What's new in the design of navigation locks?

– PIANC Workshop –

In the framework of the
PIANC Report n°106 - INCOM WG29

- PRESENTATIONS -

13th – 14th September 2011

New Orleans – USA

PIANC – www.pianc.org

Editor: Prof. Ph. RIGO, INCOM WG29 Chairman

WORKSHOP - TECHNICAL AGENDA

13th Sep 2011 (Tuesday)

8:00 **WORKSHOP INTRODUCTION**
By Prof. Ph. RIGO (BE), INCOM Vice chairman
and J. CLARKSON (U.S. Army Corps of Engineers, member of INCOM WG29)

8:30-10:00 **WORKSHOP PART 1 – THE PANAMA LOCKS**

THE DESIGN OF THE PANAMA LOCKS
By M. NEWBERY (USA) and J. AUGUSTIJN (NL)
Chair: Ph. RIGO (BE)

NUMERICAL SIMULATIONS AND EXPERIMENTAL MODELS: THE EXPERIENCE OF THE NEW PANAMA MODEL
By S. ROUX (Fr)
Discusser: R. STOCKSTILL (USA)

10:30-12:00 **WORKSHOP PART 2 – PIANC 2009 - Report n°106 - on Locks**

INNOVATIONS IN NAVIGATION LOCK DESIGN
General Presentation of the PIANC Report n°106 on Locks (2009)
By Ph. RIGO (BE) and P. HUNTER (UK),

A SELF-CONTAINED HIGH-LIFT LOCK WITH WATER-SAVING BASINS
By C. THORENZ (D)

INNOVATION IN LOCK FILLING AND EMPTYING SYSTEMS
By R. STOCKSTILL –(USA)
Discusser: D. BOUSMAR (BE)

CONSTRUCTION METHODS
By D. MILLER (USA)
Discusser: WU. PENG (China)

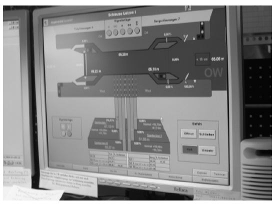
13:30 – 15:00 **WORKSHOP PART 3 – PIANC 2009 - Report n°106 – on Locks (cont.)**

COMPUTER FLUID DYNAMICS IN LOCK DESIGN
By T. DE MULDER- (BE)
Discusser: C. THORENZ (D)

NEW CONCEPT OF LOCK GATES
- Use of synthetic materials and the comeback of sliding gates versus rolling gates
  By R. DANIEL (NL) and J. AUGUSTIJN (NL)
- New materials and systems in the design of miter gates
  By R. DANIEL (NL)
- Innovation in lock equipment
  By O. HOLM (Fin) and J. BODEFELD (D)

15:30 – 17:00 **WORKSHOP PART 4 – CHALLENGES OF TOMORROW**

DESIGN FOR MAINTENANCE: DREAM OR REALITY? THE EXPERIENCE OF THE NEW PANAMA LOCKS – LIST OF REQUIREMENTS (20 min + 10 min questions)
By R GORDON and J. WONG (ACP)
Chair: J. BODEFELD (D) and P. HUNTER (UK)



IDENTIFICATION OF THE CHALLENGES OF TOMORROW
PANEL MEETING
Coordinator: Ph. RIGO
Panelists: J. AUGUSTIJN (NL), J. BODEFELD (D), R. DANIEL (NL),
R GORDON & J.WONG (ACP), M. NEWBERY (USA), R. THOMAS (BE)

17:00 – 17:30 **PROJECT REVIEWS and their value in realising innovations,** By E. PECHTOLD (NL)

17:30 **CLOSURE** By Ph. RIGO (BE)

14th September 2011 (Wednesday Afternoon)

8:30 – 12:00 **SMART-RIVERS Conference**
Keynote addresses and Plenary Session on Hurricane Surge Barrier

12:00 – 13:30 Lunch – with keynote speaker from EU commission (invited)

13:30 – 15:30 **WORKSHOP PART 5 : MOORING FORCES AND VESSEL BEHAVIOUR (in locks)**

EXPERT PANEL SESSION – Ph RIGO (BE)
The experts present their experience on this issue, which is the main focus of the new PIANC WG 155 (having their inaugural meeting during the SMART RIVERs Conf.)

Presentation of new innovative concepts for navigation locks
By S. KWOK (St. Lawrence Seaway, Canada)
Experience in Belgium
By T. DE MULDER, M. VANTORRE (BE)
Experience in China
By WU PENG (China)
Experience in France
By S. ROUX (Fr)
Experience in Germany
By C. THORENZ (D)
Experience in the Netherlands
By J.J. VELDMAN (NL)
Experience in USA
By R. STOCKSTILL (USA)

Discussion (30 minutes): Coordinated by Ph RIGO (BE)

15:30 – 16:00 **Break**

16:00 – 17:00 **WORKSHOP PART 6 : VESSEL BEHAVIOUR (in locks)**
Chair: WU PENG (China)

INTERACTION between SALT WATER INTRUSION and NAVIGATION (in locks)
By M. SAS (BE)

MANEUVRABILITY IN LOCK CHANNELS
By M. VANTORRE (BE)

17:00 -17:30 **WORKSHOP CLOSURE**
By PIANC USA Representative
PIANC HQ Representative
Prof. Ph. RIGO, Workshop Chairman and Coordinator

What's new in the design of navigation locks?

TABLE OF CONTENT

CHALLENGES OF TOMORROW (Part 4)

MOORING FORCES AND VESSEL BEHAVIOUR IN LOCKS (Parts 5 and 6)

This 2nd international workshop presenting the **Innovations in Navigation Lock Design -** PIANC Report n°106 was organized on 13th and 14th September2011 in New Orleans, USA. The first workshop in September 2009 in Brussels, Belgium was a huge success, with more than 100 participants, and therefore, it was decided to offer follow up events.

This 2nd international PIANC workshop on **Innovations in Navigation Lock Design** will be held in conjunction with the SMART-RIVERS 2011 Conference in New Orleans, Louisana.

On 13th Sept 2011, there was a detailed presentation of the main innovative issues highlighted in the PIANC 2009 report (n°106). This workshop differs from the 2009 one in that new speakers presented their experience with respect to innovative lock design, including the new Panama Locks.

On 14th Sept. 2011, the workshop was dedicated to "*Ship behavior in locks and lock approaches*".

For info about SMART RIVERS 2011: http://smart11.pianc.us

Workshop proceeding

The Workshop proceeding (including all the PowerPoint presentations given during the workshop – in PDF version) is release on the PIANC web site (www.pianc.org) and on
www.anast.ulg.ac.be ,
www.anast.ulg.ac.be/index.php/fr/nouveautes/40-categorynews/102-pianc-whats-new-in-the-design-of-navigation-locks

Proceedings of the 1st PIANC workshop (Brussels 2009) are available at:
www-new.anast.ulg.ac.be/index.php/en/news/40-categorynews/94-pianc-workshop-innovations-in-navigation-lock-designq
and
www.pianc-aipcn.be/figuren/verslagen%20activiteiten%20Pianc%20België/fotoboekjes/workgroup/locks/Locks/index.html

The participants of the PIANC 2011 workshop are:

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Juan	Wong	jwong@pancanal.com

PIANC Workshop
13-14th September 2011

WELCOME
NEW ORLEANS
SMART RIVER 2011

PIANC
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PIANC WORKSHOP
on “Navigation Locks”
–
1st Edition - 2011 Brussels

2nd Edition – 2011 New Orleans
–
3rd Edition
24-25th Sept. 2013
in Liege - Maastricht
SMART RIVERS 2013

PIANC
Setting the course

AGENDA

–

<u>13th September 2011</u> <u>(Tuesday)</u>

8:00 to 12:00 **Workshop Parts 1 & 2**
12:00 to 13:00 Lunch – Buffet (Ballroom I)
13:30 to 17:30 **Workshop Parts 3 & 4**
18:30 to 21:00 **SmartRivers Opening Reception**

<u>14th September 2011</u> <u>(Wednesday)</u>

8:30 to 12:00 **SMART RIVERs**
Plenary Session and Key note speakers
12:00 to 13:00 Lunch (Ballroom II)
13:30 to 17:30 **Workshop Parts 5 & 6**

WORKSHOP

Lock Workshop Room (both days):
in Terrace Room – 12th Floor
Westin New Orleans Canal Place

LUNCHES

Lunch Tuesday: 12:00 PM - 1:00 PM:
Ballroom I

Lunch Wednesday: 12:00 PM - 1:00 PM
Ballroom II

PROCEEDINGS
–
ABSTRACTS (text)
&
PRESENTATIONS (Powerpoint)

Available on

PIANC WEB SITE (latter) and

www.anast.ulg.ac.be

or www.anast.ulg.ac.be/index.php/fr/nouveautes/40-categorynews/102-pianc-whats-new-in-the-design-of-navigation-locks

PROCEEDINGS www.anast.ulg.ac.be

PROCEEDINGS www.anast.ulg.ac.be

Download the PDF : WORKSHOP PROCEEDING – Abstract

DOWNLOAD the PDF :
WORKSHOP PROCEEDING - Abstract

Download the PDF : WORKSHOP PROCEEDING – Presentations (ALL IN 1)

DOWNLOAD the PDF :
WORKSHOP PROCEEDING - Presentations
(ALL IN 1)

Or you can have access to each presentations indivually:

- P1-1 NEWBERY – Design of the Panama Third Line.pdf
- P2-1 RIGO-HUNTER- PIANC WG29 on LOCKS.pdf
- P2-2 THORENZ- New Lock type.pdf
- P2-3 Stockstill – Innovation_Lock_Systems.pdf
- P2-4 MILLER – Construction methods
- P3-2 Daniel Augustijn – Synthetic Materials.pdf
- P3-3 DAHL R – New Mat Systems.pdf
- P3-4 HOLM – BODEFELD – Lock Equipment.pdf
- P4-2 RIGO – Challenges for Tomorrow.pdf
- P5-2 WU PENG- Mooring forces and vessel.pdf
- P5-5 VELDMAN Experience-in-The-Netherlands.pdf
- P5-6 STOCKSTILL – Mooring Forces.pdf

13th Sep 2011 – Part 1: 8:00 to 10:00

WELCOME

By Ph. RIGO (BE)
J. CLARKSON (USA)

THE PANAMA LOCKS

THE DESIGN OF THE PANAMA LOCKS
By M. NEWBERY (USA) and J. AUGUSTIJN (NL)
Chair: Ph. RIGO (BE)

NUMERICAL SIMULATIONS AND EXPERIMENTAL MODELS: THE EXPERIENCE OF THE NEW PANAMA MODEL
By S. ROUX (Fr)
Discusser: R. STOCKSTILL (USA)

13th Sep 2011 – Part 2: 10:30 to 12:00

PIANC 2009 - Report n°106 - on Locks
INNOVATIONS IN NAVIGATION LOCK DESIGN

PRESENTATION of the PIANC Report n°106 on Locks (2009)
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Discusser : D. BOUSMAR (BE)

CONSTRUCTION METHODS
By D. MILLER (USA)
Discusser : WU. PENG (China)

13th Sep 2011 – Part 3: 13:30 to 15:00

PIANC 2009 - Report n°106 - on Locks (cont)
INNOVATIONS IN NAVIGATION LOCK DESIGN

COMPUTER FLUID DYNAMICS IN LOCK DESIGN
By T. DE MULDER (BE)
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NEW CONCEPT OF LOCK GATES

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  By R. DANIEL (NL) and J. AUGUSTIJN (NL)
- New materials and systems in the design of miter gates
  By R. DANIEL (NL)
- Innovation in lock equipment
  By O. HOLM (Fin) and J. BODEFELD (D)

13th Sep 2011 – Part 4: 15:30 to 17:30

CHALLENGES OF TOMORROW

DESIGN FOR MAINTENANCE: DREAM OR REALITY? THE EXPERIENCE OF THE NEW PANAMA LOCKS – LIST OF REQUIREMENTS

By R GORDON and J. WONG (ACP)
Chair: J. BODEFELD (D) and P. HUNTER (UK)

IDENTIFICATION OF THE CHALLENGES OF TOMORROW

PANEL MEETING
Panelists: J. AUGUSTIJN (NL), J. BODEFELD (D), R. DANIEL (NL), R GORDON & J.WONG (ACP), M. NEWBERY (USA), R. THOMAS (BE)

PROJECT REVIEWS – PIANC WG29

By E. PECHTOLD (NL)

CLOSURE

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14th Sep 2011 – Part 5: 13:30 to 15:30

MOORING FORCES AND VESSEL BEHAVIOUR (in locks)

In the framework of PIANC WG155

New innovative concepts for navigation locks

By S. KWOK (St. Lawrence Seaway, Canada)

MOORING FORCES AND VESSEL BEHAVIOUR

Experiences in :

- Belgium	T. DE MULDER and M. VANTORRE
- China	WU PENG
- France	S. ROUX
- Germany	C. THORENZ
- Netherlands	VELDMAN
- USA	R. STOCKSTILL

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14th Sep 2011 – Part 6: 16:00 to 17:30

VESSEL BEHAVIOUR IN LOCKS

Chair: WU PENG (China)

INTERACTION between SALT WATER INTRUSION and NAVIGATION (in locks)
By M. SAS (BE)

MANEUVRABILITY IN LOCK CHANNELS
By M. VANTORRE (BE)

WORKSHOP CLOSURE

By PIANC USA Representative
PIANC HQ Representative
Prof. Ph. RIGO, Workshop Coordinator

THANK YOU

And see you soon

–

WELCOME TO
3rd Edition of this PIANC WORKSHOP

SMART RIVERS 2013

24-25th Sept. 2013
in Liege & Maastricht

www.pianc.org New Orleans 2011

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Setting the course

Paper 1-1 **THE DESIGN OF THE PANAMA LOCKS**

M. NEWBERY (USA) and J. AUGUSTIJN (NL)

What's new in the design of navigation locks?

CMC-221427

PIANC Workshop 13-14th September

Workshop Part 1 – The Post-Panamax Locks

The Design of the Panama Canal Third Set of Locks

M. Newbery, *Design Manager - CICP, and Vice President - MWH*

J. Augustijn, *Rotterdam Design Center Engineer- CICP, and Project Manager – Iv-Infra*

Presentation

1. Introduction and Tender Design
2. Final Design
3. Lock Rolling Gates Design
4. Next Steps

Introduction and Tender Design

PIANC WORKSHOP "Lock Design" New Orleans Sept 2011

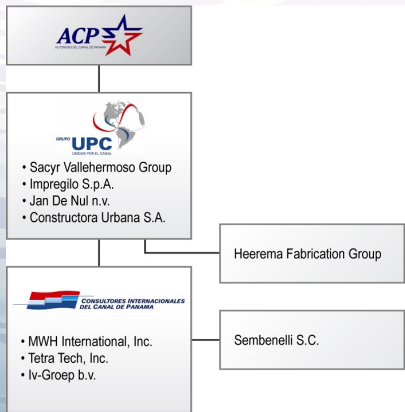
Introduction and Tender Design

GUPC

- Sacyr y Vallehermoso SA, Spain
- Impregilo, Italy
- Jan de Nul, Belgium
- Constructoras Urbanas SA (CUSA), Panama

CICP (Project Designer)

- MWH
- Tetra Tech
- Iv Groep b.v., Netherlands
- Others(Sembenelli, INA, Glosten)



PIANC WORKSHOP "Lock Design" New Orleans Sept 2011

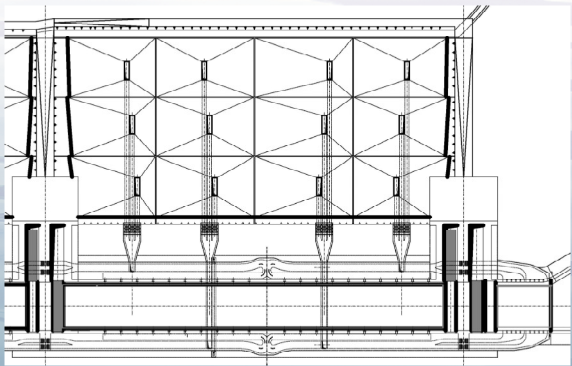
Introduction and Tender Design

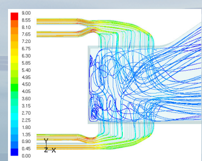
- Overall Execution Plan (400 Points)
- Key Personnel (250 Points)
- Design-Build Execution Methodology (700 Points)
- Design Plan (2,500 Points)
- Construction Plan (1,150 Points)
- Maintenance Services (400 Points)
- Training of ACP Personnel (100 Points).
- Price Proposal (4,500 Points)

TOTAL **10,000** Points

Introduction and Tender Design

Hydraulic modifications



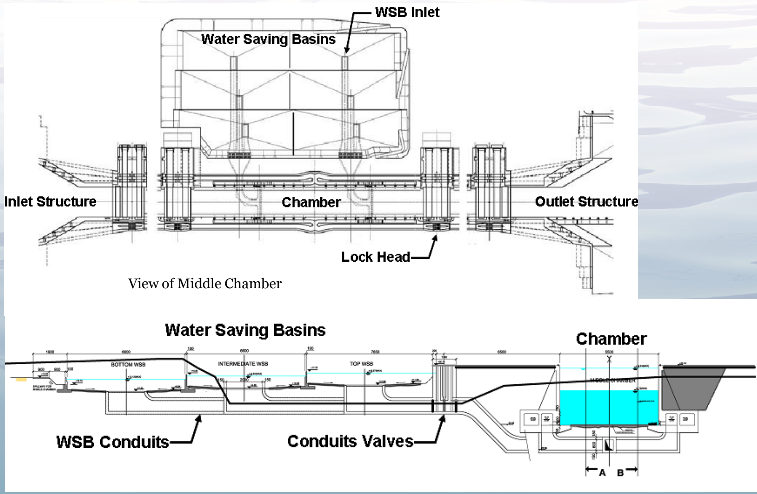


Concept Filling and Emptying System

PIANC WORKSHOP "Lock Design" New Orleans Sept 2011

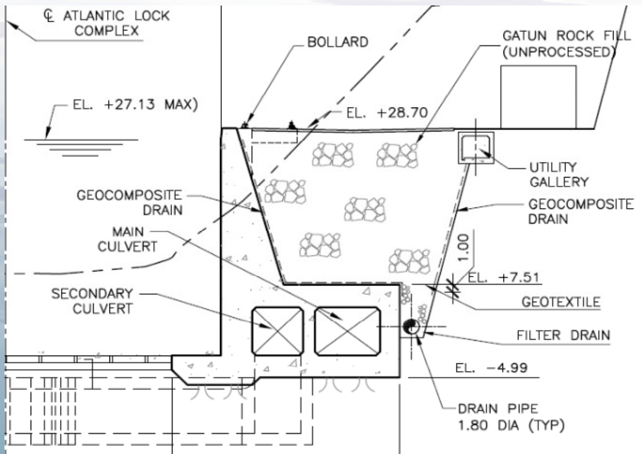
Introduction and Tender Design

Hydraulic modifications



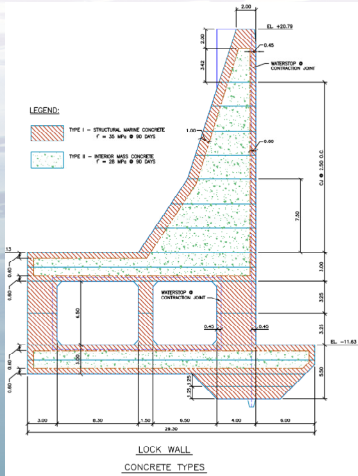
Introduction and Tender Design

Tender Lock Wall Design, Atlantic



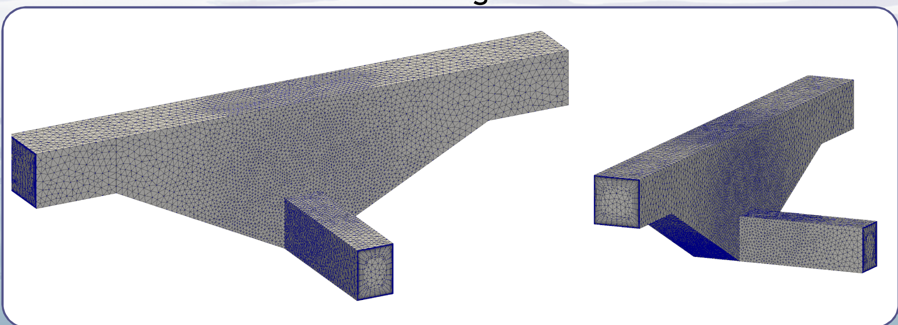
Introduction and Tender Design

- Tender Design, Pacific Locks Complex, Upper Chamber Wall



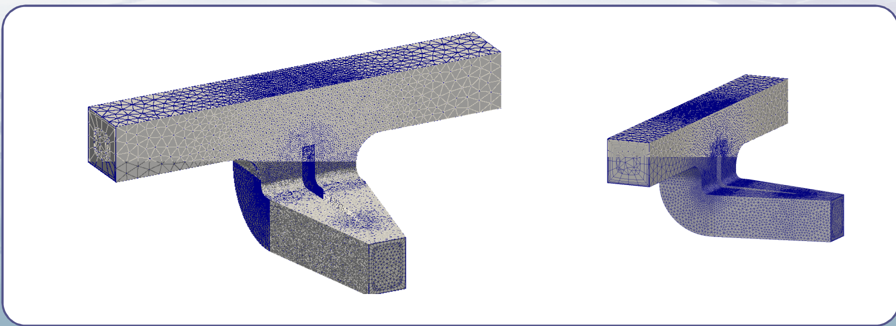
Final Design - Hydraulics

Connection to Secondary -
Tender Design

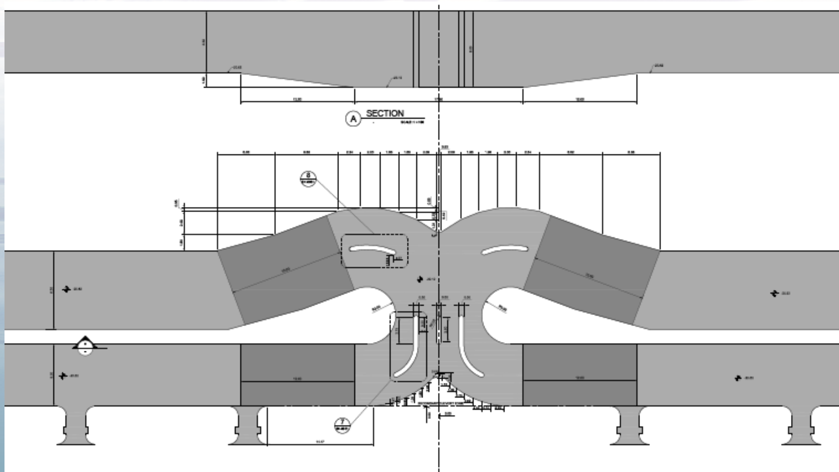


Final Design -Hydraulics

Connection to Secondary -
Final Design – Alt F.

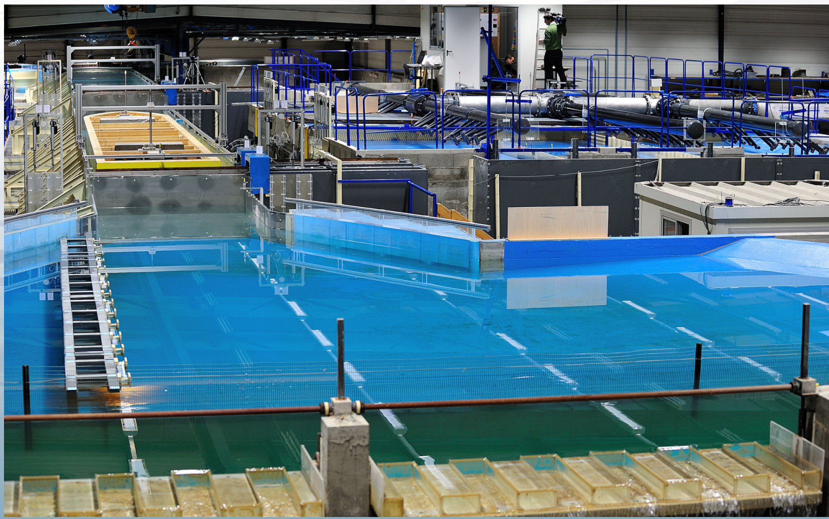


Final Design – Hydraulics
Central Connection



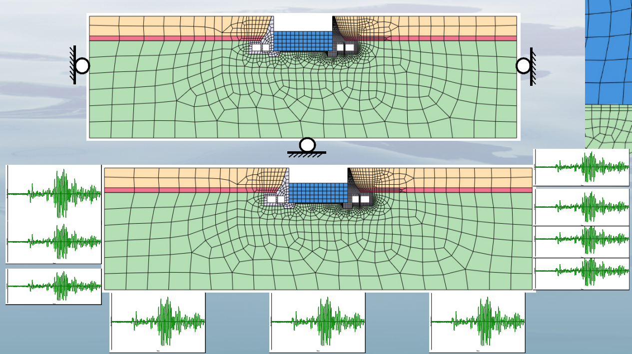
Final Design - Hydraulic

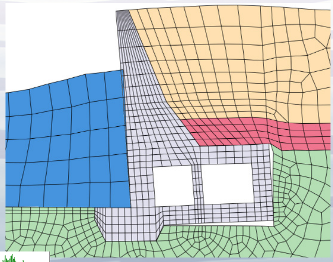
Hydraulic Model of Post Panamax Locks



Final Design - Structural

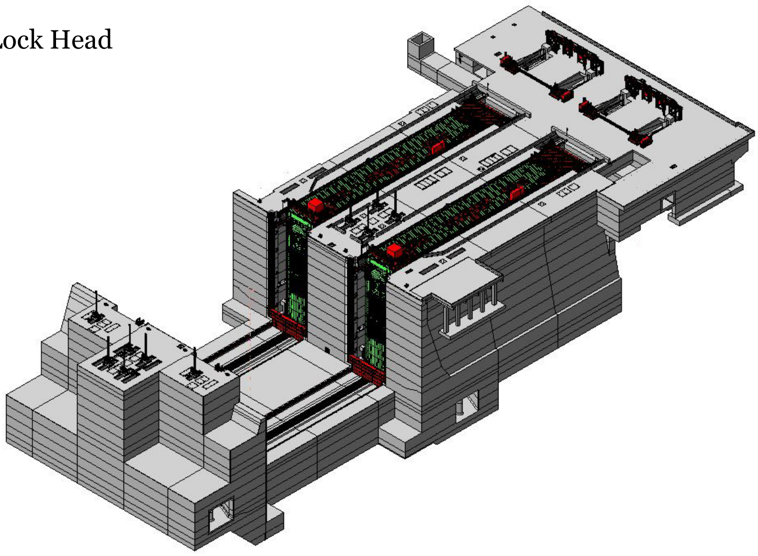
- Traditional Stability Analysis
- Analyzed with Finite Element Method
- Used Abaqus Non-linear





Final Design – Structural

Lock Head



Final Design

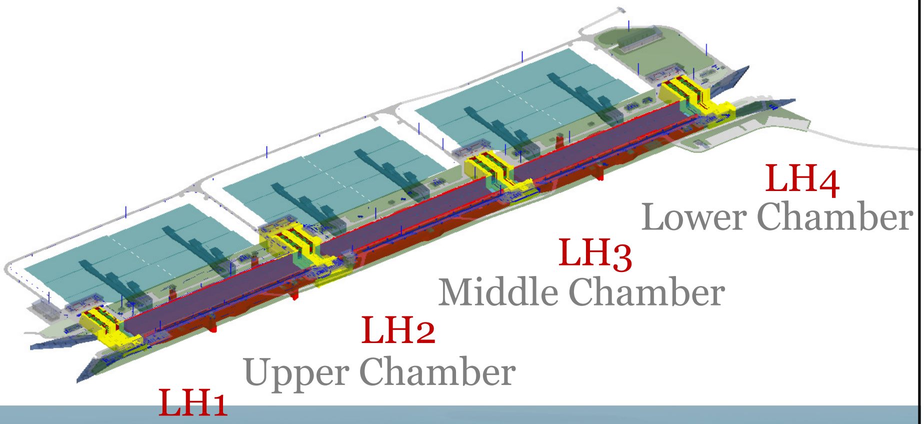
• Link to Lock Wall and Lock Head video

•Lock Wall – Overall
•Lock Wall - Detail

•Lock Head with Gate, Plan
•Lock Head with Gate, Iso
•Lock Head - Stresses

•Videos

Final Design – Revit Model



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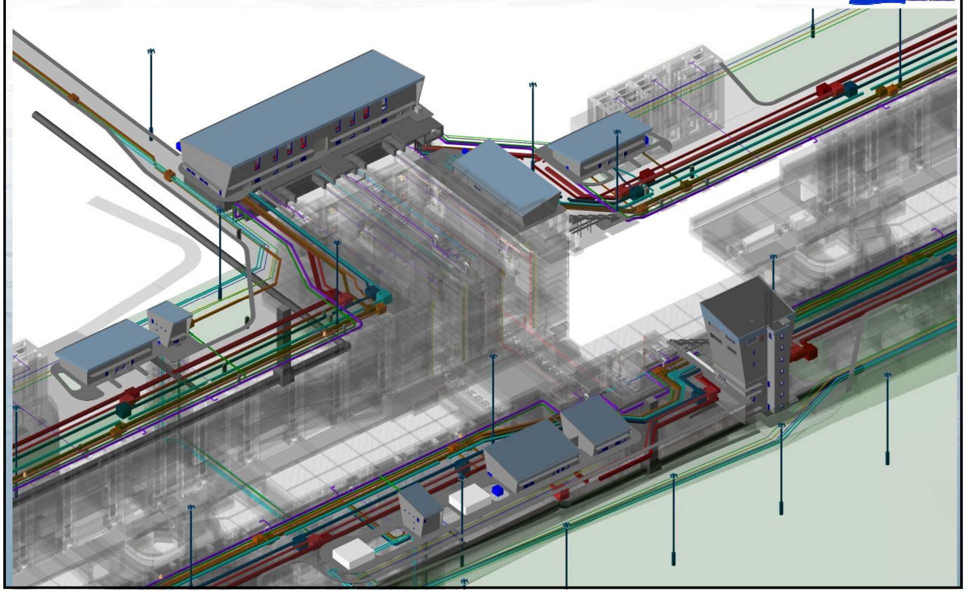
Final Design – Revit Model



Final Design

Revit Model, Atlantic Lock Complex

Final Design

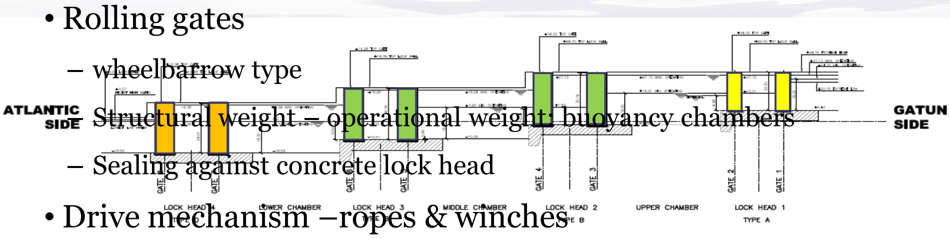
Revit Model, Atlantic Lock Complex

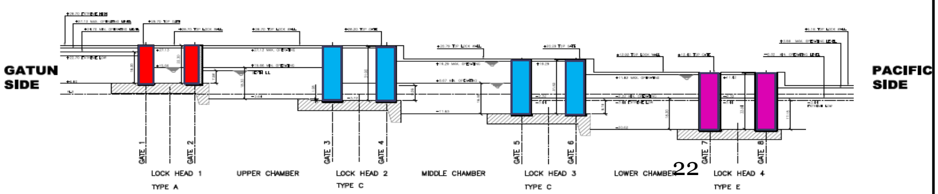
Final Design

Image of Pacific Lock Middle and Lower Chambers superimposed on aerial photograph

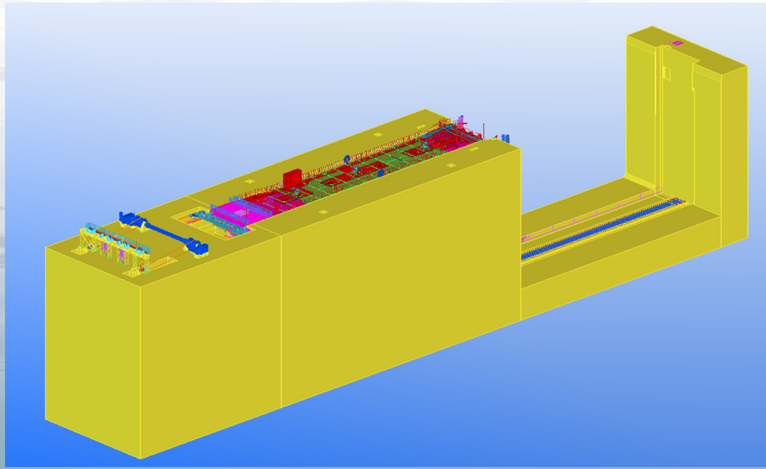
Lock Rolling Gate Design

- 2 Complexes; 8 gates each; 6 different types
- Rolling gates
  - wheelbarrow type
  - Structural weight – operational weight: buoyancy chambers
  - Sealing against concrete lock head
- Drive mechanism –ropes & winches
- Bridge function





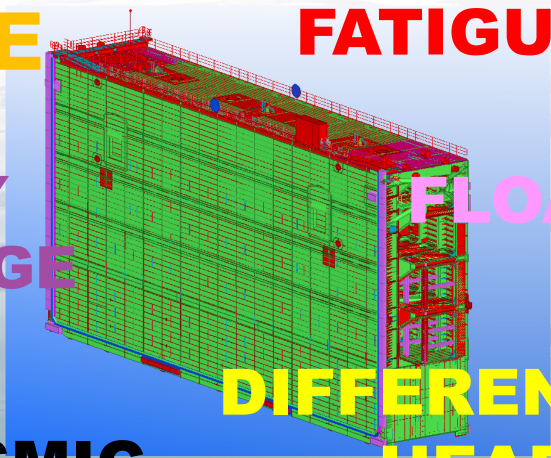
Lock Rolling Gate Design



Lock Rolling Gate Design – Special?

SIZE

FATIGUE



DRY OUTAGE

FLOATING

DIFFERENTIAL HEAD

SEISMIC

Lock Rolling Gate Design

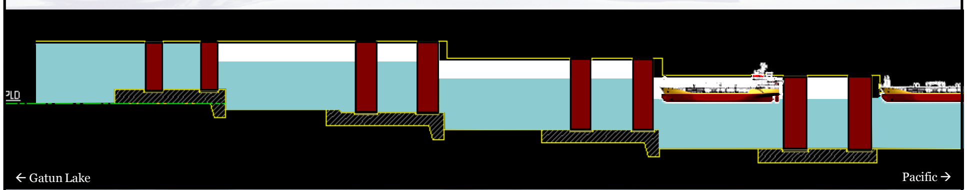
Higher loads/higher temperatures

• UHMWPE (creep) tests

Lock Rolling Gate Design

Uplockage (Ocean → Lake)

• Differential head / Fatigue



G1 G2 Lock Head 1 | G3 G4 Lock Head 2 | G5 G6 Lock Head 3 | G7 G8 Lock Head 4

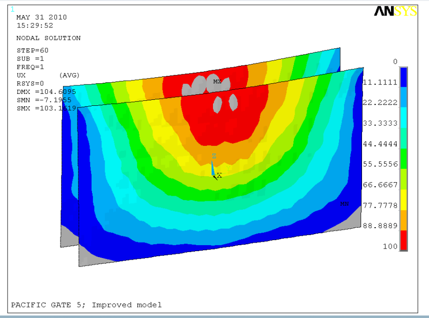
250.000 cycles of operation
Limitation allowable operational stresses
Requirements details

Lock Rolling Gate Design

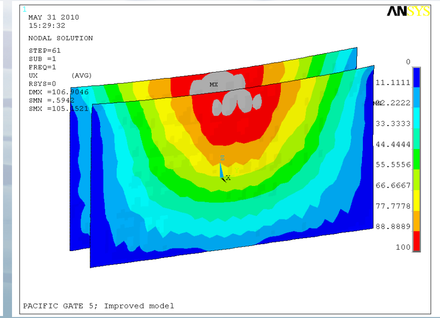
- Seismic

Rolling Gate only model, Response Spectra Analysis

Design of the skin plate: Displacements

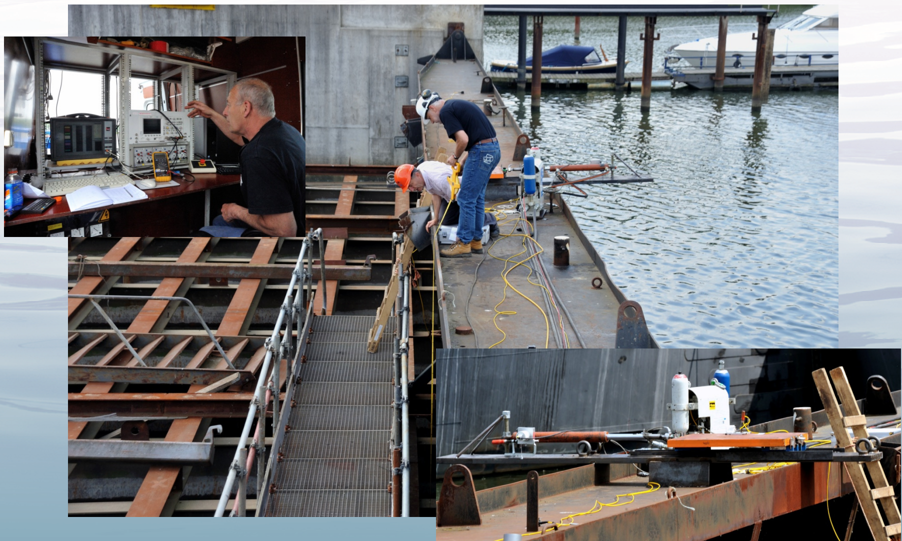


1st eigenmode used



nine eigenmodes used

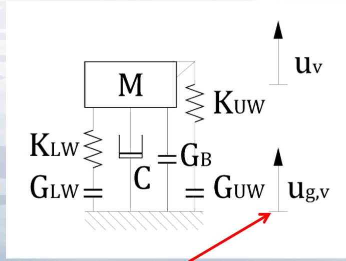
Lock Rolling Gate Design

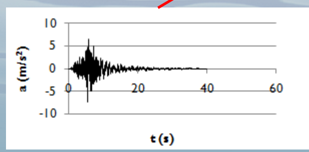


Lock Rolling Gate Design

- Seismic ctd.

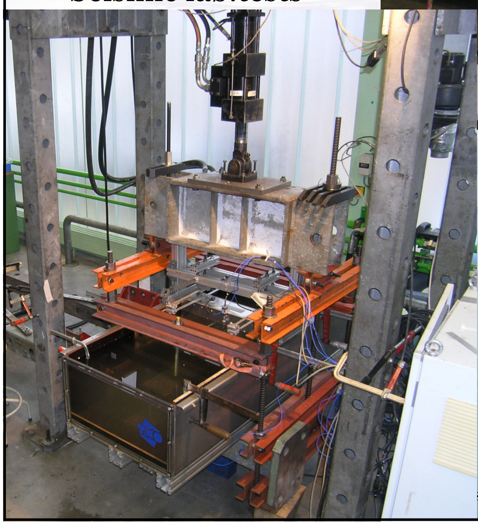
  - M: gate mass + water added Mass – Archimedes
  - K_{LW}: nonlinear spring modeling lower wagon stiffness + LLD
  - K_{UW}: nonlinear spring modeling upper wagon stiffness + LLD
  - $G_{lw/uw}$: Gap wagons to rail
  - G_B: Gap bearings (60 mm)
  - C: piston effect at the bottom of the gate

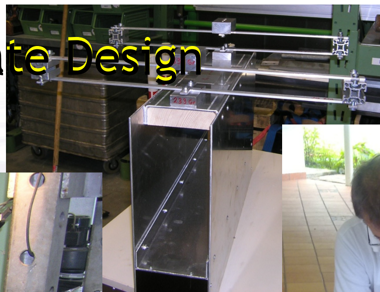




Lock Rolling Gate Design

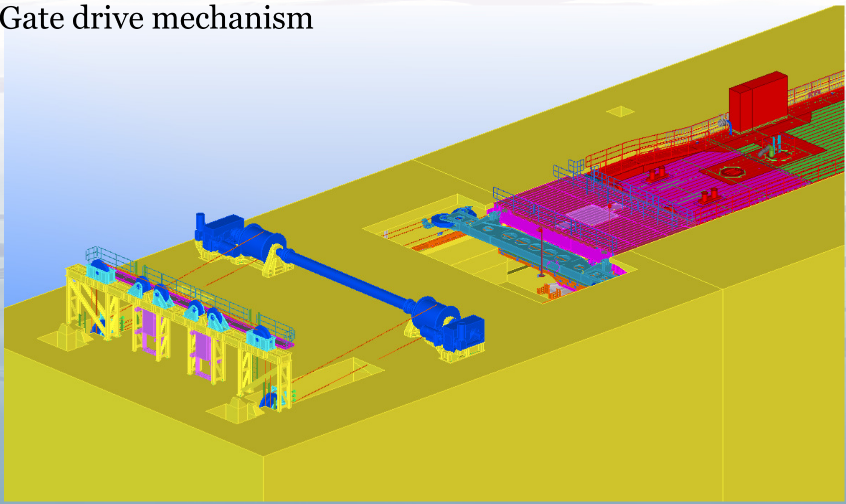
- Seismic lab.tests





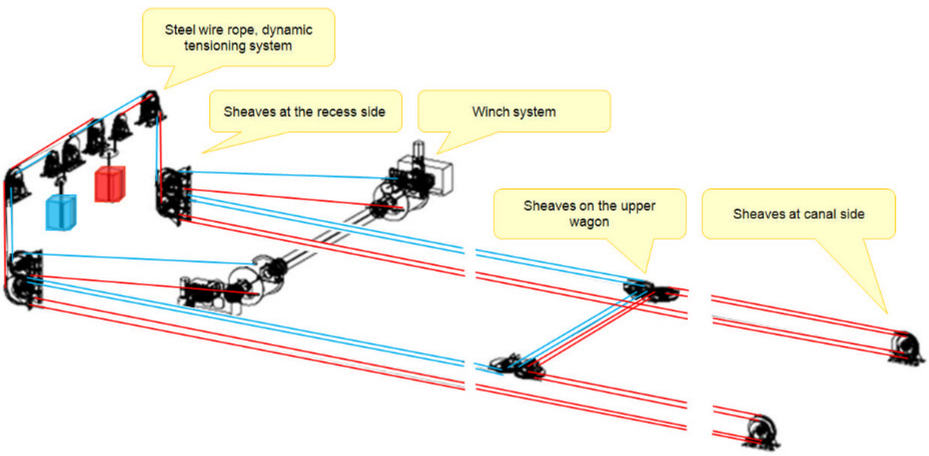
Lock Rolling Gate Design

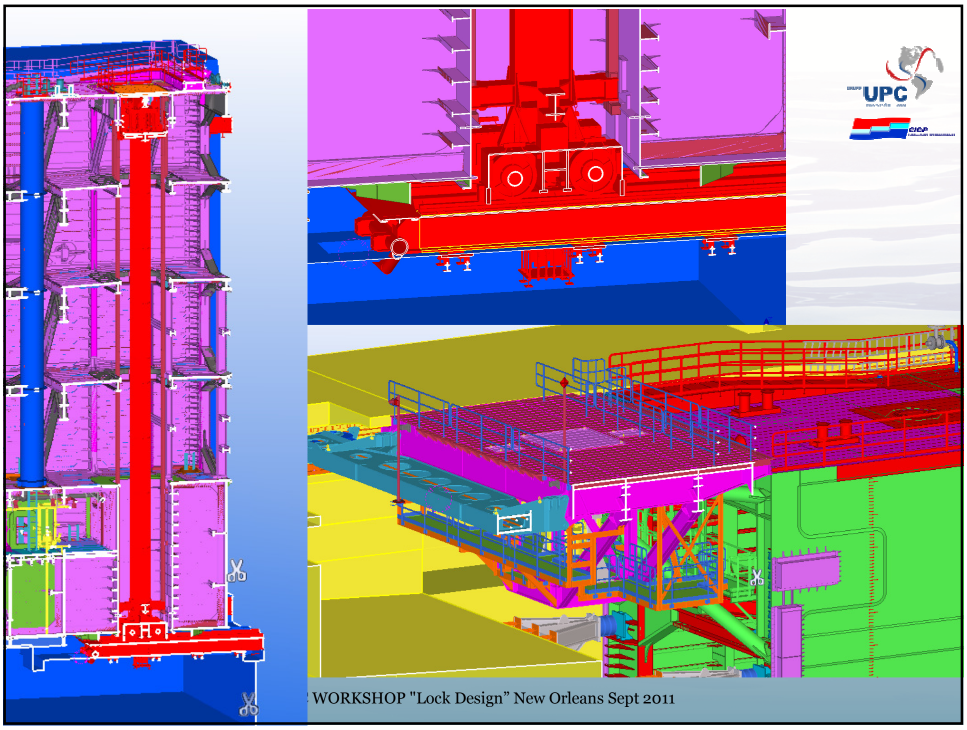
- Gate drive mechanism



Lock Rolling Gate Design

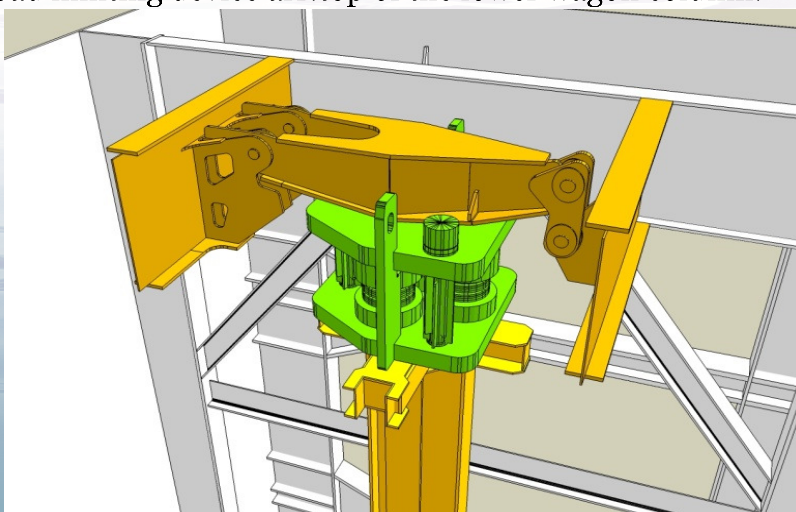
- Gate drive mechanism





Lock Rolling Gate Design

Load limiting device arr.top of the lower wagon column.



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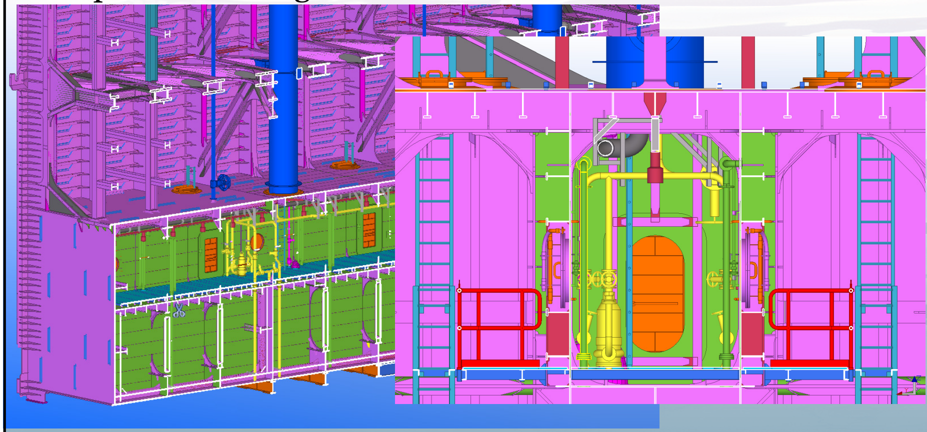
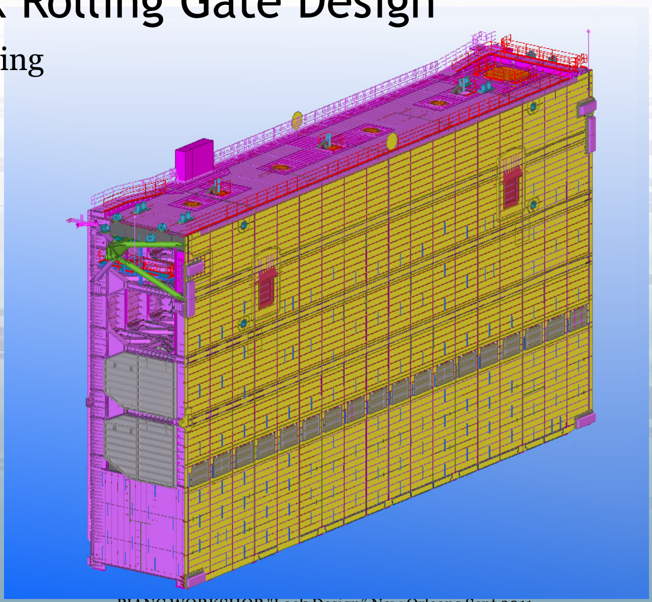
Lock Rolling Gate Design

• Operational weight control



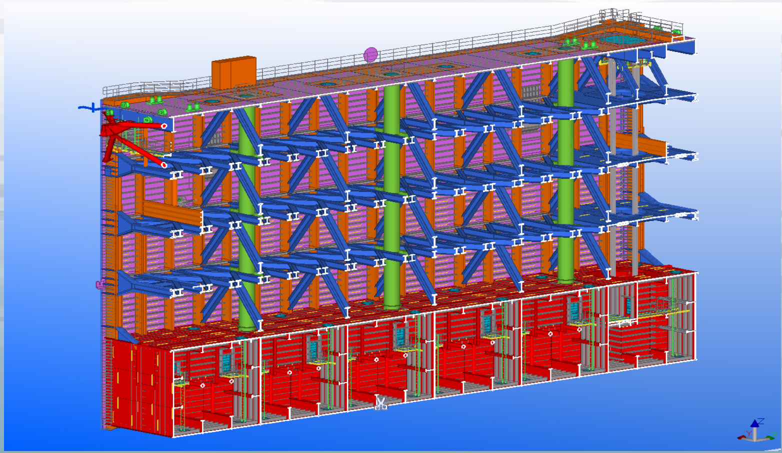
Lock Rolling Gate Design

• Floating



Lock Rolling Gate Design

Longitudinal section of a lock rolling gate showing buoyancy chambers, trusses and the upper support bracket. Tekla 3-D model



Next Steps

Design

- Buildings and Infrastructure
- Water Saving Basins
- Fenders
- Borinquen Dams
- Approach Structures
- Electrical and Controls Systems
- Mechanical Systems
- RAM and Maintenance Manual

Next Steps

Construction

(QA by CICP)

- Concrete Placement Ramping Up
- Excavation Continuing
- Lock Gate Fabrication
- Valve Fabrication
- Procurement

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Next Steps - Atlantic

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Next Steps - Atlantic

PIANC WORKSHOP "Lock Design" New Orleans Sept 2011

Next Steps - Pacific

PIANC WORKSHOP "Lock Design" New Orleans Sept 2011

Next Steps - Pacific

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QUESTIONS ???

[ATL Site Utility]

OTS Review 2011

Paper 1-2 **NUMERICAL SIMULATIONS AND EXPERIMENTAL MODELS: THE EXPERIENCE OF THE NEW PANAMA MODEL**
S. ROUX (Fr)

What's new in the design of navigation locks?

PIANC Workshop
13-14th September 2011

Numerical simulations and experimental models

Sébastien Roux — CNR, France
Nicolás Badano — MWH, Argentina

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"What's new in the design of navigation locks"
Workshop Part 1

Numerical simulations and experimental models:
the experience of the new Panama model

Sébastien Roux — CNR, France
Nicolás Badano — MWH, Argentina

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Introduction

Compagnie Nationale du Rhône

MWH

GRUPO UPC
UNIDOS POR EL CANAL

CICP
CONSULTORES INTERNACIONALES

ACP
AUTORIDAD DEL CANAL DE PANAMA

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Description of the models used during the design study

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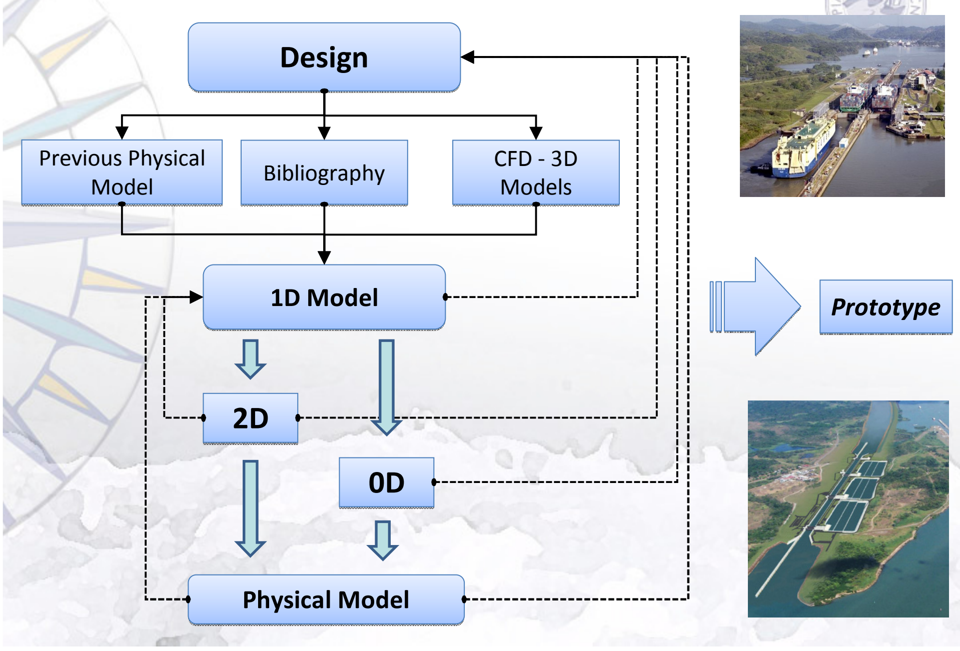
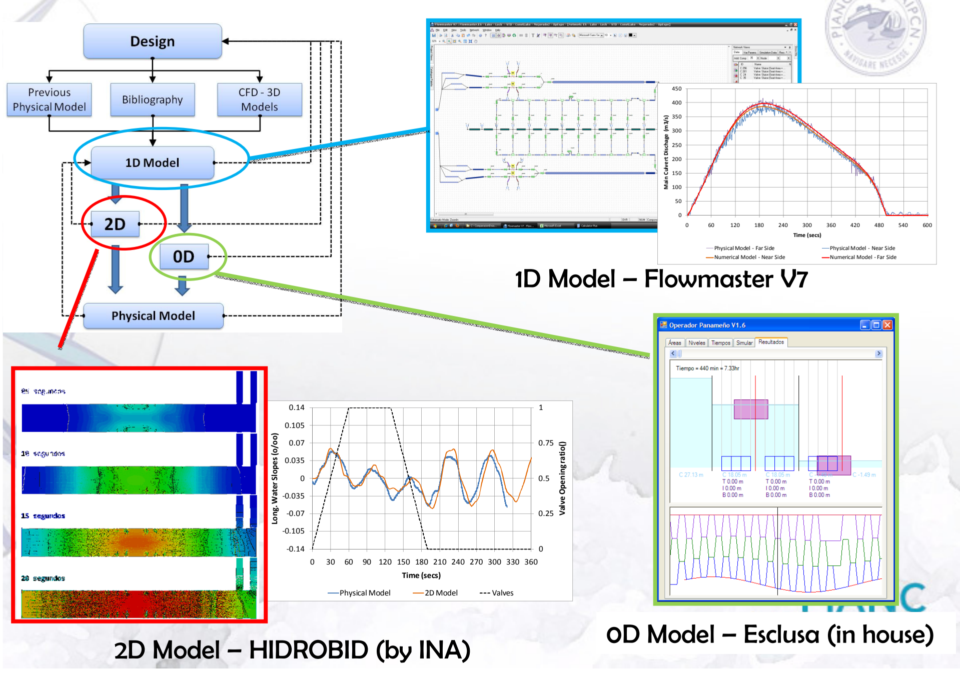
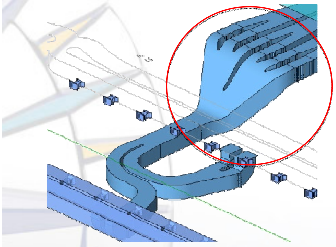
Modeling System



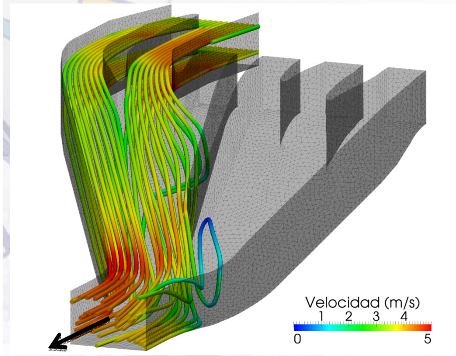
Numerical Models

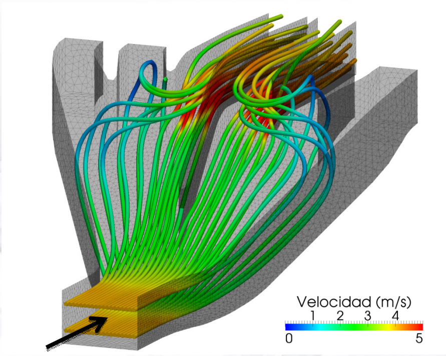


CFD - Head Loss Calculations



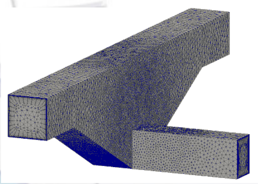
- OpenFOAM Code
- Turbulence Models $k-\varepsilon$ *realizable* and LES
- Parallel calculations
- 1 a 2 millions of elements (up to 10 millions)

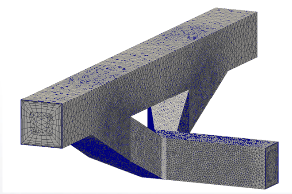


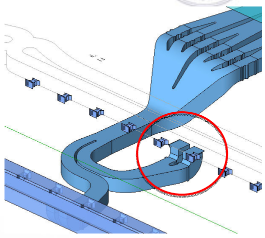


CFD - Numerical Analysis of Design Alternatives

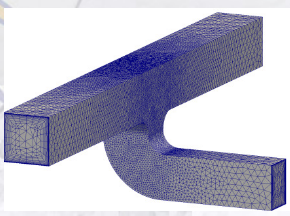
- Several alternatives were tested before the physical model construction in order to optimize the hydraulic design

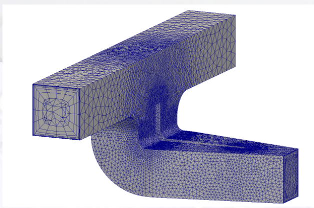






Connection to Secondary Culvert





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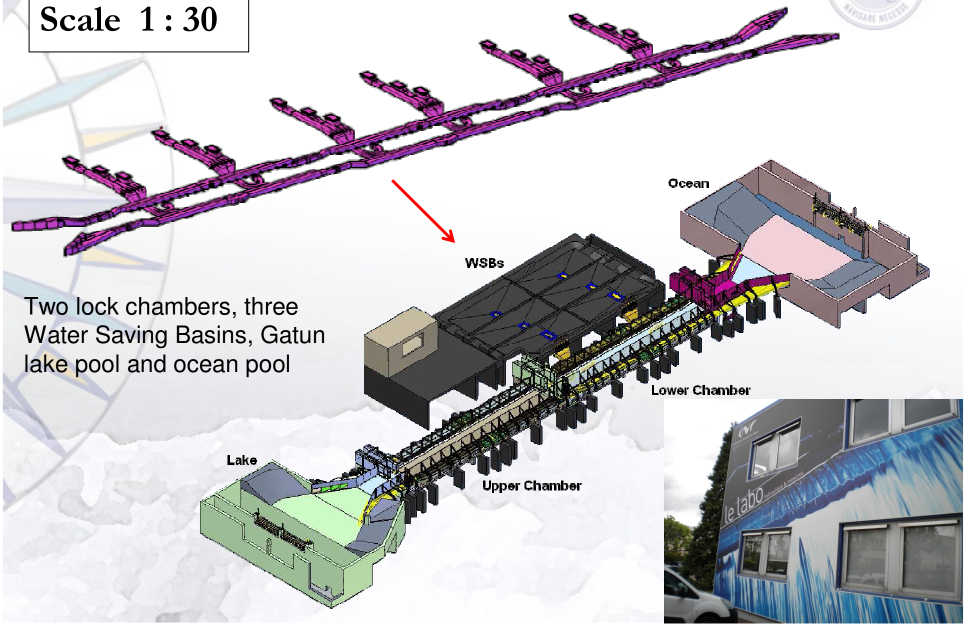
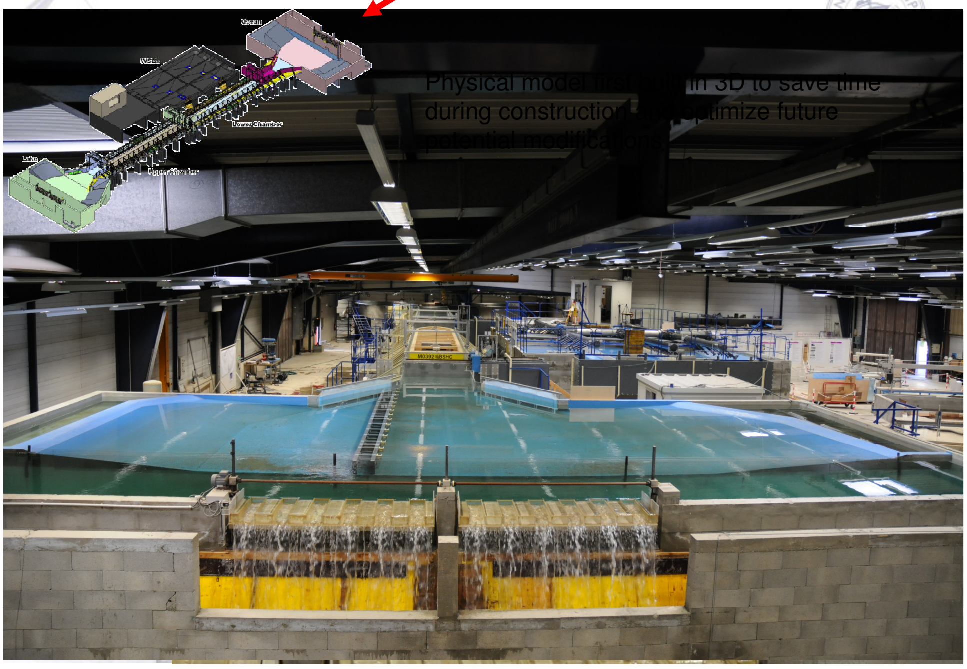
Physical Model

Scale 1 : 30

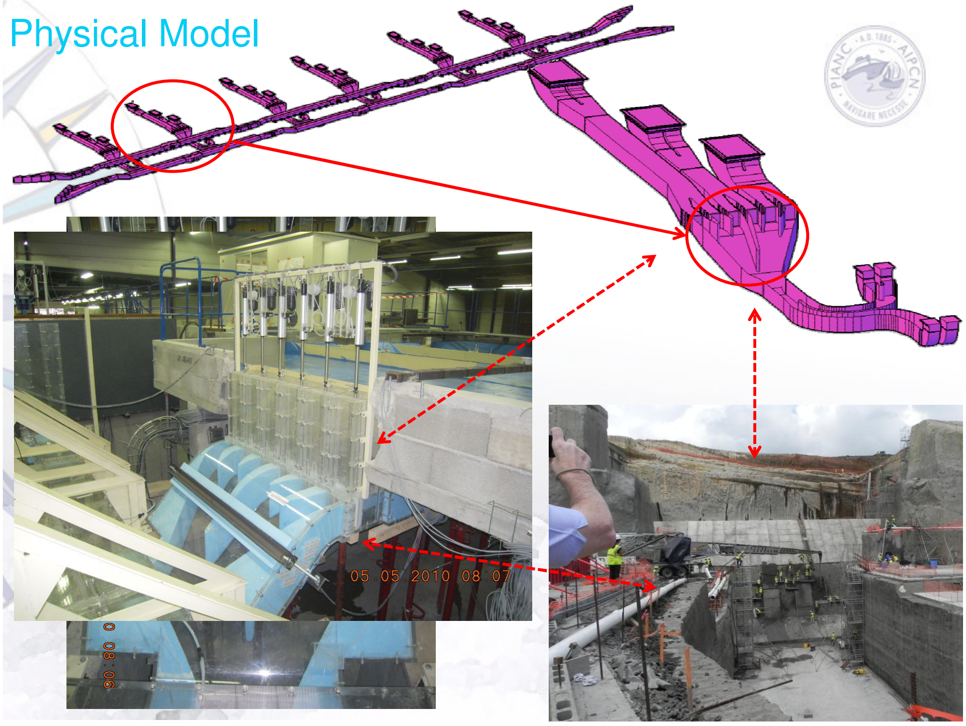


Two lock chambers, three Water Saving Basins, Gatun lake pool and ocean pool

Physical Model

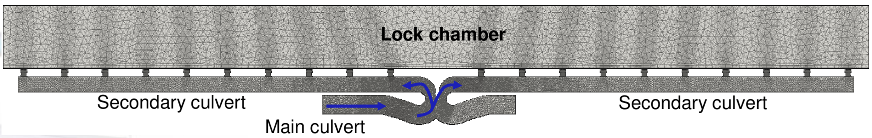


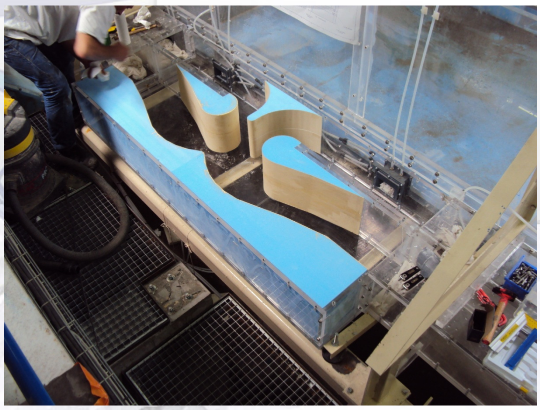
Physical Model

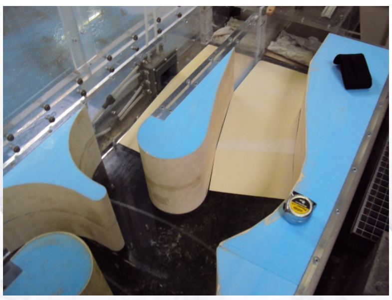


Physical Model

Central flow connection







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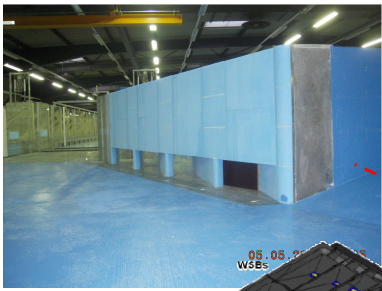
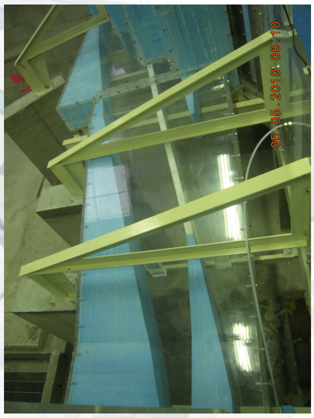
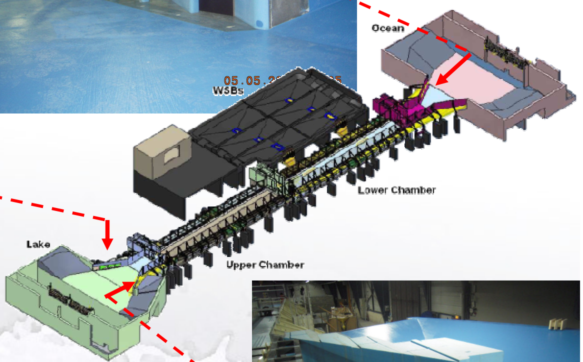
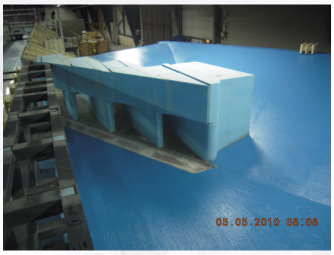
Physical Model

Lake intakes & ocean outlets



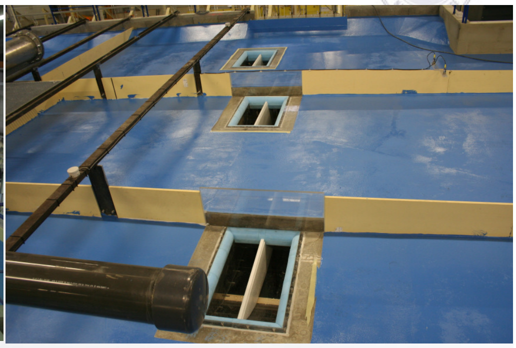


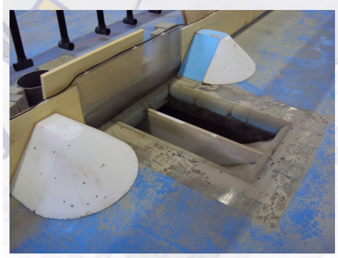




Physical Model

Water Saving Basins

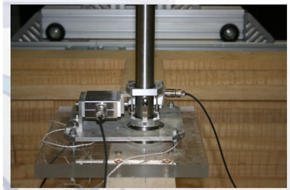
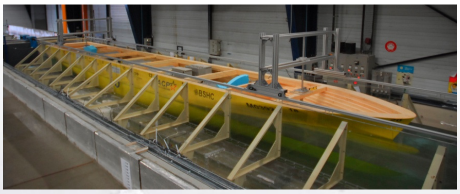


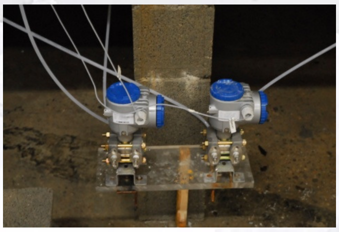


Design of vortices mitigation devices

Model equipment

The Physical Model has been instrumented with about 100 sensors in order to measure: the water levels, the velocities and the discharges, the pressures, the water slopes in the lock chamber and the forces exerted on the vessel during a F/E system operation & the corresponding valves positions.

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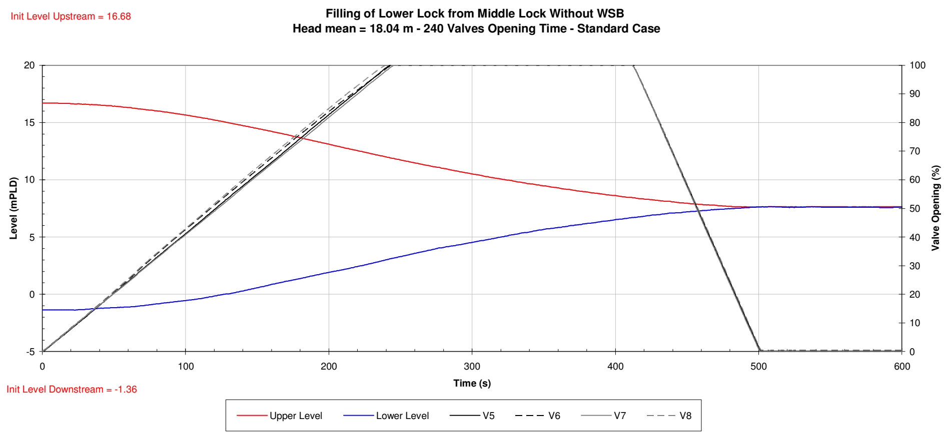
Measurements carried out

Water levels variation measured with ultra-sonic sensors
Valves opening ratio measured with positing sensors



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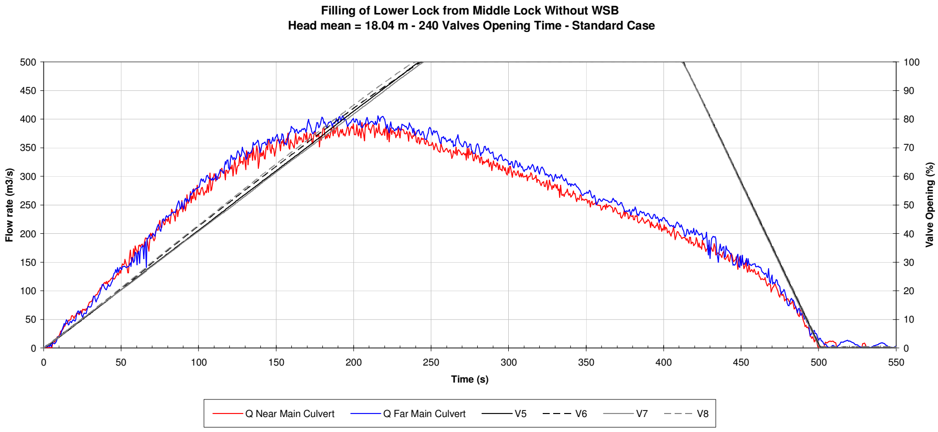
Setting the course

Measurements carried out

Discharges in the main culverts measured with ultra-sonic external flow meters



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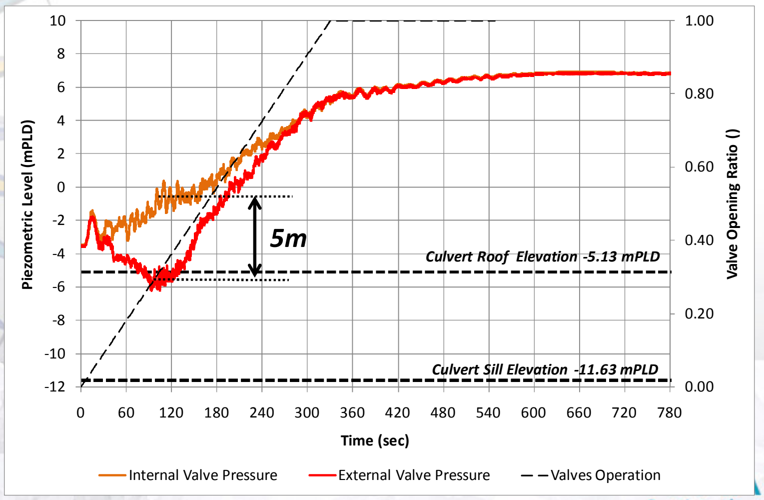
Setting the course

Measurements carried out

Pressure measured downstream of the valves with pressure transmitters



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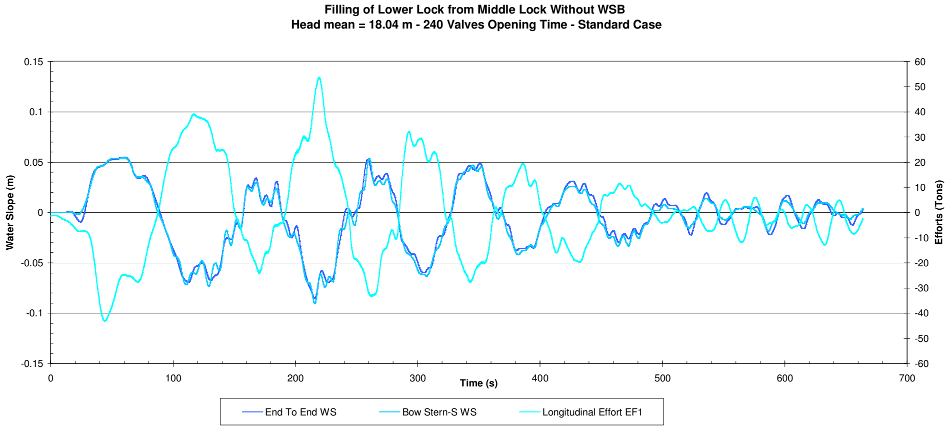
Measurements carried out

Water slopes measured with differential water level sensor
Forces measured with dynamometers



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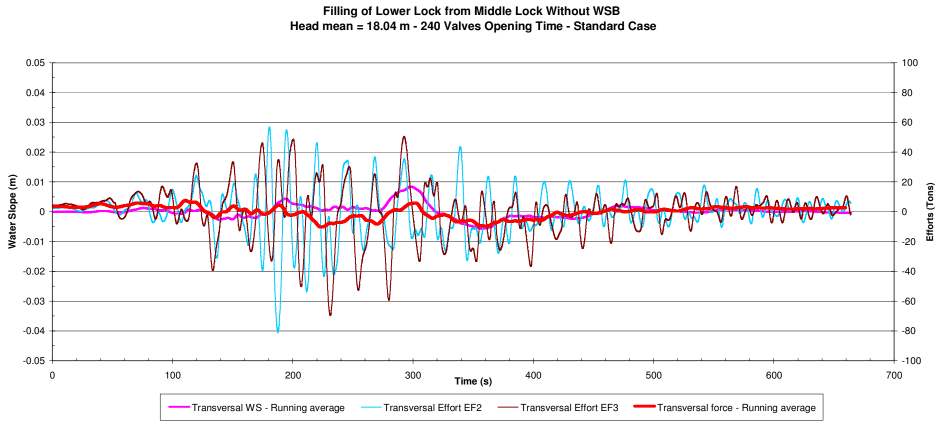
Setting the course

Measurements carried out

Water slopes measured with differential water level sensor
Forces measured with dynamometers



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Ship models

12 000 TEU container ship
(170 000 T displacement weight)

8 000 TEU container ship
140 000 T displacement weight

Dry Bulker
(87 500 T displacement weight)

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Examples of combined of physical and numerical models

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Calibration of the 1D numerical model

- The Numerical model (in scale dimensions) was validated with the Physical model observations

  → Comparison of water level, discharge and water slope time series between each model

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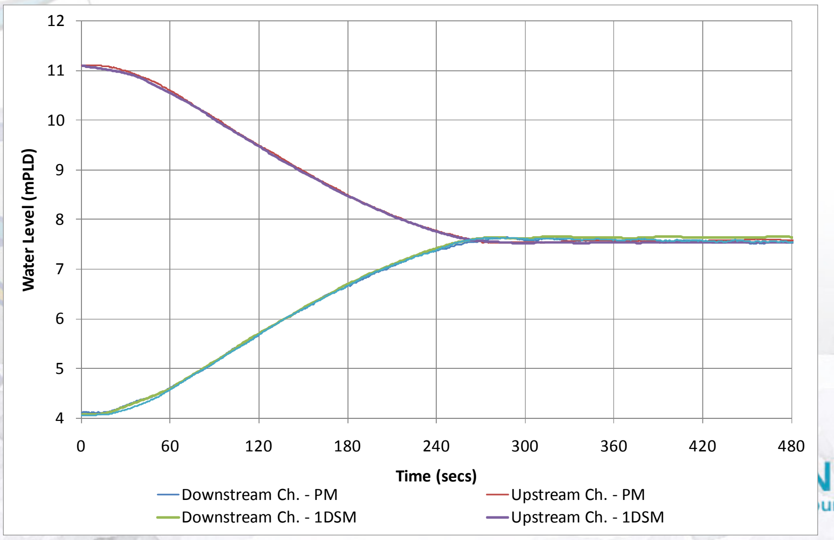
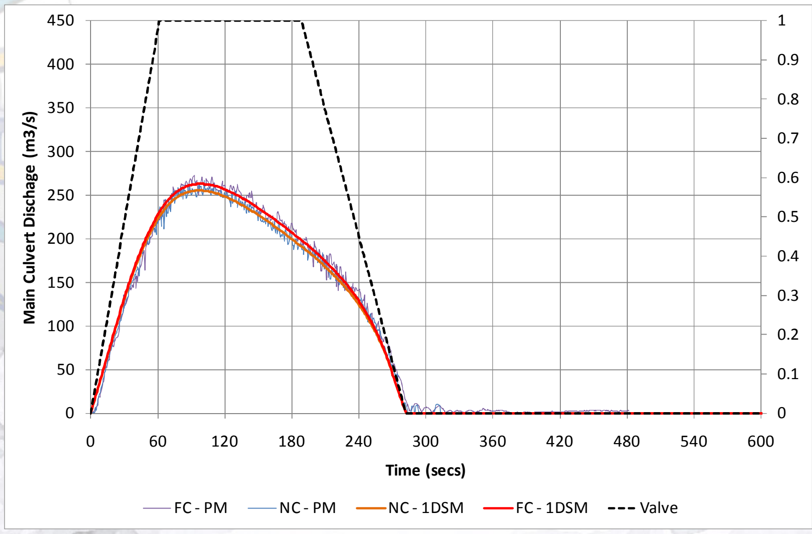
Comparison Physical/Numerical Results
Water levels

Lock - Lock Operation – Filling – Initial Head 13.5m
Standard Gates Configuration



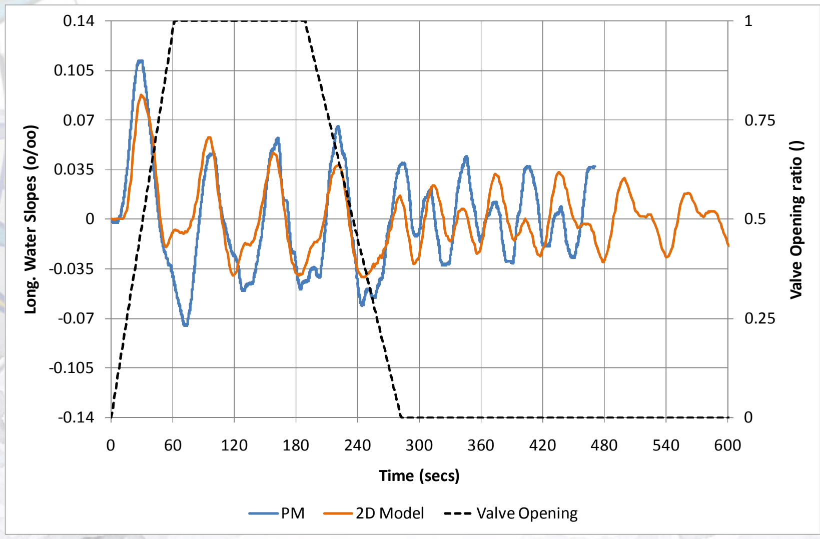
Comparison Physical/Numerical Results Discharge

Lock - Lock Operation – Filling – Initial Head 13.5m
Standard Gates Configuration



Comparison Physical/Numerical Results Longitudinal water slope

Lock - Lock Operation – Filling – Initial Head 13.5m
Standard Gates Configuration



Calibration of the 1D numerical model

- The Numerical model (in scale dimensions) was validated with the Physical model observations

  → Comparison of water level, discharge and water slope time series between each model

- After its calibration, it has been used to set the valve opening/closing schedules in a very efficient way (especially for the special operating conditions)

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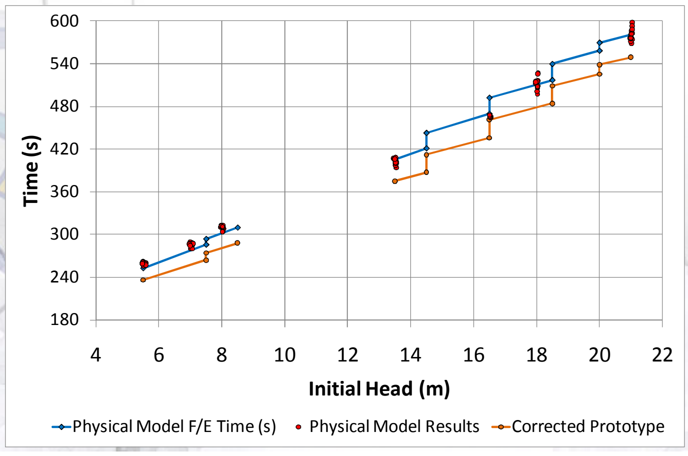
Scale Effects - Filling/Emptying Times & Discharge

- The Numerical model (in scale dimensions) was validated with the Physical model observations
- A numerical model in prototype dimension was constructed
- Differences due to scale effect were calculated (Times, Discharge)



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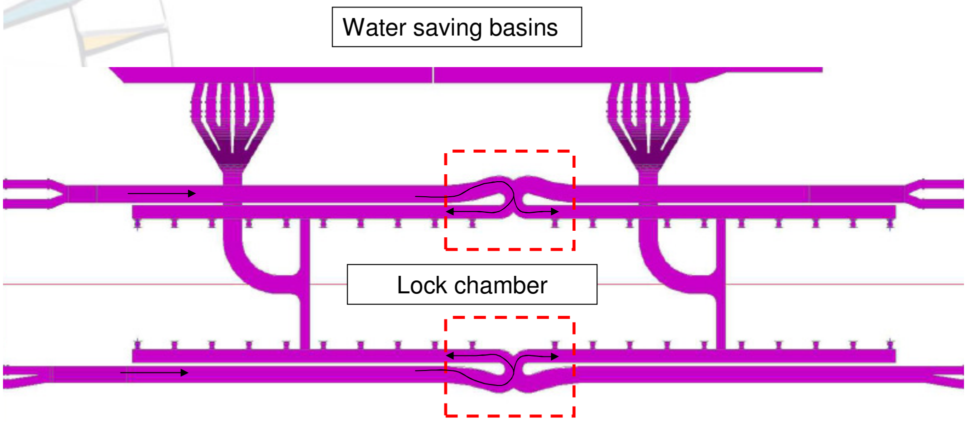
Central Connection design

The central connection is the core of the F-E system:



It must ensure a balance flow distribution between the two secondary culverts

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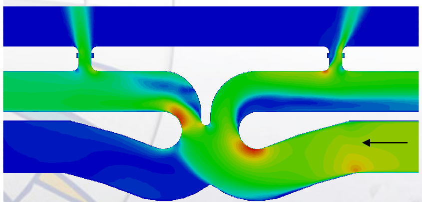
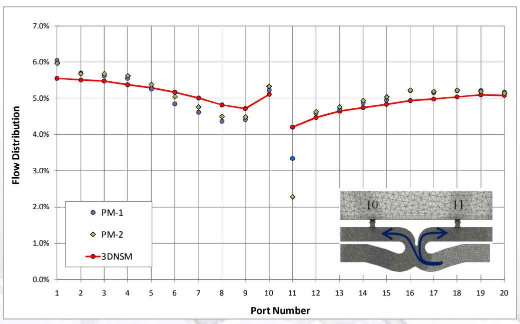
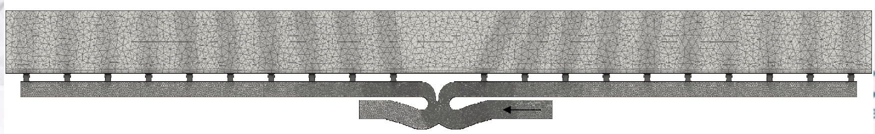
Central Connection design

- The central connection was optimized and the numerical results were validated with the Physical Model observations

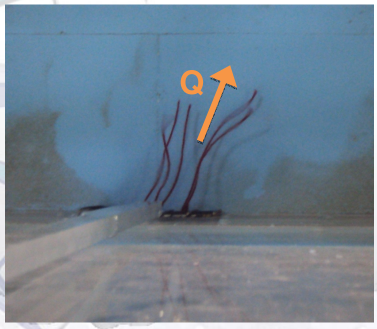


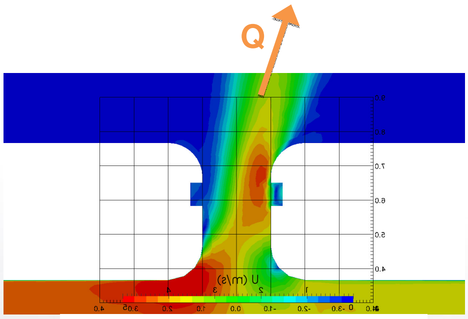


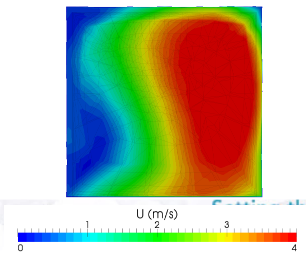


Secondary culvert Flow Distribution

- The numerical model results were used to obtain the flow distribution in each port to assist the measurements on the physical model of the flow distribution along the manifold







NC
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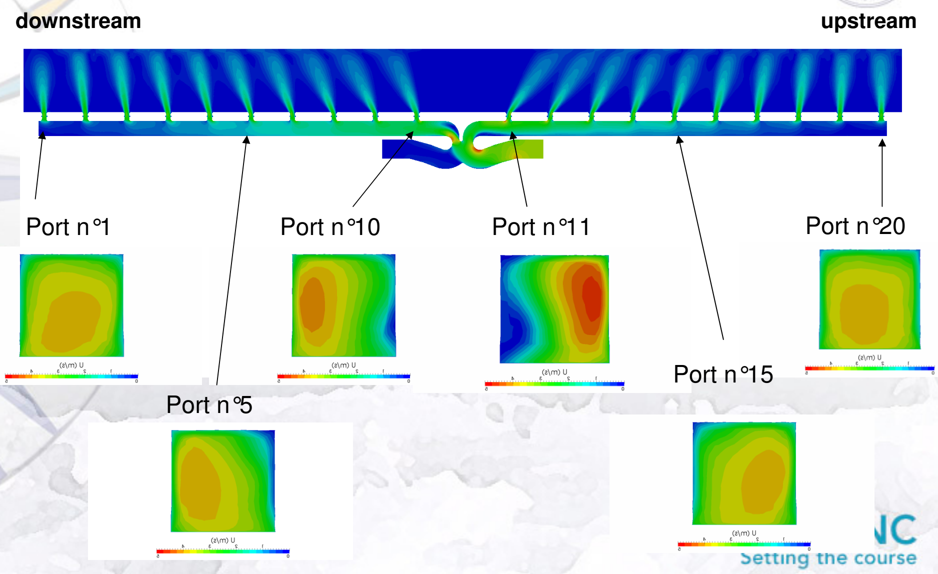
Secondary culvert Flow Distribution

Velocities distribution along and across the ports



NC
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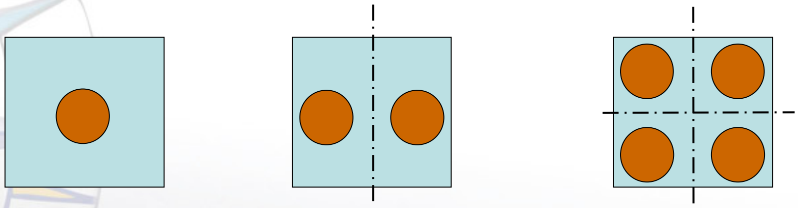
Secondary culvert Flow Distribution

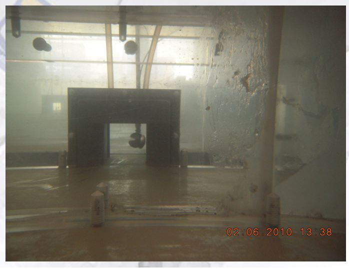
- The numerical analysis allowed to select the most suitable position for the propeller and the number of measurements to be carried out in one section

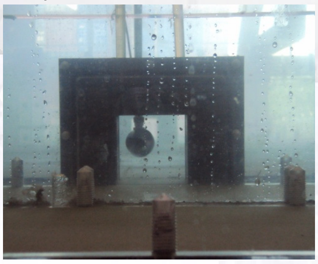


1 measurement centered

2 measurements centered in each half port section

4 measurements centered in each port's quarter





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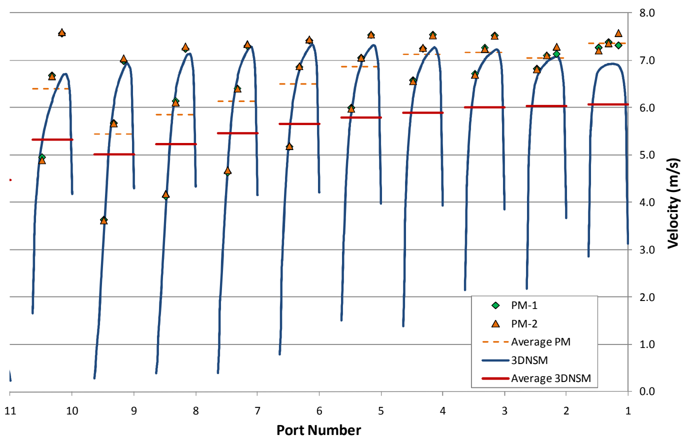
Manifold Flow Distribution

- The correlation was satisfactory

Physical Model measurements vs. Numerical Model



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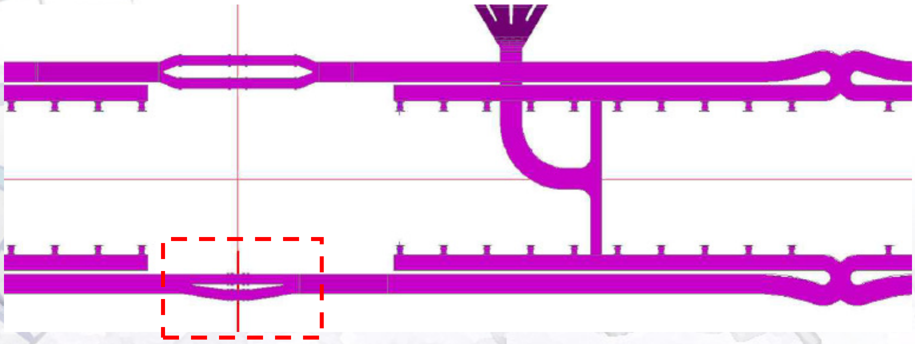
Culvert Valves – Air entrainment problems

- Due to time constraint some parts were first tested on the physical model
- One of the designs presented a high asymmetry and a insufficient submergence producing an air entrainment problem in a culvert valve



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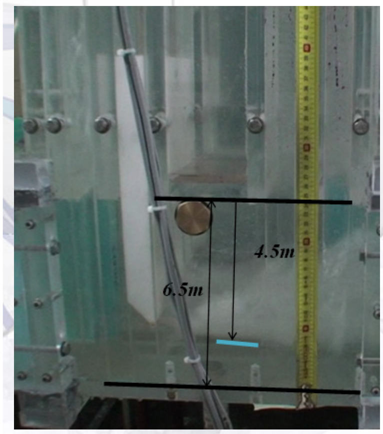
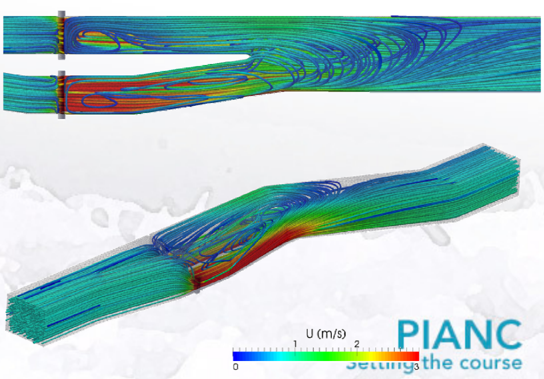
Culvert Valves – Air entrainment problems

- Due to time constraint some parts were first tested on the physical model
- One of the designs presented a high asymmetry and a insufficient submergence producing an air entrainment problem in a culvert valve
- The problem was studied and represented numerically





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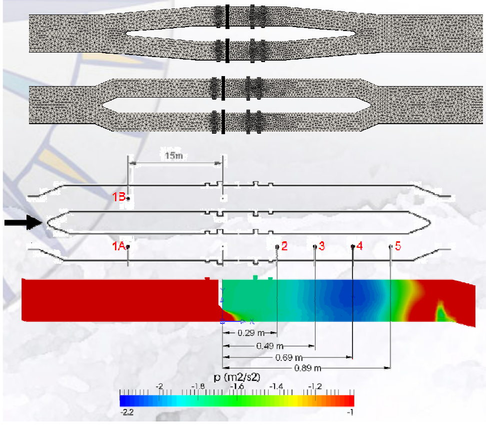
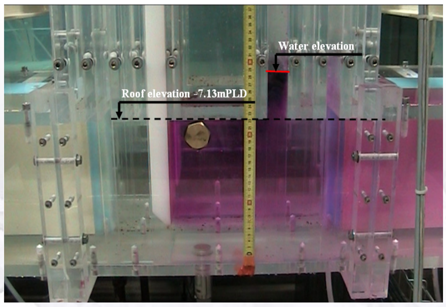
Culvert Valves – Models interaction

- Different alternatives were tested with the validated Numerical Model
- The goal of the new design was a symmetric distribution of the flow in the culvert valves and to prevent the air entrainment
- The new design achieved numerically was successfully tested in the Physical Model
- Also scale effects were estimated. The prototype is a worse condition.





New Design test

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Conclusion

- The studies to define the Final Hydraulic Design of the Panama Canal Expansion Project required the simultaneous implementation of several numerical models performed in Buenos Aires Office and a scale physical model performed in a laboratory located in Lyon, France.
- The combined use of Physical and Numerical models has demonstrated its full efficiency (results accuracy & time saving) through the modification of some system elements
- Efficient cross-check of the data on both models - Support – Complementary – Validation
- Assessment of the model and prototype performance (Scale effects)
- Due to recent progresses, the numerical modeling is mature enough to complement the traditional approach based only in the use of physical modeling. Each one provides different advantages, allowing to overcome the characteristic limitation of the other. The combined use of these two types of models becomes an efficient way of predicting the behavior of the final project.

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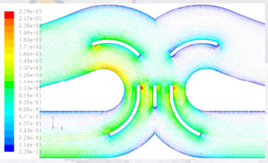
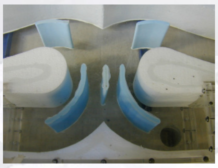
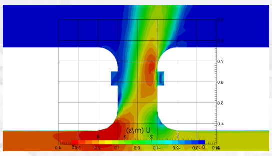
Workshop Part 1

"What's new in the design of navigation locks"

Numerical simulations and experimental models:

the experience of the new Panama model

Sébastien Roux CNR, France
Nicolás Badano MWH, Argentina


Thank you !

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Paper 2-1 **INNOVATIONS IN NAVIGATION LOCK DESIGN**
General Presentation of the PIANC Report n°106 on Locks (2009)
Ph. RIGO (BE) and P. HUNTER (UK),

What's new in the design of navigation locks?

PIANC Workshop
13-14th September 2011

Introduction to PIANC Report 106
INNOVATION IN NAVIGATION LOCK DESIGN

Ph RIGO Univ of Liege- ANAST, Belgium
P HUNTER HR Wallingford, UK

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PIANC WORKSHOP
–
What's new in the design of navigation locks?
–
13 -14 September 2011
New Orleans

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WG29: Lock Innovations

BODEFELD Jorg (DE)
BOS Jan (NL)
CLARKSON John (USA)
DALY Fabrice (Fr)
FERNANDEZ (Spain)
HIJDRA Arjan (NL)
HIVER Jean-Michel (BE)
HOLM Olli (Fin)
HUNTER Peter (UK)

MILLER Dale (USA)
PECHTOLD Erwin (NL, YP)
POLIGOT-PITSCH S. ➔
PICHON N. (Fr) YP
RIGO Philippe (BE), Chair
SARGHIUTA Radu (RO)
TARPEY Michael (USA, YP)
THORENZ Carsten (DE)
WONG Juan (Panama)
WU Peng (China)

Support Groups:
US, NL, BE, Fr, Brazil

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LOCK INNOVATIONS

The PIANC report n° 106 (2009):

- Complements the PIANC 1986 report.
- Targets innovations and changes occurring since 1986

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LOCKS: INNOVATIVE TOPICS

Hydraulics (filling and emptying),
Operations and Maintenance,
Environmental,
Design (concrete, foundations, gates, etc.),
Construction Methods,
Equipment,
…..
Design concept : Cost-Effective, Reliable,….

WG29 – Navigation Locks

- Locks are key structures for the development of commercial and leisure navigation in rivers and canals.
- Locks are also strategic infrastructure for seaport development.
- In low-lying countries, locks have an important function in flood defence.

Innovation applies to the big and fast…

GERMANY

New,
Cost-Effective
Reliable,
Sustainable….

PANAMA

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… and the small and slow…

UK (in 1720!)

Renovation
Rehabilitation

FR

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WG29 LOCK INNOVATIONS

Major changes in design since 1986 concern:

- Maintenance and Operation aspects,
- New goals at the conceptual design stages of a lock
  - ➔ RELIABILITY , LIFE CYCLE COST, …
- Renovation and rehabilitation of existing locks are also key issues for the future.

DESIGN AND OPTIMIZATION GOALS

- Reliability - system, structures and operations,
- Reduced duration of a lock cycle times,
- Reduced water motions and mooring forces
- Minimum water use ➔ Water Saving Basins
- Reduced saltwater intrusion
- Minimum life cycle cost
- Minimum energy use
- Minimum negative impacts – environment, navigation and local community
- Safety and Security

Early design stage

Key points at Early Design Stage are:

- Lock layout & Lock dimensions ,
- Life cycle of a lock ,
- Construction Methods,
- Layout of hydraulic system,
- Lock structure concepts ,
- Salt water intrusion, Ice Control,
- Communication,
- Security and Safety

DESIGN PRINCIPLES

"Risk based design" versus "Deterministic approach"

"Life cycle cost optimisation" versus "Least construction cost"

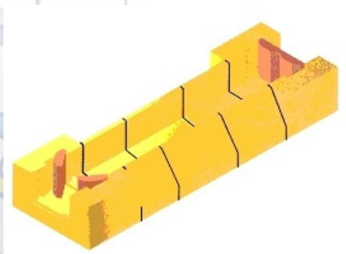
Use of "Numerical Modelling" as design tool (combined with physical model)

Complementarities between modeling

STEP	PHYSICAL MODEL	NUMERICAL MODEL
1	Definition of the problem: Identify essential acting forces	
2	Formulate similarity requirements	Formulate sets of equations
3	Formulate boundary conditions	
4	Construct model	Develop numerical solution scheme
5	Calibrate model	
	Variation of roughness	Variation of coefficients
6	Measurements & solution	Calculation and solution
7	Optimize solution according to problem formulation	
	Model geometry variations	Variation of input data
8	Transfer results from model to prototype and verify by field measurements	

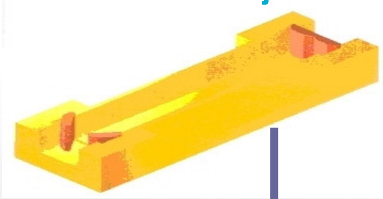
Monolith Locks

Standard Concept With dilation joints

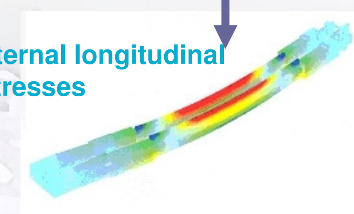


No internal longitudinal stresses

Monolith Concept Without dilation joints



Internal longitudinal stresses



LAYOUT OF HYDRAULIC SYSTEM

Hydraulic systems for filling and emptying locks can be divided into two types:

➔ Through the heads
➔ Through longitudinal culverts

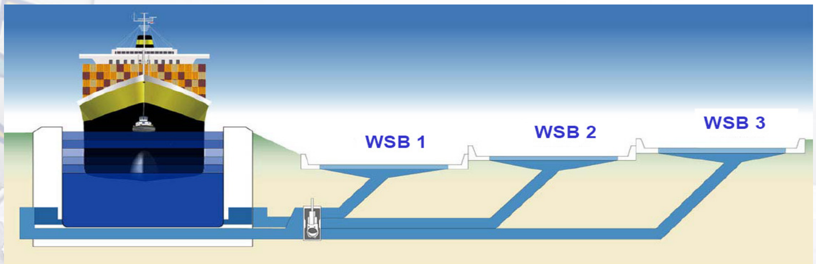
LAYOUT OF HYDRAULIC SYSTEM

Typical layouts of Longitudinal culvert system:

Wall culvert side port system
Wall culvert bottom lateral system
In-Chamber longitudinal culvert system (ILCS)
Longitudinal culverts under the lock floor
Dynamically balanced lock filling system
Pressure chamber

Water Saving Basins (WSBs) (Standard Concept)

Locks with separated WSBs
(located on one side or both sides of the lock,
on a series of steps)



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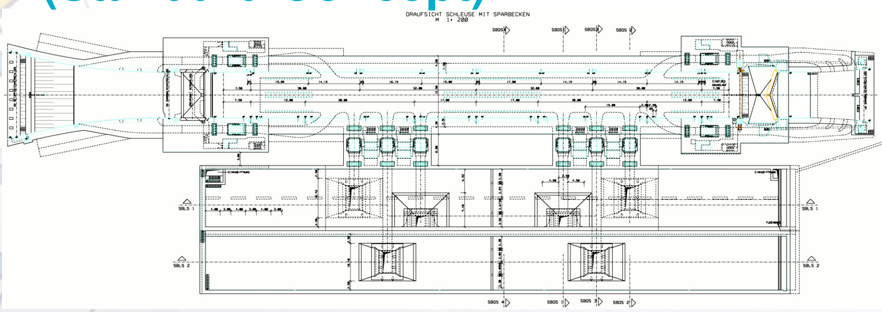
Water Saving Basins (WSBs) (Standard Concept)



Lock with Water saving basins located on
the side of the lock
- Standard concept

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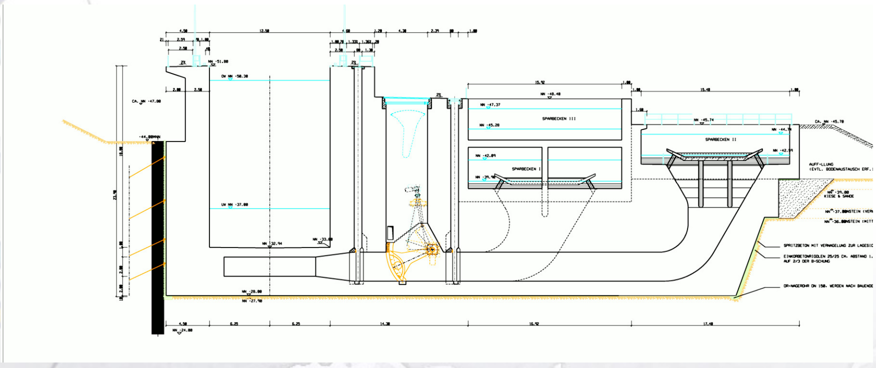
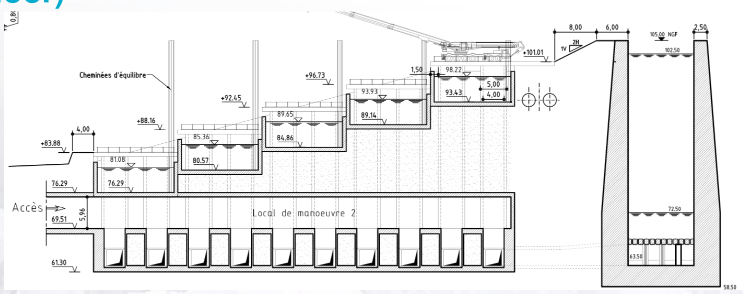
NEW LAYOUTS OF HYDRAULIC SYSTEMS



Connection of pressure chamber to WSBs basins (upper) and to main chamber (lower)➔ Germany

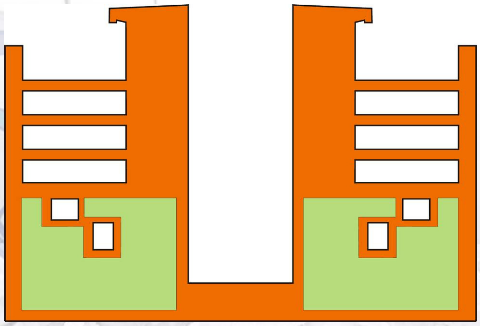
Water Saving Basins (WSBs)

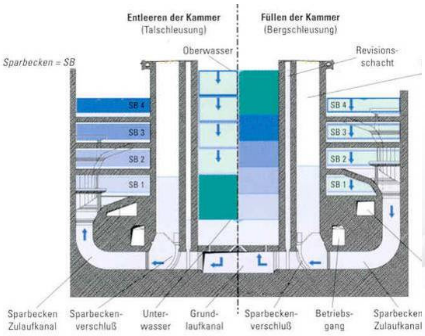
Cross-sections in a lock with 5 standard laterally located Water saving basins
(filling through the pressure chamber in the lock floor)



Integrated WSBs

The integrated system which integrates the WSBs in the two side walls, and makes the lock structure more stiff, compact and less land consuming.





Lock sidewalls with integrated WSBs

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New Lock Concepts

BAW – By C Thorenz

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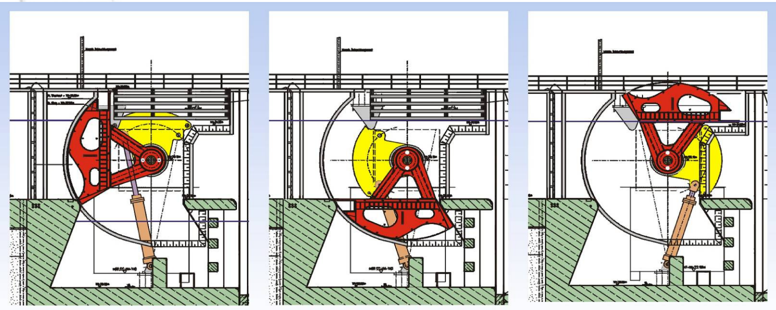
GATES AND VALVES



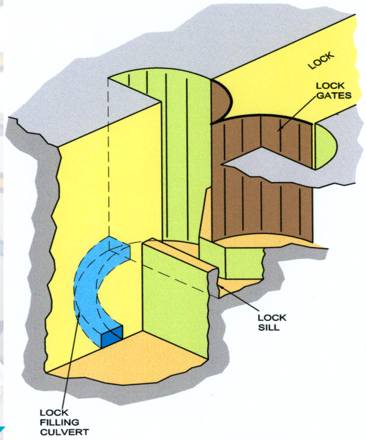
INNOVATION IN LOCK GATES

Filling & Emptying System

BAW

Upper gate at lock Lisdorf (D)

Innovative F/E Systems



UK

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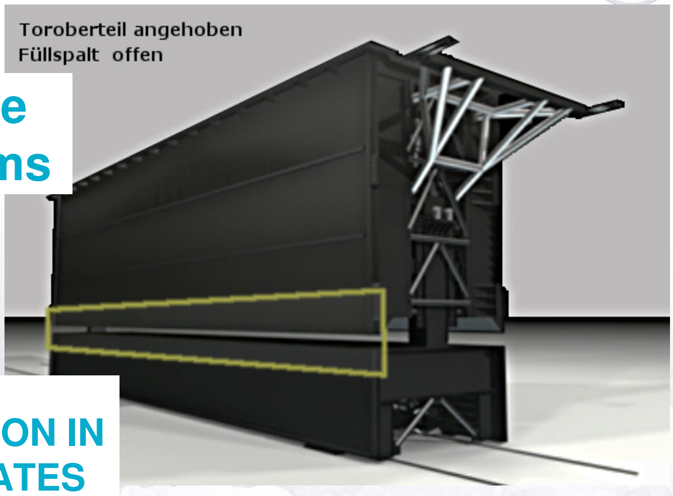
Kaiser lifting and sliding lock gate

Innovative F/E Systems



INNOVATION IN LOCK GATES

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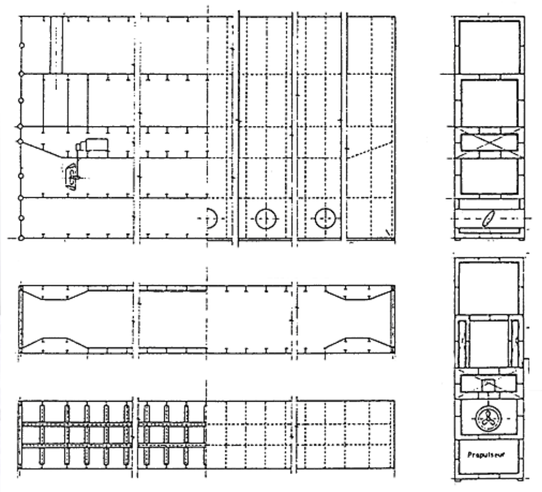
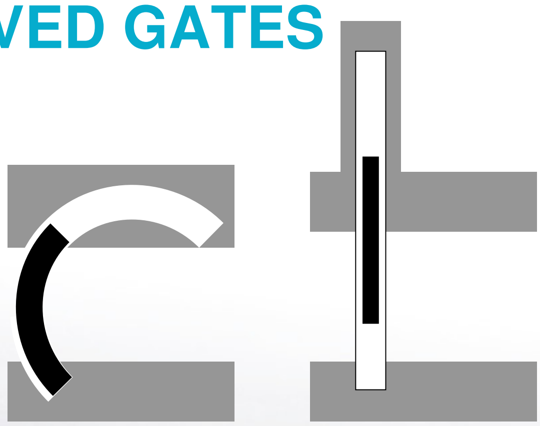
Self-Propelled Floating Lock Gate (up to 70 m long)

INNOVATION IN LOCK GATES



ANAST
ULG
(Belgium)

CURVED GATES



An innovative concept for a special requirement : SPACE

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GATES AND VALVES

MITER GATES

➔ Folded plates (low Cost)

➔ Support on 4 edges

➔ Cylinder on the dowstream side
- ➔ Protected against shock
- ➔ In the dry

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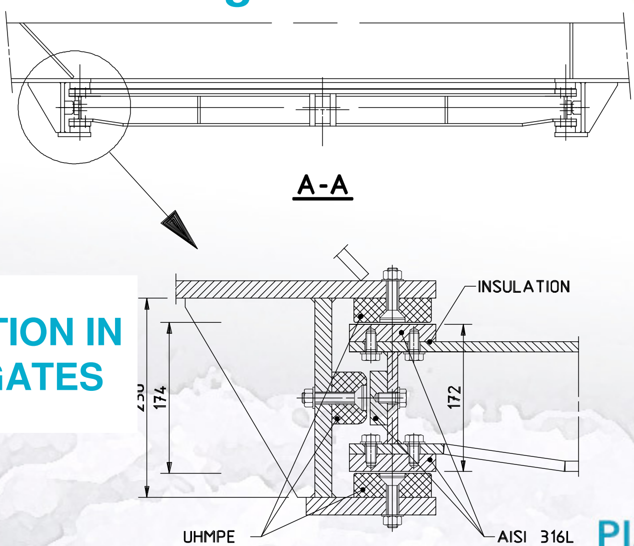
UHMPE sliding Gate/ Valves



INNOVATION IN LOCK GATES

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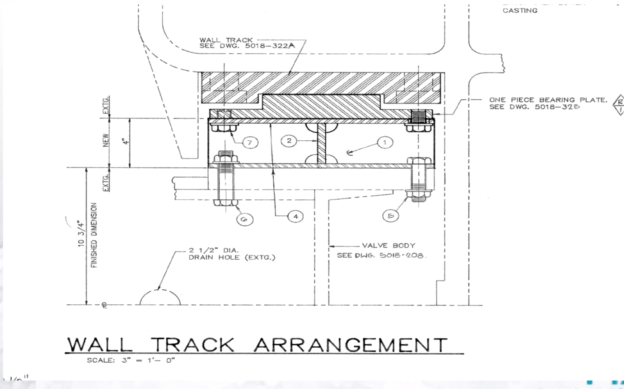
Mechanical devices

Sluice : Sliding vertical lift gate

UHMWPE : Ultra-high molecular weight polyethylene

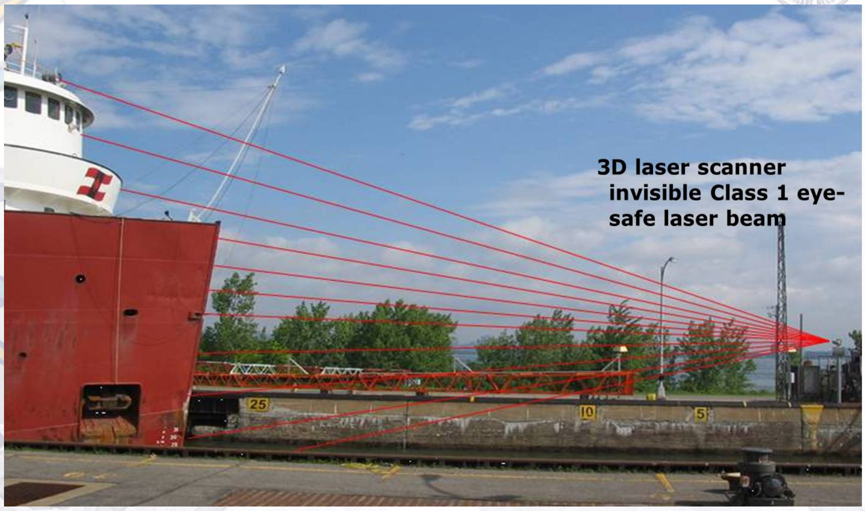


Vacuum Mooring System

- Canada -
Welland Canal

INNOVATION IN MOORING DESIGN

SHIP POSITIONING SYSTEM (Canada – Welland Canal)

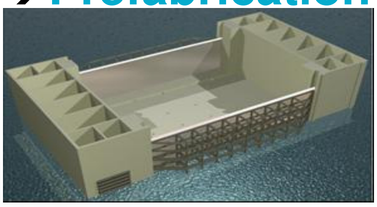


Construction Methods

The lock chamber is constructed on the ground surface.

When completed the soil is removed beneath the lock chamber and it is lowered into its final position.

➔ **Prefabrication**



InCom WG 29 CONCLUSIONS

Current Trade off problems in Lock Design:

- "HIGH RELIABILITY" is often associated with "PROVEN TECHNOLOGIES" (in lock design)

  If true ➔ Is it a the place for innovation in lock?

  WG29 ➔ Yes. Innovation is required to reach highly reliable infrastructures, to reduce cost (construction mode), fulfil new requirements (fast locking), non standard dimension,…

  Do not be afraid by innovation.

  ➔ Promote innovation.

- "RELIABILITY" versus "COST" (in lock design)

  Lock design is highly "Project Dependent".

  Ex: "Panama Canal" versus the "Renovation of a small pleasure lock in Finland"

INNOVATIONS IN LOCK DESIGN

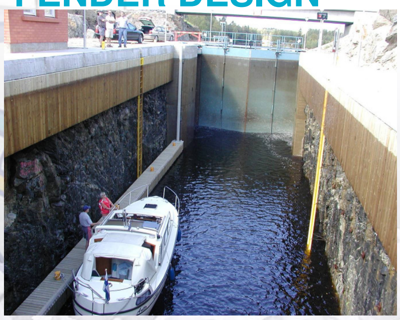
➔ Some more EXAMPLES

Experiences of Innovation

- Mooring
- Fendering
- Lock Chambers - structural design
- Lock Gates
- F/E Systems
- Automation, self-operation
- Life Cycle Management
- Safety

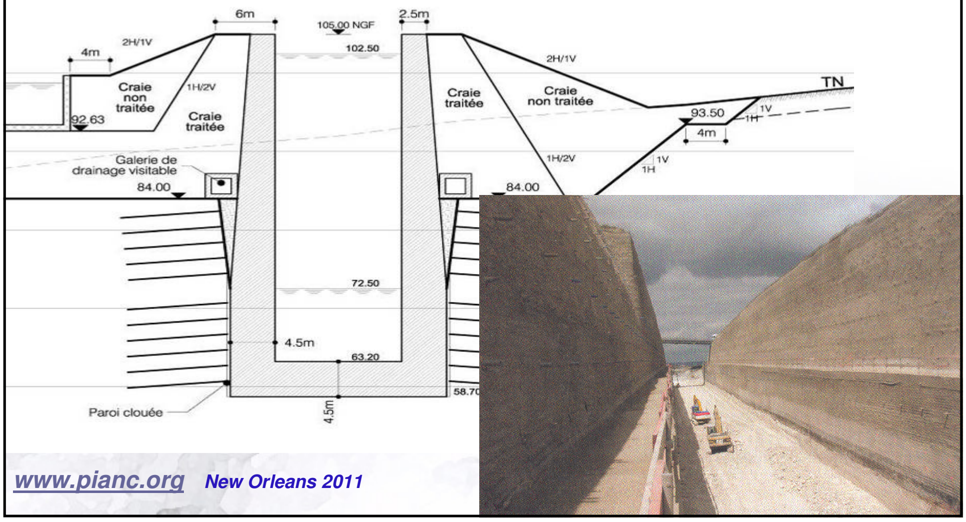
Floating Mooring Pontoons

INNOVATION IN MOORING & FENDER DESIGN

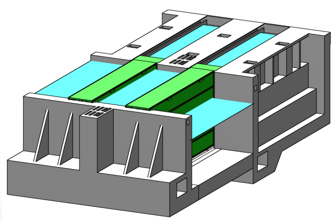


INNOVATIVE LOCK STRUCTURES

SNE - FRANCE



Third lane of locks - Panama Canal

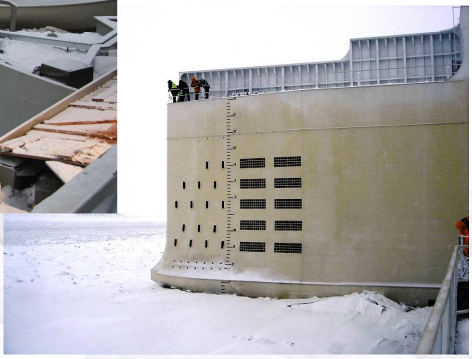


INNOVATION IN
all aspects of
LOCK DESIGN

Experiences with Giant Gates

Experiences with Giant Gates

Experiences with Giant Gates



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Experiences with Giant Gates

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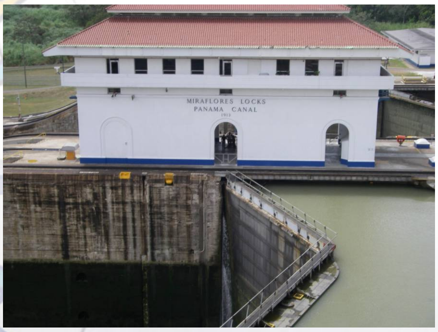
Life Cycle Management



PIANC

MarCom

Report WG42 – August 2007

Life Cycle Management of Port Structures
Recommended Practice
for Implementation

LCM is aimed at providing minimum Whole Life Costs.

dealt with in MarCom-WG42

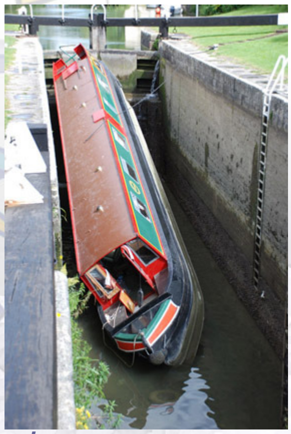
Life Cycle Management of Port Structures (August 2007)

Life Cycle Management

- Design for minimising operating & maintenance costs
- Design for minimising downtime
- Design for minimising whole life costs
- Maintenance Management

SAFETY

Locks are safety-critical structures



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Safety

Safety in design is increasingly important.

We are all more risk conscious, and are in a more litigious society.

The Report discusses protection of
- People (users, operators, bystanders)
- Locks
- Ships

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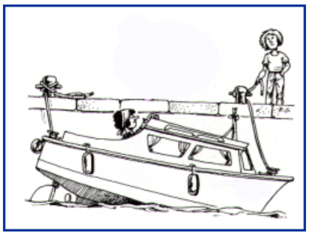
Safety

Standards of yesterday might not be sufficient today

Public access – or not?

Safety



Prevent Accidents

SAFETY

Safety in design is increasingly important.

We are all more risk conscious, and are in a more litigious society.

The Report discusses protection of

- **People (users, operators, bystanders)**
- **Locks**
- **Ships**

Water Edge Safety Classification

The Report includes

- Classification of types of water edge structure
- guidelines for suitable safety treatment for each category

PIANC Report No 106
Innovation in Navigation locks

The 2009 report…

- Described lock innovations since 1986
- Recommended good practice
- Provided a basis for future innovations

This Workshop …

- Describes and develops further innovations
- …

NEW and FUTURE

PIANC WGs

1) WG 154
" Miter Gate Design and Operation

2) WG 155
"Ship behaviour in locks and lock approaches" , Chairman C Thorenz

3) Any ideas ?

STATE OF ART OF THE NEW SLIDING GATE USING UHMWPE

UHMWPE :
Ultra-high molecular weight polyethylene

Salt Water Intrusion

1) Need system to avoid/reduce salt water intrusion

➔From low cost (air screen, …)

➔High efficiency (Full salt water exchange system)

➔ Need for innovative filling and emptying systems

2) HOW TO ASSESS (forces on gates, on ship, current, manœuvrability, …)

Paper 2-2 **A SELF-CONTAINED HIGH-LIFT LOCK WITH WATER-SAVING BASINS**
C. THORENZ (D)

What's new in the design of navigation locks?

PIANC Workshop
13-14th September 2011

A SELF-CONTAINED HIGH-LIFT LOCK

By C. Thorenz, R. Rother, G. Schulz
BAW, NBA-Hannover
GERMANY

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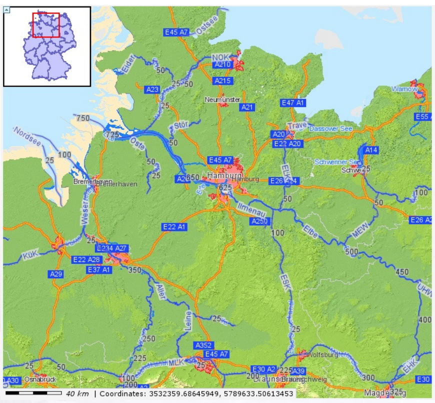
Setting the course

Back in the old days

- In the sixties the planning for the Elbe Lateral Canal started
- It bypasses the river Elbe and connects the port of Hamburg to the German canal network



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Back in the old days

- The total height difference is 61 m: First step of 38 m near the river Elbe, second step of 23 m is located 50 km south of it at Uelzen

- Both a double shiplift and a lock with integrated saving basins were evaluated as solutions for the step of 38 m

⇒ The double shiplift won the race because it is fast …

Some decades later

- Double caissons

- 3 min lift

Today‘s challenges

- The amount of traffic has increased as expected
- But not the number of vessels, mainly the size has grown

=> The double shiplift lost in the end, because it is fast but too small …

Today‘s challenges

- The caissons with 100 m useable length are way too short
- At the next height step at Uelzen, there are two locks with 185 m and 190 m useable chamber length

=> What about a new lock next to the shiplift? Let‘s have a look …

Would an additional lock be the ideal solution?

- A lock would introduce surge waves in the canal
- The shiplift can stand only very small waterlevel variations

=> the waves would change the force balance between caissons and counterweights

- The waves could be reduced by operating the lock very slowly or

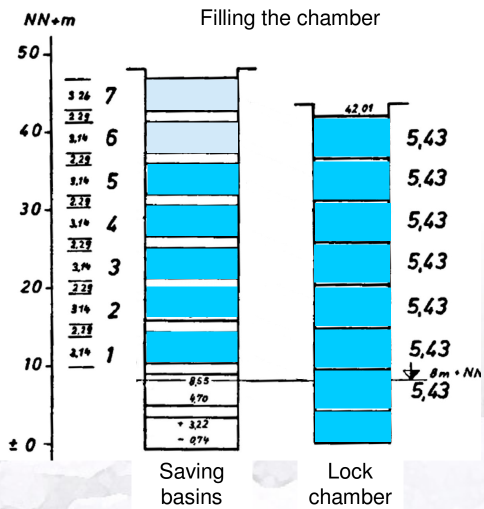
=> Keep all the water inside the lock!

An old idea from the sixties…

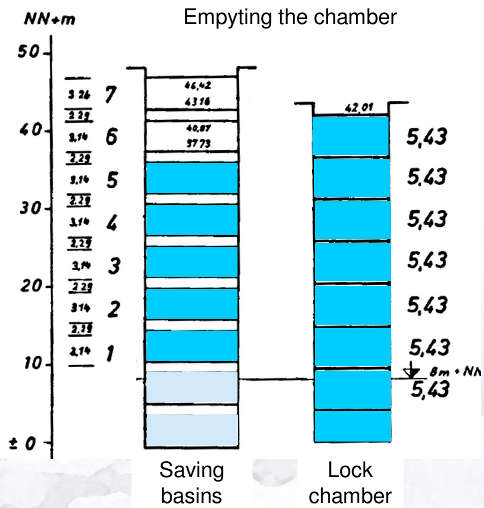
- Many canal locks in Germany are built with water saving basins in order to reduce the required pumping (since a century)
- Why shouldn‘t it be possible to add additonal basins to avoid the exchange of water with the reaches completely?

=> Extension of the well known principle of a lock with water saving basins

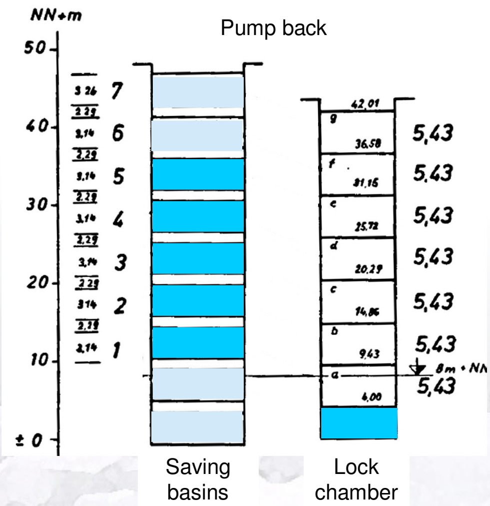
The concept from the sixties



The concept from the sixties



The concept from the sixties



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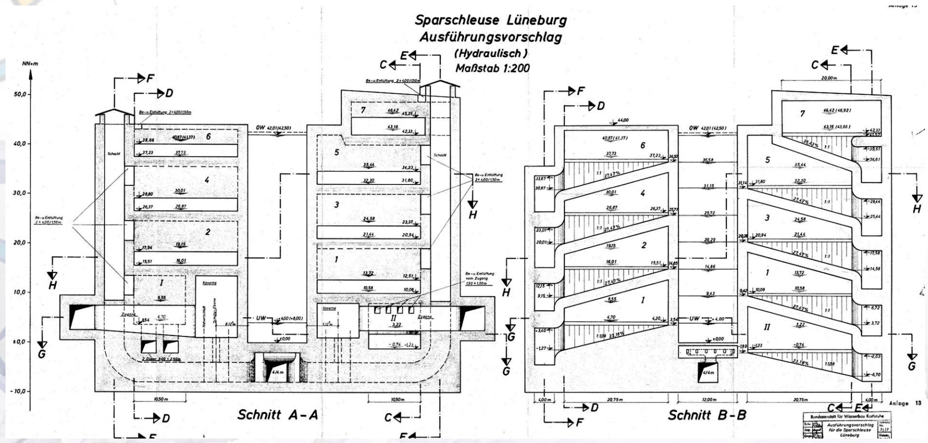
The final concept



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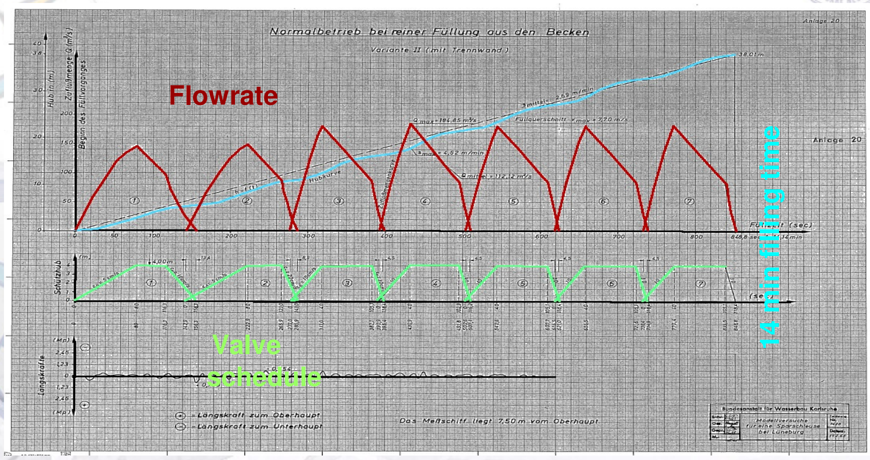
Laboratory model made in 1968

Filling batteries in the chamber

Completed model Sale 1:20

Laboratory model results

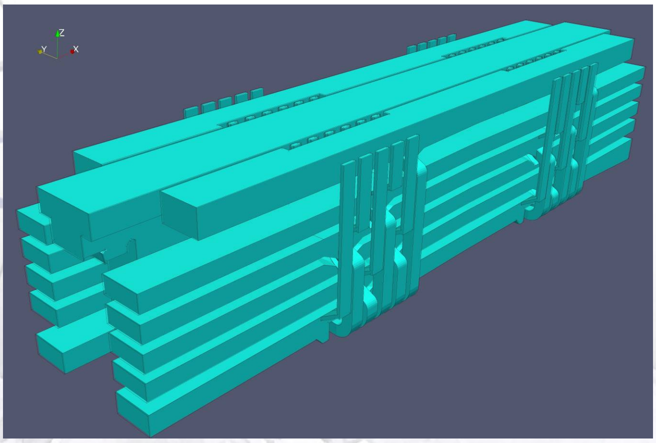


Filling the chamber

Transition to the next millenium: Shifted objectives

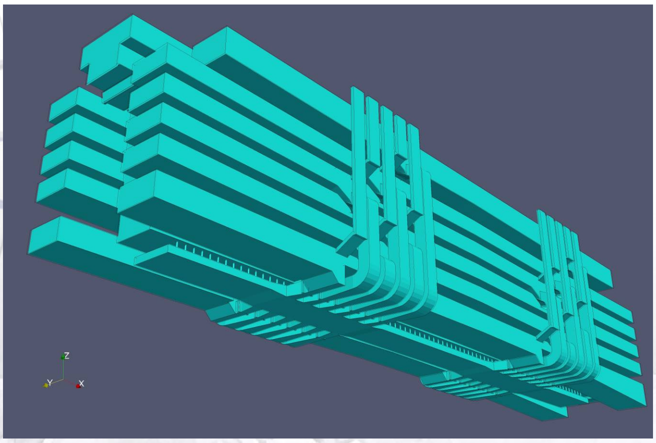
- Pumping costs have increased
- Vessels are larger
- For fast transits, there is additionally the shiplift

New hydraulic design



Hydraulically relevant surfaces

New hydraulic design

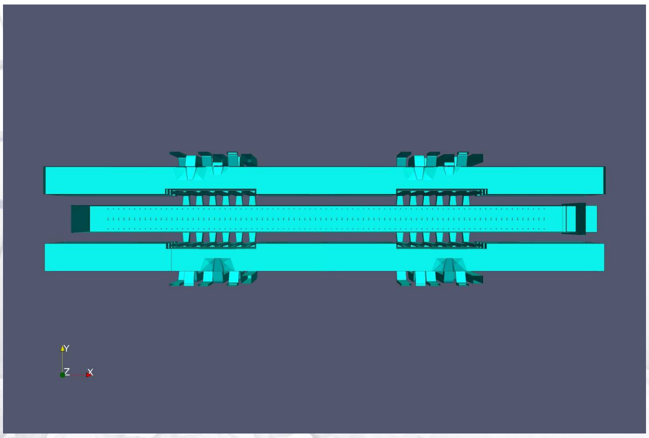


Hydraulically relevant surfaces

New hydraulic design

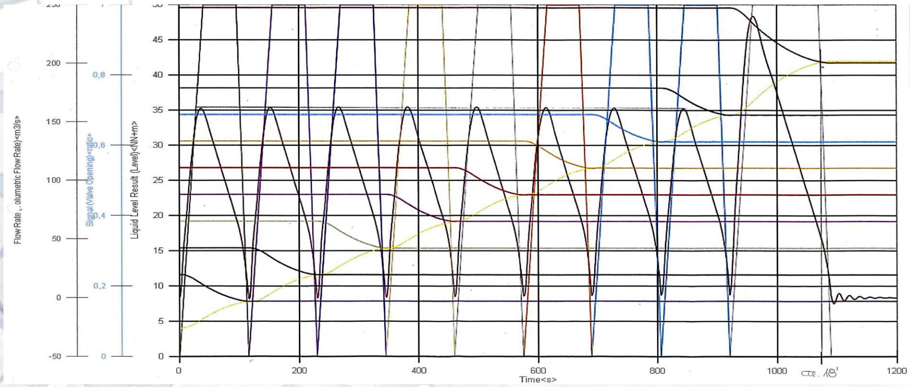
Hydraulically relevant surfaces

New hydraulic design



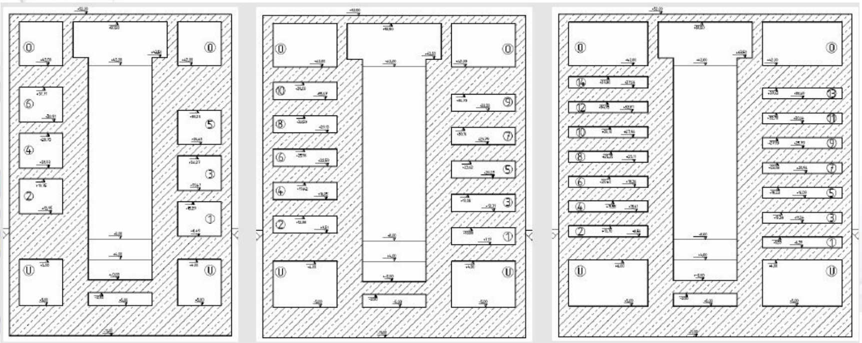
Hydraulically relevant surfaces

Initial hydraulic studies: 1D network model results



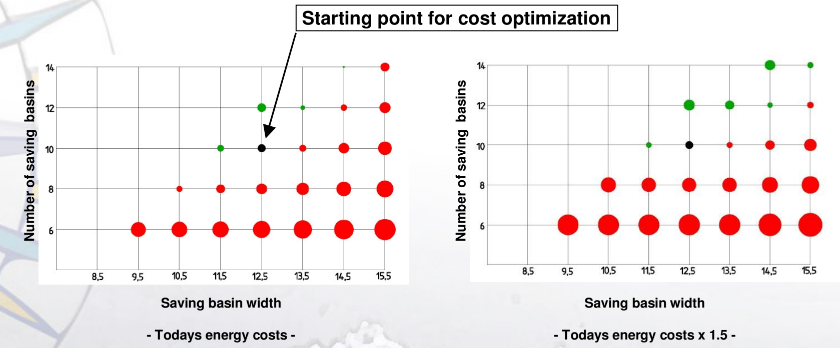
Filling time of 18 min is fast enough

Optimization of the hydraulic concept



Which number of saving basins to choose?

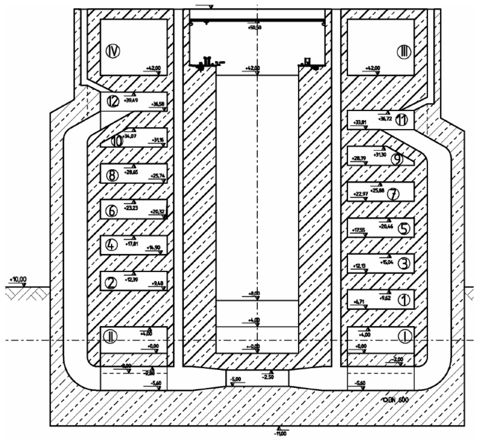
Cost optimization



Increase the number of saving basins: Energy consumption is more important than filling time!

New hydraulic system

- 12 layers of water saving basins
- 2 layers for exchange water
- Filling time increases to 24 min
- Sturdy, fault tolerant construction



Hydraulic studies

- Water hammer on structures
  => Overfilling of saving basins
  => Emergency closing of valves

- Filling time
  => Model values calibrated on lab model “Minden”

- Chamber wave generation
  => Threedimensional flow model for filling system

Conclusions

- A self-contained lock can be a feasible solution, if surge waves in the reaches are a problem

- Optimization goals can shift significantly in a few decades (in the sixties energy costs were much less important)

- The presented system is now to be evaluated by the ministry of transport.

Paper 2-3 **INNOVATION IN LOCK FILLING AND EMPTYING SYSTEMS**

R. STOCKSTILL (USA)

What's new in the design of navigation locks?

PIANC Workshop
13-14th September 2011

Innovation in Lock Filling and Emptying Systems

By R L Stockstill
and J E Hite, Jr
US Army Engineer R&D Center
USA

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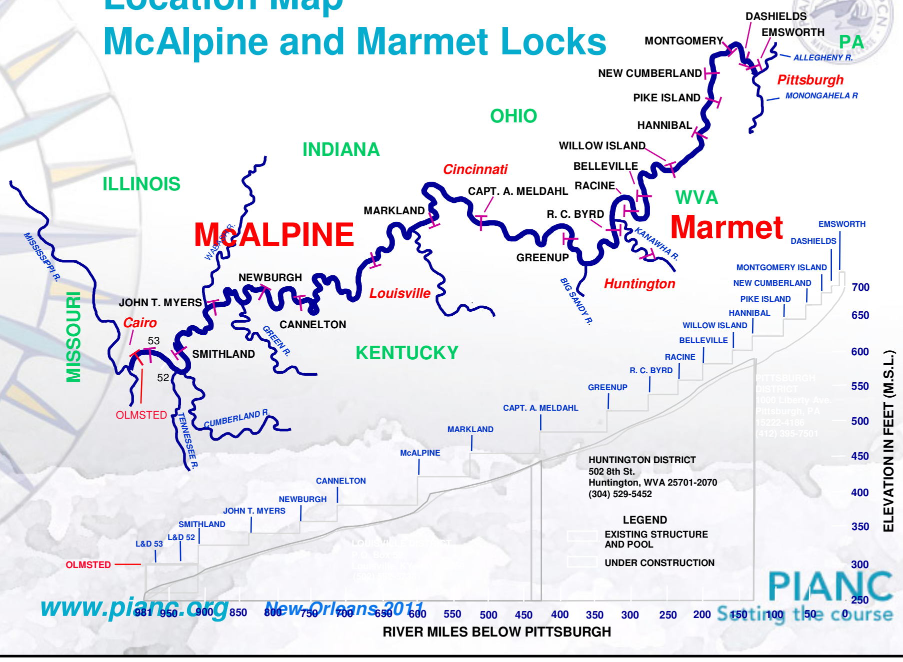
Background

- New lock designs are being considered to save construction, and operation and maintenance costs
- 2 newest locks have used innovative designs
  - New McAlpine Lock, Ohio River
    (11.3m, 37' lift)
  - New Marmet Lock, Kanawha River
    (7.3m, 24' lift)

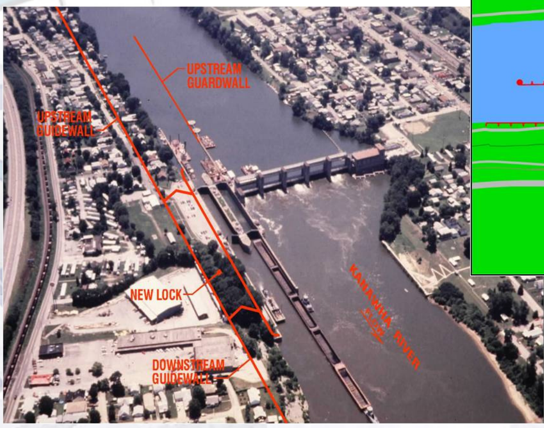
In-Chamber Longitudinal Culvert System (ILCS)

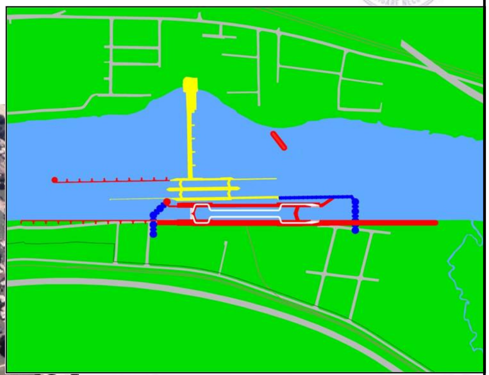
- ILCS design was briefly mentioned at the last PIANC workshop by Mr. Jerry Webb (Paper 5, Part A)
- Today's presentation will
  - Provide details of ILCS design
  - Describe project features found on Marmet and McAlpine ILCS Locks

Location Map
McAlpine and Marmet Locks



Planned Marmet Lock





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Completed Marmet Lock

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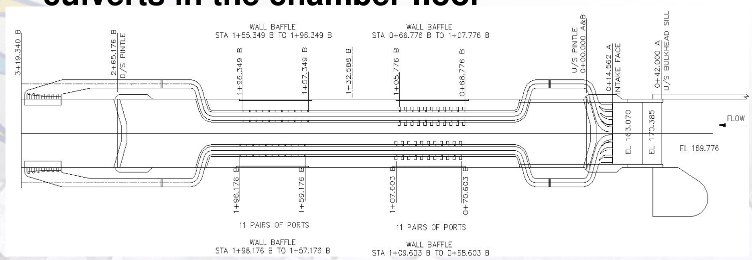
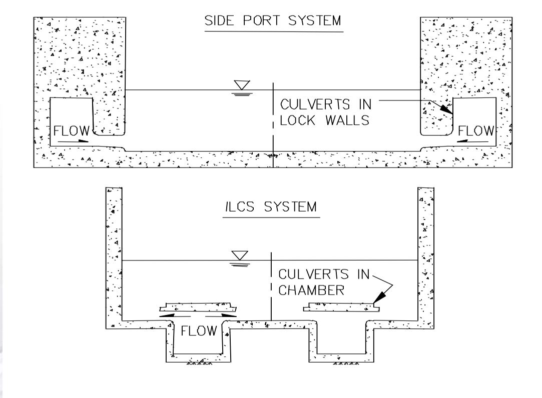
ILCS Design Philosophy

- Develop a system nearly as efficient as the side-port filling and emptying system
- Culverts in the chamber walls are replaced by culverts in the chamber floor



Marmet Lock

ILCS Offers Potential Cost Savings in Wall Construction



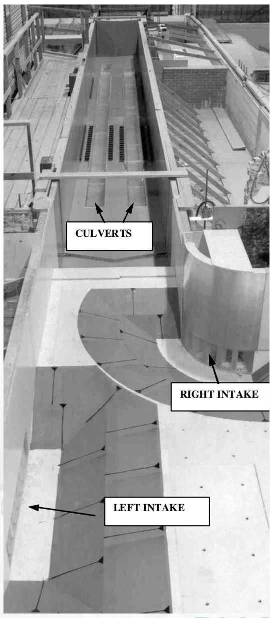
Culvert Locations for the Side-Port and ILCS Filling and Emptying Systems

Side-Port System

In-Chamber Longitudinal Culvert System

Intake Manifolds McAlpine Lock

Layout Fit Existing Conditions



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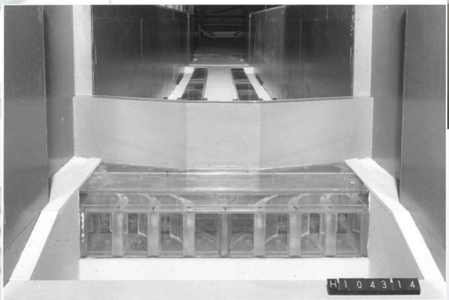
Intake Manifolds Marmet Lock



Through-the-Sill Design Reduced Cofferdam Size

Hydraulic Efficiency: Lock Coefficient

$$C_L = \frac{2A_L\left(\sqrt{H+d}-\sqrt{d}\right)}{A_C\left(T-Ut_v\right)\sqrt{2g}}$$

Where:

C_L = lock coefficient
A_L = plan area of lock chamber
H = initial head (i.e. lift)
d = lock chamber water level over-travel (or under-travel)
A_c = sum of culvert area at each operation valve
T = operational time required to fill (or empty) the lock
t_v = valve operation time
U = valve coefficient ($0.45 \le U \le 0.55$)

Lock Coefficients - Previous Model Studies

Filling: Side Port = 0.73, ILCS = 0.64

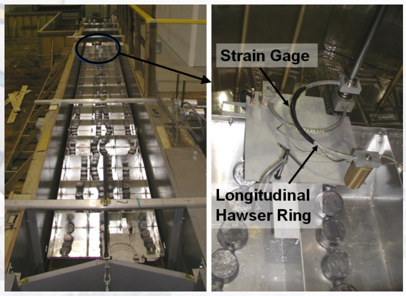
Project	Filling and Emptying System	Initial Head, m	Lock Coefficient		Reference
			Filling	Emptying	
Cannelton Model Type 45 Port Arrangement	Side Port	6.1	0.74	0.57	Ables and Boyd (1966a)
		7.9	0.74	0.60	
		9.1	0.73	0.61	
		12.2	0.74	0.60	
Cannelton Model Type 100 Port Arrangement	Side Port	6.1	0.71	0.56	Ables and Boyd (1966a)
		9.1	0.73	0.56	
		12.2	0.74	0.56	
Arkansas River Model	Side Port	3.0-15.2	0.73	0.67	Ables and Boyd (1966b)
Marmet Model Type 5 Chamber Design	ILCS	4.3	0.63		Hite (1999)
		7.3	0.63		
		10.4	0.63		
McAlpine Model Type 1 Chamber Design	ILCS	11.3	0.63	0.56	Hite (2000)
McAlpine Model Type 11 Chamber Design	ILCS	11.3	0.65	0.57	Hite (2000)

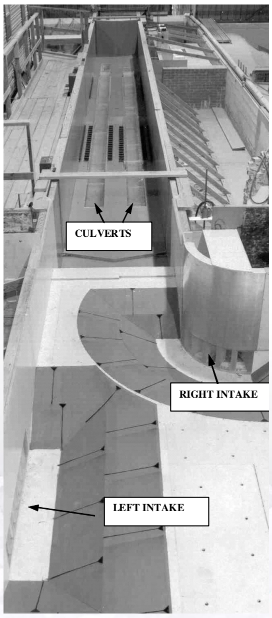
ILCS Manifolds

- Allow for alternative lock wall construction, such as RCC or in-the-wet construction
- Port extensions and wall baffles provide uniform distribution of flow and dissipate energy

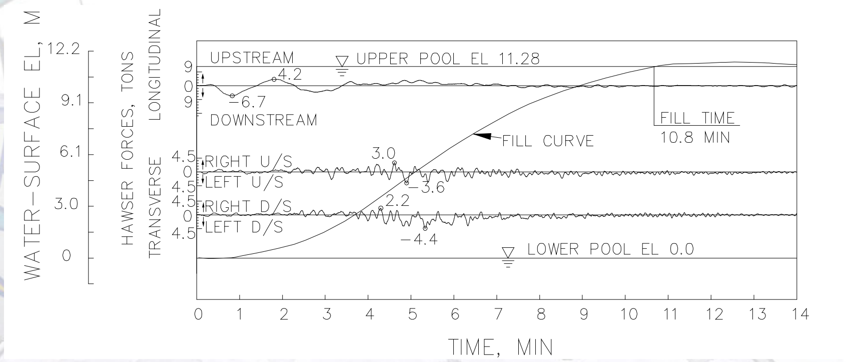
ILCS Research

1:25-Scale Hydraulic Model
- Hawser Forces
- Filling & Emptying Times





ILCS – Filling Characteristics



11.28-m lift, 5.79-m submergence, 5-min normal valve

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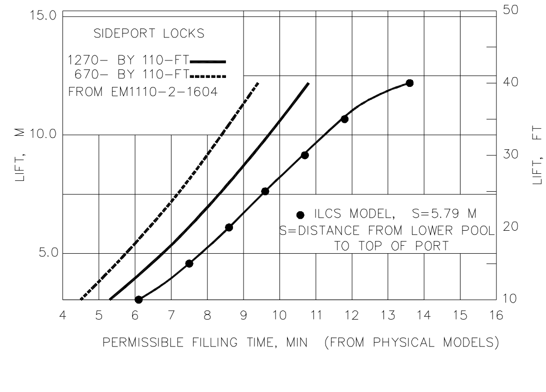
Permissible Filling Times



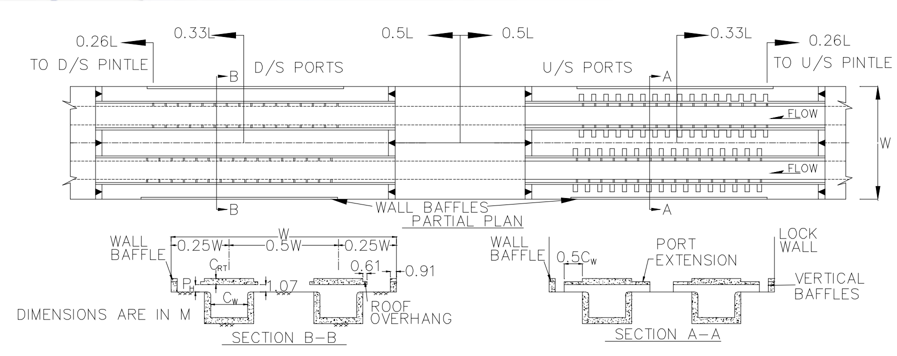
Side-Port System Allows Faster Filling than ILCS

ILCS Design Guidance

Ports:

- Spacing – chamber width dependent (~ 12m)
- Number – port-to-culvert ratio about 0.96
- 2 Groups – at 1/3 points of chamber length
- Extensions – needed on upstream group

Wall Baffles: diffuse port jets near lock floor and inhibit upwelling along walls



Questions?

Marmet Lock, Kanawha River

Paper 2-4 **CONSTRUCTION METHODS**
D. MILLER (USA)

What's new in the design of navigation locks?

PIANC Workshop
13-14th September 2011

Construction Methods

By Dale E. Miller, PE, SE
Tetra Tech INCA
United States

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Lock Construction Methods

- "Conventional"
  - Bypass
  - Cofferdam
- "Innovative"
  - Float-in
  - Lift-in
  - Trestle Construction
  - Local Cofferbox
  - Pneumatic Caisson

Bypass Construction – Panama Canal

Conventional Cofferdam Construction

Conventional Construction Advantages

- Utilize Conventional Construction Means & Methods
- Visual Observation and Measurement of performance and progress
- Visual Observation and Measurement for Quality Control

Conventional Construction Disadvantages

- Additional Costs and Schedule for:
  - Real Estate for Bypass, cofferdam, larger laydown and work areas
  - Impacts to navigation during construction
  - Site Access may be more restricted for material deliveries and construction access
  - Additional environmental impacts because of:
    - Larger construction footprint
    - More construction operations on-site

In-The Wet Construction

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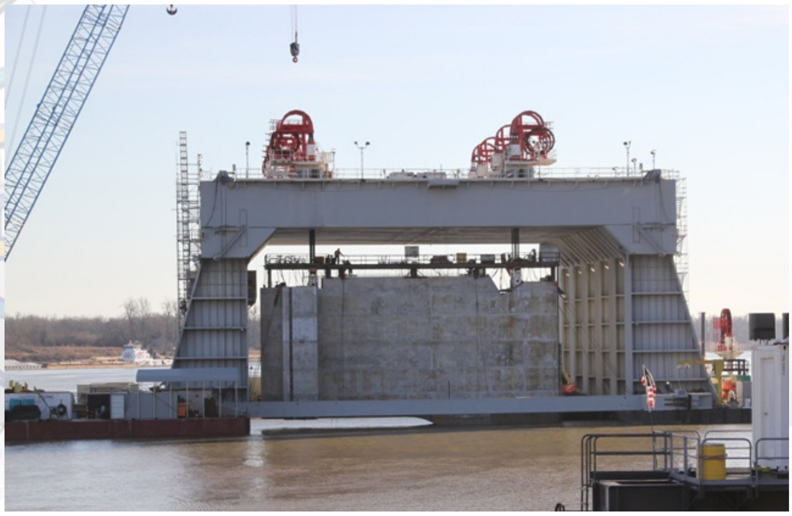
Float-In Construction – Braddock ½ Dam

Lift-In Construction – Olmsted Lower Pier



In-the-Wet Advantages

- Impacts to Navigation reduced
- Fabrication of components can optimize fabrication site to take advantage of:
  - Availability of material
  - Skilled work force
  - Use of common sites – such as commercial graving docks and dry docks
- Reduced time on site minimizing environmental and real estate impacts

In-the-Wet Disadvantages

- Construction tolerances more stringent
- Quality control more difficult without direct visual observation
- Survey and measurement more difficult
- Underwater operations require specialized equipment, skills and experience.
- Specialized equipment may be required and expensive.

Construction Material Improvements

- In-the-Wet construction facilitated by improvements in materials and construction methods:
  - Improved mix designs with Anti-Wash agents, low heat mixes, self consolidating and leveling agents
  - Improvements in precast connections and alignment devices
  - Light-weight fill and aggregates

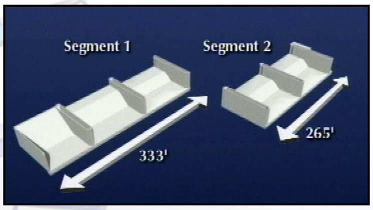
Construction Case Histories

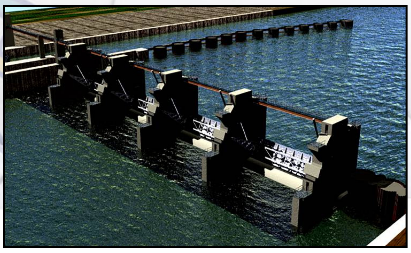
- Braddock Dam – Float-in Construction
- Olmsted Dam – Heavy Lift Construction
- Lith and Almere – Pneumatic Caisson
- Charleroi Lock – Cofferbox Construction
- IHNC FloodWall – In-the-Wet Trestle Construction

Braddock Dam – Pittsburgh, PA USA

- Monongahela River
- The lock is 183m by 33.5 m, lift of 13.7 m.
- The fixed crest dam built in 1906 was replaced in 2002 with a new 600-ft float-in flow-control structure with 5 bays for 4 tainter gates and one fixed overflow weir.
- Thanks to Bill Karaffa and USACE – LRP and Sam Yao with Ben C. Gerwick.

WG29 - LOCK INNOVATIONS
Innovations in the Braddock Dam Design





- Two 11,000 tons precast concrete float-in segments
- A unique two-stage cast & launch system for two segments
- Tow the segments 27 miles to the site through two locks
- A unique positioning system to install the float-in segments on site to a tolerance of 50 mm
- A high performance underwater grouting and tremie concrete

Leetsdale Casting Facility

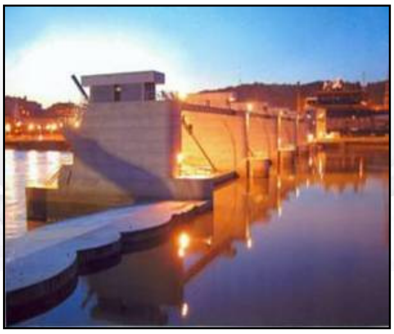
June 2001

SEGMENT TRANSPORT

July 26, 2001

BRADDOCK DAM

- 100-year old fixed crest Dam 2 demolished
- New dam fully operational
- Dedication ceremony – May 27, 2004
- Project complete – July 2004



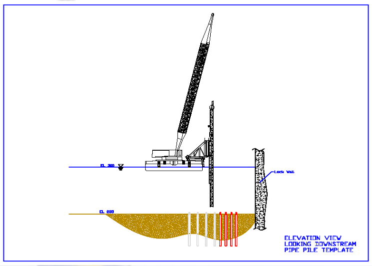
Olmsted Dam, Olmsted, Illinois, USA

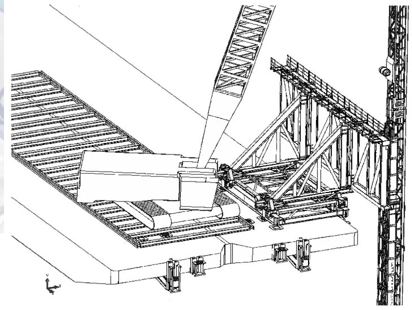
- First built in 1929 on the Ohio River
- Two 110-foot by 1200-foot locks
- The dam will consist of five tainter gates, a 1,400-foot navigable pass wicket gate dam, and a fixed weir.
- New construction should be completed in 2014.
- Thank you to Bill Gilmour, USACE-LRL

Olmsted Locks & Dam Project

Rendering of completed project

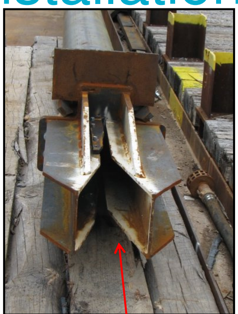
Pile Driving Equipment

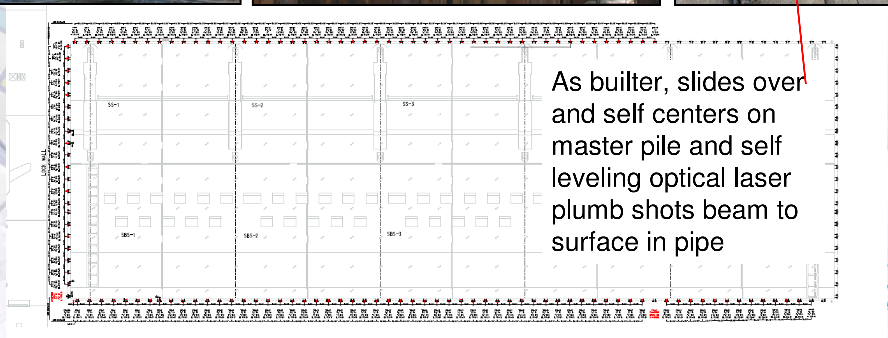




Features:
Template has multiple cylinders to allow it to be moved in nearly any direction to fit the requirements

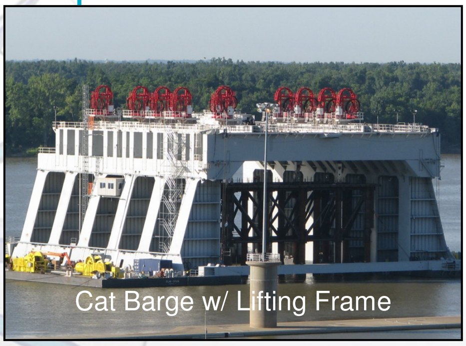
2009 Master / Sheet Pile Installation





As builter, slides over and self centers on master pile and self leveling optical laser plumb shots beam to surface in pipe

Specialized Tools to Build Olmsted Dam

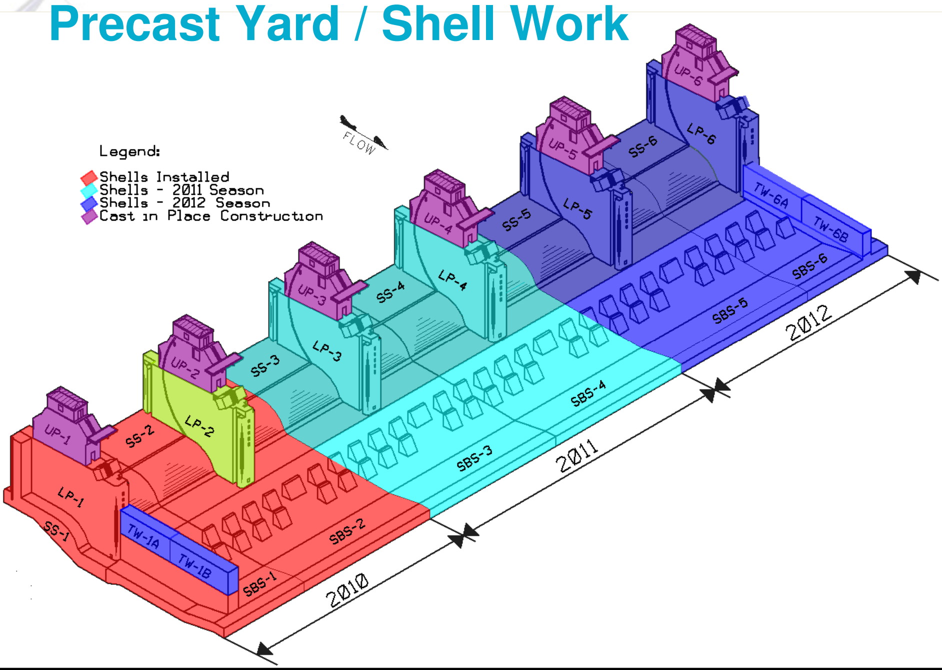

Cat Barge w/ Lifting Frame


Lifting Frame


Tremie Rebar Template on Cradle being moved by CTE


Gantry w/ Lifting Frame.

Precast Yard / Shell Work



Late May 2010 Versus Aug 2010

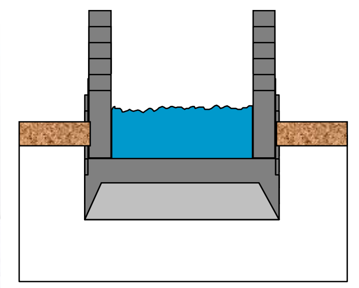
Shell Outfitting Work
Vertical Lower Pier Shells

Hookup and Move of SBS1 Dam Station

Lith and Almere Locks
The Netherlands

- Lith Lock on The Maas River in The Netherlands
- Constructed in 2001
- 200 m x 18.5 m with depth of 4.7 m
- Thank you to Erwin Pechtold with Rijkswaterstaat for use of the slides

Caisson method – Lock Lith



- Construction of sand tarp
- Construction of lock head with cutting edge
- Excavation below lock floor
- Pneumatic submersion of lock head
- Fill-up basement with concrete
- Finish construction

Alternatives

Fig 4.3 : Whole lock structure to be immersed - Almere Haven (NL)

Fig 4.4 : Upper lock head structure to be immersed – Lith (NL)

Lock Lith

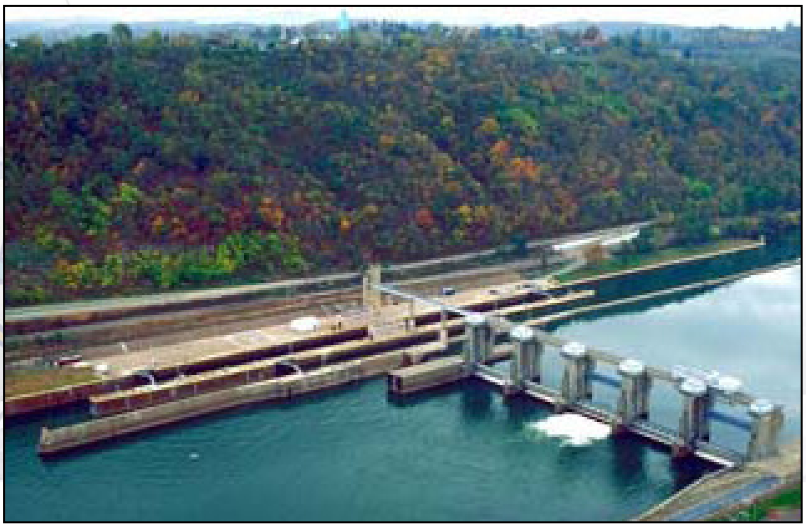
Photo; Testing the filling system of the new lock

Air view; Construction (almost) completed.

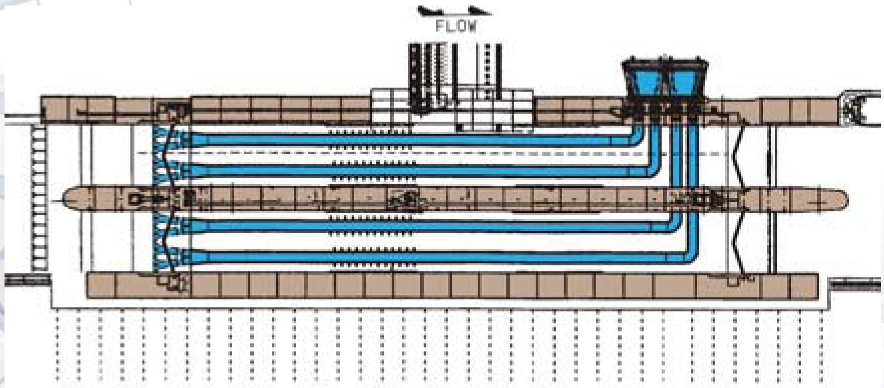
Charleroi Locks – Cofferbox Charleroi, Pennsylvania, USA

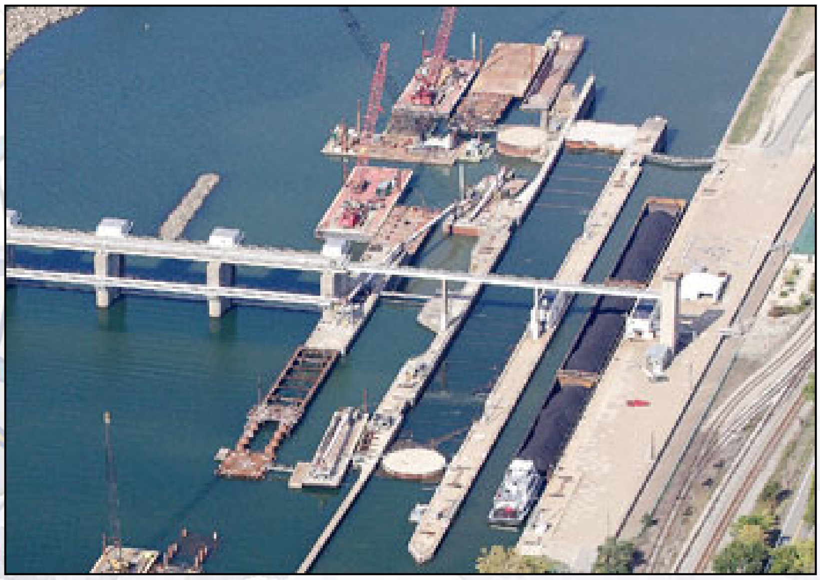
- Monongahela River
- Original locks 17 m x 220 m and 17 m x 110 m constructed in 1930's
- New Locks two–220 m x 26 m with 6 m lift
- Construction started in 2004 and is being completed in phases.
- Thanks to Steve Stoltz with USACE-LRP

Original Charleroi Locks

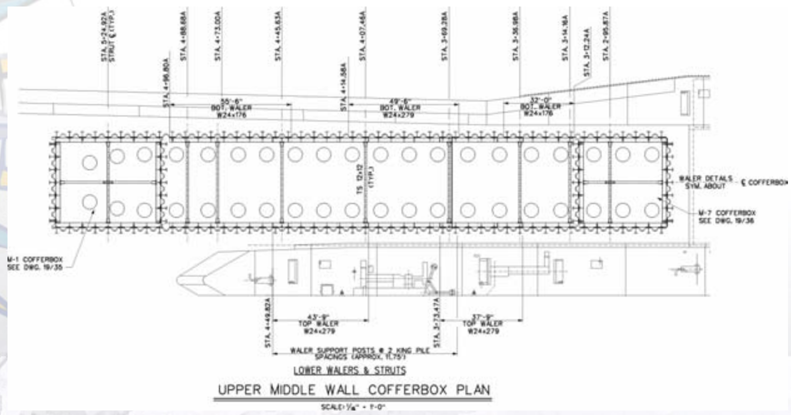


Charleroi Lock Expansion Plan

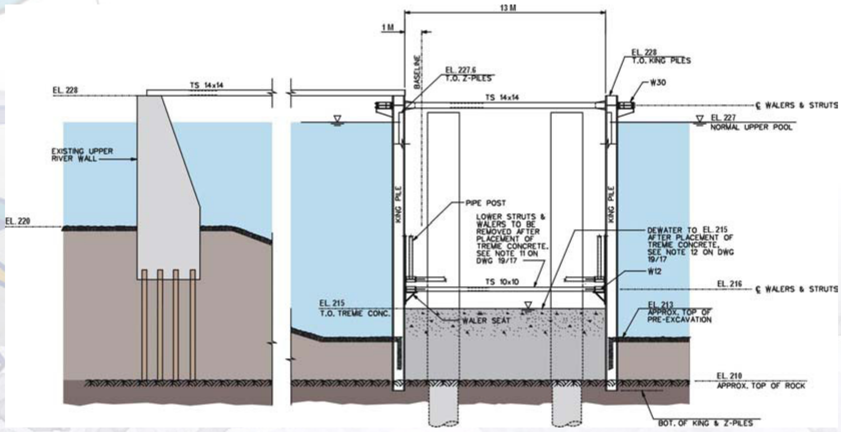




Upper Middle Cofferbox Plan



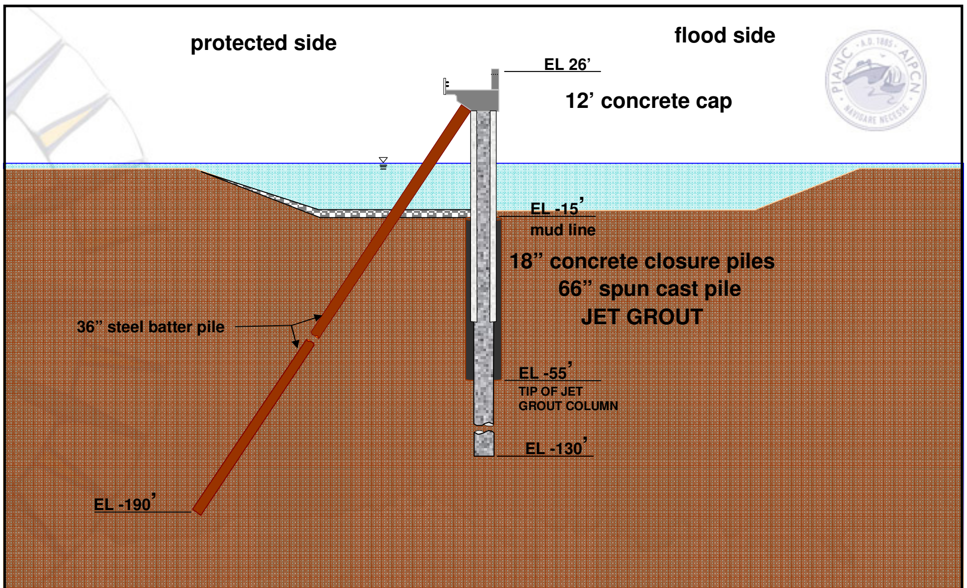
Cofferbox with Drilled Shafts & Tremie



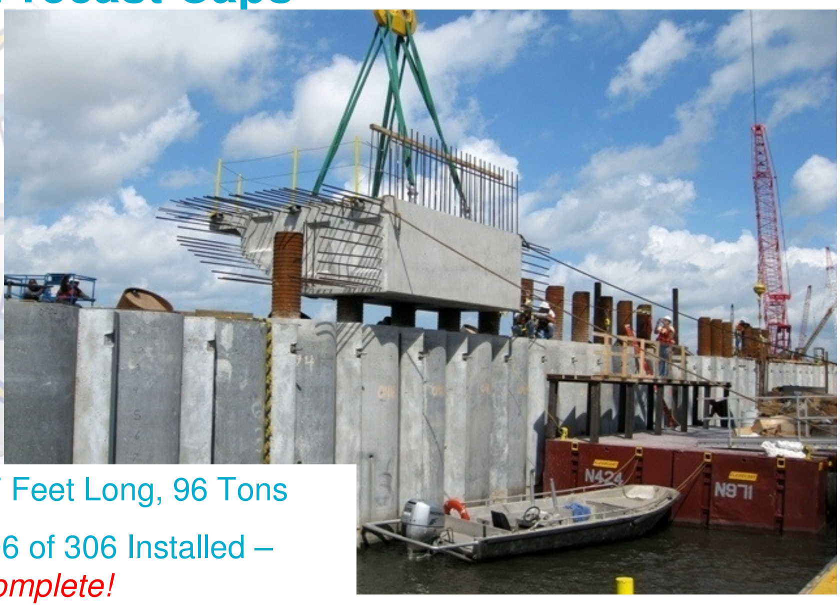
IHNC Storm Surge Barrier, New Orleans, Louisiana, USA

- Storm Surge Risk Reduction at Lake Borgne
- Construction to be completed in 2012
- 1.8 mile barrier
- 26’ above the water line
- 150’ Sector Gate
- 150’ Barge Bypass Gate
- 56’ Vertical Lift Gate

Gulf Intracoastal Waterway (GIWW) and Inner Harbor Navigation Canal (IHNC)



Precast Caps



17 Feet Long, 96 Tons

306 of 306 Installed –
Complete!

Cast in Place Concrete Section

6 Feet Wide, 339 of 339 Cast – *Complete*

Protected Side of Floodwall

Discussion?

Paper 3-1 **COMPUTER FLUID DYNAMICS IN LOCK DESIGN**
T. DE MULDER- (BE)

What's new in the design of navigation locks?

PIANC Workshop
13-14th September 2011

Part 3: CFD in lock design - progress and challenges

By Dr.ir. T. DE MULDER
BELGIUM

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Computational Fluid Dynamics (CFD) in lock design: Progress and challenges

Dr.ir. T. De Mulder

Flemish Authorities – Mobility and Public Works Department
Waterbouwkundig Laboratorium – Antwerp, Belgium

flanders
HYDRAULICS RESEARCH

- Introduction
- Terminology
- CFD: some important ingredients
- Use of CFD in design
- Concluding remarks

Introduction

PIANC Workshop "Innovations in Navigation Lock design"
Brussels, Belgium, 15-17 October 2009

*Paper 10 by **C. Thorenz** (BAW)*
"Computational Fluid Dynamics in lock design – State of the art"

RTFP !

Thank you for your kind attention !

This presentation:
- some difference in focus
- my personal (coloured) view
- some literature survey

Computational Fluid Dynamics

•Generic term for all kinds of numerical simulations of fluid flows (0D/1D/2D/3D)

vs.

•3D models based on Navier-Stokes equations (**CFD**)

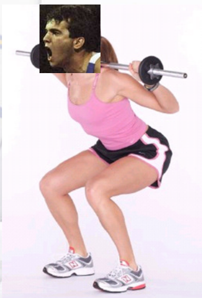
Fluent, CFX, Flow3D, Star-CD/Comet,…*(commercial)*
OpenFOAM,… *(open source, GNU)*
NaSt3DGP *(Univ. Bonn & BAW)*
ADH *(USACE)*
…

Numerical modelling in design

Huge computational effort !

0D/1D/2D models

3D CFD models
without/with free surface
without/with FSI



CFD models: some important ingredients

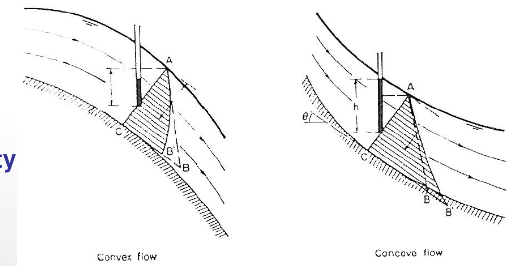
- Velocity and pressure formulation
- Free surface modelling
- Turbulence modelling
- Boundary conditions
- Mesh generation and optimization
- Fluid-structure interaction
- Numerical diffusion and dispersion
- Convergence
- Computer programme
- Computer platform
- CFD practitioner
- …

Strongly coupled !

Velocity-pressure formulation

Solvers based on **Shallow Water Equations** (1D/2D/"3D")

- gently curved streamlines
- vertical acceleration negligible
- hydrostatic pressure distribution
- unknowns: **(depth-averaged) velocity**
  water depth



CFD solvers (3D)

- unknowns: **(local) velocity** components and **pressure**
- any (i.e. non-hydrostatic) pressure distribution
- large computational effort

Free-surface modelling

CFD codes

- originally developed for pressurized flow
- **free-surface** flow is an "add-on"
- increases computational effort / burden
- experienced CFD practitioners often from outside
  "open channel hydraulics community"
- "rigid lid" approximation

Turbulence modelling

- Direct Numerical Simulation (DNS)

resolve all scales

$$\mathrm{N_x N_y N_z} \propto (L/\eta)^3 \propto \mathrm{Re}_L^{9/4}$$

- Large Eddy Simulation (LES)

resolve large (energetic) eddies
model subgrid scales

$$(\mathrm{N_x N_y N_z})_{\substack{\text{viscous sublayer}\\ \text{near wall}}} \propto \mathrm{Re}_L^{1.8}$$

- Hybrid LES / RANS
- Reynolds-Averaged Navier-Stokes models (RANS)

resolve time average flow

  - Eddy Viscosity Models
    - ✓ 1-equation-models
    - ✓ 2-equation-models

      k = turbulent kinetic energy
      ε = dissipation rate
      ω = specific dissipation rate (~k/ε)
      …
    - ✓ etc.
  - Reynolds Stress Models (6 eqs.)

$$\nu_{molecular} \approx 10^{-6}\ [\mathrm{m^2/s}]$$

$$\nu_{eddy} \approx u\,[\mathrm{m/s}] * \ell\,[\mathrm{m}]$$

model	turb.velocity scale u	turb.length scale ℓ
$k-\varepsilon$	$\sqrt{k}$	$k^{3/2}/\varepsilon$
$k-\omega$	$\sqrt{k}$	$k^{1/2}/\omega$

Turbulence modelling

k-ε models
- "standard" k-ε model (flat plate boundary layer)
- modified versions:
  - free jet
  - impinging jet
  - adverse pressure gradient
  - swirling flow,…

There are hundreds of RANS models…
Indicative of search for something better
and/or something more "universal"…

k-ω models
- "standard" k-ω model
- modified versions

etc.

Turbulence modelling

Validation of turbulence models ?

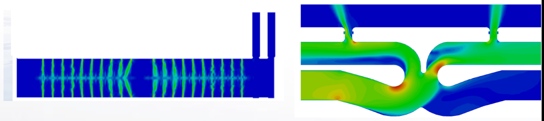
Let's make abstraction of intrinsic accuracy of experimental data against which model predictions are compared !?

➔ benchmark cases in literature

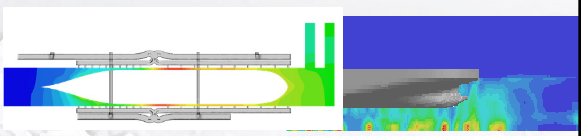
➔ some relevant for lock design (head losses and hawser forces):

- Free jet
- 3D wall jet
- Impinging jet
- Separated flow in 2D diffuser
- Separated flow in 3D diffuser
- 90° bend
- …

(GUPC/CICP, 2010 ; S. Roux & N. Badano, 2011)

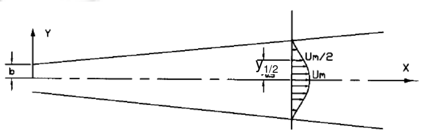


(CPP, 2007)

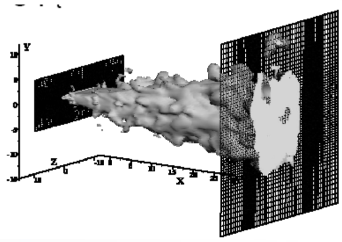


Turbulence modelling

Free jet



$$\text{spreading rate} = \frac{d}{dx}(\text{half width}) = \dot{y}_{1/2}$$



(Bardina et al., 1997)

Plane jet	Spreading rate
Experiment	0.100–0.110
Launder-Sharma k-ε model	0.108
Wilcox k-ω model	0.092–0.132
Menter *SST* model	0.112
Spalart-Allmaras model	0.143

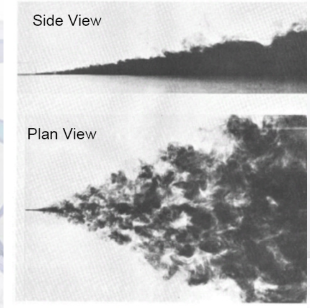
Round jet	Spreading rate
Experiment	0.086–0.095
Launder-Sharma k-ε model	0.120
Wilcox k-ω model	0.169–0.356
Menter *SST* model	0.127
Spalart-Allmaras model	0.253

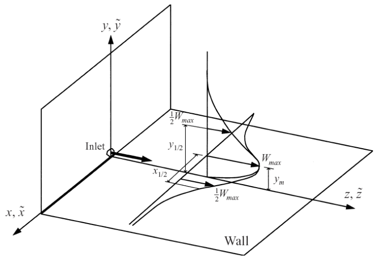
round jet / plane jet anomaly ➔ revised models (e.g. 1998 k-ω)

Turbulence modelling

3D Wall jet

(B. Launder & W. Rodi, 1983)





$$\frac{\dot{x}_{1/2}}{\dot{y}_{1/2}} = \frac{\frac{dx_{1/2}}{dz}}{\frac{dy_{1/2}}{dz}} = \frac{\text{lateral spreading rate}}{\text{spreading rate normal to wall}}$$

(T.J. Craft & B.E. Launder, 2001)

- **Experiments**: 5 to 9
- **Eddy Viscosity Models** (k-ε) : 0.9
- **Reynolds Stress Models**: 1 to 15

Turbulence modelling

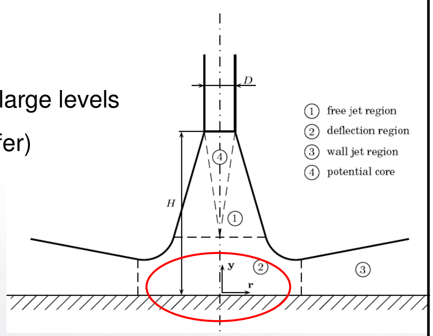
Impinging jet

(T.J. Craft et al., 1993)

Most Eddy Viscosity Models predict too large levels of turbulence (hence mixing / heat transfer) near **stagnation point**

(~streamline curvature)

(~wall treatment)



➔ ad hoc correction to models

or change in turbulence model's transported variables (e.g. RSM)

Turbulence modelling

Separated flow in 2D diffuser (G. Iaccarino, 2001)

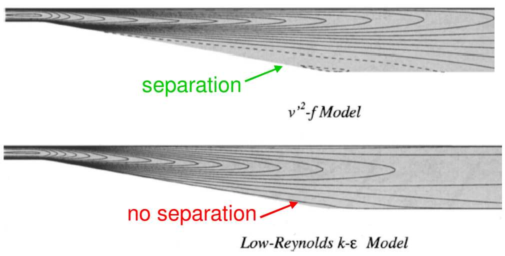
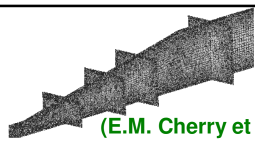


Fig. 4 Mean streamwise velocity—CFX. Contour levels Min=−0.05; max=1.0, Δ=0.05 (dashed lines negative values).

- Four equation $\overline{v'^2} - f$ model of Durbin
  - ▷ Modified form of the $k - \epsilon$ equations
  - ▷ $\overline{v'^2}$ equation – turbulence velocity scale
  - ▷ Production function f for $\overline{v'^2}$
- Low Reynolds number $k - \epsilon$ model of Launder and Sharma
  - ▷ No wall functions
  - ▷ Damping functions: algebraic relationships near the wall

Turbulence modelling

Separated flow in 3D diffuser



(E.M. Cherry et al., 2006)

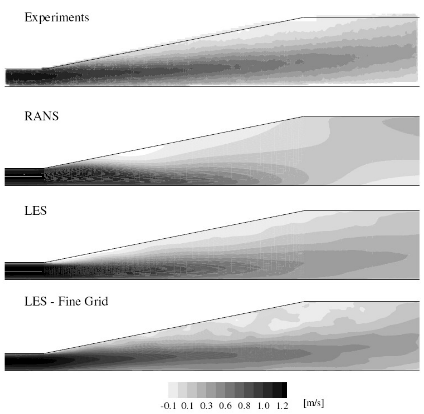


FIGURE 6. Streamwise velocity isolevels in a longitudinal section midspan in the diffuser 1

(all models: too thin boundary layer near bottom wall)

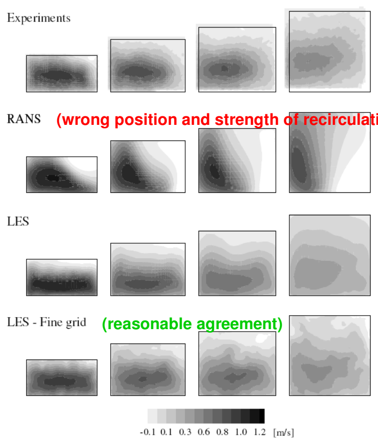


FIGURE 5. Streamwise velocity isolevels in four cross-sections along the diffuser 1.

Turbulence modelling

Separated flow in 3D diffuser (A. Karvinen & H. Ahlstedt, 2008)

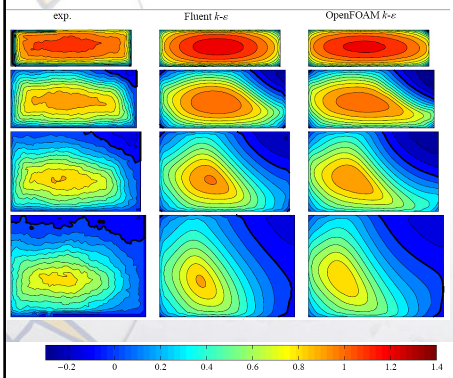


Figure 4: Mean streamwise velocities, u/u_{inlet}, at diffuser cross-sections various distances downstream from the origin using k-ε model. Contour lines are spaced 0.1 apart. The zero-streamwise-velocity contour line is thicker than others.

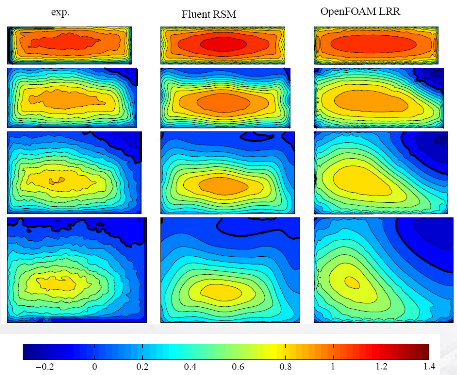


Figure 8: Mean streamwise velocities, u/u_{inlet}, at diffuser cross-sections various distances downstream from the origin using RSM and LRR. Contour lines are spaced 0.1 apart. The zero-streamwise-velocity contour line is thicker than others.

considerable differences between results of different turbulence models/codes !

(but: also differences in wall treatment, advection scheme, numerical parameters,…!)

No "Olympics" !

But burden to choose !

Turbulence modelling

Separated flow in 3D diffuser (A. Karvinen & H. Ahlstedt, 2008)

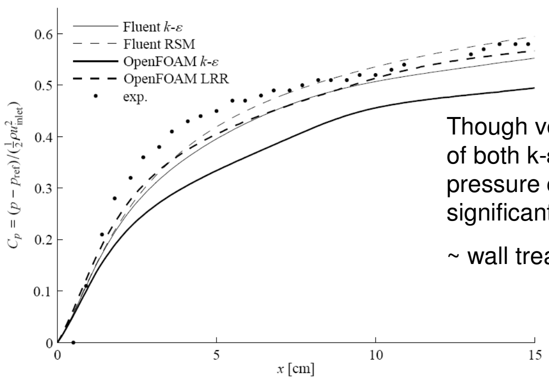


Figure 12: Pressure coefficient, C_p, along the bottom wall at the line z = 1.665 cm. p_{ref} is the pressure at x = 0 at the midpoint of the bottom flat wall (opposite the expanding wall).

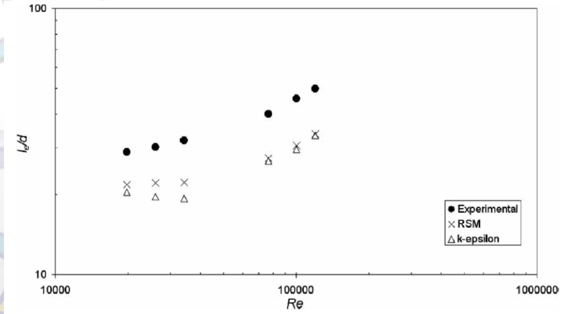
Though velocity-contour figures of both k-ε results are similar, pressure coefficients differ significantly.

~ wall treatment (?)

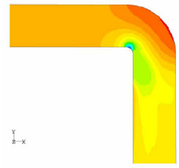
Most validation efforts in literature: velocity instead of pressure!

Turbulence modelling

90° elbow bends **(N. Crawford et al., 2009)**



Pressure drop of k–ε and RSM models expressed as an equivalent length (l_e/d), bend of $R/r = 1.3$



R = radius of curvature

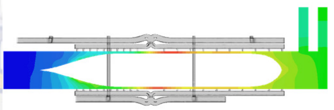
r = radius of circular cross section

discrepancy experimental vs. numerical:
- 24 to 33% for R/r = 1.3
- 7 to 9% for R/r = 5
- 1 to 5% for R/r = 2

(~ streamline curvature ; pressure gradients ; flow separation)

Turbulence modelling

The current body of knowledge arising from numerous **validation studies** does not provide unambiguous recommendations **(M.A. Leschziner, 2003)**

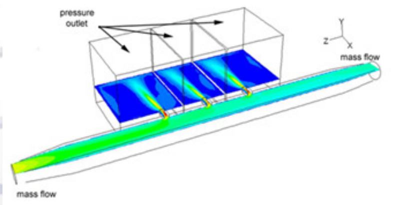


Even if it were the case…
one would need different models in
different parts of computational domain ?!

Many practical flows are highly 3D in which **inviscid pressure driven structures** occur and then turbulence stresses (hence turbulence modeling) become less important…

Boundary conditions

- where to limit computational domain ?



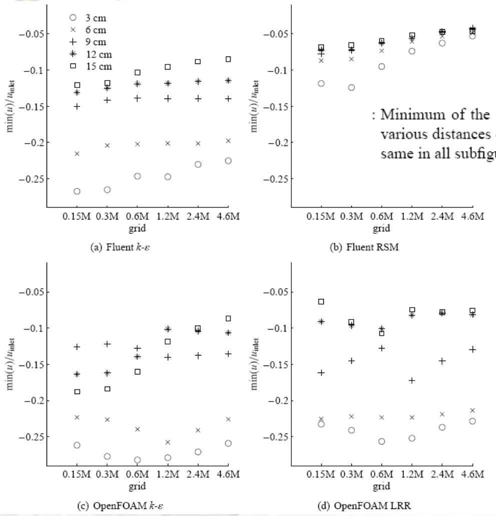
- which conditions to be imposed on boundaries ?

  ✓ wall treatment ?
  ✓ open boundaries ?

➔ burden for <u>both</u> RANS and LES !

Mesh resolution

Separated flow in 3D diffuser **(A. Karvinen & H. Ahlstedt, 2008)**



: Minimum of the mean streamwise velocity, $\min(u)/u_{inlet}$, at diffuser cross-sections various distances downstream of the origin using different grids. The legends are the same in all subfigures.

Grid dependency of results !?

Mesh resolution

Unstructured grids

e.g. **ADH** solver of USACE

incl. adaptive grid refinement (**R.L. Stockstill, 2009**)

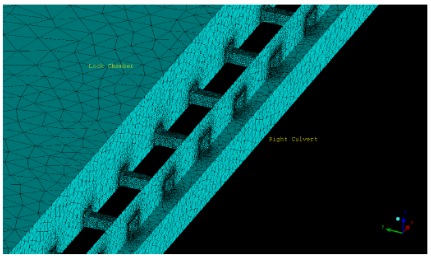


Figure 6. Surface mesh of right culvert and sidewall ports (culvert roof removed).

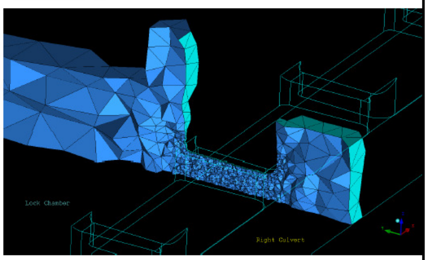


Figure 7. Volume mesh at section through the right culvert, sidewall port, and lock chamber.

Mesh quality

- Sudden transition from fine to large mesh cells (i.e. lack of smoothness) might degrade accuracy

- The *maximum angle condition* for two-dimensional triangulations states that

$$\exists \gamma_0 < \pi \quad \forall \mathcal{T}_h \in \mathcal{F} \quad \forall K \in \mathcal{T}_h : \quad \gamma_K \leq \gamma_0, \tag{4}$$

where γ_K is the maximal angle of K (compare with (2)).

The minimum angle condition (2) implies the maximum angle condition (4). To see this, denote the angles of a triangle $K \in \mathcal{T}_h$ by α, β, and γ and assume that $\alpha \leq \beta \leq \gamma$. If $\alpha \geq \alpha_0 > 0$ then

$$\gamma = \pi - \beta - \alpha \leq \pi - 2\alpha_0.$$

Too small and too large angles in 2D triangular Finite Element mesh might degrade accuracy

(3D ? ; Finite Volumes ?)

- **mesh optimization** (Laplacian smoothing, edge swapping,…) !?

Convergence

•Set of coupled, non-linear equations

•Iterative solution

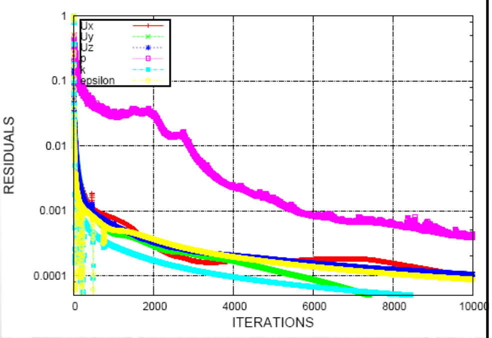
•Convergence monitoring

✓different rates for numerical and physical parameters

✓slow convergence rate or convergence stall

(~ turbulence models)

(~ free surface models)



> *"One must watch the convergence of a numerical code as carefully as a father watching his four year old play near a busy road"*
>
> **J.P. Boyd** (Univ. Michigan)

Computer programme

• availability of source code ?

• willingness to modify code (e.g. turbulence model, boundary conditions,...) ?

• documentation (manual, validation,…) ?

• availability of options (input parameters) ?

CFD models: some important ingredients

- Velocity and pressure formulation
- Free surface modelling
- Turbulence modelling
- Boundary conditions
- Mesh generation and optimization
- Fluid-structure interaction
- Numerical diffusion and dispersion
- Convergence
- Computer programme
- Computer platform
- CFD practitioner
- …

Strongly coupled !

Quality of CFD results is function of all ingredients !

So is uncertainty !

CFD practitioner

Has an extremely important role:

- selection of **ingredients**
- **validation** of flow solver
- quantification of **uncertainty** (**UQ**)

Is a permanent (lifelong ?) task !

> *"Knowledge of the flow solver as well as the flow is the key to better prediction and successful innovation"*
>
> **C.P. van Dam, paraphrasing A.B. Haines**

> *"Understanding grows only logarithmically with the number of floating point operations."*
>
> **J.P. Boyd**

Use of CFD in design

Drag prediction in aeronautics

Critical ingredients for prediction up to **10^{-4}** **(C.P. van Dam, 2003)**

- computer models that include all pertinent **geometry details**
- large meshes with high **grid resolution** in relevant areas
- well-developed numerical **solvers** (little **numerical viscosity**)
- fully-**converged** numerical solutions
- boundary-layer **transition** locations that match empirical ones
- **turbulence** models validated for flows encountered
- employing a drag evaluation methodology that is complete

Use of CFD in design

Aeronautical design

The emphasis on **simplicity**, **computational speed** and **robustness** in a design context militates against the adoption of more advanced models **(M.A. Leschziner, 2003)**

Before new methods and models can be accepted, questions concerning with **accuracy**, **reliability** and **efficiency** must be answered, in **absolute** terms and/or in **relative** terms, before they can be used with confidence **(K. Sermeus & H. Deconinck, 2003)**

Absolute truth cannot be provided…

…but relative truth is (!?)

Is this proven or is it merely a substitute for: *"Let's shut up and continue business as usual !"*

Use of CFD in design

Aeronautical design

Is **CFD** a mature technology ? **(K. Sermeus & H. Deconinck, 2003)**

- Not in the way that Computational structural mechanics (**CSM**) and Computer aided design (**CAD**) are
- CFD is not yet a component of an integrated **virtual prototype environment** used by aircraft design engineer

Lock design

More or less similar, but:

- (quasi) unique prototypes
- less strict demands for accuracy

CFD practitioner

Has an extremely important role

CFD client

Has an extremely important **role** too:

- needs to give sufficient **time** to CFD practitioner
- supplies (directly / indirectly) calibration / validation **data**
- should be **critical** and should not simply trust pretty pictures *("Colourful Fluid Dynamics")*

The way to proceed ?

Hybrid methodology **(J.M. Hiver, 2009 ; S. Roux & N.Badano, 2011)**

- numerical models with various number of spatial dimensions and physical complexity, including **CFD**

- physical models

PIANC Setting the course

The way to proceed ?

"*The parable of the blind*" ("*The blind leading the blind*")

Pieter Bruegel the Elder, 1568

PIANC Setting the course

Paper 3-2 USE OF SYNTHETIC MATERIALS AND THE COMEBACK OF SLIDING GATES VERSUS ROLLING GATES

R. DANIEL (NL) and J. AUGUSTIJN (NL)

What's new in the design of navigation locks?

PIANC Workshop
13-14th September 2011

Use of Synthetic Materials

By R. A. Daniel, Rijkswaterstaat
and J. Augustijn, Iv-Infra Group
NETHERLANDS

PIANC
Setting the course

Use of Synthetic Materials and the Comeback of Sliding Gates versus Rolling Gates

- Synthetics - benefits and application areas
- Entire gates of synthetic materials
- Synthetics in gate hinges
- Synthetics in gate guiding
- Synthetics in sliding gates and their tracks
- Other application areas
- Conclusions

Benefits of using synthetics

- Engineered materials – potency of fitting every purpose
- Very good mechanical properties (e.g. strength, friction coefficient)
- Chemical stability, no corrosion – potentially long service life
- Very well controlled processing – low dispersion of properties
- Generally very low maintenance requirements
- Environmental benefits: low energy consumption and pollution rates
- Integration of functions possible

Application areas of synthetics

<u>Thermosets (usually reinforced)</u>

- Entire hydraulic gates
- Gate subassemblies like retaining walls, sluice valves, walkways
- Contact items like hinge bushings, saddle and buffer lining

<u>Thermoplastics (reinforced or not)</u>

- Guiding for vertical lift, rolling and other gates, gate sluices etc.
- Tracks for sliding and sector gates
- Slide layers in some hinges

Gates of synthetic materials

Spiering Lock (Netherlands)

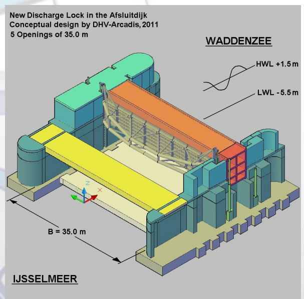
- Chamber width: 6.0 m
- Water depth: 3.3 m
- Max. water head: 2.5 m

Goleby Lock gate (France)

- Chamber width: 5.1 m
- Water depth: 2.2 m
- Max. water head: 6.0 m

Gate subassemblies

Retaining wall in discharge lock gate

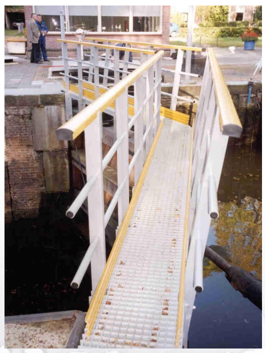


- Material: CFRP
- Width: 40.0 m
- Dif. head: 6.0 m

Sluice valves in gates and culverts

- Material: FGRP
- Width: ab. 1.5 m
- Dif. head: 2 ÷ 4 m

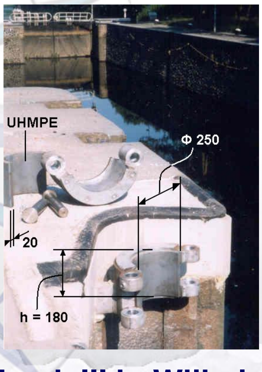
Grids, walkways

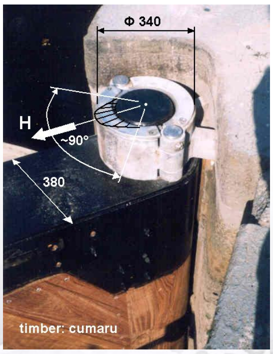


- Material: FGRP
- Width: ab. 1.5 m
- Load: 2.5 kN/m^2

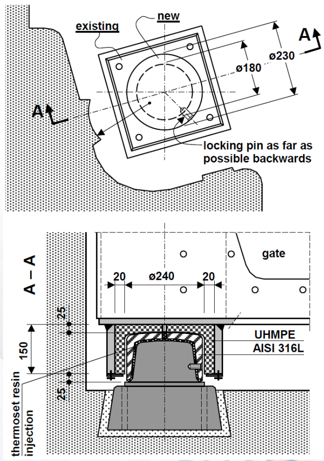
Synthetics in gate hinges (1)

UHMPE in miter gate top hinge





… and bottom pintle



Lock III in Wilhelmina Canal, Tilburg

- Deep but narrow – low hinge loads
- Large contact surfaces provided

PIANC Setting the course

Synthetics in gate hinges (2)

Thermoset resin composites in gate hinges

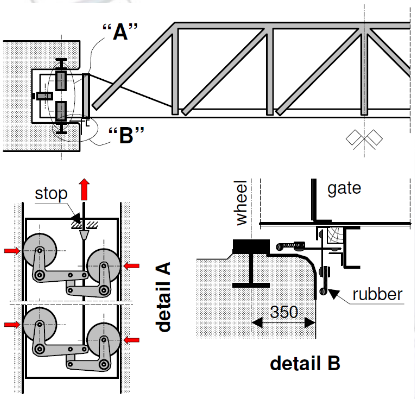
“Naviduct” Krabbersgat in Enkhuizen

- Top hinge: Feroform T814 composite in a ball bearing (Feroball)
- Bottom pintle: Feroform T814 bushing and stainless steel A316L shaft

PIANC Setting the course

Synthetics in gate guiding (1)

Conventional guiding



Diverse gates, e.g.:
Meuse St. Andries Lock

UHMPE guiding of vertical gates

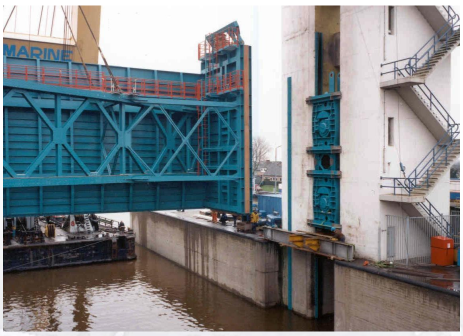
Hartel Canal Barrier, Rotterdam
- Span: 98.0 m, height: 10.0 m
- Differential head: up to 9.0 m

Synthetics in gate guiding (2)

Gate UHMPE guiding

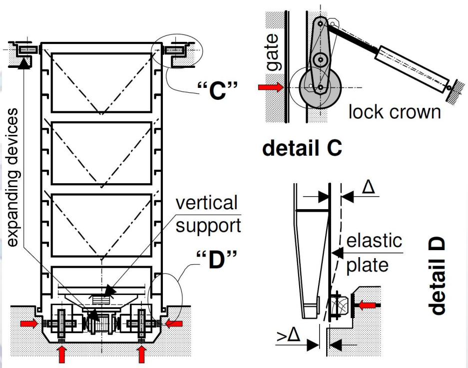
Hartel Canal Barrier:
Spans 49.0 m and 98.0 m,
height 10.0 m

Gate conventional guiding

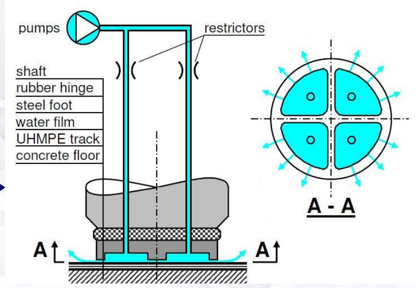


Hollandse IJssel Barrier:
Span 86.0 m, height 10.0 m

Synthetics in gate guiding (3)



Rolling gate on wagons



Sliding gate on "hydrofeet"

Three examples of applications

- Malamocco lock gates – Venice
- Seine-Nord Europe
- Panama Canal expansion project

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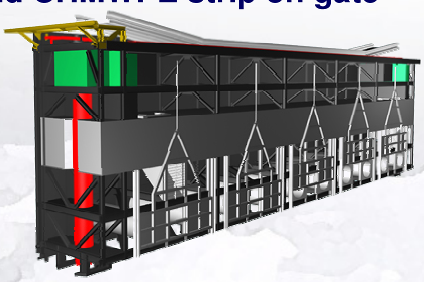
Setting the course

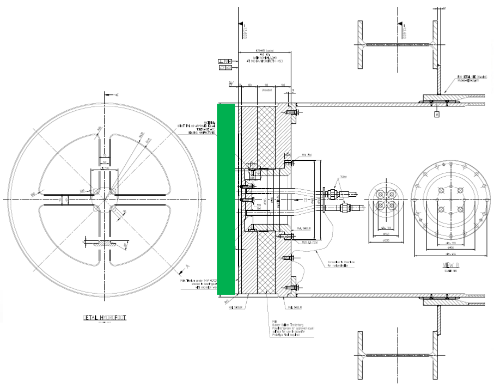
Malamocco lock gates - Venice

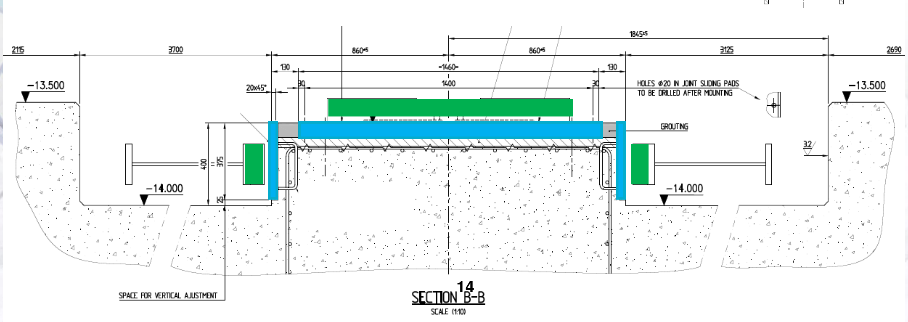
- “Sliding gate” vertical load taken by hydrofoot on UHMWPE slide track
- Horizontal loads taken by metal sliders on UHMWPE slide track
- Sealing by contact pressure between concrete surface and UHMWPE strip on gate



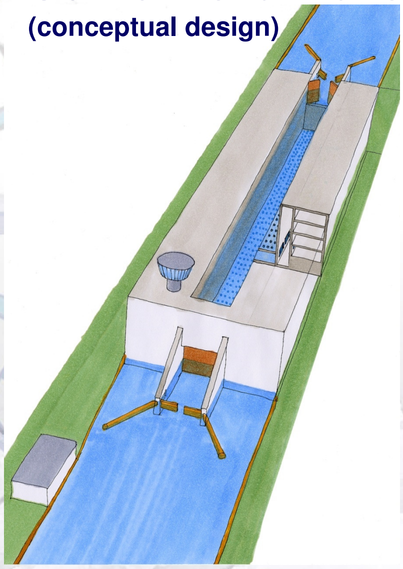
Malamocco lock

- Max. head: 3 m
- leakage no design criterium
- Desire of client to have little maintenance





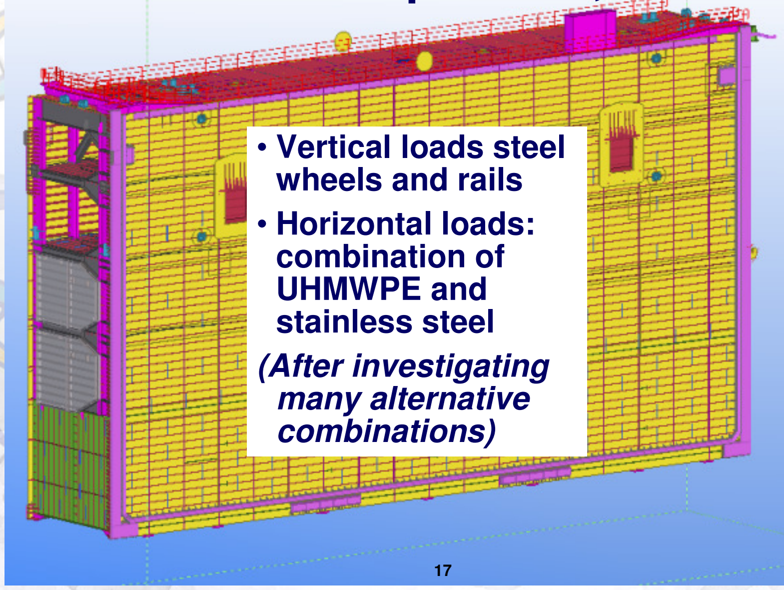
Seine Nord-Europe
(conceptual design)



Seine Nord-Europe

- Seven locks; 15 m to 32 m head
- Three types of gates:
  - Upper gates: Miter gates
  - Lower gates: Lift gates
  - Valves: Lift gates
- Bearing / sealing miter gates; UHMWPE replacing tropical hard wood
- Bearing / sealing lift gates; UHMWPE slide tracks, stainless steel sliders (low friction due to choice of gate)
- Valves: Lengthy discussions about types and capacity to seal with UHMWPE slide tracks on concrete

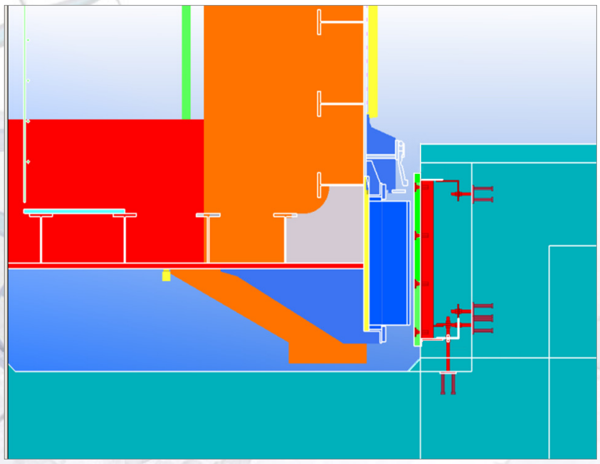
Panama Canal Expansion; Gates



- Vertical loads steel wheels and rails
- Horizontal loads: combination of UHMWPE and stainless steel

(After investigating many alternative combinations)

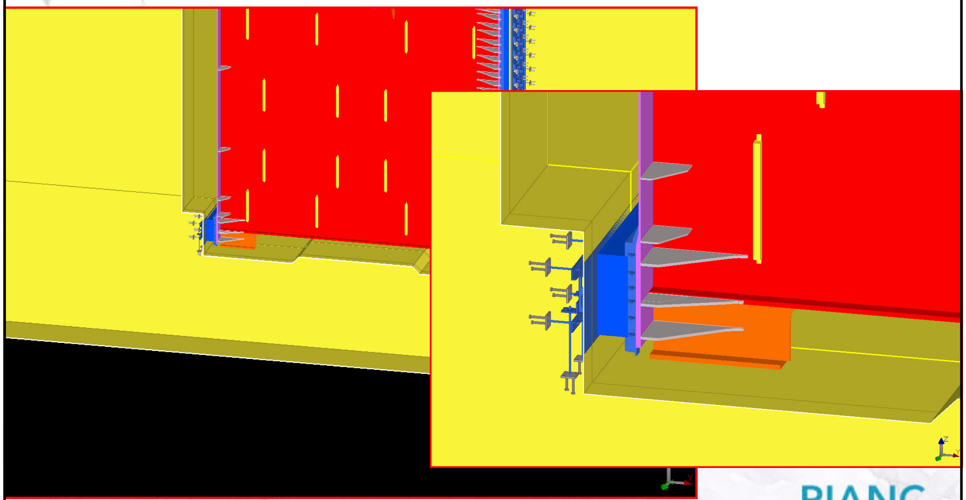
Panama Canal Expansion Gates



Evolution due to:

- Stringent leakage criteria
- Substantial (21 m) differential head
- Required accuracy of construction

Panama Canal Expansion Gates



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Conclusions

- Modern synthetic materials offer a number of advantages when applied in hydraulic gates.
- The applications of synthetics can be classified in three groups:
  - entire hydraulic gate structures,
  - subassemblies of hydraulic gates (e.g. retaining walls),
  - system components (bearings, guides, slide tracks).
- Application of synthetics allows for replacement of wheels and rollers by sliding supports in both vertical lift and rolling gates. This reduces the maintenance costs and spares the environment.
- The application of synthetics in sliding surfaces is influenced by “culture” or “what one is used to”.
- If the design parameters allow you to, using synthetic slide tracks and metal sliders is likely to be the most economic solution.
- Optimization of the design on life cycle costs is not (yet) the obvious choice.

Thank you

Paper 3-3 **NEW MATERIALS AND SYSTEMS IN THE DESIGN OF MITER GATES**

R. DANIEL (NL)

What's new in the design of navigation locks?

PIANC Workshop
13-14th September 2011

New Materials and Systems in Miter Gates

By R. A. Daniel, Rijkswaterstaat
NETHERLANDS

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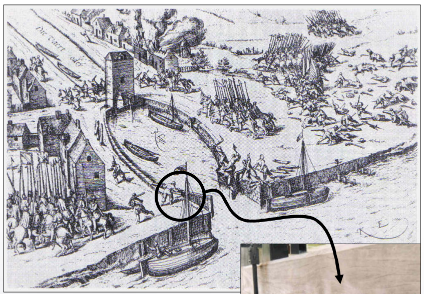
New Materials and Systems in the Design of Miter Gates

- Miter gates – proven but improvable
- New materials
  - for entire structure
  - for gate components
- System functionality extensions
  - carrying reversible hydraulic loads
  - operating in wide chambers
- System improvements
  - retaining plate position
  - suspension gate
- Conclusions

Miter gates – proven but improvable

- Some history…
- Well-proven system, appreciated by navigation
- Harmony with environment: Water itself holds it closed
- 2 feasibility limits:
  - unidirectional operation
  - unfit for wide chambers
- Gate material:
  - Timber → steel → ???
- Component improvements within the proven system



Netherlands, 16th cent.

Scotland, 21st cent.

Gate material improvements

Aluminized steel

- Material: AlMn5
- Project: Naviduct Enkhuizen (Ned.)

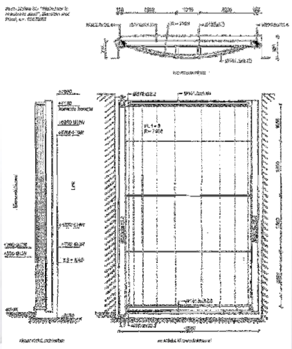
Cold-formed steel

- Material: S355J2
- Project: Uelzen Lock (Ger.)

FSC certified timber

- Material: Cumaru
- Project: Lock III, Wilhelmina Canal

New structural materials (1)

HS Concrete	Stainless steel	Composites (FRP)
		
• Material: HSC • Project: IJburg Lock, Amsterdam	• Material: 1.4462 • Project: Study for Nieuwegein Lock	• Material: FGRP • Project: Spiering Lock, Werkendam

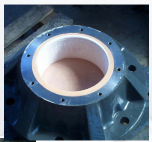
New structural materials (2)

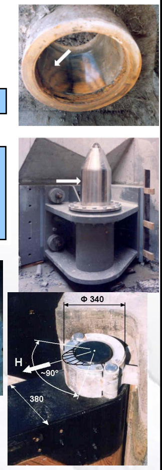
Spiering Lock (Netherlands)	Goleby Lock (France)
	
• Chamber width: 6.0 m • Water depth: 3.3 m • Max. water head: 2.5 m	• Chamber width: 5.1 m • Water depth: 2.2 m • Max. water head: 6.0 m

New contact materials (1)

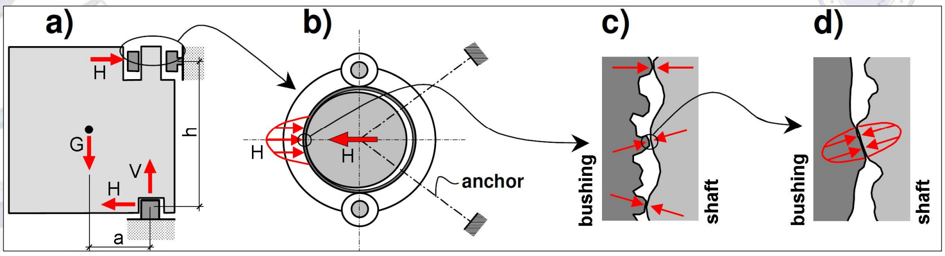
Gate hinge contacts

- Metallic
  - Steel alloys
    - Manganese steel
    - Refined steel
    - Case hardening steel
    - Stainless steel
  - Non-iron alloys
    - Bronze
    - Aluminum-copper
    - Aluminum-bronze
    - Hard chrome plating
- Non-metallic
  - Homogeneous
    - Polyethylene
    - Polyamide + PTFE +fiberglass
    - Polymer alloys (Thordon)
  - Composites
    - Phenolic resins + polyester fibers (Tenmat)
    - Phenolic resins + aramid (Railko)





New contact materials (2)

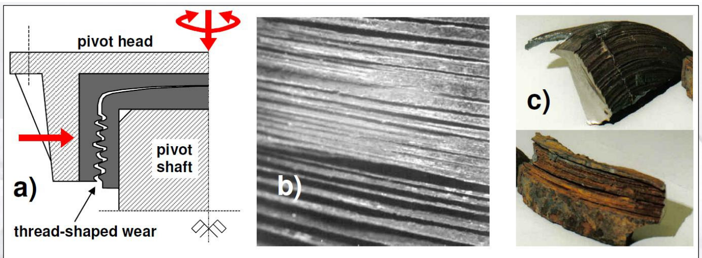


system **component** **segment** **asperity**

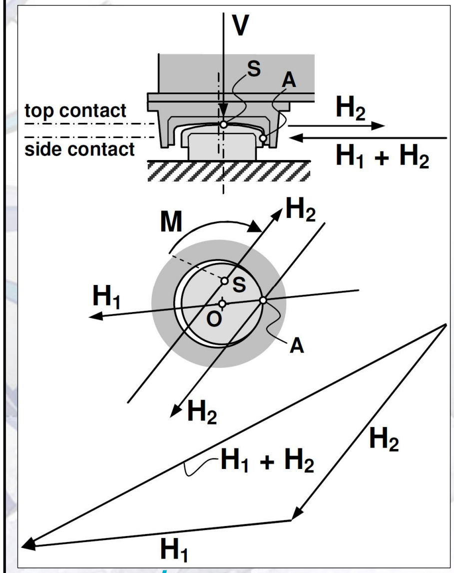
$$V = G$$

$$H = G\frac{a}{h}$$

?



New contact materials (2)



$$V = G \pm (0.1 \div 0.3) \cdot H_1$$

$$H_1 = G\frac{a}{h}$$

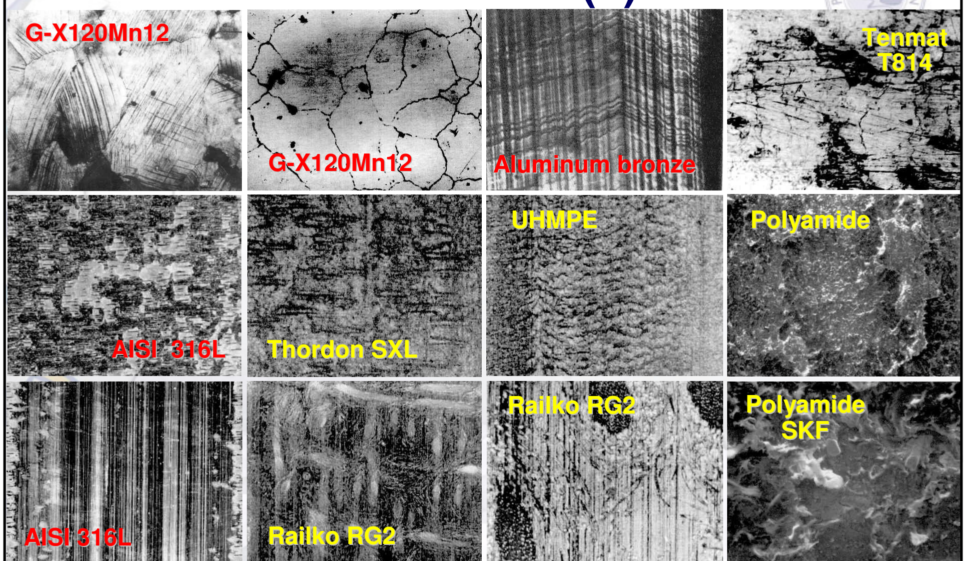
$$H_2 = \mu V$$

$$H = \vec{H}_1 + \vec{H}_2 \approx G\frac{a}{h} + \mu V$$

Conclusion:

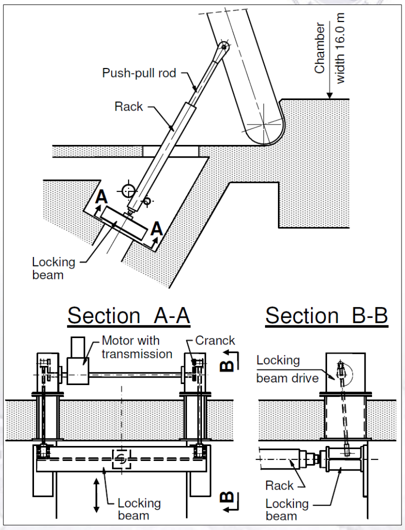
➢The actual <u>contact loads</u> in gate hinges are substantially higher than from static equilibrium conditions.

New contact materials (3)



More in: Daniel R.A.: "Contact behavior of lock gates…", LAP Publishing, Saarbruecken, 2011

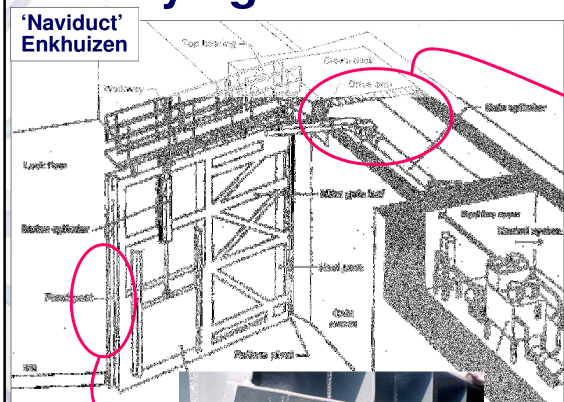
Carrying reversible water heads (1)



Other realized systems:

- Locking the front posts,
- Locking braces aside the drive rods, …
- Locking by drive cylinders.

Carrying reversible water heads (2)



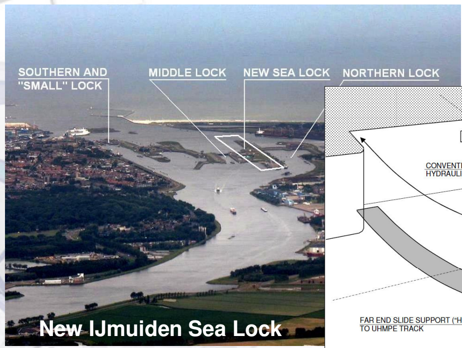
General conditions:

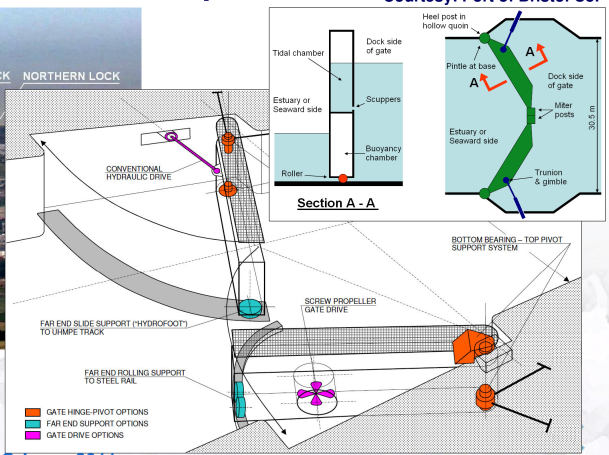
- Only for small reverse loads applicable
- Highly reliable drives
- Gate prestression on every closure - fatigue
- Additional measures against leakage

Operating in wide chambers

- Problems: high hinge loads, long closing times, …
- Wide lock chambers are a domain of rolling gates
- What if rolling gates are not an option ?

Courtesy: Port of Bristol Co.

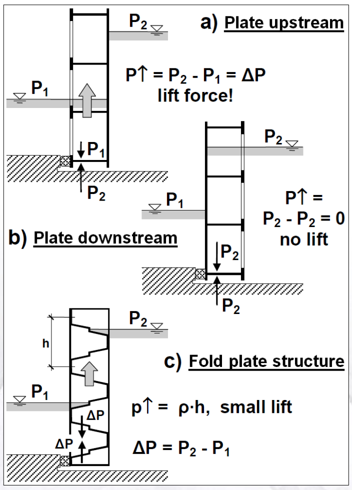




System improvements (1)

Retaining plate position:

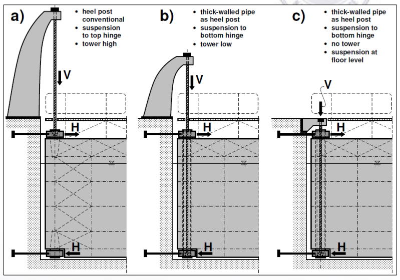
- Phenomenon of gate "climbing"
- Relation with retaining plate position

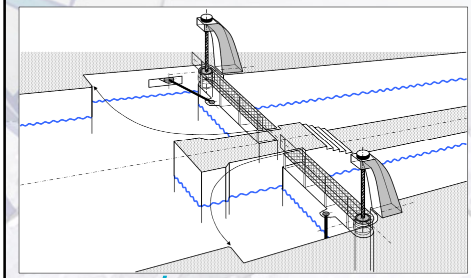


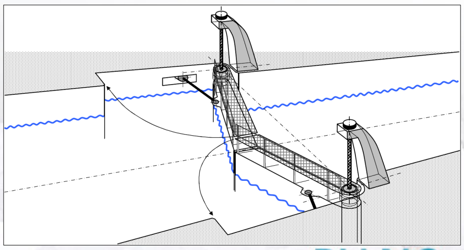
System improvements (2)

<u>Suspension gate concept:</u>

- No vertical loads in hinges – low wear, low maintenance
- Less fatigue in heel posts
- Longer service life of hinges, heel posts a.o.
- Aesthetical values







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Conclusions

- Miter gate as a system remains favorable. Modern technology offers improvements but no basic changes of this system.
- Improvements can be found in three directions:
  - application of new materials,
  - extension of system functionality,
  - modification of system components.
- From new material applications, polymers and FRP's are particularly interesting. This applies to both gate structure and its components.
- Extensions of system functionality include e.g. carrying small reverse water heads and closing wide lock chambers.
- Diverse system component modifications are possible. Examples are: downstream position of retaining plate, gates of trough sections, gate support at its top bearings, gate suspension.

Thank you

Paper 3-4 **INNOVATION IN LOCK EQUIPMENT**
O. HOLM (Fin) and J. BODEFELD (D)

What's new in the design of navigation locks?

PIANC Workshop
13-14th September 2011

Innovations in Lock Equipment

Olli Holm,
Finnish Transport Agency, Finland
Jörg Bödefeld,
Bundesanstalt für Wasserbau, Germany

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Setting the course

Contents

- Mooring Equipment
- Protection of the Gates and Gate Maintenance Equipment
- Signalling, Marking and Illumination
- Aids to Navigation
- Security
- Safety of Public, Users and Personnel

Mooring Equipment

Failure modes

- High strength mooring lines available nowadays
  - Mooring line is no more the weakest link in the system
  - Danger of bollards being catapulted (dangerous!)
  - Danger of damaged construction (expensive!)

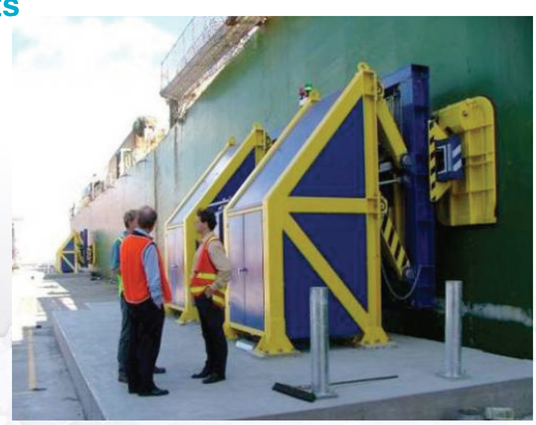
Influence on design

  - Replacable bollards
  - Avoiding damage of the construction

Mooring Equipment

Automatic Mooring units

- For sea locks
- Vacuum principle
- Uniform shape of vessels necessary



Cavotec®, New Zealand

Mooring Equipment

Floating pontoon

- Two parallel steel piles attached to two steel pillars
- Bollards for mooring on the pontoon
- Wooden boarding for walking

Fit well for

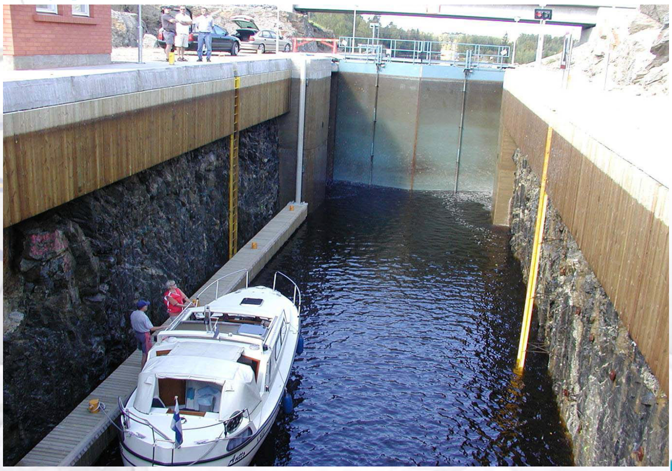
- Recreational navigation or smaller ships
- Locks in rock

Mooring Equipment

Floating pontoon (Juankoski Canal, Finland)

Mooring Equipment

Floating pontoon (Juankoski Canal, Finland)



Protection of Gates and Gate Maintenace Equipment

Gate protection

- In open position usually wooden planking or rubber pumpers
- In closed position several option to hinder vessels from colliding with gates
  - Traditionally rubber or spring pumpers
  - Double set of gates
  - Special protecting structure

Flood control

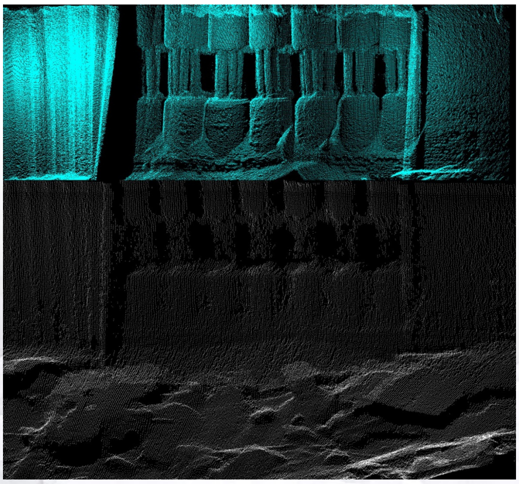
- Possible in some gate types; enabling that gates can be secured in any partially open position. Public safety also vital!

Protection of Gates and Gate Maintenace Equipment

Maintenance

- Usually bulkheads for dewatering of the lock
- Inspection tunnels etc. also used in some locks
- Minor maintenance by divers
- Multi-beam sonar in surveys

Example of Multi-beam Survey Results



www.pianc.org New-Orleans 2011

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Signalling, Marking and Illumination

Signalling
- Local legislation and international agreements
- Illumination should support colour recognisation

Marking
- Visual guidance is important
- White stripes are efficient
- Moderate use of reflecting surfaces

Illumination
- Low level of illumination
- Illumination directed into most important places in locks only

www.pianc.org New-Orleans 2011

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Setting the course

Aids to Navigation

National or international standards or legistlation must be followed

Extra navigational aids in locks, which are not usually covered by standards or legistlation

- Stop stripes
- Marks on the gates
- Distance marks

Freedom of choice in type and colour, but clarity is very important

Should be similar in every lock

Security

Level of needed security measures varies

- Locks often interests public, so a suitable combination is needed
- Sightseeing places for public (also a safety question…)
- Risk level i.e. hazardous cargo, results of lock failure etc…
- Nature, landscape, cultural heritage
- Some features from airports and railway stations can be adopted
  - Fenches, controlled entrances and electronic monitoring is needed
- Security features should be intergrated in lock desing to minimise negative influences
- In existing locks security features should be designed as an entinity

Safety of Public, Users and Personnel

Typical risks

- Person falling into the lock
- Accidents caused by moving gates
- Fire or spill of hazardous cargo
- Vandalism

Safety risks for public and vandalism can be reduced by security measures

Safety of Public, Users and Personnel

Public safety

- Life rescue equipment
- Monitoring

Users and personnel safety

- Prevention of gate misuse
- Safety sensors

In addition in remote operated locks and user-operated locks

- Enough cameras to monitor the lock traffic
- Possibility to take over the lock operation
- Telephone connections, instructions signs, loudspeakers
- Possibility for local operation of lock

Safety of Public, Users and Personnel

In addition in user-operated locks

•Slow operation speed

•Stand-by personnel

Note! Quality of data connections is important (damages from thunder, damages caused by humans etc..)

Flood control

•Warning system and prevention of entering the lock

Fire fighting

•Fire-fighting equipment

•At least two evacuation routes

•Routes for fire brigade both from land and water side

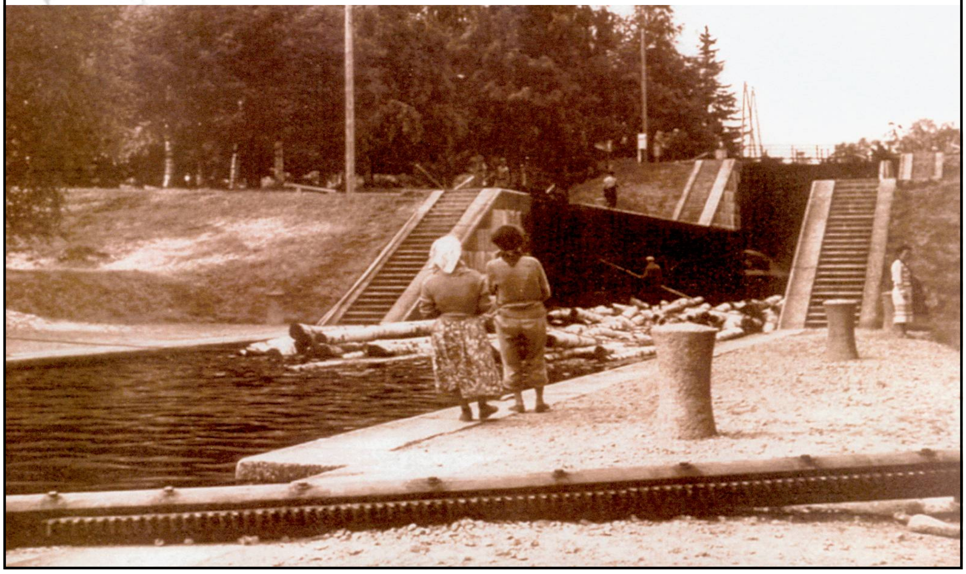
Safety of Public, Users and Personnel

Hazardous cargo

Codecs usually set demands

- Distances to other vessels, other facilities and public
- Operation of locks
- Lock equipment and escape routes
- Safety procedures

Thank you!



MeriTaito

Possibilities of High Resolution Multibeam and Laser Scanning Technology for Engineering Support Inspections under and above water line

Kari Pohjola

NordPIANC, 01-03 September, Tallinn

MeriTaito

Possibilities of High Resolution Multibeam and Laser Scanning Technology

Structure

- Meritaito Ltd past and today
- Multibeam survey
- Multibeam survey, new application
- Laser scanning
- Combination
- Suplementary inspections, traditional and modern
- Service package

Finnish Maritime Administration

Background of FMA

The Finnish Maritime Administration has been the national authority responsible for maritime safety, fairway maintenance, hydrography, winter traffic assistance, archipelago ferry services, marine traffic management and authority duties in pilotage.

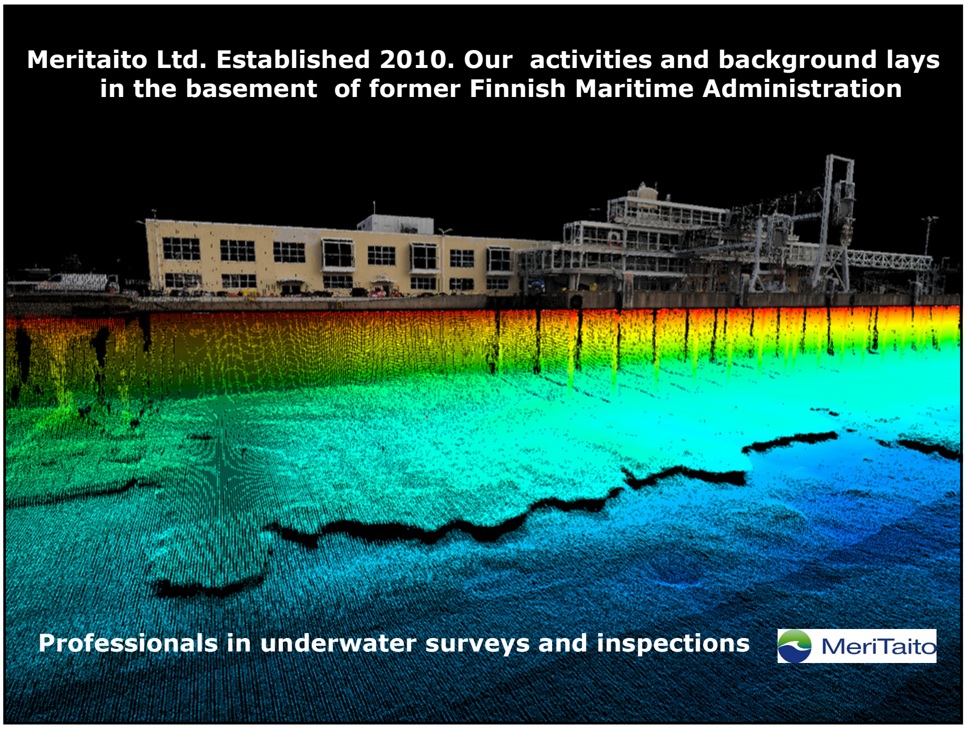
The history of maritime authority in Finland dates back to 1696.

The Administration itself was established as a Finnish national institute in 1917, within two weeks of the declaration of independence.

MeriTaito

Finnish Maritime Administration were split into three elements from 1.1.2010:

- **Finnish Transport Agency**
  - Implementation of national traffic policy
  - To take care of traffic infrastructure by evaluating new practices and methods for that purpose
  - Developing frame to lead and purchase f.ex. hydrographic surveys of Finnish seas and inland waters
  - International co-operation (f.ex. IHO) and EU matters
- **Finnish Transport Safety Agency**
  - Transport safety matters
  - Ship inspections, manning, certifications
  - International co-operation and EU regulation
- **Meritaito Ltd**
  - Providing services and resources for fairway maintenance, planning, channel operations, hydrographic and underwater surveys
  - To ensure the availability of such an activities in Finland
  - To be an independent self sustaining company


Meritaito Ltd. Established 2010. Our activities and background lays
in the basement of former Finnish Maritime Administration
Professionals in underwater surveys and inspections
MeriTaito

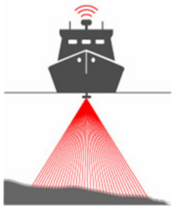

MeriTaito
Activities

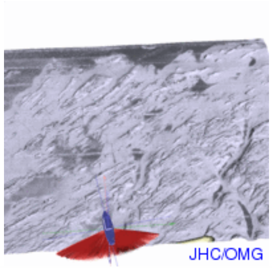
MeriTaito

Bottom bathymetry
Multibeam surveys

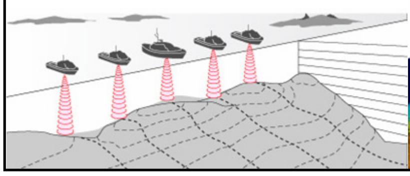
Multibeam Sonar

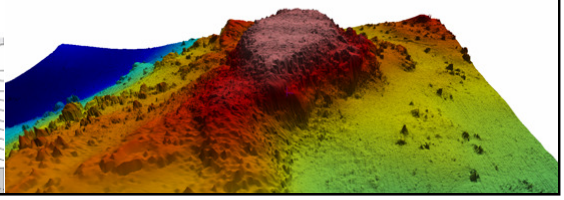
- Full bottom coverage to make 3D model
- more than 25000 survey points per second
- Meritaito Ltd has eight (8) units, SB7111, SB7101, SB8101 and SB7125
- 100 kHz-400 kHz





Animaatio: John Hughes Clarke, Ocean Mapping Group





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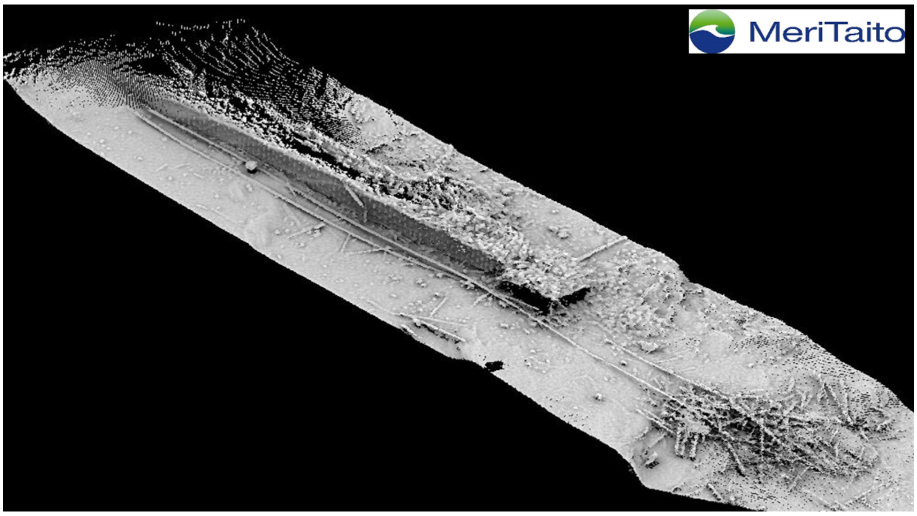
Multibeam Survey Vessels

SeaBat 8101/7111/7101/7125

Underwater structures and cables, Suomenlinna, Helsinki



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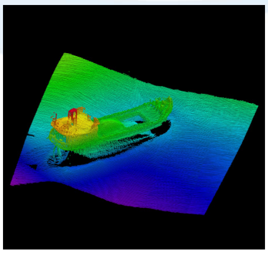
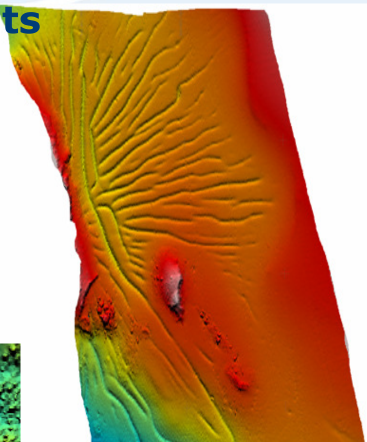
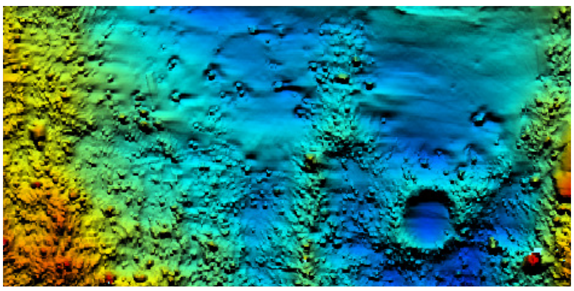
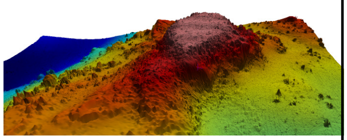
Other results









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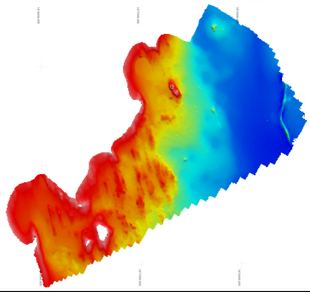
Multibeam survey technology, advantages

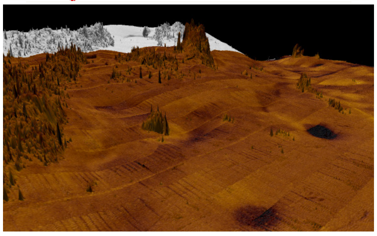
Compared to olf fashion siglebeam soundings you get full coverage bottom information

Technical development has been fast, 10 years ago one sweep had 100 points, now there is 500 points

The resolution in shallow waters has developed accordingly and smaller targets can be located

All points have xyz-coordinates





New application: Tilted MBES-sensor

Meritaito surveyboat has sensor in 45 degree angle
It gives survey results up the water surfase

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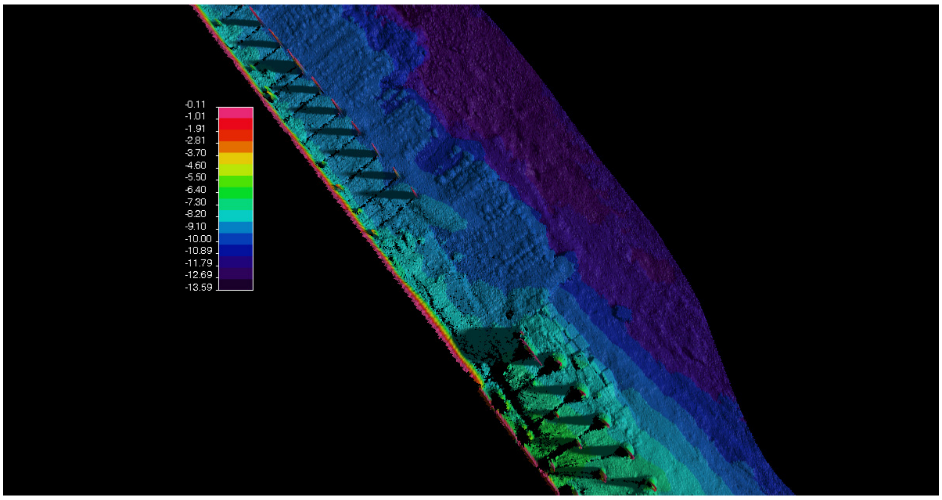
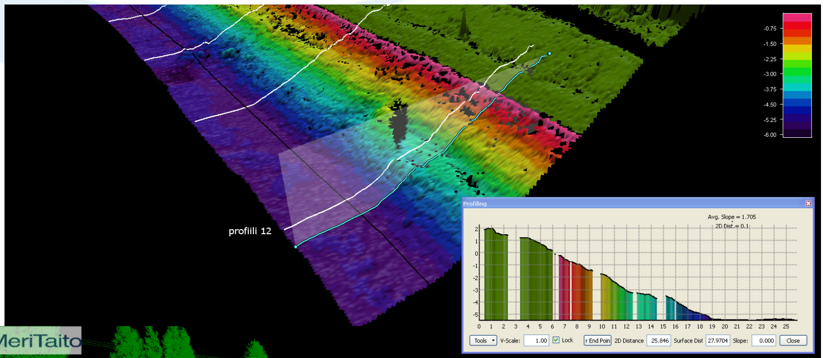
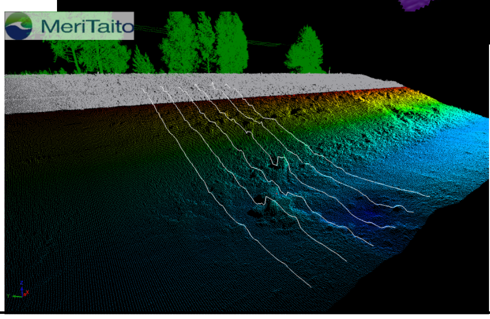
Scouring protection and dock structure in Port of Turku



Inspection of canal slope, Saimaa canal, damages





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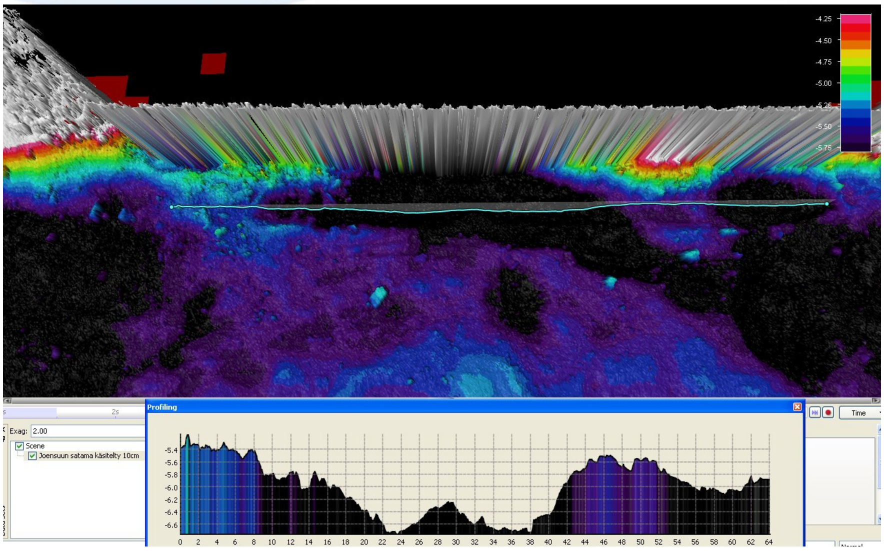
Port of Joensuu, section of the berth



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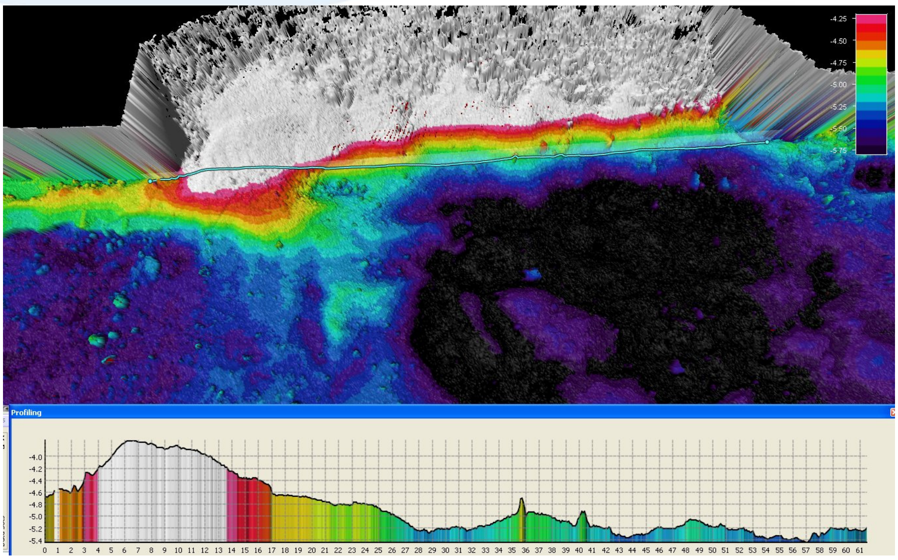
Port of Joensuu, section of the slope



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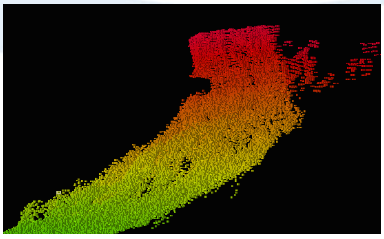
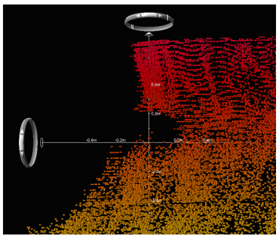
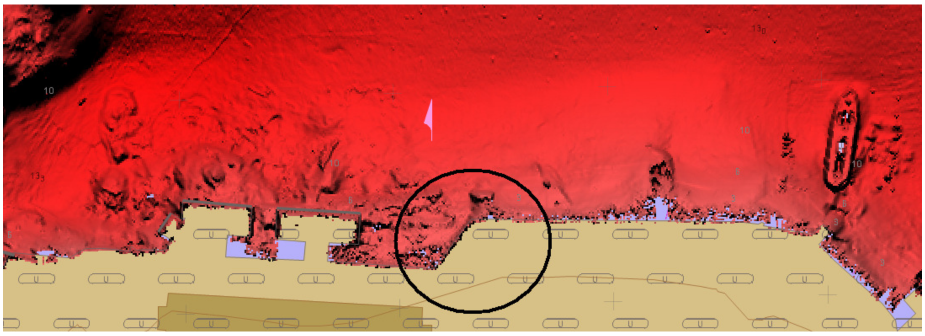
Damage in stone wall, Suomenlinna







MeriTaito

Tilted Multibeam sensor

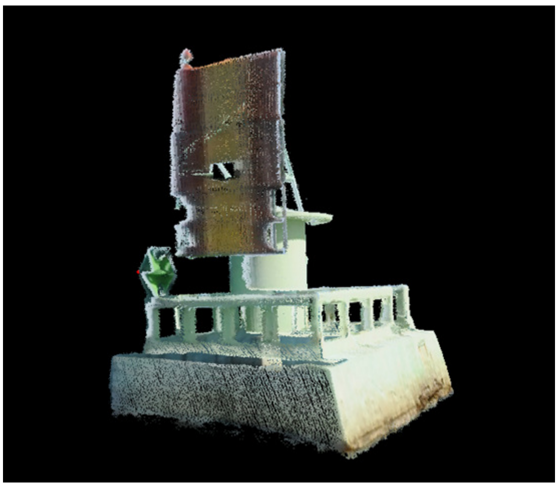
- New high resolution MBES sensors in 400 kHz up to 500 survey points in one sweep gives better information of the sea bed than the earlier MBES equipments
- Tilting the sensor gives information up to the water surface
- This introduce new possibility to survey properly harbour structures and other underwater civil engineering targets
- Visibility in water does not effect to the study
- All results are 3D point clouds and are compatible to the modern planning softwares for designing and planning purposes

MeriTaito

Laserscanning

- Riegl VZ-400 3D-laser scanner
  - 125000 points/second
  - multiple targets

Storhästen leading mark



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Laser scanning tecnology, advantages

Point cloud is very accurate, internal accuracy is in millimeters

Mobile scanning allows measurement done simultaniously with multibeam survey

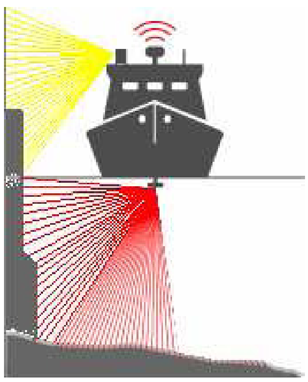
Static scanning gives you also calours for each scanning points

All scanning ponts have xyz-coordinates

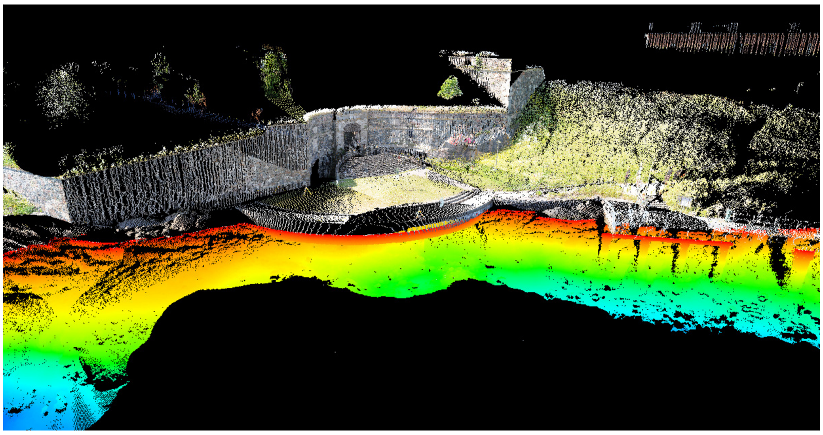
MeriTaito

Multibeam survey and laser scanning simultaniously gives you total information

- **Survey result can be done by combining multibeam and laser scanning point clouds**
  - **better resolution**
  - **no gap between poin clouds**
- **This gives a possibility to take laser scanner as a part of modern hydrographic syrvey system**
  - **positioning- and motion sensors works normally with both instruments**
  - **RTK or VRS positioning**



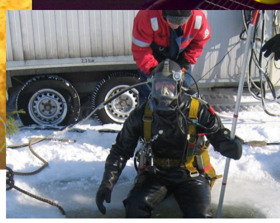
Multibeam survey and laser scanning simultaniously gives you total information
Suomenlinna, Kings Gate



Other Site Investigations in Harbours

ROV and Diving inspection

- Remote operated underwater vehicle
- Realtime still- ja videorecording
- Manipulator
- MeriTaito Ltd has two different size of ROVs (150m, 4,5 kg ja 500m, 50 kg)
- Meritaito has several professonial divers for differend kind of diving works



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Traditional methods: Diving and ROV inspections

Diving is widely used in Finland to inspect dock structures

- **Advantage is that skilled inspection diver has good skills to estimate structure in situ**
- **Diving inspection is time consuming and rather expensive. Results are drawings and written text on paper.**
- **Bad underwater visibility lower the accuracy of the inspection**

ROV-inspections have more rare.

- **Advantage is that you can operate ROV from surfase and it is not so manual labor**
- **To make proper study you need undervater positioning system and good steering ability for ROV (more expensive equipments)**
- **Bad underwater visibility common in harbour areas has same effect than to the diving work**

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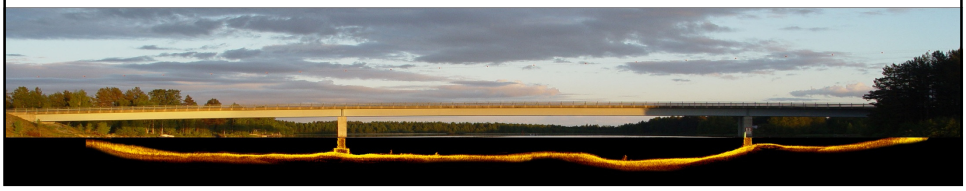
New possibility to make suplementary inspections

New technology gives new possibilities to makes suplementary inspections

Next I will introduce a combination of Multibeam Surveys and Scanning underwater sonar

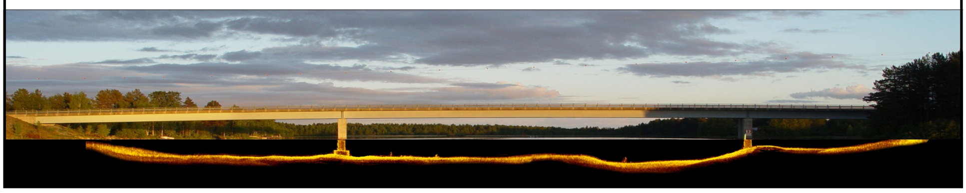
VRT Vesirakennetutkimus Ltd

- VRT Vesirakennetutkimus Ltd is a company specialised in underwater examination and inspection. We offer a high quality inspection of a wide range of underwater facilities.
  - All inspections , results and repair recommendations are performed by specialized civil engineers.
  - VRT offers an all-encompassing control of 3D material. We have at our disposal the necessary equipment to gather a point cloud data of any structure under or over the water level.
  - The point cloud data will be connected to a coordinate system after which it may be transferred into a three dimensional model.
  - We master a large variety of programmes aimed at handling point cloud data and building information models (BIM).



VRT Vesirakennetutkimus Ltd

- **Scanning sonar**
  - Operating frequenzy from 600-1500 kHz
  - Most accurate method for inspecting underwater strutures
  - The examined structures could be anything from piers, bridges, power plants, dams or shoreline barriers to riverbeds
  - Equipment is also suitable for directing diver, locating missing persons or objects.
  - The work may be performed on a platform appropriate for the environment in question, for instance using a barge, a crane or working on ice
  - Able to detect and define possible deviations and changes in the underwater structure or the surrounding area also in murky waters or in a fast current
  - The result is an accurate 3D point cloud data or a 2D photographic rendering of the underwater structure



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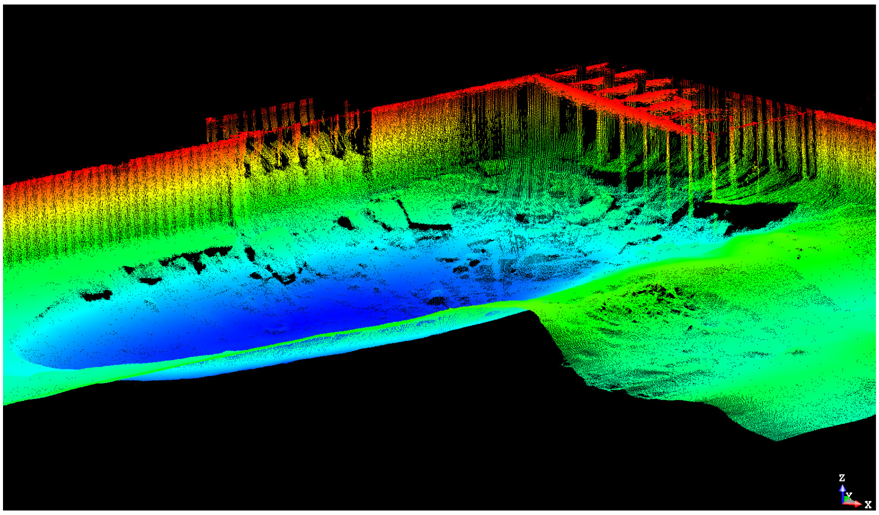
Multibeam survey in Sörnäinen berth in Helsinki



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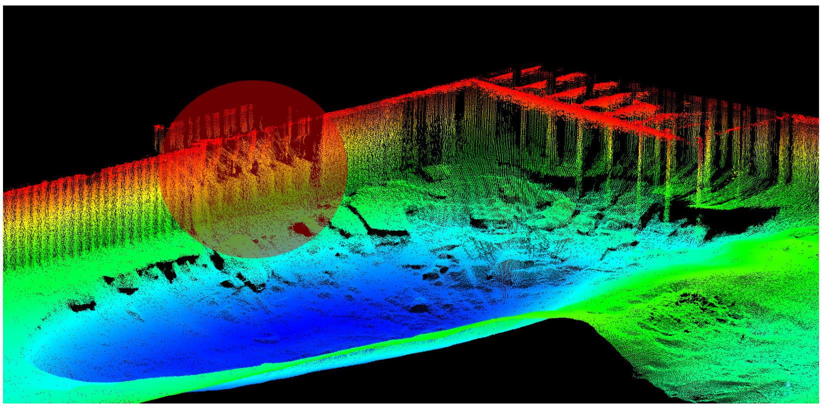
Point of interest 1



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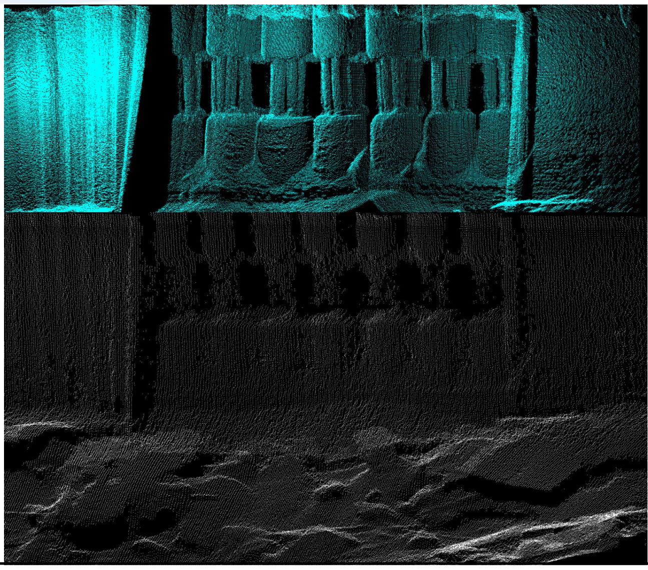
VRT

Multibeam data and scanning sonar data



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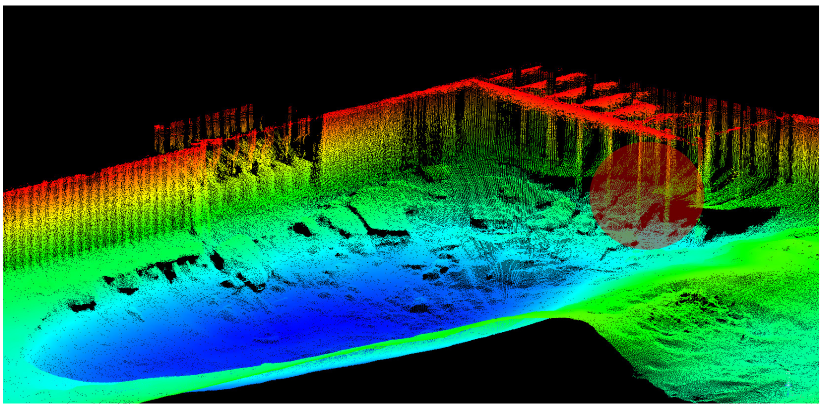
Point of interest 2

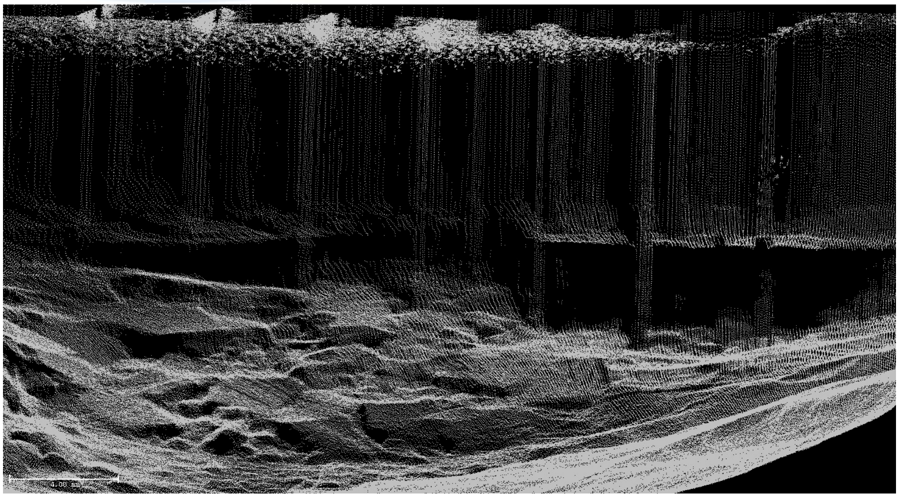


MeriTaito

VRT

VESIRAKENNETUTKIMUS OY

Multibeam data of the area



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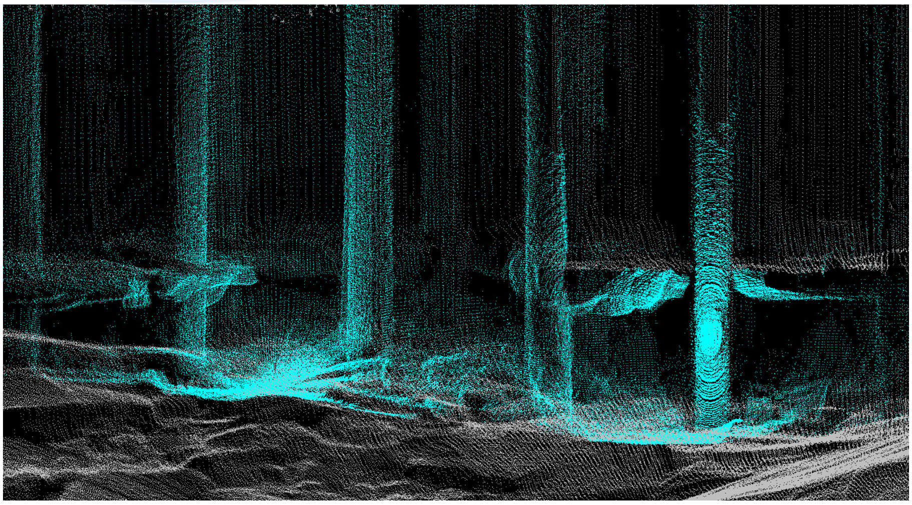
VRT

VESIRAKENNETUTKIMUS OY

Scanning sonar data of the piles



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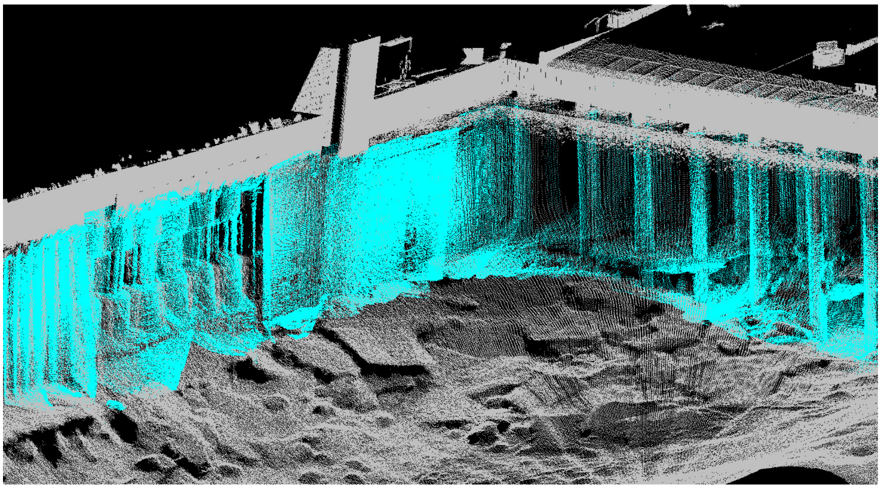
Overall picture of the area with both methods and laser scanning of the upper structure



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Method and service provided

- MBES gives a good picture of the situation and structures under the water
- MBES 3D point cloud gives excellent information about the critical areas for closer examinations and planning
- At the same time mobile laser scanner gives you almost photograph quality picture in 3D above water structures
- Closer inspections with scanning sonar gives more detailed information about damages, also in 3D point cloud
- All this information in digital form can be modelled and it is usable in modern planning softwares for further maintenance planning and design

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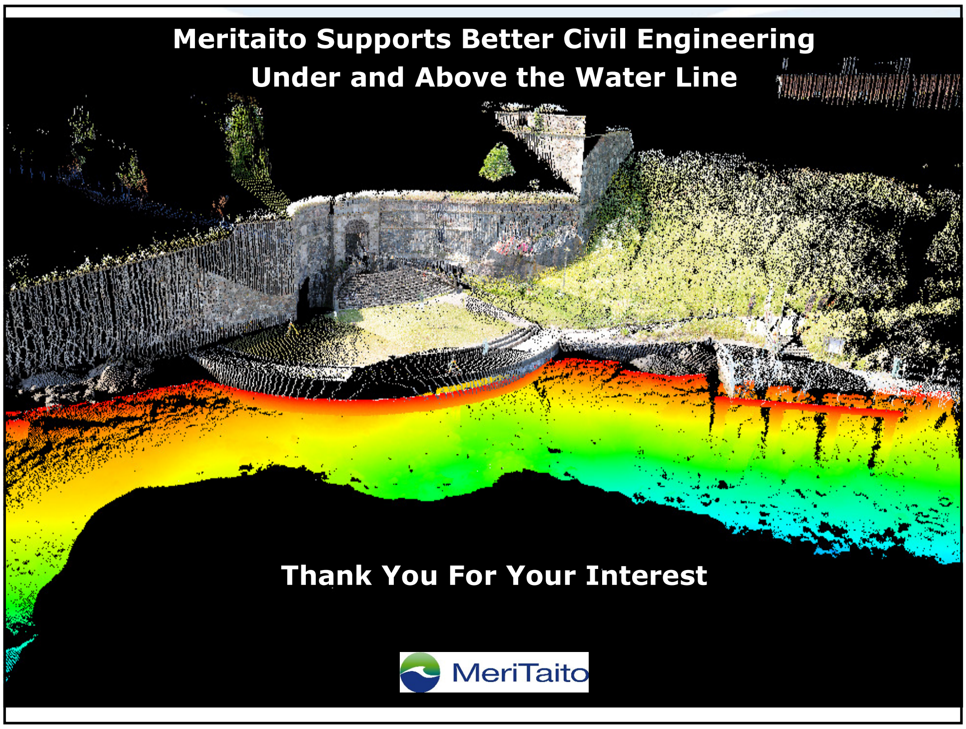
Possibilities of High Resolution Multibeam
and
Laser Scanning Technology

Structure

- Meritaito Ltd past and today
- Multibeam survey
- Multibeam survey, new application
- Laser scanning
- Combination
- Suplementary inspections, traditional and modern
- Service package



Paper 3-5 **PROJECT REVIEWS** and their value in realising innovations
E. PECHTOLD (NL)

What's new in the design of navigation locks?


PIANC Workshop
13-14th September 2011
Project Reviews
and their value in realizing innovations
By Erwin Pechtold, Rijkswaterstaat
THE NETHERLANDS
PIANC
Setting the course


Introduction
PIANC
Report n° 106 - 2009
Innovations in navigation lock design
The World Association for Waterborne Transport Infrastructure
Many innovations are developed worldwide
However often not realized
Why ?
• Unknown
• Uncertain
www.pianc.org
New-Orleans 2011
2
PIANC
Setting the course

How to solve that ?

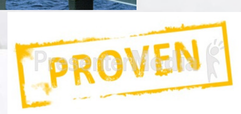
To know what is possible
an easy accessible overview can help.

To know the certainty of solutions
experience from actual projects can help.

A possible answer:

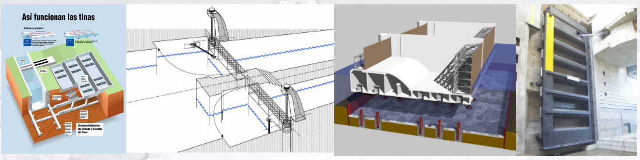
Project Reviews

Benefits of Project Reviews

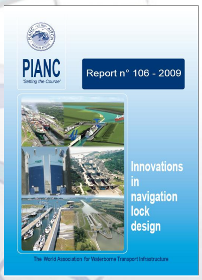
- Possible solutions 
- Chances and risks 
- Time and money 
- Learn by mistakes of others 
- It works, so it's easily accepted 

Project Reviews in Report 106

- Selection of 56 projects worldwide
- Innovative features / unusual aspects.
- Show type of innovations and level of today's technology.
- Facts / Photographs / techn drawings



3 steps to get your information:



1.	Summary Table	(= 1 page)
2.	Summary in the report	(= Chapter 2)
3.	Case studies on DVD.	(=750 pages, 65 MB)

1 - Summary table

Project Reviews	Hydraulics		O & M					Environmental				Design / Construction							Misc.		
	Filling and Emptying Systems	Water Management (Water Saving Basins)	Energy Management	Life Cycle Cost	Maintenance	Vessel Operations and Impact	Silt and Debris Mitigation	Environmental Concerns	Salt Water Intrusion	Ice Control	Fish Mitigation	Design Guidance	Lock Size, Cycle & Capacity; Vessel Geometry, Lock cycle	Struct Systems – Fdns, Lock Walls, approaches	New Materials	Gates – materials, systems, type	Construction Means and Methods	Renovation, Rehab & Size Modifications	Lock Equipment	Communications – 3D modeling	Public Safety – Terrorism, Public Access
1 1-01 Kallo Sea Lock					PT	PT						PT					UT	UT			
2 1-03 Self-Propelled Floating Lock																AC					
3 1-04 High-Rise Navigation Lock	AC															AC					
4 1-05 Van Cauwelaert Lock							PT									PT		PT			
5 2-01 Tucurui Lock		PT											PT								
6 2-02 Lajeado Lock	PT												PT								
7 3-02 Grand Canal	PT												PT								PT
8 3-04 Jinjitan	PT																				PT
9 3-05 Mengli	PT																				
10 3-06 Qiaogong	PT																				PT
11 3-08 Three Gorges	PT												PT	PT		PT					
12 4-01 Juankoski Canal				PT		PT								PT			PT		PT		
13 4-02 Keitele	PT			PT	PT	PT							PT	PT							
14 4-03 Saarikoski																		PT			
15 4-04 Saimaa						PT	PT					PT				PT			PT		
16 5-01 Composite Miter Gates - Golbey				PT	PT							PT			PT	PT		PT			
17 5-02 Composite Vertical Lift Gate					NC										NC	NC					
18 5-03 Gate Protection - Rhone lock			PT			PT						PT		PT	PT	PT					
19 5-04 Horizontal Translation Gate												PT				PT					
20 5-05 Rhone Chautagne et Belley						UT						PT									
21 5-06 Rhone Locks Stoplogs Protection					PT														PT		
22 5-07 Seine-Nord Europe	PT	PT		PT												PT	UT				
23 5-08 Rhone Fish Ladder Lock	PT										UT										

1 - Summary table – Example Lith

Project Reviews	Hydraulics		O & M					Environmental				Design / Construction							Misc.		
	Filling and Emptying Systems	Water Management (Water Saving Basins)	Energy Management	Life Cycle Cost	Maintenance	Vessel Operations and Impact	Silt and Debris Mitigation	Environmental Concerns	Salt Water Intrusion	Ice Control	Fish Mitigation	Design Guidance	Lock Size, Cycle & Capacity; Vessel Geometry, Lock cycle	Struct Systems – Fdns, Lock Walls, approaches	New Materials	Gates – materials, systems, type	Construction Means and Methods	Renovation, Rehab & Size Modifications	Lock Equipment	Communications – 3D modeling	Public Safety – Terrorism, Public Access
25 6-01 Bolzum	PT													PT		PT					
26 6-02 Doerverden														NC							
27 6-03 Hohenwarthe														PT							
28 6-04 Uelzen II	PT													PT	PT	PT	PT				
29 6-05 Kaiserschleuse Bremerhaven	NC					PT								PT		NC			PT		
31 7-02 Lith Lock								PT						PT			PT				
33 7-04 Oranje Locks																PT		PT			
34 7-05 Suspended Miter Gate															PT	PT					
35 7-06 Zuid-Willemsvaart												PT					PT				
36 7-07 Spiering lock - Composite Mitre Gate								UT							UT	UT					
37 8-01 Panama - New Locks	UT	PT		PT	PT	UT		PT	PT			PT	UT	UT							

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2 - Summary

Areas of innovation

Hydraulics	Operations & Maintenance	Environment	Design / Construct	Misc
A	*B*	*C*	*D*	*E*

Categories

- PT: Proven technology
- UT: Unproven technology
- NC: New Concept
- AC: Advanced concept

A: Filling and emptying, water saving.
B: Energy, LCC, Vessel ops & impact.
C: General, salt water, ice control, fish migration
D: Structure, materials, gates, construction methods.
E: Lock equipment, communic,3Dmod, public safety

PT	[1] **Proven Technology (PT) – The feature has been built and validated by time and experience**
UT	[2] **Unproven Technology (UT) – The feature has been built but it has not yet been validated by time and experience.**
NC	[3] **New Concept (NC) – The feature is currently in the design process, but has not yet been built.**
AC	[4] **Advanced Concept (AC) – the feature is been evaluated and/or tested in the research stage.**

2 – Summary – Example Lith

2.3.31 Lith Lock (PR 07-02 The Netherlands)

Areas of Innovation

Hydraulic	O & M	Environ	Design / Construct	Misc

Lock Dimensions

Length:	200.0 m	Lift:	5.55 m
Width:	18.5 m	Depth:	4.7 m

Project Description

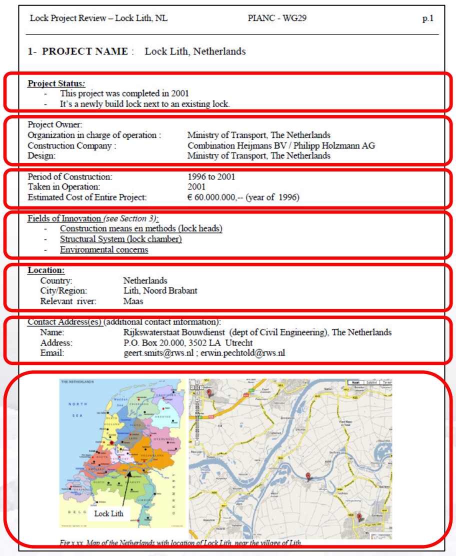
A new lock chamber has been build to replace a small existing lock. Innovative features are:

- The lock heads have been constructed as a pneumatic caisson as described in PR 07-01.
- The chamber walls consist of concrete deep walls provided with prefab concrete slabs and fixed with grout anchoring system.

3 – Case Study (DVD)

- Status
- Who
- When
- Innovations
- Where
- Contact
- Map

6 pages of info



Lock Project Review – Lock Lith, NL PIANC - WG29 p.1

1- **PROJECT NAME** : Lock Lith, Netherlands

Project Status:
- This project was completed in 2001
- It's a newly build lock next to an existing lock.

Project Owner:	
Organization in charge of operation :	Ministry of Transport, The Netherlands
Construction Company :	Combination Heijmans BV / Philipp Holzmann AG
Design:	Ministry of Transport, The Netherlands
Period of Construction:	1996 to 2001
Taken in Operation:	2001
Estimated Cost of Entire Project:	€ 60.000.000,-- (year of 1996)

Fields of Innovation *(see Section 3)*:
- Construction means en methods (lock heads)
- Structural System (lock chamber)
- Environmental concerns

Location:

Country:	Netherlands
City/Region:	Lith, Noord Brabant
Relevant river:	Maas

Contact Address(es) (additional contact information):

Name:	Rijkswaterstaat Bouwdienst (dept of Civil Engineering), The Netherlands
Address:	P.O. Box 20.000, 3502 LA Utrecht
Email:	geert.smits@rws.nl ; erwin.pechtold@rws.nl

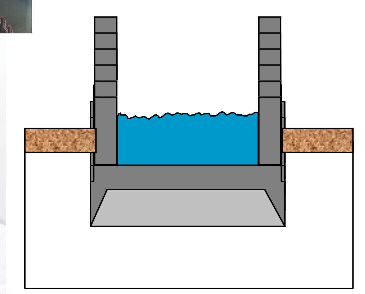
Fig x.xx Map of the Netherlands with location of Lock Lith, near the village of Lith

PIANC Setting the course

3 – Case Study – Example Lith

Caisson method

1. temporary mound of soil
2. Construction of lock head
3. Excavation under lock floor
4. Pneumatic submersion
5. Fill-up of basement with concrete
6. Finishing works



PIANC Setting the course

Reasons for innovation

- lack of construction space
- Piling causes damage
- reduce environmental impact

Lessons learned

4- EXPERIENCES

Apart from the other advantages, the use of concrete deep walls in combination with the reinforced concrete front walls was expected to be noticeable cheaper than a regular U-shaped concrete chamber.

However, during detail design it turned out to be just as expensive, because the thickness of the concrete deep walls needed to be thicker than expected.

Furthermore the innovations mentioned in this document gave no significant problems during development and appliance. As far as is known today there are no problems at all concerning the resulting structure.

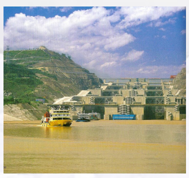
- No significant problems afterwards
- Chamber walls: Neutral cost balance compared to regular techniques.

So what do we have ?

Project Reviews in Report

- a lot of useful information
- valuable source for ideas
- gives confidence in the feasibility





But … there are limitations

- No updates
- Not complete:
  Many more locks
- Not interactive compared
  to other modern media

How to use this effectively
for the future ?

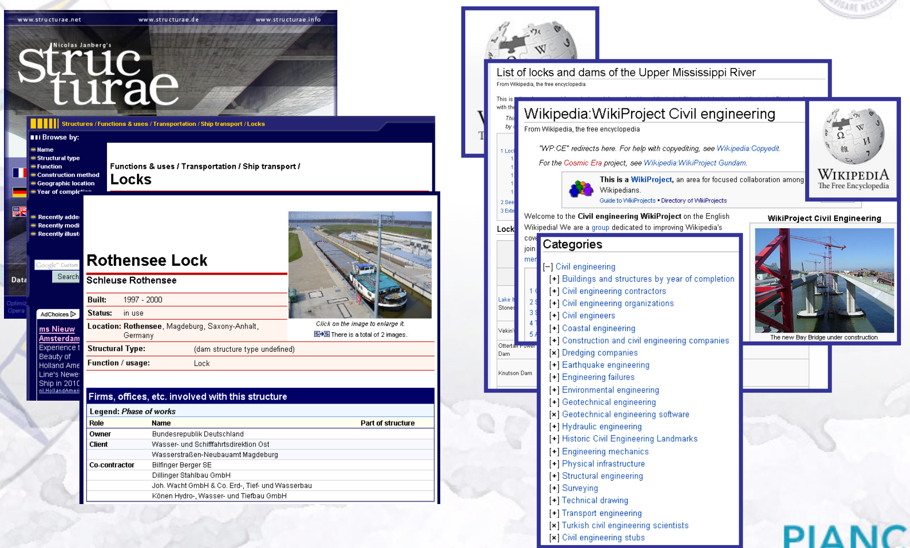
So what should we need

- Database > What are its criteria?
- Easy accessibility
- Easy exchange of ideas and solutions
- Use of new media

An online PIANC database
with Wikipedia features ??

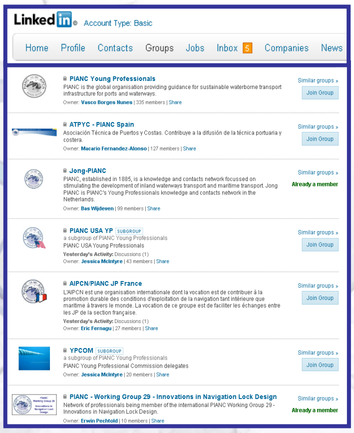
How can a database look like …

What already exists for technology



…. and for the people network

• The PIANC network !



Could the Internet help to share our questions, discussions and findings ?

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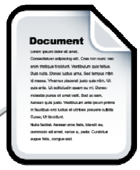
What can be done ?

projects

facts

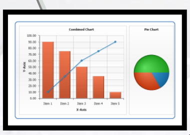


Our challenge for tomorrow ….

people

ideas

countries



results

New Working group ?

PIANC Setting the course

Paper 4-1 **DESIGN FOR MAINTENANCE: DREAM OR REALITY? THE EXPERIENCE OF THE NEW PANAMA LOCKS LIST OF REQUIREMENTS**

R. GORDON and J. WONG (ACP)

What's new in the design of navigation locks?

PIANC Workshop
13-14th September 2011

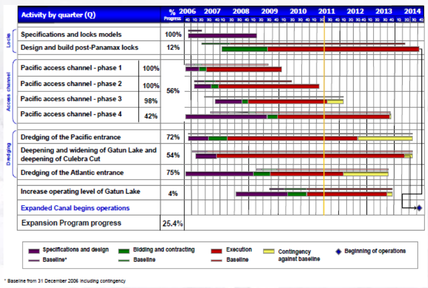
Design for Maintenance
The Experience of the New Panama Locks

(Cheryl George)
Rogelio Gordon
Juan (Johnny) Wong
Panama Canal Authority

PIANC
Setting the course

Project chronology

- 1998-2005 Studies and Master Plan (dream?)
- 2006-2009 Referendum and Contracting
- 2009-2011 Design, set up, excavation
- 2012-2014 Construction
- 2015-2017 Operation and maintenance (reality?)



Project set-up

- Build the team
  - ACP expertise, Technical Experts and Project Management
- Benchmarking
  - USACE and European Post-Panamax locks (Germany, Netherlands, Belgium, France, Great Britain)
  - PIANC

Procurement process

- Design-build contract
  - Performance specifications
- FIDIC yellow book
- Meeting with Consortia
  - Amendments
- Bid best value
  - Technical 55% and Financial 45%

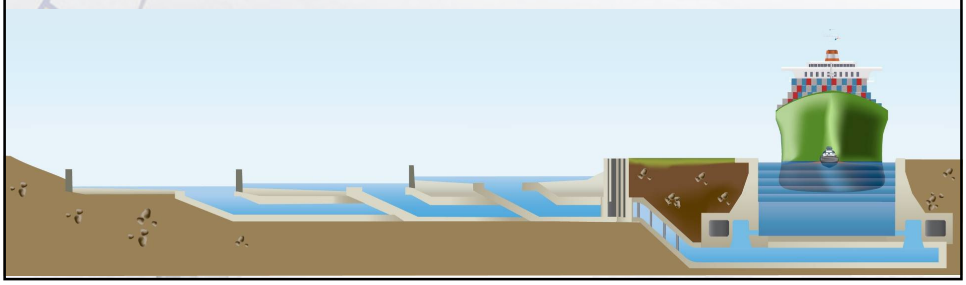
PIANC
Setting the course

Top level decisions

- Post-panamax size vessel and locks
- Tugs vs locomotives
  - Life cycle cost: initial, operations and maintenance costs

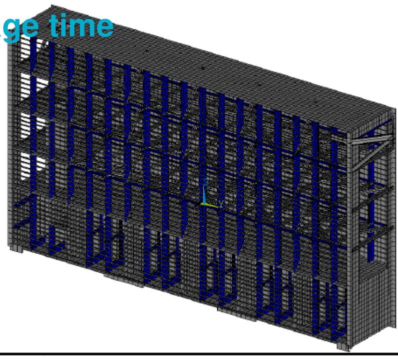
Top level decisions (2)

- Three lift locks
  - Water, environmental, technical
- Water saving basins
  - Proven technology German locks barge traffic
  - Numerical & physical models



Rolling gates

- Gate size and weight
  - Double set of gates for safety and reliability
  - Standardized middle gates
- Able to dry dock and maintain in place
  - Bulkheads, pumps, outage time
- Operating cycles
- Replacement of buggies
- Corrosion
- Traffic gates

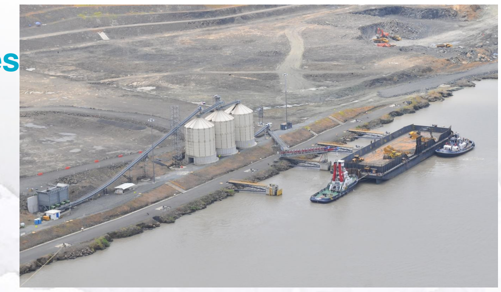


Civil and structural

- Seismic
  - Different levels of damage to structures
  - Fit for purpose
- Durability (100 years)
  - Concrete strength and permeability
  - Culvert water velocities

Reliability

- Third set of locks requires very high reliability
  - Fault tree analysis
  - Redundancy
- Reduced outage times



Filling and Emptying

- Side F-E system
- F-E times and hawser forces
- Limit max water velocity
- Water velocity approach channels
- Valves main and conduit
  - Standard
  - Bulkheads to isolate repair and maintenance

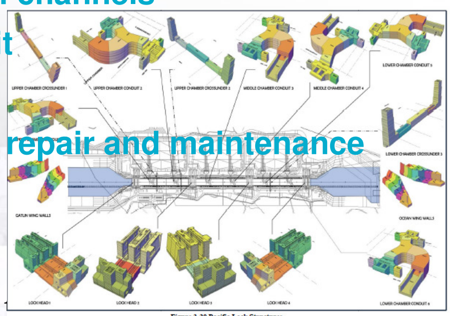
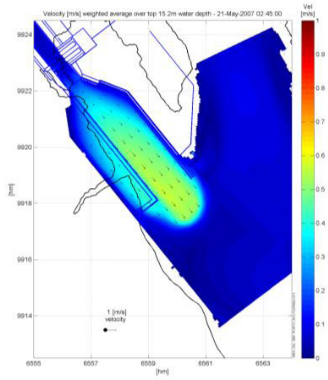


Figure 3-20 Pacific Lock Structures

Electrical, mechanical, control

- Reliability feed two loops
- Crossunders and cable trays/raceways
- Standard off-the-shelf parts
- Current technology
- Three years maintenance option



Gracias

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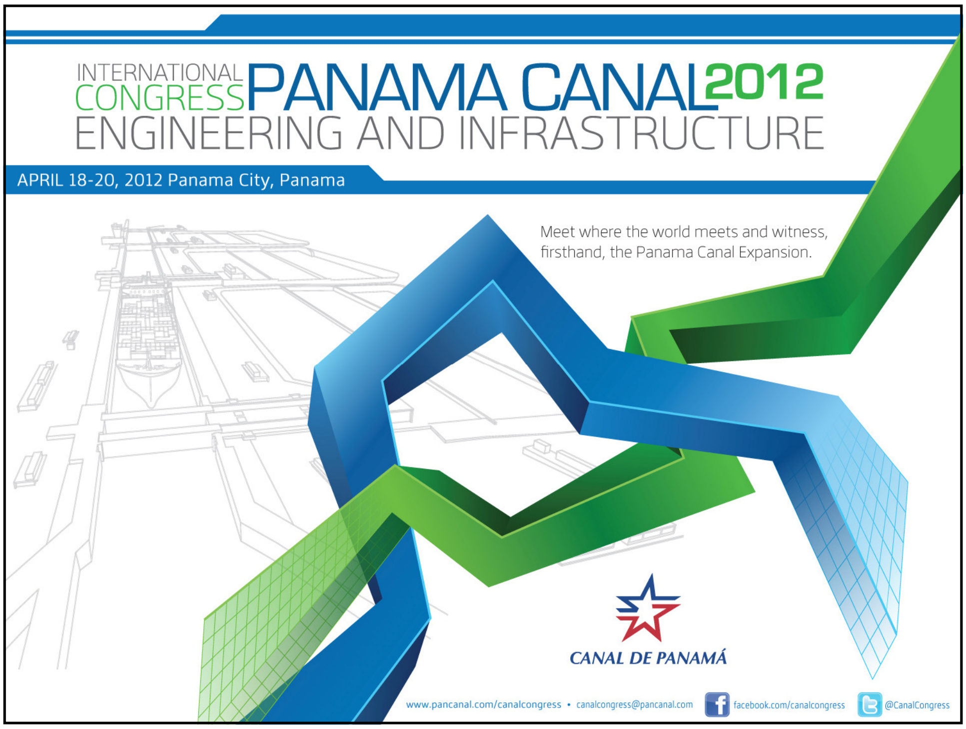
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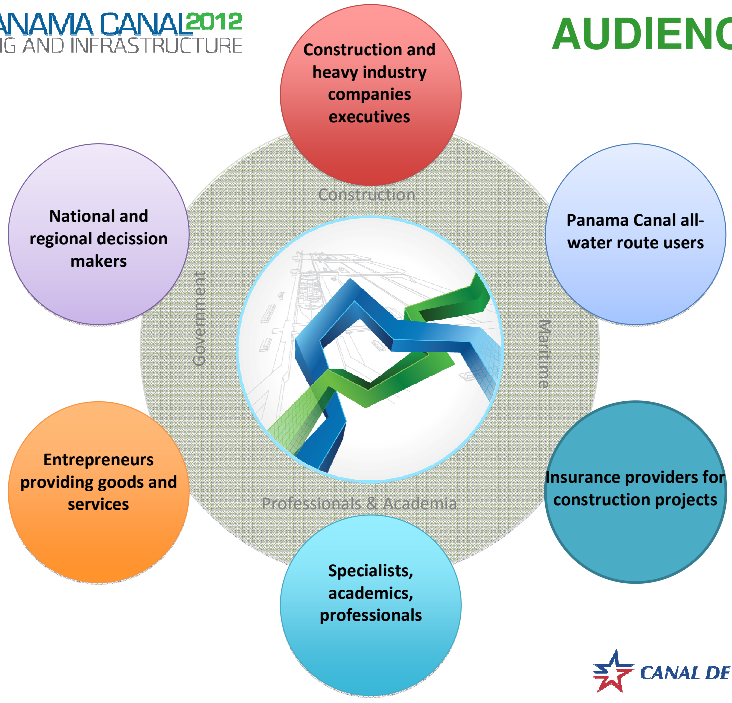

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INTERNATIONAL CONGRESS PANAMA CANAL 2012
ENGINEERING AND INFRASTRUCTURE

ORGANIZATION

- Panama City, Panama
- *From 18 to 20 April 2012*
- more than 600+ participants
- 25 conferences national and internationals
- More than 30+ presentations and forums
- Site tours of Canal Expansion works
- Closed circuit transmission

CANAL DE PANAMÁ

INTERNATIONAL CONGRESS PANAMA CANAL 2012
ENGINEERING AND INFRASTRUCTURE

NETWORKING

- **Interaction with decision makers.**
  - National
  - Regional
- **Information on on-going and future projects.**
  - National
  - Regional
- **Networking with key players of sector.**
- **Oportunity for new businesses.**
- **Field visits to Canal Expansion works.**

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Cemento Panamá
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CEMEX PANAMA
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GRACIAS

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Paper 4-2 IDENTIFICATION OF THE CHALLENGES OF TOMORROW - PANEL MEETING

Experts: J. AUGUSTIJN (NL), J. BODEFELD (D), R. DANIEL (NL), R. GORDON (ACP), M. NEWBERY (USA), Ph. RIGO (BE), R. THOMAS (BE), J.WONG (ACP).

What's new in the design of navigation locks?


PIANC Workshop
13-14th September 2011
IDENTIFICATION OF THE CHALLENGES FOR TOMORROW
PIANC Panel Group
LOCKS EXPERTS
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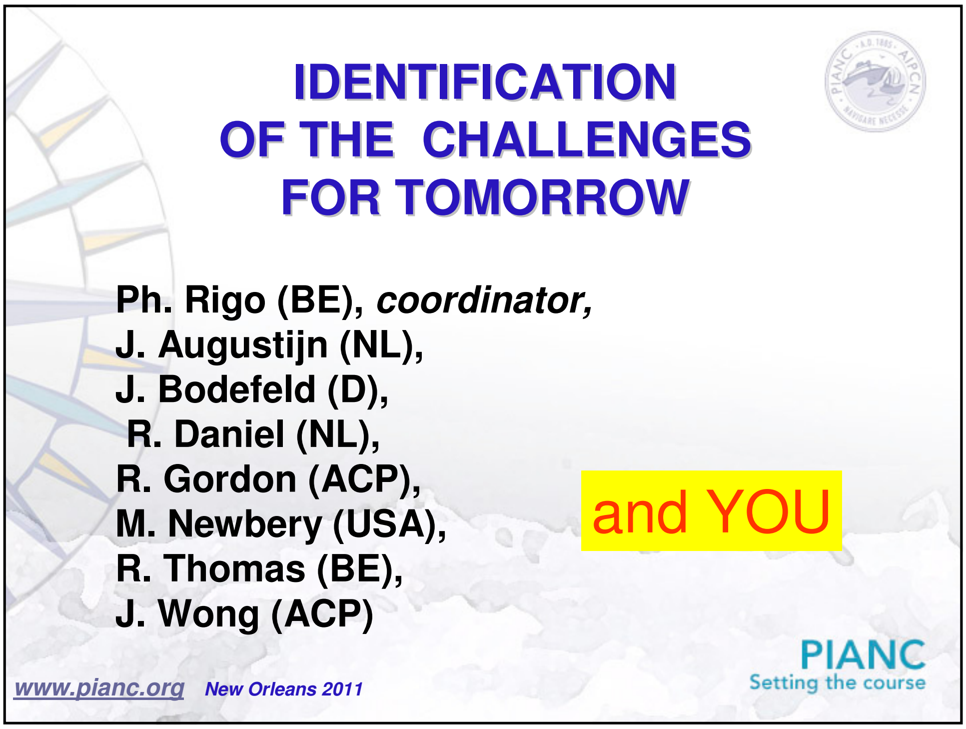
IDENTIFICATION
OF THE CHALLENGES
FOR TOMORROW
Ph. Rigo (BE), coordinator,
J. Augustijn (NL),
J. Bodefeld (D),
R. Daniel (NL),
R. Gordon (ACP),
M. Newbery (USA),
R. Thomas (BE),
J. Wong (ACP)
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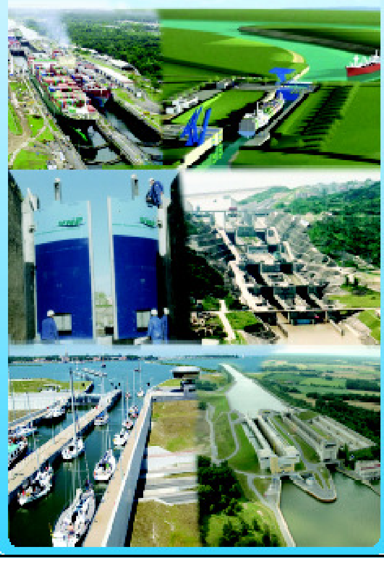
Report n° 106 - 2009



Innovations in navigation lock design

IDENTIFICATION OF THE CHALLENGES FOR TOMORROW

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IDENTIFICATION OF THE CHALLENGES FOR TOMORROW

GOAL: Identify the pending issues, which remain in 2011 key challenges for the design of navigation locks.

The PIANC experts will highlight
➔ the relevant topics
- requiring more extensive researches,
- relevant for new PIANC working groups.

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CHALLENGES OF TOMORROW

Identify key issues to consider for the **NEXT PIANC WORKSHOP - 2013**

Based on experiences gained in projects as

- PANAMA, Seine Nord Europe (Fr)
- ANTWERP (Sea lock)
- LYS River and MEUSE river (BE)
- IJMUIDEN (NL, Amsterdam)
- China, Germany, US,….

1- IDENTIFICATION OF THE CHALLENGES FOR TOMORROW

- The seismic effect, which is currently investigated by PIANC WG151,
- Ship entrance/maneuvering and ship behavior in locks, which is currently investigated by PIANC WG155,
- Ship impact on lock gates, which is currently investigated by PIANC WG151,
- Reliable design and operation of miter gates, which will be investigated by a new PIANC WG 154,

1- IDENTIFICATION OF THE CHALLENGES FOR TOMORROW

- Use of composite material for the design of locks,
- Design of monolith lock (versus a structure with joints),
- High rise navigation locks (above 40 m),
- Water management (lack of or too much),
- Salt water intrusion,

1- IDENTIFICATION OF THE CHALLENGES FOR TOMORROW

- Life cycle cost: “Design for Maintenance”,
- Durability of structures,
- Maintainability of equipment and structures,
- Environmental and social aspects,
- Stakeholders’ management,
- Etc.

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2- CHALLENGES FOR LOCK GATES

- Reliability under all conditions. Sometimes engineers complicate their systems too much, increasing in fact the probability of failures.
- Service life (durability and maintainability) of gate components like tracks, wheels, hinges, seals, buffers and heel posts (mitre gates); and not the main structures that usually serve long enough.

2- CHALLENGES FOR LOCK GATES

- Maintainability in the sense of: low, easy, safe, healthy and environment-friendly maintenance.
- Vessel-friendly service. How to improve the comfort and safety of the vessels and their passengers (crews)?
- Etc.

PIANC Workshop
13-14th September 2011

Identification of the Challenges of Tomorrow

German point of view – construction of locks

By Jörg BÖDEFELD
BAW
GERMANY

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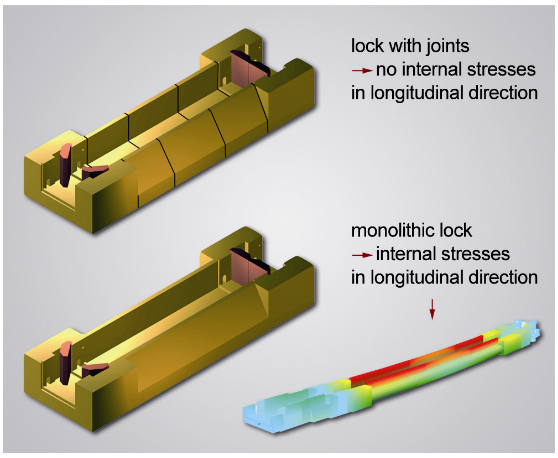
Challenges of Tomorrow

Monolithic construction



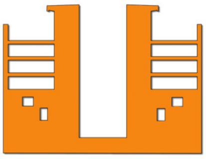
Challenges of tomorrow

Monolithic construction

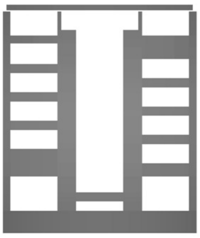
Working joints !

Challenges of tomorrow

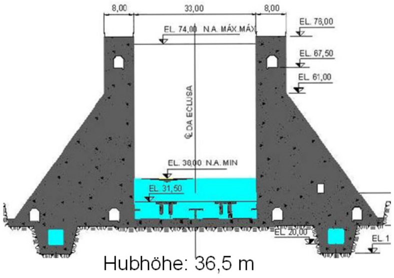
High Rise Naviation Lock



Hubhöhe: 23,0 m



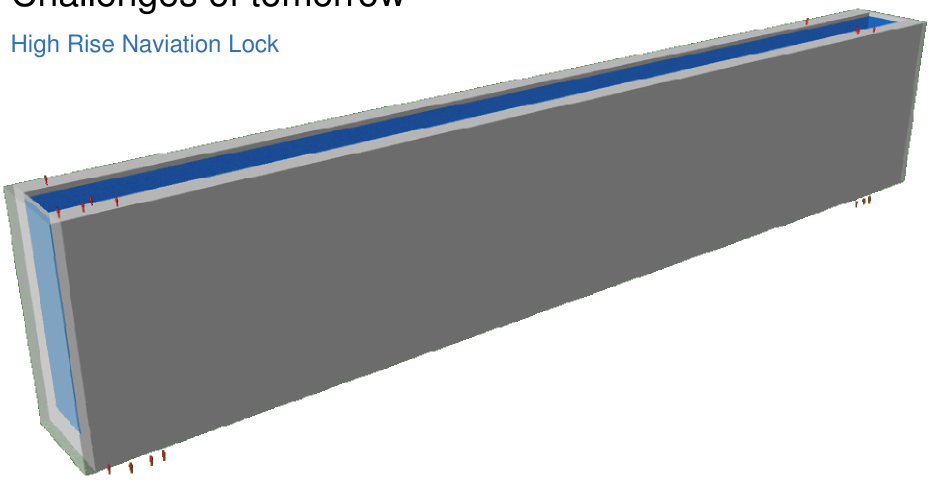
Hubhöhe: 38,0 m



Hubhöhe: 36,5 m

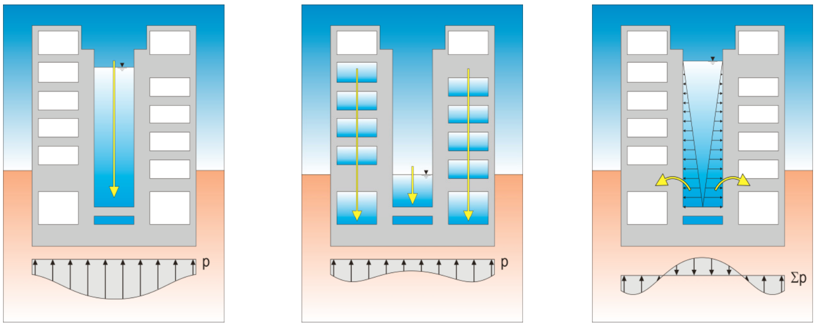
Challenges of tomorrow

High Rise Naviation Lock



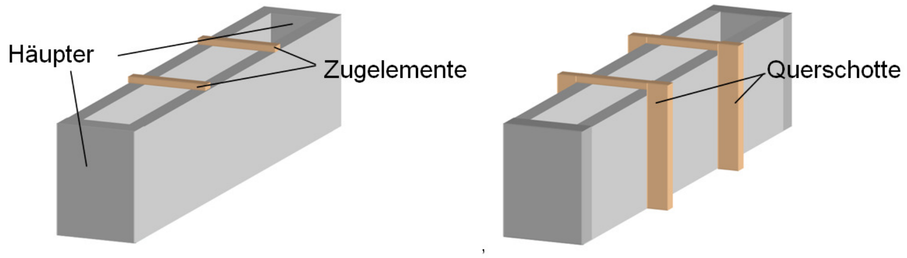
Challenges of tomorrow

High Rise Naviation Lock



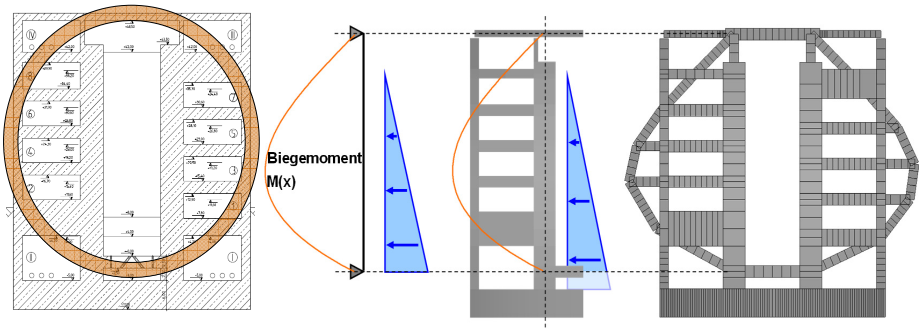
Challenges of tomorrow

High Rise Naviation Lock



Challenges of tomorrow

High Rise Naviation Lock



Challenges of tomorrow

Standardization

- Past:
  optimal solutions of each project
  - regional standards
  - a lot of one of a kind
  - complex and expensive
  - big efforts for planning
  - low cost certainty

Challenges of tomorrow

Standardization

- Future:
  standardization
  - low cost solutions
  - safe level of quality
  - efficient planning, tender and construction
  - modular packages

Challenges of tomorrow

Standardization

- First steps:
  Lengthening of 27 locks at one river with a construction kit
  Filling/emptying through the gates for locks with a small lift
  Standardized gates for locks with a small lift
  ….

Paper 5-1 MOORING FORCES AND VESSEL BEHAVIOUR
Experience in Belgium

T. DE MULDER (BE), M. VANTORRE (BE)

What's new in the design of navigation locks?

PIANC Workshop
13-14th September 2011

Part 5: Mooring forces and vessel behaviour in locks – Experience in Belgium

By T. DE MULDER & M. VANTORRE
BELGIUM

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Mooring forces and vessel behaviour in locks: Experience in Belgium

T. De Mulder & M. Vantorre

flanders HYDRAULICS RESEARCH
Antwerp

MARITIEME TECHNIEK UNIVERSITEIT GENT
Ghent

Mooring forces

Classical approach to ensure smooth and safe F/E of lock:
"**hawser force** criterion"

- misleading term
- **hydrodynamic force** exerted by water on should be below a given **threshold value**
- measure force on (centrally positioned) vessel in **scale model** (no mooring lines)

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Mooring forces

Threshold values for **inland** navigation:

- popular value for quite sometime:
  1‰ of displacement weight
- since 1980's (~neighbouring countries, mainly NL):

CEMT class	LxBxT	Filling (fixed bollards)	Filling (floating bollards), emptying
IV	80m x 9.45m x 2.8m	1.1 ‰	1.5 ‰
Va	135m x 11.4m x 3.5m	0.85 ‰	1.15 ‰
Vb	190m x 11.4m x 3.5m	0.75 ‰	0.75 ‰

Conservative…?
(in comparison to on site measurements)

Recreational vessels: 3 ‰

- relative approach: e.g. actual situation normative for situation after renovation of F/E system

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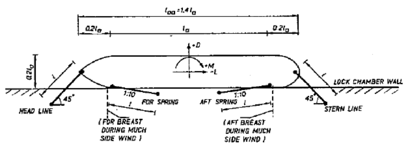
Mooring forces

Threshold values for **sea-going** navigation:

- A. Vrijburcht (1977)



Conservative…?
(in comparison to on site measurements)

ship's size tons DW	rope's type	rope T_{pr}/T_u	criteria in ‰: long. force x	transv. force y	moment z_1	z_2	z_3
40,000	steel	0.15	0.24	0.14	0.075	0.050	0.025
40,000	steel	0.10	0.15	0.10	0.051	0.034	0.017
40,000	nylon	0.20	0.26	0.20	0.102	0.068	0.034
40,000	nylon	0.10	0.14	0.10	0.051	0.034	0.017
80,000	steel	0.15	0.21	0.12	0.066	0.044	0.022
80,000	steel	0.10	0.13	0.085	0.044	0.029	0.015
80,000	nylon	0.20	0.22	0.16	0.087	0.058	0.029
80,000	nylon	0.10	0.115	0.08	0.043	0.029	0.015
120,000	steel	0.15	0.19	0.11	0.060	0.040	0.020
120,000	steel	0.10	0.12	0.08	0.041	0.027	0.014
120,000	nylon	0.20	0.205	0.16	0.081	0.054	0.027
120,000	nylon	0.10	0.105	0.08	0.040	0.027	0.013

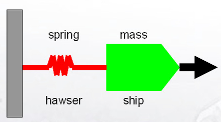
- relative approach: e.g. existing lock normative for (± comparable) new lock

Mooring forces

Threshold values:

- (too?) often only longitudinal force component considered
- $$\text{threshold} = \sum_{\text{mooring lines}} \frac{T_u \cos(\theta_i)\cos(\phi_i)}{f_s \cdot f_m}$$

T_u = minimum tensile strength
f_s = safety factor w.r.t. T_u
f_m = dynamic magnification factor
θ_i, ϕ_i = line orientation

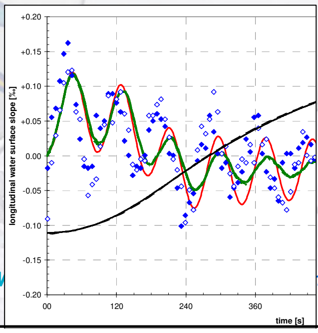


cf. H.-W. Partenscky (1986) ; A. Vrijburcht (1994) ; T. De Mulder (2007)

Mooring forces

Mathematical models for “**lateral**” F/E systems

- lock chamber flow based on Shallow Water Eqs. (1D or 2D)
- (pre)calculated timeseries of filling/emptying discharges
- vessel represented by means of artificial field of atm.pressure
- longitudinal water surface slope (bow-stern)

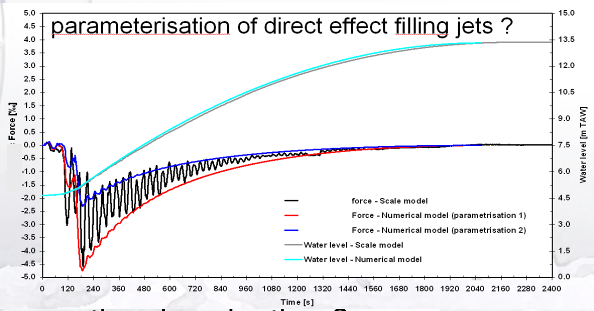


numerical predictions (LOCKSIM,DELFT3D)
and values measured on site

Mooring forces

Mathematical model for “**longitudinal**” F/E systems

- LOCKFILL (NL ; developed since 1990’s)
- similar programme developed in house at FHR
- intensive validation



- recreational navigation ?

“Hawser Forces”

Numerical calculation / Physical model test on immobilized vessel

➔ (horizontal) force and moment components on ship due to Filling/Emptying = **“exciting forces”**

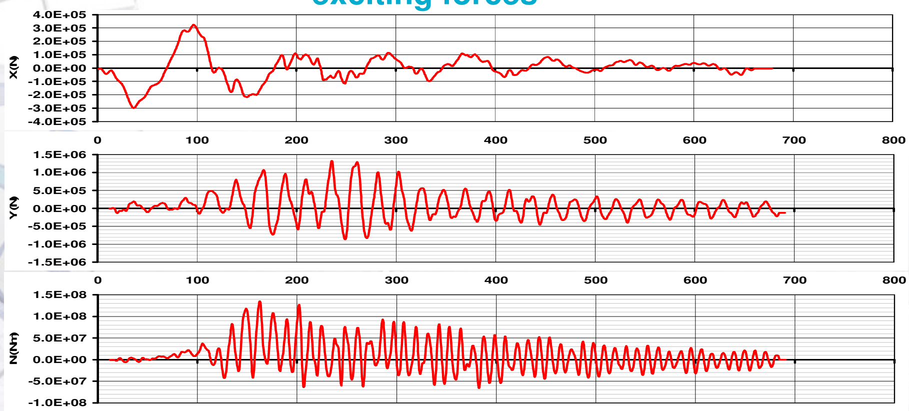
➔ to be applied to ship + moorings/control

➔ dynamic system

➔ forces in mooring system + lateral displacement

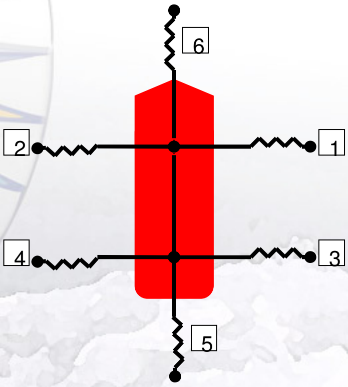
“Hawser Forces”

“exciting forces”



“Hawser Forces”

Dynamic system ?



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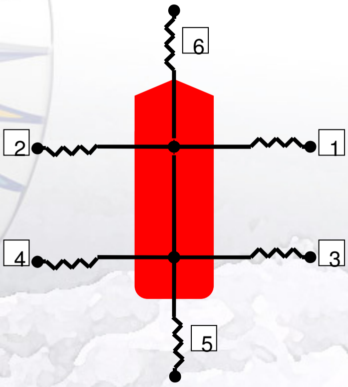
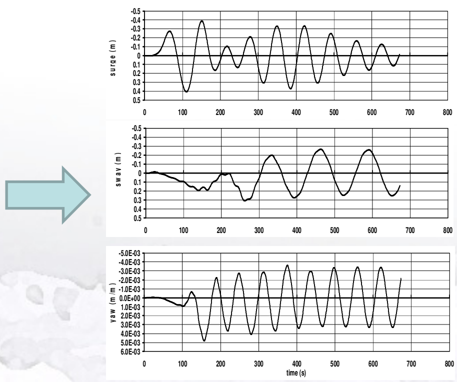
“Hawser Forces”

Dynamic system: pure springs



motions



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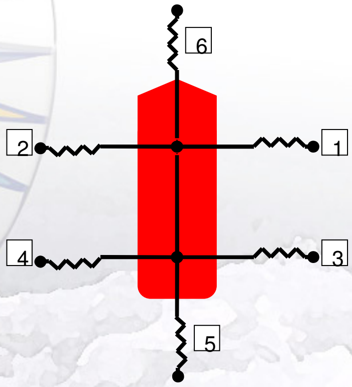
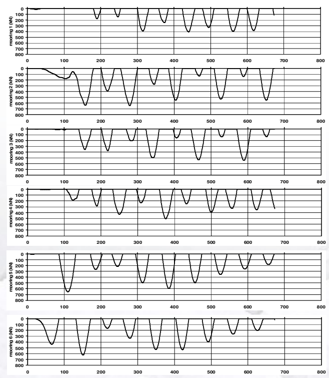
"Hawser Forces"

Dynamic system: pure springs



line forces



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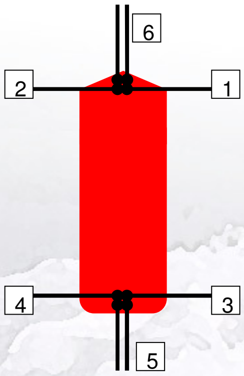
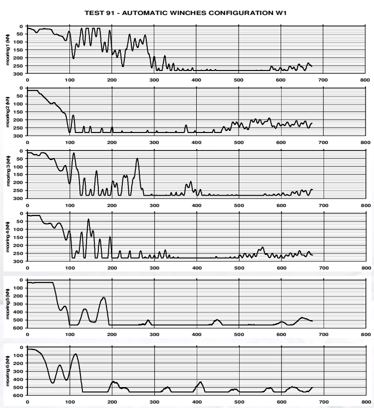
"Hawser Forces"

Dynamic system: automatic winches



line forces



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"Hawser Forces"

Increase realism:

- Realistic mooring configuration
- Vertical motion!
- Winch control

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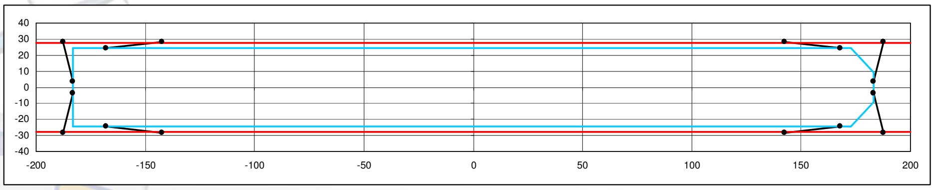
"Hawser Forces"



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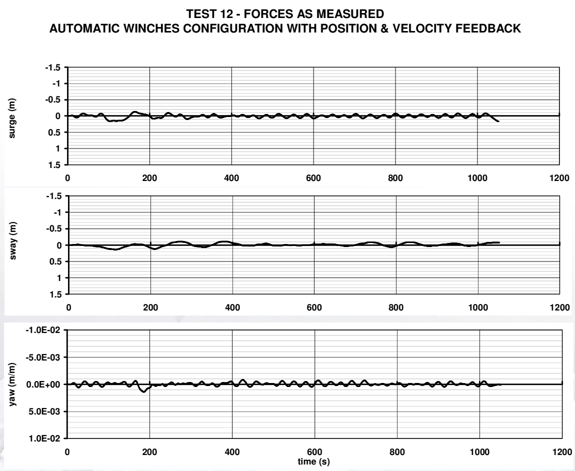
"Hawser Forces"

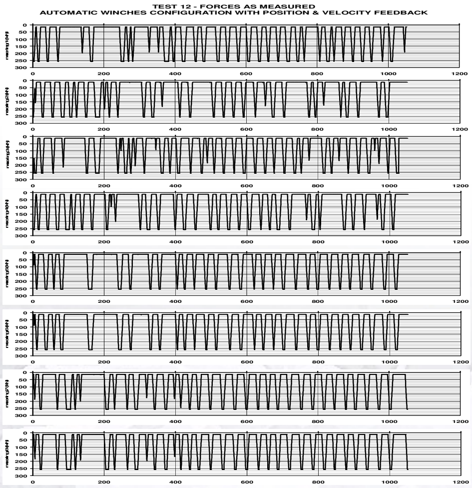
Control algorithm:

- Initially constant force of 0.2 MBS to each line.
- If bow/stern is closer to SB side of the lock, or if bow/stern is moving to SB, breast line fore/aft starboard will be rendered.
- If bow/stern is closer to PS of lock, or if bow/stern is moving to port, breast line fore/aft port will be rendered.
- If ship is moving ahead/astern, or if ship's position is ahead/astern of her initial position, springs fore/aft will be rendered.
- In case a line is rendered, it is assumed that line force is reduced to 1% of MBS. It is assumed that line length can be adjusted with a maximum speed of 0.25 m/s.
- During the simulations, the necessity of rendering the lines is evaluated with a time interval of 2 s.

"Hawser Forces"



“Hawser Forces”



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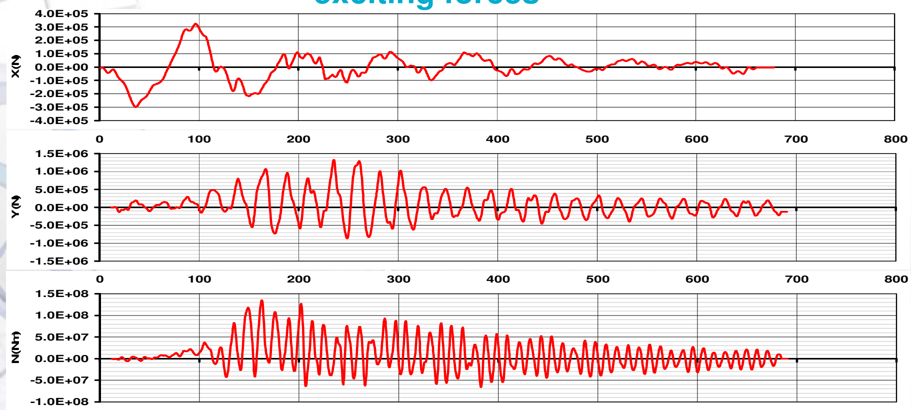
“Hawser Forces”

“exciting forces”



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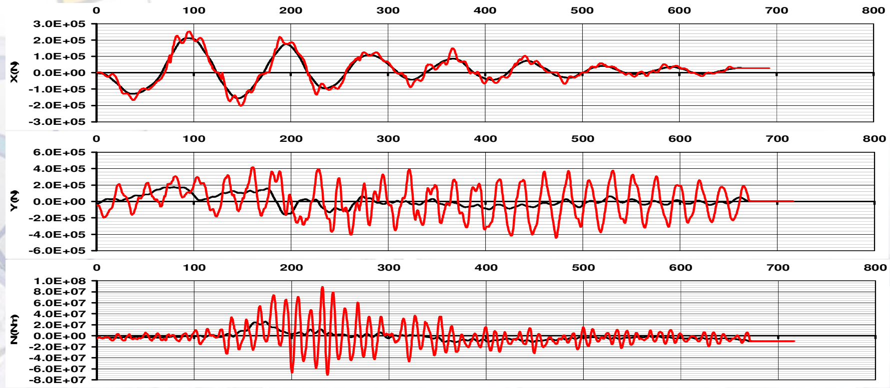
"Hawser Forces"

"exciting forces" ➔ running average



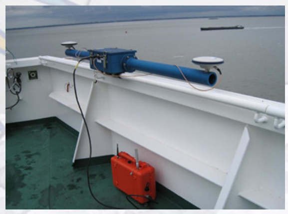
Mooring forces

On site measurements by FHR

Water surface slopes (end-to-end)

- with/without vessel(s) in lock
- ≈ hydrostatic force on vessel

Vessel motion



For on site measurements by

Wallonie SPW Service public de Wallonie

see D. Bousmar (Smart Rivers 2011)

More on mooring forces

• **T. De Mulder (2007):** *Specification of hawser force criteria.* Report TO1-Task 1.2.4-CNR-FHR-R013 of Consorcio Pos-Panamax, commissioned by ACP.

➔ **Report n° 106 of PIANC WG 29 ; CD-ROM ; Directory C14**

•**T. De Mulder (2009):** *Mooring forces and ship behaviour in navigation locks*. Paper 7 in Int. Workshop on "Innovations in Navigation Lock Design", PIANC-Brussels, 15-17 Oct. 2009.

➔ **http://www-new.anast.ulg.ac.be/index.php/fr/nouveautes/40/94-pianc-workshop-innovations-in-navigation-lock-designg**

• **T. De Mulder et al. (2010):** *On hawser force criteria for navigation lock design: Case study of maritime locks in Port of Antwerp.* Paper 290 in Proc. PIANC MMX Congress, Liverpool-UK, 10-14 May 2010.

More on mooring forces

• **on site tests & inquiries** at stakeholders

(e.g. systematic variation of valve opening laws)

• **intercomparison** of scale models, numerical models, on site measurements

- in **absolute** terms (?)
- in **relative** terms (!): for a given lock (+vessel), do results show the same **trends?** w.r.t. influence on peak force / peak slope of:
  - ➔ initial head
  - ➔ valve opening time
  - ➔ distance bow to filling gate
  - ➔ ship size (displacement, blockage,…)
  - ➔ etc.

Paper 5-2 **MOORING FORCES AND VESSEL BEHAVIOUR**
Experience in China
WU PENG (China)

What's new in the design of navigation locks?

PIANC Workshop
13-14th September 2011

Mooring forces and vessel behaviour in locks -- experience in China

By WU Peng
CHINA
Chief engineer of Planning and Design Institute for Water transportation, Beijing

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---

1 INTRODUCTION

2 SAFE MOORING

3 HYDRAULIC CRITERION FOR APPROACH CHANNELS

4 REDUCING THE FORCE ON VESSEL

1 INTRODUCTION

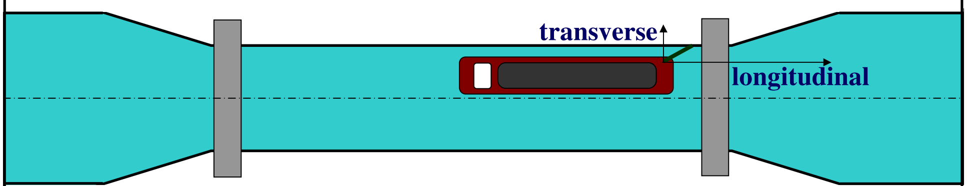
Technical codes for the design of locks used by inland vessels in China:

- *Code for Master Design of Locks*
- *Design Code for Hydraulic Structure of Locks*
- *Design Code for Filling and Emptying System*
- *Design Code for Lock Gates and Valves*
- *Design Code for Operational Machine of Locks*
- *Design Code for Electrical Facilities of Locks*

2 SAFE MOORING

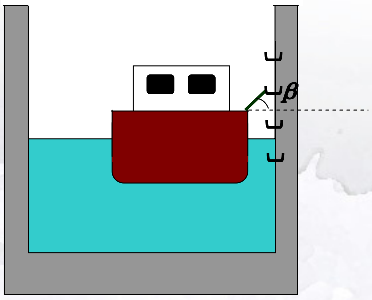
Table 1: Acceptable mooring forces of vessels

Vessel Tonnage (t)	3000	2000	1000	500	300	100	50
Horizontal longitudinal components of allowable mooring forces (kN)	46	40	32	25	18	8	5
Horizontal transverse components of allowable mooring forces (kN)	23	20	16	13	9	4	3



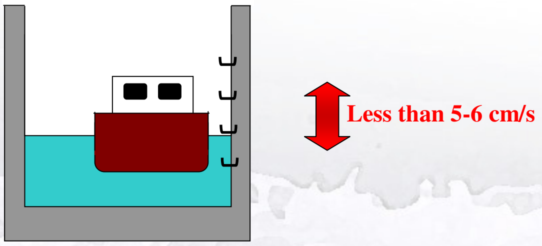
2 SAFE MOORING

The vessel tonnage means the deadweight of the motor barge. For a push train it means the deadweight of one barge of the train. Allowable mooring force on a push train shall be determined by the minimum barge tonnage in the train. When the fixed bollard or hook is used the mooring force shall be multiplied by cos β, where β refers to the maximum angle of the hawser and water level.



2 SAFE MOORING

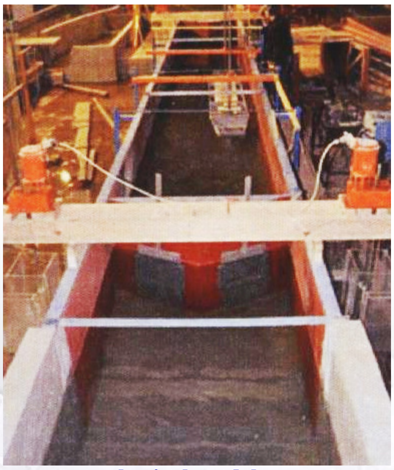
For locks with only fixed mooring equipment, the maximum water surface lifting speed in lock chamber during filling and emptying shall not exceed 5-6 cm/s. When floating bollards are used, there is no similar limitation.



2 SAFE MOORING

To simplify the problem the vessel forces are used to compare with the acceptable mooring forces of vessels and to evaluate the design of filling and emptying system of the lock.

The vessel forces are usually got by analytical method for loop culvert system and physical model for more complicated system.



physical model test

2 SAFE MOORING

For the short culvert system the vessel forces could be calculated by the following formula. In the process of filling:

$$P_1 = P_B = \frac{k_r \omega D W \sqrt{2gH}}{t_v(\omega_c - \chi)}$$

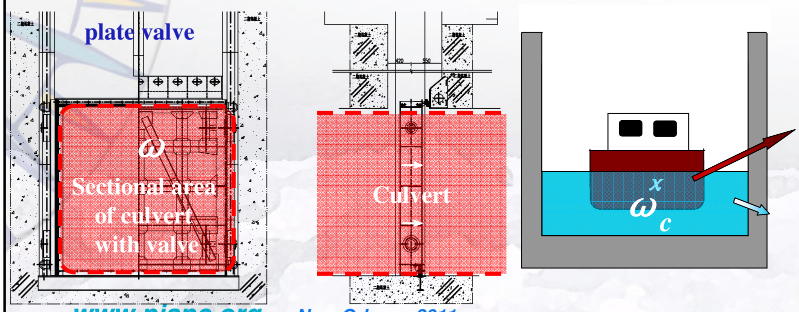
In the process of emptying:

$$P_1 = P_i + P_V$$

P_1: Hydrodynamic force on vessel (kN);
P_B: Wave force in the initial stage of filling (kN);
P_i: Force produced by water-surface gradient during the emptying process (kN);
P_V: Force produced by longitudinal velocity in lock chamber;

2 SAFE MOORING

ω : Sectional area of culvert with valve (m^2);
k_r: Coefficient concerning valve configuration (could be 0.725 for a plate valve);
D: Wave force coefficient;
W: ships displacement (t);
H: Design lift height (m);
t_v: Valve opening time (s);
ω_c: Sectional area of lock chamber at the initial water level (m^2);
x: Area of wetted cross section of vessels (m^2);
g: Acceleration of gravity (m/s^2).

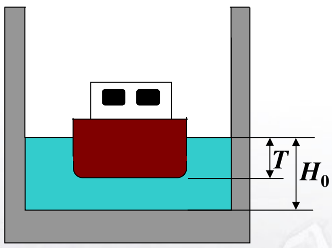


2 SAFE MOORING

The water depth on sill should be decided as follows:

$$\frac{H_0}{T} \geq 1.50$$

H_0: the water depth on sill at the lowest navigation water level (m);
T: full loaded draft of design vessel (m).



2 SAFE MOORING

Site investigation at Three-gorges lock

Design fleet dimension of three gorges shiplocks

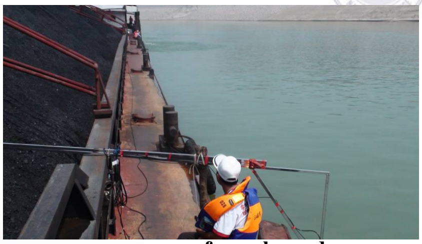
No.	Fleet (push boat + barge)	fleet dimension(m) (length×width ×draft)
1	1+6×500t	126×32.4×2.2
2	1+9×500t	264×32.4×2.8
3	1+9×1500t	248×32.4×3.0
4	1+6×2000t	196×32.4×3.1
5	1+4×3000t	196×32.4×3.3
6	1+4×3000t (tanker)	219×32.4×3.3

Dimension of large scale ship passing three gorges shiplocks at present

No.	fleet dimension(m) (length×width ×draugh)	types of vessels
1	133.8×19.22×2.7	Passenger ship
2	126.9×15×3.65	cargo ship
3	126.4×25.4×2.8	roll-on/roll-off ship
4	118×20.26×5.1	multi-purpose ship
5	118×19.66×4.7	bulk cargo ship
6	112×17.2×3.8	container ship
7	100×17.23×4.7	tanker
8	100×17.2×4.7	chemical tanker

2 SAFE MOORING

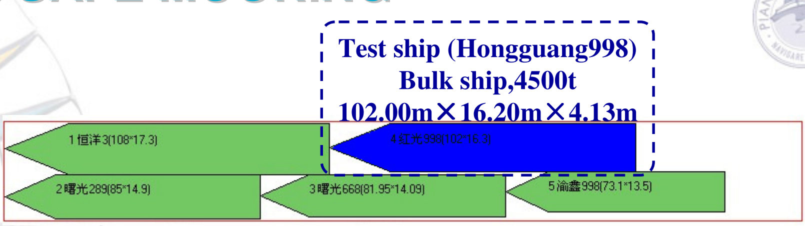
Three gorges 5-stage shiplocks

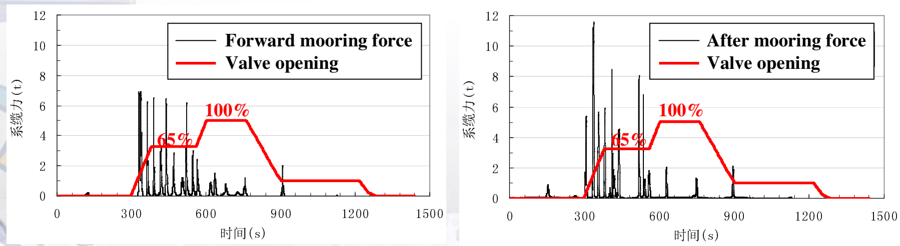


measure of vessel speed

measure of mooring forces

2 SAFE MOORING

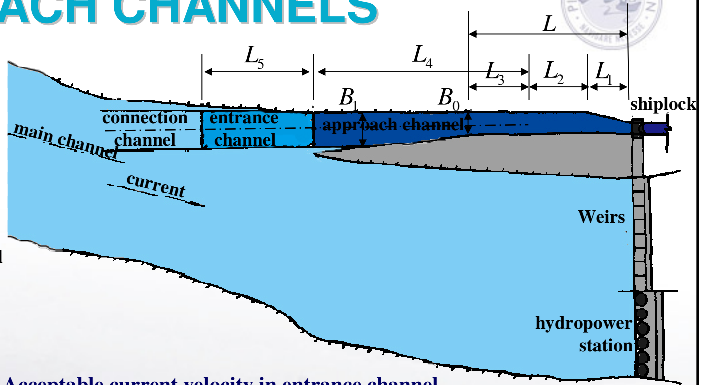




The maximum forward mooring force is 7t, the maximum after mooring force is 11.6t, the average mooring force is 6t~7t, slightly exceeding the acceptable value. So the limiting draft of large ship is 4.2m.(The water depth is 5m in shiplock champer)

3 HYDRAULIC CRITERION FOR APPROACH CHANNELS

- L straight-line segment
- L_1 guiding segment
- L_2 guiding segment
- L_3 berthing segment
- L_4 braking segment
- L_5 entrance channel segment
- B_1 width of entrance channel
- B_0 width of approach channel



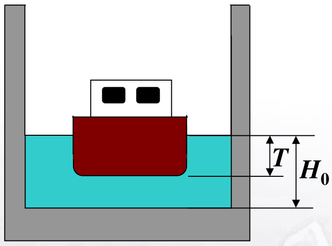
Acceptable current velocity in entrance channel

Shiplock class	longitudinal current velocity (m/s)	cross current velocity (m/s)	returnflow velocity (m/s)
I~IV	≤2.0	≤0.30	≤0.4
V~VII	≤1.5	≤0.25	

HYDRAULIC CRITERION FOR APPROACH CHANNELS

The water depth in approach channel should be decided as follows:

$$\frac{H_0}{T} \geq 1.50$$



H_0: the water depth in approach channel at the lowest navigation level (m);

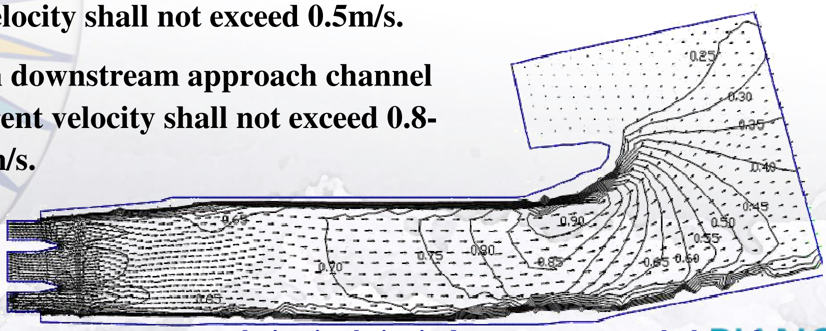
T: full loaded draft of design vessel (m).

HYDRAULIC CRITERION FOR APPROACH CHANNELS

Then the current velocity should be limited to guarantee vessels safe manoeuvring in approach channel.

In upper pool the maximum longitudinal current velocity in approach channel shall not exceed 0.5-0.8m/s and in the waiting area the velocity shall not exceed 0.5m/s.

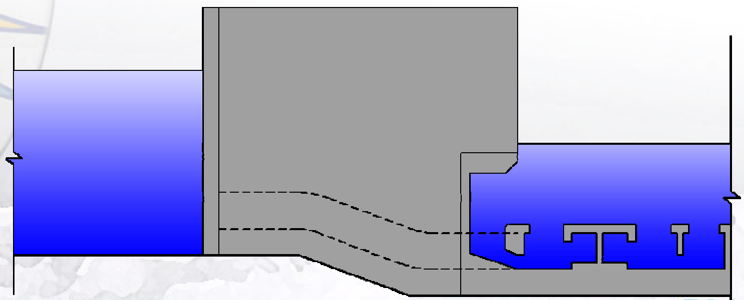
In downstream approach channel current velocity shall not exceed 0.8-1.0m/s.



current velocity simulation in downstream approach channel

4 REDUCING THE FORCE ON VESSEL

The forces acting on the vessel are determined by the water level differences around the vessel, the flow velocity and friction on the vessel. The forces acting on the vessel depend mainly on the design of the hydraulic system of the lock. Fine design could evidently reduce the forces.



short culvert system in Shihutang lock

4 REDUCING THE FORCE ON VESSEL

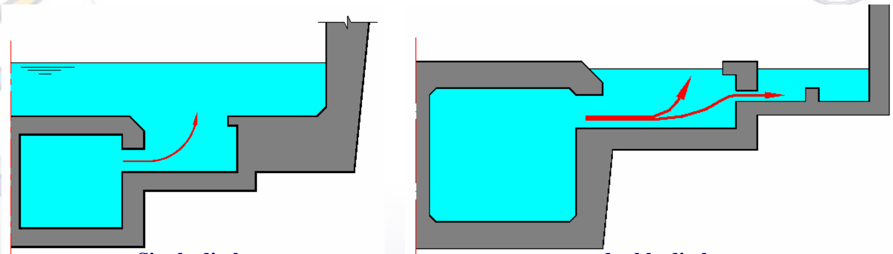
In the longitudinal filling system, the transverse force on vessels is limited. A new type of short culvert system is used in Shihutang lock in China. The forces acting on vessel during filling and emptying are mainly longitudinal and some results got from laboratory model test are shown in Table 2.

Table 2: Forces on vessel of Shihutang lock (chamber dimension 180×23×3.5m)

Lift(m)	F/Etime(min)	Max. longitudinal force	Max. Transverse force
11.14	11.2 (F)	30.8	15.2
	8.4 (E)	31.4	5.6
10.54	10.76 (F)	31.4	8.7
	7.53(E)	24.1	3.8
9.77	9.63 (F)	29.4	9.4
	6.72(E)	23.5	3.0

Note: Acceptable longitudinal force is 32 kN and transverse force is 16kN.

4 REDUCING THE FORCE ON VESSEL



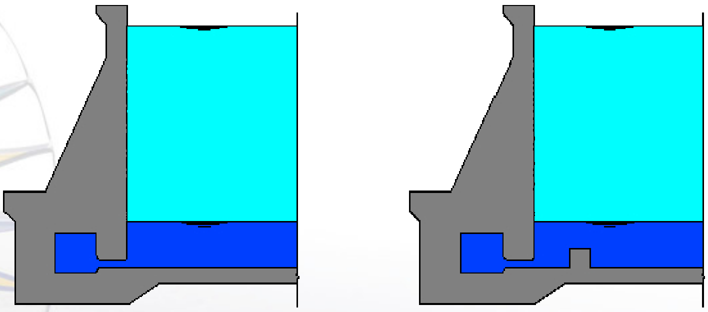
Single ditch double ditches

GuiPing shiplock, chamber dimension(280m×34m×5.5m)

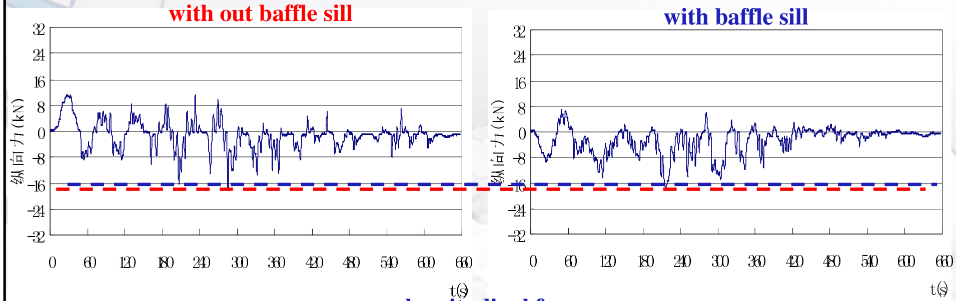
	Filling time	Max. transverse hawser force
Single ditch	9min	56 kN
Double ditches	9min	11.2 kN

Note: Acceptable transverse force is 20 kN

4 REDUCING THE FORCE ON VESSEL

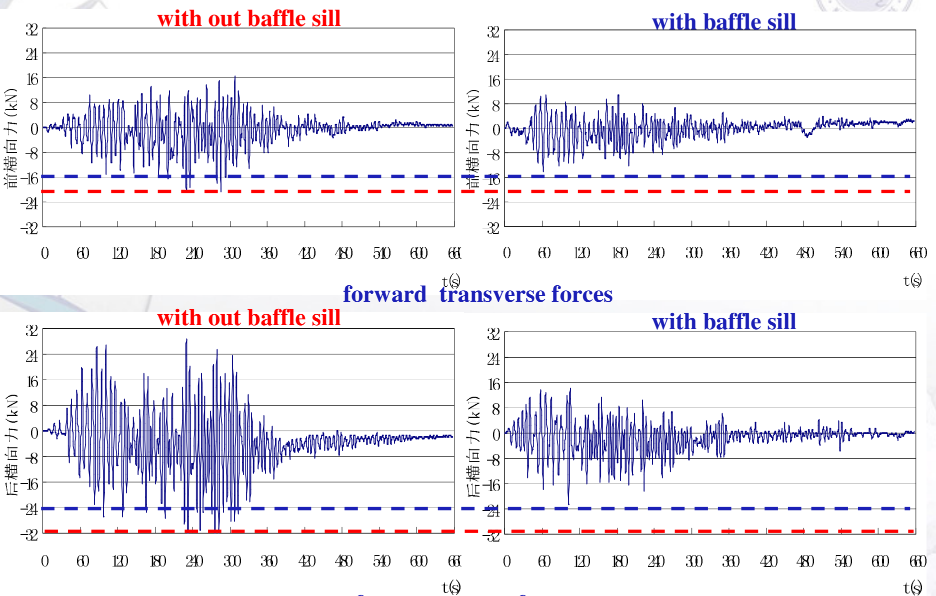


with out baffle sill with baffle sill



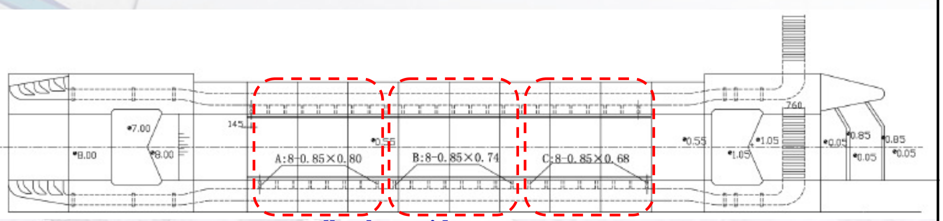
longitudinal force

4 REDUCING THE FORCE ON VESSEL



4 REDUCING THE FORCE ON VESSEL

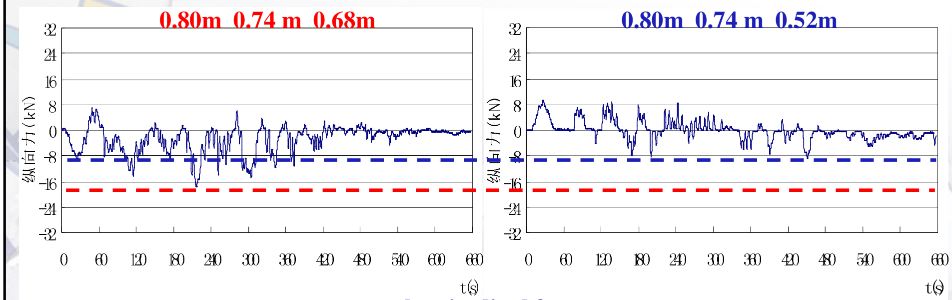
But in the wall culvert side port system, the longitudinal force could be reduced by a fined design to the port size. Along the flow direction the port size could be divided into three groups. The height of all ports can be the same and the width can be narrower along the water flow direction during filling and emptying. This makes the water into the chamber more uniform in the longitudinal direction and reduces the slope of the water surface during filling. So the longitudinal mooring force becomes smaller.



wall culvert side port system

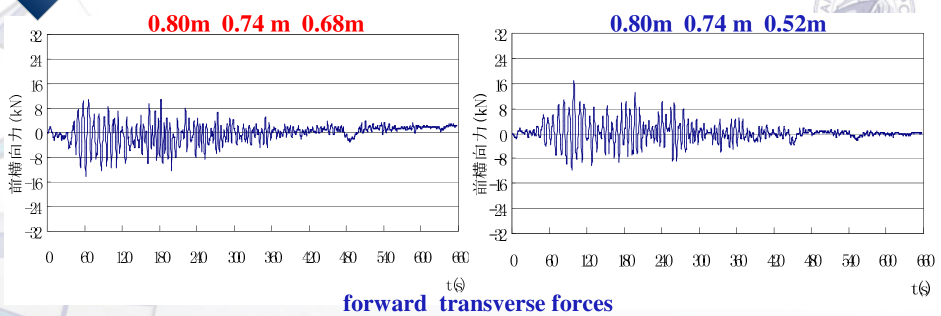
4 REDUCING THE FORCE ON VESSEL

For example, there are 24 ports on one side wall. All have the same height of 0.85m. They were divided into three groups which has the width of 0.80, 0.74 and 0.68m separately. In the test the width of the third group of ports was reduced from 0.68m to 0.52m. The maximum longitudinal force acting on vessel was reduced from 16.2kN to 8kN.

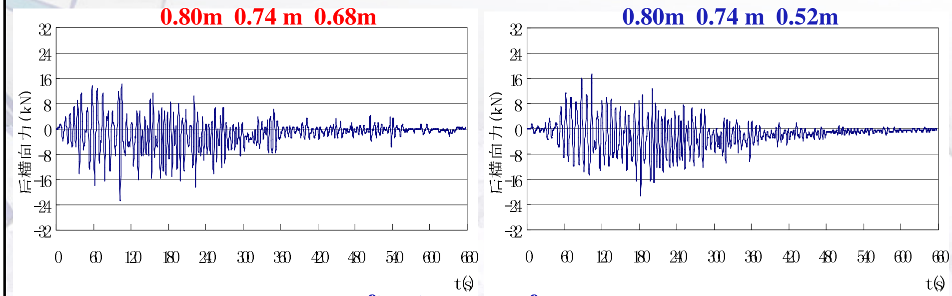


longitudinal force

4 REDUCING THE FORCE ON VESSEL



forward transverse forces



after transverse forces

Thank you for your attention

Mooring forces and vessel behaviour in locks -- experience in China

WU Peng

Chief engineer of Planning and Design Institute for Water transportation, Beijing, P.R. China

Paper 5-3 **MOORING FORCES AND VESSEL BEHAVIOUR**
Experience in France
S. ROUX (Fr)

What's new in the design of navigation locks?

PIANC Workshop
13-14th September 2011

Part 5 – *Mooring forces and vessel behavior*

PIANC
Setting the course

"What's new in the design of navigation locks"

Workshop Part 5

Experience in France

Sébastien Roux CNR, France
Fabian Pecot Sirehna, France

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Introduction

Lock F-E system hydraulic design

F-E times
- System efficiency
- Easily accessible (1D, physical model)

"Hawser forces"
- System safety
- Which model should be used (1D, 2D, 3D, physical model) and when (conceptual design, final design)?
- Which component is calculated or measured (hydrostatic force, hydrodynamic force, reaction force in the mooring line) and how can you connect it to an acceptable value?

seems it raises some question…

…that will hopefully be answered by WG 155!!

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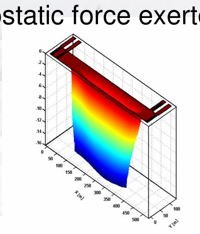
Available tools

- **1D numerical model**:
  - assessment of the longitudinal water slope in the lock chamber and of the longitudinal hydrostatic force exerted on the vessel (F~ P x i)
  - Fast track
  - Results reliability (no consideration of dynamic effects)

- **2D numerical model (SWE)**:
  - Calculation of the pressure field around the ship's hull
  - Assessment of longitudinal a transversal water slopes in the lock chamber and of the longitudinal hydrostatic force exerted on the vessel (F~ P x i).
  - Requires discharge time series



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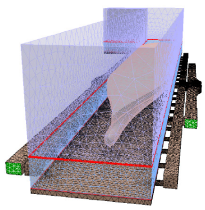
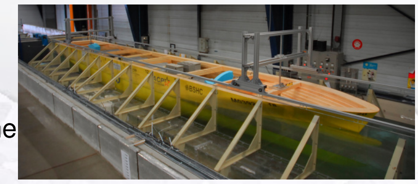
Available tools

- **3D numerical model**:
  - Modeling of the complete F-E system, lock chamber, vessel,
  - Can take into account FSI,
  - Calculation of the hydrodynamic force exerted on the vessel,
  - Calculation of the reaction forces in the mooring lines and vessel displacement,
  - Can do everything??!! → Restriction due to computational time & cost



- **Physical model**:
  - Allows to measure the hydrodynamic force (exerted on the vessel) and the water slopes
  - Can sometime be used to measure the reaction force in the mooring lines (depending on the mooring system)



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Studies carried out in CNR laboratory

	Lock dimensions	Vessel type	Methodology applied
Cremona Lock (Pô River - Italy)	200 x 12 m	Barges & tug - 5 900 T Barges & tug - 3 300 T	- Measurement on the physical model of the longitudinal and transversal forces & longitudinal water slope - Assessment of the hydrostatic force (F = Pxi)
New locks on the Rhône River	48 x 5 m	Leisure craft	Measurement on the physical model of the longitudinal force & longitudinal water slope
New Locks of Panama Preliminary design	430 x 55 m	12 000 TEU Container ship	- 1D model --> Discharge time series - 2D model --> Longitudinal & transversal WS - 3D model --> Longitudinal hydrodynamic force - Physical model --> Longitudinal & transversal hydrodynamic forces combined with a mechanical model in order to calculate the reaction forces in the mooring lines
New Locks of Panama Final design	430 x 55 m	12 000 TEU Container ship 8 000 TEU Dry Bulker	- 1D model --> Longitudinal water slope - Physical model --> longitudinal & transversal hydrodynamic forces combined with a mechanical model in order to calculate the reaction forces in the mooring lines and the vessel displacement

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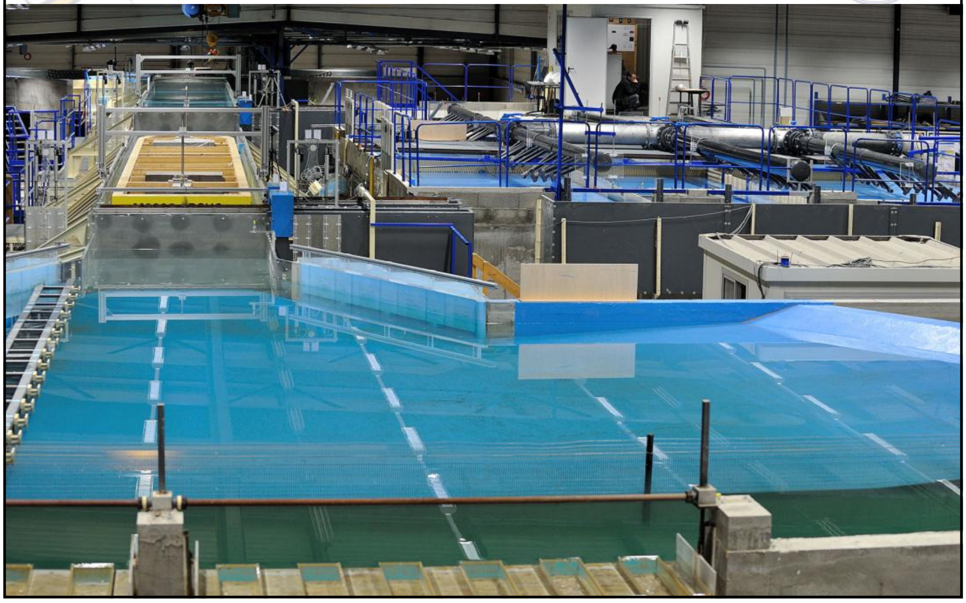
Panama Third Set of Lock – Final design study



"Hawser forces" measurement

Why not modeling of the mooring lines system on the physical model?

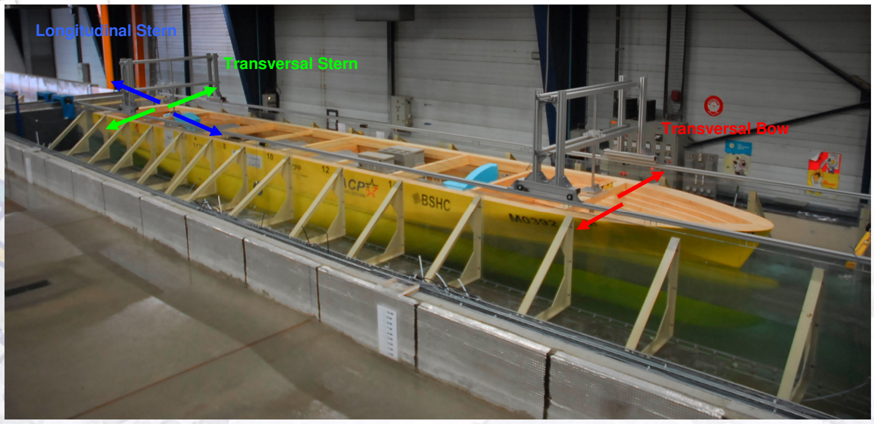
➢ It raises technical problem to represent faithfully the winches action on the lines and to manage the lines tension when the vessel is raising up or going down,

➢ It gives very unique tests conditions according to the number, positions, tension of the mooring lines that does not permit tests repeatability.

➡ Decision was made to measure the forces exerted on the vessel and to use a numerical mechanical model of the mooring line system to determine reaction forces and vessel displacement

Measurements on the physical model

3 dynamometers:
- 1 longitudinal sensor (stern)
- 2 transversal sensors (1 stern, 1 bow)



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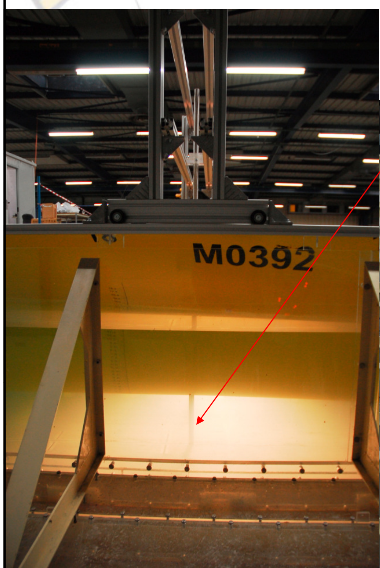
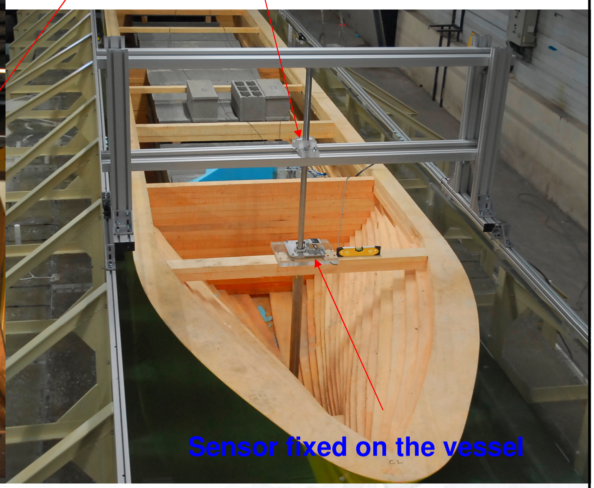
Measurements on the physical model

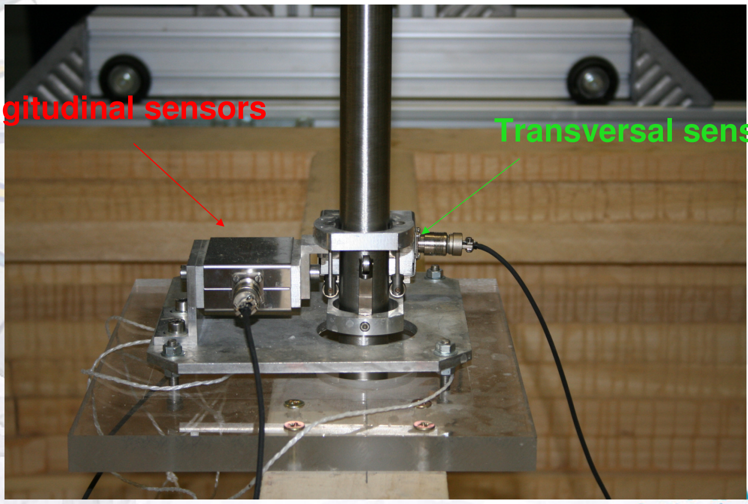


Vertical bar fixed to the bottom floor and above the vessel



Measurements on the physical model

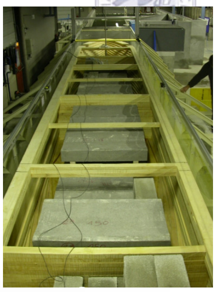
Stern sensor details

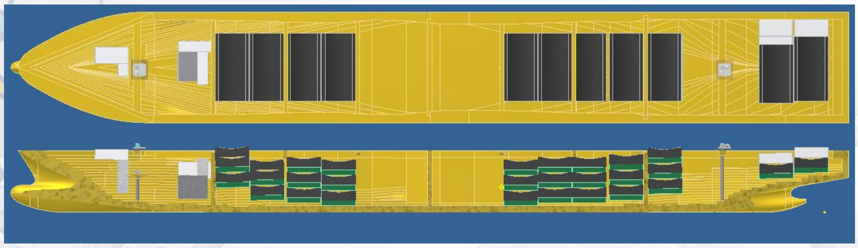


Measurements on the physical model

Definition of the loads position in order to reach the correct value of:

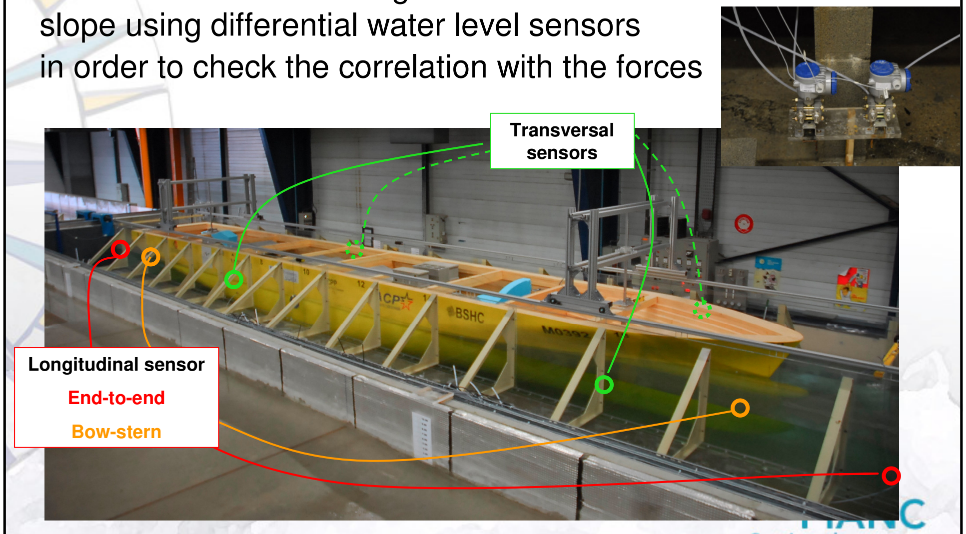
- the total mass,
- the position of the centre of gravity,
- the inertia momentum (Izz)





Measurements on the physical model

Measurements of the longitudinal and transversal water slope using differential water level sensors in order to check the correlation with the forces



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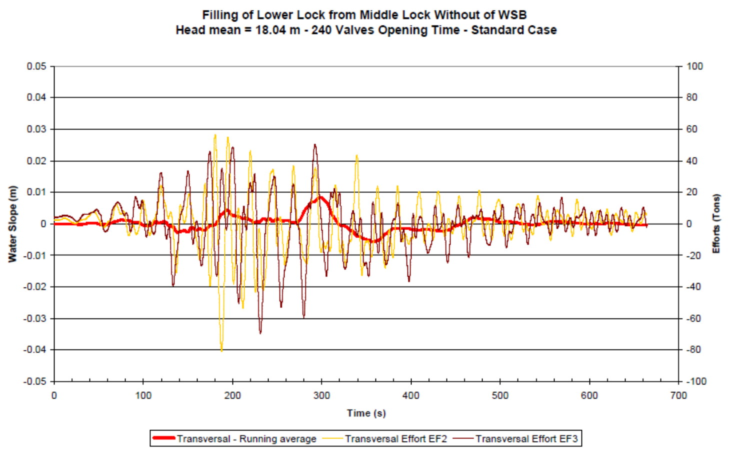
Measurements on the physical model

Characteristic results from a test:



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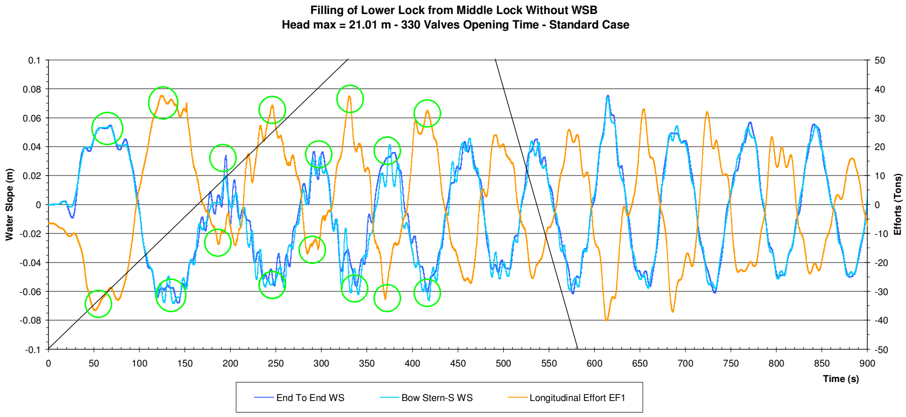
Prediction of the forces



Search for correlation between longitudinal water slope with the vessel in the lock chamber and the longitudinal hydrostatic forces exerted on the ship's hull

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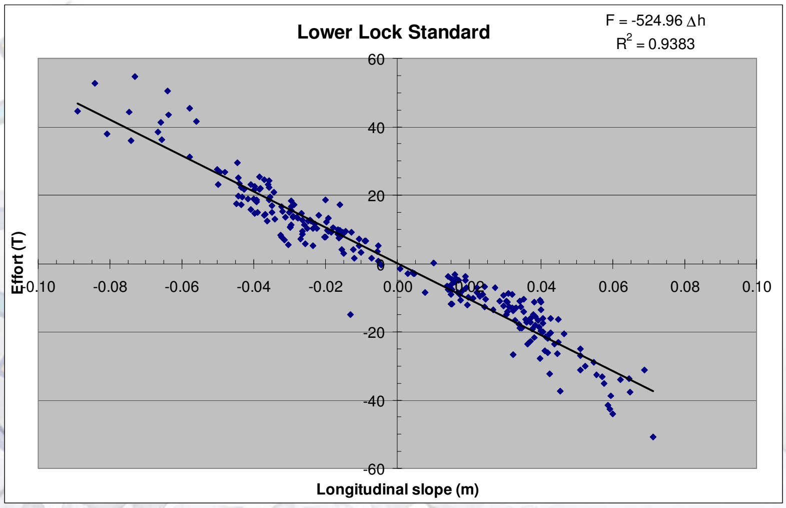
Prediction of the forces



→ Can be used to assess the weight of the hydrostatic force component in the total force

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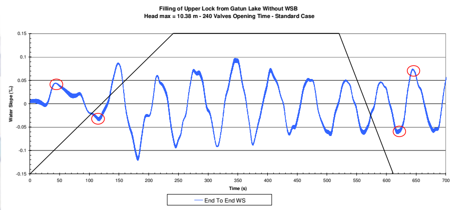
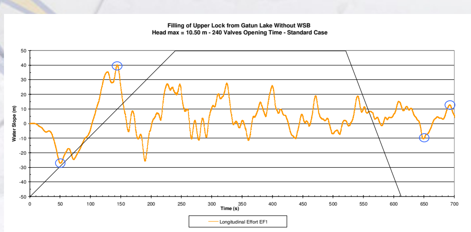
Prediction of the forces

For every hydraulic scenario, two tests have been performed, one with the vessel and one without

Search for correlation between longitudinal water slope without the vessel in the lock chamber and the longitudinal hydrostatic forces exerted on the ship's hull → Characterization of the F-E smoothness??



Measurement of the longitudinal water slope without the vessel in the lock chamber



Measurement of the longitudinal forces exerted on the vessel

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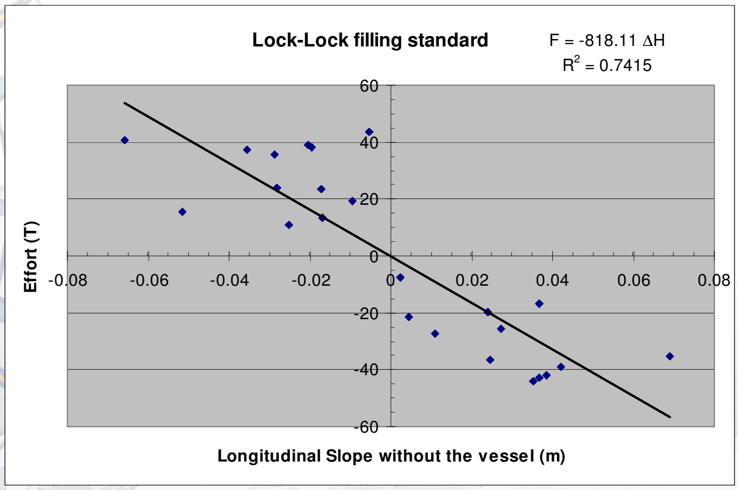
Prediction of the forces



→ As expected, the correlation is not so good but can still give valuable information

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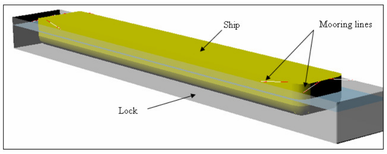
Numerical calculation of forces in the mooring lines

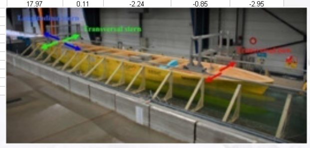
To study the ship dynamic behaviour and the mooring lines forces in post-Panamax lock, a numerical simulation model of the ship and its mooring lines has been built with MSC-Adams software(1) by SIREHNA



This numerical model is fed by measurements time series performed by CNR on the experimental model :

- *Water height in the lock chamber*
- *Longitudinal hydrodynamic forces exerted on the ship*
- *Transversal (bow and stern) hydrodynamic forces exerted on the ship*

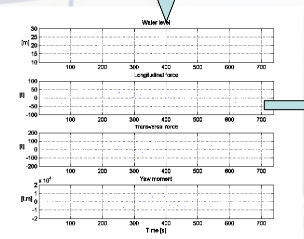
Lock-lock filling - Maximum initial head without WSB						
Water level in the lock chamber (Sampling frequency 10 Hz)			Hydrodynamic forces (Sampling frequency 150 Hz)			
Time	Water level in the lower chamber	Water level in the upper chamber	Time	Longitudinal effort EF1 (Stern)	Transversal effort EF2 (Stern)	Transversal effort EF4 (Bow)
time step (s)	0.1	0.1		0.0067	0.0067	0.0067
sampling nb.	2193	2193		32895	32895	32895
Average	5.3484	10.376		4.3671	-4.3187	-0.9351
TCL	Z5	Z8	TCR	EF1	EF2	EF4
s	mPLD	mPLD	s	T	T	T
0.00	-2.20	17.97	0.00	-2.21	-0.61	-3.13
0.55	-2.20	17.97	0.04	-2.19	-0.63	-3.04
1.10	-2.19	17.97	0.07	-2.18	-0.70	-3.03
1.64	-2.19	17.97	0.11	-2.24	-0.85	-2.95
2.19	-2.19					
2.74	-2.19					
3.29	-2.19					
3.83	-2.19					
4.38	-2.19					
4.93	-2.19					
5.48	-2.19					
6.02	-2.20					
6.57	-2.19					
7.12	-2.19					



(1) Used to study the 3D full-motion behavior (displacements, velocities, accelerations, forces) of complex mechanical systems

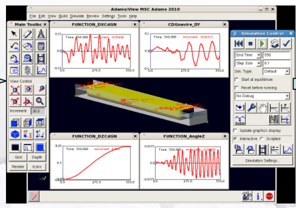
Process synopsis

Physical model operated by CNR

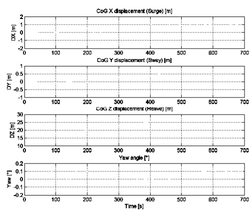


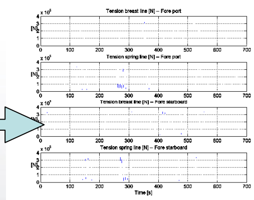
Water height and hydrodynamic forces

Longitudinal force, transversal forces at bow & stern



Numerical model operated by SIREHNA



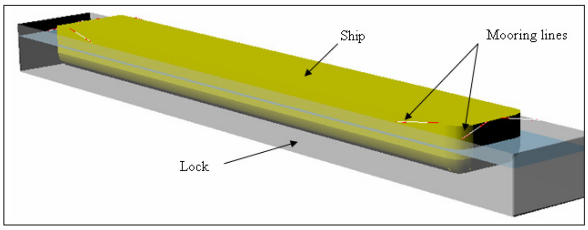


Ship displacements and forces in mooring lines

Numerical modelling

The numerical model (built at full scale) includes :
- The lock chamber,
- The vessel modelled as a rigid body
- The mooring lines attached to the ship and to fixed bollards on top of the lock wall

Contacts between ship and lock walls are automatically detected and are managed with simplified reactions models (no accurate enough for the modelling of fenders)



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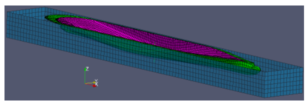
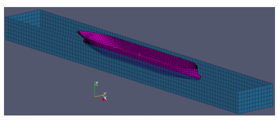
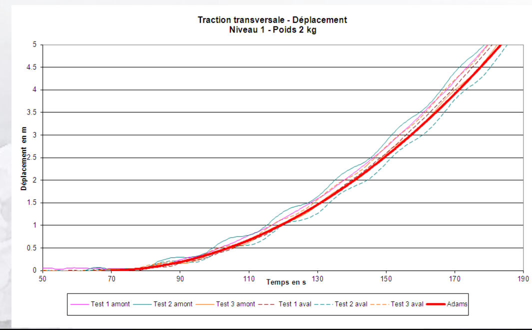
Ship modelling

Ship modelled as a rigid body
Defined by its geometry, inertial characteristics, its added masses and damping coefficients.





Added masses and damping coefficients (surge, sway and yaw) have been determined experimentally from model tests, by identification approach. Coefficients also assess with a potential flow code



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Ship modelling

➢ ***Hydrodynamic forces***
Surge, sway and yaw forces result from measurements carried out on t physical model. These hydrodynamic forces, functions of time, are applied at the ship's centre of gravity

➢ ***Ship Motions***
Ship lift and descent taken into account : heave motion results from the measurements and imposed at the ship's centre of gravity
Roll and pitch motions are not taken into account (set to zero)

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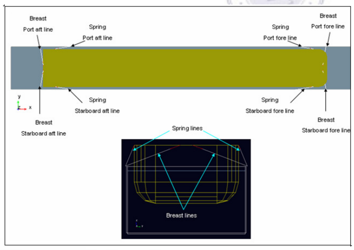
Mooring lines modelling



➢ **Mooring system lines configuration & location**
4 breast lines + 4 spring lines

➢ **Mooring lines characteristics**
Samson Proton-8 strand lines (∅ 57 mm)
Min. Breaking Strength (MBS): 174t
Linear elongation assumed: 0.87% at 20% of the MBS

➢ **Definition of mooring lines operating mode**
Mooring line modeled by an effort function of the distance between the 2 ends. It behaves like a spring with linear stiffness : $T(t) = k\,(L(t) - Lo)$ with k : stiffness; L (t) : distance between 2 ends; L_0 distance relative to initial tension

Operating mode
• *Selection of an initial pre-tension T0 for each line: 0.2 x MBS*
• *Selection of the maximum allowable tension in a line (when lines tension rises over this value, the mooring line is released)*
•*The mooring lines can be completely slack (tension equal to 0)*

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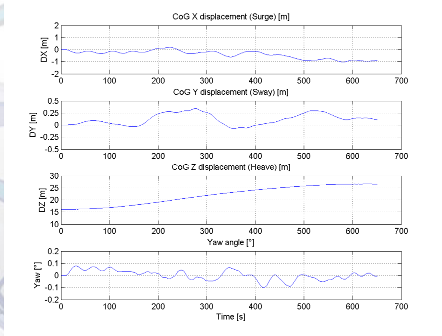
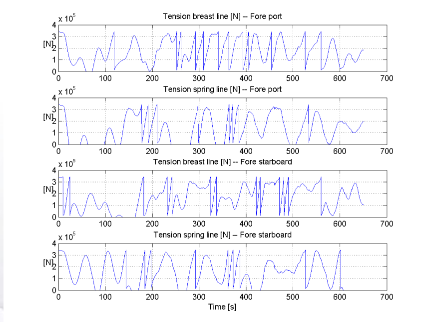
Results achieved

Vessel displacements, tensions in mooring lines and detection of collisions with lock walls or lock gates





Modal analyses of the different mechanical models done in order to assess the risk of resonance (comparison of the mooring line system natural periods with the hydrodynamic force periods)

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Conclusions

- A numerical model of a ship and mooring lines system, fed by measurements made on a physical model has been developed
- This methodology gives access to the forces exerted in the mooring lines and to the vessel displacements
- This methodology is very flexible. It allows to investigate a large number of configurations and situations in short time allowing to compare different mooring lines systems for one given hydraulic scenario
- Measurements are done with a ship fixed and centered in the lock, therefore the main hypothesis concerning the hydrodynamic input forces, is that during the simulation (F-E operations) the ship remain sufficiently close to its initial position. The results show, that in the majority of the cases studied, the displacements remain at low level.

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Thank you

Sébastien Roux CNR, France
Fabian Pecot Sirehna, France

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Paper 5-4 MOORING FORCES AND VESSEL BEHAVIOUR
Experience in Germany
C. THORENZ (D)

What's new in the design of navigation locks?

PIANC Workshop
13-14th September 2011

Mooring forces and ship behavior in locks (and lock approaches)

German experiences

By C. Thorenz
BAW
GERMANY

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Allowable ship force for inland navigation vessels during locking

A lock in canal near Chester / England

Allowable ship force for inland navigation vessels during locking

Sportbootverkehre an ausgewählte Strecken

Schleuse Canow

Allowable ship force for inland navigation vessels during locking

For a 110 m ship (~3200 t), selfpropelled:

- BAW-inhouse criterion for allowable ship force: *< 23 kN*
- Based on studies by *Partenscky* and others taking into account hawser geometry, ship dynamics as a spring-mass system, security factors, hawser slack and pretension, some magic numbers ….

Allowable ship force for inland navigation vessels during locking

- German Lloyd's has (had?) requirements for hawsers depending non-linearily on ship mass
  (for 3200 t ship: Four hawsers of 206 kN)
- "It is generally accepted, that the hawser force should be less than 1/600 of ship mass force" (1951, for a 3200 t ship this means: 53 kN)

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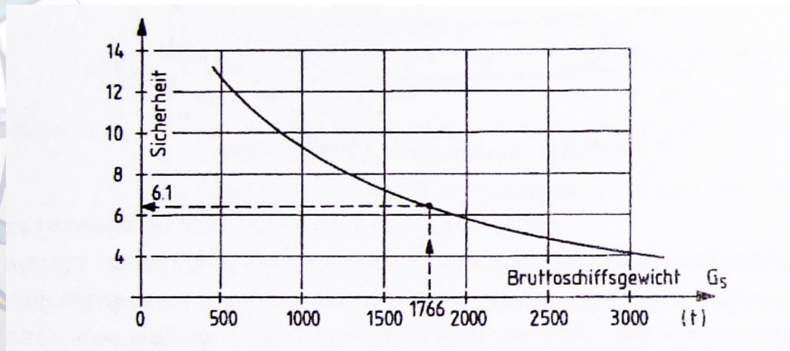
Hawser strength versus load



Security depends on ship mass?!

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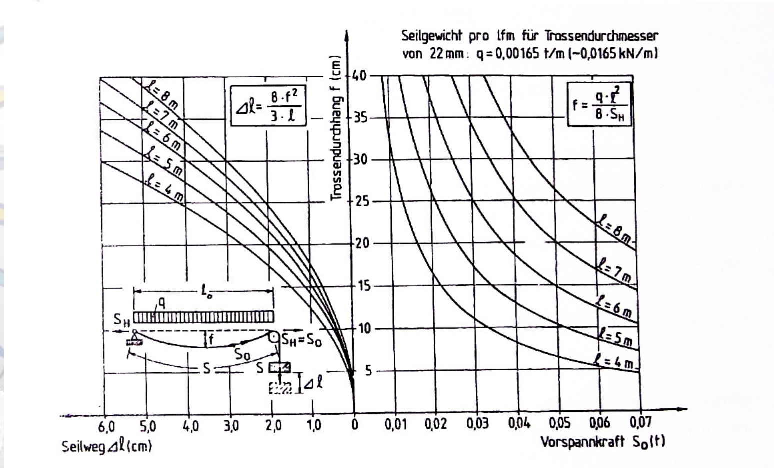
Hawser pretension



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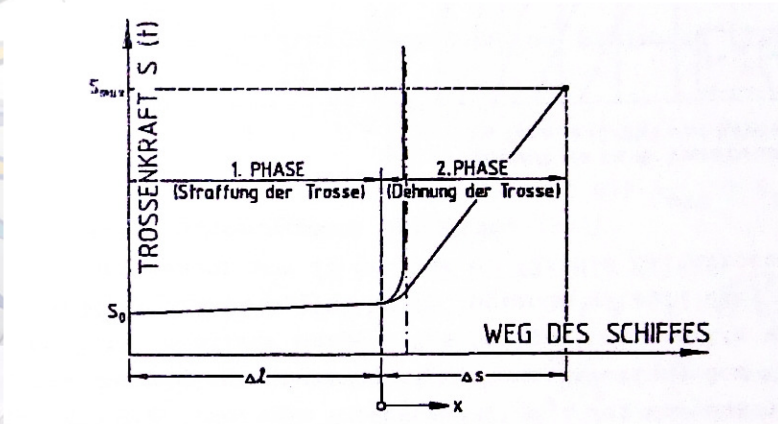
Reaction force of pretensioned hawsers



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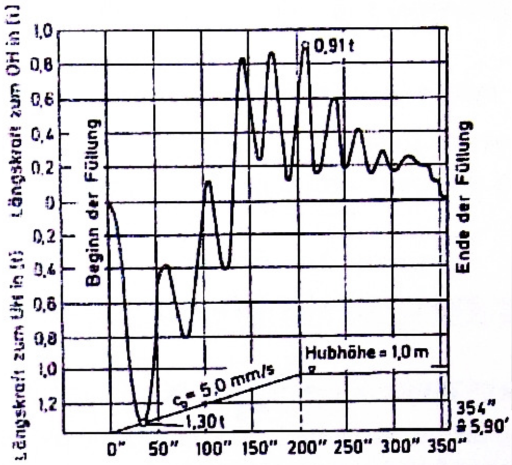
Typical ship force measurement



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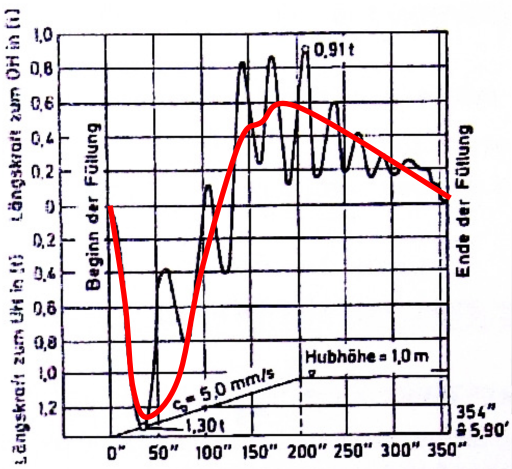
Decomposition: Filling effects



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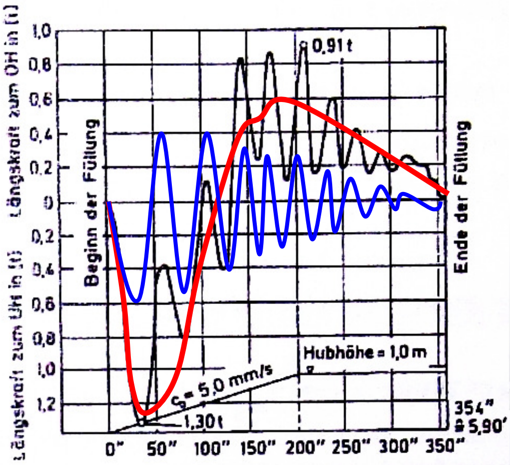
Decomposition: Sloshing



Ship forces versus hawser forces

- Ship moves back and forth during locking
- Hawser pretension is assumed to be "man pulled" with 0.3 kN
- Remaining line slack allows ship to "hammer" into the hawsers

⇒Difference between 23 kN and ~200 kN is reserve for the dynamic behavior, mishandling of hawsers…

What about the results?

- Partenscky ended up after lot's of computation with a max. slope of 0.4 0/00
- But the Dutch colleagues use 0.8 0/00 ?
- Well, with the assumption of a little more pretension and slightly shorter hawsers we can use that, too …
- Then, a BAW colleague converted this with some magic into 23 kN

The times, they are a changing'

23 kN max. ship force is "fixed", though hawser strength requirements changed:

1953: Hawser strength > 511 kN (!)

1976: Hawser strength > 206 kN per hawser (4x)

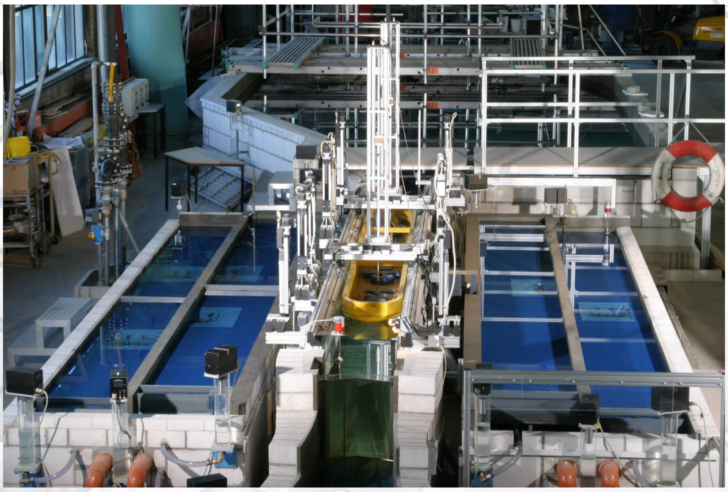
today: ???

and required design load for bollards changed in the DIN code:

100 kN 'til the 70th

200 kN today

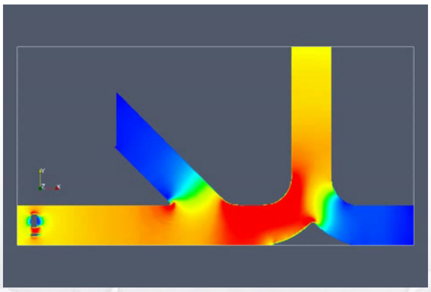
Evaluation methods for the 23 kN



Physical model tests

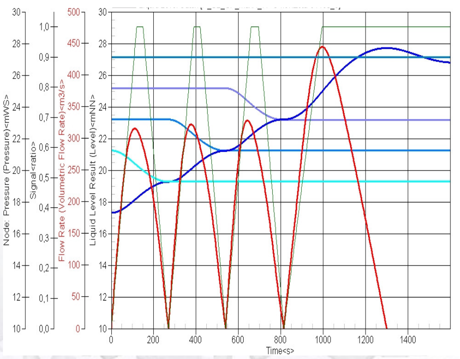
Numerical modeling strategy

- 3D-CFD model (or hydraulic model) for local loss coefficients



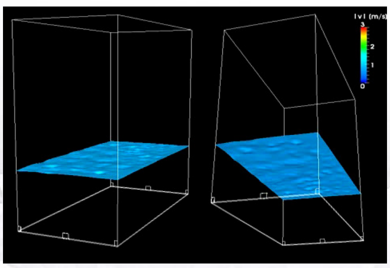
Numerical modeling strategy

- 3D-CFD model (or hydraulic model) for local loss coefficients
- 1D-network model for the lock complex



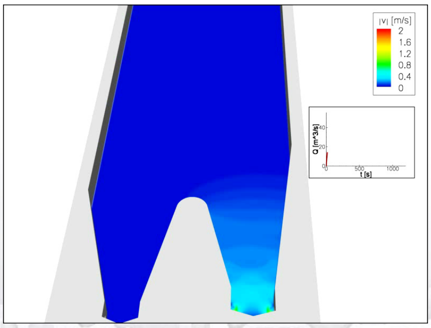
Numerical modeling strategy

- 3D-CFD model (or hydraulic model) for local loss coefficients
- 1D-network model for the lock complex
- 3D-CFD model (or hydraulic model) for flow in inlet/outlet, chamber, …

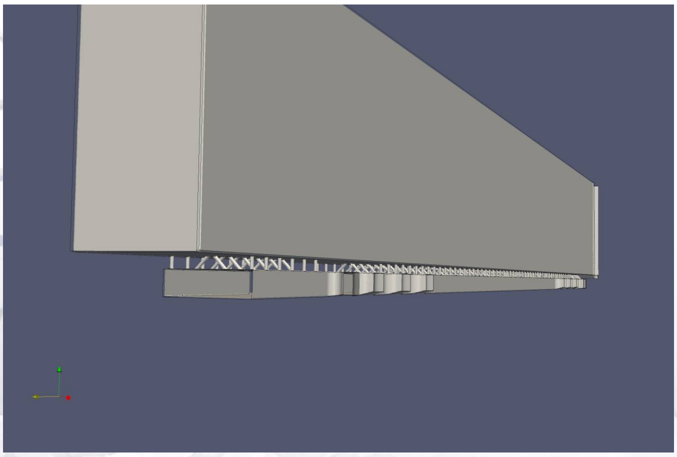


Numerical modeling strategy

- 3D-CFD model (or hydraulic model) for local loss coefficients
- 1D-network model for the lock complex
- 3D-CFD model (or hydraulic model) for flow in inlet/outlet, chamber, ...
- 2D-CFD model (or 3D-CFD or hydraulic model) for flow in approach areas, adjacent rivers or canals

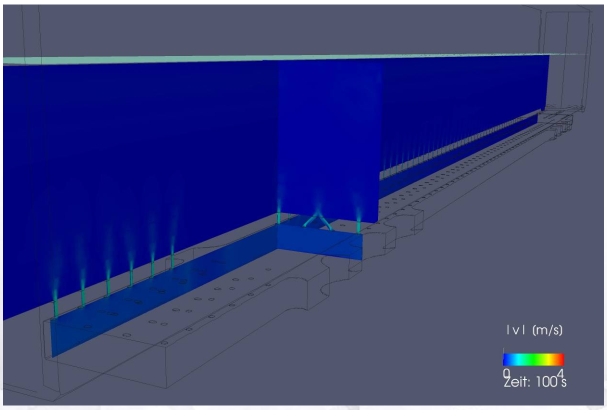


Evaluation methods



Simplified geometrie modell for 3D-Simulation

Evaluation methods



3D-Simulation of filling process

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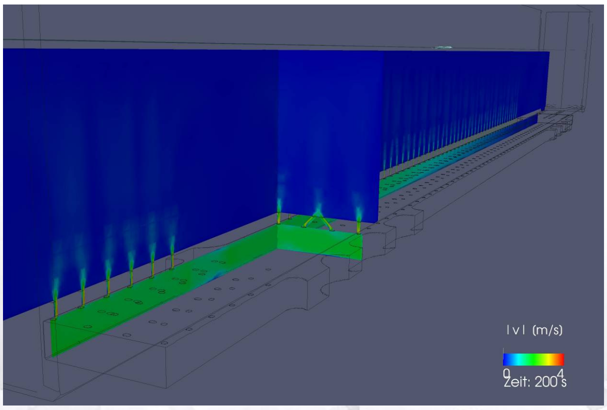
Evaluation methods



3D-Simulation of filling process

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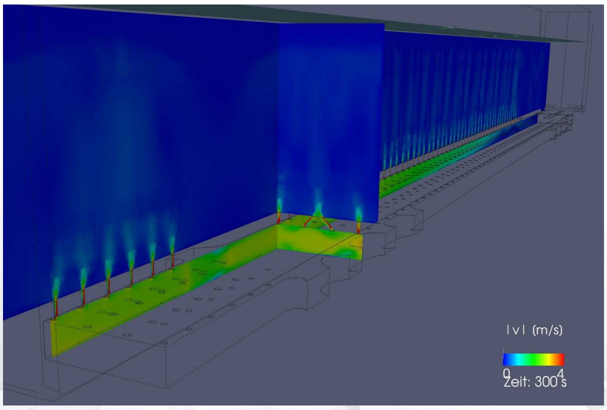
Evaluation methods



3D-Simulation of filling process

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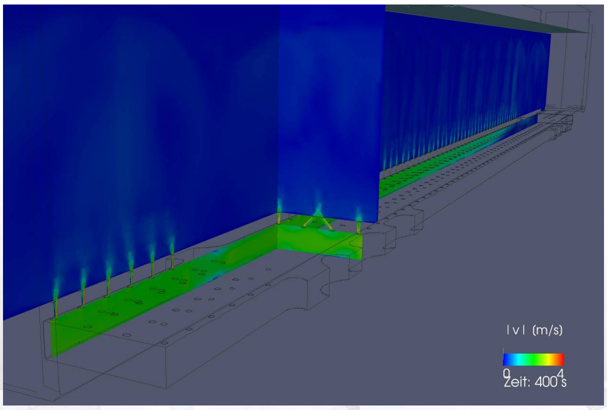
Evaluation methods



3D-Simulation of filling process

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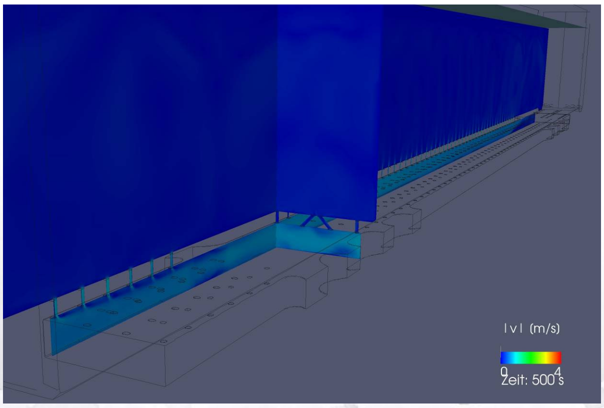
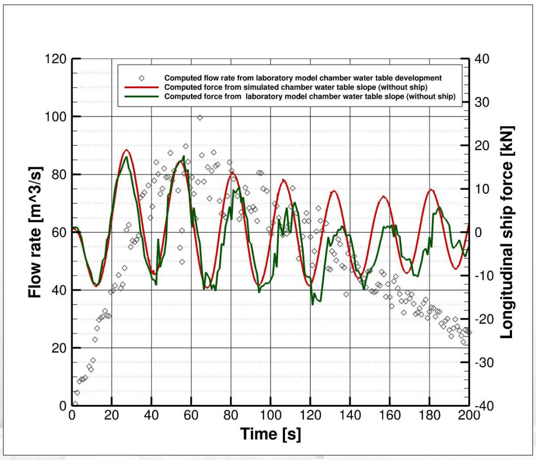
Evaluation methods



3D-Simulation of filling process

Evaluation methods



Comparison of numerical and physical model test results

Evaluation of ship forces

- Physical models and numerical models deliver reliable results
- Ship force is a far, far away from real hawser forces
- … but they are a reliable, repeatable, measurable quantity, while hawser forces rely on uncertain parameters

Evaluation: Known accidents

- Some accidents because of wrong handling of hawsers
- Some accidents because of misoperation of the lock
- Some accidents during entering / leaving the lock
- No known accidents because of "high loads" on the hawsers because of the filling process

Guidelines for flow field in the approaches

- Based on force balances for a ship that tries to enter a canal
- Valid for entering a lock?

⇒ Old guideline: Max. 0.3 m/s transversal flow, to be reduced "under special circumstances"

Lock approaches: Simulator

Navigation simulator for critical situations. Human factor?

Lock approaches: Simulator

- Based on a simulator for seagoing vessels by Rheinmetall Defense Electronics (RDE)
- Recalibration for inland navigation vessels and changes for narrow, constraint fairways finished
- Integrated physical assumptions clearly not valid for entering the lock => Future work: Real-time CFD

Summary

- Reliable approaches to evaluate forces on a ship in the lock
- Many (unreliable) parameters (hawser pretension, angles, dynamics, human factors) impact forces in the hawsers
- Ship behavior in approaches depends on pilots skills. How to put that in numbers?

=> Hopefully WG155 will find some answers to these questions. Let‘s have a look later …

Paper 5-5 **MOORING FORCES AND VESSEL BEHAVIOUR**
Experience in The Netherlands
J.J. VELDMAN (NL)

What's new in the design of navigation locks?

PIANC Workshop
13-14th September 2011

Part 5: Mooring Forces & Vessel behaviour (in locks)

Experience in The Netherlands

By J.J. (Hans) Veldman
Alkyon HC&R/Arcadis
(per Aug'11 at BMT ARGOSS)
The Netherlands

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Developments in Netherlands

- Historical levelling techniques in NL
- Lock modelling in the 20 century (LOCKFILL)
- Demand for modelling of complex levelling system (e.g. for Canal Seine Nord Europ)

Modelling chain developed by Alkyon/Arcadis:

1. 1-D flow model for simulation of high lift locks
2. 2-D flow model of outer harbours and canal
3. Vessel response in time domain: motions and mooring forces in and around lock.

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Lock levelling in The Netherlands

- Centuries of lock building experience (wood, brick, concrete, sheet pile, etc.)
- Small and large locks, low lift (few meters)

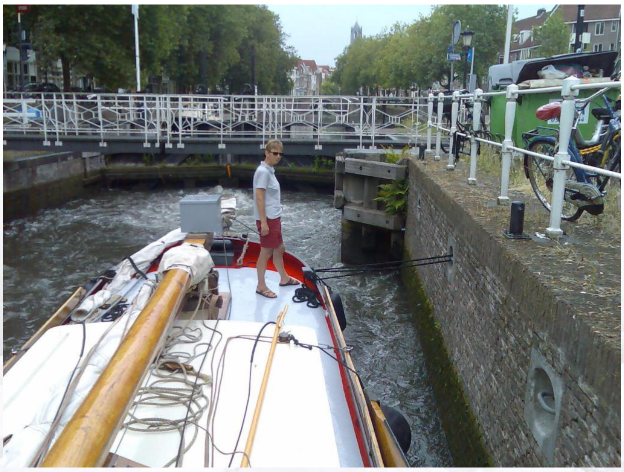
Leveling system in head (in gate, culverts, lifting):

- ➢Flow and turbulence in lock chamber
- ➢High mooring forces and ship motions
- ➢Controlled by (slow) opening speed of valve (tranquility in lock depends on lock operator)

Example of old levelling system 1

Leveling through opening in the lock gate:

- ➢Turbulence
- ➢Motions
- ➢Line forces



Example of old levelling system 2

Leveling through culverts in the lock head:

- ➢Turbulence
- ➢Flow
- ➢Motions
- ➢Line forces

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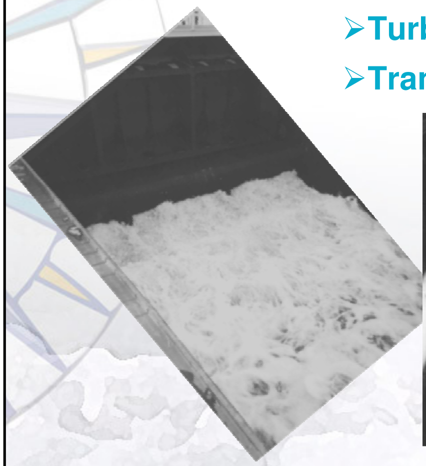
Example of old levelling system 3

Filling by lifting of the gate:

- ➢Turbulence and
- ➢Translatory waves



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Lock levelling model LOCKFILL

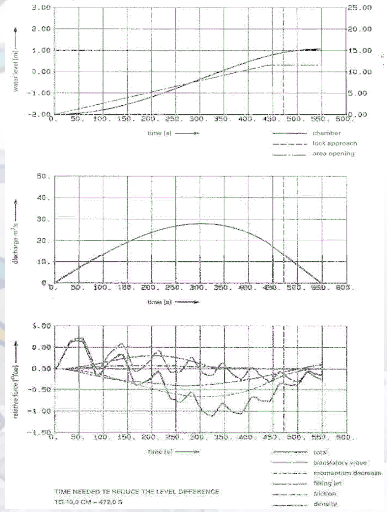
Developed by Delft Hydraulics (1990-1995):
✓For Ministry of Transport, Public Works and Water Management in the Netherlands
✓Verified by model test at Delft Hydraulics

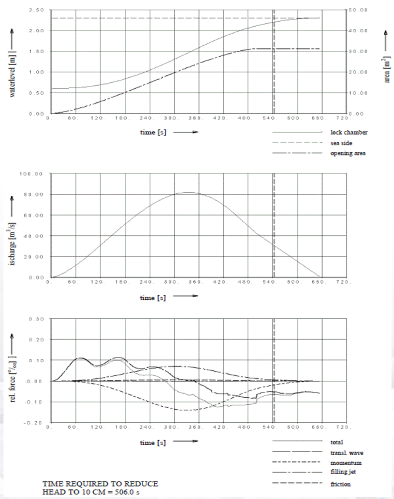
Present status:
➢Maintained and applied by Delft Hydraulics
➢Design/verification tool for locks for Ministry of Infrastructure & Environment

Main features of LOCKFILL

1. Simulation of the leveling (filling/emptying) process of the lock chamber in time domain:
   - ➢ Water levels
   - ➢ Discharges
2. Longitudinal forces on the vessel:
   - ➢ Translatory wave in lock chamber
   - ➢ Momentum decrease over the vessel length
   - ➢ Jet of filling flow at bow
   - ➢ Friction along the vessel hull

The LOCKFILL results

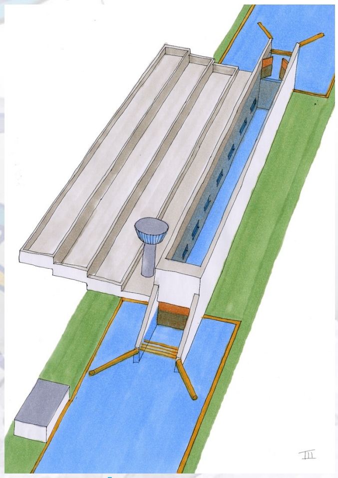




Limitations of LOCKFILL

- ✓ Filling at the lock head
  (no side-filling or bottom filling)
- ✓ Maximum lift of about 4 m
  (not verified for higher lift heights)
- ✓ Through and at Delft Hydraulics
  (No commercial software package available)

Complex navigation locks (e.g. for Canal Seine Nord-Europ)



The locks characteristics:

- ✓Lock chamber 200*12.5 m;
- ✓Lock lift up to 30 m;
- ✓Up to 5 saving basins;
- ✓Levelling-time: <15 minutes;
- ✓Water level inclination <0.1%.

Need for:

- ➢New modelling approach

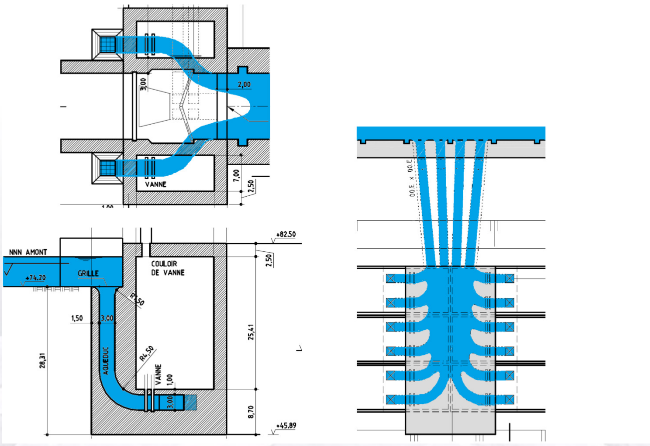
Design philosophy for levelling

1. Levelling through bottom-filling
2. Minimise the inertia of the water in the culverts
   - ➢ short distances
3. Minimise the energy losses in the culverts
   - ➢ culverts internally fluent (gradually changing cross-sections, no sharp corners, no lee areas with turbulence);
4. Discharges controlled by (partly) opened valves
   - ➢ Balanced valve opening and closing strategy to minimise the water level inclination

Minimise energy losses in culverts

Apply:
- **Gradual changing profiles**
- **Large radius**

Avoid:
- **Sharp corners**
- **Lee areas**



Mathematical modelling for CSNE

Integrated modelling (in time-domain) in 3 steps:

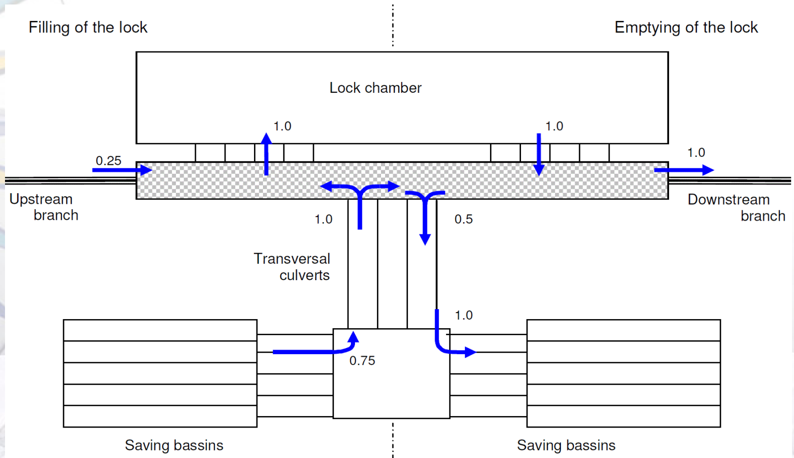
1. Filling en empting of lock with saving basins
   - Sensitivity runs (hydraulic losses in culverts)
   - Valve operation strategy
2. Water-level inclination and flow velocity in:
   - lock chamber
   - lock outer-harbours
3. Mooring forces and vessel behaviour in:
   - lock camber and
   - lock outer-harbours

Model for lock-levelling

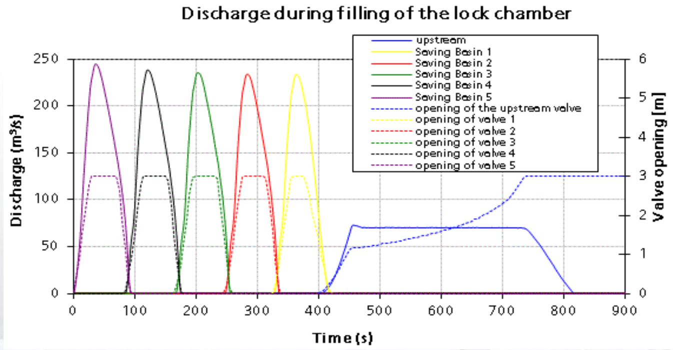
1-D Flow model InfoWorks-RS (from HR-Wallingford):

- Outer harbours with canal section
- Lock chamber
- Double bottom with openings
- Short culverts with valves in lock heads
- Culverts to saving basins
- Saving basins with valves

1-D Flow model: elements and applied energy loss-coefficients



Lock with 30 m lift and 5 basins
Valves and discharges during filling



- Filling from basins with over 200 m3/s
- Filling from canal at 70 m3/s

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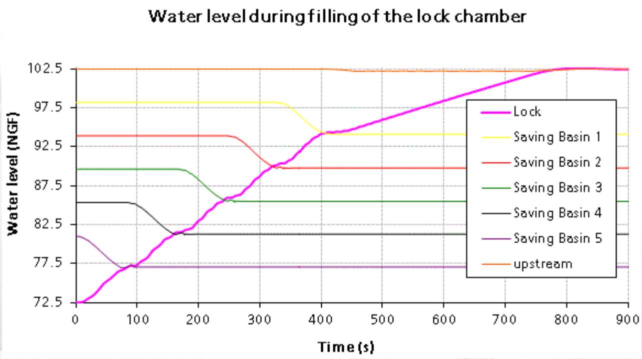
Lock with 30 m lift and 5 basins
Levels during filling



- 5 basins filling each 5.5 m in 90 s (22 m in 450 s)
- Remaining 8 m filled from the canal in 350 sec

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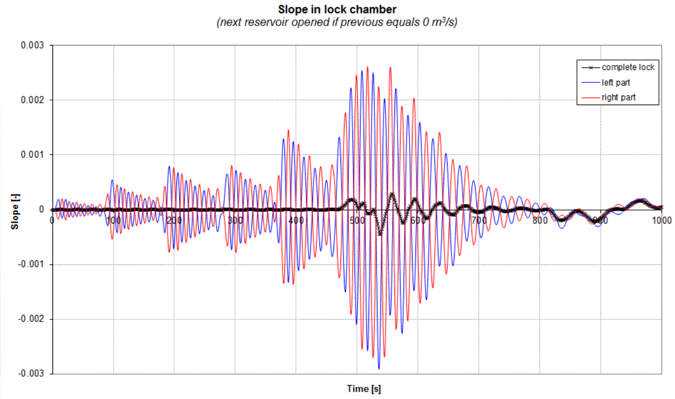
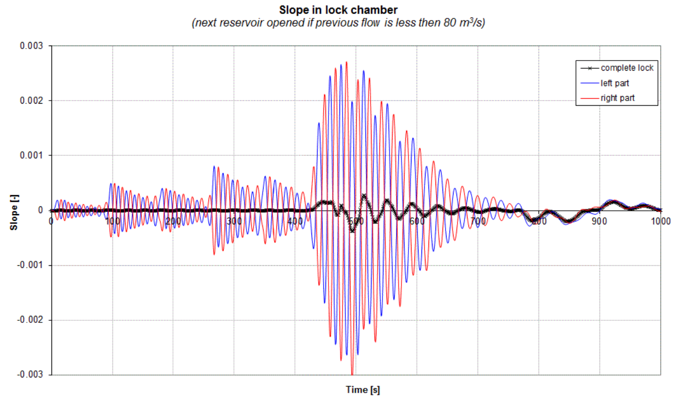
Water-level inclination: next valve open at 0 m3/s



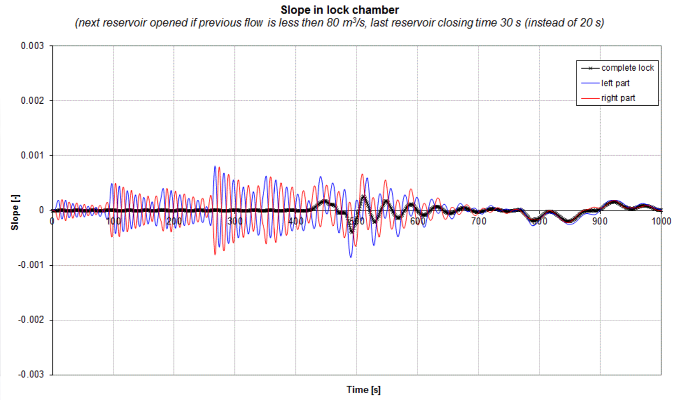
- Inclination increases leveling 5 basins: > 0.01%
- During leveling canal: >> 0.01%

Water-level inclination: next valve open at 80 m3/s



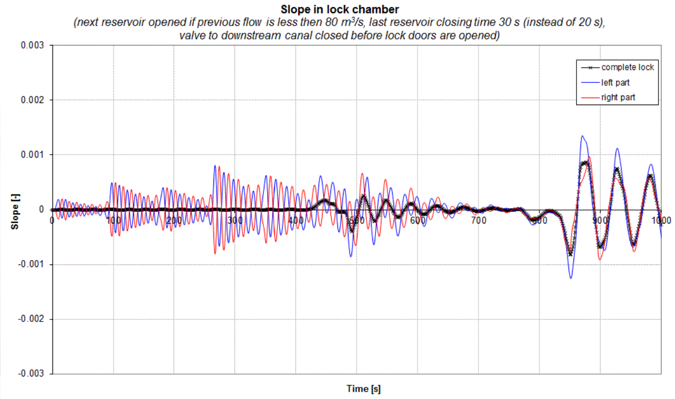
- Acceptable inclination leveling 5 basins : < 0.01%
- During leveling canal: >> 0.01%

Water-level inclination: slow closure of valves of 5 basin



- Acceptable inclination leveling 5 basins : < 0.01%
- Acceptable inclination leveling canal: < 0.01%

Water-level inclination: valves to canal closed before opening of gate



- Acceptable inclination during 5 basins : < 0.01%
- During leveling from canal: > 0.01%

Valve opening rules

Valve	Rule	Condition for Emptying Lock3				Valve movement
Reservoir 1	open	starts at a certain time				0.15*
	close	F1 <135			LC-R <1	0.15
Reservoir 2	open	F1 =80	LC < 100.36	LC > 96.07		0.15*
	close	F2 <135			LC-R <1	0.15
Reservoir 3	open	F2 =80	LC < 96.07	LC > 91.79		0.15*
	close	F3 <135			LC-R <1	0.15
Reservoir 4	open	F3 =80	LC < 91.79	LC > 87.5		0.15*
	close	F4 <135			LC-R <1	0.15
Reservoir 5	open	F4 =80	LC < 87.5	LC > 83.21		0.15*
	close	F5 <165			LC-R <2.35	0.075
DS	open_1	F5 =80	LC < 83.21	LC > 78.93	Fds <70	0.04*
	open_2	Fds >0	Fds <70			0.04*
	stop	Fds >70				0
	close	Fds <40	LC-ds < 0			0.15

** starts with a decelerate valve velocity*
F1 = flow at valve of reservoir or canal, with corresponding number 1(or 2, 3, 4, 5, ds, us)
LC = lock chamber level
R = corresponding reservoir or reach level
DS = downstream
US = upstream

Vessel response on levelling

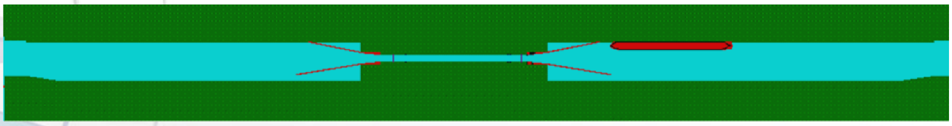
- Hydraulic forces on vessel
- Mass and added mass of the (moored) vessel
- Vessel in (elastic) mooring lines
- Pretension in mooring lines
- Dynamic system (mass–spring system)
- Response of vessel
- Forces in mooring lines

Applied model:

➢SHIP-MOORINGS (developed at Alkyon/Arcadis)

Moored ship response

SHIP-MOORINGS simulates the 3-D motions of the vessel, the mooring forces and the fender forces.

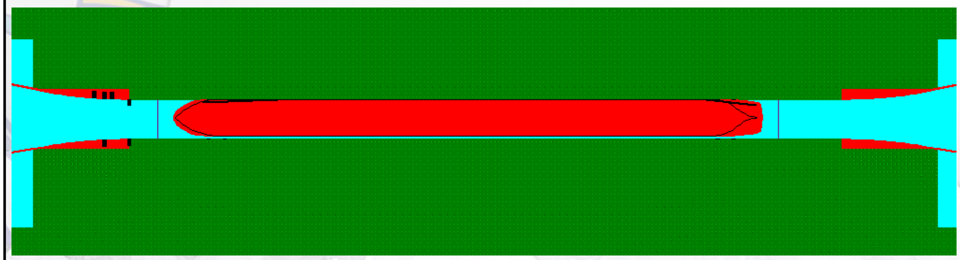


Model input is a mathematical description of:

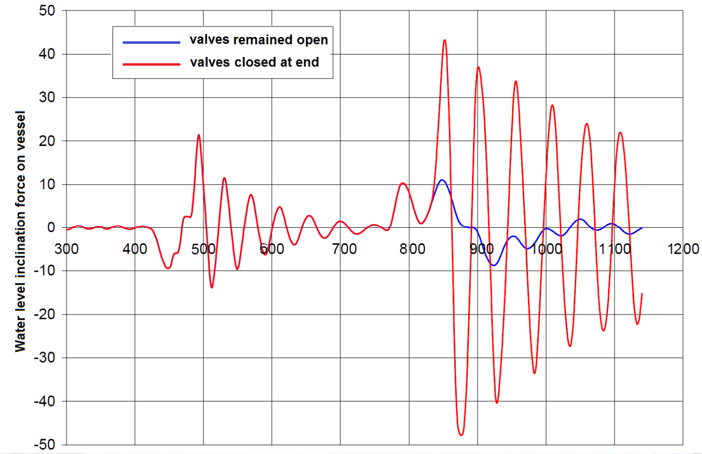
- Vessel (mass and hydrodynamic-reaction forces)
- The environment (plan and water depth)
- External (hydraulic) forces
- Mooring lines (with or without pretension)

SHIP-Mooring model of lock chamber

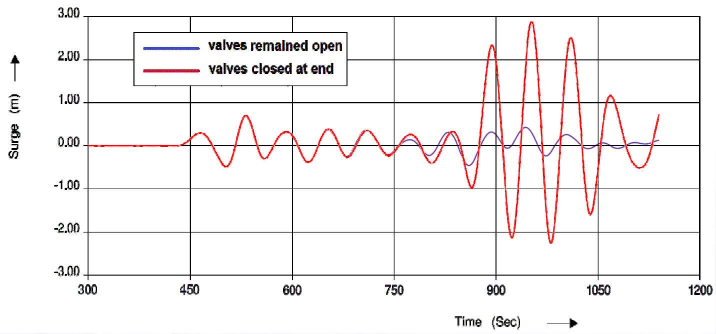
CEMT Class Vb vessel moored in lock chamber



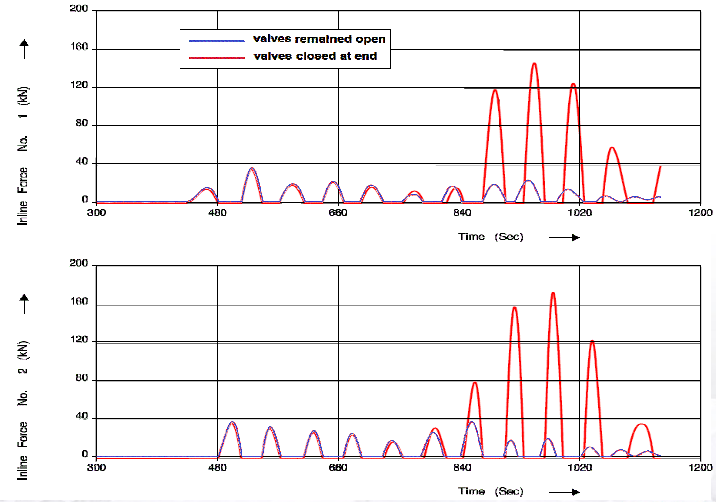
Forces on vessel in lock
From water level inclination



Surge motion of vessel in lock

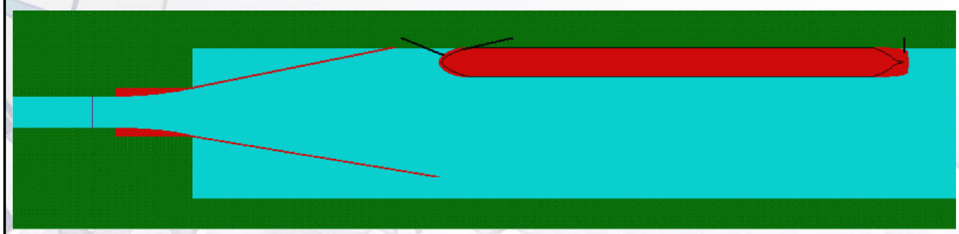


Mooring line forces of vessel in lock



SHIP-Mooring model of lock outer harbour

CEMT Class Vb vessel moored in outer harbour

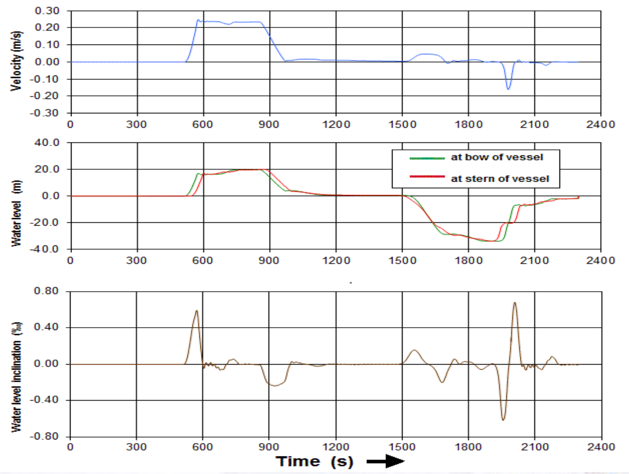


Lock levelling induced water motion in outer harbour

Flow velocity during leveling (Delft3D model)

Water level at bow and stern

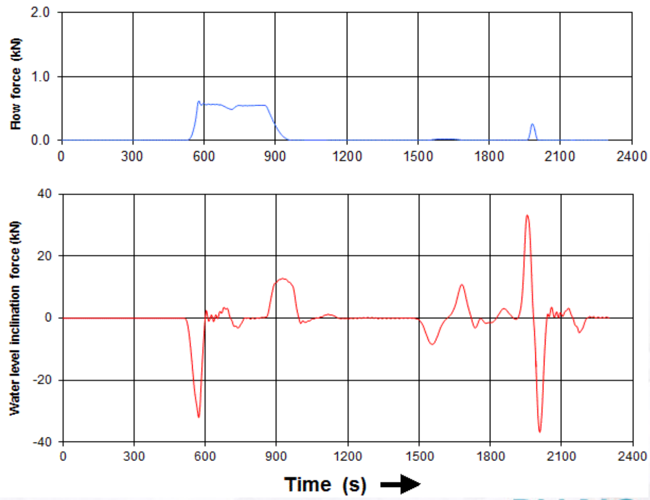
Water level inclination



Forces on vessel in outer harbour

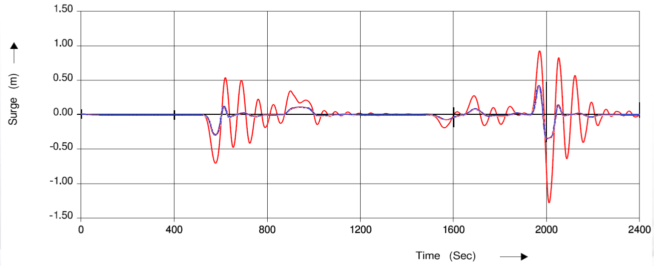
Friction force

Water level inclination force



Surge motion of vessel in outer harbour

without
and
with
pretension



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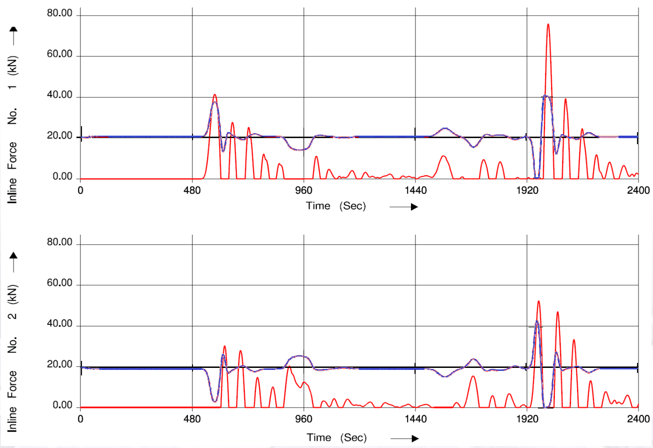
Mooring line forces of vessel in outer harbour

without
and
with
pretension



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Summary and conclusions 1

- 1-D and 2-D flow modelling and simulation of moored vessel was successfully used for simulation of vessel behaviour due to lock levelling
- Discharge, water level, water-level inclination, levelling time, vessel behaviour and mooring forces were simulated
- Results appeared in line with physical model tests at Sogreah, France; see: Pianc-WG-locks(2009).

Summary and conclusions 2

- Low hydraulics losses in culverts enable the high discharges required for fast levelling
- The water-level inclination and ship motions appeared very sensitive for valve opening and closing speed and procedure
- Pretension in mooring lines significantly affects the ship motions

Thank you for your attention.

Questions?

My question to you:
Will this knowledge
take you somewhere?

Paper 5-6 **MOORING FORCES AND VESSEL BEHAVIOUR**
Experience in USA
R. STOCKSTILL (USA)

What's new in the design of navigation locks?


PIANC Workshop
13-14th September 2011
Mooring Forces and Vessel Behaviour in Locks: Experiences in USA
By R L Stockstill
US Army Engineer R&D Center
USA
PIANC
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Tows Setting Up for Lock Operation
Check Posts
Line Hooks
Floating Mooring Bitts
www.pianc.org
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U.S. Army Corps of Engineers

USACE Lock Performance Criteria:

- Hawser force in physical model must not exceed 4.5 t (metric tons) for barge tows

- Water-surface slope that produces a 4.5 t hydrostatic force on a 3-wide by 5-long barge train moored in a nominal 360-m by 33.5-m lock is 0.0002.

Prototype Experience

Field experiments at

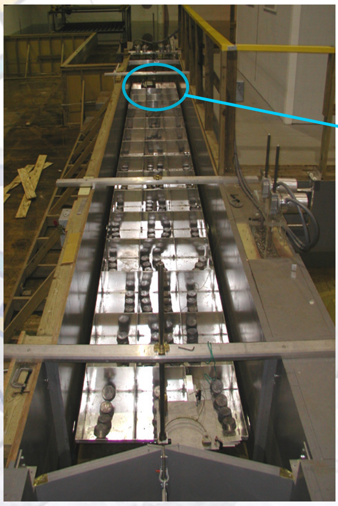
- Barkley Lock, Cumberland River (split-lateral system) and
- Jackson Lock, Tombigbee River (side-port system)

have shown that there is good agreement between hawser force measurements in physical models and corresponding prototype locks

Physical & Numerical Models are used to Evaluate Lock Systems

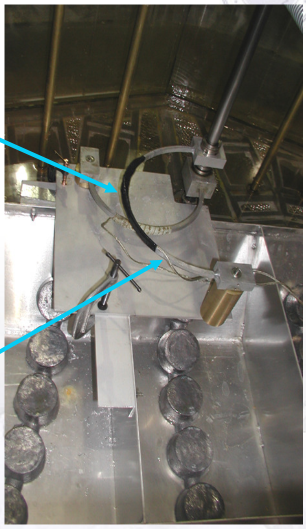
- **Physical Models (1:25-scale)**
  - Pressures are measured with pressure cells
  - Hawser forces are measured with strain gages
  - Time variance of the chamber water surface is measured with pressure cells
- **Numerical Model (LOCKSIM)**
  - Pressures and velocities throughout the system are calculated
  - Hawser forces are computed during post-processing

Physical Model Setup

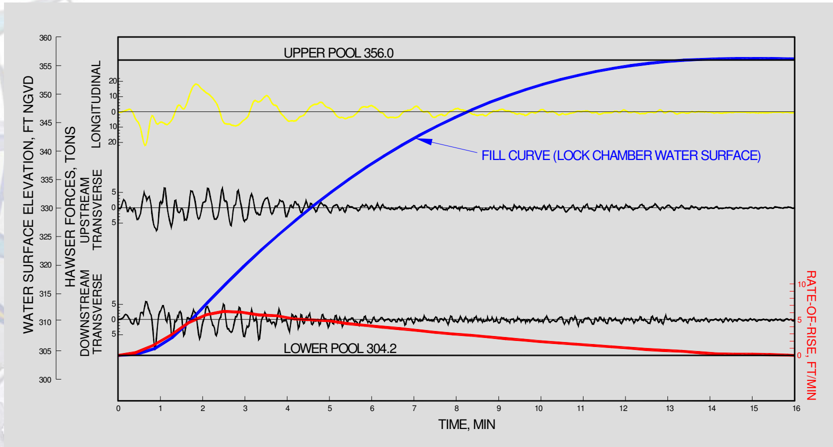


Strain Gage

Longitudinal Hawser Ring



Physical Model Filling Test Data



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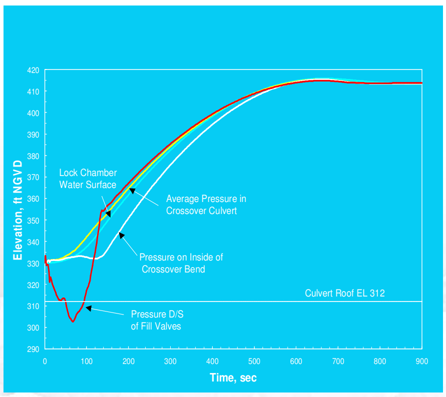
Numerical Model Solution

Hydrodynamic solutions using 1-D model such as LOCKSIM:

- Water-surface elevations
- Pressures
- Velocities



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Numerical Model with Tow

Equations are modified to account for the effect of drafted tow moored within the chamber:

Barge affects the flow by …

- Reducing the flow area
- Increasing the wetted perimeter

Hydrodynamics and vessel response can be computed separately if we assume the vessel is flexible

Mooring System Model

$$(1+C_a)\, m_v \ddot{s} + C_h \dot{s} + (k_0 + k s) = F$$

s = displacement

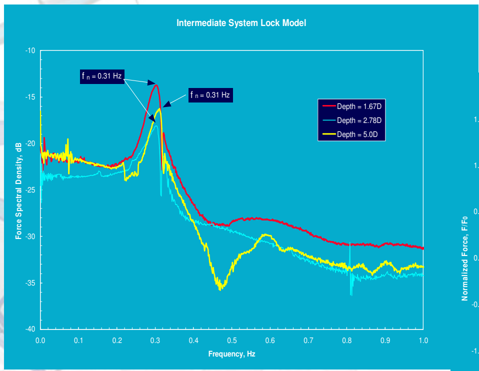
F = hydrostatic force, drag, and shear

Need to quantify coefficients:

C_a = *added mass* C_h = *damping*

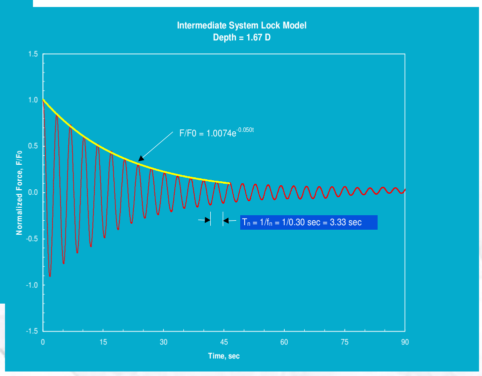
k = *hawser property*

Laboratory Experiments: Still Water



System Frequency

System Damping



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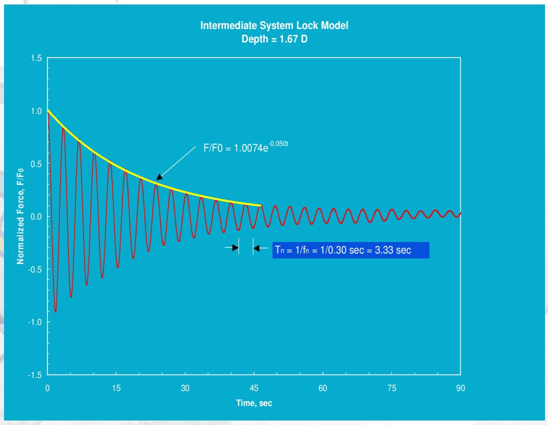
Determining System Coefficients

- **Added Mass Coefficient**



$$f_n = \frac{1}{2\pi}\sqrt{\frac{k}{m_{eff}}}$$

$$m_{eff} = \frac{k}{4\pi^2 f_n^{\,2}}$$

$$m_{eff} = m_v(1 + C_a)$$

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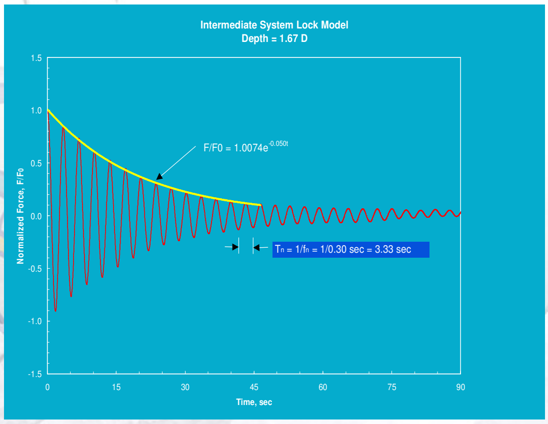
Determining System Coefficients

- **Hydrodynamic Damping Coefficient**



$$F/F_0 = \alpha e^{-\beta t}$$

$$\beta = \frac{C_h}{2m_v}$$

Determining System Coefficients: Lock Chamber Sizes

33.5-m x 360-m (110’ x 1200’) Locks

- **McAlpine Lock model ⇒ 387 m**
- **Intermediate System Lock model ⇒ 408 m**
- **JT Myers Lock model ⇒ 402 m**

25.6-m x 240-m (84’ x 790’) Lock

- **Monongahela No. 4 Lock model**

System Coefficients

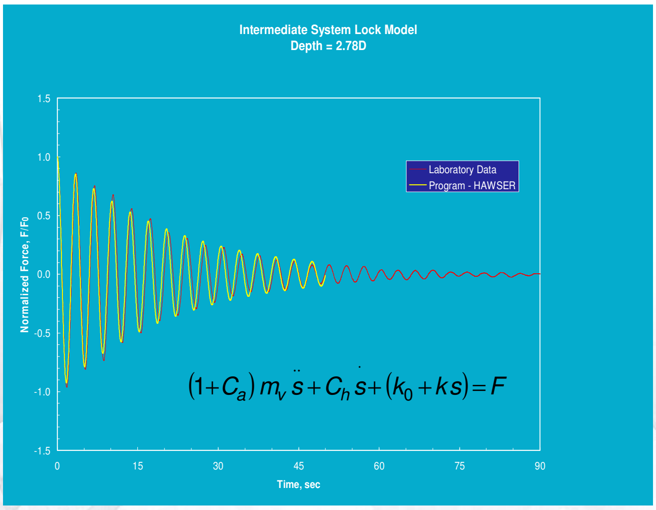
C_a = ***added mass*** = 0.50 for all chambers tested

C_h = ***damping*** *(dimensions of M/T)*

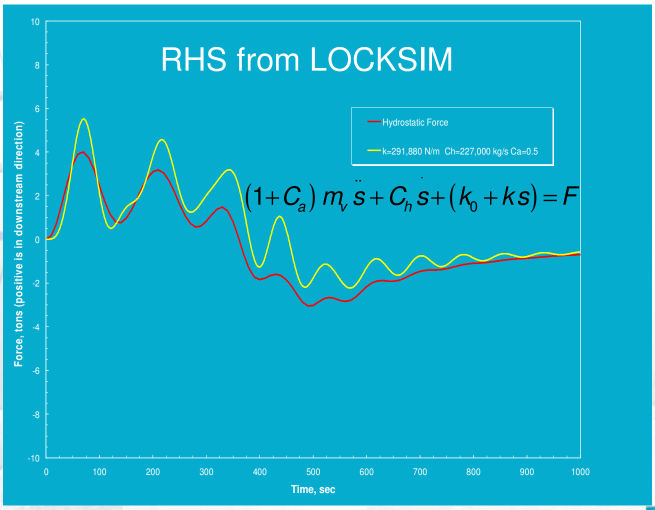
$$\text{Nondimensional damping} = C_h^* = \frac{C_h}{\rho b^2 d}\sqrt{\frac{b}{g}}$$

C_h^*: 0.146 for 33.5-m x 360-m locks
0.156 for 25.6-m x 240-m lock

Validation



Slope Method vs. Equation Of Motion



Conclusions

- Added mass is 0.50 for barge tows in lock chambers
- Damping coefficient varies with lock chamber size
  0.146 for 33.5-m x 360-m locks
  0.156 for 25.6-m x 240-m lock
- Hydrostatic calculation is not necessarily conservative in computing maximum hawser forces

Questions?

Marmet Lock, Kanawha River

Paper 5-7 **Presentation of new innovative concepts for navigation locks**
S. KWOK (Canada)

What's new in the design of navigation locks?

PIANC Workshop
13-14th September 2011

Part 4: Innovation

By Stephen Kwok
SLSMC, Canada

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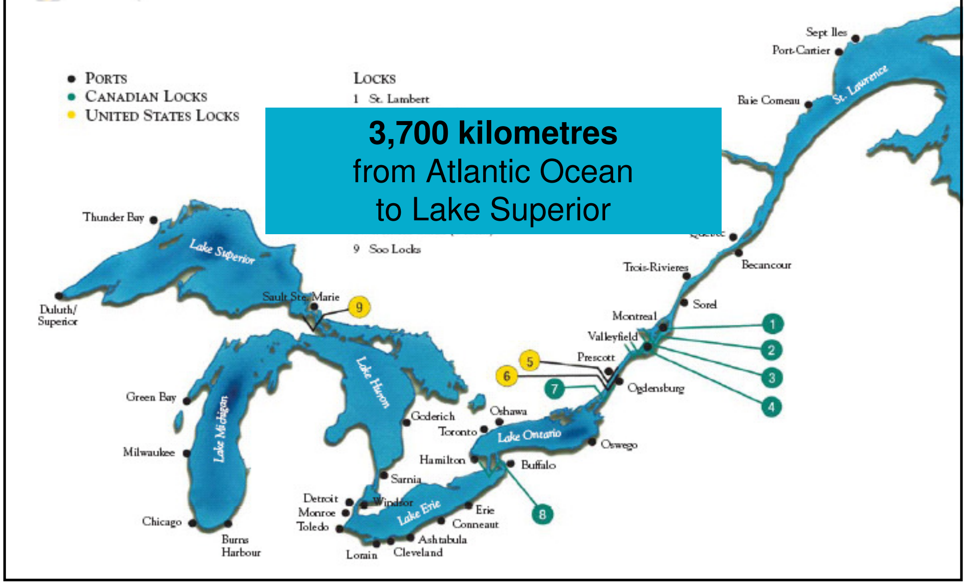
Presentation Outline

The St. Lawrence Seaway
- Overview

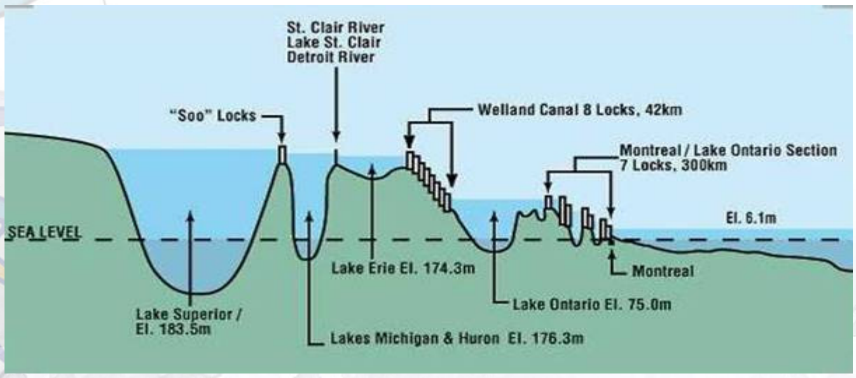
Innovations
•Vessel self spotting
•Hands free mooring

Great Lakes St Lawrence Seaway

3,700 kilometres
from Atlantic Ocean
to Lake Superior



The St. Lawrence Seaway includes 13 Canadian and 2 U.S. locks



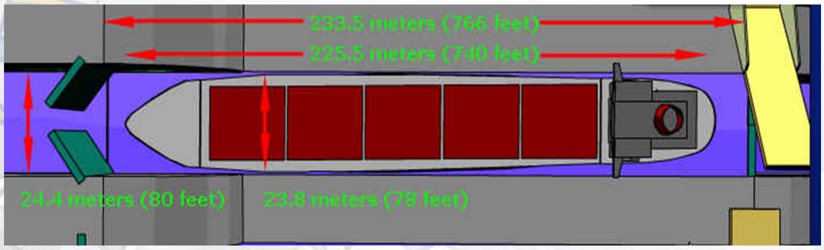
The Seaway accepts vessels up to 30,000 tonnes

Lock Dimensions

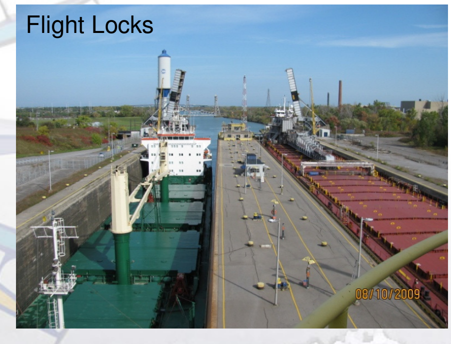
- Length = 233.5m
- Width = 24.4m
- Depth = 9.1m

Max Vessel Size

- Length = 225.5 m
- Beam = 23.7 m
- Draft = 8.08 m



Locks in Niagara & Montreal



VESSEL SELF SPOTTING

Objectives of Vessel Self Spotting

- Optimize lock cycle time by having all lock personnel available for mooring operations sooner in the process.
- Set the stage for potential automation of the lockage process.

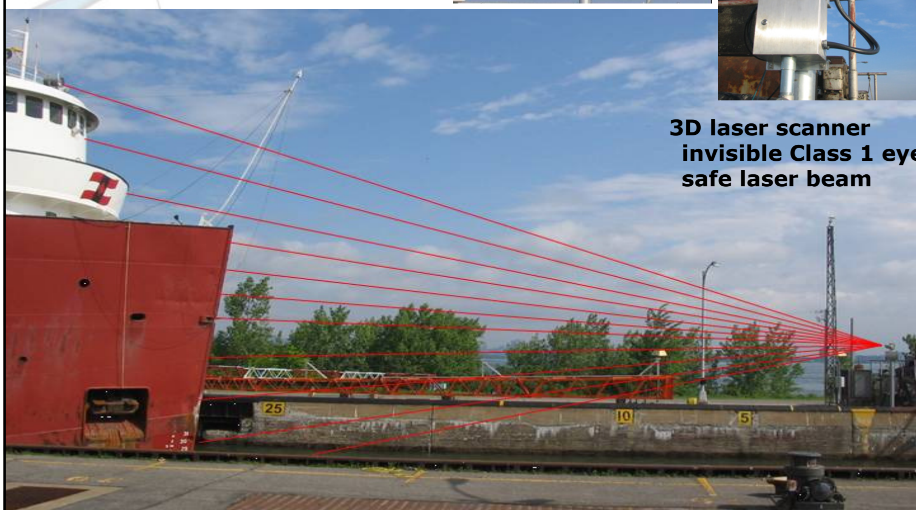
System Description

- Measures the distance from the vessel entering the lock chamber to its final mooring position
- This distance is available to the ship master via two display panels and through an automated marine radio transmission
- The system is composed of two scanner assembly (one per direction) and two display panels

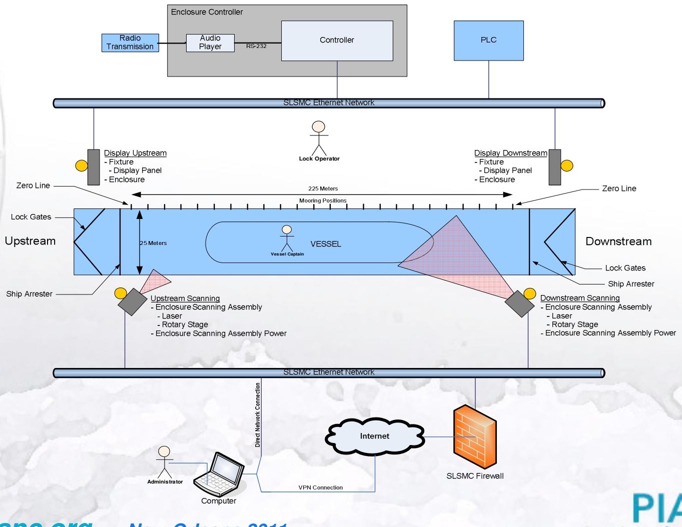
VSSS

Large LED display panel

3D laser scanner invisible Class 1 eye-safe laser beam



Schematic Layout



MOVIE 1 -

HANDS FREE MOORING

Objectives of Hands-Free Mooring

- Enhance operations efficiencies and reduce costs
- Remove the need to have non-standard equipment to transit the Seaway
- Enhance safety and eliminate possible mooring related injuries
- Provide customers with faster and more efficient service

Technologies Considered

- Mechanical
  - – Robotic arm with mooring wires
- Electro-magnetic
  - – Experimented by Delft University
- Vacuum Pads
  - – Developed in New Zealand by MSL
    - Successful installations for ferries
    - Pilot installation in Dover, England for 7m tide

Why did we select vacuum mooring?

- Vacuum mooring is a proven technology
- Floating bollards are widely used in many locks around the world
- Least complicated system among the options

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Timeline

2007	Prototype #1 – Proof of Concept One floatation unit installed at a “Low Head” Lock
2008	Prototype #2 – Pilot Test Two floatation units installed at a deep lock with 12m lift
2009	Prototype #3 Two additional “winched” units installed at the deep lock
2012	Prototype #4

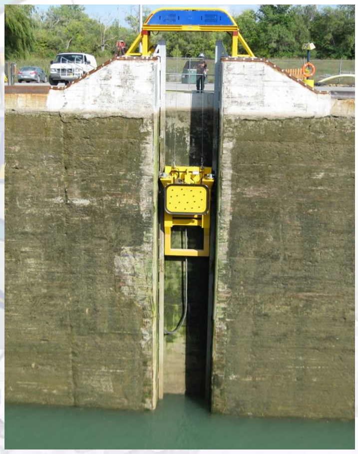
Prototype #1 confirmed that the concept is feasible

- Vacuum pad can hold 20 kN perpendicular force and 16 kN sliding force
- Rubbing bar & other obtrusions on hull can be an issue with seal
- Needs redesign of vertical travel mechanism

Prototype #2 showed that floatation units have limitations

- Generally work as per design
- Two units inadequate for large vessels
- Rubbing bar and obstructions continue to be an issue
- Ice build-up on floatation tank and track

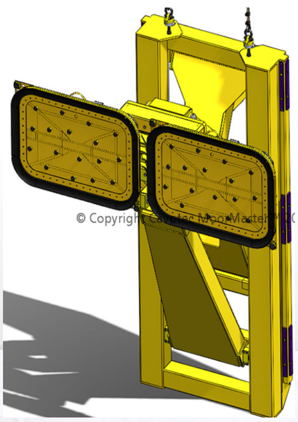
Prototype #3 exhibited major improvement in performance

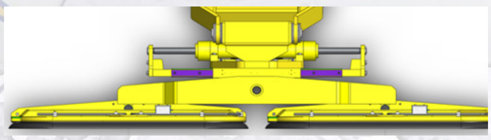


- Ability to be positioned vertically to avoid obstacles
- Can be parked at top when not in use
- More complicated operation & control system
- 4 units still inadequate for vessel induced surge forces

MOVIE 2 -

Prototype #4 will boost energy absorption capabilities





Challenges of technology innovations

- Lack of means to simulate real conditions
- Initial reliability not optimal
- Adaptation by vessel masters
- Impact on lock crews

Paper 6-1 **INTERACTION between SALT WATER INTRUSION and NAVIGATION (in locks)**

M. SAS (BE)

What's new in the design of navigation locks?

PIANC

The World Association for
Waterborne Transport Infrastructure

IMDC International Marine & Dredging Consultants

Salinity and Locks

Marc Sas
International Marine and Dredging Consultants
(Belgium)

PIANC Workshop
13-14th September 2011

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Salinity and Locks

1. Salinity and nautical aspects
2. Salinity and the environment
3. Salinity and sedimentation
4. Mitigating measures

Salinity and Locks

1. Salinity and nautical aspects
2. Salinity and the environment
3. Salinity and sedimentation
4. Mitigating measures

Salinity and Locks

1. Salinity and nautical aspects

- Salinity differences cause density currents
- Major phenomena :
  - Spilling (leveling of the chamber)
  - Exchange current (opening of the doors)
- They have impact on the navigation :
  - What you see is NOT what you get
  - Asymmetric flow distribution in the tail bay/ access channel of the lock
  - Increased hawser forces

Salinity and Locks

What's new in the design of navigation locks
New Orleans 13-14/09/2011
Marc Sas

1. Salinity and nautical aspects


Spill in East Tail bay (Miraflores Locks – Panama)

Salinity and Locks

What's new in the design of navigation locks
New Orleans 13-14/09/2011
Marc Sas

1. Salinity and nautical aspects


Exchange current in East Tail bay (Miraflores Locks – Panama)

Salinity and Locks

1. Salinity and nautical aspects

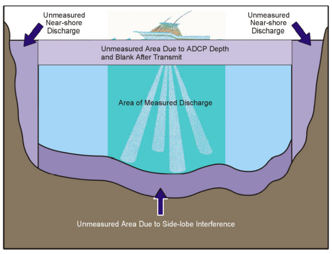
Study approach

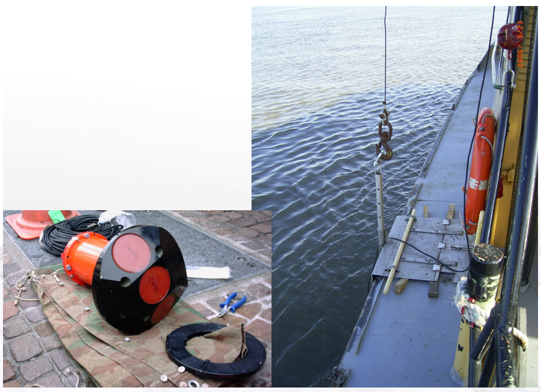
- Data collection
  - To better understand flow and salt exchange between chamber and the ocean during leveling (spilling) and after opening the gates (density current);
  - To determine the velocities caused by density currents that effect ship navigation;
- 3D Modeling of present situation
  - Set-up, validation and results
- 3D Modeling of future situation
  - Set-up, scenarios and results

Salinity and Locks

1. Salinity and nautical aspects

Current Measurements - ADCP





Salinity and Locks

1. Salinity and nautical aspects

Salinity Measurements – rapid drop SiltProfiler

High Frequency (100 Hz)

Wireless (acquisition & transmission)

Freefall Profiling

3 Silt sensors:

- 1 Seapoint BS sensor (0-700 mg/l)
- 2 Transmittance Extinction Sensors (500-5000 mg/l & 5000 – 35000 mg/l)

CTD sensor + backup sensor

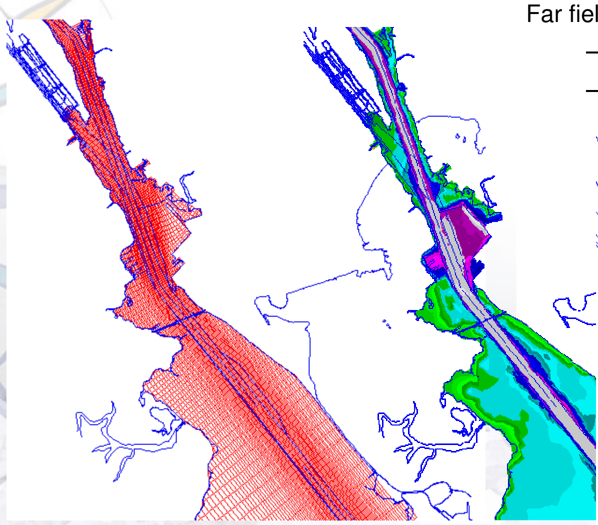
Salinity and Locks

1. Salinity and nautical aspects

Study approach

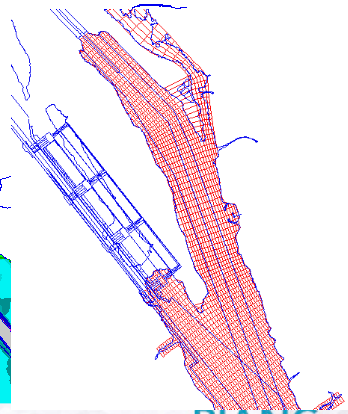
- 3D Modeling of present situation (Set-up, validation and results)
  - far field model (global hydrodynamics)
  - Near field (density currents)

Salinity and Locks



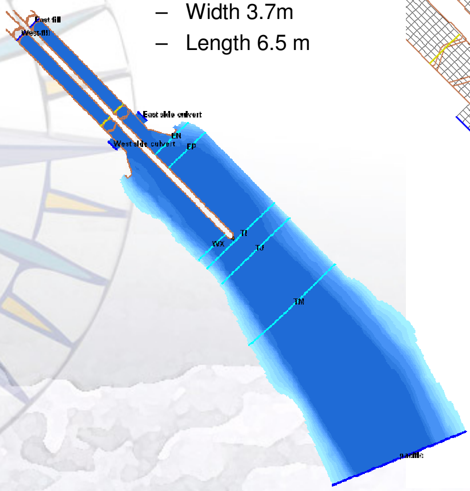
Far field Grid cells:

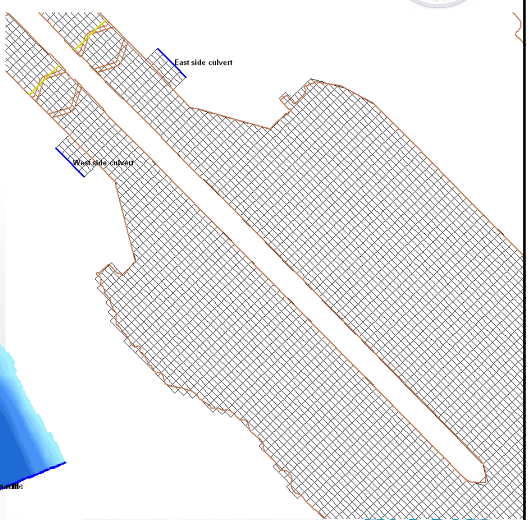
- Width : 20m in channel
- Length : 40m – 80m



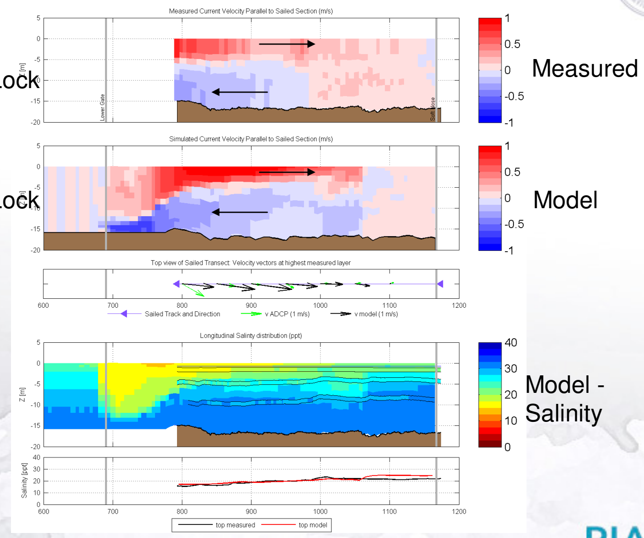
Salinity and Locks

- Near field :Grid cells:
  - Width 3.7m
  - Length 6.5 m





Salinity and Locks



Salinity and Locks

1. Salinity and nautical aspects

Study approach

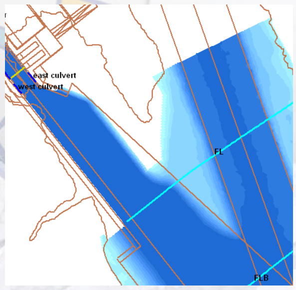
- 3D Modeling of future situation (Set-up, scenarios and results)
- Focus on alternative designs of the tail bay and the centre wall

Salinity and Locks

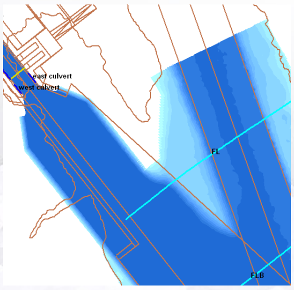
1. Salinity and nautical aspects

- Base line scenarios
- To study the effect of the permeability of the center wall
- permeable wall without and with Water Saving Basins

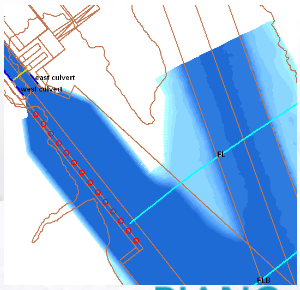
closed wall



no center wall



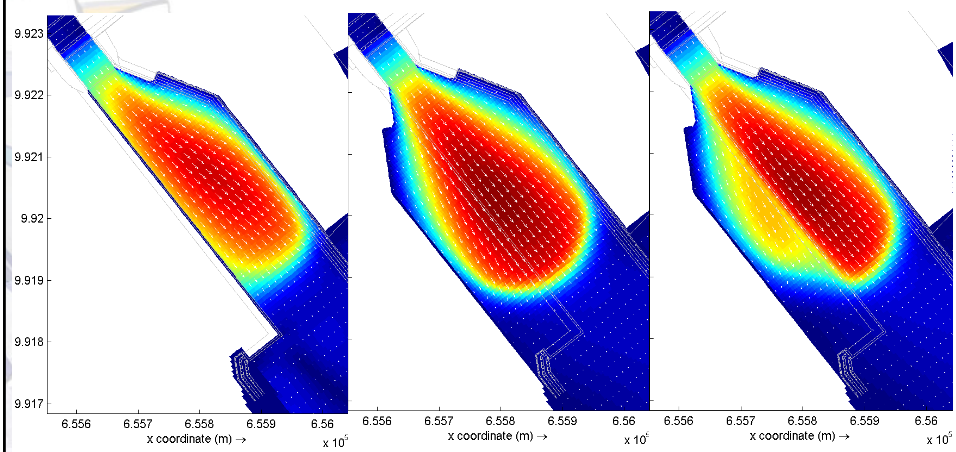
permeable center wall



Salinity and Locks

1. Salinity and nautical aspects

closed wall | no center wall | permeable center wall

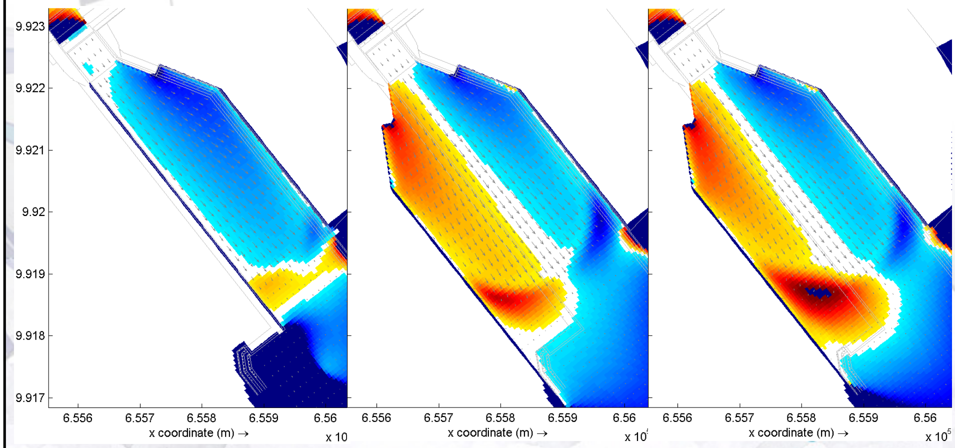


Salinity and Locks

1. Salinity and nautical aspects

Flow direction

closed center wall | no center wall | permeable center wall



Salinity and Locks

What's new in the design of navigation locks
New Orleans 13-14/09/2011
Marc Sas

1. Salinity and nautical aspects
2. Salinity and the environment
3. Salinity and sedimentation
4. Mitigating measures

Salinity and Locks

2. Salinity and the environment

Salt water intrusion from sea locks into inland waterways induces problems :

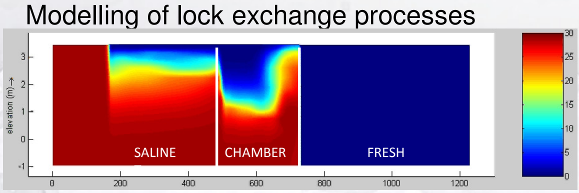
- Surface water (drinking, agriculture, industry, ecosystem)
- Examples :
  - Saline intrusion into Gatun lake (from the Pacific)(Panama)
  - Saline intrusion into canal Gent-Terneuzen (the Netherlands)
  - Saline intrusion Zeebrugge in case of Seine-Schelde West Canal (Belgium)

Salinity and Locks

2. Salinity and the environment

Salt water intrusion from sea locks into inland waterways induces problems :

- Surface water (drinking, agriculture, industry, ecosystem)
- Approach :
  - In situ measurements of exchange processes
  - Modelling of lock exchange processes

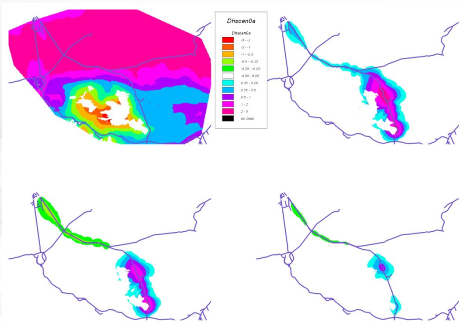


Salinity and Locks

2. Salinity and the environment

Salt water intrusion from sea locks into inland waterways induces problems :

- Groundwater (drinking, agriculture, industry, ecosystem)
- Example : Seine-Scheldt West canal study

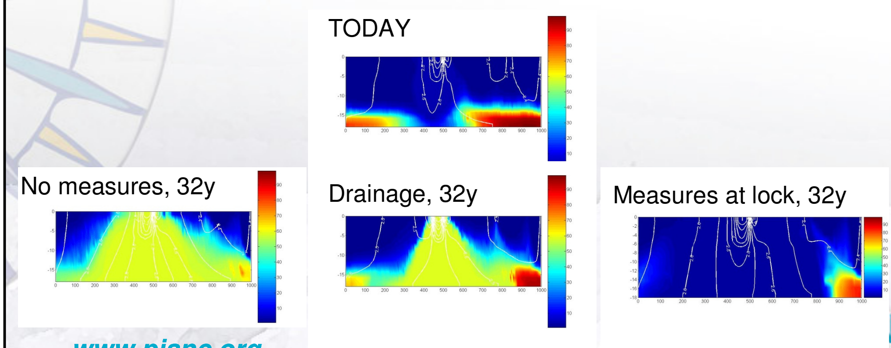


Salinity and Locks

2. Salinity and the environment

Salt water intrusion from sea locks into inland waterways induces problems :

- Example : Seine-Scheldt West canal study

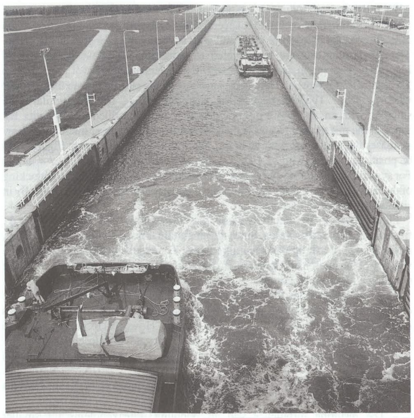


3. Salinity and sedimentation

- Density currents entrain fine sediments into the lock chamber
  Examples :
  - Deposition of mud on the doors (e.g. rolling gates Zandvliet/Berendrecht)
  - Future Deurganckklock (Antwerp)
- Density currents entrain fine sediments in the access channels to the locks, and are responsible (in general) for more than 50% of the sedimentation rate (see PIANC WG 43 on Minimisation of harbour Siltation)
  Examples :
  - Kallo lock (river Scheldt – Belgium) :
    - tidal filling : 20%
    - Eddy : 10%
    - Density currents : 70%

4. Mitigating measures

- Pumping back the saline lockage prism
- Use of air bubble curtain (Volkerak locks – the Netherlands, Kerstma et al.)



Salinity and Locks

4. Mitigating measures

- Gravitational discharge of saline water via receptor basin (Terneuzen, PIANC 1986)

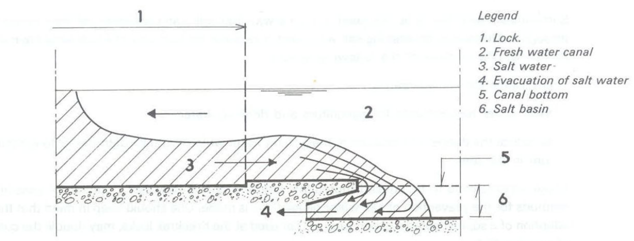
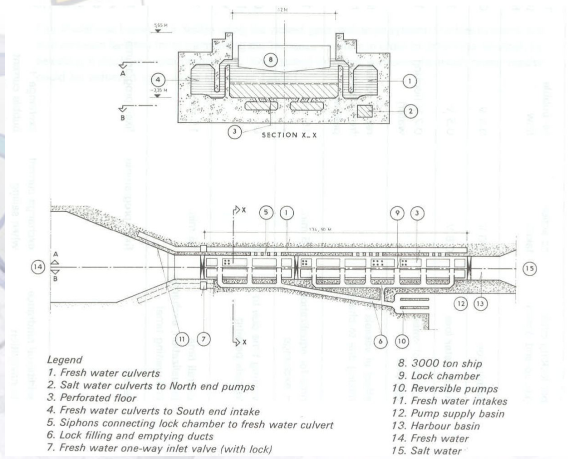


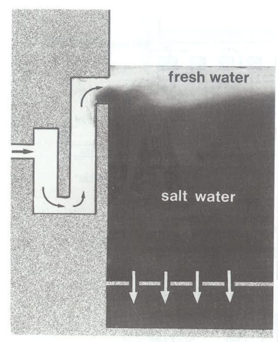
Fig. 2 - System of Terneuzen: Selective withdrawal of salt water intruded in the fresh water canal

Salinity and Locks

4. Mitigating measures

- Complete lock chamber exchange (Dunkirk - France, Kreekrak and Krammer – the Netherlands) (PIANC 1986, Kerstma et al.)






Many Thanks
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IMDC
EXPERTISE IN WATER

Paper 6-2 **MANEUVRABILITY IN LOCK CHANNELS**
M. VANTORRE (BE)

What's new in the design of navigation locks?

PIANC Workshop
13-14th September 2011

Maneuverability in Lock Access Channels

by M VANTORRE
Ghent University
& J RICHTER
Flanders Hydraulics Research, Antwerp
BELGIUM

PIANC
Setting the course

Maneuverability in lock access channels

- Introduction
- Hydrodynamics of lock access
- Practice of lock approach
- Research tools
- Conclusions

Introduction

- **Sea-going ⇔ inland vessels**
- **Important to be aware of all phenomena that affect the behavior of a ship during lock approach**

Hydrodynamics of lock access

- **Effect of lock approach configurations**
- Currents during lock approach
- Lock chamber entry
- Lock chamber exit
- Other effects

Hydrodynamics of lock access

- Effect of lock approach configurations
  - ➢Geometry of approach channel / structures

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Hydrodynamics of lock access

- Effect of lock approach configurations
  - ➢Geometry of approach channel: asymmetry

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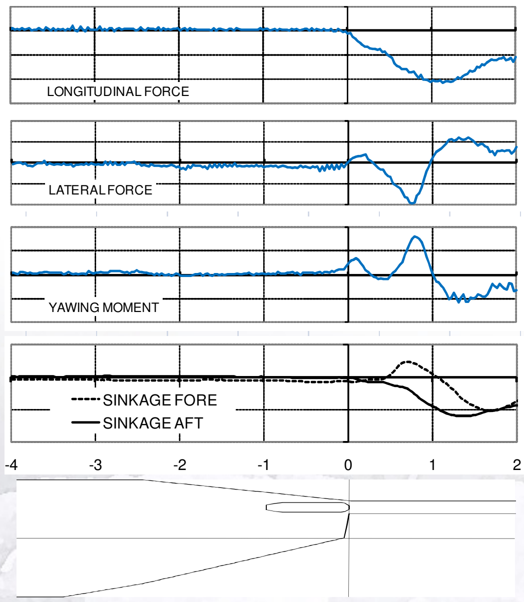
Hydrodynamics of lock access

- Effect of lock approach configurations
  - ➢Geometry of approach channel: asymmetry



Source: Flanders Hydraulics Research

Hydrodynamics of lock access

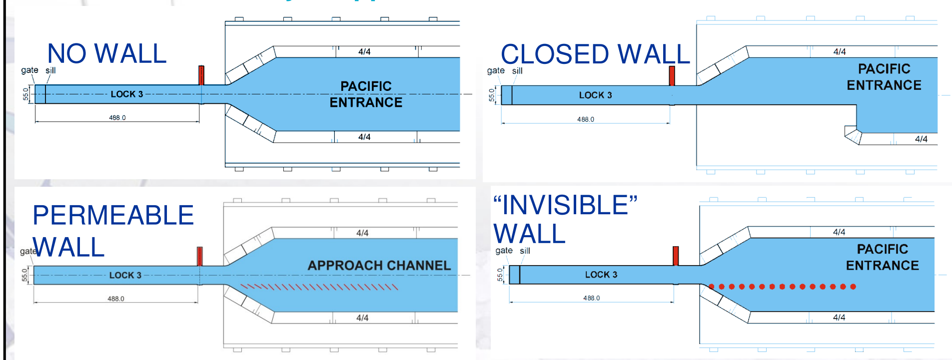
• Effect of lock approach configurations

➢Geometry of approach structures

Hydrodynamics of lock access

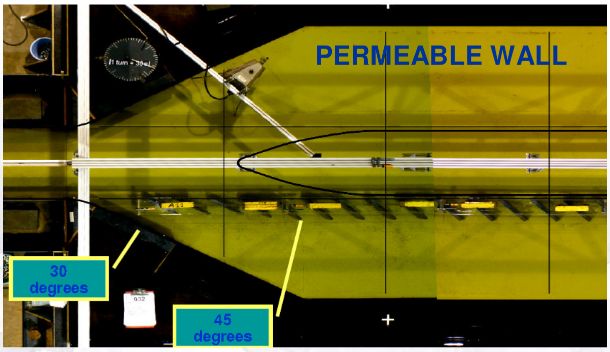
• Effect of lock approach configurations

➢Geometry of approach structures



Hydrodynamics of lock access

- Effect of lock approach configurations
  - ➢Geometry of approach structures



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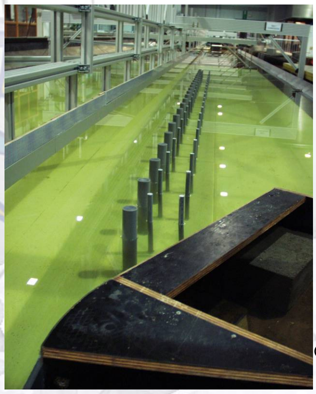
Hydrodynamics of lock access

- Effect of lock approach configurations
  - ➢Geometry of approach structures



INVISIBLE WALL

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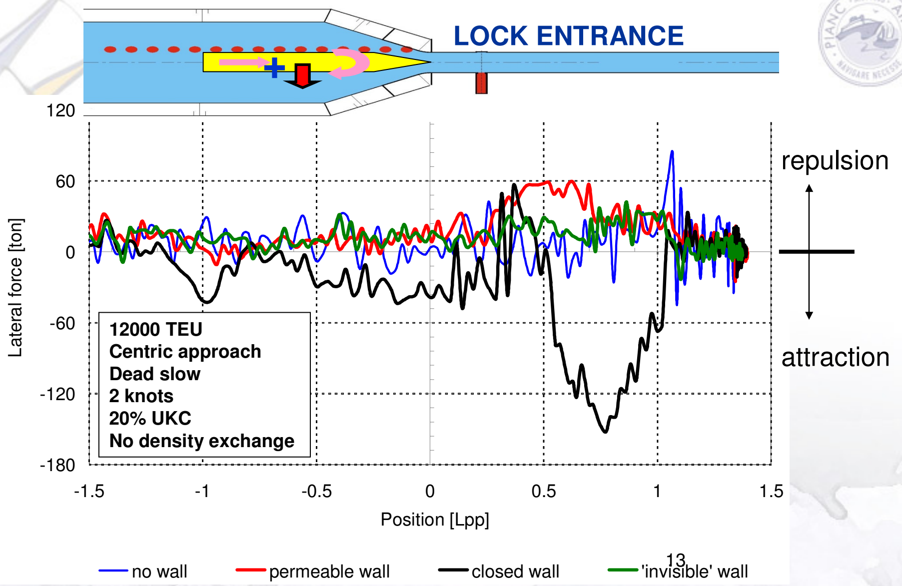
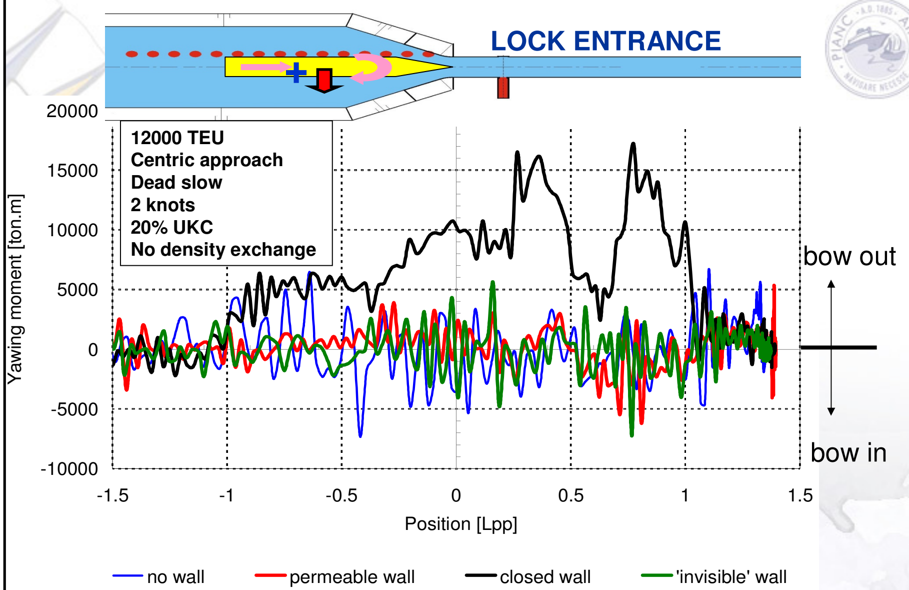


LOCK ENTRANCE
Lateral force [ton]
120
60
0
-60
-120
-180
-1.5
-1
-0.5
0
0.5
1
1.5
Position [Lpp]
12000 TEU
Centric approach
Dead slow
2 knots
20% UKC
No density exchange
repulsion
attraction
no wall
permeable wall
closed wall
'invisible' wall
13



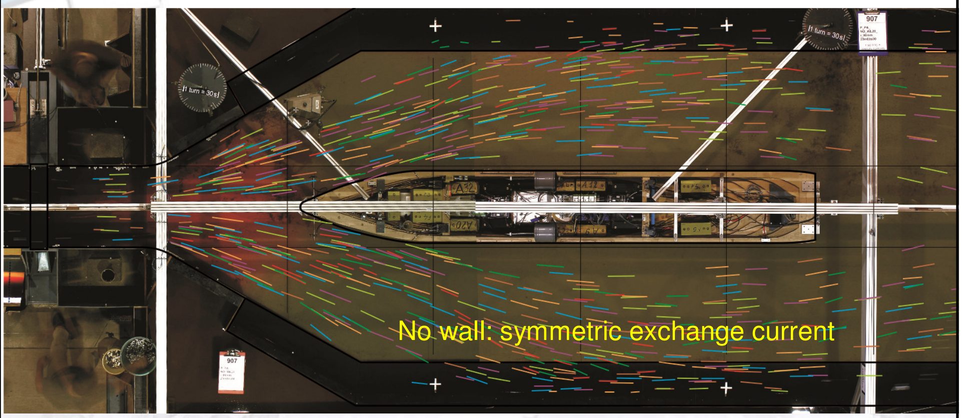
LOCK ENTRANCE
Yawing moment [ton.m]
20000
15000
10000
5000
0
-5000
-10000
-1.5
-1
-0.5
0
0.5
1
1.5
Position [Lpp]
12000 TEU
Centric approach
Dead slow
2 knots
20% UKC
No density exchange
bow out
bow in
no wall
permeable wall
closed wall
'invisible' wall

Hydrodynamics of lock access

- Effect of lock approach configurations
- **Currents during lock approach**
  - Tidal currents, river, …
  - Density currents
- Lock chamber entry
- Lock chamber exit
- Other effects

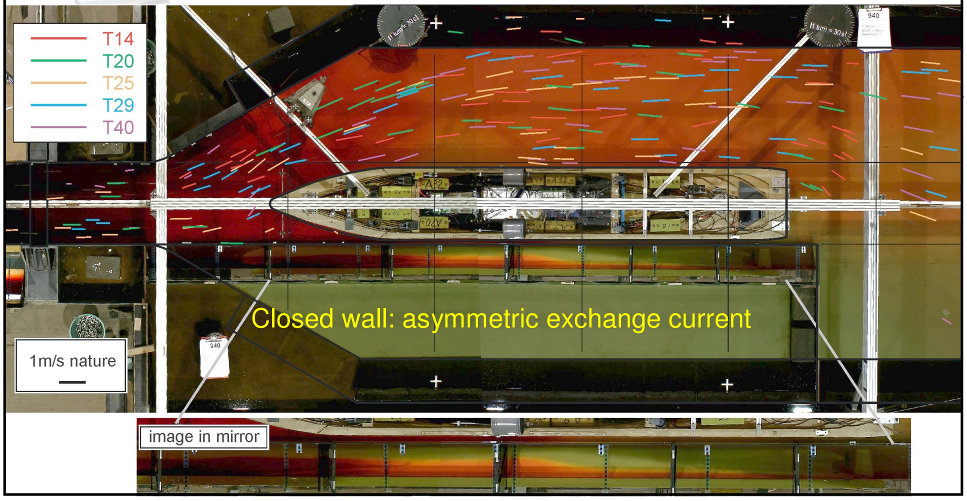
Hydrodynamics of lock access

- **Currents during lock approach**



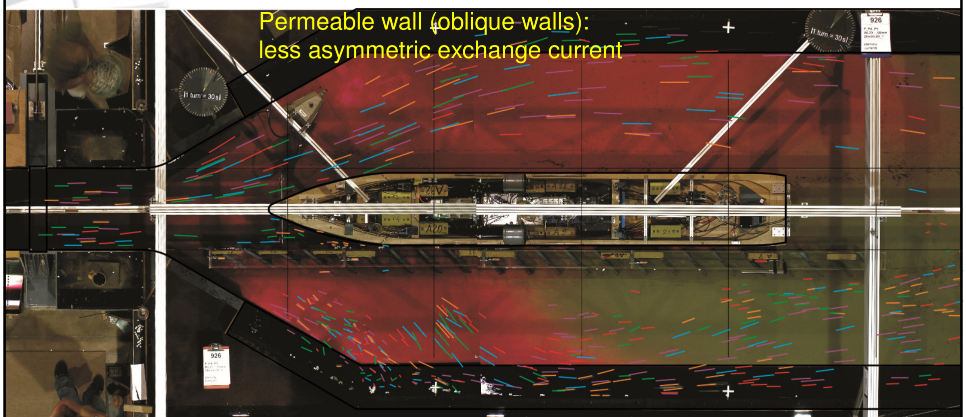
Hydrodynamics of lock access

- Currents during lock approach



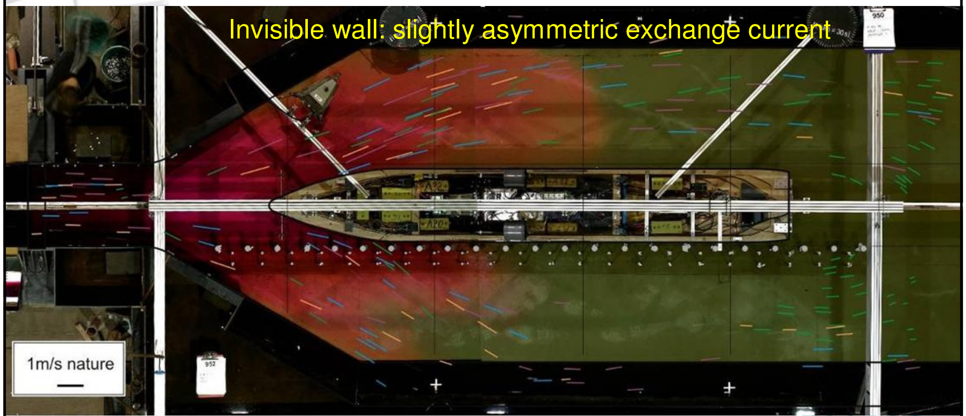
Hydrodynamics of lock access

- Currents during lock approach



Hydrodynamics of lock access

- **Currents during lock approach**



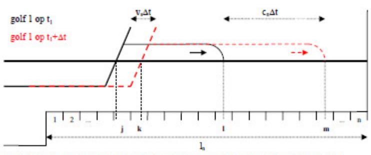
Hydrodynamics of lock access

- Effect of lock approach configurations
- Currents during lock approach
- **Lock chamber entry**
- Lock chamber exit
- Other effects

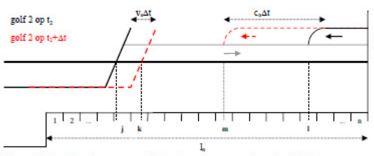
Hydrodynamics of lock access

- Lock chamber entry
  - ➢Translation waves
  - ➢Return flow
  - ➢Cushion effects
  - ➢Retardation forces (memory effects)

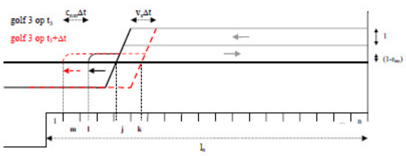
➢Translation waves



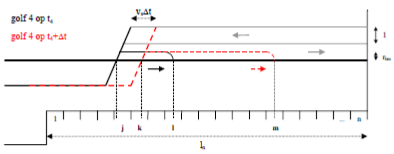
Figuur 2.3: Verloop van golf 1 op twee opeenvolgende tijdstippen.



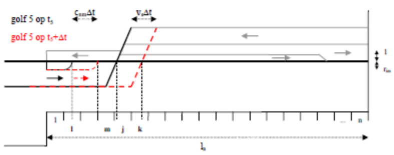
Figuur 2.4: Verloop van golf 2 op twee opeenvolgende tijdstippen.



Figuur 2.5: Verloop van golf 3 op twee opeenvolgende tijdstippen.



Figuur 2.6: Verloop van golf 4 op twee opeenvolgende tijdstippen.



Figuur 2.7: Verloop van golf 5 op twee opeenvolgende tijdstippen.

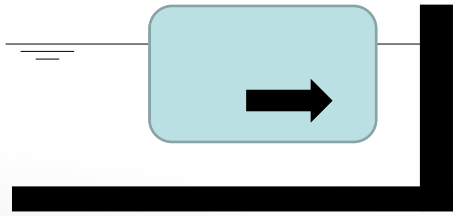
Hydrodynamics of lock access

- Lock chamber entry
  - ➢Return flow
    - ➢Increased resistance
    - ➢Flow on rudder(s) and propeller(s) affected
    - ➢Vertical motions

Hydrodynamics of lock access

- Lock chamber entry
  - ➢Return flow
    - ➢Increased resistance
    - ➢Flow on rudder(s) and propeller(s) affected
    - ➢Vertical motions

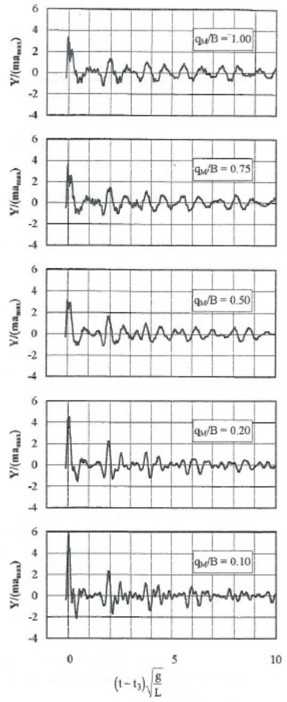
Hydrodynamics of lock access



- **Lock chamber entry**
  - Translation waves
  - Return flow
  - **Cushion effects**
  - Retardation forces (memory effects)

Hydrodynamics of lock access

- **Lock chamber entry**
  - Translation waves
  - Return flow
  - Cushion effects
  - **Retardation forces (memory effects)**
    - High accelerations / decelerations
    - Wave effect
    - Depends on boundaries of waterway, water depth, …
    - Non-stationary effect

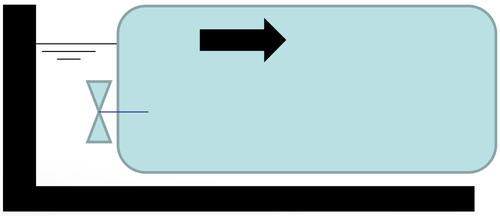


Sudden lateral deceleration of a ship near a vertical wall

Source: Vantorre & Laforce (1998), MAN98, Val de Reuil.

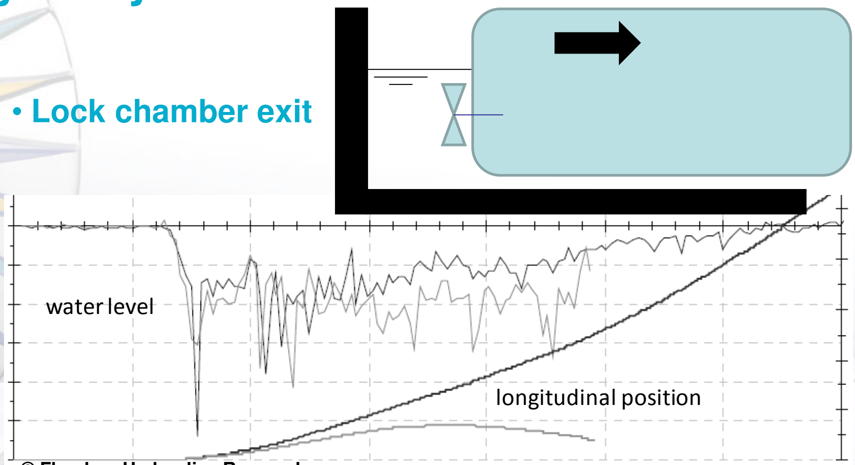
Hydrodynamics of lock access

- Lock chamber exit



Hydrodynamics of lock access

- **Lock chamber exit**



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Hydrodynamics of lock access

- Effect of lock approach configurations
- Currents during lock approach
- Lock chamber entry
- Lock chamber exit
- **Other effects:**
  - Wind
  - Contact forces (e.g. with fenders)

Practice of lock approach

- **Panama: present locks**
- Terneuzen: West Lock
- Antwerp: Berendrecht Lock

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Practice of lock approach

- **Panama: present locks**

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Practice of lock approach

- Panama: present locks

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• **Panama: present locks**

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Practice of lock approach

• Panama: present locks
• **Terneuzen: West Lock**
• Antwerp: Berendrecht Lock

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Practice of lock approach

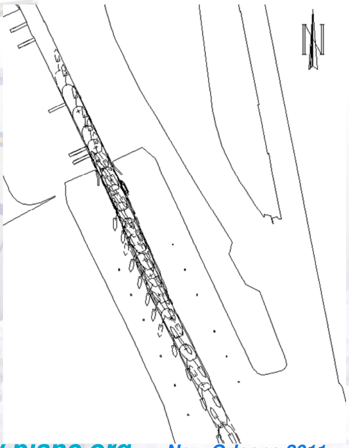
• Terneuzen West Lock

Practice of lock approach

• Terneuzen West Lock

Practice of lock approach

- **Terneuzen West Lock**



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Practice of lock approach

- Panama: present locks
- Terneuzen: West Lock
- **Antwerp: Berendrecht Lock**

Practice of lock approach

- Antwerp: Berendrecht Lock

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- Antwerp: Berendrecht Lock

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• Antwerp: Berendrecht Lock

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Practice of lock approach

- Antwerp: Berendrecht Lock

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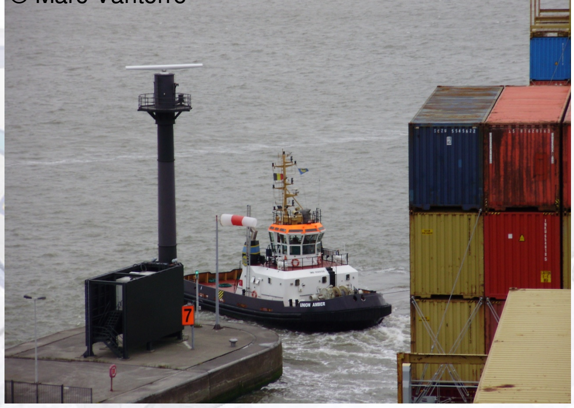

Practice of lock approach

- Antwerp: Berendrecht Lock

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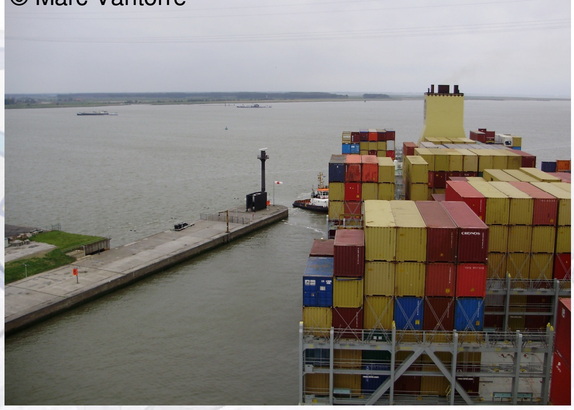

Practice of lock approach

- Antwerp: Berendrecht Lock

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- Antwerp: Berendrecht Lock

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Practice of lock approach

- Antwerp: Berendrecht Lock

SNMS:

Scheldt
Navigator
for
Marginal
Ships

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Research tools

- Maneuvering simulation
- Model tests
- Full scale measurements

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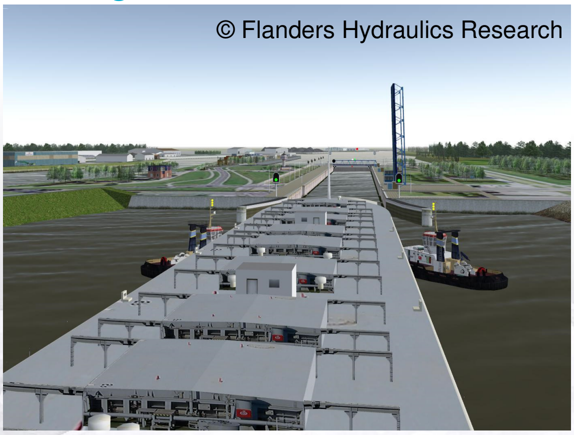
Research tools

• **Maneuvering simulation**



Research tools

• **Maneuvering simulation**
  • Realism
  • Reliability

Research tools

- Maneuvering simulation

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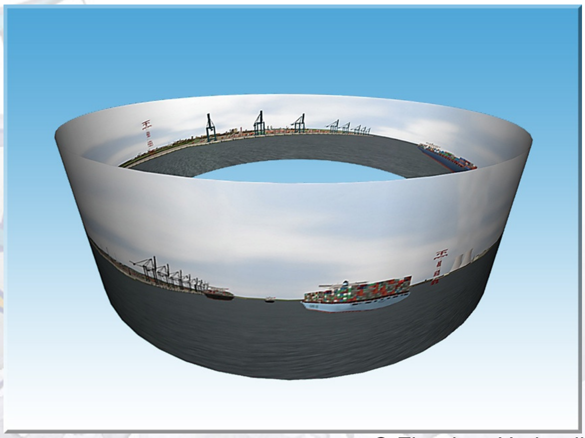
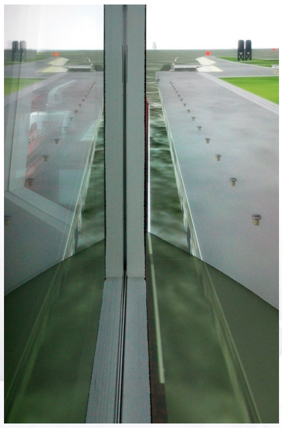
Research tools





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Research tools

- **Maneuvering simulation**

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Research tools

- **Maneuvering simulation**
  - Visuals
  - Bridge mock-up
  - Mathematical model:
    - Include all relevant effects
    - May require introduction of non-stationary effects (memory effects, return flow, translation waves, …)

Research tools

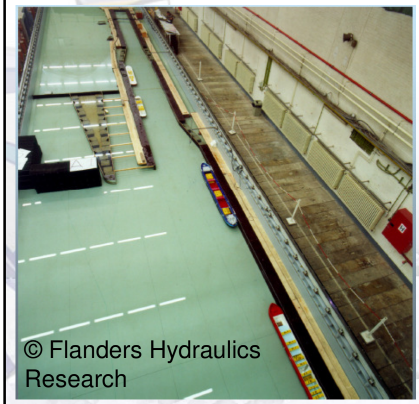
- **Maneuvering simulation**
  - Visuals
  - Bridge mock-up
  - Mathematical model
  - Human control: pilot(s), tug masters, wheelmen

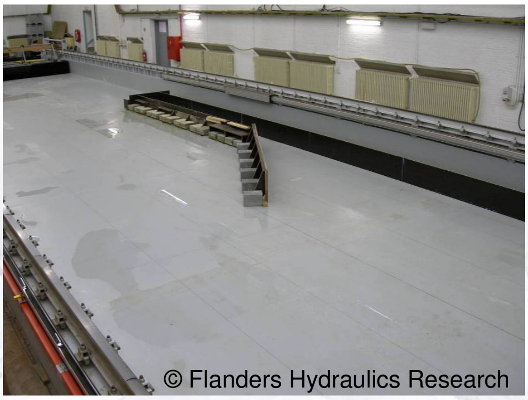
Research tools

- **Model tests**
  - Captive

Research tools

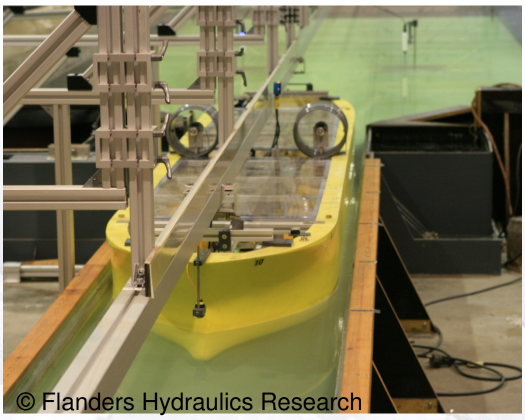
- **Model tests**





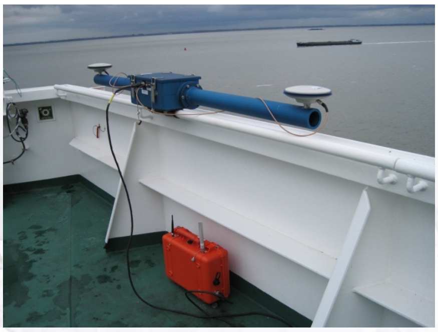
Research tools

- **Model tests**
  - Captive
  - Self-propelled



Research tools

- Maneuvering simulation
- Model tests
- **Full-scale measurements**
  - Horizontal
  - Vertical



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Conclusions

- Safe and efficient use of locks requires approach strategy depending on:
  - Ship characteristics,
  - Lock approach and lock chamber geometry
  - Tug assistance
  - Aids to navigation
  - Environmental conditions
- Maneuvering simulation offers useful tool for
  - Optimising lock design
  - Assessing accessibility of existing lock for new traffic
  - Training

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Conclusions

- Maneuvering simulation offers useful tool, BUT:
  All phenomena affecting/dominating ship behavior of a ship entering a lock should be represented in a realistic and reliable way in the mathematical simulator model

PIANC Workshop
13-14th September 2011

Maneuverability in Lock Access Channels

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