

PIANC INTERNATIONAL WORKSHOP “Innovations in Navigation Lock Design”

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



PIANC - <http://www.pianc.org> -

15-17 October 2009, Brussels, Belgium

Editor: Prof. Ph. RIGO, INCOM WG29 Chairman



PIANC – Report n°106 (2009)

“Innovations in Navigation Lock Design”

In 1986, PIANC produced a comprehensive report on Locks. For about 20 years this report was considered as a world reference guideline, but it was becoming outdated. Today PIANC is publishing a new report (PIANC Report 106, done by INCOM WG29, 200 pages and a DVD).

The new report focuses on new design techniques and concepts that were not reported in the former report. It covers all the aspects of the design of a lock but does not duplicate the material included in the former report. Innovations and changes since 1986 are the main target of the present report.

The report includes more than 50 project reviews of existing locks (or lock projects under development) which describe the projects and their innovative aspects.

The core of the report has three major parts. The first part presents an exhaustive list of design goals associated with locks. This section is particularly

important for decision makers who have to launch a new project.

The second part reviews the design principles that must be considered by lock designers. This section is methodology oriented.

The third part is technically oriented. All the technical aspects (hydraulics, structures, foundations, etc.) are reviewed, focussing on changes and innovations occurring since 1986. Perspectives and trends for the future are also listed. When appropriate, recommendations are listed.

Major changes since 1986 concern maintenance and exploitation aspects, and more specifically how to consider these criteria as goals for the conceptual and design stages of a lock. Renovation and rehabilitation of existing locks will be a key issue for the future.



Van Cauwelaert lock (BE)



Floating Pontoon (Fin)



Hohenwarthe
(Luftbild & Pressefoto)



Myers Lock (US)



Turucui Lock and Dam



Keitele Lock (Fin)



Lock Gates in Cardiff



McAlpine Lock (US)



Qiaogong Lock (China)



Lock on the Rhone (Fr)



Englis Lock (US)



Cover page (left to right, top to bottom): Panama Canal, Seville Lock (Spain)
Composite Gate (France), Three Gorges (China)
Naviduct (Netherlands), Uelzen locks (Germany)

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Acknowledgments:

-W. Meinhold (D),
-R. Daniel (NL),
-C. Ribeiro (Brazil),
-M. Scotti (F),
-T. Silverblatt (USA),
-N.M Dehousse (B),
-C. Kunz (D),
-A. Vrijburcht (NL) and to Flanders
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-SBE,
-University of Liege-ANAST (BE),
-BAW and German Waterways and
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-Finnish Maritime Administration (Fin),
-CNR and SOGREAH (FR),
-Grontmij,
-Delta Marine Consultants and
Rijkswaterstaat (NL),
-Planning and Design Institute for Water
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-Port Authority of Seville (Spain).

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Germany:

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PIANC BELGIUM - PIANC Workshop

INNOVATIONS IN NAVIGATION LOCK DESIGN

15th - 17th October 2009 - Brussels - Belgium

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

The workshop is a 2-days event to launch and promote the new PIANC Report n° 106 on **Innovations in Navigation Lock Design** (published by PIANC in August 2009).

For the PIANC Belgian Section it is also an opportunity to combine the workshop with the 25th Anniversary of the PIANC Belgium Section at Tervuren (in the close vicinity of Brussels). So the workshop participants may also attend the celebration and dinner organised by the Belgian Section (*need registration*).

AGENDA for the PIANC WORKSHOP - 15th -17th October 2009 on LOCKS

Workshop Title: **Innovations in Navigation Lock Design**

15th October 2009 (Thursday)

- 8:30: Arrival and registration - PIANC Headquarter Brussels
- 9:00 to 12:30 **Workshop Part 1**
- 12:30: Lunch
- 14:00: Transfer to Tervuren (in the close vicinity of Brussels)
(by Car, Bus –Subway or Taxi – cost not included)
- 15:00-18:00: **25th Anniversary of Belgium Section at TERVUREN** at Royal African Museum
- 18:00-19:00: Cocktail
- 19:00-22:00: **PIANC Dinner**, TERVUREN at Royal African Museum

16th October 2009 (Friday)

- 8:45: Arrival - PIANC Headquarter Brussels –
- 9:00 to 12:30 **Workshop Part 2**
- 12:30: Lunch
- 14:00:1700: **Workshop Part 3**

17th October 2009 (Saturday)

8:00 – 13:00: **Technical visit at the Van Cauwelaert and Berendrecht Locks** in Antwerp.

Departure time and location will be confirmed during the conference



WORKSHOP – TECHNICAL AGENDA

Location: PIANC Headquarter, Brussels



15th October 2009 (Thursday)

8:30 Arrival and registration - PIANC Headquarter Brussels

8:50 **Welcome** by Ph. RIGO, WORKSHOP CHAIRMAN

9:00- 10:00 **INNOVATIONS IN NAVIGATION LOCK DESIGN –
Presentation of the PIANC Report n°106 on Locks**

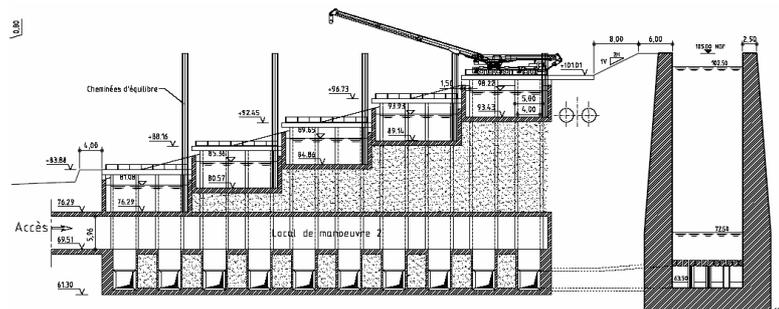
By E. PECHTOLD (RWS, NL) – Project review
P. HUNTER (HR Wallingford, UK) – Design Methodology ,...
J. BOEDEFELD (BAW, D) – Lock Structure and foundation
Ph. RIGO, WG Chairman (Univ. of Liege, BE)

at the name of the 16 PIANC-Lock-Report authors

10:00 – 10:45 **THE LOCKS OF THE SEINE NORD EUROPE CANAL**
(Chairs: C Thorenz - Ph Rigo)

Key note speaker

Benoît DELEU (Voies Navigables de France - VNF)



10:45 - 11:15 Break

11:15 - 12:30 **INNOVATIONS IN LOCK FILLING AND EMPTYING SYSTEMS**
(Chairs: J-M Hiver and J Clarkson)

State of art by **Jerry WEBB** (Corps of Engineering, USA)

Discusser: **Wu PENG** (Planning and Design Institute for W.R., China)

12:30-14:00 Lunch

15:00 - 18:00 **25th Anniversary of Belgium Section** – TERVUREN (with 2 technical presentations)

19:00 - 22:00 **Dinner** – TERVUREN (Organised by PIANC Belgium Section)

16th October, at Graaf Ferraris, Brussels - PIANC headquarter

8:45 - 9:00 **Welcome** by Ph RIGO, PIANC INCOM WG29 Chairman

9:00- 10:00 **THE NEW LOCKS OF THE PANAMA CANAL**
(Chairs: P.HUNTER and Olli HOLM)

Key note speaker:
Juan WONG (ACP, Panama)

10:00 – 10:45 **SALT WATER INTRUSION AND NAVIGATION LOCK & MOORING FORCES AND SHIP BEHAVIOUR**
(Chairs : A HIJDRA and D. MILLER)

State of art by :
Marc SAS (IMDC, Belgium)
Tom DE MULDER (FHR, Belgium)

Discussor: **V. FAIVRE** (Sogreah, France)

10:45 - 11:15 Break

11:15 - 12:15 **MOORING FORCES AND SHIP BEHAVIOUR (IN LOCKS)**

Panel Discussion

Chairman: **A. HIJDRA** (Rijkwaterstaat, NL)

Panel of experts: **T DE MULDER (BE)**, **V. FAIVRE (Fr)**, **D.MILLER (USA)**,
W. MOLENAAR (NL) and **M. SAS (BE)**

12:15- 12:30 **Mr. VAN DEN EEDE E** , PIANC, President

Mr. STELMASZCZYK, Head of Unit B.3 DG TREN (European Commission)

12:30 – 13:45 Lunch

14:00- 14:30 **CONSTRUCTION METHODS - IN-THE-WET – STATE OF ART**
(Chairs : O. HOLM and R. SARGHIUTA)

by **J. CLARKSON** (Corps of Engineering, USA) and
S. YAO (Ben Gerwick Inc, USA)

14:30- 15:00 **LOCK GATES – SHIP IMPACT – STATE OF ART**
(Chairs : R. THOMAS and FERNANDEZ JL)

by **Ph. RIGO** and **T. GERNAY** (Univ. of Liege - ANAST, Belgium)

15:00– 15:30 **COMPUTATIONAL FLUID DYNAMICS (CFD) IN LOCK DESIGN – STATE OF ART**

(Chairs J-M HIVER and M. TARPEY)

by **C. THORENZ** (BAW, Germany)

15:30 - 16:00 Break

16:00 - 17:00 **NUMERICAL SIMULATIONS AND EXPERIMENTAL MODELS: HOW TO CHOOSE?**

Panel Discussion:

Chairman: **J-M HIVER** (SPW, Belgium)

Panel of experts: **O. CAZAILLET (Fr)**, **S. ROUX (Fr)**, **M. TARPEY (USA)**
and **C. THORENZ (D)**

17:00- 17:15 **CONCLUSION:**

E. VAN DEN EEDE, PIANC President, and

Ph. RIGO, Chairman of INCOM WG29 (Report 106 on Locks)



PIANC BELGIUM - PIANC Workshop
INNOVATIONS IN NAVIGATION LOCK DESIGN

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- 3- NAVIGATION LOCKS: DEVELOPMENTS IN DESIGN OBJECTIVES AND METHODS**
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- 4- SEINE NORD EUROPE CANAL – HYDRAULIC DESIGN OF LOCKS**
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*The FULL PRESENTATIONS – including the Powerpoint (in Pdf format) -
will be available on the web site of the Belgium PIANC Section*

<http://www.pianc-aipcn.be/>

Paper 1 - Presentation of the PIANC Report n°106 on Locks

Ph. Rigo

Chairman of INCOM WG29, Prof. ULG-ANAST, Belgium

J. Bödefeld, J. Bos, J. Clarkson, F. Daly, J.L. Fernandez, A. Hijdra,
J-M Hiver, O. Holm, P. Hunter, D. Miller, E. Pechtold, N. Pichon, S. Poligot-Pitsch,
R. Sarghiuta, C. Thorenz, M. Tarpey, J. Wong, W. Peng

Members of the INCOM WG29

ABSTRACT: This introductory paper of the Brussels International Workshop (Oct 2009) on “Innovations in Navigation Lock Design” introduces the report 106 published by PIANC in August 2009. Main objectives and issues are highlighted in this paper. This report has been achieved by the INCOM Working Group 29 of PIANC from 2006 to 2009.

1 INTRODUCTION

Locks are key structures for the development of the navigation in canals and in natural rivers where weirs regulate water levels to enable navigation. They may also be strategic infrastructure for port development.

In lower elevation regions, such as New Orleans and the Netherlands, locks are structures in dikes and also have an important task in flood defence.

In 1986, PIANC produced a comprehensive report of 445 pages on Locks (PIANC, 1986). For about twenty years this report has been considered as a world reference guideline, but it now needs updating to include new design techniques and concepts. PIANC decided in 2006 to launch a new Working Group (WG) to update the report, and this present report is the result.. The new report must be considered more as a complement to the 1986 report than a replacement version, and focuses on new design techniques and concepts that were not reported in the former report. It covers all the aspects of the design of a lock but does not duplicate the material included in the former report. Innovations and changes that have occurred since 1986 are the main target of the present report.

The core of this report has three major parts. The first part (Section 3) presents an exhaustive list of design goals associated with locks. This section is particularly important for decision makers who have to launch a new project. The second part (Section 4) reviews the design principles that must be considered by designers. This section is

methodology oriented. The third part (Section 5) is technically oriented. All main technical aspects (hydraulics, structures, foundations, etc.) are reviewed, focussing on changes and innovations occurring since 1986. Perspectives and trends for the future are also listed. When appropriate,, recommendations are listed.

Major changes since 1986 concern maintenance and operational aspects, and more specifically how to consider these criteria as goals for the conceptual and design stages of a lock. Renovation and rehabilitation of existing locks will be an increasingly important topic for the future.

In natural rivers, locks are usually associated with movable weirs, and in coastal areas with flood protection structures. In 2006 PIANC published the InCom-WG26 report “Design of Movable Weirs and Storm Surge Barriers” (PIANC 2006). That report can be considered as a companion report to the present report as locks and weirs have many design aspects in common. Some design aspects are not discussed in this report since they have already been developed in the InCom WG26 report on weirs (for instance: multi-criteria assessment for comparison of design alternatives, ...).

Section 2 of this report also includes more than 50 project reviews of existing (or lock projects under development) which describe the projects and their innovative aspects. Some purely innovative and untested concepts are also mentioned as references although with no guarantee of validity.

2 AIMS OF THE INCOM-WG29 AND TERMS OF REFERENCE

The objectives of the InCom-WG29 have been defined by the Terms of Reference (ToR) proposed by the Inland Navigation Commission (InCom) and approved by the PIANC Executive Committee (ExCom) in late 2005. These PIANC committees required establishing a comprehensive review of modern technologies and research results used to design and build navigation locks. A clear commitment was that only concepts and technologies not discussed in the previous PIANC 1986 report were to be considered and reported in this new report.

So, topics investigated here include:

- a) Design objectives and optimization goals for locks
- b) Innovative lock design concepts
- c) Innovative technical solutions.

Recent lock projects of interest are listed, reviewed and analyzed. Detailed **Project Reviews** are provided on the DVD attached to the report.

Recommendations for studies needed at the conceptual and design stages of a lock are established.

In addition, maintenance and operational requirements are discussed and listed.

A relevant **reference list** has been prepared. Documents were analysed and compared by the WG to give engineers, designers and authorities a reference list allowing them to access relevant information to solve their problems.

To assist continuity and to avoid duplication of existing PIANC material the former 1986 PIANC Report on Locks is included on the attached DVD (Directory A3). In addition, its Table of Contents is given in Annex I of the present document. These should be used as support to this report and as a baseline of standard practice.

3 WG29's DVD

Due to publishing constraints the number of pages of the InCom-WG29's hardcopy report was limited. Therefore additional information has been saved on a companion DVD (attached to this PIANC hardcopy report). Care should always be taken to use the current versions of standards and other publications that might supersede the versions on the DVD.

This DVD includes the following directories:

- A1: The Project Reviews of 56 lock projects.
- A2: PIANC'2009 Lock Report (pdf)
- A3: PIANC'1986 Lock Report (pdf) – in French and English
- A4: PIANC Dictionary on Locks & Waterways
- A5: LIST of LOCKS (Worldwide list)

- Additional information to various sections of this report (Directories B) such as:
 - o B4.6.1: Salt Water Intrusion
 - o B4.6.5: 3D Video Modelling of Construction Process
 - o B5.2: Hydraulic (Manoeuvring, Fendering, ...)
 - o B5.5: Gates and Valves
 - o B5.7: Lock Equipment
 - o B5.8.5: Lubricants and Bio Oils

- Various technical guidelines (Directories C) :
 - o C1- Estoril'2006 - PIANC Congress Papers
 - o C2- Beijing'2008 - AGA-2008 Papers.
 - o C3- Navigation Lock - Ecluse de Navigation (by N.M Dehousse, 1985) in French
 - o C4- Corps of Engineering, USA - Reports on Innovation
 - o C5- Chinese Codes
 - o C6- French Guidelines - Lubaqua (CETMEF)
 - o C7- Fish Passage In Lock
 - o C8- Corrosion Protection
 - o C9- Planning of Lock Maintenance (example)
 - o C10- European Code For Inland Waterways (CEVNI)
 - o C11- Ship Impact
 - o C12- Seismic Impact of Lock Gates
 - o C13- ISPS Code 2003 - IMO (Safety and Security of Ship and Port)
 - o C14- Panama Third Lock Lane
 - o C15- Seine Nord Europe Canal (France)
 - o C16- Three Gorges Locks, China
 - o C17- Specifications for Lock Design (Lanaye Lock, Belgium)

- Sponsor Company's References (Directory D):
 - o Bureau GREISCH (B)
 - o IMDC (B)
 - o TECHNUM (B)
 - o Planning and Design Institute for Water Transportation (PDI), China
 - o Guanxi Xijiang Navigation Construction Co. Ltd. (China)
 - o Compagnie Nationale du Rhône (CNR, France)
 - o Grontmij / BGS Ingenieurgesellschaft mbH (D)
 - o Delta Marine Consultants (NL)
 - o Rijkswaterstaat (NL)
 - o ISPH (Romania)
 - o IDOM (Spain)
 - o Ben C. Gerwick, Inc. (USA)

- InCom WG29 meeting pictures, (Directory E)

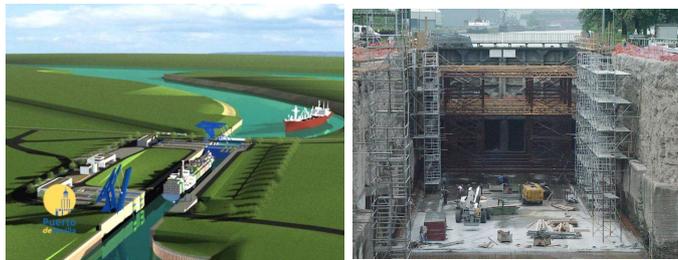
Paper 2 - Project Reviews

E.E.M. Pechtold

Rijkswaterstaat, Ministry of Transport, Public Works and Water Management, The Netherlands

1 INTRODUCTION

An important feature of Report 106 is the availability of many detailed project reviews in which the practical use of innovations is presented.



Representative samples of each lock type included in this document are summarized in chapter 2 of the report. Case studies (57 in total!) of each of these locks are included on the attached WG 106-CD-Rom (Directory A1).

The case studies include a more complete description of the locks, foundations, gate types, hydraulic systems, construction methods and, where available, cost. Photographs and selected engineering drawings are also presented for many of the locks.



Each project was reviewed and the innovative features applied to that project are described.



These innovative features were ranked into five general classifications. Those innovations and their classifications are shown in Table 2.1 in the report.

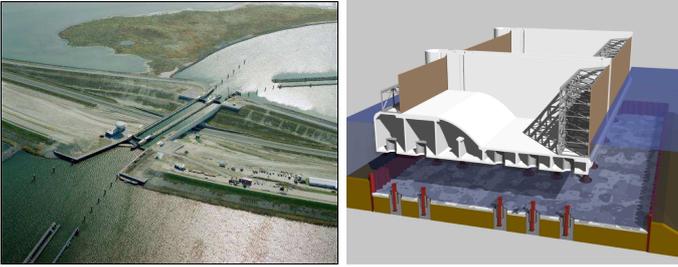
		Hydraulics		O & M		
Project Reviews		Filling and Emptying Systems	Water Management (Water Saving Basins)	Energy Management	Life Cycle Cost	Maintenance
1	1-01 Kallø Sea Lock					PT
2	1-03 Self-Propelled Floating Lock					
3	1-04 High-Rise Navigation Lock	AC				
4	1-05 Van Cauwelaert Lock					
5	2-01 Tucuruí Lock		PT			

Figure 1. Layout of table 2.1 in the report

2. LOCK INNOVATIONS

The selected project reviews included are not meant to cover all different aspects, but representative for the innovations currently in use or in the phase of research or design.

Members of WG 106 selected projects for which they or their associates have experience in the lock design or construction. Many of the projects fall under multiple categories in their areas of innovation.



In order to show what these areas are in a systematic way, five major categories and appropriate subcategories were created as follows:

1. Hydraulics
2. Operation and Maintenance
3. Environmental
4. Design / Construction
5. Miscellaneous



Each project summary includes a table to allow a comparison of innovations by project. The innovations were categorized to indicate the status of the innovations. The following definitions were used.

A **PROVEN INNOVATION** is one which has been researched, designed and constructed. It is been in service for a number of years and has possibly been constructed at multiple locations.

An **UNPROVEN CONCEPT** is one that has been recently constructed and as such the viability of the concept has not been validated by time and sufficient use for potential shortcomings or needed modifications to become apparent.

A **NEW CONCEPT** is a concept that has been validated by a client and is in design. Construction is currently scheduled or will be as funding becomes available.

An **ADVANCED CONCEPT** is one that is currently in research. A prototype may have been built to establish proof of the concept but it has not yet been accepted for construction or for regular operations.



Because each review may represent multiple innovations the project reviews have not been categorized by innovation. They are organized alphabetically by country.

Short summaries of each project review are included in Section 2.3 of the report. Detailed reviews and contact information for each project are included on the WG 106-CD-Rom.



Paper 3 - Navigation Locks: Developments in Design Objectives and Methods

P. Hunter
(HR Wallingford, U.K)

ABSTRACT: This abstract reviews the main changes given in the new PIANC Report No.106 regarding the objectives dominating the planning and design of navigation locks that have developed since the 1986 PIANC Report on locks.

1 INTRODUCTION

The comprehensive 1986 PIANC report on Locks (PIANC, 1986) provides a mass of detailed data and recommendations for the planning and design of locks. Since then there have been many developments in design methods, concepts and materials, and even more importantly there have been various changes in the priorities and objectives of the design process. The new PIANC report (PIANC, 2009) covers the new techniques without attempting to duplicate the material included in the former report. This paper focuses on new areas of design objectives that have become more important since 1986.

2 GENERAL PROJECT OBJECTIVES

The objectives and priorities of planning and design vary depending on the viewpoint of the assessor, but they can usually be grouped into financial, economic and environmental categories. Safety is a theme running through all these categories. They all require detailed evaluation to allow logical decisions when selecting optimum solutions or deciding whether to proceed with a proposed project.

2.1 *Economic and Financial Objectives*

There can be more than one reason for constructing a new lock or waterway. It might be to reduce maintenance costs, or to allow larger ships to reduce overall transport costs and to increase capacity of a canal. Alternatively a waterway project may be justified because it brings increased economic activity in the form of tourism and leisure,

both on the waterway and in the surrounding waterfront land areas.

Financial objectives depend on the type of developer. While a public sector developer might not need to raise revenue directly from users, a private sector project such as a marina may require revenues from users to fund the project directly.

2.2 *Environmental Objectives*

This issue has become of overriding importance since the 1986 PIANC report, and often governs the decision whether a project should go ahead. Local and regional environmental impacts of all aspects of construction and operation now have to be evaluated, to assess whether the project complies with statutory requirements.

2.3 *Priorities*

The design approach can have four different priorities:

- Design for lowest initial (construction) cost
- Design for minimum maintenance.
- Lowest whole life cost, which is a logical combination of the two previous approaches
- Best performance (fastest operation, least down-time).

The selection of priorities depends on the objectives of the owner/developer of a project.

3 MAIN DESIGN OBJECTIVES

The following are the main design objectives for lock design, and many of these were relatively low priority at the time of the previous report (*PIANC, 1986, numbered as in that report*)

3.2 *Reliability and proven technology*

3.3 *Reliable lock operations*

- 3.4 *Life Cycle Management*
- 3.5 *Lock navigation cycle*
- 3.6 *Water motions inducing ship displacement and mooring forces*
- 3.7 *Water resource problems:*
 - *Water shortage*
 - *Saltwater intrusion*
- 3.8 *Minimizing energy use*
- 3.9 *Environmental impacts*
- 3.10 *Minimizing impacts of construction*
- 3.11 *Security and Safety*

Of course the first of these conflicts with the use of innovation, and a major reason for adopting innovative concepts and materials is to achieve improved performance or reduced costs.

4 LIFE CYCLE MANAGEMENT (LCM)

LCM is a management approach to infrastructure construction to achieve optimum quality and minimum Whole Life Cost (WLC). For locks, a reduced WLC should imply optimum levels of reliability (which must be determined specifically

for each project), and more efficient maintenance. This does not mean less inspection and survey or less maintenance.

5 SAFETY

Safety has become another increasingly important aspect of design for locks. As well as highlighting many areas of design that can lead to increased safety (e.g. mooring, lighting, signs, channel design and gate protection), the report (PIANC, 2009) also provides a classification of different types of water edge structure and gives guidelines for suitable safety treatment for each type. This is shown in Table 1 below.

REFERENCES

- PIANC, 1986, Final Report of the International Commission for the Study of Locks, PIANC, Brussels.
- PIANC, 2009, Report No.106, Innovations in Navigation Lock Design, PIANC, Brussels.

Description	Typical Treatment
Class 1 <ul style="list-style-type: none"> • Water less than 0.5 m depth, providing ornamental function • Solid well-defined edge, e.g. coping stone • Minimal height above water. The edge may be stepped, allowing a gradual approach to the water • Site unlikely to be accessible to young unaccompanied children 	<ul style="list-style-type: none"> • No balustrade, lifebuoy, ladder or warning sign
Class 2 <ul style="list-style-type: none"> • Water depth between about 0.5 m and 1.5 m • Solid well-defined edge not more than about 2 m above the water • Presence of people, walking or seated • Site unlikely to be accessible to young unaccompanied children 	<ul style="list-style-type: none"> • Post-and-chain balustrades at least 1m high • Exit routes from water; fixed ladders or sloping or stepped waterfront structures
Class 3 <ul style="list-style-type: none"> • Water more than about 1.5 m deep • Solid well-defined edge not more than about 2 m above the water • Unlikely to be near dwellings, bridges, weirs or locks • Site unlikely to be accessible to young unaccompanied children 	<ul style="list-style-type: none"> • Post-and-chain handrails • Grab chains on wall • Wall ladders • Lifebuoys • Warning signs (“Danger Deep Water” and “No Swimming”)
Class 4 <ul style="list-style-type: none"> • Water more than about 1.5 m deep plus one or more additional hazards as below • More than 2 m above water • Fast-flowing water • Presence of vulnerable groups such as children • Presence of dwellings, schools etc 	<ul style="list-style-type: none"> • Exclusion of general public and/or the following - • Vertical-rail balustrades at least 1.1 m high (or similar alternatives, without horizontal footholds, that are difficult to climb) • Hazard warning signs (“Danger Deep Water” and “No Swimming”) • Ladders, lifebuoys, grab chains unless water conditions make these impractical (noting that “exclusion” can also prevent easy access by would-be rescuers)

Table 1 - Safety features classification (proposed by PIANC WG 106)

Paper 4 - Seine Nord Europe canal – Hydraulic design of locks

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ABSTRACT: hydraulic operation of a lock with separate water-saving basins and introduction of water through the chamber bottom, adopted as the reference solution during the preliminary design studies of the Seine Nord Europe Canal, has been studied using numerical and physical models.

These studies were used to size the chamber water supply system and define the most suitable design for the gate chamber controlling flows between the water-saving basins and the lock chamber.

The 1:25 scale model built for the lock with the largest drop height (30m) enabled the numerical simulation results to be validated and fine-tuned, and certain operating parameters to be optimised.

1 INTRODUCTION

The Seine Nord Europe canal will operate by recycling lockage water. Recycling is planned for all locks, in other words the lock in the Oise valley, with a drop height of just 6.4 m, and the six locks with large drop heights (19.6 m, 15.5 m, 30 m, 22.5 m, 20 m and 25 m) between Noyon and the Dunkirk-Scheldt canal.

In order to limit discharges and thus the pumping costs at the locks, the locks with large drop heights are fitted with "water-saving basins". The advantage of these basins, situated on the sides of the lock chambers (integrated into the side walls or built as separate structures) is that they recover part of the lockage water for a descending boat (going from the upstream reach to the downstream reach) and restore it at the following lockage for an ascending boat (from the downstream reach to the upstream reach).

2 SCALE-MODEL STUDY

A 1:25 scale model was built in order to study the following aspects of operation of a lock, which has a drop height of 30 m:

- the total filling and emptying times
- the change in water level and longitudinal slope of the chamber water surface during filling and emptying

- water-saving basin filling and emptying procedures
- the lockage wave in the downstream reach
- forces on boat moorings during filling and emptying operations, for different boat types: boats 110 m long with a 3 m draught, 85 m long with a 2.5 m draught, and 10 m long (pleasure boats).

The model operates with Froude similitude conditions, with a time ($\lambda=1/25$) and velocity scale of $\lambda^{0.5}=1/5$ and a flow rate scale of $\lambda^{2.5}=1/3125$.



Figure 1. General view of the scale model.

Levels are measured continuously at a high frequency at 6 points in the lock chamber and upstream and downstream reaches, as well as in a

water-saving basin. Forces are measured simultaneously on the two mooring lines of one of the boats.

2.1 Results obtained in normal operation

The filling time is of the order of 13 min to 13 min 30 sec and the emptying time is of the order of 13 min 15 s to 14 min.

The longitudinal slope in the lock chamber remains at 1‰ or less during filling and emptying. The slope over half of the chamber reaches values of the order of 0.8‰ during filling and 3‰ during emptying.

A wave with a maximum amplitude of 1.15 m is observed in the water-saving basins during filling. The wave is gradually damped in the basin. The period is of the order of 26 s.

In spite of the necessary streamlining of the angles of the stoplog wells, a short-duration eddy occasionally occurs at the end of emptying the water-saving basins (the existence of these stoplog wells in the basins, reserved for the stoplogs of the duct gates, and not represented during the initial tests, considerably reduced the initiation and development of this eddy phenomenon). There is a possibility that this eddy could entrain air into the distribution chamber in the case of the lowest basin.

The downstream lockage wave remains less than 0.27 m high (0.23 m on average).

The mooring lines of the 105 m boat are mainly placed under strain during chamber/water-saving basin transfers, when the amplitude of slope variations on half of the chamber is greatest. The maximum forces measured during all the tests were 5.1 tf during chamber emptying. Chamber emptying puts more strain on mooring lines, in a more jerky manner, in the case of a loaded 105 m boat. The maximum forces reached on the mooring lines of the 85 m boat remain lower (< 3 tf). The maximum forces on the boat mooring lines, loaded to produce maximum squat, are shown in the table below for the case of the 110 m boat. No significant variation in mooring line forces was observed when two boats are in the lock chamber simultaneously, regardless of their size and position upstream or downstream.

Table 1. Maximum forces acting on mooring lines

Maximum forces (tf) Emptying	
Upstream mooring line	3.76
Downstream mooring line	5.08
Maximum forces (tf) Filling	
Upstream mooring line	1.29
Downstream mooring line	1.28

2.2 Results obtained in downgraded mode

Two downgraded modes were studied for the entire duration of chamber emptying of filling:

- failure of the lower water-saving basin to operate during chamber filling or emptying (shut-down for maintenance, failure of the gates to open, for example), thus doubling the load when emptying each water-saving basin and in the final stage of filling via the upstream headworks,
- only one of the two gates in the downstream headworks opens during chamber emptying.

These downgraded operating modes do not produce any modification in the longitudinal slopes observed in comparison with normal operation.

When the lowest water-saving basin is not in service, the downstream lockage wave is 0.35 m high at the most (0.30 m on average). There is no aggravation of the lockage wave when only one downstream gate operates.

Maximum forces on the moorings are observed at the end of chamber emptying, owing to the greater disturbance (basin out of service or one downstream gate out of use) but the maximum normal operating values are rarely exceeded (a single maximum case of 6.4 tf observed with the 105 m boat).

The downgraded modes studied do not therefore aggravate conditions in the lock chamber. Only the chamber emptying wave in the event of a water-saving basin being out of service is increased owing to the fact that the peak flow rate is greater. This problem for navigation in the reach or for the safety of boats moored in the waiting area, can be solved by lengthening the end of emptying via the downstream gates.

3 OPTIMISATION OF THE HYDRAULIC SYSTEM

With the hydraulic concept studied here, there is potential for optimising the lockage durations.

For structures of identical height, a reduction in lockage duration would make it possible to improve the flow capacity of the traffic using the system, or for an identical traffic flow capacity, it would be possible to increase the maximum lift of the locks, thereby providing an opportunity to optimise the earthworks for the canal by raising the level of the watershed reach, hence reducing excess excavation.

There are two main possibilities for optimising the system:

- Optimising gate operation in the water-saving basins,
- Modifying the criterion of maximum discharge into or removal from the adjacent reaches.

The limitation on the rate at which water is discharged into or taken from the adjacent reaches is a very severe constraint on lockage time. For example, for a lock with a drop height of 30 m and 5 water-saving basins, this limitation currently means that about half the total lockage time is required to empty or fill the unsaved fraction, which represents only 2/7ths of the total volume. A more detailed study of the effects of the surge wave, its dissipation and the impact of currents on navigability may enable the intake or discharge rates authorised in the reaches to be increased and hence the lockage times to be reduced.

The exploratory calculations carried out show a potential gain by increasing the flow rate from 72 m³/s to 108 m³/s (maximum velocity in the running section of the reaches increasing from 0.35 m/s to 0.55 m/s). The time required for the last stage of emptying would thus drop from 370 s to 310 s. The maximum velocities in the water ducts would also drop from 4 m/s to 6 m/s, which remains low in comparison with the permissible velocities currently adopted in the USA and China, for example (10 m/s and over).

It may be possible to reduce even further or even remove the requirement concerning the flow rate for filling or emptying the first or last layer of water by creating additional basins that would temporarily store some or all of the quantities not saved at present (2/7ths of the chamber for a lock with a 30 m lift). The manner in which these communicate with the adjacent reaches would be designed in such a way as to stagger the flow taken from or discharged into the canal (by spreading and lowering the peak flow rate).

Paper 5, part A - Innovations in Lock Filling and Emptying Systems

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ABSTRACT: Hydraulic systems for filling and emptying locks can be divided into two main types. One is the filling and emptying “through the heads”; and the other is the “through longitudinal culverts” system. Within these filling and emptying systems, the “In Chamber Longitudinal Culvert System” (ILCS) and “Pressure Chamber under the Floor System” are new types developed after 1986. In recent years some locks in Germany have been equipped with a filling system which uses a pressure chamber beneath the floor. This type of filling system has proven to be very efficient especially in combination with water saving basins. In general the ILCS system could be used for intermediate lift locks. Under specific conditions, such as in rock, a large saving in lock wall construction costs could be realized if the lock filling and emptying culverts were located inside the lock chamber rather than within the lock walls. This paper and the accompanying presentation review these systems, previous implementations, guidelines for the selection of a system, utilization in combination with other methods such as water saving basins, and optimization of the systems.

1 TYPES OF HYDRAULIC SYSTEMS

The hydraulic systems for filling and emptying locks can be divided into two main types. One is the filling and emptying “through the heads”; and the other is the “through longitudinal culverts” system.

1.1 *Through the Heads Systems*

The use of the “through the heads” systems may induce potentially dangerous currents and considerable waves in the lock during filling and emptying.

To avoid these problems, several measures are possible: the lock can be operated with a very slow valve schedule, the lock can be equipped with an energy dissipation system to reduce the current and waves, or the lock can be monitored continuously to avoid safety hazards, so that a lock keeper can bypass the automated filling/emptying mode under certain conditions.

1.2 *Through Longitudinal Culverts Systems*

“Through longitudinal culvert” systems are a more sophisticated method of filling compared to the methods described above. The “longitudinal culvert” systems can be subdivided into two categories according to the way the water goes into the lock chamber.

Systems with asymmetric distribution of flow along the length of lock chamber include wall culvert side port systems, In Chamber Longitudinal Culvert Systems (ILCS), wall culvert bottom lateral systems, wall culvert bottom longitudinal systems, and longitudinal culverts under the lock floor.

Systems with symmetric distribution of flow along the length of lock chamber include dynamically balanced lock filling systems and pressure chamber systems.

2 NEW HYDRAULIC SYSTEM CONCEPTS

Within the filling and emptying systems mentioned the “In Chamber Longitudinal Culvert System” and “Pressure Chamber under the Floor System” are new types developed after 1986. The PIANC, 2009 Report (PIANC, 2009) addresses these new concepts.

2.1 *Pressure Chamber System*

In recent years some locks in Germany have been equipped with a filling system which uses pressure chambers beneath the floors. This type of filling system has proven to be very efficient, especially in combination with water saving basins.

The pressure chamber is connected to the main chamber through arrays of nozzles. This type of filling system results in a very smooth filling of the

chamber even for high lifts, combined with a short filling time. Additionally water saving basins can easily be attached to the pressure chamber, so that a smooth operation is possible for filling and emptying through the culverts and the saving basins.

2.2 In-Chamber Longitudinal Culvert System

The design philosophy for the ILCS was to develop a system that performed almost as efficiently as the side-port filling and emptying system. In recent years the investigations of the ILCS were carried out in the United States (Hite J, 2003). In general the ILCS system could be used for intermediate lift locks, but it has been used in USA for low lift. With the ILCS the culverts are taken out of the wall and moved to the floor of the chamber, which allows for alternative lock wall construction such as RCC or in-the-wet construction.

Under specific conditions, such as in rock, a large saving in lock wall construction costs could be realized if the lock filling and emptying culverts were located inside the lock chamber rather than within the lock walls.

2.3 Guidelines for the Selection of the Hydraulic System and its Layout

In the selection of a filling and emptying system, the following factors should be taken into consideration: lift height, time for filling or emptying the lock, lock chamber sizes, permissible investments for the lock, and maximal forces on the vessel.

The following principles should be used in selecting a filling and emptying system: the filling time should be as short as possible (based on the specified capacity and construction costs), water movement and turbulence in the chamber must be limited, the forces on the vessels and thus in the hawsers must not exceed established criteria, entrapment of large air bubbles in the filling system must be avoided, cavitation should be avoided if economically possible or adequate protective measures must be taken, and currents in lock approaches should be reduced to a minimum so that there will be no adverse effect on vessels waiting to lock or maneuvering in the approaches.

There are several ways to select the hydraulic system. Generally, the admissible forces on the vessel and the filling time govern the choice of the system. As these parameters are difficult to assess during initial design phase, simple approaches are often used. Two will be discussed here.

As a general guideline, it is important to maintain the symmetry of the filling system with respect to the water surface if filling times are to be minimized without creating excessive ship forces.

The traditional way to achieve this is based on the lock lift height (H). As discussed in the PIANC’86 Report (PIANC, 1986), locks can be classified according to the lift height as follows: low lift height ($H < 10\text{m}$), intermediate lift ($10\text{m} < H < 15\text{m}$), and high lift height ($H > 15\text{m}$). It must be pointed out that this classification was derived for inland waterway navigation and is not valid for seagoing vessels and sea locks.

For “low lift locks” a through the heads system or simple longitudinal culvert system can be used. Note that a short culvert system may require advanced energy dissipation chamber if a short filling time is a requirement. In any case, the filling process is not balanced along the chamber length.

For “intermediate lift locks” wall culvert side port systems and simple longitudinal culvert systems may be suitable. Here, the filling process is a better balanced along the chamber length. We can mention in this category: wall culvert side port systems, and longitudinal culverts under the floor with side or top outlets.

“High lift locks” require a more complex culvert system. It is necessary that the filling process is as symmetric in relation to the chamber as possible.

A second selection approach is based on the M coefficient (Eq. 1), as proposed by the (Chinese Code, 2002) for filling and emptying system of ship locks.

$$M = T/H^{1/2} \quad (\text{Eq. 1})$$

Where, $H(\text{m})$ is the lift height of lock and $T(\text{min})$ the time to fill the chamber. The value of M could be used to choose the relevant types of the hydraulic system. These values have to be based on reference values based on allowable ship forces during the locking process.

In the first approach, the lock **lift height** (H) is the only factor involved in the selection of the filling and emptying system. In the second approach, the use of the M coefficient allows considering both the **lift height** (H) and the **locking time** (T) simultaneously. The **admissible ship forces** must be regarded separately and will influence the decision process. Therefore, for seagoing vessels, the coefficient M must be considered differently.

Finally it should be noted that these approaches can be a helpful estimate if enough experience is available. These guidelines are not one-size-fits-all

approaches, as neither the admissible ship forces nor the chamber dimensions are regarded directly. Another key parameter for the selection of the relevant hydraulic system is the **flow variation** (“how fast is the flow velocity changing during the locking”). Such variations tend to lead to waves in the chamber. Obviously a slow variation is better, as a faster variation requires a more complex and expensive hydraulic system or the locking times have to be increased.

If water enters only through the lock heads (short culverts or through the gates), translation waves occur in the longitudinal direction of the lock chamber and will be reflected against the ships and the opposite lock gate head.

If water-jets coming out of the lock chamber inlets act directly on the ship hull, the momentum of these jets directly produces forces on the hull, and in addition the water level in the chamber will be locally affected. This phenomenon induces unsteady longitudinal loads to the moored ships and even some transversal forces. This can be avoided if the lock chamber is deep enough and if the flow is passing below the ship hull (Fig. 1).

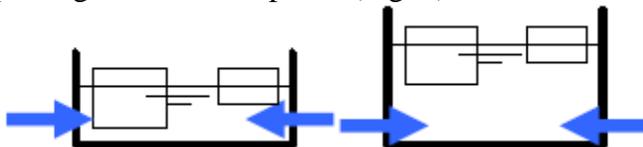


Fig. 1: Impact of the Culvert Side Port System

From the users’ point of view transverse forces can be a major problem. The main reasons for transverse forces are: asymmetric filling system / operation, asymmetric position of the vessel, and jets which directly touch the hull.

With a wall culvert side port system direct flow acting on the ship side (if the outlet ports are not deep enough beneath the vessel) can induce significant transverse forces (Fig. 1). In addition, if the culverts are not fed perfectly symmetrically to the centre of the lock (along the length of the lock), additional forces occur.

There are different practices concerning the positions of the outlet ports in the lock chamber. Practice in USA and China is to stagger the positions of the outlet ports so that the jets from one side of the lock do not directly collide with the jets from the other side. In some European countries, such as Belgium, it is usual to arrange the ports face-to-face to force the energy dissipation to occur at localised points.

If leveling is not carried out uniformly over the entire length of the lock chamber, longitudinal loads will also act on the ships. With wall culverts and even with longitudinal culverts, the discharge is not uniformly distributed along the lock length. Uniform distribution can be enhanced by using bigger culverts and even more by using symmetric systems like the dynamically balanced lock filling systems or a pressure chamber system. The dimensioning of the culverts is additionally influenced by the need to limit cavitation and wear in the culverts. In many countries, limitations on the average flow speed in the culverts are used for this purpose (12m/s in China and 6-10m/s in Europe). It should be pointed out, that the flow speed is not a sufficient criterion, as cavitation is largely influence by the pressure field and the shape of the hydraulic system.

For locks with a deep and perforated bottom, flow enters in the chamber vertically by small holes in the floor. If there is a great volume of water under the perforated floor and a great number of holes distributed regularly in the surface of the floor, water is transferred uniformly by the bottom of the lock chamber into or out of the lock chamber. With this kind of system, only very small waves are generated even if the rate of flow strongly varies during the locking. Then, the moored ships are not heavily loaded in the longitudinal and transverse directions.

Thus, the choice of the lock hydraulic system depends not only on the lift height (H), the time of locking, the presence of WSBs, the lock dimensions and the available budget, but also on the variation of the discharge (translation waves in the lock chamber and in the adjacent reaches) and the allowable forces on the mooring cables of vessels.

3 WATER SAVNG CONCEPTS

3.1 Determination of Saving Needs and Selection of the Water Saving System

The water saving needs are defined during the studies of water resources management, taking into account the assumed traffic, evaporation, infiltration, canal water tightness and climate changes. From these studies the expected water consumption of the lock itself is assessed.

The global water saving system of the lock is a combination or choice of different systems: pumping, WSBs, intermediate gate inside the chamber, twin synchronized locks, and lock ladders.

In order to select the best option, these various systems/devices have to be designed and optimized

simultaneously by a technical and economic assessment in relation to the existing lift height and the energy cost. The main choice criteria are: construction cost, operating cost, energy saving and environmental cost, filling time and traffic, available space, and the influence on water level in the upper and lower reaches.

The intermediate gate, twin lock or lock ladder can lead to considerable water saving. Nevertheless they can be very expensive and are the best solutions only in specific cases. Twin synchronized locks can be accepted only if they are economically justified by the traffic, and an intermediate gate may be a good solution if a significant number of lockages are to be made with small boats. The shortcoming of a lock ladder instead of a single lock is to increase the number of gates and ship operations (mooring, etc.), therefore the traffic capacity is lower.

The water saving basin solution has some shortcomings too: high initial investment (compared to pumping station), more complex structure, numerous gates and a slightly longer filling /emptying time.

Nevertheless, because of reasons of life cycle cost, energy saving and environmental cost, this solution will be probably the best one where the need for water saving is permanent and larger than a minimum value (specific to each case).

Due to the uncertainties linked to traffic evolution and energy cost a possibility is to build the lock first without WSB but with pre-connection for future WSBs to be eventually built in the future.

3.2 Water Saving Basins (WSBs)

Recent examples of locks with saving basins are described in project reviews.

In the Panama 3rd lane project, a triple lift lock has been designed combined with 9 saving basins (3 basins for each lock chamber) allowing a very high saving rate (87%) when compared to a single lift lock without WSBs .

A lock with WSBs better fits to a filling/emptying system with longitudinal culverts and inlets on the sidewalls or even distributed through the floor because the successive openings/closures of valves induce significant discharge and therefore higher risk of disturbance of the water level on the lock chamber (balancing waves along the lock chamber).

Division into symmetrical half saving-basins to facilitate the maintenance and reduce the impact in case of problem (closure of ½ basin versus 1 basin). That may be a useful solution if a short filling time

is required. In this case, half basins can be placed symmetrically on both sides of the lock.

It is better to have multiple culverts between a basin and the chamber for reliability reasons and to avoid a high degradation of performance during the maintenance of a valve or a culvert. With multiple culverts per basin the water distribution along the axis can be enhanced and thus faster filling can be achieved (for a higher building cost).

The choice of the hydraulic filling system must be done considering the real water lift height between 2 basins. However, when the use of WSBs is economically relevant, that also means that the lock lift height is rather important and that a reduced filling time is expected. This is why an advanced and performing hydraulic system (longitudinal culverts) is generally needed (no matter what the value of the M coefficient).

The M equation (1) must be evaluated differently for locks with WSBs, because the hydraulic situation is not exactly the same than without WSB. It is necessary to consider the lift height and the filling time of each single WSB (and the residual filling) separately to achieve a multitude of M values. Then, the smallest M value governs the choice of the hydraulic system.

3.3 High Rise Navigation Lock Using WSBs

Traditionally the maximum lift height of a lock is considered as being limited at 25, 30 or 40 m due to hydraulic aspects, mainly cavitation. If WSBs are used there is no limit for the lock height. Locks of 100 or 150 m height can be considered if the filling and emptying of each WSB is studied to avoid cavitation. This means that cavitation limits the height of the saving basins but not their number and therefore the total lift height of a lock (Dehousse 1985, Dehousse et al., 1989 and 1993). For instance a lock of 100m lift height with 6 water saving basins is similar for cavitation and hydraulic aspects to a series of four locks of 25m lift height.

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Paper 5, part B - Innovations in Traditional Filling and Emptying Systems

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ABSTRACT: Energy dissipation is a major problem in filling and emptying systems. For a specific filling and emptying system, you can raise the hydraulic efficiency of the system (or shorten the filling time) by optimizing the energy dissipation measures. Some examples are introduced here.

1 INTRODUCTION

The objectives to choose a proper filling and emptying system are to get a proper filling/emptying time (not as short as possible) and to get a lower cost with the proper filling time.

In general the simpler the filling and emptying system is, the lower the lock cost as shown in table 1.

Table 1: Complexity categories of hydraulic systems

Complexity	Hydraulic systems	Lock cost
1. Simple systems	<ul style="list-style-type: none"> - Through the head system - Wall culvert side port system - In Chamber longitudinal culvert system (ILCS) 	Low
2. More complex systems	<ul style="list-style-type: none"> - Wall culvert bottom lateral system - Longitudinal culverts under the lock floor - Wall culvert bottom longitudinal system - Longitudinal culverts under the lock floor 	Higher
3. Very complex systems	<ul style="list-style-type: none"> - Dynamically balanced lock filling system - Pressure chamber under the floor 	Highest

For a specific filling and emptying system, if you can raise the efficiency of the system (or shorten the filling time) you can make the lock cost lower (or save money).

Following are some examples to improve the efficiency of filling and emptying systems.

2 PARTIAL DISTRIBUTED SYSTEM

Through the head system is a very simple and low cost system. But it can be only used for locks with very low lift height.

Based on the principle that distributed (longitudinal culvert) filling and emptying system could improve the operation efficiency of locks, a partial distributed system could be used to raise the efficiency and reduce the cost. The short culverts of the system were extended into chamber walls with bottom lateral branch culverts (Fig.1).

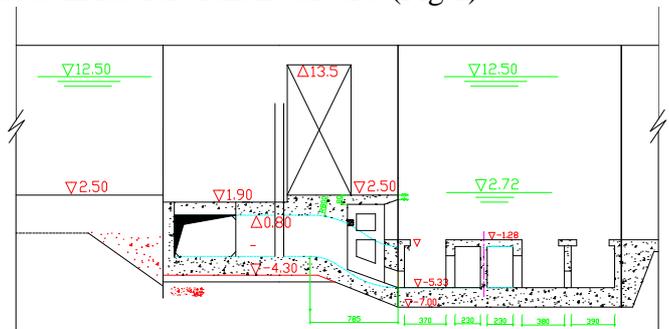


Figure 1 Partial distributed filling system

3 DOUBLE DITCHES ENERGY DISSIPATION SYSTEM

To avoid dangerous currents at the outlets of filling and emptying system, measures should be taken for energy dissipation. Double ditches are effective system for energy dissipation. Figure 2 shows the double ditches used in bottom lateral system and Figure 3 used in In-chamber Longitudinal Culvert System (ILCS). Compared with one ditch system the filling time was shortened.

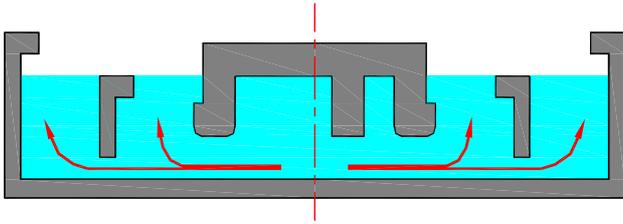


Figure 2 Double ditches used in bottom lateral system

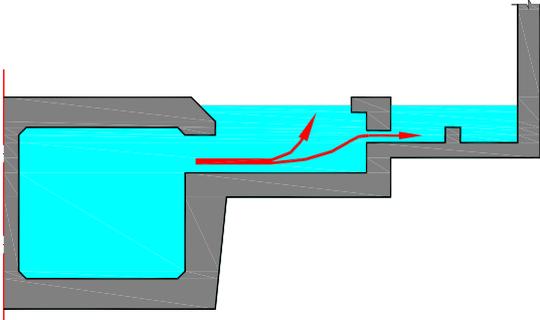


Figure 3 Double ditches used in ILCS system

4 ENERGY DISSIPATION FOR SIDE PORT SYSTEM

For side port system enough submergence is required to prevent direct action of the port jets against the bottom of the vessel. But in many cases a little more submergence will lead to much cost.

Tests have shown that if port deflectors was arranged in chamber (Figure 4) the jet into the chamber was spread by the deflectors evenly and the hydraulic condition was improved. So the minimum submergence could be reduced.

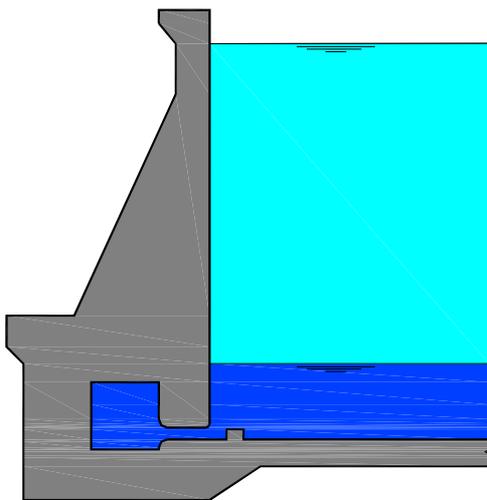


Figure 4 Side Port System with Port Deflectors

Figure 5 and figure 6 are results of numerical tests of port jet without and with deflectors.

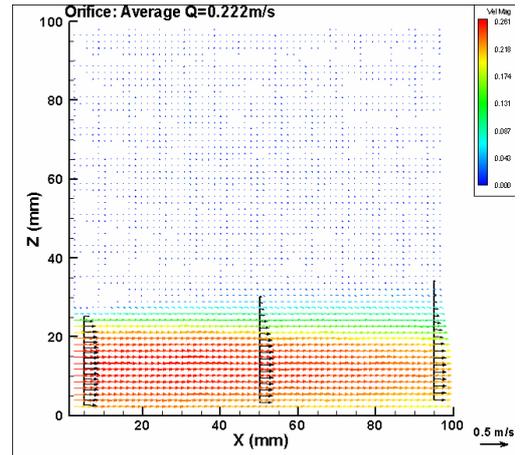


Figure 5 Flow Distribution without Deflectors

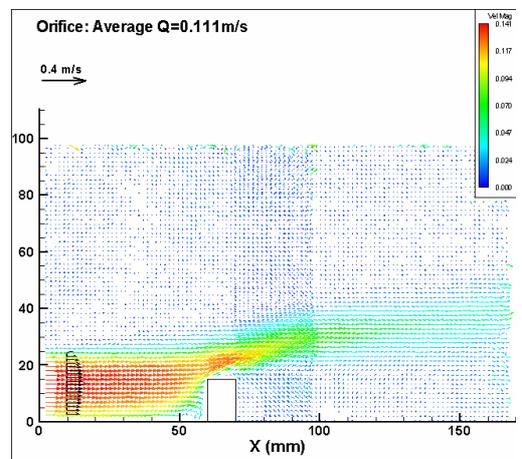


Figure 6 Flow Distribution with Deflectors

The height of the deflectors and the distance between the deflectors and the port should be decided carefully.

Paper 6 - The Panama Canal’s Third Set of Locks Project

Juan Wong H.

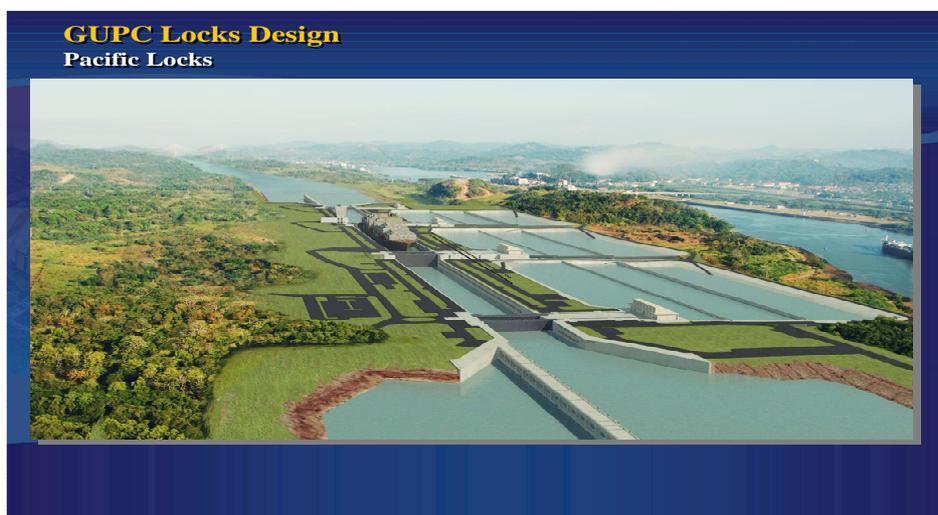
Panama Canal Authority, Panama, Republic of Panama

ABSTRACT: One of the world’s greatest engineering achievements, the Panama Canal plays a vital role in world shipping. But even though at the time of their construction the dimensions of the existing locks set the standard that defined the ‘Panamax’ size container ships and bulk carriers, today’s locks are nearing their maximum throughput capacity in spite of all the infrastructure improvements of past decades. To accommodate growing traffic demand, particularly by containerships in the route between Northeast Asia and ports on the US East Coast, and also to accommodate post-Panamax ships, the Panama Canal has started executing its ambitious expansion plan, which is scheduled for completion by 2014.

The Panama Canal conducted more than 120 studies that were analyzed and integrated into the decision making process to select the most suitable, efficient, effective alternatives that would enable the optimization of the Third Set of Locks Project. The studies for the Panama Canal Capacity Expansion Program are described in full in the Panama Canal Master Plan 2005-2025 and in the Proposal for the Canal Expansion approved on October 22, 2006 through national referendum. The Master Plan and summaries of many of the relevant studies can be found at <http://www.pancanal.com/eng/plan/index.html>.

The Panama Canal Expansion Program involves six main projects, mainly: 1) the construction of two set of locks at the Atlantic and Pacific ends of the Canal; 2) the dry excavation of an access channel connecting the Gaillard (Culebra) Cut to the new Pacific locks; 3) dredging of the existing navigational channels of the Atlantic Ocean entrance; 4) dredging of the existing navigational channels Pacific Ocean entrance, 5) dredging the Gatun Lake and Gaillard Cut fresh water navigational channels; and 6) raising the level of Gatun lake by 45 cm through modifications to existing land based infrastructure. Overall the activities of the Expansion Program will span over the 80 kilometers of the Panama Canal.

One set of locks will raise/lower vessels on the Atlantic end of the Canal, east of the existing Gatun Locks, and the other set of locks will raise/lower vessels on the Pacific end, southwest of the existing Miraflores Locks. Each facility will be comprised of three consecutive lock chambers, which will use gravity to lift the vessels from one ocean to an average height of 26 meters at lake level and lower them back to ocean level on the opposite end. Each chamber will be accompanied by three lateral water-saving basins for a total of nine water-saving basins per lock. Each lock chamber will be 427 m to 458 m long, 55 m wide and 18.3 m deep as a minimum, to allow the transit of vessels up to 49 meters in beam, and overall length of up to 366 meters and a draft up to 15.2 meters in tropical fresh water, which corresponds to a 12,000 TEU nominal capacity containership loaded with 19 container rows across deck.



Paper 7 - Mooring forces and ship behaviour in navigation locks

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ABSTRACT: This contribution reflects upon the issue of mooring line forces and ship behaviour during filling/emptying of inland and maritime navigation locks. The philosophy behind the so-called hawser force criterion and the classical approach to deal with it in design studies, is described first. Secondly, some innovations in the definition, verification and validation of the design criteria are highlighted.

1 INTRODUCTION

The hydraulic design of a lock filling/emptying system aims at (among other issues) minimization of the filling/emptying time, constrained by the so-called hawser force criterion. The latter criterion is meant to guarantee a certain degree of safety and comfort to a moored vessel during lockage.

2 HAWSER FORCE CRITERION

2.1 Philosophy

The hawser force criterion attempts to quantify the necessary limitation of ‘turbulence’ (in the wide sense) generated by the lock filling/emptying, in order to limit the displacement of the vessel and the associated forces in the vessel-positioning system (e.g. mooring lines). Notice that the water flow, the lock (chamber and filling/emptying system), the vessel and its positioning system mutually interact, see Figure 1.

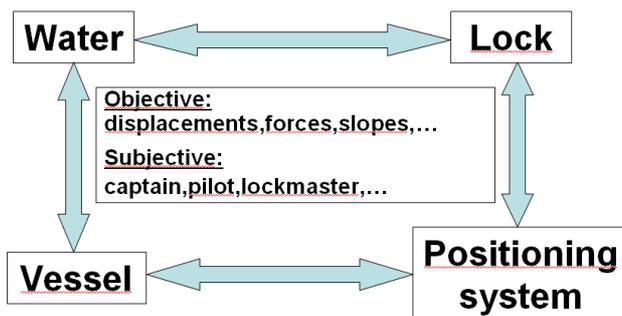


Figure 1. Constituting elements of a hawser force criterion

2.2 Criterion

The appreciation of safety and comfort during a lockage contains both objective (e.g. forces on the vessel, forces in the mooring lines, slope of the water surface, slope of the vessel, displacement of the vessel) and subjective elements (e.g. feeling of the captain, pilot, lockmaster).

The hawser force criterion sets an upper bound (i.e. a threshold) to an objective element (i.e. definition of the criterion). To assess whether a given filling/emptying system meets the defined criterion, a verification tool should be available. In order to assess that the adopted definition and its associated verification tool lead to both safe and comfortable as well as economic lockages, validation efforts should be carried out.

2.3 Classical approach

The ‘classical’ approach consists of a hawser force criterion being defined in terms of the hydrodynamic force on the vessel. This force should not exceed a given threshold value, expressed in absolute terms or in relative terms (as a fraction of the vessel’s displacement weight).

A scale model is used as a verification tool. To avoid a complicated measurement set-up, no attempt is (usually) made to represent the real vessel-positioning system (consisting of e.g. mooring lines, winches, bollards) in the scale model.

Note that the selected definition and verification tool of the classical approach on purpose aim at methodological simplicity.

Validation is mainly restricted to gathering (in an often unsystematic way and often triggered by incidents) feedback from the authorized personnel, once the lock is operational.

2.4 Innovations

Several innovations can be distinguished in ‘modern’ design studies, see PIANC (2009). Some of these will be briefly presented in this section (and in section 3). The overview is inevitably biased by the specific working experience of the author and does not aim at completeness.

2.4.1 Definition of threshold values according to vessel-positioning system characteristics

Originally, the threshold value for the hydrodynamic force of a vessel used to be specified as a (often country-specific) constant (depending somewhat on the vessel size). Later on, it was attempted to define the threshold as a function of the characteristics of the vessel-positioning system.

Focusing on inland navigation, Partensky (1986) and Vrijburcht (1994) developed a methodology to account for the mooring line characteristics. Dynamic effects are accounted for by considering the ship and its mooring lines as an (idealized) mass-spring system, for which the relation between a given external force F and the (maximum) reaction force R in the spring is known (by means of a so called dynamic magnification factor which represents the ratio R/F). Application of this methodology resulted in differentiated threshold values by Rijkswaterstaat (2000) for filling operations of inland navigation locks with fixed vs. floating bollards.

The above-mentioned methodology was also explored by De Mulder (2007) during the conceptual design studies for the Third set of Panama locks (e.g. for the 12,000 TEU container design vessel). For large ocean-going vessels, however, another particular methodology was developed earlier by Vrijer (1974, 1977), accounting for mooring line and winch characteristics. The latter methodology resulted in a set of threshold values (for the hydrodynamic forces and moments), depending on line type, pre-tension in the cables and vessel size.

2.4.2 In situ measurements for validation purposes

Thanks to evolutions in measuring and data-acquisition equipment, in situ measurements of water surface slopes are feasible (albeit sometimes with a limited accuracy, especially in the transversal direction of the lock chamber). Water surface slopes are representative for the hydrostatic component of the hydrodynamic force on the vessel, which is often (but not always !) the dominant force component. Even measurements of the ship motion itself have become feasible nowadays (both during sailing in/out of the lock as well as during lockage).

Direct measurement of mooring line forces would be most interesting for gaining insight but is less practical to set-up (without perturbing the lock operations).

Based on several measurement campaigns of water surface slopes by FHR (in both maritime and inland navigation locks and with different types of filling/emptying systems) it turns out that hawser force threshold values published in literature seem to be rather conservative, i.e. the measurements show that in reality the moored vessels are subjected to larger slopes than could be expected from the published threshold values.

2.4.3 Application of numerical models as verification tools

Thanks to the enormous increase of computational power, numerical models of different types (and physical/numerical complexity) have become available to predict hydrodynamic (or hydrostatic) forces on a ship’s hull, hence as a verification tool for the hawser force criterion.

On one side of the numerical model spectrum, there are 1D or 2D models solving the shallow water equations (SWE) for the water flow in a lock in the presence of a (schematized) ship’s hull. On the other side of the spectrum, there are 3D Computational Fluid Dynamics (CFD) codes solving the Reynolds-averaged Navier-Stokes (RANS) equations in the filling/emptying system and in the lock chamber around a (realistic) ship’s hull. The latter models can optionally even account for fluid-structure interaction. It is good to know that most (if not all) CFD codes were originally developed for internal flows, hence applications which involve free surface flow still might cause some extra problems.

Whereas the SWE based models are computationally cheap and within reach of all consulting engineers, the RANS based models still require huge computational resources which are not

readily available. Moreover, they require skilled operators. The consequence is that - especially during conceptual design studies (but actually also during further design) - the number of filling/emptying scenarios and layouts that can be studied with the CFD tools is limited. Yet, CFD codes are certainly helpful in detailed design of parts of the filling/emptying system.

In general terms, it can be stated that numerical models are capable of predicting the longitudinal component of the hydrodynamic (hydrostatic) force with sufficient (engineering) accuracy (although the parametrization of the effect of direct filling jets is still a challenge), but the performance is still weak in the transversal direction.

Summarizing, numerical modeling is a valuable tool in the (conceptual) design studies. Yet, a scale model to finalize the design is still to be advocated nowadays.

3. MOORING LINE FORCES AND SHIP BEHAVIOUR

Inspired by the study of wind wave effects on a ship moored at an (off shore or port) terminal, there is a trend towards numerical modeling of the complete system, i.e. the water flow, the mooring line forces and the motion of the ship moored in a lock.

Yet, it should not be overlooked that navigation locks are characterized by shallow and confined flow effects, which are still less well known (resulting in a wide range of e.g. estimated added mass and hydrodynamic damping coefficients).

A dynamic modeling of the complete system should ideally be carried out in a fully coupled way (i.e. with one integrated computer model). Alternatively, a chain of one-way-coupled independent models can be used (e.g. one model for predicting the time history of the water flow, which is used as input for a model which predicts the time history of the ship's motion and the mooring line forces). The latter methodology has been applied by Vantorre (Ghent University) and De Mulder (FHR, 2007) during the conceptual design for the new Panama locks.

Notice that the aforementioned methodologies result in time histories of the mooring line forces and the ship motion, which allows to directly assess the degree of safety during a lockage (by comparison to the mooring line strength characteristics and to the available space in the lock chamber).

In any case, the above-mentioned modeling efforts require the specification of many input parameters, some of which are only roughly known during the design studies. Yet, it turns out that the resulting ship motion is sometimes very sensitive to the particular choice of some parameters and to the assumed mooring line (and winch) handling strategy.

4. CONCLUSIONS

Notwithstanding numerous innovations, the issue of mooring line forces and ship behaviour in navigation locks is still not fully understood. No matter how sophisticated methodologies and tools have become, more efforts should be made to carry out in situ observations and measurements, for validation purposes and (above all) to gain insight.

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Paper 8 - In-the-Wet Construction

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ABSTRACT: The in-the-wet method has been recently applied to construction of locks and dams. This innovative method demonstrates several advantages over the conventional construction method, because the prefabrication can be performed in a well-controlled environment, the quality of the construction can be better ensured with this method than with cast-in-place concrete construction. This technique can also provide greater flexibility to the construction process to adapt to varying needs of the site and the community, such as accommodation of off-season work and easy access of personnel and materials. As a result it can substantially reduce the construction time, helps to reduce adverse environmental impact and construction risks. In general, the method requires little shutdown of navigation, and can provide considerable cost saving. This paper and the accompanying presentation present these methods, their respective advantages and disadvantages in comparison with conventional methods, and case studies.

1 INTRODUCTION

In-the-wet construction techniques were first used in the offshore oil industry before evolving into the immersed tunnel and bridge building industry and are a recent development in the construction of locks and dams. This innovative method prefabricates precast concrete or steel modules on land and places them in rivers as the in-situ form into which underwater concrete and mass concrete are placed directly. The tremie and mass concrete is designed to work in composite structural action with the prefabricated modules. Therefore, a lock or a dam may be constructed without use of a cofferdam.

2 METHODS

Selection of a proper erection method for transporting and placing prefabricated modules is an important design decision. The erection method can be generally categorized into the float-in method and the lift-in method. Each method has its special implications on project cost, construction schedules, river traffic, and level of construction risks. In general, a thorough evaluation of the erection

method is preferably made in the early design phase, because it affects the structural concept and layout.

2.1 *Float-In Method*

Float-in construction entails transportation of prefabricated modules from their fabrication yard or outfitting site to the project site by flotation, possibly using compressed air or buoyancy tanks. The modules for float-in construction are usually thin-shell floating structures with internal ballasting compartments.

Once the float-in modules are transported to and precisely positioned over the site, they are lowered down to a prepared foundation by means of ballasting. In comparison with the lift-in method, the float-in method has several advantages: it avoids heavy lift equipment which sometimes represents a substantial portion of the project cost, and the float-in modules can be made as large as practical without any concern for equipment capacity. Use of large modules generally leads to shorter construction time and lower cost.

The float-in method does, however, have its limitations: the float-in constructability is severely limited by river conditions such as the river flow velocity and available river depth at the site and

along the tow route. It requires a large casting yard and a launching system for loading out the float-in modules from the casting yard into river. Availability of the casting yard and the launching system may sometimes become a significant cost factor. On-site installation of a large float-in module, either with a flotation bottom slab or equipped with air cushion system, requires a sophisticated positioning system and relatively complex set-down process. The positioning and set-down process entails intensive on-site coordination of several operations, such as surveying, operations of ballast systems, operations of positioning guide systems, and, at times, diving inspection. Survey tasks carried out during the placement operations will require a high degree of accuracy for vertical and horizontal positioning of the precast shells. Details on some useful positioning and set-down systems for float-in construction of locks and dams are provided by Yao etc (2002).

In general, the float-in method is used effectively where the environmental constraints are not too severe, and the size and configurations of a structure are favorable for use of large float-in modules.

2.2 *Lift-In Method*

In lift-in construction, the prefabricated modules themselves do not float. Barges and/or lift equipment are used to transport the modules from their fabrication site to project sites.

Installation of lift-in modules generally requires large cranes, and auxiliary guiding systems are frequently needed in order to position and install the modules within acceptable tolerance. Lift-in construction is largely independent of river level, but is somewhat constrained by river flow velocity, with a normal upper limit of 2 to 3 meters per second. Since the lift-in modules are not required to float over water, their fabrication is substantially simpler than the float-in modules. In general, the lift-in method is usually efficient when a large number of prefabricated modules have to be installed on site or where environmental conditions impose restrictions on the float-in method.

Design plans and specifications generally prescribe only the desired end result of the construction. With the lift-in method, however, construction quality and productivity can be significantly improved, if the design is optimized to take into account of anticipated general construction procedures, timing, and sequencing. For example, the weight, size and configuration of lift-in modules

should be designed with due consideration of the requirements for heavy lift equipment and construction process, including (1) availability of the lift equipment in the local area and commercial market; (2) the meteorological and hydrological river conditions on site for the anticipated lift work window (e.g., river flow velocity, water elevation, draft limitation, etc); (3) logistics of positioning the lift equipment and lift-in modules at the site, maneuverability and productivity of the heavy lift equipment for intended operations; (4) the ability for lift equipment to position lift-in modules within required tolerance; (5) cost of the equipment and equipment utilization rate; and (6) requirements for lift apparatus such as lift frames, which must be accommodated by the lift-in module configuration. A guideline for these design and construction considerations is provided by Gerwick etc (2001).

Joining multiple lift-in modules under water is one of the most complex operations of in-the-wet construction. In order to minimize the marine work and risks, designers generally prefer large lift-in modules. However, large lift-in modules may have significant cost implication. In the U.S. inland waterways, for example, many marine contractors own or can easily rent floating cranes with the lift capacity up to approximately 500 tons. Heavy lift equipment with even high capacities, such as those used in offshore industry, may not be available due to various constraints of the inland waterways, such as bridge headroom clearance, river draft, and the lock size en route. For installation of very large lift-in modules, therefore, special heavy lift equipment may have to be manufactured for a project.

2.3 *Pneumatic Caisson Method*

Pneumatic sinking of locks, also referred to as the caisson method, has proved to be a useful alternative construction method when an insufficient work area is available around the construction site or when environmental impacts such as noise and vibration have to be minimized.

In short, this technique involves the construction of the lock or the lock head at ground level, after which it is immersed to its final position by excavating the soil underneath. The method has been used in the Netherlands for lock heads as well as for a complete recreational lock.

2.4 *Advantages of In-The-Wet Construction*

Several navigation lock projects in the United States have demonstrated advantages of in-the-wet

technology. One advantage is its ability to maximize offsite fabrication on land. Because the prefabrication can be performed in a well controlled environment, the quality of the construction can be better ensured with this method than with cast-in-place concrete construction. In-the-wet construction provides greater flexibility to the construction process and to adapt to varying needs of the site and the community, such as accommodation of off-season work and easy access of personnel and materials. As result, it can substantially reduce the construction time. The construction requires neither cofferdam nor blockage of the river during the construction and reduces adverse environmental impact and construction risks such as scour and flooding. Without a costly cofferdam and with a shortened construction schedule, in-the-wet construction often provides considerably cost saving. In-the-wet construction minimizes marine work in the river. In general, it requires little or no shut down of the navigation through the construction site. In some projects, it is unacceptable to construct a cofferdam that occupies large spaces. In such cases, the in-the-wet construction alleviates site congestion and improves construction logistics.

2.5 *Disadvantages of In-The-Wet Construction*

In-the-wet technology is relatively new so it lacks many “rules of thumb” of past experience. Many of the new details have to be developed by the designers or contractors; may require a steep learning curve for the first time users. There may be limited pool of available contractors. In-the-Wet technology may have less flexibility during construction.

Particular attention needs to be made to the connection between pre-constructed elements and tolerances between each pre-constructed element are critical for success of the project. Since a cofferdam is not used the substructures or foundations are not visible.

3 CASE STUDIES

3.1 *Braddock Lock and Dam, USA (PR 11-01)*

The replacement of the lock and dam was completed by means of the float-in method. Two precast concrete modules, each being approximately 100-m long and 33-m wide, are prefabricated in a two-level casting basin and outfitted while floating. The modules were towed 46 km to the project site and ballasted down onto drilled shafts. High performance grout and mass tremie concrete were

placed to tie the structure to the shafts foundation and to fill the float-in modules. The piers and gates were constructed in the dry condition. This successful project demonstrated the technical feasibility and advantages of in-the-wet construction of navigation structures, including favorable construction logistics, shorter construction schedule, cost saving, and reduced river risks such as flood overtopping and scour.

3.2 *Chickamauga Lock, USA (PR 11-03)*

This new navigation lock is being constructed to replace an existing and smaller lock that has been plagued with alkali-aggregates reactions in concrete. The new lock is located downstream of the dam spillways and adjacent to the existing lock. The complex geologic site conditions require large cofferdam for stability, but there is a very limited space adjacent to the existing lock. In-the-wet construction is found to be the optimum method to address the unique project challenges. The innovative cofferdam consists of 16 lift-in precast concrete box modules. They were installed on pre-installed drilled shaft foundations with lift frames and hydraulic jacks. The lift-in concrete boxes were then filled with tremie concrete, thereby locking the precast cofferdam to the rock surface and the drilled shafts. This concrete lift-in concrete structure serves two purposes: it first functions as a cofferdam to allow dewatering of the main lock site, and it is incorporated into the final lock wall and thereby provides a significant proportion of the stability for the permanent lock wall. This successful project shows that in-the-wet method can be combined with the conventional cofferdam method to take advantages of both methods and address various risks and complexity of a lock construction project.

3.3 *Greenup, USA (PR 11-04)*

The Greenup plan of improvement includes a 183 m extension of the existing 183 m auxiliary lock to provide an overall length of 366 m. This also includes an extension of the lock approach walls, filling and emptying system improvements, installation of a miter gate quick change out system for faster repairs to the gates, and environmental mitigation. Extension of the auxiliary lock will be accomplished by lengthening the lock chamber with float-in concrete sections. This technique will utilize a dry dock at R.C. Byrd Locks and Dam to construct a concrete shell base raft. After the base raft is complete, the raft will be floated to a fit-out area at

Greenup Locks and Dam where the walls are constructed on the base raft. The structure is then transported, positioned, and ballasted so that it will sink to its final position.

3.4 *J.T. Meyers, USA (PR 11-07)*

This project extends an existing lock from 34 m to 366 m using float-in construction for the approach walls and supplemental thru sill filling system for newly extended chamber.

3.5 *Kentucky Lock Addition, USA (PR 11-08)*

This project adds a new 366.0 m chamber adjacent to an existing 183.0 m chamber. Construction utilizes two innovative float-in cofferdam segments that are later incorporated into the river wall of the final lock. The float-in segments are to be prefabricated on barges and launched from the existing adjacent lock. The float-in cofferdam is a reinforced concrete shell structure with open top and bottom. Installing airtight lids on each of the compartments provides a seal to allow flotation with compressed air. In order to float-in the segments during the low water season, the compartments are completely dewatered. Stabilizing pontoons are attached to the sides of the segments to increase transverse stability during launch, transport and set down. The ballast system for each float-in segment consists of four independent compressed air piping systems. Each system provides compressed air to the compartments in one quarter of the float-in segment. The ballast system will be designed to level and trim the segments as well as to adjust segment draft. This cofferdam serves two purposes: it serves as a cofferdam to allow dewatering of the lock site, but it is also tied to the completed river wall and becomes part of the river wall, providing a significant proportion of the lock walls final stability.

3.6 *Olmstead Lock and Dam, USA (PR 11-11)*

Expensive and deep foundations, high seismic design loads, large water level fluctuations and heavy bed loads provided an impetus to develop a floating solution for the Olmsted Approach walls. Because of the high seismic forces, it was desirable to reduce the mass of any structure provided. A floating structure, isolated from the ground motion by the river provides the greatest possible reduction in mass. A structure that floats would also never be submerged; thus eliminating the requirement to wash mud from the structure.

The Olmsted Dam is being constructed with the lift-in method. Very large precast concrete modules,

weighing up to approximately 5000 ton, are to be transported and set down on prepared river bed by a catamaran crane barge. High performance tremie concrete is then placed to tie the dam segments with pre-driven piles foundation.

3.7 *Lith Lock, The Netherlands (PR 7-02)*

A new lock chamber has been build to replace a small existing lock using the pneumatic caisson method.

5 CONCLUSION

In-the-wet technology is innovative and cannot depend on “rules of thumb” of past experience. Many engineering solutions have to be identified, evaluated, and carefully developed from concepts to details. Therefore, the application of this technology may require a steep learning curve for the first time users.

Recent experience demonstrates that in-the-wet construction of navigation locks and dams is technically feasible. An important lesson learned from the experience is that a large and complex in-the-wet construction project must give high priority to an accurate assessment of the market conditions and provide sufficient accommodation for anticipated construction risks. Prior to the final design, a thorough assessment should be made regarding construction schedule and cost, constructability and risks, suitability of river conditions, effects on navigation and environment.

In general, both the conventional cofferdam construction and innovative in-the-wet construction have their own merits and limits. The conventional method is best suited for some lock projects while the in-the-wet construction is best suited for the others. In some case, it is advantageous to combine the conventional method and the innovative method in the same project and take advantage of both methods to deal with the risks and complexity in various parts of the project.

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Paper 9, part A - LOCK GATES – INNOVATIVE CONCEPTS

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ABSTRACT: This paper introduces some new innovative concepts identifies by the INCOM WG29 and reported in the PIANC report 106 “Innovations in Navigation Lock Design”, 2009.

1. LOAD AND STRENGTH ASSESSMENT

Load and strength are linked when structural engineers design lock gates and valves, first at the early design stage (to assess weight and cost) and later at the final design stage (construction drawings).

Nowadays most difficult issues concern :

- ➔ Seismic effect on lock gate
 - additional loads (external and internal)
 - behavior during gate motion
 - ...
- ➔ Ship collision on lock gates

The challenge for the next years is to identify relevant and cost/effective specifications and requirements.

2. MECHANICAL PARTS: SEALS, BEARINGS, HYDRAULIC CYLINDERS, OPERATING EQUIPMENT

The main points about the mechanical parts are given in the Table 1.

The key points to consider during the design of mechanical parts is the **Gate operation**. Operating machinery is critical locks equipment because this equipment is subjected to intensive operation. Lock availability depend mainly on the machinery performance and reliability.

For navigation locks, there are typically four types of drives, which are used to develop operating forces:

- Electric-mechanical drives,
- Oil hydraulic drives
- Electromechanical actuators, using a capsulated threaded pin. Due to the head sealing of the mitre gate the drive is always dry (Fig. 1)
- Oil hydraulic compact drives

The last two types of drives relate to recent developments, which were mainly designed to **reduce maintenance**.

Table 1 - Main Mechanical Parts

FUNCTIONS	ELEMENTS
Gate operation and power supply (transmission of a force to the mobile structure)	<ul style="list-style-type: none"> - actuators - drives (cylinders, electro-mechanical drives, etc.) - motors - chain, cables
Guiding (rotation, translation)	<ul style="list-style-type: none"> - rails - wheels and rollers - pivot , bearing
Bearing and contacts (sliding, rolling or static) (transmission of forces to the foundation of the lock)	<ul style="list-style-type: none"> - rails - wheels and rollers - pivot , bearing - fixed elements for guiding or sealing
Sealing	<ul style="list-style-type: none"> - seals
Maintenance	<ul style="list-style-type: none"> - accessibility - capacity to remove and change elements

3. NEW INNOVATIVE GATE CONCEPTS

3.1 Reverse Mitre Gate.

Recently innovative gate operating systems were designed to combine the link between the gate and the operating cylinder plus a retaining strut to resist the effects of a reverse head imposed by flood conditions. Such system is, in principle, suitable for limited water heads and rehabilitation works.

Nevertheless the progress performed in hydraulic cylinder reverse water heads of 2 and 3 m can be reached (for instance in the IJmuiden locks in the Netherlands). In these cases the cylinders work in compression (reversed head) or in tensile (standard head) – See Fig. 1.



Fig. 1 : Reverse Mitre Gates (IJmuiden-NL)

3.2 Folded plate gates

It is now possible to use complex geometric folded plate for lock gate structures (Fig. 2). Therefore the advantages are:

- Some redundancy in the bearing capacity
- Simplified maintenance and inspection
- Well designed to avoid fatigue damage
- Favourable corrosion protection characteristics



Fig. 2 - Folded plate of a mitre gate at Uelzen II

3.3 Suspended Mitre gates

There is an innovative solution to the problem of gate hinge wear, so-called ‘suspension gate’, for mitre or single-leaf gate system (Figs 3 and 4). The gate leaves are suspended to a rope, chain or other torque-flexible member – anchored in the leaf

rotation axis and hooked to a small tower or console. Both the top and the bottom hinge carry only horizontal reactions in this way, which significantly decreases the wear and helps solving some fatigue related problems.

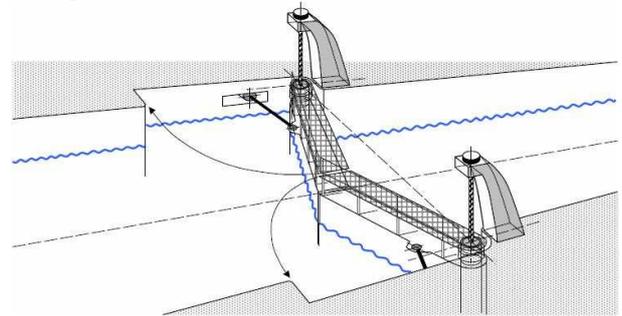


Fig. 3 - Suspended Mitre Gate



Fig. 4 -Mitre gates supported only at their top hinges

3.4 Rotary segment gates with horizontal axis

Rotary segment gates (Fig 5) can be used as a upper lock gate for a large water head if a separate filling systems exists. When filling the lock through the gate, a lift height of 8 m is the maximum lift which are currently planned in Germany.



Fig. 5 - Upper gate at lock Lisdorf during inspection (left) and during a test for flood discharge

3.5 Vertical-axis Sector Gates

Vertical-axis sector gates (Fig 6) are an efficient and economical solution where there is a requirement for a lock gate to accept a head difference in either direction. They can allow simple filling and emptying of the locks without provision of separate sluice gates or culverts.



Fig.6 - Vertical-axis sector gates

3.5 Composite lock gates

CETMEF (France) has studied a vertical lift arch gate made out of composite materials. Similarly the “Spieringsluis” in the Netherlands was designed with a high strength synthetic composite material to reduce the higher maintenance costs of wooden or steel gates. The average preventative maintenance duration with wood or steel gates is 15 to 25 years.

Main advantages of composite arch gates are:

- No corrosion;
- Good resistance to aging in damp environment;
- Finishing paint useless, thereby seriously reducing maintenance costs;
- Lightness, easing transportation and fitting of the gate;
- Lightness reducing the purchasing and maintenance costs of the machinery;
- Gate positioning on the river side of the lock heads, easing maintenance and reducing the risk of collision of the gate and/or machinery.

3.6 Self-propelled floating lock gates

Self-propelled floating lock gates may replace traditional wheel barrows gates. Such gate (Fig 7) is an alternative to the standard rolling gates

(wheelbarrow) and hydrolift gates that are commonly used for large maritime locks. The idea is to use a floating gate that is self propelled to close/open the lock (as a transversally rolling gate does).

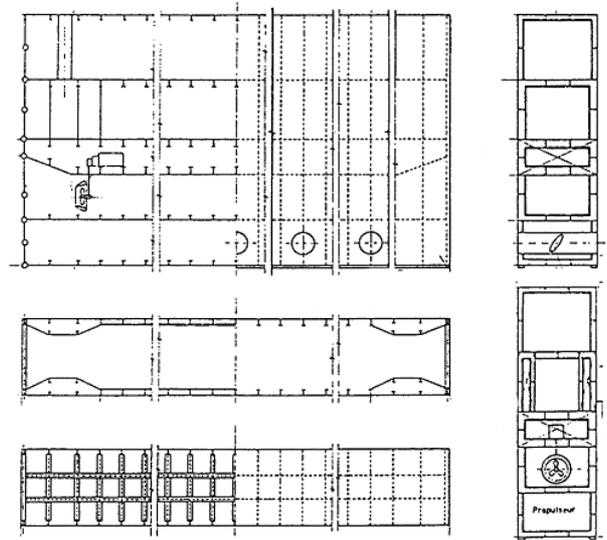


Fig.7 - Typical Cross Sections in a Self-Propelled Floating Lock Gate – 70 m long

3.7 Sliding gate – Hydrojet (Fig 8)

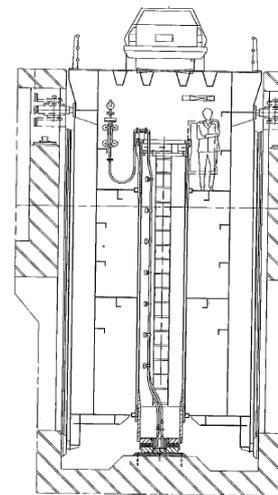


Fig. 8 - Hydrojet – Oranje lock (NL)

3.8 Rolling gates with integrated filling/emptying system

In Germany, an innovative gate system (Fig 9) combines the advantages of a lifting gate, where the gate body also forms the closure for filling and emptying the lock chamber, with those of a sliding gate.

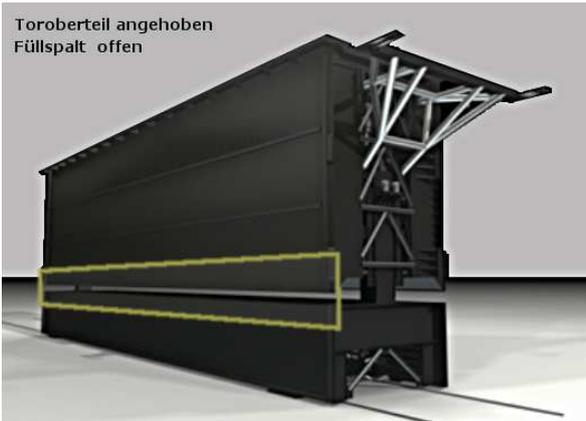


Fig. 9 - Kaiser lifting and sliding lock gate

4. GATE TIGHTNESS, LININGS AND SEALS

→ The “come back” of sliding gates/valves

In the Netherlands, Germany, Panama, etc. UHMPE (ultra-high molecular weight polyethylene) is nowadays considered a reliable technology and a very durable material to be used for sliding gate and lock filling and emptying valves.

It is a durable material a) long-service and b) environmentally favourable. It is chemically very stable and its mechanical properties are little sensitive to time, weather etc.

It is also recyclable (products: regenerate UHMPE down to low density PE e.g. for garden furniture) and at the very end it still has a high energy value when burned.

5. VALVES FOR FILLING AND EMPTYING SYSTEM

There are four main types of valves (also called gates) that are currently used as filling and emptying regulation system:

- a) Radial gates (used as valves)
- b) Fixed wheel gates (fixed roller gates)
- c) Butterfly valves
- d) Sliding lift gates

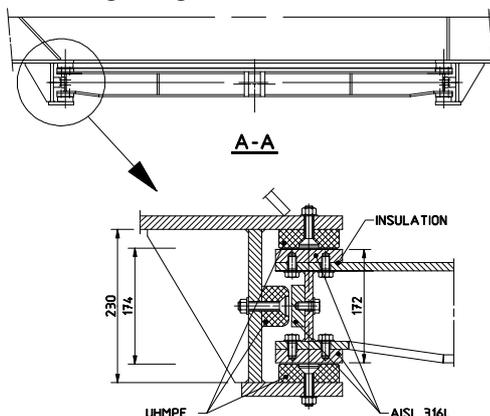


Fig. 10 -UHMPE sliding Gate sluice (Naviduct, NL)

The sliding lift gate is based on a high mechanical performance sliding material with a low friction coefficient. The material provides both guiding and sealing functions. It is placed on both sides of double-sealed gates and embedded parts depending on the mechanical design adopted. UHMWPE has the following characteristics:

- low friction coefficient (significantly less than 0.2);
- low wear index, which would mean the installation would not require any significant maintenance (wear < 4 mm in 35 years – working life);
- maximum stress = 2 N/mm² < 6 N/mm².

UHMPE is nearly a standard solution for such contacts in the modern Dutch vertical lift gate sluices e.g. see as the valves of the Naviduct Enkhuizen (NL)-Fig 10..

6. CORROSION PREVENTION and CORROSION PROTECTION

In the last decade, the costs associated with the maintenance of infrastructure (bridges, locks, etc.) have increased dramatically due to the development of more stringent environmental regulations.

Durability and economic maintainability are both directly proportional to corrosion preventive measures taken.

Corrosion prevention of metal, which should be built into the design, must not be confused with **corrosion protection**, which is regarded as a secondary item to be apply to the structures at the building stage.

7. GATE EQUIPMENT

As example of new technologies, there is the magnetic automatic innovative mooring systems are now available (Fig. 11).

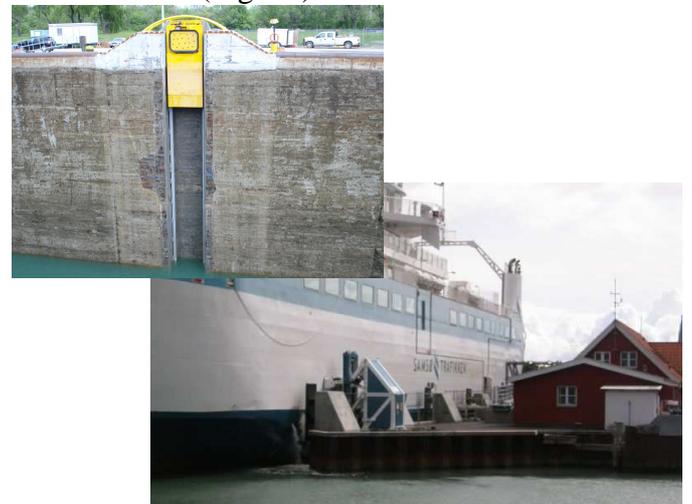


Fig. 11 - Magnetic Mooring System at KaiserLock Germany (Cavotec Ltd)

Paper 9, part B - Lock gates ship impact

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ABSTRACT: This paper presents an overview of the state of art of ship impact analysis on lock gates. First, the different kinds of analysis are presented, which are: empirical approach, analytical-rational approach, and finite element methods performed with quasi-static analysis or dynamic analysis. A discussion on the hypothesis and the calculus time required by each method is carried out with a view to clarify the state-of-practice for engineers. Then, a quasi-static analysis by finite elements modeling a ship impact is performed on the specific case of a new lock gate designed in Belgium for the “Seine-Escaut Est” project. The results suggest some design recommendations to provide a ductile behavior and so impact strength for the gate structure.

1 INTRODUCTION

At the beginning of a new project, design recommendations for the ship impact load case are hard to find, while there obviously are decisive decisions to take. First of all, the “vessel impact” must be defined in terms of ship weight and speed. Then, a decision must be taken on whether the gate must have sufficient impact strength or protective measures must be designed in order to prevent the ship from impacting the gate. In the first case, the analysis to perform to design the gate structure has to be decided.

2 SPECIFICATIONS

2.1 *Vessel impact design criterion*

The ship weight and speed to take into account for designing the gate structure or the protective device have to be defined by the client. Of course, this “vessel impact” has to be consistent with the project. For instance, the design & build request for proposals for the third set of locks of the Panama Canal explicitly adopted a “vessel impact” of 160 000 t with a speed of 0.5 m/s (PIANC, 2009), which is consistent with the design ship and the expected ship velocities in the lock.

2.2 *Protective measures VS gate designed to sustain ship impact*

Both solutions have to be compared on economical basis. In Germany, the downstream side is generally equipped with a protection system (on the chamber side). This protection system can't be very stiff because it must avoid destroying the ship, since a sinking ship will result in a long downtime period for the lock (PIANC, 2009).

2.3 *Ship impact analysis*

If the gate has to serve as a ship stopping device, an analysis of the ship impact must be performed on the gate structure. Different kinds of analysis are possible. The decision depends notably on the importance of the project and the time and money that can be spent on this analysis.

3 SHIP IMPACT ANALYSIS: STATE OF ART

3.1 *Empirical approach*

These methods are based on empirical data and practice experience. They offer a very simple way to evaluate an order of magnitude of the impact strength of a lock gate but their simplicity does not allow to reflect correctly the phenomenon of an impact. They can only be used as a rule of thumb. Always more detailed analysis must be performed (see here after).

3.2 Analytical-rational approach

Analytical models can represent simple cases of impact with a good accuracy. Some hypothesis have to be made on the strain state of the gate but numerical studies with uniform gate structures have highlighted the ways of dissipating energy that should be considered, i.e. a local deformation of structure elements in the vicinity of the impact and a global bending around plastic hinge lines (Le Sourne et al., 2004). The principal assumption in analytical analysis is that the totality of the energy brought by the ship is dissipated by the gate. Various numerical studies have validated this assumption (Le Sourne et al., 2004).

Those models do not take into account phenomenon's of instability that could appear during the rotation of the plastic hinge lines, considering the global plastic failure mechanism. Such instabilities could reduce the structure capacity for energy dissipation.

However, such models, if they are correctly applied, can be seen as very effective and time-saver for gate structure with plane geometry.

3.3 FEM, quasi-static analysis

Finite elements methods can be used to analyze the ship impact. As dynamic effects are usually not significant for lock gate, a quasi-static analysis can be seen as sufficient to model the impact. One possible method is to consider the bow of the ship as perfectly stiff and so to apply a quasi-static load on the gate structure until equalization of the strain energy of the gate with the initial kinetic energy brought by the ship.

The approximations of this method are that the totality of the energy is dissipated by the gate; there is no dynamic effect and no evolution of the contact between the bow and the gate. Nevertheless, this kind of analysis gives good results when a dynamic analysis can't be performed.

3.4 FEM, dynamic analysis

Such analysis allows modeling the deformable bow of the ship so that giving an initial position and speed, the contact between the bow and the gate can be considered. Moreover, dynamic effects are taken into account. This is unfortunately highly time consuming method –main disadvantage.

Using this method for few study cases can offer reference results to validate assumptions made in analytical models or quasi-static finite elements methods.

4 ONE EXAMPLE: SEINE-ESCAUT EST

A quasi-static analysis by finite elements using the FINELG software (de Ville de Goyet, 1994) has been performed on a lock gate designed for the “Seine-Escaut Est” project in Belgium, which includes the upgrading of 4 locks. The dimensions of the gate are 13.7 m length and 13.6 m height. The design ship is a 2400 t barge. The lock gate is first elastically designed with the LBR-5 lock gate optimization software (Rigo, 1999) considering the hydrostatic load cases. The total weight of the gate is 51.4 t.

4.1 Ship impact analysis

Three scenarios of impact are studied:

1. The ship impacts the gate at upstream water level (U.W.L.), but the hydrostatic loads are neglected.
2. The ship impacts the gate at U.W.L. while the hydrostatic service loads are already applied to the gate
3. The ship impacts the gate at downstream water level (D.W.L.).

The analysis of the first scenario applied on the initially optimized structure shows a fragile behavior of the gate. The gate structure has a low capacity for dissipating energy (max. 80 kJ). Here, it should be noted that the gate was elastically designed to resist to hydrostatic loads. Consequently, the slenderness ratio of the stiffened panel respects Hugues' criteria for T-elements (Hugues, 1995), which fit with the Eurocode class-3 of cross sections. It explains why the collapse appears very early by buckling of the frame when the gate is impacted by a ship.

After reinforcing the gate to obtain class-1 cross sections for the frames and girders, the observed behavior of the gate structure is very ductile (Fig. 1). Instability phenomenon's are avoided and the gate is able to develop a global plastic failure mechanism and to dissipate until 2 MJ. However, the total weight is gone up from 51.4 t to 68.7 t (+34%).

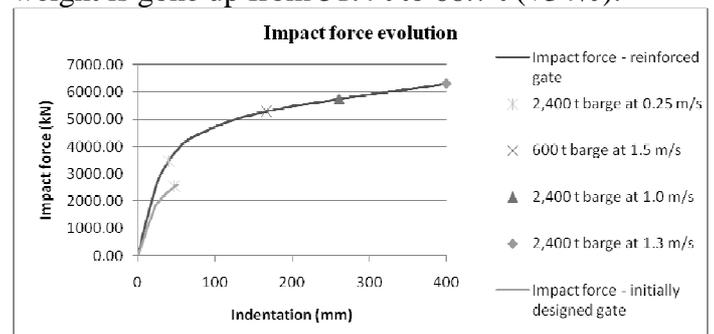


Figure 1. Impact force evolution for a U.W.L. impact

When taking into account the hydrostatic load, the global behavior of the gate structure is identical but the structure is more deformable. The reason is that the gate is already submitted to a stress field.

The gate structure is more fragile for a downstream side impact compared with an upstream side impact, the stiffness being much higher and the collapse arising suddenly for an impact of energy in the order of 450 kJ (Fig. 2). The strain pattern in the gate at the collapse stage shows that there were strain concentrations in the impact zone, mainly in the frame in contact with the barge bow. This strain peak is due to the small ratio between the transverse and longitudinal stiffness in this zone, which prevented the propagation of yielding and thus the development of a global plastic failure mechanism (Fig. 3).

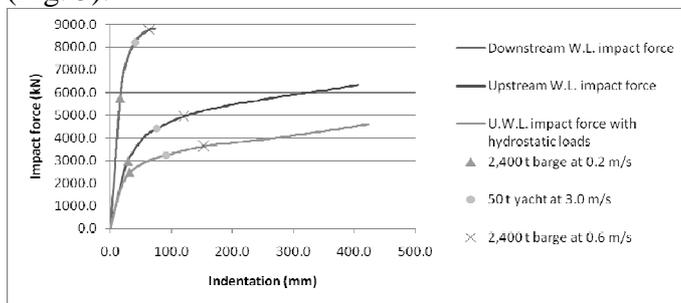


Figure 2. Impact force evolution for different impact cases.

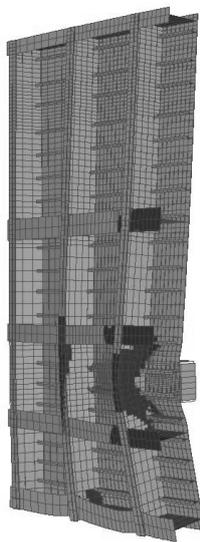


Figure 3. Yielding at the collapse stage, D.W.L. impact.

4.2 Conclusion

In this considered example, the aim was to design a gate able to resist the ship impact by itself. To provide the gate a good capacity for dissipating energy, it is necessary to provide a ductile behavior for the gate structure, i.e. to avoid instability

phenomenon and to allow the gate forming a global plastic failure mechanism. Ductility of the elements can be achieved by using EN class-1 cross sections. Ductility of the structure requires a good propagation of yielding, which can be achieved by an adequate design of the stiffness ratios in the potential impact zones.

Nowadays, it becomes a current practice to perform an elastic design and optimization of the lock gates considering hydrostatic load cases. However, the gate impact analysis may force the designer to increase the dimensions (cross section) of the frames and the girders of the optimum solution to obtain class-1 cross sections.

Consequently for design purpose the main recommendation is to implement in the optimization software a new constraint that consists in using only class-1 cross sections for the frames and the girders. It would permit to obtain optimized solutions considering impact strength. Then, this solution should be compared in term of cost with the elastic optimum solution coupled with protective measures against ship impact.

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Paper 10 - Computational Fluid Dynamics in lock design- State of the art

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ABSTRACT: The numerical simulation of the fluid flow in locks and their vicinity has improved significantly in the last years. Different modeling approaches have to be distinguished and their practical limits have to be understood for a successful application. Here, a short of overview of model types and areas of application is given.

1 INTRODUCTION

The recent developments in computational methods and the tremendous rise in available computing power have shifted the regions of applicability of numerical models in the last years. Still it must be stated that the filling and emptying of a lock is a complex process, which is not easily replicated in computational models.

2 CLASSES OF NUMERICAL MODELS

2.1 Introduction

Numerical models can be distinguished by the range of physics they are covering, their dimensionality, the applied numerical methods and other parameters.

2.2 Zero-dimensional model

This class of models mainly deals with fluid mass balances. It is useful e.g. to estimate the water consumption of a lock complex. Furthermore the filling times can be estimated for simple systems, if calibration data for the loss coefficients is available.

2.3 One-dimensional models

In the scope of locks, these models are typically networks of tubes and basins, so-called network models (Figure 1). They can be used to estimate the filling time of the lock chamber or model the speed of the fluid exchange between water saving basins and the lock chamber.

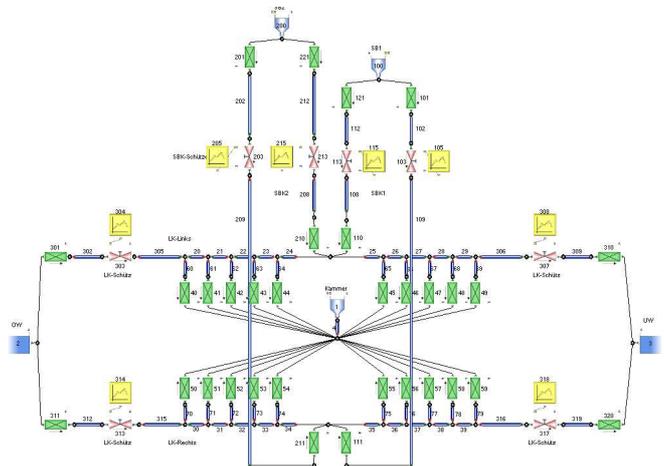


Figure 1: Typical network for a lock with saving basins (simplified).

The major drawback is the necessity to parameterize the hydraulic system. For standard components like single bends or T-junctions these parameters can be taken from textbooks or the database of the simulation program. For locks, special shapes are common. For these shapes hydraulic models or highly resolved three dimensional numerical models are necessary to evaluate their hydraulic properties.

Another more general problem is that this class of software was derived for the use in chemical engineering, where singular special shapes are connected with large lengths of straight tubes. In locks, the flow field after a bend/junction/... can often not develop across the full width of the culvert again, before the next bend/junction/... is met. Thus, the accuracy of the local losses is often limited and may decrease the total quality of the results.

2.4 Two-dimensional models

These are mainly used in the approach areas and the surrounding areas of locks. Here, the flow field is approximated with the shallow-water equations. These are applicable if the vertical movement of the fluid flow is negligible. This approximation is well established and gives reasonable results for large scale shallow water situations.

For the movement of water in the chamber this type of models is sometimes applied, too. It can be used to simulate the sloshing of water in the chamber. In this case the flow rates of the filling systems are computed with a network model and used as boundary conditions for the shallow water model. If no ship is in the chamber, this approach can give reasonable results. With a ship in the chamber, the damping effect of the ship on the sloshing can not be adequately reproduced.

2.5 Three-dimensional models without free surface

In order to evaluate the hydraulic losses at bends or junctions, three dimensional numerical models can be applied. For this purpose stationary boundary conditions are sufficient, as the fluid travel time through the model is much faster than changes of the flow speed. In order to accurately catch areas of flow separation, reasonably fine computational grids are necessary. For singular points of interest reasonable accuracy can nowadays be achieved on PCs. If larger parts of the filling system should be computed, in many cases a sufficiently fine grid can not be achieved on a single PC. In this case it is necessary to perform the computation on clustered machines or larger parallel computers.

2.6 Three-dimensional models with free surface

If the movement of the free water surface is an important effect and three dimensional flow patterns must be evaluated, this class of models must be applied. These models require very high computer resources, which can not easily be fulfilled.

Here, one must distinguish between cases where the exact shape of the water surface is relevant and others, where only an approximation is needed (e.g. in order to simulate large scale effects like chamber sloshing). For certain applications like the generation of eddies, fine grid resolutions are necessary in order to catch the governing processes. For the example presented in Figure 2, a computational grid with 50 Mio. nodes was used.

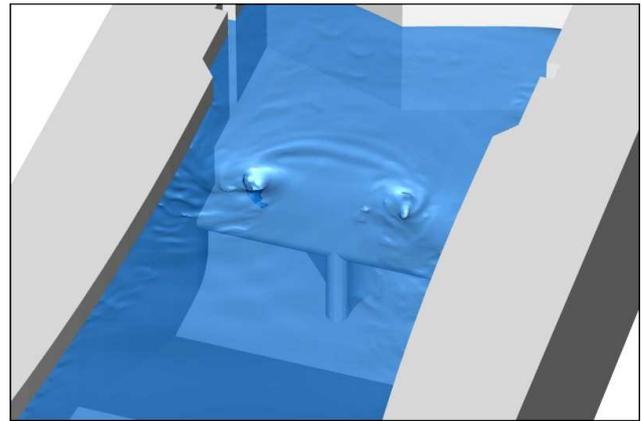


Figure 2: Simulated water surface deformation with eddy formation at the water intake of a lock (with upper gates visible in the background)

3 DRAWBACKS

3.1 Impact of parameters

As a general rule of thumb, the impact of parameters on the model results is the highest for the lowest dimensionality (and therefore complexity) of the model. This makes it virtually impossible to predict the filling time of a lock with a zero- or one-dimensional model if no calibration data is available or already integrated into the model. On the other hand, with three-dimensional models the amount of necessary calibration data is much smaller. Additionally, the possible impact of calibration is much smaller, resulting in a smaller range of the possible results. But the required computational effort is many orders of magnitude higher, so that the choice of the model might be governed by this aspect.

3.2 Impact of turbulence models

In three dimensional models, one of the major drawbacks is the requirement to choose an appropriate turbulence model. Turbulence models are necessary, because at the time given it is impossible to model the movement of the fluid down to its smallest scales. Thus, only the large scale movement of the fluid is directly computed in terms of velocities and pressures and the small scale movement, which finally results in dissipation, is subsumed in simplified statistical approaches. The so-called Reynolds-Averaged-Navier-Stokes (RANS) approach approximates the internal turbulent movement and replaces it with an additional viscosity at the larger scales. The most prominent members of RANS group are the k-epsilon and k-omega models. These solve two additional transport equations for the “turbulent

kinetic energy” and the “turbulent dissipation rate” and use them to estimate the additional “turbulent viscosity” for the large scale movement. The drawback is, that these approaches require several parameters which are practically impossible to calibrate in engineering practice. Normally, the standard parameter sets are being used and different turbulence models should be used in order to judge in how far the results depend on the choice of the turbulence model. For some cases, turbulence models can even completely fail (Durbin, 1996).

If higher quality for the modeling of turbulent movement is necessary, the smaller scales of fluid movements must be resolved. “Large Eddy Simulation” (LES) is an approach, where some scales of the turbulent fluid movement are directly computed and the remaining turbulent movement on the sub-grid scale is described by (simple) turbulence models. Figure 3 shows the differences between the two approaches. Obviously the large scale results are comparable, while the reproduction of the small scale movement is much better with the LES approach, which has been computed with NaSt3DGP (Croce et al., 2004). The drawback is, that much larger computational resources are required. An additional problem is wall friction. For LES models a very fine grid (or a local two-equation model) would be required if wall friction should be adequately reproduced. Luckily, flow resistance in locks is mostly governed by shape and not by wall friction.

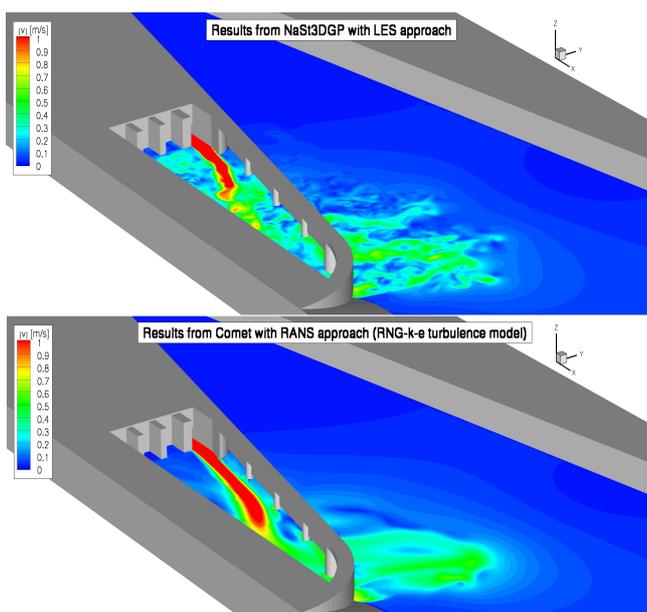


Figure 3: Detail of computed flow field in the lower approach area of a lock, computed with LES and RANS turbulence models

3.2 Different geometric scales

For locks, very different scales of the hydraulically relevant features can be observed. On the one hand there are large features like the lock chamber and the flow of water within. On the other, there are very much smaller features like nozzle arrays for the filling of the lock (Figure 4).



Figure 4: Nozzles in the new lock Sülfeld, during construction of the chamber floor.

If these features should be computed in a single numerical model, which resolves the flow within the nozzles (in order to correctly catch the flow resistance) and on the other hand covers all of the lock chamber and its filling system, the necessary numerical effort would (at the time given) be unbearable.

To circumvent this, models of different types are coupled. This coupling approach is called “hybrid modeling”. For example physical model data can be used to estimate the flow resistance of the aforementioned nozzles and hydraulically equivalent units can be fitted in the large scale numerical model. Though this approach is currently the most successful way to predict the behaviour of a lock, it must be pointed out that there is always a loss of information on the seams between the models.

3.3 Moving objects in three-dimensional models

During the filling and emptying process, several objects will be moved within the fluid. For simple locks at least some valves have to be moved, for locks with saving basins many valves can be necessary. Additionally, the movement of ships in the chamber can be relevant in order to judge the quality of the locking process. Currently the movement of objects can be considered in many three dimensional simulation packages. But it requires a lot of work, significant skills and

computer power to do this, so that modeling the full process of a lockage in a three dimensional model is cumbersome and ambitious at least.

4 SUMMARY

The development of computers and numerical models has shifted the range of applicability largely in the last years. Many aspects of fluid flow in locks can be described with computer models. But it must be stated that the most accurate and complete way to predict the behavior of a lock is still a physical model. On the other hand, numerical models can be very helpful for many aspects of lock design. If a new design is based on an older design for which data is available, it can be sufficient to use numerical models to extrapolate this know-how to the new design. In conjunction with physical models, they can be helpful to eliminate unnecessary variants or to model aspects of the fluid flow which are difficult to see or measure in physical models.

Nowadays, Computational Fluid Dynamics (CFD) software is available “from the shelf”. Additionally, computing resources have increased substantially, so that many people start to do CFD simulations. If the person who is doing the

simulations is not very well trained and/or of good will to produce quality results, there is a significant danger that only nice pictures will be rendered. For external parties, only looking at the resulting pictures, it is impossible to judge the quality of the results. Especially commercial packages have a tendency to produce results under any circumstances, even if for example the grid resolution is not sufficient for the problem. This is triggered by the tendency that only models of higher dimensionality are “accepted”, so that three dimensional models are being used, even if the available computing resources are not sufficient for quality results. As a result “Colored fluid dynamics” pictures are produced, which have nothing in common with real CFD.

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Paper 11 – Numerical simulations and experimental models: how to choose?

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1 PHYSICAL MODELLING

Since Leonardo da Vinci stated as a basic premise to “remember when discoursing on the flow of water to adduce first experience and then reason”, the experiment has attained a leading and continuously growing role in fluid mechanics research.

It is a prime merit of some scientists at the beginning of 20th century that they developed experimental methods for the solution of hydraulic engineering problems and they succeeded in convincing the profession of the usefulness and validity of this approach. Hydraulic physical modelling developed rapidly into engineering tool of a general recognition for the solution of hydraulic engineering problems.

2 NUMERICAL MODELLING

During the second part of the 20th century, there is fundamental research concerning the development of some mathematical tools to describe the flow evolution. In parallel, the progress in numerical and algorithmic increases considerably.

Than more numerical models have been applied in some areas of technical hydromechanics with great success. The greater flexibility of numerical models is often compensated by the more convincing intuitive power of the physical model. The market shares of the numerical models have increased in the last century against the physical models.

3 COMPARISON BETWEEN EACH MODELS, LIMITATIONS

Scale model studies have proven a cost-effective means of investigating performance of a proposed structure, provided requirements for hydraulic similitude are met. Idealistically, this requires

matching the ratio of appropriate pairs of forces in both scaled model and prototype that play significant roles in the physical being examined.

The effort in constructing a hydraulic physical model is comparable to the effort of working out a solution scheme for the numerical model. Both methods must make use of certain simplifications and approximations and have to be adapted to the real situation in nature – in the one case by adapting the empirical coefficients, in the other case by changing the model roughness.

In numerical models, the decisive limitation is the fact that the majority of flows processes are complex and no closed system of equations can be formulated (incomplete set of equations, turbulence hypothesis,...). Another practical limitation is given by the resolution of the model, which is determined by the choice of the grid size for the solution scheme.

For the credibility of a model, it is important to know on the one hand, which experiences are already available with similar types of models, and on the other hand to know the extend of possible feedback between nature and model.

Thus, the results of both physical and numerical models should be carefully examined. For physical models, the model set-up is not very error-prone, but the measuring and interpretation process can be lead to errors. In numerical models, most errors are introduced in the conception and set-up phase of the model.

4 HYBRID MODELLING

A comparison of experimental and numerical models shows at first glance that both type of model have very much in common. Each must be preceded by a conceptual phase, in which the physical

relationships are identified which is to be simulated by the model.

Because these two types of model lead to approximate solutions, when using them one has to know how approximate the solution is, the most important role in the decision making process is played undoubtedly by the limiting factors of either of model and the negative effects in modelling.

A modelling approach is to combine both techniques to minimize the parasite effects and to optimize the resolution time is more that a utilization of both modelling methodologies because these two concepts be able to couple and integrate off or on line to calibrate, validate and treat the boundaries conditions. The approach consists in the combination of limited model experiments, extensive numerical simulations together with a dedicated error correction facility and an optimisation procedure.

The strengths of physical and numerical models thus lie in different points, which can be optimally used by combining both models in a hybrid overall model (Scotti 2006).

The added values of the hybrid modelling are limitation of the parasite effects, guarantying the precision and accurate way of the design results,

flexibility, cost efficiency, learning, efficient mean of communication which improve multidisciplinary approach.

5 DEVELOPMENTS OF MODELS IN HYDRAULIC STRUCTURES

The hydraulic structures, so navigation locks, are a good example to demonstrate the interest to combine together these two methodologies.

The hydraulic engineering problems for a lock design concern both the lock chamber (filling-emptying system, gate hydraulic characteristics, water surface deformation, forces acting on ships, ...) , the upstream and downstream canals (currents near the lock, waves in navigation canals,...) and the mechanical effects (flow-induced forces, vibrations, cavitations,...). There is many examples to demonstrate the efficiency of this approach.

Another point of view is the vessel manoeuvring at the lock entrance (design of approach wall, manoeuvrability, accessibility, safety, ...). The hybrid approach integrates the results produced by physical and numerical modelling to simulate the current optimised with the help of navigation simulators.

PIANC InCom WG29

'Innovations in Navigation Lock Design'
A selection of photo's of the 8 working group meetings

1st meeting, Brussels, Belgium, February 2006



Figure 1 Start-up meeting at head office PIANC



Figure 2 Visit of Châtelet Hydraulic Laboratory

PIANC InCom WG29



Figure 3 Explanation of measurement equipment by Jean Michel Hiver



Figure 4 Explanation of the Lanaye lock scale model

PIANC InCom WG29



Figure 5 Lunch in the Laboratory



Figure 6 The scale model of the projected Lanaye lock

PIANC InCom WG29

2nd meeting, Lappeenranta , Finland, June 2006



Figure 7 The Chairman (Ph Rigo) at work



Figure 8 Sailing over the Finnish waterways

PIANC InCom WG29



Figure 9 Cooling down in a very warm Finland



Figure 10 Explanation by a Finnish official

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Figure 11 Group photo - Finland
(for names see group photo of de Bilt, the Netherlands)



Figure 12 Inspection of a wooden lock - Finland

PIANC InCom WG29

3rd meeting, Magdeburg, Germany, November 2006.



Figure 13 Group members paying attention.



Figure 14 Chairman (Philippe Rigo, right) and vice chairman (Dale Miller, left)

PIANC InCom WG29



Figure 15 Visiting the Sulfeld lock under construction



Figure 16 Group photo on the boat on the Elbe

PIANC InCom WG29



Figure 17 Discussion at the site for the Sulfeld Lock



Figure 18 Close by inspection of floating bollard recess

PIANC InCom WG29

4th meeting, Grenoble, March 2007, France



Figure 19 Visit of the Sogreah Laboratories



Figure 20 Renovation works in progress at the Rhone Locks

PIANC InCom WG29



Figure 21 A coffee break during the meeting



Figure 22 Group photo Grenoble

PIANC InCom WG29



Figure 23 Close by inspection of Seine Nord Lock scale model



Figure 24 Explanation of scale model of Seine Nord lock

PIANC InCom WG29

5th meeting, de Bilt, The Netherlands. October 2007.



Figure 25 Boarding for a trip on the Dutch waterways



Figure 26 Overseeing the lock complex at Amsterdam

PIANC InCom WG29



Figure 27 Working group in session



Figure 28 : WG29

From left to right, front lane: Dale MILLER (USA); Radu SARGHIUTA (ROM); Olli HOLM (FIN); Jorg BODEFELD (D)

First step on stairs: Peter HUNTER (UK); Michael TARPEY (USA); Jean Michel HIVER (BE); Philippe RIGO (BE), Jan BOS (NL), Carsten THORENZ (D)

Second step on stairs: Cpt. D. PORRAS (PAN), John Clarkson (USA), Peng WU (CHINA)

Above: Francisco MIGUEZ (PAN), Juan WONG (PAN), Arjan HUIDRA (NL), Erwin PECHTOLD (NL), Rik THOMAS (BE); Wilfred MOLENAAR (NL), Jose Luiz FERNANDEZ (Spain), Nicolas PICHON (FR), Bart SPAARGAREN (NL), Fabrice DALY (FR)

PIANC InCom WG29



Figure 29 Posing in front of a spare turbine of IJmuiden pumping station



Figure 30 Inspecting the inner side of the sliding gate on water pressure

PIANC InCom WG29

6th meeting, Brussels, Belgium. January 2008

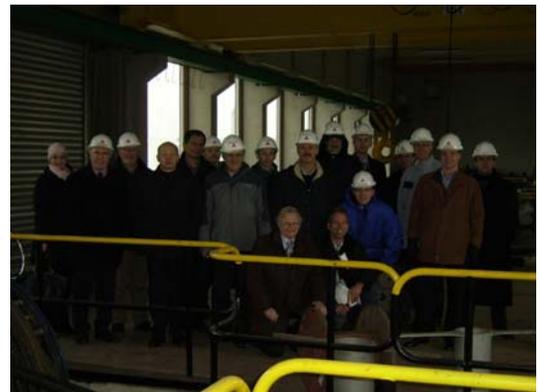


Figure 31 Group photo at the Antwerp locks



Figure 32 Attention for the details

PIANC InCom WG29

7th meeting, Yichang, China. June 2008



Figure 33 Explanation of the operating room of the Three Gorges locking system



Figure 34 Working group paying attention

PIANC InCom WG29



Figure 35 Meeting in the Three Gorges project hotel



Figure 36 Three Gorges Locks photo shoot

PIANC InCom WG29

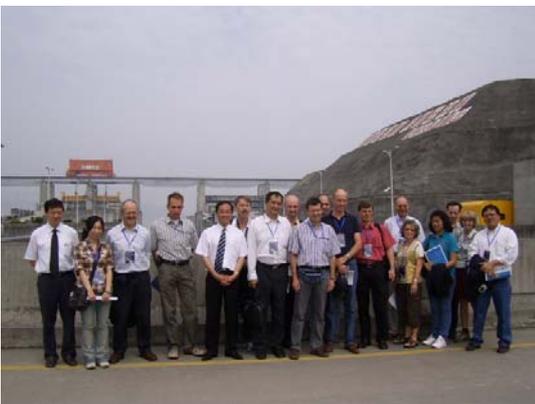


Figure 37 Group photo



Figure 38 Official dinner with the Director of the Three Gorges Lock complex

PIANC InCom WG29

8th (last) meeting Seville, Spain, November 2008.



Figure 39 Working group in session on the boat



Figure 40 Visiting the construction site of the new lock for Seville port



Figure 41 The water inlet of the culvert system



Figure 42 Culvert system and gate under construction



Figure 43 Jose Luis Fernandez explaining about the lighthouse of Chippiona



Figure 44 Group photo at Seville Port

Chairman of the Workshop

Philippe RIGO, INCOM WG29 Chairman (ULG, Belgium)

Invited speakers

B. DELEU (VNF, France)

J. WONG (ACP, Panama)

Official representatives

E. VAN DEN EEDE (PIANC, President)

STELMASZCZYK (DG TREN)

Speakers and members of technical panels

J. BOEDEFELD (BAW, Germany)

O. CAZAILLET (SOGREAH, France)

J. CLARKSON (US Army, United States)

B. DELEU (VNF, France)

T. DE MULDER (MOW Flanders Hydr., Belgium)

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D. MILLER (INCA Engineers Inc., United States)

W. MOLENAAR (TUDelft, Netherlands)

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WU PENG (CCCC Water Transp. Cons, China)

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R. SARGHIUTA (UTCB, Romania)

M. SAS (IMDC nv, Belgium)

M. TARPEY (US Army, United States)

R. THOMAS (ULg, Belgium)

C. THORENZ (BAW, Germany)

J. WEBB (US Army Corps, United States)

J. WONG (Aut del Canal de Panama, Panama)

S. YAO (Ben C. Gerwick Inc., United States)

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