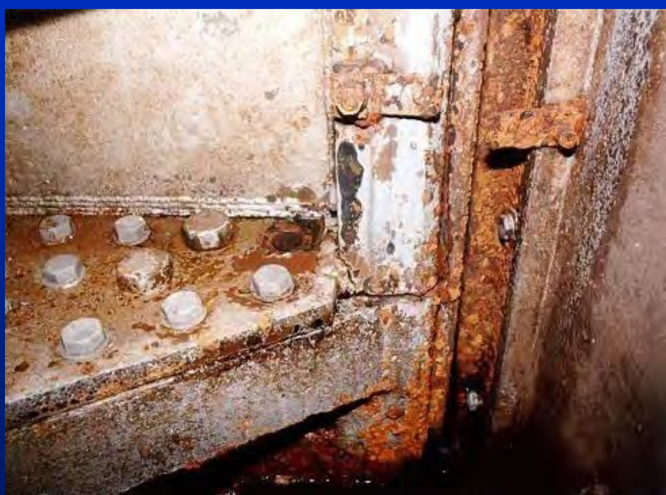
Walla Walla District

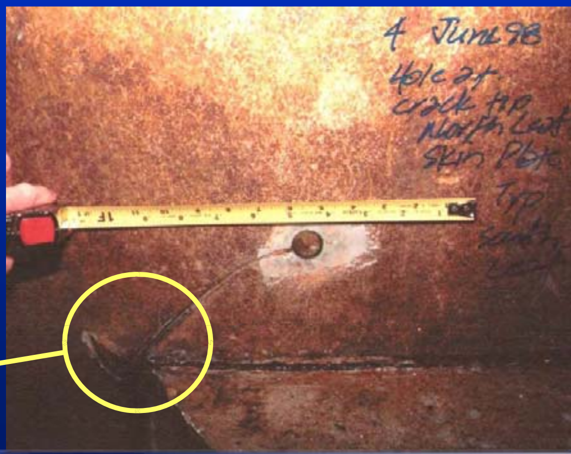
Lower Granite Dam Navigation Lock Downstream miter gate

Additional cracks were found along the horizontal stiffener and quoin contact block recess, along with broken bolt head(s)

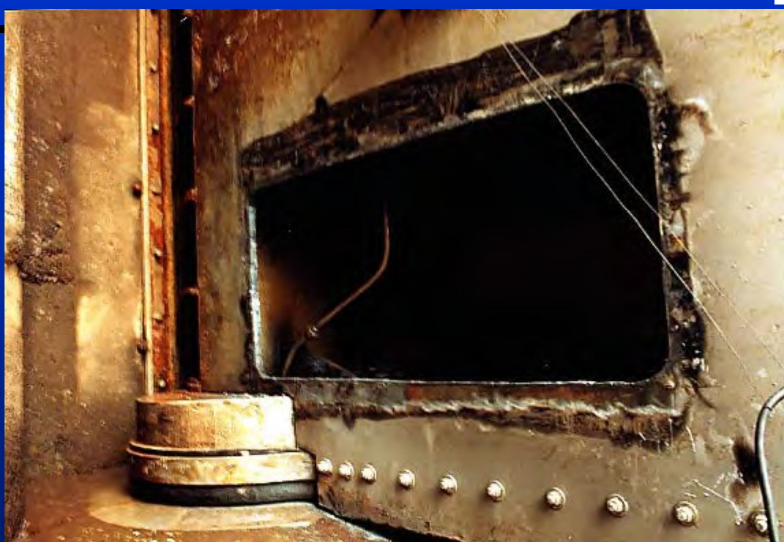


Lower Granite Dam Navigation Lock, Downstream miter gate

Drilled out the tip of the crack on the skin plate and inserted a bolt



Lower Granite Dam Navigation Lock, Downstream miter gate



Temporary repairs, removed skin plate

Lower Granite Dam Navigation Lock,

Downstream miter gate

Temporary repairs, new cover plate

Lower Granite Dam Navigation Lock,

Downstream miter gate temporary repairs crack preparation

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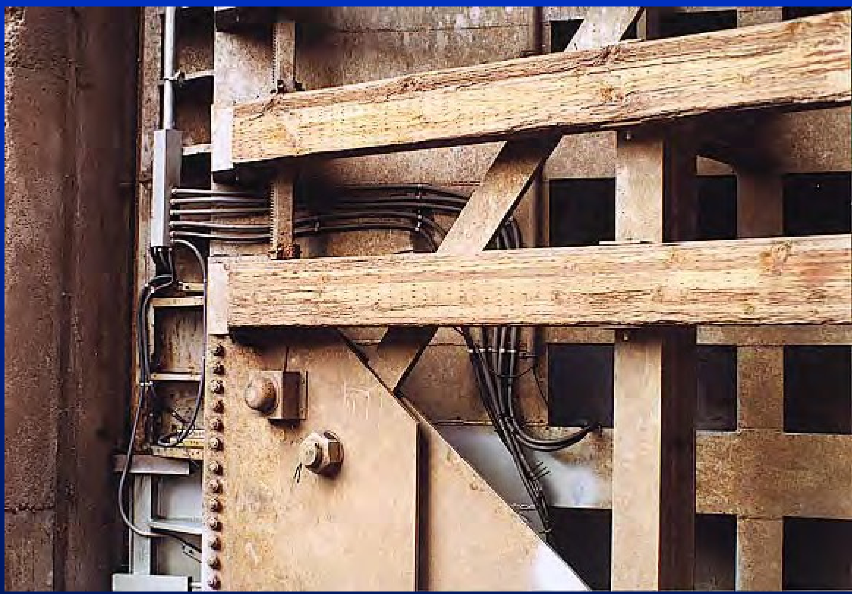
Lower Granite Dam Navigation Lock,

Downstream miter gate, permanent instrumentation



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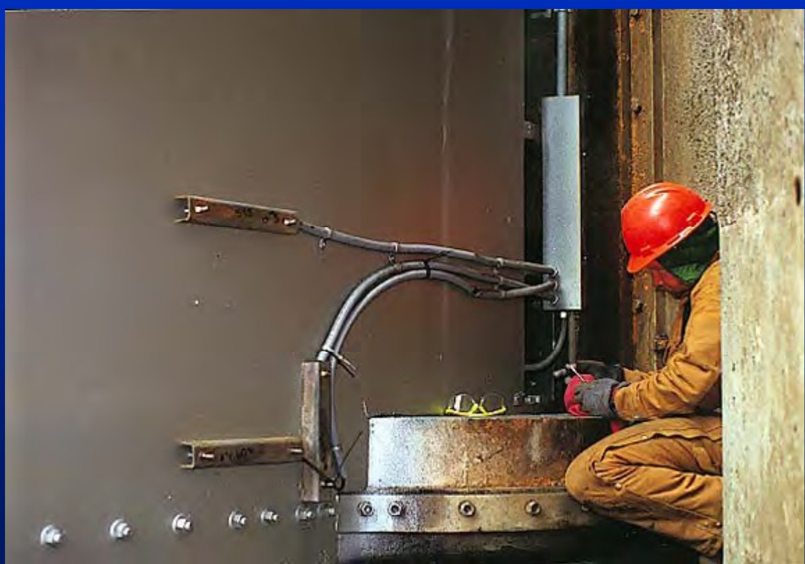
Lower Granite Dam Navigation Lock, Downstream miter gate skin plate repaired, permanent instrumentation installed



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Lower Granite Dam Navigation Lock, Downstream miter gate

Permanent Repairs FY 02

- Install temporary bridge
- Raise gate off pintles
- Replace pintle assembly
- Replace and realign gate quoin and miter contact blocks
- Replace and repair damaged steel members
- Re-align bottom sill angle
- Set gate on pintles, reattach gudgeon, pre-stress diagonals, set sill angles, test gate operation

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Lower Granite Dam Navigation Lock

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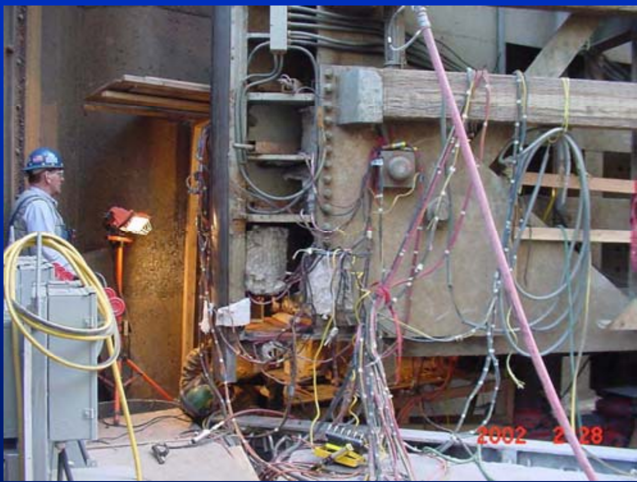
Lower Granite Dam Navigation Lock



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Lower Granite Dam Navigation Lock

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Lower Granite Dam Navigation Lock

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Walla Walla District

Questions? Comments?

Thank You for Your Kind Attention

MITER GATE EMBEDDED ANCHORAGE
SOO LOCKS
Sault Ste. Marie, MI

INDC
INLAND NAVIGATION DESIGN CENTER

SOO LOCKS

• The Soo Locks are located on the St. Marys River at Sault Ste. Marie, Michigan, on the international border with Canada.
• There are two operating locks at the Soo, the MacArthur Lock, (1943) and the Poe Lock (1968).
• POE Lock - Approximately **70 percent** of the Great Lakes fleet carrying capacity can only pass.
• Approximately $160 million – 30 day unscheduled closure of the Soo Locks would have a **direct economic impact to the shipping industry**
• Half of all steel produced in the U.S. is manufactured with domestically mined ore and over **92% of the iron ore mined in the U.S**. traverses through the Soo Locks. Steel-dependant industries contribute more than 10% to the total U.S. Gross Domestic Product.
•The Soo Locks shut down from mid January to early April because of ice and extreme weather

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INLAND NAVIGATION DESIGN CENTER

POE Lock General Information

- The POE lock was formally dedicated and placed into service on 26 June 1969 (47 years old).
- POE Lock chamber 110 ft x 1200 ft (33.5m x 365.7m)
- 32 ft (9.7m) depth of water over the sills at normal lower pool.
- Head of 21.5 feet (6.6m)
- Approx. 63 ft (19.2m) wide gate leaf between contact blocks
- Approx. 37 ft (11.3m) tall between CL gudgeon and sill
- Miter angle 1:3, or 18.4 degrees
- 1-Upstream Operating Gate, 2 Downstream Operating Gates, and 1 Downstream maintenance Gate
- ASTM A36 Steel

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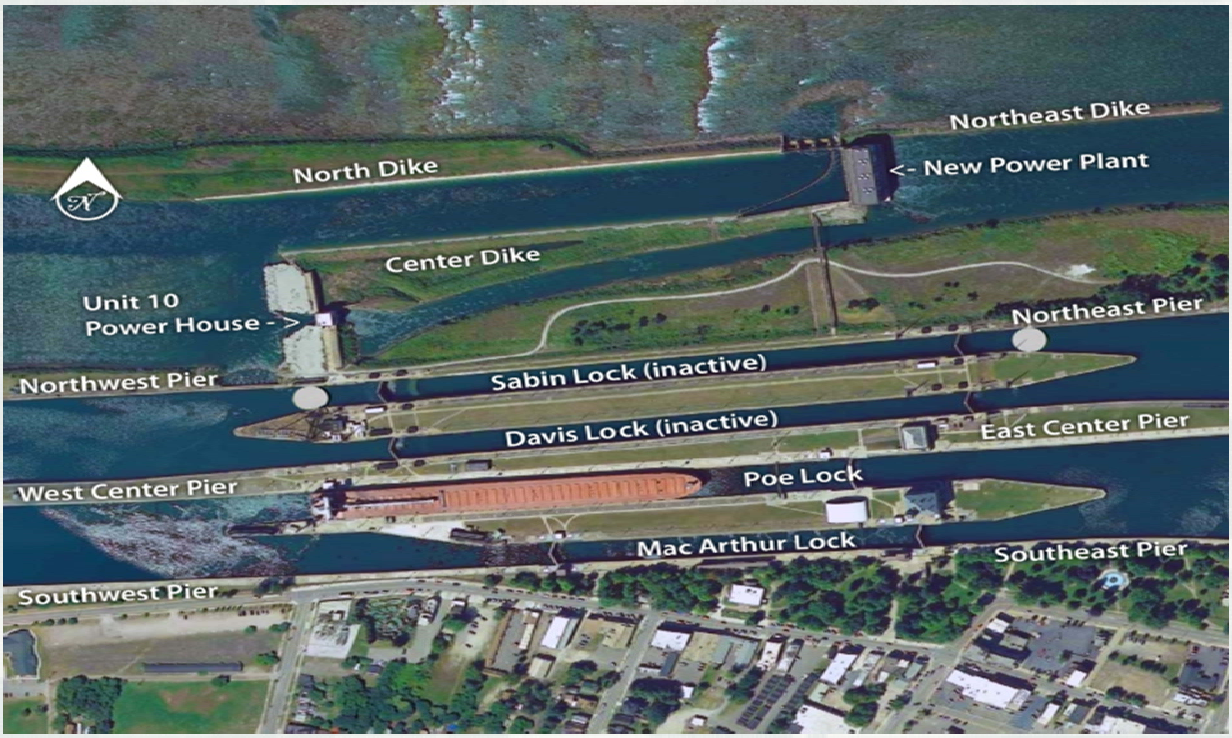

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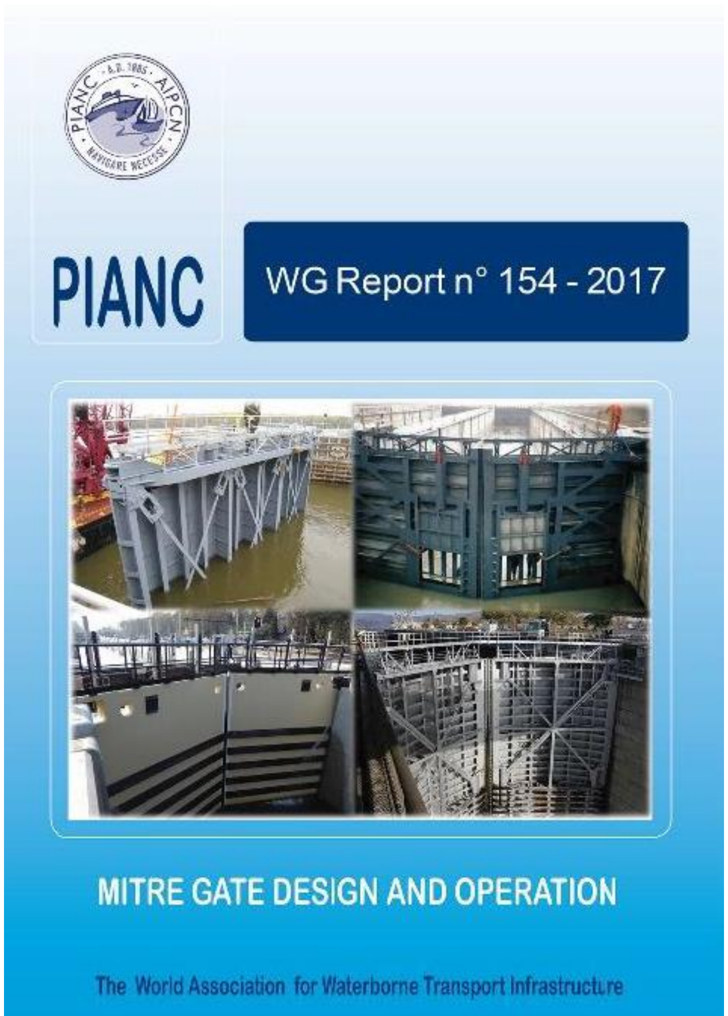


Rijkswaterstaat
Ministerie van Verkeer en Waterstaat

INCOM PIANC Working Group 154

Case study:

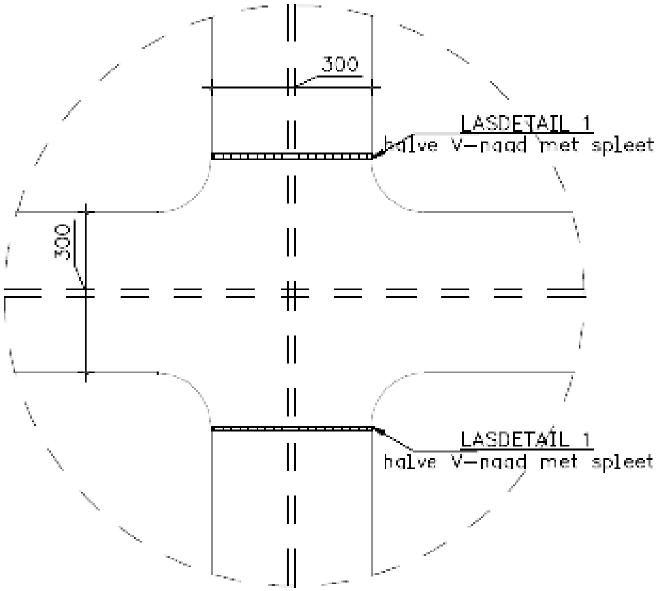
MAASBRACHT Lock Mitre Gates

Jos Vorstenbosch, Brussels, November 6 th 2017

Working Group 154 MAASBRACHT Lock Gates

Fatique Design

Cracks in Old Gates



New Gate details

Fatigue analysis must include hydraulic loads + machinery loads.

Working Group 154 MAASBRACHT Lock Gates

FRP Composite Hinges

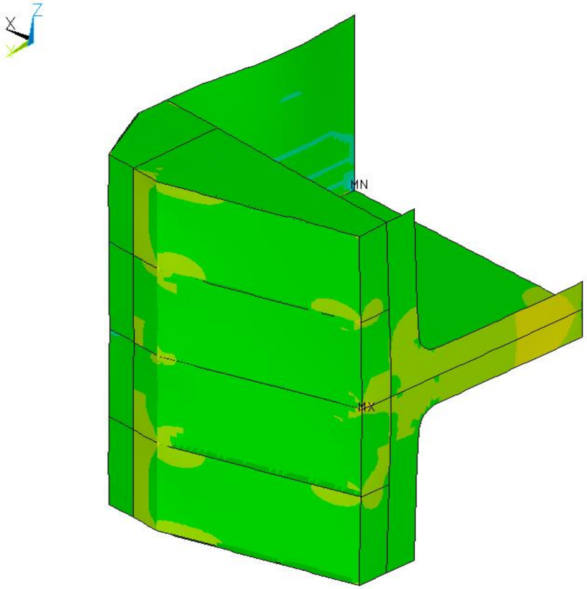
Bottom Pivot

Top Hinge

Design includes obstruction by obstacle + wear + connections to steel.
High Engineering efforts and Testing is needed.

Working Group 154 MAASBRACHT Lock Gates

Heel post design:



Closed structure

Entrapment of floating obstacle caused high loads at top Hinge

Working Group 154 MAASBRACHT Lock Gates

Top Hinge failure:

Entrapment of floating obstacle caused anchorage failure

Re-design top Hinge

Anchorage is > 1.5 x stronger than sacrificial bolts (issue fatigue life)

Working Group 154 MAASBRACHT Lock Gates

Heel post re-design:

Thick horizontal plates replaced closed structure as ‘obstacle crushers‘

Lessons learnt MAASBRACHT Lock Gates

- Curved / smooth steel plate design
- Welds in low stress locations
- Fatigue analysis must include hydraulic loads + machinery loads

- FRP Composite Hinges need high Engineering effort and Testing

- Closed Heel post structure is susceptible for high obstacle loads on Hinges and Gate itself
- Sacrificial bolts / Pins for Anchorage is recommended

CALL FOR ABSTRACTS

- Abstract deadline: October 15, 2017 -

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in Panama city, Panama

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PIANC World Congress presents and discusses topics relevant to the waterborne transport and infrastructure sector. It rotates among PIANC's member countries every four years and it is open to members and non-members.
Participants, will have the opportunity to exchange knowledge and experiences.

The PIANC 2018 Congress will include:

- Technical Short Courses
- Plenary Sessions
- Concurrent Technical Session Tracks
- Industry Exhibition
- Technical Tours
- Networking Events
- Accompanying Persons Cultural Tours

Key Dates

Abstracts Due: October 15, 2017
Author Notification: November 15, 2017
Papers Due: March 16, 2018
Conference: May 7-12, 2018

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PIANC's goal is to advance the sustainable development of shallow and deep-draft navigation issues including dredging and dredged material disposal, navigation and port infrastructure, recreational navigation and related environmental matters.

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When submiting your abstract choose the theme/topic below that is most appropriate.

Themes/Topics

Inland navigation

- Waterway infrastructures: locks, weirs, riverbanks, others.
- Advances in navigation locks design after the Panama Canal Expansion
- Inland navigation channels: safety and reliability
- Integration of inland waterways into inter-modal supply chain
- Inland navigation, waterways, ports & terminals
- Systems and Infrastructures: design & management for inland navigation projects
- River Information Services (RIS, AIS, others)
- River navigation flow control
- Salt water intrusion
- Maintenance and operation of IW, transport & infrastructures
- Inland navigation in South America

Dredging (in the framework of port and navigation projects)

- Effective planning and execution of dredging projects
- Lessons learned from dredging projects worldwide
- Risk management in dredging projects
- Disposal site planning taking into account alternate land uses
- Current dredging & management innovations

Logistics & Infrastructure

- Challenges for capitalizing navigational channels bordering lands
- Synergies among airports, ports and inter-modal assets
- Integrated management of global supply chains
- Integrating ports and economic special zones
- Provision of added value logistic services in maritime hubs
- Project management in the Panama Canal Expansion

Ports

- Impact and innovative solutions for hinterland ports
- Dry ports: better and more efficient
- Ports of the future: technologies, automation, traceability
- Port management models
- Maritime Port planning and operations
- Inter-modal connections
- Coastal and Port Engineering (in relation with navigation)
- Storm Surge & Tsunami barriers and Flood protection gates

Marinas

- Sustainable and resilient marina design – Marinas Working with Nature (best practices and case studies)
- Marinas as part of Tourism, Ports and Urban Master Plans (best practices and case studies)
- Planning Framework for Recreational & Tourism Navigation Infrastructure Systems (goals, strategies and challenges)
- Regulatory Framework and Private Marina Development in Countries in Transition (best practices and case studies)
- Regional Cooperation and Standardization of Recreational Navigation Information Systems Transition (best practices and case studies)
- Recreational components of mitigation plans for large navigation infrastructure projects

Environment

- Environmental management in navigation
- Climate change and emissions, energy efficiency, international regulations, carbon markets
- Fresh water availability for operations
- New technologies on infrastructure, pollution prevention, port reception facilities and ballast water
- Multiple purpose water resource systems (transport, energy, recreation, ecosystems, watersheds, potable water, ...)
- Navigation as a green transportation mode
- Societal awareness and responsibility, combining economic growth, environment/sustainability and welfare
- Climate Change Mitigation in the Maritime Industry

Abstract Submission

Each abstract must be written in English and limited to 1000 words. It should not include graphics/figures. Abstracts shall be submitted online at:
https://www.conference-service.com/pianc-panama

Deadline for abstract submissions: October 15, 2017

When submitting Your Abstract:

- Choose the theme/topic from the available list that best fits your presentation.
- Provide the required contact information (name, company, business address, phone, and email) for the corresponding author and any co-authors. Also, indicate who you expect to make the presentation at the conference.
- Submit a text-only summary description (limited to 1000 words) of the presentation.
- Submit a statement about why the presentation will be of interest and benefit to conference attendees.

Prospective authors, whose abstracts are accepted, are expected to attend the conference, pay the appropriate fees, and make the presentation in person. ACP/PIANC will accept or reject proposed presentations based on the information provided in the abstract.

To the extent possible, the appropriate presentations will be assigned to conference technical sessions based on the theme identified by the author. ACP/PIANC reserves the right to assign presentations to other conference sessions.

For questions about abstract submission, please contact ACP at Congress2018@pancanal.com

Expenses

All expenses associated with the preparation, submission and presentation of abstracts are the responsibility of the authors and co-authors. All attendees are required to pay conference registration fees.